BS EN 62271-201:2014

BSI Standards Publication

High-voltage switchgear and controlgear

Part 201: AC solid-insulation enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV

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National foreword

This British Standard is the UK implementation of EN 62271-201:2014. It is identical to IEC 62271-201:2014. It supersedes BS EN 62271-201:2006 which is withdrawn.

The UK participation in its preparation was entrusted by Technical Committee PEL/17, Switchgear, controlgear, and HV-LV co-ordination, to Subcommittee PEL/17/1, High-voltage switchgear and controlgear.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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High-voltage switchgear and controlgear - Part 201: AC solid-insulation enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV (IEC 62271-201:2014)

Appareillage à haute tension - Partie 201: Appareillage sous enveloppe isolante solide pour courant alternatif de tensions assignées supérieures à 1 kV et inférieures ou égales à 52 kV
(CEI 62271-201:2014)

Hochspannungs-Schaltgeräte und -Schaltanlagen - Teil 201: Isolierstoffgekapselte Wechselstrom-Schaltanlagen für Bemessungsspannungen über 1 kV bis einschließlich 52 kV
(IEC 62271-201:2014)

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

Foreword

The text of document 17C/594/FDIS, future edition 2 of IEC 62271-201, prepared by SC 17C "High-voltage switchgear and controlgear assemblies" of IEC TC 17 "Switchgear and controlgear" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 62271-201:2014.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2015-02-01
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2017-05-01

This document supersedes EN 62271-201:2006.

EN 62271-201:2014 includes the following significant technical changes with respect to EN 62271-201:2006:

a) apart from updating with the second edition of EN 62271-200:2012, definitions, classifications and testing procedures have been specified more precisely;
b) access to the solid-insulation enclosed switchgear and controlgear is now restricted to authorized personnel only. This implies that "accessibility class B" (public access) has been deleted throughout the document;
c) the term "protection category" has been introduced to replace the term "protection grade" (PA, PB1 and PB2)

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 62271-201:2014 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60059:1999	NOTE	Harmonized as EN 60059:1999.
IEC 60243-1:2013	NOTE	Harmonized as EN 60243-1:2013.
IEC 60507:1991	NOTE	Harmonized as EN 60507:1993.
IEC 60909-0:2001	NOTE	Harmonized as EN 60909-0:2001.
IEC 61936-1:2010	NOTE	Harmonized as EN 61936-1:2010.
IEC 62271-200:2011	NOTE	Harmonized as EN 62271-200:2012.
IEC 62271-4:2013	NOTE	Harmonized as EN 62271-4:2013.
IEC/TS 62271-304:2008	NOTE	Harmonized as CLC/TS 62271-304:2008.

Annex ZA
(normative)
Normative references to international publications with their corresponding European publications

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu

Publication	Year	Title	EN/HD	Year
IEC 60050	series	International Electrotechnical Vocabulary - Part 103: Mathematics - Functions	-	series
IEC 60060-1	2010	High-voltage test techniques -- Part 1: General definitions and test requirements	EN 60060-1	2010
IEC 60270	2000	High-voltage test techniques - Partial discharge measurements	EN 60270	2001
IEC 60529	1989	Degrees of protection provided by enclosures (IP Code)	EN 60529	1991
			+EN 60529:1991/corrigendum May 1993	1993
IEC 62262	2002	Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)	EN 62262	2002
IEC 62271-1	2007	High-voltage switchgear and controlgear -- Part 1: Common specifications	EN 62271-1	2008
IEC 62271-100	2008	High-voltage switchgear and controlgear -- Part 100: Alternating current circuit-breakers	EN 62271-100	2009
IEC 62271-102	2001	High-voltage switchgear and controlgear -- Part 102: Alternating current disconnectors and earthing switches	EN 62271-102	2002
			+EN 62271-102:2002/corrigendum Jul. 2008	2008
			+EN 62271-102:2002/corrigendum Mar. 2005	2005
+A1	2011		+A1	2011
+A2	2013		+A2	2013
IEC 62271-103	2011	High-voltage switchgear and controlgear -- Part 103: Switches for rated voltages above 1 kV up to and including 52 kV	EN 62271-103	2011
IEC 62271-105	2012	High-voltage switchgear and controlgear -- Part 105: Alternating current switch-fuse combinations for rated voltages above 1 kV up to and including 52 kV	EN 62271-105	2012
IEC 62271-106	2011	High-voltage switchgear and controlgear -- Part 106: Alternating current contactors, contactor-based controllers and motor-starters	EN 62271-106	2011
ISO/IEC Guide 51	1999	Safety aspects - Guidelines for their inclusion in standards	-	-

CONTENTS

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 201: AC solid-insulation enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV

1 General

1.1 Scope

This part of IEC 62271 specifies requirements for prefabricated solid-insulation enclosed switchgear and controlgear for alternating current of rated voltages above 1 kV and up to and including 52 kV for indoor installation and for service frequencies up to and including 60 Hz.

Access to the switchgear and controlgear is restricted to authorized personnel.

NOTE 1 For the use of this document high-voltage (IEC 60050-601:1985, 601-01-27) is the rated voltage above 1 000 V. However, medium voltage (IEC 60050-601:1985, 601-01-28) is commonly used for distribution systems with voltages above 1 kV and generally applied up to and including 52 kV; refer to [1] of Bibliography.

NOTE 2 Although primarily dedicated to three-phase systems, this standard can also be applied to single-phase or two-phase systems.

Enclosures may include fixed and removable components and may be filled with fluid (liquid or gas) to provide an extra insulation. For switchgear and controlgear containing gas-filled compartments, the design pressure is limited to a maximum of 300 kPa (relative pressure).

Solid-insulation enclosed switchgear and controlgear complying with this standard can be safely touched when energised.

Solid-insulation enclosed switchgear and controlgear for special use, for example, in flammable atmospheres, in mines or on board ships, may be subject to additional requirements.

Components contained in solid-insulation enclosed switchgear and controlgear are designed and tested in accordance with their various relevant standards. This standard supplements the standards for the individual components regarding their installation in switchgear and controlgear assemblies.

This standard does not preclude that other equipment may be included in the same enclosure. In such a case, any possible influence of that equipment on the switchgear and controlgear should be taken into account.

NOTE 3 Switchgear and controlgear assemblies having a metal enclosure are covered by IEC 62271-200 refer to [9] of Bibliography.

1.2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050 (all parts), *International Electrotechnical Vocabulary (IEV)* (available at www.electropedia.org)

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

IEC 60270:2000, *High-voltage test techniques – Partial discharge measurements*

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*

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

IEC 62271-1:2007, *High-voltage switchgear and controlgear – Part 1: Common specifications*
Amendment 1:2011

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

IEC 62271-102:2001, *High-voltage switchgear and controlgear – Part 102: Alternating current disconnectors and earthing switches*
Amendment 1:2011
Amendment 2:2013

IEC 62271-103:2011, *High-voltage switchgear and controlgear – Part 103: Switches for rated voltages above 1 kV up to and including 52 kV*

IEC 62271-105:2012, *High-voltage switchgear and controlgear – Part 105: Alternating current switch-fuse combinations for rated voltages above 1 kV up to and including 52 kV*

IEC 62271-106:2011, *High-voltage switchgear and controlgear – Part 106: Alternating current contactors, contactor-based controllers and motor-starters*

ISO/IEC Guide 51:1999, *Safety aspects – Guidelines for their inclusion in standards*

2 Normal and special service conditions

Clause 2 of IEC 62271-1:2007 is applicable with the following addition:

Unless otherwise specified in this standard, the solid-insulation enclosed switchgear and controlgear is designed to be used under normal indoor service conditions.

Solid-insulation enclosed switchgear and controlgear, under the scope of IEC/TS 62271-304 and intended to be used in service conditions more severe with respect to condensation and pollution than the normal service conditions specified in this standard, may be classified with a "Design Class" 1 or 2 according to IEC/TS 62271-304 to demonstrate its ability to withstand such severe conditions.

3 Terms, definitions and abbreviations

3.1 Terms and definitions

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

NOTE Additional definitions are classified so as to be aligned with the classification system used in IEC 60050-441.

3.101
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 60050-441:1984, 441-11-01]

3.102
assembly (of switchgear and controlgear)
combination of switchgear and/or controlgear completely assembled with all internal electrical and mechanical interconnections

[SOURCE: IEC 60050-441:1984, 441-12-01]

3.103
solid-insulation enclosed switchgear and controlgear
switchgear and controlgear assemblies with an external solid insulating enclosure and completely assembled, except for external connections

Note 1 to entry: The external insulation may be supplied with a (semi-)conducting layer.

[SOURCE: IEC 60050-441:1984, 441-12-06, modified – modification of the wording]

3.104
functional unit (of an assembly)
part of solid-insulation enclosed switchgear and controlgear comprising all the components of the main circuits and auxiliary circuits that contribute to the fulfilment of a single function

Note 1 to entry: Functional units may be distinguished according to the function for which they are intended, for example, incoming unit, outgoing unit, etc.

[SOURCE: IEC 60050-441:1984, 441-13-04, modified – modification of the wording]

3.105
multi-tier design
design of metal-enclosed switchgear in which the main switching devices of two or more functional units are arranged vertically (one above the other) within a common enclosure

3.106
transport unit
part of solid-insulation enclosed switchgear and controlgear suitable for shipment without being dismantled

3.107
solid insulating enclosure
part of solid-insulation enclosed switchgear and controlgear providing a specified degree of protection of equipment against external influences and a specified degree of protection against electric shock by limiting the approach to or contact with live parts and against contact with moving parts

Note 1 to entry: The main part of the enclosure is of solid insulating material, and may have added (semi-) conductive layers.

Note 2 to entry: If the resistance of the enclosure of the switchgear and controlgear to the earthing point provided is everywhere less than, or equal to, 100 mΩ, IEC 62271-200 is applicable.

[SOURCE: IEC 60050-441:1984, 441-13-01, modified – modification of the wording]

3.108
high-voltage compartment
compartment of solid-insulation enclosed switchgear and controlgear containing high-voltage conducting parts, enclosed except for openings necessary for interconnection, control or ventilation.

Note 1 to entry: General definition of "compartment" is provided by IEC 60050-441:1984, 441-13-05, as "a part of an assembly enclosed except for openings necessary for interconnection, control or ventilation".

Note 2 to entry: A compartment may contain barriers, structures or components that are intended to provide various functions, such as mechanical or dielectrical, but not to function as a partition or enclosure.

Note 3 to entry: High-voltage compartments are identified according to the main component(s) contained therein (refer to 5.103.1).

Note 4 to entry: Four types of high-voltage compartments are distinguished, three that can be opened, called accessible (see 3.108.1 to 3.108.3) and one that cannot be opened, called non-accessible (see 3.108.4)

3.108.1
interlock-controlled accessible compartment
high-voltage compartment, intended to be opened for normal operation and/or normal maintenance as stated by the manufacturer, in which access is controlled by integral design of the switchgear and controlgear

Note 1 to entry: Installation, extension, repairing, etc. are not considered as normal maintenance.

3.108.2
procedure-based accessible compartment
high-voltage compartment, intended to be opened for normal operation and/or normal maintenance as stated by the manufacturer, in which access is controlled by a suitable procedure combined with locking

Note 1 to entry: Installation, extension, repairing, etc. are not considered as normal maintenance.

3.108.3
tool-based accessible compartment
high-voltage compartment that may be opened only through the use of tools, but not intended for opening during normal operation and maintenance

Note 1 to entry: Tool-based accessible compartment are submitted to special procedures.

3.108.4
non-accessible compartment
high-voltage compartment, that must not be opened

Note 1 to entry: Opening may destroy the integrity of the compartment.

3.109
connection compartment
high-voltage compartment in which electrical connections are made between the main circuit of the switchgear assembly and the external conductors (cables or bars) to the electrical network or high-voltage apparatus of the installation

Note 1 to entry: A connection compartment is not needed for a solid insulation enclosed switchgear, if the external connection can be safely touched.

3.110
partition
part of solid-insulation enclosed switchgear and controlgear separating one high-voltage compartment from other compartments and providing a specified degree of protection

Note 1 to entry: Movable shutters intended for shielding may become an integral part of the partition.

Note 2 to entry: Partitions may be fitted with parts that allow interconnection between compartments (e.g. bushings).

Note 3 to entry: In 3.111 the only partition class considered in this standard is defined. This separate clause is introduced to keep the structure similar to the corresponding clauses in IEC 62271-200.

[SOURCE: IEC 60050-441:1984, 441-13-06, modified – modification of the wording]

3.111
partition class PI
solid-insulation enclosed switchgear and controlgear having one or more non-metallic partitions or shutters between opened accessible compartments and live parts of the main circuit

3.112
shutter
part of solid-insulation enclosed switchgear and controlgear that can be moved from a position where it permits contacts of a removable part, or moving contact of a disconnector, to engage fixed contacts, to a position where it becomes a part of the solid insulating enclosure or partition shielding the fixed contacts

[SOURCE: IEC 60050-441:1984, 441-13-07, modified – modification of the wording]

3.113
segregation (of conductors)
arrangement of conductors with earthed metal interposed between them in such a manner that disruptive discharges can only occur to earth

Note 1 to entry: A segregation may be established between the conductors as well as between the open contacts of a switching device or disconnector.

Note 2 to entry: This definition does not specify any mechanical protection (IP and IK).

[SOURCE: IEC 60050-441:1984, 441-11-11, modified – new notes]

3.114
bushing
structure carrying one or more conductors through an enclosure or partition and insulating the conductors from the enclosure or partition, including the means of attachment

3.115
component
essential part of the main or earthing circuits of solid-insulation enclosed switchgear and controlgear which serves a specific function (for example, circuit-breaker, disconnector, switch, fuse, instrument transformer, bushing, busbar)

3.116
solid-insulation embedded component
component, the live parts of which are integrally surrounded by solid insulating material, with the exception of the terminals, interfaces for driving mechanisms and secondary wiring

Note 1 to entry: The insulation may form part of the solid insulating enclosure.

3.117
main circuit
all the high-voltage conductive parts of solid-insulation enclosed switchgear and controlgear included in a circuit which is intended to carry the rated normal current

Note 1 to entry: Connections to voltage transformers are not considered part of the main circuit.

[SOURCE: IEC 60050-441:1984, 441-13-02, modified – modification of the wording and new note]

3.118
earthing circuit
conductors, connections and the conducting parts of earthing devices intended to connect the high-voltage conductive parts to the earthing system of the installation

3.119
auxiliary circuit
all the conductive parts of solid-insulation enclosed switchgear and controlgear included in a circuit (other than the high-voltage parts) intended to control, measure, signal and regulate

Note 1 to entry: The auxiliary circuits of solid-insulation enclosed switchgear and controlgear include the control and auxiliary circuits of the switching devices.

[SOURCE: IEC 60050-441:1984, 441-13-03, modified – modification of the wording]

3.120
pressure-relief device
device intended to relieve over pressure from a compartment

3.121
fluid-filled compartment
high-voltage compartment of solid-insulation enclosed switchgear and controlgear filled with a fluid, either gas, other than ambient air, or liquid, for insulation purposes

3.121.1
gas-filled compartment
high-voltage compartment of solid-insulation enclosed switchgear and controlgear in which the gas pressure is maintained by one of the following systems:

a) controlled pressure system;

b) closed pressure system;

c) sealed pressure system.

Note 1 to entry: Several gas-filled compartments may be permanently interconnected to form a common gas-system (gastight assembly).

Note 2 to entry: For pressure systems related to gas tightness, refer to 3.6.5 and 3.6.6 of IEC 62271-1:2007.

[SOURCE: IEC 62271-1:2007, 3.6.6.1, modified – modification of the wording]

3.121.2
liquid-filled compartment
high-voltage compartment of solid-insulation enclosed switchgear and controlgear in which the liquid is at atmospheric pressure, or under pressure that is maintained by one of the following systems:

a) controlled pressure system;

b) closed pressure system;

c) sealed pressure system

Note 1 to entry: For pressure systems, refer to 3.6.5 of IEC 62271-1:2007.

3.122
relative pressure
pressure, referred to the standard atmospheric pressure of 101,3 kPa

3.123
minimum functional level (of fluid-filled compartments)
gas pressure (relative pressure) in Pa (or density) or liquid mass at and above which the rated values of the solid-insulation enclosed switchgear and controlgear are maintained

3.124
design level (of fluid-filled compartments)
gas pressure (relative pressure) in Pa (or density) or liquid mass used to determine the design of a gas-filled compartment or mass for a liquid-filled compartment

3.125
design temperature (of fluid-filled compartments)
highest temperature which can be reached by the gas or liquid under service conditions

3.126
ambient air temperature (of solid-insulation enclosed switchgear and controlgear)
temperature, determined under prescribed conditions, of the air surrounding the enclosure of solid-insulation enclosed switchgear and controlgear

3.127
removable part
part of solid-insulation enclosed switchgear and controlgear connected to the main circuit and that may be removed entirely from the solid-insulation enclosed switchgear and controlgear and replaced, even though the main circuit of the functional unit is live

[SOURCE: IEC 60050-441:1984, 441-13-08, modified – modification of the wording]

3.128
withdrawable part
removable part of solid-insulation enclosed switchgear and controlgear that can be moved to positions in which an isolating distance or segregation between open contacts is established, while the part remains mechanically attached to the enclosure

[SOURCE: IEC 60050-441:1984, 441-13-09, modified – modification of the wording]

3.129
service position
connected position
position of a removable part in which it is fully connected for its intended function

[SOURCE: IEC 60050-441:1984, 441-16-25]

3.130
earthing position (of a removable part)
position of a removable part or state of a disconnector in which the closing of a mechanical switching device causes a main circuit to be short-circuited and earthed

[SOURCE: IEC 60050-441:1984, 441-16-26, modified – modification of the wording]

3.131
test position (of a withdrawable part)
position of a withdrawable part in which an isolating distance or segregation is established in the main circuit and in which the auxiliary circuits are connected

[SOURCE: IEC 60050-441:1984, 441-16-27]

3.132
disconnected position (of a withdrawable part)
position of a withdrawable part in which an isolating distance or segregation is established in the circuits of the withdrawable part, that part remaining mechanically attached to the enclosure

Note 1 to entry: In high-voltage solid-insulation enclosed switchgear and controlgear, the auxiliary circuits may not be disconnected.

[SOURCE: IEC 60050-441:1984, 441-16-28, modified – modification of the wording]

3.133
removed position (of a removable part)
position of a removable part when it is outside and mechanically and electrically separated from the enclosure

[SOURCE: IEC 60050-441:1984, 441-16-29, modified – modification of the wording]

3.134
loss of service continuity category
LSC
category defining the possibility to keep other compartments and/or functional units energized when opening an accessible high-voltage compartment, if any, as stated in definitions 3.108.1 to 3.108.3.

Note 1 to entry: The LSC category describes the extent to which the switchgear and controlgear is intended to remain operational in case access to a main-circuit compartment is provided. The extent to which it is considered necessary to open high-voltage compartments with a live installation might be dependent on several aspects (refer to 8.103).

Note 2 to entry: The LSC category does not describe ranks of reliability of switchgear and controlgear (refer to 8.103).

Note 3 to entry: According to accessible compartments and service continuity, four categories are possible: LSC1, LSC2, LSC2A, LSC2B.

3.134.1
category LSC2 functional unit
functional unit having at least an accessible compartment for the high-voltage connection, such that, when this compartment is open, at least one busbar can remain energized and all other functional units of the switchgear and controlgear can be operated normally

Note 1 to entry: When LSC2 functional units have accessible compartments other than the connection compartment, further subdivisions into LSC2A and LSC2B are defined.

Note 2 to entry: An accessible compartment for the high-voltage connection is called connection compartment.

3.134.1.1
category LSC2A functional unit
functional unit of category LSC2 such that, when any accessible compartment (other than the busbar compartment of single-busbar switchgear and controlgear) is open, at least one busbar can remain energized and all other functional units of the switchgear and controlgear can be operated normally

3.134.1.2
category LSC2B functional unit
functional unit of category LSC2A, where the high-voltage connections (e.g. cable connections) to the functional unit can remain energized when any other accessible high-voltage compartment of the corresponding functional unit is open

3.134.2
category LSC1 functional unit
functional unit having one or more high-voltage accessible compartments, such that, when any of these accessible high-voltage compartments is open, at least one other functional unit cannot remain energised

3.135
internal arc classified switchgear and controlgear
IAC
solid-insulation enclosed switchgear and controlgear for which prescribed criteria for protection of persons are met in the event of internal arc as demonstrated by type tests

Note 1 to entry: The internal arc classification is described by the characteristics given from 3.135.1 to 3.135.4.

3.135.1
type of accessibility
characteristic related to the level of protection given to people accessing a defined area around the enclosure of switchgear and controlgear

3.135.2
classified sides
characteristic related to the accessible sides having a defined level of protection of persons given by the enclosure of the switchgear and controlgear in the event of internal arc

3.135.3
arc fault current
three-phase and – where applicable – the single phase-to-earth r.m.s. value of the internal arc fault current for which the switchgear and controlgear is designed to protect persons in the event of an internal arc

3.135.4
arc fault duration
duration of the internal arc fault current for which the switchgear and controlgear is designed to protect persons in the event of an internal arc

3.136
degree of protection
extent of protection provided by an enclosure, partition or shutter if applicable against access to hazardous parts, against ingress of solid foreign objects and/or ingress of water and verified by standardized test methods

[SOURCE: IEC 60529:1989, 3.3, modified – modification of the wording]

3.137
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

Note 1 to entry: Refer to Clause 4 for individual rated values.

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

3.138
disruptive discharge
phenomena associated with the failure of insulation under electric stress, in which the discharge completely bridges the insulation under test, reducing the voltage between the electrodes to zero or nearly to zero

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

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

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

3.139
electric shock
physiological effect resulting from an electric current through a human or animal body

[SOURCE: IEC 60050-195:1998, 195-01-04]

3.140
protection category against electric shock
category of protection of the accessible solid insulating surfaces against electric shock

Note 1 to entry: This protection category against electric shock is treated separately from the degree of protection, as defined in 3.136

3.140.1
protection category PA
Category of protection against electric shock in which the insulation consists of at least one layer of solid insulating material

3.140.2
protection categories PB
categories of protection against electric shock in which the insulation consists of at least one extra layer to the protection category PA layer

Note 1 to entry: Two different designs for category PB are recognized, PB1 and PB2.

Note 2 to entry: The extra layer is added as a safeguard for touching, even in case the protection category PA insulation is damaged.

3.140.2.1
protection category PB1
category of protection against electric shock in which an extra insulation layer is added to the category PA insulation

Note 1 to entry: One layer can consist of an insulating fluid.

3.140.2.2
protection category PB2
category of protection against electric shock in which an earthed conductive layer with resistance less than 100 mΩ is added to the category PA insulation

Note 1 to entry: The resistance less than 100 mΩ is defined between the accessible points of the conductive layer to the earthing point provided.

3.2 Index of definitions

R, S & T

rated value	**3.137**
relative pressure	**3.122**
removable part	**3.127**
removed position	**3.133**
segregation	**3.113**
service position	**3.129**
shutter	**3.112**
solid insulating enclosure	**3.107**
solid-insulation embedded component	**3.116**
solid-insulation enclosed switchgear and controlgear	**3.103**
switchgear and controlgear	**3.101**
test position	**3.131**
tool-based accessible compartment	**3.108.3**
transport unit	**3.106**
type of accessibility	**3.135.1**

W

withdrawable part	**3.128**

4 Ratings

Clause 4 of IEC 62271-1:2007 is applicable, with the following addition:

The ratings of solid-insulation enclosed switchgear and controlgear are the following:

a) rated voltage (U_r) and number of phases;
b) rated insulation level;
c) rated frequency (f_r);
d) rated normal current (I_r) (for main circuits);
e) rated short-time withstand current (I_k, I_{ke}) (for main and earthing circuits);
f) rated peak withstand current (I_p, I_{pe}), if applicable (for main and earthing circuits);
g) rated duration of short circuit (t_k, t_{ke}) (for main and earthing circuits);
h) rated values of the components forming part of the solid-insulation enclosed switchgear and controlgear including their operating devices and auxiliary equipment;
i) rated filling level (of fluid-filled compartments);
j) ratings of the internal arc classifications (IAC), if assigned by manufacturer.

4.1 Rated voltage (U_r)

Subclause 4.1 of IEC 62271-1:2007 is applicable, except as follows.

NOTE Components forming part of solid-insulation enclosed switchgear and controlgear can have individual values of rated voltage in accordance with their relevant standards.

4.1.2 Range II for rated voltages above 245 kV

Subclause 4.1.2 of IEC 62271-1:2007 is not applicable.

4.2 Rated insulation level

Subclause 4.2 of IEC 62271-1:2007 is applicable.

4.3 Rated frequency (f_r)

Subclause 4.3 of IEC 62271-1:2007 is applicable.

4.4 Rated normal current and temperature rise

4.4.1 Rated normal current (I_r)

Subclause 4.4.1 of IEC 62271-1:2007 is applicable with the following addition:

Some main circuits of solid-insulation enclosed switchgear and controlgear (for example, busbars, feeder circuits) may have differing values of rated normal current.

4.4.2 Temperature rise

Subclause 4.4.2 of IEC 62271-1:2007 is applicable with the following addition:

The temperature rise of solid-insulation enclosed switchgear and controlgear containing components which are subject to individual specifications shall not cause these components to exceed the temperature limits permitted in the relevant standard for those components.

The maximum permissible temperatures and temperature rises to be taken into account for busbars are those specified for contacts, connections and metal parts in contact with insulation, as the case may be.

The temperature rise for accessible enclosures and covers shall not exceed 30 K for metal surfaces and 40 K for solid insulating and semi-conductive surfaces. In the case of enclosures and covers that are accessible but need not be touched during normal operation, the temperature-rise limit may be increased by 10 K.

4.5 Rated short-time withstand current (I_k)

For the rated short-time withstand currents I_k and I_{ke}, 4.5 of IEC 62271-1:2007 is applicable with the following additions:

Additional subclauses:

4.5.101 Rated short-time withstand current (I_k)

NOTE In principle, the rated short-time withstand current of a main circuit cannot exceed the corresponding rated values of the weakest of its series connected components. However, for each circuit or high-voltage compartment, advantage can be taken of apparatus limiting the short-circuit current, such as current-limiting fuses, reactors, etc.

4.5.102 Rated short-time phase to earth withstand current (I_{ke})

A rated short-time withstand phase to earth current shall be assigned to the earthing circuit (I_{ke}). This value may differ from that of the main circuit.

NOTE The short-circuit current ratings applicable to the earthing circuit depend upon the type of system neutral earthing for which it is intended. See 8.106.

4.6 Rated peak withstand current (I_p)

Subclause 4.6 of IEC 62271-1:2007 is applicable with the following additions:

Additional subclauses:

4.6.101 Rated peak withstand current (I_p)

NOTE In principle, the rated peak withstand current of a main circuit cannot exceed the corresponding rated values of the weakest of its series connected components. However, for each circuit or high-voltage compartment, advantage can be taken of apparatus limiting the short-circuit current, such as current-limiting fuses, reactors, etc.

4.6.102 Rated peak phase to earth withstand current (I_{pe})

A rated peak withstand phase to earth current shall be assigned to the earthing circuit (I_{pe}). This value may differ from that of the main circuit.

4.7 Rated duration of short circuit (t_k)

Subclause 4.7 of IEC 62271-1:2007 is applicable with the following additions:

Additional subclauses:

4.7.101 Rated duration of short circuit (t_k)

NOTE In principle, the rated duration of short circuit for a main circuit cannot exceed the corresponding rated value of the weakest of its series connected components. However, for each circuit or high-voltage compartment, advantage can be taken of apparatus limiting the duration of the short-circuit current, such as current-limiting fuses.

4.7.102 Rated duration of phase to earth short circuit (t_{ke})

A rated duration of phase to earth short circuit shall be assigned to the earthing circuit (t_{ke}). This value may differ from that of the main circuit.

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

Subclause 4.8 of IEC 62271-1:2007 is applicable.

4.9 Rated supply frequency of closing and opening devices and of auxiliary circuits

Subclause 4.9 of IEC 62271-1:2007 is applicable.

4.10 Rated pressure of compressed gas supply for controlled pressure systems

Subclause 4.10 of IEC 62271-1:2007 is applicable.

4.11 Rated filling levels for insulation and/or operation

Subclause 4.11 of IEC 62271-1:2007 is applicable, except as follows.

Additional subclauses:

4.101 Ratings of the internal arc classification (IAC)

4.101.1 General

If an IAC classification is assigned by the manufacturer, several ratings shall be specified. These ratings are subdivided into type of accessibility, classified sides, arc fault currents and arc fault durations.

4.101.2 Types of accessibility

One type of accessibility to the enclosure of solid-insulation enclosed switchgear and controlgear at the site of installation is defined:

Accessibility Type A: restricted to authorized personnel only.

NOTE IAC classification as defined in this Standard does not apply to opened compartments and to arc protection between compartments. IEEE C.37.20.7 addresses these topics in Suffix B designation for opened low-voltage compartments and in Suffix C designation for arc protection between compartments; refer to [12] of Bibliography.

4.101.3 Classified sides

For accessibility type A the sides of the enclosure which meet the criteria of the internal arc test are designated as

F for front side
L for lateral side
R for rear side

The front side shall be clearly stated by the manufacturer.

4.101.4 Rated arc fault currents (I_A, I_{Ae})

The standard value of rated arc fault currents should be selected from the R 10 series specified in IEC 60059; refer to [3] of Bibliography

Two ratings of the arc fault currents are recognised:

a) three-phase arc fault current (I_A),

b) single phase-to earth arc fault current (I_{Ae}), when applicable.

When only a three-phase rating is specified, the single phase rating is by default 87 % of the three-phase rating, and need not be specified.

NOTE 1 The manufacturer specifies the compartments to which the single phase-to earth arc fault current rating applies. Such value is assigned to switchgear and controlgear where its construction will prevent the arc from becoming multiphase, as demonstrated during the internal arc test.

NOTE 2 Rationale for this 87 % is the arc fault test with 2-phase ignition; refer to AA.5.2

In the case where all high-voltage compartments are only designed for single phase-to-earth arc faults, I_A rating shall not be assigned (refer to AA.5.2).

NOTE 3 Information about the relationship between type of neutral earthing and the single phase-to-earth arc fault current is provided in 8.104.6.

4.101.5 Rated arc fault duration (t_A, t_{Ae})

Standard recommended values for the three-phase arc fault duration (t_A) are 0,1 s, 0,5 s and 1 s.

If applicable, the test duration (t_{Ae}) of the single phase-to-earth arc fault shall be stated by the manufacturer.

NOTE It is in general not possible to calculate the permissible arc duration for a current which differs from that used in the test.

4.102 Rated cable test voltages

4.102.1 General

If switchgear is designed to allow the dielectric testing of cables while the cables are connected to the switchgear, one or more rated cable test voltages shall be assigned by the manufacturer.

4.102.2 Rated power-frequency cable test voltage U_{ct} (a.c.)

The rated power frequency cable test voltage is the maximum a.c. test voltage that may be applied to cables when connected to the switchgear and controlgear, which may be in service.

4.102.3 Rated d.c. cable test voltage U_{ct} (d.c.)

The rated d.c. cable test voltage is the maximum d.c. test voltage that may be applied to cables when connected to the switchgear and controlgear, which may be in service.

NOTE A rated d.c. cable test voltage can be considered to also apply for very low frequency testing (e.g. 0,1 Hz). Guidance can be found in IEEE 400.2; refer to [13] of Bibliography

5 Design and construction

Clause 5 of IEC 62271-1:2007 is applicable, with the following addition:

Solid-insulation enclosed switchgear and controlgear shall be designed so that the following operations can be carried out safely:

– normal service, inspection and maintenance,
– determination of the energized or de-energized state of the main circuit, including the checking of phase sequence,
– earthing of connected cables, locating of cable faults, voltage tests on connected cables or other apparatus and the elimination of dangerous electrostatic charges.

For solid-insulation enclosed switchgear and controlgear it is necessary to take into account condensation and humidity conditions because such equipment has to be safe for persons touching it, not only in a dry state, but also with condensation on solid insulating surfaces.

All removable parts and components of the same type, rating and construction shall be mechanically and electrically interchangeable.

Removable parts and components of equal or greater current and insulation ratings may be installed in place of removable parts and components of equal or lesser current and insulation ratings where the design of these removable parts and components and compartment allows mechanical interchange ability. This does not generally apply for current-limiting devices.

NOTE Installing a removable part or component of a higher rating does not necessarily increase the capabilities of a functional unit or imply the functional unit is capable of operation at the increased ratings of the removable part or component.

The various components within the solid insulating enclosure are subject to the individual specifications applying to them.

For main circuits with current-limiting fuses, the manufacturer of the switchgear and controlgear may assign the maximum peak and Joule integral of the let-through current of the fuses to the main circuit downstream of the fuse.

5.1 Requirements for liquids in switchgear and controlgear

Subclause 5.1 of IEC 62271-1:2007 is applicable.

5.2 Requirements for gases in switchgear and controlgear

Subclause 5.2 of IEC 62271-1:2007 is applicable.

NOTE For handling of SF_6, refer to IEC/TR 62271-4. ([10] of Bibliography) .

5.3 Earthing of switchgear and controlgear

Subclause 5.3. of IEC 62271-1:2007 is applicable with the following additions:

Additional subclauses:

5.3.101 Earthing of the high-voltage conductive parts

To ensure personnel protection during maintenance work, all of the high-voltage conductive parts to which access is required or provided shall be capable of being earthed prior to becoming accessible. This does not apply to removable parts from which the high-voltage conductive parts become accessible after being separated from the switchgear and controlgear.

5.3.102 Earthing of the enclosure

If the enclosure has conductive layers intended to be earthed, there are two options:

– for category PA and PB1, the resistance to the earthing point provided is not prescribed;
– for category PB2, the resistance from any position on these conductive layers shall not exceed 100 mΩ resistance (at 30 A d.c.) to the earthing point provided.

5.3.103 Earthing of earthing devices

Where earthing connections have to carry the full three-phase short-circuit current (as in the case of the short-circuiting connections used for earthing devices), these connections shall be dimensioned accordingly.

5.3.104 Earthing of withdrawable and removable parts

The normally earthed metallic parts of a withdrawable part shall remain connected to earth in the test and disconnected positions and in any intermediate position. Connections to earth in any position shall not exceed 100 mΩ resistance (at 30 A d.c.) to the earthing point provided.

On insertion, the normally earthed metallic parts of a removable part shall be connected to earth prior to the making of the contacts of the fixed and removable parts of the main circuit.

If the withdrawable or removable part includes any earthing device, intended to earth the main circuit, then the earthing connection in the service position shall be considered as part of the earthing circuit with associated rated values (4.5, 4.6 and 4.7).

5.3.105 Earthing circuit

An earthing conductor shall be provided extending the whole length of the solid-insulation enclosed switchgear and controlgear. The earthing conductor shall be capable of carrying the rated short time and peak phase to earth withstand currents from each functional unit to the terminal which is intended for connection to the earth system of the installation. Its cross-section shall be not less than 30 mm^2.

NOTE 1 The current density in the earthing conductor, if of copper, does not exceed 200 A/mm^2 for a rated duration of short circuit of 1 s, and 125 A/mm^2 for a rated duration of short circuit of 3 s under the specified earth-fault conditions.

NOTE 2 A method of calculating cross-sectional areas of conductors is given in IEC 60724; refer to [6] of Bibliography.

The earthing circuit is normally designed to withstand one occurrence of a single short-circuit fault, and maintenance could be needed after such an event; refer also to 8.106.

5.4 Auxiliary and control equipment

Subclause 5.4 of IEC 62271-1:2007 is applicable.

5.5 Dependent power operation

Subclause 5.5 of IEC 62271-1:2007 is applicable.

5.6 Stored energy operation

Subclause 5.6 of IEC 62271-1:2007 is applicable.

5.7 Independent manual or power operation (independent unlatched operation)

Subclause 5.7 of IEC 62271-1:2007 is applicable.

5.8 Operation of releases

Subclause 5.8 of IEC 62271-1:2007 is applicable.

5.9 Low- and high-pressure interlocking and monitoring devices

Subclause 5.9 of IEC 62271-1:2007 is applicable.

5.10 Nameplates

Subclause 5.10 of IEC 62271-1:2007 is applicable with the following additions:

Solid-insulation enclosed switchgear and controlgear shall be provided with durable and clearly legible nameplates which shall contain the information in accordance with Table 101.

The information according to Table 101, of the complete switchgear and controlgear shall be legible during normal service. If applicable, one common nameplate for the complete switchgear and controlgear may apply with the general information, with a separate nameplate for each functional unit, containing the specific information.

Detailed information of the fixed components applied need not to be legible during normal service.

Nameplates for removable parts, need only be legible in the removed position.

Table 101 – Nameplate information

	Symbol	Unit	(**)	Condition: Marking only required if
(1)	(2)	(3)	(4)	(5)
Manufacturer			X	
Manufacturer's type designation			X	
Serial number			X	
Instruction book reference			X	
Year of manufacture			X	
Applicable standard			X	
Rated voltage	U_r	kV	X	
Rated frequency	f_r	Hz	X	
Rated lightning impulse withstand voltage	U_p	kV	X	
Rated power frequency withstand voltage	U_d	kV	X	
Rated power-frequency cable test voltage	U_{ct} (a.c.)	kV	(X)	
Rated d.c. cable test voltage	U_{ct} (d.c.)	kV	(X)	
Rated normal current	I_r	A	X	
Rated short-time withstand current	I_k	kA	X	
Rated peak withstand current	I_p	kA	Y	Different from 2,5 for 50 Hz and 2,6 for 60 Hz
Rated duration of short circuit	t_k	s	X	
Rated short-time withstand current for earthing circuits	I_{ke}	kA	Y	Different from I_k (main circuit)
Rated peak withstand current for earthing circuits	I_{pe}	kA	Y	Different from I_p (main circuit) and different from 2,5 I_{ke} for 50 Hz and 2,6 I_{ke} for 60 Hz
Rated duration of short circuit for earthing circuits	t_{ke}	s	Y	Different from t_k (main circuit)
Mass of solid insulating material		kg	X	
Rated filling level for insulation (*)	p_{re}	kPa, MPa or kg	(X)	
Alarm level for insulation (*)	p_{ae}	kPa, MPa or kg	(X)	
Minimum functional level for insulation (*)	p_{me}	kPa, MPa or kg	(X)	
Loss of Service Continuity category	LSC		X	
Insulating fluid and mass		kg	(X)	
Internal arc classification	IAC		(X)	
Type of accessibility		A	(X)	
Classified sides		F,L,R	(X)	
Arc fault current and duration	I_A, t_A	kA, s	(X)	
Single phase to earth arc fault current and duration	I_{Ae}, t_{Ae}	kA, s	Y	IAC is assigned and I_{Ae} differs from 87 % of I_A
(*) Absolute pressure (abs.) or relative pressure (rel.) to be stated (**) X = the marking of these values is mandatory; (X) = the marking of these values is as applicable; Y = conditions for the marking of these values are given in column (5).				
NOTE 1 The symbol in column (2) can be used instead of the terms in column (1). NOTE 2 When terms in column (1) are used, the word "rated" need not appear.				

5.11 Interlocking devices

Subclause 5.11 of IEC 62271-1:2007 is applicable with the following additions:

Interlocks between different components of the equipment are provided for reasons of protection and for convenience of operation. Interlocks shall not be damaged by attempted incorrect operations of any associated switching devices under the conditions specified in 6.102.2. The following provisions are mandatory for main circuits:

a) Solid-insulation enclosed switchgear and controlgear with removable parts:

   The withdrawal or engagement of a circuit-breaker, switch or contactor shall be prevented unless it is in the open position.

   The operation of a circuit-breaker, switch or contactor shall be prevented unless it is in the service, disconnected, removed, test or earthing position.

   The interlock shall prevent the closing of the circuit-breaker, switch or contactor in the service position unless all auxiliary circuits associated with the automatic opening of these devices are connected. Conversely, it shall prevent the disconnection of any auxiliary circuits with the circuit-breaker closed in the service position.

b) Solid-insulation enclosed switchgear and controlgear provided with disconnectors:

   Interlocks shall be provided to prevent operation of disconnectors under conditions other than those for which they are intended (refer to IEC 62271-102). The operation of a disconnector shall be prevented unless the circuit-breaker, switch or contactor is in the open position.

   NOTE 1 This rule can be disregarded if it is possible to have a busbar transfer in a double busbar system without current interruption.

   The operation of the circuit-breaker, switch or contactor shall be prevented unless the associated disconnector is in the closed, open or earthing position (if provided).

   The provision of additional or alternative interlocks shall be subject to agreement between manufacturer and user. The manufacturer shall give all necessary information on the character and function of interlocks.

   Earthing switches having a rated short-circuit making capacity less than the rated peak withstand current of the main circuit should be interlocked with the associated disconnector or main switching device in opened position.

   Apparatus installed in main circuits, the incorrect operation of which can cause damage or which are used for securing isolating distances during maintenance work, shall be provided with locking facilities (for example provision for padlocks).

   If earthing of a circuit is provided by the main switching device (circuit-breaker, switch or contactor) in series with an earthing switch, the earthing switch shall be interlocked with the main switching device. Provision shall be made for the main switching device to be secured against unintentional opening, for example, by disconnection of tripping circuits and blocking of the mechanical trip.

   NOTE 2 Instead of an earthing switch, any other device in its earthing position is possible.

   If non-mechanical interlocks are provided, the design shall be such that no improper situations can occur in case of lack of auxiliary supply. However, for emergency control, the manufacturer may provide additional means for manual operation without interlocking facilities. In such case, the manufacturer shall clearly identify this facility and define the procedures for operation.

5.12 Position indication

Subclause 5.12 of IEC 62271-1:2007 is applicable with the following addition.

In addition, for all devices involved in disconnecting and earthing functions, subclause 5.104.3 of IEC 62271-102:2001 is applicable.

5.13 Degrees of protection provided by enclosures

Subclause 5.13 of IEC 62271-1:2007 is applicable.

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

Subclause 5.13.1 of IEC 62271-1:2007 is applicable with the following addition:

Specific requirements are specified in 5.102 and 5.103.

5.13.2 Protection against ingress of water (IP coding)

Subclause 5.13.2 of IEC 62271-1:2007 is applicable.

5.13.3 Protection of equipment against mechanical impact under normal service conditions (IK coding)

Subclause 5.13.3 of IEC 62271-1:2007 is applicable with the following addition.

The minimum impact level is IK06 to IEC 62262 (1 J).

5.14 Creepage distances for outdoor insulators

Subclause 5.14 of IEC 62271-1:2007 is not applicable.

5.15 Gas and vacuum tightness

Subclause 5.15 of IEC 62271-1:2007 is applicable with the following addition:

Refer to 5.103.2.3.

5.16 Liquid tightness

Subclause 5.16 of IEC 62271-1:2007 is applicable with the following addition:

Refer to 5.103.2.3.

5.17 Fire hazard (flammability)

Subclause 5.17 of IEC 62271-1:2007 is applicable.

5.18 Electromagnetic compatibility (EMC)

Subclause 5.18 of IEC 62271-1:2007 is applicable.

5.19 X-ray emission

Subclause 5.19 of IEC 62271-1:2007 is applicable.

5.20 Corrosion

Subclause 5.20 of IEC 62271-1:2007 is applicable.

Additional subclauses:

5.101 Internal arc fault

Solid-insulation enclosed switchgear and controlgear that satisfy the requirements of this standard is designed and manufactured, in principle, to prevent the occurrence of internal arc faults. However, where internal arc classification is assigned, the switchgear and controlgear shall be designed to give a defined level of protection of persons in the event of an internal arc, when the switchgear and controlgear is in normal service condition.

If an internal arc classification is assigned by the manufacturer and verified by type tests according to 6.105, the classification shall be indicated by means of a designation as follows:

– Classification: IAC (Internal Arc Classified)
– Type accessibility: A
– Classified sides of the enclosure: F, L, R
– Rated three-phase arc fault values: current [kA] and duration [s]
– Rated single-phase arc fault values (where applicable): current [kA] and duration [s]

This designation shall be included in the nameplate (refer to 5.10)

Some examples for designations of the IAC classification are given in 8.104.6.

5.102 Solid insulating enclosure

5.102.1 General

The complete solid insulating enclosure as well as the materials used in the construction shall be capable of withstanding the mechanical, electrical and thermal stresses as well as the effects of humidity which are likely to be encountered under the specified service conditions.

When the solid-insulation enclosed switchgear and controlgear is installed, the enclosure shall provide at least the degree of protection IP 2X, according IEC 62271-1:2007, Table 7. The specified degree of protection shall be provided by the enclosure with all the doors and covers closed as under normal service conditions, independent of how these doors and covers are held in position.

The walls of a room shall not be considered as parts of the enclosure. The floor surface below the installed switchgear and controlgear may be considered as part of the enclosure. The measures to be taken in order to obtain the degree of protection provided by floor surfaces shall be given in the installation manual.

A higher degree of protection may be specified in accordance with IEC 60529.

Parts of the enclosure bordering non-accessible compartments shall be provided with a clear indication not to be dismantled.

The horizontal surfaces of enclosures, for example, roof plates, are normally not designed to support personnel or additional equipment not supplied as part of the assembly. If the manufacturer states that it is necessary to stand or walk upon the switchgear or controlgear during operation or maintenance, the design shall be such that the relevant areas will support the weight of the operator without undue distortion and the equipment will remain suitable for its purpose. In such case, those areas on the equipment where it is not safe to stand or walk, for example, pressure relief flaps, shall be clearly identified.

5.102.2 Protection category of the solid insulating enclosure against electric shock

The solid insulating enclosure shall provide protection of persons against electric shock when touching the enclosure or operating solid-insulation enclosed switchgear and controlgear in service conditions. The following two categories of protection are distinguished:

– Protection category PA with an insulation which meets all the requirements given in the items a) to d) of 5.102.3 is generally sufficient for those parts of the enclosure which are touched by persons only accidentally or inadvertently. The insulation may be supplied with a conductive layer.

NOTE The impedance to earth of the conductive layer for category PA is not specified, as the requirement of 5.102.3 d) applies.

– Protection category PB is considered as suitable for parts of the enclosure which are liable to be touched when operating, when replacing removable parts or when carrying out other normal maintenance work. Two different designs for category PB are distinguished:

- PB1 with an insulation which meets, in addition to those of protection category PA, the requirements given in item e) or f) of 5.102.3 as a safeguard in case the protection category PA insulation is damaged;
- PB2 with an insulation of protection category PA, supplied with an earthed conductive layer. This earthed conductive layer shall meet the requirements given in item g) of 5.102.3.

5.102.3 Requirements for protection categories

Reference is made to the informative Annex EE for clarification.

For protection category PA, the solid insulating enclosure shall meet the following requirements:

a) The insulation between parts of the main circuit and the accessible surface of the solid insulating enclosure of the total assembly shall be capable of withstanding the test voltages specified in 6.2.6 for dielectric tests to earth and between phases;

b) Apart from mechanical considerations, the thickness of the insulating material of solid insulating enclosures shall be sufficient to withstand the test voltages specified in item a). The methods specified in IEC 60243-1 may be applied;

c) The insulation between live parts of the main circuit and the inner surface of solid insulating partitions and shutters facing these shall withstand at least 150 % of U_r;

d) Capacitive and leakage currents shall not be greater than 0,5 mA under the specified test conditions (refer to 6.104.3). Leakage currents may reach the accessible side of the insulation by a continuous path over solid insulating surfaces or by a path broken only by small gaps of gas or liquid.

For protection category PB1, the requirements of protection category PA and one of the following additional requirements shall be met by the solid insulating enclosure.

e) The solid insulating enclosure shall consist of at least two layers of insulating material, one of which shall comply with the requirements of item b). The other layer shall be able to withstand only a 1 min power-frequency test voltage equal to 150 % of U_r. It shall not be possible to remove the additional insulation without the aid of a tool;

f) The solid insulating enclosure contains an insulation fluid. In these cases, it shall be ensured that the insulation of the main circuit with respect to the internal surface of the solid insulating enclosure is capable of withstanding a 1 min power-frequency test voltage equal to 150 % of U_r, even when the gaseous or liquid insulation fluid is replaced by ambient air at normal atmospheric pressure.

NOTE 1 In this case, the extra requirement for PB protection is achieved on the inside of the PA protection. Refer also to Figure EE.2b.

For protection category PB2, the requirements of protection category PA and the following additional requirement shall be met.

g) The resistance of the earthed conductive layer shall be maximum 100 mΩ (at 30 A d.c.) to the earthing point provided.

NOTE 2 If the category PB2 is complete for the whole switchgear, IEC 62271-200 is applicable.

NOTE 3 If the resistance of the earthed conductive layer to the earthing point provided is higher than 100 mΩ (at 30 A d.c.) category PA is applicable.

5.102.4 Covers and doors

When covers and doors that are part of the enclosure are closed, they shall provide the degree of protection specified for the solid insulating enclosure.

When ventilating openings, vent outlets or inspection windows are incorporated in the cover or door, reference is made to 5.102.6 or to 5.102.7.

Covers or doors that exclusively give access to compartments which are not high-voltage compartments (e.g. low-voltage control compartment, or possible mechanism compartment), are not subject to this subclause.

Several categories of covers or doors are recognized with regard to the type of high-voltage accessible compartments they provide access to:

a) Covers or doors that give access to tool-based accessible compartments.

   These covers or doors (fixed covers) need not be opened for the normal purposes of operation and/or maintenance as stated by the manufacturer. It shall not be possible for them to be opened, dismantled or removed without the use of tools;

   NOTE 1 They are opened only when precautions to ensure electrical safety have been taken.

   NOTE 2 Attention is paid to the requirement (if any) to carry out operation of the switching devices without voltage/current on the main circuit with doors and covers open as part of the maintenance procedures.

b) Covers or doors that give access to interlock-controlled accessible or procedure-based accessible compartments.

   These covers or doors shall be provided if there is a need to access the compartment for normal operation and/or normal maintenance as stated by the manufacturer. These covers or doors shall not require tools for their opening or removal and shall have the following features.

   – Interlock controlled accessible compartments:

     These shall be provided with interlocking devices so that opening of the compartment shall only be possible when the part of the main circuit contained in the compartment being made accessible is dead and earthed, or in the disconnected position with corresponding shutters closed;

   – Procedure-based accessible compartments:

     These shall be provided with provision for locking, for example, padlocking.

     NOTE 3 Suitable procedures are put in place by the user to ensure that a procedure-based accessible compartment can be opened only when the high-voltage parts contained in the compartment being made accessible is dead and earthed, or in the disconnected position with corresponding shutters closed. Procedures can be dictated by legislation of the country of installation or by user safety documentation.

     NOTE 4 If interlock-controlled or procedure-based accessible compartments have other covers that can be opened by tools, proper procedures or specific warning labels can be applicable.

5.102.5 Partition or shutter being part of the enclosure

If partitions or shutters become part of the enclosure with the removable part in any of the positions defined in 3.130 to 3.133, they shall provide the degree of protection specified for the enclosure. In this case shutters also shall meet the requirements specified for protection category PB, if liable to be touched.

In this respect it may be noted:

– a partition or shutter becomes a part of the enclosure, if it is accessible in any of the positions defined in 3.130 to 3.133 and if no door is provided which can be closed in the positions defined in 3.129 to 3.133;
– if a door is provided which can be closed in the positions defined in 3.129 to 3.133 the partition or shutter behind the door is not considered to be a part of the enclosure.

5.102.6 Inspection windows

Inspection windows shall provide at least the degree of protection specified for the enclosure.

Inspection windows shall be covered by transparent sheets of mechanical strength comparable to that of the solid insulating enclosure. They shall meet at least the requirements of solid insulating enclosures specified for protection category PB.

5.102.7 Ventilating openings, vent outlets

Ventilating openings and vent outlets shall be so arranged or shielded that the same degree of protection as that specified for the solid insulating enclosure is obtained. Such openings may make use of wire mesh or the like provided that it is of suitable mechanical strength.

Ventilating openings and vent outlets shall be arranged in such a way that gas or vapour escaping under pressure does not endanger the operator.

5.103 High-voltage compartments

5.103.1 General

A high-voltage compartment shall be designated by the main component contained therein, for example, circuit-breaker compartment, busbar compartment, or by the main functionality provided, for example connection compartment, etc.

Where cable terminations are contained in a compartment with other main components (for example, circuit-breaker, busbars, etc.) then the designation shall primarily be that of the other main component.

NOTE Compartments can be further identified according to the several components enclosed, for example, connection /CT compartment, etc.

Compartments may be of various types, for example:

– air insulated;
– liquid-filled (see 5.103.2);
– gas-filled (see 5.103.2).

Openings necessary for interconnection between compartments shall be closed with bushings or other equivalent means.

Busbar compartments may extend through several functional units without the need for bushings or other equivalent means. However, in case of LSC2 equipment (see 8.103.3), separate compartments shall be provided for each set of busbars, for example, in double busbar systems and for sections of switchable or disconnectable busbars.

High-voltage parts with solid insulating material, that are intended to remain live when accessing the high-voltage compartment, shall comply with 5.102.2.

5.103.2 Fluid-filled compartments (gas or liquid)

5.103.2.1 General

Compartments shall be capable of withstanding the normal and transient pressures to which they are subjected in service.

Gas-filled compartments, when permanently pressurized in service, are subjected to particular conditions of service which distinguish them from compressed air receivers and similar storage vessels. These conditions are as follows:

– gas-filled compartments are normally filled with a non-corrosive gas, thoroughly dried, stable and inert; since measures to maintain the gas in this condition with only small fluctuations in pressure are fundamental to the operation of the switchgear and controlgear and since the compartments will not be subjected to internal corrosion, there is no need to make allowances for these factors in determining the design of the compartments;

– the design pressure is below, or equal to, 300 kPa (relative pressure).

5.103.2.2 Design

The design of a fluid-filled compartment shall be based on the nature of the fluid, the design temperature and, when applicable, on the design level as defined in this standard.

The design temperature of the fluid-filled compartment is generally the upper limit of ambient air temperature increased by the temperature rise of the fluid due to the flow of rated normal current. The design pressure of the compartment shall not be less than the upper limit of the pressure reached within the compartment at the design temperature and under the installation conditions as defined in Clause 2.

Fluid-filled compartments shall withstand:

a) the full differential pressure possible across the compartment walls or partitions, including any evacuation process if used during filling or maintenance operations;

b) the resulting pressure in the event of an accidental leak between the compartments in the case of adjacent compartments having different service pressures.

5.103.2.3 Tightness

The manufacturer shall state the pressure system used and the permissible leakage rate for the fluid-filled compartments (refer to 5.15 and 5.16 of IEC 62271-1:2007). This shall take into account the relative limits fixed in Table 13 of IEC 62271-1:2007 for temporarily increased leakage rates at temperatures other than 20 ºC.

If requested by the user, in order to permit entry to a fluid-filled compartment of closed or controlled pressure systems, the permissible leakage across partitions should also be stated by the manufacturer.

For gas-filled compartments where the minimum functional level exceeds 100 kPa (relative pressure), an indication should be provided when the pressure at 20 °C has fallen below the minimum functional level (refer to 3.123).

A partition, separating a compartment filled with insulating gas from a neighbouring compartment filled with liquid shall not show any leakage affecting the dielectric properties of the two media.

5.103.2.4 Pressure relief of fluid-filled compartments

Where pressure-relief devices or designs are provided, they shall be arranged so as to minimize the danger to maintenance personnel and operators during the time that they are performing normal operating duties if gases or vapours are escaping under pressure. The pressure-relief devices shall not operate below 1,3 times the design pressure. The pressure-relief device may be a designed, for example, weak area of the compartment or a dedicated device, for example, a bursting disc.

5.103.3 Partitions and shutters

For the purpose of this standard, only class PI is defined for partitions and shutters between opened compartments and live parts of the main circuit, refer to 3.111.

Partitions and shutters shall provide at least the degree of protection IP2X according to IEC 62271-1:2007, Table 7.

Conductors passing through partitions shall be provided with bushings or other equivalent means to provide the required IP level.

Openings in the enclosure of solid-insulation enclosed switchgear and controlgear and in the partitions of compartments through which contacts of removable or withdrawable parts engage fixed contacts shall be provided with automatic shutters operated in normal service operations to assure the protection of persons in any of the positions defined in 3.129 to 3.133. Means shall be provided to ensure the reliable operation of the shutters, for example, by a mechanical drive, where the movement of the shutters is positively driven by the movement of the removable or withdrawable part.

The status of shutters may not in all situations be readily confirmed from an open compartment, (for example, cable compartment open but shutters mounted in breaker compartment). In such situations, verification of the shutter status may require access to the second compartment or provision of a inspection window or reliable indicating device.

If, for maintenance or test purposes, there is a requirement that one or more sets of fixed contacts shall be accessible through opened shutters, the shutters shall be provided with means of locking each set independently in the closed position. When, for maintenance or test purposes, the automatic closing of shutters is made inoperative in order to retain them in the open position, it shall not be possible to return the switching device to the service position until the automatic operation of the shutters is restored. This restoration may be achieved by the action of returning the switching device to the service position.

It may be possible to use a temporary inserted partition to prevent the live set of fixed contacts being exposed (refer to 10.4).

Partitions and shutters shall meet the following requirements:

a) the insulation between high-voltage live parts and the accessible surface of solid insulating partitions and shutters shall withstand the test voltages specified in 4.2 of IEC 62271-1:2007 for voltage tests to earth and between poles;

b) the solid insulating material shall withstand the power-frequency test voltage specified in item a). The appropriate test methods given in IEC 60243-1 should be applied; refer to [4] of Bibliography;

c) the insulation between high-voltage live parts and the inner surface of solid insulating partitions and shutters facing these shall withstand at least 150 % of U_r;

d) if a leakage current may reach the accessible side of the solid insulating partitions and shutters by a continuous path over insulating surfaces or by a path broken only by small gaps of gas or liquid, it shall be not greater than 0,5 mA under the specified test conditions (refer to 6.104.3).

If partitions or shutters become part of the enclosure, refer to 5.102.5.

5.104 Removable parts

Removable parts for ensuring the isolating distance (in removed position) between the high-voltage conductors shall comply with IEC 62271-102, except for mechanical operation tests (refer to 6.102 and 7.102). This disconnection facility is intended for maintenance purposes only.

If removable parts are intended to be used as a disconnector or intended to be removed and replaced more often than only for maintenance purposes, then testing shall also include the mechanical operation tests according to IEC 62271-102.

The requirement that it shall be possible to know the operating position of the disconnector or earthing switch is met if one of the following conditions is fulfilled:

– the isolating distance is visible;
– the position of the withdrawable part, in relation to the fixed part, is clearly visible and the positions corresponding to full connection and full isolation are clearly identified;
– the position of the withdrawable part is indicated by a reliable indicating device.

NOTE Refer to IEC 62271-102 and also to Annex CC.

Any removable part shall be so attached to the fixed part that its contacts will not open inadvertently due to forces which may occur in service, in particular those due to a short circuit.

In IAC classified switchgear and controlgear, the transfer of withdrawable parts to or from the service position shall not reduce the specified level of protection in the event of an internal arc. This is achieved, for example, when the operation is only possible when doors and covers intended to ensure personnel protection are closed. Other design measures providing equivalent level of protection are acceptable.

5.105 Provisions for dielectric tests on cables

Solid-insulation enclosed switchgear and controlgear may be designed to allow the testing of cables while they are connected to the switchgear and controlgear. This may be performed either from a dedicated test connection, or from the cable terminations. The switchgear and controlgear shall then be capable of withstanding the rated cable test voltage(s) as specified in 4.102 applied to those parts which remain connected to the cable, at the same time as the rated voltage is applied to those parts of the main circuit designed to remain live during testing cables.

6 Type tests

Clause 6 of IEC 62271-1:2007 is applicable, with the following addition:

6.1 General

Subclause 6.1 of IEC 62271-1:2007 is applicable with following modifications:

Components contained in solid-insulation enclosed switchgear and controlgear which are subject to individual specifications not covered by the scope of IEC 62271-1 shall comply with, and be tested in accordance with, those specifications, taking into account the following subclauses.

The type tests shall be made on a representative functional unit. Because of the variety of types, rating and possible combinations of components, it is not practicable to make type

tests with all arrangements of the switchgear and controlgear. The performance of any particular arrangement may be substantiated by test data of comparable arrangements.

A representative functional unit may take the form of one extensible unit, However, it may be necessary to bolt two or three of such units together.

The type tests and verifications comprise:

		Subclause
Mandatory type tests:		
a)	Tests to verify the insulation level of the equipment	6.2
b)	Test to prove the temperature rise of any part of the equipment and measurement of the resistance of circuits	6.5 and 6.4
c)	Tests to prove the capability of the main and earthing circuits to be subjected to the rated peak and the rated short-time withstand currents	6.6
d)	Tests to prove the making and breaking capacity of the included switching devices	6.101
e)	Tests to prove the satisfactory operation of the included switching devices and removable parts	6.102
f)	Tests to verify the IP protection code	6.7.1
g)	Tests to verify the protection of persons against electric shock	6.104
h)	Tests to evaluate the insulation of the equipment by the measurement of partial discharges	6.2.9
i)	Tests to verify auxiliary and control circuits	6.10
Mandatory type tests, where applicable:		
j)	Tests to verify the protection of the equipment against mechanical impact	6.7.2
k)	Tests to verify the strength of gas-filled compartments	6.103
l)	Tightness tests of gas- or liquid-filled compartments	6.8
m)	Tests to assess the effects of arcing due to an internal fault (for switchgear and controlgear classification IAC)	6.105
n)	Electromagnetic compatibility tests (EMC)	6.9
o)	X-radiation test procedures for vacuum interrupters	6.11
p)	Dielectric tests on cable testing circuits	6.2.101
q)	Tests to verify the thermal stability of solid insulating materials	6.106
r)	Tests to assess the effects of condensation on solid insulating surfaces	6.107

Type tests may impair the suitability of the tested parts for subsequent use in service. Therefore, specimens used for type test shall not be used in service without agreement between manufacturer and user.

6.1.1 Grouping of tests

Subclause 6.1.1 of IEC 62271-1:2007 is applicable with the following modification:

The mandatory type tests (not including items m), n), o), q) and r)) shall be carried out on a maximum of four test specimens.

6.1.2 Information for identification of specimens

Subclause 6.1.2 of IEC 62271-1:2007 is applicable.

6.1.3 Information to be included in type-test reports

Subclause 6.1.3 of IEC 62271-1:2007 is applicable with the following addition:

For the report regarding internal arc tests, refer to 6.105.6.

6.2 Dielectric tests

Subclause 6.2 of IEC 62271-1:2007 is applicable, unless otherwise stated in the subclauses below.

6.2.1 Ambient air conditions during tests

Subclause 6.2.1 of IEC 62271-1:2007 is applicable.

6.2.2 Wet test procedure

Subclause 6.2.2 of IEC 62271-1:2007 is not applicable.

6.2.3 Conditions of switchgear and controlgear during dielectric tests

Subclause 6.2.3 of IEC 62271-1:2007 is applicable with the following addition:

For solid-insulation enclosed switchgear and controlgear using fluid (liquid or gas) for insulation, dielectric tests shall be performed filled with the insulating fluid specified by the manufacturer, to the minimum functional level also specified by the manufacturer.

6.2.4 Criteria to pass the test

Subclause 6.2.4 of IEC 62271-1:2007 is applicable, with the following modification:

The second paragraph of item a) that refers to wet test is not applicable.

NOTE For fluid-filled compartments tested with test bushings that are not part of the switchgear and controlgear, impulses resulting in flashover across the test bushings are not considered as part of the test series.

6.2.5 Application of the test voltage and test conditions

Subclause 6.2.5 of IEC 62271-1:2007 is applicable with the following additions. Subclause 6.2.5.1 of IEC 62271-1:2007 is not applicable.

Because of the great variety of designs, it is not feasible to give specific indications of the tests to be performed on the main circuit, but, in principle, the power frequency – and lightning impulse voltage tests shall cover the following:

a) To earth and between phases

   The test voltages specified in 6.2.6 shall be applied connecting each phase conductor of the main circuit in turn to the high-voltage terminal of the test supply. All other conductors of the main circuit and the auxiliary circuits shall be connected to the earthing conductor and to the earth terminal of the test supply.

   The dielectric tests shall be made with all switching devices closed and all removable parts in their service position. Attention shall be given to the possibility that switching devices in their open position or removable parts in the disconnected, removed, test or earthing position, may result in less favourable field conditions. Under such conditions the

tests shall be repeated. However, the removable parts shall not be subjected to these voltage tests whilst they are in the disconnected, test or removed position.

For these tests, devices such as current transformers, cable terminations, overcurrent releases/indicators shall be installed as in normal service. For impulse voltage tests, the arrangements according to 6.2.6.2 are allowed. In case of doubt about the most unfavourable arrangement, tests shall be repeated with alternative configurations.

Earthed metal plates or foils shall be placed to simulate installation conditions with lowest clearances to e.g. floor and walls, as stated by the manufacturer.

In order to check compliance with the requirement of item a) of 5.102.3, the solid insulating enclosure as well as inspection windows, partitions and shutters of solid insulating material shall be covered, on the side(s) accessible during operation or maintenance, in the most unfavourable situation for the test, with a circular or square metal foil. This foil shall have an area as large as possible, but not exceeding 100 cm^2, which shall be connected to earth. In case of doubt about the most unfavourable situation, the test shall be repeated in different situations. This foil shall be applied on the external surface of the enclosure without protruding into small gaps. For convenience of testing, subject to agreement between manufacturer and user, more than one metal foil may be applied simultaneously or larger parts of the enclosure may be covered.

NOTE If a subassembly is tested, it should include joints of solid insulation-embedded components if these are used.

b) Across the isolating distance

Each isolating distance of the main circuit shall be tested using the test voltages specified in 6.2.6 according to the test procedures as stated in subclause 6.2.5.2 of IEC 62271-1:2007.

The isolating distance may be formed by

– a disconnector in open position;

– the distance between the two parts of the main circuit intended to be connected by a withdrawable or removable switching device.

If there is no segregation between the fixed part and the withdrawable part when an isolating distance is established, the test voltages specified for the isolating distance shall be applied in the following way: the withdrawable part shall be in whichever of the disconnected or test positions that creates the shortest distance between the fixed and movable contacts. The switching device of the withdrawable part shall be in the closed position. When it is not possible to have the switching device in the closed position (e.g. by interlocking), then two tests shall be performed as follows:

– with the withdrawable part in the position with shortest distances between the fixed and movable contacts and the switching device of the withdrawable part open;

– with the withdrawable part in the other defined position and the switching device closed.

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

Subclause 6.2.6 of IEC 62271-1:2007 is applicable with the following modifications.

The tests shall be performed with the applicable test voltages given in Table 1a or 1b of 4.2 of IEC 62271-1:2007. For test voltages to earth and between phases columns (2) and (4) shall be used. For test voltages across isolating distances columns (3) and (5) shall be used.

6.2.6.1 Power-frequency voltage tests

Subclause 6.2.6.1 of IEC 62271-1:2007 is applicable with the following provisions:

Switchgear and controlgear shall be subjected to short-duration power-frequency voltage withstand tests in accordance with IEC 60060-1. The test voltage shall be raised for each test condition to the test value and maintained for 1 min.

The tests shall be performed in dry conditions.

Instrument transformers, power transformers or fuses may be replaced by replicas reproducing the field configuration of the high-voltage connections. Overvoltage protective devices may be disconnected or removed. A transformer, a coil, or a similar device normally connected between phases shall be disconnected from the pole stressed with test voltage.

During the power-frequency voltage tests, one terminal of the test transformer shall be connected to the earthing terminal and to the metal foil or conducting cloth at the applicable points on the solid-insulation enclosed switchgear and controlgear. An exception is made for the situation where, during the tests in accordance with item b) of 6.2.5, the mid-point or another intermediate point of the voltage source should be connected to the earthing terminal in order that the voltage appearing between any of the live parts and the parts, intended to be earthed will not exceed the test voltage specified in item a) of 6.2.5.

If this is not practicable, one terminal of the test transformer may, with the agreement of the manufacturer, be connected to earth and the parts intended to be earthed of the switchgear and controlgear, shall, if necessary, be insulated from earth.

6.2.6.2 Lightning impulse voltage tests

Subclause 6.2.6.2 of IEC 62271-1:2007 is applicable with the following additions:

Instrument transformers, power transformers or fuses may be replaced by replicas reproducing the field configuration of the high-voltage connections.

Overvoltage protective devices shall be disconnected or removed. Current transformer secondary windings shall be short-circuited and earthed. Current transformers may have their primaries short-circuited too.

Procedure B of IEC 60060-1:2010 should be applied: Fifteen consecutive lightning impulses at the rated withstand voltage shall be applied for each test condition and each polarity. As an alternative, procedure C of IEC 60060-1:2010 may be applied. In this case the test consists of three consecutive impulses for each test condition and each polarity. This test procedure is referred to as the 3/9 method. The 3/9 method is accepted only when all three phases are tested.

It may be necessary for certain types of solid insulating material to eliminate residual charges before starting the tests with the opposite polarity.

During the lightning impulse voltage tests, the earthed terminal of the impulse generator shall be connected to the earthing terminal and to the metal foil or conducting cloth at the applicable points on the enclosure of the solid-insulation enclosed switchgear and controlgear, except that, during the tests in accordance with item b) of 6.2.5, the parts intended to be earthed shall, if necessary, be insulated from earth in order that the voltage appearing between any of the live parts and the parts, intended to be earthed will not exceed the test voltage specified in item a) of 6.2.5.

6.2.7 Tests of switchgear and controlgear of U_r >245 kV

Subclause 6.2.7 of IEC 62271-1:2007 is not applicable.

6.2.8 Artificial pollution tests for outdoor insulators

Subclause 6.2.8 of IEC 62271-1:2007 is not applicable.

6.2.9 Partial discharge tests

Subclause 6.2.9 of IEC 62271-1:2007 is applicable with the following additions:

The tests shall be according to Annex BB.

This test shall be made after the lightning impulse and power-frequency voltage tests. Instrument transformers, power transformers or fuses may be replaced by replicas reproducing the field configuration of the high-voltage connections.

NOTE In the case of designs consisting of a combination of conventional components (for instance, instrument transformers, bushings) that can be tested separately in accordance with their relevant standards, the purpose of this partial discharge test is to check the arrangement of the components in the assembly.

This test may be carried out on assemblies or subassemblies. Care should be taken that external partial discharges do not affect the measurement.

Additional subclause:

6.2.9.101 Maximum permissible partial discharge intensity

The maximum permissible partial discharge intensity shall not exceed 20 pC for each functional unit, at 1,1 U_r phase-to-phase voltage, see Table BB.1.

NOTE For systems with no solidly earthed neutral, no maximum partial discharge intensity is prescribed in case of earth fault; for information only, 100 pC at 1,1×U_r phase-to-earth voltage seems to be an acceptable limit.

As a general rule, the intensity permitted for an assembly or subassembly should be the highest value permitted for its components.

6.2.10 Dielectric tests on auxiliary and control circuits

Subclause 6.2.10 of IEC 62271-1:2007 is applicable.

Current transformer secondary windings may be short-circuited and disconnected from earth. Voltage transformer secondary windings may be disconnected.

Voltage-limiting devices in the low-voltage circuit, if any, shall be disconnected.

Functions like voltage indication or detection (e.g. VPIS, VIS and VDS) which are tested according to their relevant standards are excluded.

6.2.11 Voltage test as condition check

Subclause 6.2.11 of IEC 62271-1:2007 is applicable.

Additional subclause:

6.2.101 Dielectric tests on cable testing circuits

This type test applies only to switchgear and controlgear having one or more rated cable test voltage(s).

For each rated cable test voltage value, the following test voltages shall be applied:

a) U_r shall be applied as a single phase voltage between earth and all phase conductors on the busbar side connected together;
b) the rated cable test voltage U_{ct} (a.c.) or U_{ct} (d.c.) shall be applied to each pole in turn of the cable test connection. The other cable test connections shall be connected to earth.

Test voltages shall be applied simultaneously.

For a.c. cable test voltages U_{ct} (a.c.) the duration of the test shall be 1 min. For d.c. cable test voltages U_{ct} (d.c.) the duration of the test shall be 15 min.

For a.c. test voltages of same frequency, the polarity of the two test voltages shall be opposite.

6.3 Radio interference voltage (r.i.v.) test

Subclause 6.3 of IEC 62271-1:2007 is not applicable.

6.4 Measurement of the resistance of circuits

6.4.1 Main circuit

Subclause 6.4.1 of IEC 62271-1:2007 is applicable with the following addition:

The measured resistance across the complete main circuit of an assembly of solid-insulation enclosed switchgear and controlgear is indicative of the proper condition of the current path. This measured resistance shall be the reference for the routine test (refer to 7.3).

6.4.2 Auxiliary circuits

Subclause 6.4.2 of IEC 62271-1:2007 is applicable.

Additional subclause:

6.4.101 Requirement for protection category PB2

If the requirement of item g) of 5.102.3 is applicable, the resistance of the earthed conductive layer shall be maximum 100 mΩ to the earthing terminal of the switchgear and controlgear. This is demonstrated by feeding at the most onerous points 30 A d.c. to the conductive layer. The corresponding voltage drop from a point on the layer nearby the point of infeed shall be a maximum of 3 V.

It might be necessary to feed the current on the conductive layer through a larger area of, for example, 1 cm^2, to avoid a too high density on the spot.

6.5 Temperature-rise tests

Subclause 6.5 of IEC 62271-1:2007 is applicable, with the following addition:

Where the design provides alternative components or arrangements, the test shall be performed with those components or arrangements for which the most severe conditions are obtained. The representative functional unit shall be mounted approximately as in normal service, including all normal enclosures, partitions, shutters, etc., and the covers and doors closed.

The tests shall be made normally with the rated number of phases and the rated normal current flowing from one end of the length of busbars to the terminals provided for the connection of cables.

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

Where there are other main functional components installed within the enclosure they shall carry the currents which produce the power loss corresponding to the rated conditions. Equivalent procedures to generate the same power dissipation are acceptable.

The temperature rises of the different components shall be referred to the ambient air temperature outside the enclosure and shall not exceed the values specified for them in the relevant standards. If the ambient air temperature is not constant, the surface temperature of an identical enclosure under the same ambient conditions may be taken as reference.

6.5.1 Conditions of the switchgear and controlgear to be tested

Subclause 6.5.1 of IEC 62271-1:2007 is applicable.

6.5.2 Arrangement of the equipment

Subclause 6.5.2 of IEC 62271-1:2007 is applicable with the following change:

When the connection is realised in a compartment, the temperature of the temporary connections shall be measured at the point where they leave the enclosure and at a distance of 1 m externally. The temperature difference shall not exceed 5K.

6.5.3 Measurement of the temperature and the temperature rise

Subclause 6.5.3 of IEC 62271-1:2007 is applicable.

6.5.4 Ambient air temperature

Subclause 6.5.4 of IEC 62271-1:2007 is applicable.

6.5.5 Temperature-rise test of the auxiliary and control equipment

Subclause 6.5.5 of IEC 62271-1:2007 is applicable.

6.5.6 Interpretation of the temperature-rise tests

Subclause 6.5.6 of IEC 62271-1:2007 is applicable.

6.6 Short-time withstand current and peak withstand current tests

Subclause 6.6 of IEC 62271-1:2007 is applicable, with the following addition:

a) Test on main circuits

Main circuits of solid-insulation enclosed switchgear and controlgear shall be tested to verify their capability to withstand the rated short-time and peak withstand current under the intended conditions of installation and use, i.e. they shall be tested as installed in the solid-insulation enclosed switchgear and controlgear with all associated components influencing the performance or modifying the short-circuit current.

Connections to auxiliary devices (such as voltage transformers, auxiliary transformers, surge arresters, surge capacitors, voltage detection devices, and similar items) are not considered as parts of the main circuit.

The short-time withstand current and peak withstand current tests shall be carried out according to the rated number of phases. Current transformers and tripping devices that may be present shall be installed as in normal service, but with the release made inoperative.

Equipment which does not include any current-limiting device may be tested at any convenient voltage. Equipment which incorporates a current-limiting device shall be tested at U_r. Other test voltages can be used, if it can be demonstrated that both the applied peak current and resulting thermal effects are equal or higher than those with U_r.

For equipment including current-limiting devices the prospective current (peak, r.m.s. value and duration) shall not be less than the rated value.

Self-tripping circuit-breakers, if any, shall be set on their maximum tripping values.

Current-limiting fuses, if any, shall be provided with fuse-links having the maximum rated current specified.

After the test, no deformation or damage to components or conductors within the enclosure, which may impair good operation of the main circuits, shall have been sustained. The insulating properties of the solid insulating enclosure shall in particular be unimpaired. It may be possible to detect the presence of cracks in the insulation of solid-insulation embedded components by performing a partial discharge test (refer to 6.2.9).

b) Tests on earthing circuits

Earthing conductors, earthing connections and earthing devices of solid-insulation enclosed switchgear and controlgear shall be tested to verify their rated short-time and peak withstand currents (I_k and I_{ke}, as applicable). They shall be tested as installed in the solid-insulation enclosed switchgear and controlgear with all associated components influencing the performance or modifying the short-circuit current.

The short-time withstand current and peak withstand current tests with earthing devices shall be carried out according to the rated number of phases. Single-phase tests shall be performed on all the circuits that are intended to provide the connection between the earthing device and earthing point provided.

When there are removable earthing devices, the earthing connection between the fixed part and the removable part shall be tested under earth fault conditions. The earth fault current shall flow between the earthing conductor of the fixed part and the earthing point of the removable part. Where the earthing device in the switchgear or controlgear can be operated in alternative positions to the normal service position, for example, in double busbar switchgear and controlgear, a test shall be made in alternative positions.

After the test some deformation and degradation of the earthing conductor, earthing connections or earthing devices is permissible, but the continuity of the circuit shall be preserved.

Visual inspection should be sufficient to check that continuity of the circuit has been preserved.

In case of doubt, if certain earth connections are (still) adequate, the earthing shall be verified testing with 30 A (d.c.) to the earthing point provided. The voltage drop shall be lower than 3 V.

6.6.1 Arrangement of the switchgear and controlgear and of the test circuit

Subclause 6.6.1 of IEC 62271-1:2007 is applicable, with the following addition:

The equipment to be tested shall be arranged in such a way that the most onerous conditions are obtained concerning the maximum lengths of unsupported busbar(s), configuration of the conductors and connections within the equipment. In the case of switchgear and controlgear incorporating the same switching device in multiple high-voltage compartments, either side-by-side or in multi-tier designs, the tests shall be made with the most onerous location of the switching device.

The test connections to the terminals of the switchgear and controlgear shall be arranged in such a way as to avoid unrealistic stressing of, or support to, the terminals. The distance between the terminals and the nearest supports of the test conductors on both sides of the switchgear and controlgear shall be in accordance with the instructions of the manufacturer but taking into account the requirement above.

The switching devices shall be in the closed position and fitted with clean contacts in a new condition.

Each test shall be preceded by a no-load operation of the mechanical switching device and, with the exception of earthing switches, by measurement of the resistance of the main circuit.

The test arrangement shall be noted in the test report.

6.6.2 Test current and duration

Subclause 6.6.2 of IEC 62271-1:2007 is applicable.

6.6.3 Behaviour of switchgear and controlgear during test

Subclause 6.6.3 of IEC 62271-1:2007 is applicable.

6.6.4 Condition of switchgear and controlgear after test

Subclause 6.6.4 of IEC 62271-1:2007 is applicable.

6.7 Verification of the protection

6.7.1 Verification of the IP coding

Subclause 6.7.1 of IEC 62271-1:2007 is applicable, with the following addition:

For solid-insulation enclosed switchgear and controlgear the service conditions are with all doors and covers closed, no matter how they are expected to be locked or not.

6.7.2 Verification of the IK coding

Subclause 6.7.2 of IEC 62271-1:2007 is applicable.

6.8 Tightness tests

Subclause 6.8 of IEC 62271-1:2007 is applicable.

6.9 Electromagnetic compatibility tests (EMC)

Subclause 6.9 of IEC 62271-1:2007 is applicable.

Stationary emission tests should be performed on a typical lay out of the switchgear and controlgear, based on the standard wiring rules of the manufacturer.

6.10 Additional tests on auxiliary and control circuits

6.10.1 General

Subclause 6.10.1 of IEC 62271-1:2007 is applicable.

6.10.2 Functional tests

Subclause 6.10.2 of IEC 62271-1:2007 is not applicable:

A functional test of all low-voltage circuits shall be made to verify the proper functioning of auxiliary and control circuits in conjunction with the other parts of the switchgear and controlgear.

The tests shall be performed with the upper and lower value limits of the supply voltage defined in 4.8.

For low-voltage circuits, sub-assemblies and components, functional tests can be omitted if they have been fully performed during a test applied to similar switchgear and controlgear.

6.10.3 Electrical continuity of earthed metallic parts test

Subclause 6.10.3 of IEC 62271-1:2007 is applicable.

6.10.4 Verification of the operational characteristics of auxiliary contacts

Subclause 6.10.4 of IEC 62271-1:2007 is applicable.

6.10.5 Environmental tests

Subclause 6.10.5 of IEC 62271-1:2007 is applicable with the following limitations:

– tests do not apply for indoor switchgear and controlgear operated under normal service conditions as defined by Clause 2 of IEC 62271-1:2007;

– when the tests as stated in 6.10.5 of IEC 62271-1:2007 have been performed on the separate components of a representative auxiliary and control circuit, no further environmental tests are needed;

– when tests are performed, 6.10.5 of IEC 62271-1:2007 is applicable on a typical lay out of the auxiliary and control circuits.

6.10.6 Dielectric test

Subclause 6.10.6 of IEC 62271-1:2007 is applicable.

6.11 X-radiation test procedures for vacuum interrupters

Subclause 6.11 of IEC 62271-1:2007 is applicable.

NOTE This test is applied to the vacuum interrupter not to a functional unit.

Additional subclauses:

6.101 Verification of making and breaking capacities

6.101.1 General

Switching devices forming part of the main circuit and earthing switches of solid-insulation enclosed switchgear and controlgear shall be tested to verify their rated making and breaking capacities according to the relevant standards and under the proper conditions of installation and use. That is, they shall be tested as normally installed in the solid-insulation enclosed switchgear and controlgear with all associated components, the arrangement of which may influence the performance, such as connections, supports, provisions for venting, etc. These tests are not necessary if making and breaking tests have been performed on the switching devices installed in solid-insulation enclosed switchgear and controlgear with more onerous conditions.

In determining which associated components are likely to influence the performance, special attention should be given to mechanical forces due to the short circuit, the venting of arc products, the possibility of disruptive discharges, etc. It is recognized that, in some cases, such influences may be quite negligible.

As it is not possible to cover all possible configurations and designs of switching devices, the following procedures shall be followed:

a) if the appropriate making and breaking current test series have been made with the switching device in a representative compartment, then the tests referred to above are also valid for compartments with similar or less onerous conditions;

b) if type tested switching devices, tested with or without an enclosure, are used and a) is not applicable, the test duties set out in 6.101.2 and 6.101.3 below shall be repeated in each of the compartments;

c) where compartments are designed to accept more than one particular type or design of switching device, each variant of switching device shall be fully tested in accordance with the requirements of item a) or, where appropriate item b) above.

Where multiple high-voltage compartments, either side-by-side or multi-tier designs, are not identical but are designed to accept the same switching device, the above stated tests/test-duties shall be performed in the compartment in which the most severe conditions are obtained, as appropriate to the requirements of the relevant standard.

6.101.2 Test requirements for main switching devices

The following test duties shall be performed as appropriate for the switching device.

IEC 62271-100: Test duty T100s, T100a, and critical current tests (if any) also taking into account the requirements of 6.103.4 of IEC 62271-100:2008 or the test connection arrangement, where applicable.

IEC 62271-103: Ten CO operations with rated mainly active load-breaking current (Test duty TD_{load}). Test duty TD_{ma} according to class E1, E2 or E3, as applicable, unless the switch does not have a rated short-circuit making capacity.

IEC 62271-105: Test duties TD_{Isc} and and the highest value of $TD_{Itransfer}$. and TD_{Ito}.

IEC 62271-106: Verification of coordination with SCPDs to 6.106 of IEC 62271-106:2011.

6.101.3 Test requirements for earthing function

The earthing function shall be tested in accordance with the requirements of IEC 62271-102 for short-circuit making operations. The tests shall be performed in accordance with the requirements for earthing switches of class E1 or class E2, as applicable.

Where the earthing function is performed by the main switching device in combination with a class E0 earthing switch, class E1 or E2 for the earthing function may be assigned as defined in IEC 62271-102. For this arrangement the test sequence shall then be:

– for Class E1: 2C;
– for Class E2: 2C – x – 2C – y – 1C, where x and y represent arbitrary switching or no-load operations, and 2C represents two C operations with one no-load opening operation in between, i.e. C – O (no-load) – C.

The requirements of subclauses 6.101.8 and 6.101.9 of IEC 62271-102:2001, Amendment 1:2011 and Amendment 2:2013, shall apply to both the class E0 earthing switch and the main switching device.

NOTE The classification for the earthing function is not applicable when the earthing is always performed by a circuit-breaker with the protection operative until the earthed situation is attained.

6.102 Mechanical operation tests

6.102.1 Switching devices and removable parts

Switching devices shall be tested in accordance with their own product standard, unless they have already been tested. If a removable part is intended to be used as a disconnector, then the mechanical endurance shall be in accordance with IEC 62271-102.

In addition all switching devices shall be operated 50 times C-O when installed in the solid-insulation enclosed switchgear.

Removable parts shall be inserted 25 times and removed 25 times to verify satisfactory operation of the equipment. The force required to insert and remove the parts shall be less than 150 % of that required for the first operation.

For functional units including several switching devices the operations may be performed as part of a sequence of operations involving all these switching devices. If the insertion / removal of a removable part is involved in the sequence, the number of such sequences shall be reduced to 25. Any operations not included in this sequence shall be separately tested.

In the case of manually operated equipment, the normal manual operation handle shall be used to perform the tests.

6.102.2 Interlocks

The interlocks shall be set in all positions intended to prevent the operation of the switching devices, the access to operation interfaces, and the insertion or withdrawal of removable parts. The following tests shall be made in order to attempt to defeat the interlocks:

– 25 attempts to open any interlocked door or cover;
– 50 attempts to access or engage the operation interface, when access or engagement is prevented due to an interlocking device (shutter, selector lever, etc.);
– 50 attempts to operate the switching devices manually, when the operation interface is accessible;
– 10 attempts to operate the switching device manually in the wrong direction shall be carried out in addition to, but anywhere in, the above sequence of 50 attempts;
– 25 attempts to insert and 25 attempts to withdraw the removable parts.

The normal manual operation handle shall be used to perform these tests. During the tests double the normal forces shall be employed, except that in the case of an interlock blocking the operating shaft, a prospective force of 750 N shall be applied halfway along the length of the gripping part of the operating handle. Where operating handles incorporate a feature which limits the operating force the maximum test force shall be limited to that which can be applied by the handle, provided that the handle is not interchangeable with other handles.

No adjustment shall be made to the switching devices, removable parts or interlocks during these tests.

The integrity of sliders or other devices preventing access to the operation interface shall be verified in accordance with 6.7.2 (verification of the IK coding).

Where only mechanical interlocks are designed to prevent the operation of motorised switching devices, the following additional tests shall be performed using the motor:

– 50 attempts to operate the switching devices;
– 10 attempts to operate the switching device in the wrong direction shall be carried out in addition to, but anywhere in, the above sequence of 50 attempts.

110 % of the rated supply voltage of auxiliary circuits shall be applied for a duration of 2 s.

The interlocks are considered satisfactory, if

a) the switching devices cannot be operated;
b) access to the interlocked compartments is prevented (verification by IP2X as a minimum; Refer to 6.7.1);
c) the insertion and withdrawal of the removable parts are prevented;
d) the switching devices, removable parts and the interlocks are still operative and the effort to operate them before and after the tests, does not differ from the maximum hand operating forces (manual operation) or peak energy consumption (motor operation) by more than 50 %. In case of the test with 750 N, damage is acceptable, provided that the interlock still prevents operation.

NOTE These tests can be performed as part of the mechanical operations test sequence.

6.103 Pressure withstand test for gas-filled compartments

6.103.1 Pressure withstand test for gas-filled compartments with pressure relief devices

Each design of gas filled compartment shall be subjected to a pressure test according to the following procedure:

– the relative pressure shall be increased in order to reach a value of 1,3 times the design pressure of the compartment for a period of 1 min. The pressure relief device shall not operate;

– then the pressure shall be increased up to a maximum value of 3 times the design pressure. It is acceptable that the pressure relief device may operate, as designed by the manufacturer, below this value. This opening pressure shall be recorded in the type test report. After the test, the compartment may be distorted, but the compartment shall not rupture.

During the tests, the adjacent compartments shall be at atmospheric pressure.

NOTE These tests are intended to demonstrate the over-pressure behaviour under service conditions. Care is taken of the pressure difference when evacuating adjacent compartments.

6.103.2 Pressure withstand test for gas-filled compartments without pressure relief devices

Each design of a gas-filled compartment shall be subjected to a pressure test according to the following procedure.

– the relative pressure shall be increased up to 3 times the design pressure of the compartment for 1 min. After the test, the compartment may be distorted, but the compartment shall not rupture.

During the tests, the adjacent compartments shall be at atmospheric pressure.

NOTE This test is intended to demonstrate the over-pressure behaviour under service conditions. Care is taken of the pressure difference when evacuating adjacent compartments.

6.104 Tests to prove the protection of persons against electric shock

6.104.1 General

This subclause applies to the solid insulating enclosure and to partitions (and shutters) intended for protection from live parts. When these partitions contain bushings, tests shall be carried out under the appropriate conditions, i.e. with the primary parts of the bushings disconnected and earthed.

The solid insulating enclosure, partitions and shutters, as well as solid-insulation embedded high-voltage parts that are intended to remain live when accessing the high-voltage compartment, shall be tested.

6.104.2 Dielectric tests

a) The insulation between live parts of the main circuit and the accessible surface of the solid insulating enclosure and solid insulating partitions and shutters shall withstand the test voltages specified in 4.2 of IEC 62271-1:2007 for voltage tests to earth and between poles. For the test set up, refer to item a) of 6.2.5.

b) A representative sample of the solid insulating material shall withstand the power-frequency test voltage specified in item a). The appropriate test methods given in IEC 60243-1 should be applied; refer to [4] of Bibliography.

In the case of high-voltage parts embedded in solid insulating material it is not necessary to perform this test.

c) The insulation between live parts of the main circuit and the inner surface of solid insulating partitions and/or shutters (if any) facing these shall be tested at 150 % of U_r for 1 min. For the test, the inner surface of the partition or shutter shall be earthed by applying a conductive layer (e.g. an earthed metal foil) of at least 100 cm^2, at the most onerous point.

d) Complementary tests (for protection category PB1 only).

If the requirements of items e) or f) of 5.102.3 are applicable, evidence shall be given of the required ability to withstand a power-frequency test-voltage of 150 % of U_r for 1 min.

In the case of a second solid insulating layer, this layer shall be subjected to a power-frequency test voltage of 150 % of U_r for 1 min. Refer to item c). It is allowed to test this layer separately in its intended shape.

In the case of fluid insulation, this fluid insulation shall be replaced by ambient air. Then test c) above shall be repeated with the conductive layer of at least 100 cm^2, at the applicable points.

6.104.3 Measurements of leakage currents

For enclosures, partitions, shutters or solid-insulation embedded high-voltage parts intended to remain live when exposed in an accessed compartment, the following tests shall be made in order to check compliance with the requirements in item d) of 5.102.3

The main circuit shall, at the discretion of the manufacturer, be connected either to a three-phase supply of power-frequency voltage equal to U_r, with one phase connected to earth, or to a single-phase supply of U_r, the live parts of the main circuit being connected together. For three-phase tests, three measurements shall be made with the different phases of the supply successively connected to earth. In the case of single-phase tests, only one measurement is necessary.

A metal foil shall be placed in the most unfavourable situation for the test on the accessible surface of the solid insulation providing the protection against contact with live parts. In case of doubt about the most unfavourable situation, the test shall be repeated with different situations.

The metal foil shall be approximately circular or square, having an area as large as possible but not exceeding 100 cm^2 and shall be connected to the earthing conductor with no deliberately added impedance. The leakage current flowing through the metal foil to earth shall be measured with the insulation dry and clean.

The value of the leakage current measured shall not exceed 0,5 mA. If, as indicated in item d) of 5.102.3, the continuous path over solid insulating surfaces is broken by small gaps of gas or liquid, such gaps shall be shorted out electrically. If these gaps are incorporated to avoid the passage of the leakage current from live parts to accessible parts of solid insulating partitions and shutters, the gaps shall withstand the test voltages specified in 4.2 of IEC 62271-1:2007 for voltage tests to earth and between poles.

The leakage current shall also be measured in conditions representing condensation and light pollution where applicable, refer to 6.107.

6.105 Internal arcing test

6.105.1 General

The test is applicable to solid-insulation enclosed switchgear and controlgear, intended to be qualified as IAC classified covering the event of an arc fault within the enclosure or within components having housings which form part of the enclosure in normal operation conditions. The internal arc test makes allowance for effects acting on all parts of the enclosure, such as internal overpressure, thermal effects of the arc or its roots, the effects of ejected hot gases and glowing particles.

The tests are not intended to cover e.g.:

– the influences of an internal arc between compartments, nor the damage to internal partition and shutters not being accessible in normal operating conditions;
– external connections outside the enclosure;
– the effects caused by an explosion of high-voltage components;
– the presence of gases with potential toxic characteristics, or the hazard of fire propagation to combustible materials or equipment placed in the proximity of the solid-insulation enclosed switchgear and controlgear;
– the change of state of shutters while withdrawable or removable parts are moving.

NOTE The applicable requirements are identical to the ones stated in IEC 62271-200.

6.105.2 Test conditions

The test shall be carried out with the switchgear and controlgear in normal operating conditions. This means the position of high-voltage switching devices, connecting and disconnecting withdrawable parts is set to realise the supply circuit according to AA.5.1. All other equipment, for example measuring instruments and monitoring equipment shall be in the position as it is in normal service. If any cover has to be removed and/or any door has to be opened to perform switching operations, the internal arc test shall be carried out with the cover and/or door removed.

Removing or replacing components (for example high-voltage fuses or any other removable component) is not considered to be normal operation, neither to carry out maintenance work.

The test shall be performed in every high-voltage compartment of representative functional units (refer to 6.105.3).

Compartments which are protected by type-tested current-limiting fuses shall be tested with the fuse type that causes the highest cut-off current (let-through current). The actual duration of the current flow will be controlled by the fuses. The tested compartment will be designated as ‘fuse-protected’. The tests shall be performed at the rated maximum voltage of the equipment.

Application of suitable current limiting fuses in combination with switching devices can limit the short-circuit current and minimize the fault duration. It is well documented that the arc energy transferred during such tests is not predictable by I^2t. In the case of current limiting fuses, the maximum arc energy can occur at current levels below the maximum interrupting rating. Further, the effects of using current-limiting devices that employ pyrotechnic means to commutate current to a current limiting fuse must be considered when evaluating designs utilizing such devices.

Any device (for example protection relay) that may automatically trip the circuit before the end of the prospective duration of the test shall be made inoperative during the test. If compartments or functional units are equipped with devices intended to limit the duration of the arc itself by other means (for example, by transferring the current to a metallic short circuit), they shall be made inoperative during the test. If these devices are integral part of the design of the compartment or assembly which prevents to make them inoperative without modification of the construction, the relevant compartment of the switchgear and controlgear may be tested with the device operative; but this compartment shall be qualified according to the actual duration of the arc. The test current shall be maintained for the rated short-circuit duration of the main circuit.

Because in general arc limiting devices are out of the scope of this standard and if the switchgear and controlgear has previously been tested with the limiting device made inoperative, an additional test may be performed to demonstrate the behaviour of this arc limiting device.

6.105.3 Arrangement of the equipment

The equipment shall be arranged as follows:

– The test specimen shall be fully equipped. Mock-ups of internal components are permitted provided they have the same volume and external material as the original items and they do not affect the main and earthing circuits;

– Each high-voltage compartment of a functional unit shall be tested. In case of switchgear and controlgear consisting of extensible (modular) stand-alone units, the test specimen in general shall consist of two units connected together as in service, unless the manufacturer specifies a minimum number of functional units. Testing shall be made at least in all compartments of the functional unit of the switchgear and controlgear farthest away from the wall of the room simulation. If units are tested, which are not intended to be used as an end unit under service conditions, they shall be placed as close as possible to the classified lateral side of the assembly in an arrangement of more than two units.

NOTE 1 A stand-alone unit is an assembly that may contain within a single common enclosure one or more functional units in horizontal or vertical arrangement (multi-tier design).

– The test specimen shall be earthed at the earthing point provided;

– Tests shall be carried out on compartments not previously subjected to arcing, or, if subjected, being in a condition which does not affect the result of the test;

– In the case of fluid-filled compartments (other than SF_6) the test shall be made with the original fluid at its rated filling pressure (±10 %);

– For environmental reasons, it is recommended to replace SF_6 with air at the rated filling pressure (±10 %).

NOTE 2 Test results with air instead of SF_6 are considered to be representative.

6.105.4 Test procedure

The method to verify the internal arc classification is defined in AA.5.

6.105.5 Criteria to pass the test

IAC classification is demonstrated for the solid-insulation enclosed switchgear and controlgear (according to the relevant accessibility type) if the following criteria are met:

Criterion No. 1

Correctly secured doors and covers do not open. Deformations are accepted, provided that no part comes as far as the position of the indicators or the walls (whichever is the closest) on every side. The switchgear and controlgear do not need to comply with its IP code after the test.

To extend the acceptance criterion to an installation mounted closer to the wall than tested, two additional conditions shall be met:

– the permanent deformation is less than the intended distance to the wall;

– exhausting gases are not directed to the wall.

Criterion No. 2

– No fragmentation of the enclosure occurs;

– No ejection of fragments or of other parts of the switchgear of an individual mass of 60 g or more occur;

– Objects of an individual mass of 60 g or more falling to the floor in the immediate vicinity of the switchgear are accepted (in the case of accessible sides, this means between the switchgear and the indicator rack).

Criterion No. 3

Arcing does not cause holes by burning through in the classified sides up to a height of 2 000 mm.

NOTE Holes in the enclosure which are created after the duration of test by other effects than burning through, are disregarded.

Criterion No. 4

Indicators do not ignite due to the effect of hot gases or burning liquids.

If indicators have been ignited, the assessment criterion may be regarded as having been met, if proof is established of the fact that the ignition was caused by glowing particles rather than hot gases. Pictures taken by high-speed cameras, video or any other suitable means can be used by the test laboratory to establish evidence.

Indicators ignited as a result of paint or stickers burning are also excluded.

Criterion No. 5

The continuity of the earthing connection shall be checked (refer to 6.6, point b)).

6.105.6 Test report

In addition to 6.1.3 the following applies:

– description of the test unit with a drawing showing the main dimensions, details relevant to the mechanical strength, the arrangement of the pressure relief flaps and the method of fixing the solid-insulation enclosed switchgear and controlgear to the floor and/or to the walls;
– the distance between the upper part of the switchgear and controlgear and the ceiling of the room / building. For this purpose the manufacturer shall state the point of the switchgear and controlgear from which this distance is measured. Because the distance between the upper part of the switchgear and controlgear and the ceiling under internal arc conditions may be different from the distance under normal operating conditions, the test report should give an information about the validity of the test results regarding the ceiling height for installation. The ceiling height is always stated from the floor or false floor level where the switchgear is actually placed. This is also the level where the indicator racks are placed during the IAC test, refer to Figure AA.5.
– point and method of initiation of the internal arc fault;
– drawings of test arrangement (room simulation, test specimen and mounting frame of indicators) with respect to the type of accessibility (A), classified sides (F, L or R) and installation conditions;
– applied voltage and frequency;
– for the prospective or test current:
  a) r.m.s. value of the a.c. component during the first three half-cycles;
  b) highest peak value;
  c) average value of the a.c. component over the actual duration of the test;
  d) test duration;
– oscillogram(s) showing currents and voltages;
– assessment of the test results, including a record of the observations in accordance with 6.105.5;
– other relevant remarks.

6.105.7 Transferability of test results

The validity of the results of a test carried out in a functional unit of a particular solid-insulation enclosed design of switchgear and controlgear can be extended to another one (refer to 6.1), provided that the original test was more onerous and the latter can be considered as similar to the tested one in the following aspects:

– dimensions;

– structure and strength of the enclosure;

– architecture of the partition;

– performance of the pressure relief device, if any;

– insulation system;

– physical influences (pressure rise, gas flow and thermal effects).

6.106 Thermal stability test

Where the major part of the insulation between conductive parts consists of solid insulation, the manufacturer shall provide evidence that the stability of the solid insulating materials used will not be impaired by dielectric stresses and thermal influences.

This evidence can be given on the basis of tests on comparable configurations, on the basis of the properties of the solid insulating materials (dielectric losses as a function of temperature) or by carrying out a thermal stability test on the whole equipment or a representative part of it.

This test is not necessary if gas or liquids form the major part of the insulation.

The thermal stability test consists of a 100 h test with a power-frequency voltage of 180 % of U_r at the temperature reached during a temperature-rise test according to 6.5 when the ambient air temperature is 40 °C.

The main circuit shall be energized by an earthed supply, using a three-phase supply with an earthed-neutral for three-phase switchgear. The earthing conductor and any metal parts intended to be earthed shall be connected to earth.

The test may be carried out separately from the temperature-rise test at the highest temperature rise measured during the temperature-rise test, increased by 40 °C.

If no disruptive discharge occurs, the solid-insulation enclosed switchgear and controlgear shall be considered to have passed the test.

6.107 Humidity test

The humidity test shall be made if the enclosure is not completely covered by a conductive layer, connected to earth and having a resistance less than 96 kΩ, when measured from any point on the enclosure to the earthing point provided

NOTE The value of 96 kΩ is chosen in order to keep the maximum touch voltage below 48 V.

The test shall be performed according to Annex DD.

7 Routine tests

Clause 7 of IEC 62271-1:2007 is applicable, with the following addition:

The routine test shall be carried out on each transport unit and, whenever practicable, at the manufacturer's factory to ensure that the product is in accordance with the equipment on which the type test has been carried out.

Refer to Clause 7 of IEC 62271-1:2007 with the addition of the following routine tests:

– partial discharge measurement: 7.101
– mechanical operation tests: 7.102
– pressure tests of gas-filled compartments (if applicable): 7.103
– tests of auxiliary electrical, pneumatic and hydraulic devices (if applicable): 7.104
– tests after erection on site: 7.105
– measurement of fluid conditions after filling on site: 7.106

It may be necessary to verify the interchangeability of components of the same rating and construction (refer to Clause 5).

7.1 Dielectric test on the main circuit

Subclause 7.1 of IEC 62271-1:2007 is applicable, with the following addition and exception:

The power-frequency voltage test shall be performed according to the requirements in 6.2.6.1. The test voltage specified in Tables 1a and 1b, column 2, of IEC 62271-1:2007 shall be applied connecting each phase conductor of the main circuit in turn to the high-voltage terminal of the test supply, with the other phase conductors connected to earth, and the continuity of the main circuit assured (for example, by closing the switching devices or otherwise).

In order to check compliance with the requirement of item a) of 5.102.3 the solid insulating enclosure shall be surrounded by earthed metal plates or equivalent. These plates shall have clearances equal to or less than specified for service conditions to walls, ceiling and floor. For accessible sides, the earthed metal plates shall be put in direct contact with the enclosure. Refer to 6.2.5.

The test voltage may be applied at higher than the rated frequency in order to avoid the disconnection of voltage transformers.

For gas-filled compartments of sealed pressure systems, the tests shall be performed at the rated filling pressure (or density) of the insulating gas (refer to 4.11). For closed- or controlled pressure systems, the tests shall be performed at the minimum functional pressure (or density) of the insulating gas.

7.2 Tests on auxiliary and control circuits

Subclause 7.2 of IEC 62271-1:2007 is applicable.

7.3 Measurement of the resistance of the main circuit

Subclause 7.3 of IEC 62271-1:2007 is applicable with the following modifications:

This test is subject to agreement between manufacturer and user.

Where there is no temperature rise test for the configuration being tested, the conditions of the test and the limits of resistance values should also be subject to agreement between manufacturer and user.

7.4 Tightness test

Subclause 7.4 of IEC 62271-1:2007 is applicable.

7.5 Design and visual checks

Subclause 7.5 of IEC 62271-1:2007 is applicable.

Additional subclauses:

7.101 Partial discharge test

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

Partial discharge tests shall be according to Annex BB with test criteria as stated in 6.2.9.101.

At least the power frequency tests according 6.2.6.1 shall have passed before the partial discharge validation test can be performed.

7.102 Mechanical operation tests

Operation tests are made to ensure that the switching devices and removable parts comply with the prescribed operating conditions and that the mechanical interlocks work properly.

The tests shall be performed as specified in 6.102 except that:

– normal operating forces shall be used;
– 5 operations or attempts shall be performed in each direction.

These tests shall be performed without voltage on or current in the main circuits. It shall be verified that:

– the switching devices open and close correctly within the specified limits of the supply voltage and pressure of their operating devices;
– each removable part can be inserted and removed correctly;
– all interlocks function correctly.

7.103 Pressure tests of gas-filled compartments

Pressure tests shall be made on all gas-filled compartments after manufacture. Each compartment shall be subjected to a test at 1,3 times the design pressure for 1 min.

This does not apply for sealed compartments with a rated filling pressure of 50 kPa (relative pressure) and below.

After this test the compartments shall show no signs of distress or any distortion likely to affect the operation of the switchgear and controlgear.

7.104 Tests of auxiliary electrical, pneumatic and hydraulic devices

The electrical, pneumatic and other interlocks together with control devices having a predetermined sequence of operation shall be tested five times in succession in the intended conditions of use and operation and with the most unfavourable limit values of auxiliary supply. During the test no adjustment shall be made.

The tests are considered to be satisfactory if the auxiliary devices have operated properly, if they are in good operating condition after the tests and if the effort to operate them is practically the same before and after the tests.

7.105 Tests after erection on site

After erection, solid-insulation enclosed switchgear and controlgear shall be tested to check correct operation.

For parts which are assembled on site and for gas-filled compartments which are filled on site, the following tests should be carried out:

a) Voltage test of the main circuit:

   When agreed between manufacturer and user, power-frequency voltage tests in dry conditions may be carried out on the main circuits of solid-insulation enclosed switchgear and controlgear after the erection on site in exactly the same manner as specified in 7.1 for the routine test at the manufacturer's premises.

   The power-frequency test voltage shall be 80 % of the values indicated in 7.1 and shall be applied to each phase conductor of the main circuit in succession with the other phase conductors earthed. For the tests, one terminal of the test transformer shall be connected to the earthing system of the solid-insulation enclosed switchgear and controlgear.

   If the voltage test after erection on site replaces the routine test at the manufacturer's premises, the full power-frequency test voltage shall be applied.

   Voltage transformers should be disconnected during dielectric site tests, unless the test frequency used for site test is high enough to prevent core saturation.

   Overvoltage limiting devices shall be disconnected.

b) Tightness tests: 7.4 is applicable.

c) Measurement of fluid condition after filling on site: 7.106 is applicable.

7.106 Measurement of fluid condition after filling on site

The condition of the fluid in fluid-filled compartments shall be determined and shall meet the manufacturer's specification.

8 Guide to the selection of switchgear and controlgear

Clause 8 of IEC 62271-1:2007 is applicable with following additions:

Additional subclauses:

8.101 General

Solid-insulation enclosed switchgear and controlgear has either

– protection category PB throughout for generally accessible installations (operating areas), or

– partly protection category PA and partly protection category PB for installations accessible to skilled operators only (closed electrical operating areas).

NOTE 1 The application of category PA and PB is explained in 5.102.2.

NOTE 2 For the definitions of “operating area” and “closed electrical operating area” refer to IEC 61936-1 in [8] of the bibliography.

Solid-insulation enclosed switchgear and controlgear may be constructed in various forms that have evolved with changing technologies and functional requirements. The selection of solid-insulation enclosed switchgear and controlgear essentially involves an identification of the

functional requirements for the service installation and the form of internal partitioning that best meets these requirements.

Such requirements should take account of applicable legislation and user safety rules.

Table 104 provides a summary of the considerations for specifying switchgear and controlgear.

8.102 Selection of rated values

For a given duty in service, solid-insulation enclosed switchgear and controlgear is selected by considering the individual rated values of their components required by normal load and fault conditions. The rated values of an assembly of switchgear and controlgear may differ from those of its component parts.

The rated values should be chosen in accordance with this standard having regard for the characteristics of the system as well as its anticipated future development. A list of ratings is given in Clause 4.

Other parameters such as local atmospheric and climatic conditions and the use at altitudes exceeding 1 000 m should also be considered.

The duty imposed by fault conditions should be determined by calculating the fault currents at the place where the solid-insulation enclosed switchgear and controlgear is to be located in the system. Reference is made to IEC 60909-0 in this regard; refer to [7] of Bibliography.

8.103 Selection of design and construction

8.103.1 General

Solid-insulation enclosed switchgear and controlgear is normally identified by insulating technology (for example, solid insulating material, air- or gas-insulated) and by fixed or withdrawable design. The extent to which individual components should be withdrawable, or removable, is primarily dependent upon the requirement (if any) for maintenance and/or the provisions for testing.

Development of switching devices with low maintenance requirement has reduced the need for frequent attention to some items subject to arc erosion. However, there remains a need for accessibility to expendable items, for example, fuses and for occasional inspection and testing of cables. Lubrication and adjustment of mechanical parts may also be required, for which reason some designs may make mechanical parts accessible outside the high-voltage compartments.

The extent to which access may be required for maintenance, and/or whether complete switchgear and controlgear shutdowns can be tolerated, may determine a user preference for solid insulating material, air or fluid insulation and fixed or withdrawable pattern. If maintenance demands are infrequent, as is often preferred practice nowadays, then assemblies equipped with low maintenance components, may provide a practical solution. Fixed pattern assemblies, particularly those employing low maintenance components may provide a cost-effective through-life arrangement.

In the case where a main circuit compartment is opened, safe operation of switchgear and controlgear requires (irrespective of whether of fixed or withdrawable pattern) that the parts on which work is to be carried out should be isolated from all sources of supply and earthed. Furthermore, the disconnecting devices used to isolate should be secured against re-connection.

8.103.2 Architecture and accessibility to high-voltage compartments

The forms of internal partitioning defined in this standard attempt to balance such requirements as service continuity and maintainability. In this subclause, some guidance is given regarding the extent to which the different forms can provide maintainability.

NOTE 1 Temporarily inserted partitions are intended to prevent incidental contact with live parts, while performing certain maintenance procedures, are addressed in 10.4.

NOTE 2 If the user employs alternative maintenance procedures, for example, the establishment of safety distances and/or setting-up and use of temporary barriers, these are outside the scope of this standard.

The complete description of switchgear or controlgear includes the list and type of high-voltage compartments, for example, busbar compartment, circuit-breaker compartment, etc., the type of accessibility provided to each, and the pattern (withdrawable/non-withdrawable).

There are four types of high-voltage compartment; three being accessible to the user and one non-accessible.

Three methods of controlling the opening of accessible high-voltage compartment are defined:

– The first is by use of interlocks to ensure that all live parts inside are dead and earthed before opening, or are in the disconnected position with corresponding shutters closed. Such compartments are designated an “interlock-controlled accessible compartments”. Excluded in this respect are solid-insulation embedded high-voltage parts intended to remain live when accessing the high-voltage compartment; they should have a protection category in accordance with this standard;

  Generally, it may be possible to open shutters or temporary inserted partitions manually after accessing the high-voltage compartment.

– the second relies on user procedure and locking to ensure safety, the compartment being supplied with facilities for padlocking or equivalent; this type of compartment is designated a “procedure-based accessible compartment”;

– the third does not provide any built-in feature to ensure electrical safety before opening. Such compartments need tools to be opened, they are designated “tool-based accessible compartments”.

The first two types of accessible high-voltage compartment are available to the user and are provided for normal operation and maintenance. Corresponding covers and/or doors of these two types of accessible high-voltage compartments do not require tools for opening.

If a high-voltage compartment requires tools for opening, then this is normally a clear indication that the user should take other measures to ensure safety, and possibly to ensure performance integrity, for example, insulating conditions.

Non-accessible high-voltage compartment: No user access is provided and the opening may destroy the integrity of the compartment. A clear indication not to open is provided on, or by a feature of, the compartment, for example, a complete mould with solid insulation.

8.103.3 Service continuity of the switchgear and controlgear

The solid insulating enclosure is intended to provide a level of protection of persons against access to hazardous parts and protection of the equipment against ingress of solid foreign objects. With appropriate sensing and auxiliary control devices, it is also possible to provide a level of protection against failure of insulation to earth (ground).

For each functional unit of switchgear and controlgear the Loss of Service Continuity category (LSC) describes the extent to which other high-voltage compartments and/or functional units may remain energized when a main circuit compartment of this functional unit is opened.

Category **LSC1**: This form is not intended to provide service continuity during opening of any accessible compartment(s) and may require complete disconnection of the switchgear and controlgear from the system and making dead before such opening.

Category **LSC2** family: These forms are intended to allow maximum continuity of service of the network during access to the high-voltage compartments inside the switchgear and controlgear. It means that opening of accessible high-voltage compartments in a functional unit is possible while keeping the other functional units of the same section energised. This implies that at least one busbar can be kept energised. Insertion of a movable partition may be used to achieve this category.

LSC2 as a minimum requires that it is possible to open the connection compartment while keeping the busbar(s) live. There may or may not be other accessible high-voltage compartments (e.g. main switching device).

LSC2A applies to switchgear and controlgear which has accessible compartments other than for high-voltage connection (for instance the main switching device compartment); this requires that it is allowed, after making the relevant high-voltage circuit dead and earthed, to open any high-voltage compartment while keeping the busbar(s) energised (it is of course not allowed to open the live busbar compartment(s)).

It could be of additional value to keep the high-voltage connection (e.g. cables) energised when accessing such other compartments of the corresponding functional unit. This situation can occur when alternative power supplies are part of the installation (loop operation, generators, etc.). For these situations switchgear and controlgear can be specified to be LSC2B; this requires that the connection (cable) compartment can be kept energised when any other accessible high-voltage compartment is open.

The three categories of the LSC2 family can be summarised as follows:

– LSC2: Designation for functional units with accessible high-voltage connection compartments where opening the connection compartment does not require the busbar(s) nor the other functional units to be put out of service;
– LSC2A: Designation dedicated to LSC2 functional units in which all accessible high-voltage compartments (other than the busbar of single busbar equipment) can be opened with a busbar live;
– LSC2B: In addition to the requirements of LSC2A, the high-voltage connections (e.g. cables) to the functional unit being accessed may be kept energized. This implies that there also is a point of disconnection, as well as proper partitioning, between the accessed compartment and the high-voltage connections.

Examples:

1) LSC1 (Figure 101): a circuit-breaker functional unit with cable connections in the same compartment as the circuit-breaker and busbar will be classified as LSC1.
2) LSC2 (Figure 102): a non-withdrawable circuit-breaker functional unit has two accessible high-voltage compartments (other than the busbar compartment), and a disconnector in the circuit-breaker compartment. It is not allowed to open the circuit-breaker compartment with the busbar live. However the high-voltage connection may be earthed via the circuit-breaker: if there is full partitioning between the connection compartment and the circuit-breaker compartment, then the connection compartment may be opened with the busbar live. The functional unit should be defined as LSC2.
3) LSC2 (Figure 103): a circuit-breaker functional unit with cable connections in the same compartment as the circuit-breaker, this compartment being accessible with the busbar live because it can be isolated and earthed by disconnector and earthing switch placed in the busbar compartment. Similar to Figure 103, a typical Ring Main Unit design (RMU) where the busbar compartment contains the switch-disconnectors or circuit-breakers of several functional units is also designated as LSC2.

4) LSC2A (Figure 104): this is similar to example 2, except that the disconnector is located in the busbar compartment, and there is full partitioning between the busbar and circuit-breaker compartments. Both the circuit-breaker compartment and the connection compartment may be opened safely with the busbar live after the disconnector is opened and the earthing switch is closed. Access to the circuit-breaker compartment requires that the cables are dead and earthed.

5) LSC2B (Figure 105): for non-withdrawable main switching device designs.
This is similar to example 4, but in addition a second disconnector and earthing switch are provided in the connection compartment; there is full partitioning between the circuit-breaker compartment and connection compartment. This allows the circuit-breaker compartment to be opened with both the busbars and connection compartment live.

6) LSC2B (Figure 106): for withdrawable designs. If the main switching device of each LSC2B functional unit is fitted in its own accessible compartment, maintenance may be performed on this main switching device without de-energizing the corresponding connection compartment. As a consequence, a minimum of three compartments for each LSC2B functional unit is necessary in this example:
   – for each main switching device;
   – for components connected to one side of a main switching device, for example, feeder circuit;
   – for components connected to the other side of the main switching device, for example, busbar. For double busbar switchgear and controlgear, each busbar shall be in its own, separate compartment.

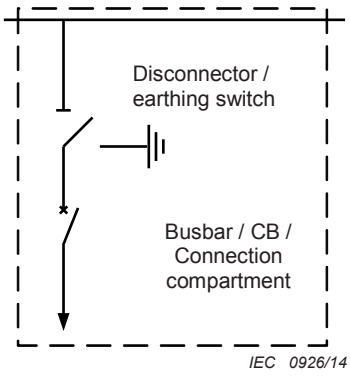


Figure 101 – LSC1

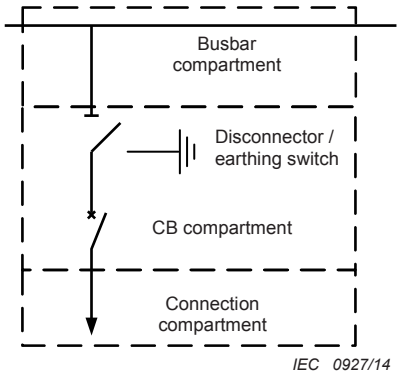


Figure 102 – LSC2

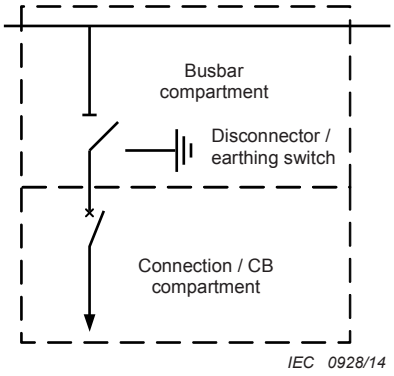


Figure 103 – LSC2

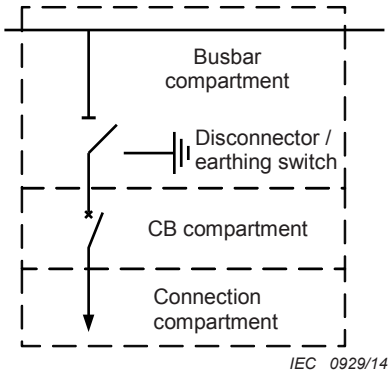


Figure 104 – LSC2A

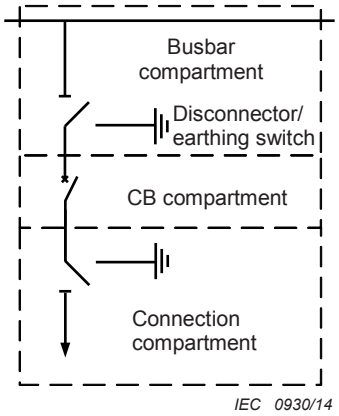


Figure 105 – LSC2B

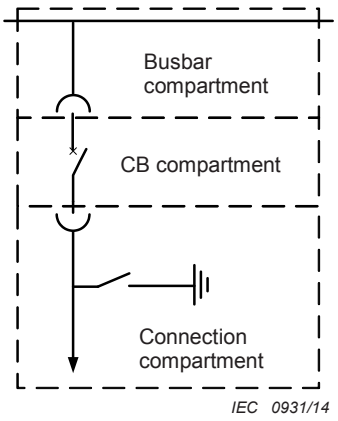


Figure 106 – LSC2B

8.103.4 Partition classes

There is one type of defined partitioning class, Class PI (3.111).

The partition class does not necessarily ensure personnel protection in the case of an internal arc in an adjacent compartment; refer to 6.105.1 and also to 8.104.

8.104 Internal arc fault

8.104.1 General

If the switchgear and controlgear is installed, operated and maintained in accordance with the instructions of the manufacturer, there should be little probability that an internal arc occurs, but it may not be completely disregarded. Failure within the enclosure of solid-insulation enclosed switchgear and controlgear due either to a defect or an exceptional service condition or maloperation may initiate an internal arc, which constitutes a hazard, if persons are present.

When selecting an solid-insulation enclosed switchgear and controlgear, the possibility of the occurrence of internal faults should be properly addressed, with the aim to provide an acceptable protection level for operators and, where applicable, for the general public.

This protection is achieved by reducing the risk to a tolerable level. According to ISO/IEC Guide 51, risk is the combination of the probability of occurrence of a harm and the severity of the harm. (Refer to Clause 5 of ISO/IEC Guide 51:1999 on the concept of safety.)

Therefore, the selection of adequate equipment, in relation to internal arcing, should be governed by a procedure to achieve a level of tolerable risk. Such a procedure is described in Clause 6 of ISO/IEC Guide 51:1999. This procedure is based on the assumption that the user has a role to play in the risk reduction.

8.104.2 Causes and preventive measures

Experience has shown that faults are more likely to occur in some locations inside an enclosure than in others. For guidance, Table 102 gives a list of locations where experience shows that faults are most likely to occur. It also gives causes of failure and possible measures to decrease the probability of internal faults. If necessary, the user should implement those applicable to the installation, commissioning, operation and maintenance.

8.104.3 Supplementary protective measures

Other measures may be adopted to provide the highest possible level of protection to persons in case of an internal arc. These measures are aimed to limit the external consequences of such an event.

The following are some examples of these measures.

– rapid fault clearance times initiated by detectors sensitive to light, pressure or heat or by a differential busbar protection;

– application of suitable fuses in combination with switching devices to limit the let-through current and fault duration;

– fast elimination of arc by diverting it to metallic short circuit by means of fast sensing and fast closing devices (arc eliminator);

– remote operation instead of operation in front of the switchgear and controlgear;

– pressure-relief device;

– transfer of a withdrawable part to or from the service position only when the front door is closed.

Table 102 – Locations, causes and examples of measures to decrease the probability of internal arc faults

Locations where internal arc faults are most likely to occur (1)	Possible causes of internal arc faults (2)	Examples of possible preventive measures (3)
Connection compartments	Inadequate design	Selection of adequate dimensions Use of appropriate materials
	Faulty installation	Avoidance of crossed-cable connections. Checking of workmanship on site. Correct torque
	Failure of solid or liquid insulation (defective or missing)	Checking of workmanship and/or dielectric test on site. Regular checking of liquid levels, where applicable
Disconnectors Switches Earthing switches	Maloperation	Interlocks (refer to 5.11). Delayed reopening. Independent manual operation. Making capacity for switches and earthing switches. Instructions to personnel
Bolted connections and contacts	Corrosion	Use of corrosion inhibiting coating and/or greases. Use of plating. Encapsulation, where possible
	Faulty assembly	Checking of workmanship by suitable means. Correct torque. Adequate locking means
	During racking-in or racking-out of withdrawable parts. E.g. due to dielectric change of state in combination with damage or distortion of the plugging contacts and/or shutters	Checking of workmanship at site.
Instrument transformers	Ferro-resonance	Avoidance of these electrical influences by suitable design of the circuit
	Short circuit on LV side for VT's	Avoid short circuit by proper means e.g. protection cover, low-voltage fuses
Circuit breakers	Insufficient maintenance	Regular programmed maintenance Instructions to personnel
All locations	Error by personnel	Limitation of access by compartmentalisation. Solid-insulation embedded live parts Instructions to personnel
	Ageing under electric stresses	Partial discharge routine tests
	Pollution, moisture ingress of dust, vermin, etc.	Measures to ensure that the specified service conditions are achieved (refer to Clause 2). Use of tight compartments
	Overvoltages	Surge protection. Adequate insulation co-ordination. Dielectric tests on site

8.104.4 Considerations for the selection and installation

The user shall make a proper selection, taking into account the characteristics of the network, operating procedures and service conditions. As well, considering the protection of the persons during service, the following points shall be considered:

– not all switchgear and controlgear will be IAC classified;

– not all switchgear and controlgear is of withdrawable design;

– not all switchgear and controlgear is fitted with a door which can be closed in the positions defined in 3.129 to 3.131.

As a guide for the selection of the adequate switchgear and controlgear with respect to internal arcs, the following criteria may be used.

– Where the risk is considered negligible: Solid-insulation enclosed switchgear and controlgear which is IAC classified is not necessary.
– Where the risk is considered to be relevant: Only solid-insulation enclosed switchgear and controlgear which are IAC classified should be used.

For the second case, the selection should be made by taking into account the foreseeable maximum level of current and duration of the fault, in comparison with the rated values of the tested equipment. In addition, the installation instructions of the manufacturer should be followed (refer to Clause 10). In particular, the location of personnel during an internal arc event is important. The manufacturer should indicate which sides of the switchgear and controlgear are classified as accessible, according to the testing arrangement and the user should follow the instruction carefully. Allowing personnel to enter an area not designated as accessible may lead to personnel injury.

The protection of persons in case of an internal arc is not only a matter of design and IAC classification of the switchgear and controlgear, but depends also on the installation conditions. Internal arc faults inside solid-insulation enclosed switchgear and controlgear can occur in a number of locations and can cause various physical phenomena. For example, the arc energy resulting from an arc developed in any insulating fluid within the enclosure will cause an internal overpressure and local overheating which will result in mechanical and thermal stressing of the equipment. Moreover, the materials involved may produce hot decomposition products, either gaseous or vaporous, which may be discharged to the outside of the enclosure. From this point of view, immediate evacuation and further ventilation of the switchgear room, before re-entering the site, is required and appropriate measures should be considered for the installation on site.

8.104.5 Internal arc test

The internal arc test is intended to verify the effectiveness of the design in protecting persons in case of an internal arc, when the switchgear and controlgear is in normal service condition. The test does not assess the behaviour of the switchgear and controlgear under any condition of maintenance or work, when parts of the enclosure, including the low-voltage compartment, are open or dismantled.

The internal arc test is only applicable to solid-insulation enclosed switchgear and controlgear, intended to be qualified as IAC classified.

It is in general not possible to calculate the permissible arc duration for a current which differs from that used in the test. The maximum pressure during the test will generally not decrease with a shorter arcing time and there is no universal rule according to which the permissible arc duration may be increased with a lower test current.

8.104.6 IAC classification

Classification IAC gives a tested level of protection of persons under normal operating conditions as stated in 6.105.2. It is concerned with personnel protection under these conditions; it is not concerned with personnel protection under maintenance conditions nor with service continuity.

In the case where classification IAC is proven by the tests, according to 6.105, the solid-insulation enclosed switchgear and controlgear will be designated as follows:

– general: classification IAC (initials for Internal Arc Classified);

– accessibility: A (according to 4.101.2);

– rated values: arc fault current in kiloamperes (kA), and duration in seconds (s). Single phase values may be assigned to switchgear and controlgear, having one or more compartments where its construction will prevent the arc from becoming multiphase, as demonstrated during the internal arc test. The relationship between neutral earthing and single phase-to-earth arc fault current is given in Table 103. Users should specify a single phase to earth arc fault current rating when they require a value higher than 87 % of the three phase rating, or can accept a lower value, depending on the neutral earthing.

Table 103 – Single phase-to-earth arc fault current depending on the network neutral earthing

Type of network neutral earthing	Single phase-to-earth arc fault current
Isolated neutral	up to 87 % of the three-phase rated arc fault current
Impedance earthed neutral	100 % of the rated single phase-to-earth arc fault current
Solidly earthed neutral	100 % of the three-phase rated arc fault current
For systems with isolated neutral, the maximum single phase-to earth fault current could theoretically reach levels up to 87 % of the three phase rated arc fault current (single phase-to-earth fault current under conditions of double-earth fault). However, double-earth faults at independent locations in the proximate vicinity of a single phase-to-earth fault subjected switchgear and controlgear have a very low probability. Therefore this condition may not be applicable and the user may specify a reduced single phase-to-earth arc fault current rating. NOTE 1 If the rated single phase-to-earth arc fault current covers the condition of solidly earthed neutral, all other earthing conditions of the network are also covered. NOTE 2 Resonant earthed (neutral) systems are covered in this table by the term ‘isolated neutral’.	

The designation shall be included in the nameplate (refer to 5.10)

Example 1: A solid-insulation enclosed switchgear and controlgear tested for a fault current (r.m.s.) of 12,5 kA, for 0,5 s, accessibility in front, lateral and rear side, is designated as follows:

IAC	AFLR
Arc fault current	12,5 kA
Arc fault duration	0,5 s

Designation: IAC AFLR 12,5 kA, 0,5 s

Example 2: A solid-insulation enclosed switchgear and controlgear, intended to be used only with plug-in connectors in earth fault protected, isolated neutral or impedance earthed networks where a maximum earth fault current of 2 kA prevails. When tested for a fault current (r.m.s.) of 20 kA, for 0,5 s, but for the connection compartment only for 2 kA for 1 s, with indicators placed in front, lateral and rear side, the designation is as follows:

IAC	AFLR
Arc fault current	20 kA
Arc fault duration	0,5 s
Single phase to earth arc fault current	2 kA
Single phase to earth arc fault duration	1 s

Designation: IAC AFLR 20 kA, 0,5 s (I_{Ae}: 2 kA, 1 s)

8.105 Summary of technical requirements, ratings and optional tests

Technical requirements, ratings and optional tests for solid-insulation enclosed switchgear are summarized in Table 104.

Table 104 – Summary of technical requirements, ratings and optional tests for solid-insulation enclosed switchgear

Information	Clause/subclause of this standard	User to indicate requirement as appropriate
Particulars of system (not equipment rating):		
Nominal voltage kV		
Frequency Hz		
Number of phases		
Type of neutral earthing	8.106	
Switchgear characteristics		
Number of poles		
Class indoor – ~~(~~special service conditions)	2	
Name of compartment: Busbar Main device Connection CT VT (etc.)	3.108 (refer to 5.103.1)	Busbar compartment = Main device compartment = Connection compartment = CT compartment = VT compartment = Connection/CT compartment = Main switching device/CT compartment = Other compartment (state)=
Type of compartment (specify type for each high-voltage compartment) if applicable: Interlock-controlled accessible compartment Procedure-based accessible compartment Tool-based accessible compartment Non-accessible compartment	3.108 3.108.1 3.108.2 3.108.3 3.108.4	
Partition class PI	3.111	
Withdrawable / non-withdrawable (main device type)	3.128	(Withdrawable/non-withdrawable) =
Loss of service continuity category (LSC) LSC2 LSC2A LSC2B LSC1	 3.134.1 3.134.1.1 3.134.1.2 3.134.2	
Rated voltage U_r 3,6 kV; 7,2 kV; 12 kV; 17,5 kV; 24 kV; 36 kV, etc.	4.1	
Number of phases 1, 2 or 3		
Rated insulation level: power-frequency withstand voltage U_d Lightning impulse withstand voltage U_p	4.2	(Common value/across the isolating distance) a) / b) /
Rated frequency f_r	4.3	
Rated normal current I_r Incomer Busbar Feeder	4.4	 a) b) c)

Information	Clause/subclause of this standard	User to indicate requirement as appropriate
Rated short-time withstand current	4.5	
Main circuit (incomer/busbar/feeder) I_k		a)
Earthing circuit I_{ke}	8.106	b)
Rated peak withstand current	4.6	
Main circuit (incomer/busbar/feeder) I_p		a)
Earthing circuit I_{pe}	8.106	b)
Rated duration of short circuit	4.7	
Main circuit (incomer/busbar/feeder) t_k ,		a)
Earthing circuit t_{ke}	8.106	b)
Rated supply voltage of closing and opening devices and of auxiliary and control circuits U_a	4.8	
a) Closing and tripping		a)
b) Indication		b)
c) Control		c)
Rated supply frequency of closing and opening and of auxiliary circuits	4.9	
Internal arc fault IAC	3.135	Y/N
Types of accessibility to switchgear/ controlgear (for A, specify the side(s) for which they are required)	4.101.2	
A restricted to authorized personnel only		F for front side =
Classification test value in kA and duration in s	Examples in 8.104.6	L for lateral side =
	AA.4	R for rear side =
Rated cable test voltages U_{ct}	4.102	a.c. and/or d.c.
Low- and high-pressure interlocking and monitoring devices (state requirements for example, lock-out on low-pressure indication, etc.)	5.9	
Interlocking devices	5.11	
(state any additional requirements to 5.11)		
Degrees of protection by enclosures (if not IP2X):	5.13.1	
With doors closed		a)
With doors open		b)
Thermal stability test	6.106	
Humidity tests	6.107	
Additional information E.g. Installation conditions		

8.106 Ratings of earthing circuits

For systems with a solidly earthed neutral, the maximum short-circuit current of the earthing circuit may reach levels up to the rated short-time withstand current of the main circuit.

For systems with other than solidly earthed neutral, the maximum short-time current of the earthing circuit could theoretically reach levels up to 87 % of the rated short-time withstand current of the main circuit (short circuit under conditions of double-earth fault). However, double-earth faults at independent locations have a very low probability of occurring

completely through the earthing circuit of the switchgear and controlgear. Therefore this condition may not be applicable and the user may select a reduced earth fault current.

8.107 Ratings for cable testing

Users should specify values of rated cable test voltages allowing adequate margins above the actual cable test voltages expected to be applied.

9 Information to be given with enquiries, tenders and orders

Clause 9 of IEC 62271-1:2007 is not applicable.

9.1 Information with enquiries and orders

Subclause 9.1 of IEC 62271-1:2007 is not applicable:

When enquiring about or ordering an installation of solid-insulation enclosed switchgear and controlgear the following information should be supplied by the enquirer.

1) Particulars of the system:

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

2) Service conditions if different from standard (refer to Clause 2):

   Minimum and maximum ambient air temperature; any condition deviating from the normal service conditions or affecting the satisfactory operation of the equipment, such as, for example, unusual exposure to vapour, moisture, fumes, explosive gases, excessive dust or salt, thermal radiation, for example, solar, the risk of earth tremors or other vibrations due to causes external to the equipment to be delivered.

3) Particulars of the installation and its components:

   a) protection category PA or PB to be provided by the solid insulating enclosure;

   b) number of phases;

   c) number of busbars, as shown in the single-line diagram;

   d) rated voltage;

   e) rated frequency;

   f) rated insulation level;

   g) rated normal currents of busbars and feeder circuits;

   h) rated short-time withstand currents (I_k, I_{ke});

   i) rated duration of short circuit (if different from 1 s);

   j) rated peak withstand current (if different from 2,5 I_k for 50 Hz or 2,6 I_k for 60 Hz);

   k) rated cable test voltages;

   l) rated values of components;

   m) degree of protection for the solid insulating enclosure and partitions;

   n) circuit diagrams;

   o) description by name and type (accessibility) of the various compartments, if required;

   p) If applicable, loss of service continuity category (LSC1, LSC2, LSC2A or LSC2B);

   q) classification IAC, if required, with corresponding arc fault current and duration, as applicable.

4) Particulars of the operating devices:

   a) type of operating devices;

   b) rated supply voltage (if any):

c) rated supply frequency (if any);
d) rated supply pressure (if any);
e) special interlocking requirements.

Beyond these items the enquirer should indicate every condition which might influence the tender or the order, as, for example, special mounting or erection conditions, the location of the external high-voltage connections, the rules for pressure vessels, requirements for cable testing, treatment of exhausting gases, specific dimensions.

Information should be supplied if special type tests are required.

9.2 Information with tenders

Subclause 9.2 of IEC 62271-1:2007 is not applicable.

The following information, if applicable, should be given by the manufacturer with descriptive material and drawings.

1) Rated values and characteristics as enumerated in item 3 of 9.1.
2) Type test certificates or reports on request.
3) Constructional features, for example:
   a) mass of the heaviest transport unit;
   b) overall dimensions of the installation;
   c) arrangement of the external connections;
   d) facilities for transport and mounting;
   e) mounting provisions;
   f) description by name and category of the various compartments;
   g) classified sides;
   h) instructions for installation, operation and maintenance;
   i) type of gas-pressure or liquid-pressure system;
   j) rated filling level and minimum functional level;
   k) volume of liquid or mass of gas or liquid for the different compartments;
   l) specification of gas or liquid condition.
4) Particulars of the operating devices:
   a) types and rated values as enumerated in item 4 of 9.1;
   b) current or power for operation;
   c) operating times;
5) List of recommended spare parts which should be procured by the user.

10 Transport, storage, installation, operation and maintenance

Clause 10 of IEC 62271-1:2007 is applicable.

10.1 Conditions during transport, storage and installation

Subclause 10.1 of IEC 62271-1:2007 is applicable.

10.2 Installation

Subclause 10.2 of IEC 62271-1:2007 is applicable with the following addition to subclause 10.2.3.

10.2.3 Mounting

In the case of IAC classified switchgear and controlgear, guidance on safe installation conditions for the case of an internal arc should be provided as well. The hazards of the actual installation condition should be assessed with respect to installation conditions of the test specimen during the internal arc test (refer to 6.105). However, if the purchaser (user) considers that the risk is not relevant, the switchgear and controlgear can be installed without the restrictions indicated by the manufacturer.

10.3 Operation

Subclause 10.3 of IEC 62271-1:2007 is applicable.

10.4 Maintenance

Subclause 10.4 of IEC 62271-1:2007 is applicable with the following addition:

If temporarily inserted partitions are required, while performing certain maintenance procedures, to prevent accidental contact with live parts, then

– the manufacturer shall offer to supply the required partitions or their design;
– the manufacturer shall give advice direction as to the maintenance procedure and use of partitions;
– when installed according to the manufacturer's instructions, the requirements IP2X (according to IEC 60529) shall be met;
– such partitions shall meet the requirement of 5.103.3;
– the partitions and their supports shall have sufficient mechanical strength to avoid incidental contact of live parts.

NOTE Barriers and supports provided for mechanical protection only are not subject to this standard.

After a short-circuit event in service, the earthing circuit should be examined for potential damage and replaced in whole or in part if needed.

11 Safety

Clause 11 of IEC 62271-1:2007 is applicable, with the following addition:

Additional subclauses:

11.101 Procedures

Suitable procedures should be put in place by the user to ensure that a procedure-based accessible compartment may be opened only when the part of the main circuit contained in the compartment being made accessible is dead and earthed, or in the withdrawn position with corresponding shutters closed. Procedures may be dictated by legislation of the country of installation or by user safety documentation (e.g. EN 50187- refer to [14] of Bibliography).

11.102 Internal arc aspects

As far as the protection of persons is concerned, the correct performance of the solid-insulation enclosed switchgear and controlgear in case of an internal arc is not only a matter of design of the equipment itself, but also of the installation conditions and operating procedure, for instance, see 8.104.

Arcing due to an internal fault in the solid-insulation enclosed switchgear and controlgear may cause overpressure within the switchgear room. This effect is not within the scope of this standard but it should be taken into consideration when designing the installation.

12 Influence of the product on the environment

Clause 12 of IEC 62271-1:2007 is applicable.

Annex AA
(normative)

Internal arc fault – Method to verify the internal arc classification (IAC)

AA.1 Room simulation

The room shall be represented by a floor, ceiling and two walls perpendicular to each other. Where appropriate simulated cable access ways and/or exhaust ducts shall also be built.

NOTE 1 The dimensions of the room simulation establish defined test condition, however real installation conditions generally deviate, refer to 10.2.

Ceiling:

The test shall be performed at a ceiling height as specified by the manufacturer.

The ceiling height is always stated from the floor or false floor level where the switchgear is actually placed. This is also the level where the indicator racks are placed during the IAC test, refer to Figure AA.5.

However, the ceiling shall be located as a minimum:

– at a distance not less than 200 mm (± 50 mm) above the height of the test specimen and
– at a distance of 2 000 mm (± 50 mm) from the floor or false floor, if the height of the test specimen is less than 1 800 mm.

The height of the test specimen is determined by its most upper part that influences the gas flow, including pressure relief flaps in the highest open position by design and construction. The pressure relief flaps shall not strike the ceiling during opening.

The test results performed with these conditions are valid for all distances between test specimen and ceiling larger than the tested ones.

EXAMPLE A test performed with a distance between test specimen and ceiling of 600 mm is valid for this and all higher distances.

If the manufacturer states a distance between ceiling and the height of the test specimen between 0 mm and 200 mm, the test results are only valid for this ceiling distance and this distance may be declared as admissible for the installation instructions.

Lateral wall:

The lateral wall shall be placed at 100 mm ± 30 mm from the right or left lateral side of the test specimen. A lower distance can be chosen provided that it can be demonstrated that any permanent deformation of the lateral side of the test specimen is not interfered with or limited by the wall.

The test results performed with these conditions are valid for all distances between test specimen and lateral wall larger than the tested ones, provided that the gases are not directed to the walls.

Rear wall:

The test specimen shall be placed at a distance to the rear wall depending on the accessibility of the rear side of the switchgear and controlgear. Test specimens consisting of functional units with various depths shall have the required distances at the unit with the biggest depth.

In all cases the distance from the rear wall to the switchgear and controlgear is measured from the surface of the enclosure, disregarding protruding elements not expected to influence the evacuation of hot gases (e.g. handles).

Non-accessible rear side:

Unless the manufacturer states a larger minimum clearance, the wall shall allow a clearance to the rear of the test specimen of 100 mm ± 30 mm. A lower clearance can be chosen provided that it can be demonstrated that any permanent deformation of the rear side of the test specimen is not interfered with or limited by the wall.

This test arrangement is deemed valid for an installation mounted closer to the wall than the test arrangement, provided that two additional conditions are met (refer to 6.105.5, Criterion no.1).

If these conditions cannot be demonstrated, or the manufacturer requires direct qualification of a wall-mounted design, a specific test without clearance to the rear wall shall be carried out. However, the validity of such a test shall not be extended to any other installation condition.

When the test is carried out at any larger clearance to the rear wall, as stated by the manufacturer, this clearance shall be declared as a minimum admissible for the installation instructions. The instructions shall also include guidance on the obligation to adopt measures preventing persons to enter that area.

Accessible rear side:

The rear wall shall leave a standard clearance of 800 mm ($^{+100}_{0}$ mm) from the rear side of the test specimen.

The test is also valid for non-accessible rear side with a distance to the wall of 300 mm and more.

When the test is carried out at any larger clearance to the rear wall, as stated by the manufacturer, this clearance may be declared as a minimum admissible for the installation instructions.

Special case, use of exhausting ducts:

If the manufacturer claims that the design requires that cable access way and/or any other exhausting duct needs to be used to evacuate gases generated during the internal arc, their minimum cross-section dimensions, location and output features (flaps or grid, with their characteristics) shall be stated by the manufacturer. The test shall be carried out with simulation of such exhausting ducts. The output end of the exhausting ducts shall be at least 2 000 mm (± 50 mm) away from the switchgear and controlgear tested.

For tests performed with an exhausting duct, the absolute ceiling height is not relevant. If the exhausting duct is installed on top of the specimen, a minimum distance of the test specimen to the ceiling of 100 mm shall be ensured to document permanent deformations of the exhausting duct. If such a test is performed for accessible rear side, the test arrangement is

deemed valid for an installation for non-accessible rear side at any distance to the wall, if two additional conditions are met, refer to 6.105.5, Criterion No. 1.

NOTE 2 The possible effects of hot gases at the end and around the exhausting duct beyond the indicators, are not covered by the tests in this standard.

AA.2 Indicators (for assessing the thermal effects of the gases)

AA.2.1 General

Indicators are pieces of black cotton cloth so arranged that their cut edges do not point toward the test specimen.

Black cretonne (cotton fabric approximately 150 g/m^2) or black cotton-interlining lawn (approximately 40 g/m^2) shall be used for indicators, depending on the accessibility condition.

Care shall be taken to see that the vertical indicators can not ignite each other. This is achieved by fitting them in a frame of steel sheet, with a depth of $2 \times 30\,^{0}_{-3}$ mm, refer to Figure AA.1.

With the horizontal indicators, care shall be taken that glowing particles do not accumulate. This is achieved if the indicators are mounted without frame, refer to Figure AA.2.

The indicator dimensions shall be 150 mm × 150 mm ($^{+15}_{0}$ mm).

AA.2.2 Arrangement of indicators

Indicators shall be placed at each classified side, on a mounting rack, at distances defined for accessibility type A.

The length of the mounting rack shall be larger than the test specimen to take into account the possibility of hot gases escaping at angles of up to 45° from the surface under test. This means that the mounting frame on each side – if applicable – shall be at least 300 mm, provided that the position of the wall in the arrangement of the room simulation does not limit this extension.

The distance from the indicators fitted vertically to the switchgear and controlgear is measured from the surface of the enclosure, disregarding protruding elements not expected to influence the evacuation of hot gases (for example the handles). If the surface of the switchgear and controlgear is not regular, the indicators should be placed to simulate as realistically as possible the position that a person may usually adopt in front of the equipment, at the above- indicated distance, according to the type of accessibility A (authorized personnel).

Black cretonne (cotton fabric approximately 150 g/m^2) shall be used for the indicators.

Indicators shall be fitted vertically at all classified sides of the solid-insulation enclosed switchgear and controlgear up to a height of 2 000 mm (± 50 mm) evenly distributed, arranged in a checkerboard pattern, covering 40 % to 50 % of the area (refer to Figures AA.3 and AA.4).

The distance from the indicators to the switchgear and controlgear shall be 300 mm (± 15 mm).

Indicators shall also be arranged horizontally at a height of 2 000 mm (± 50 mm) above the floor as described in Figures AA.3 and AA.4 and covering the whole area between 300 mm (± 30 mm) and 800 mm (± 30 mm) from the solid-insulation enclosed switchgear and controlgear. When the ceiling is placed at a height of 2 000 mm (± 50 mm) above the floor

(refer to AA.1) no horizontal indicators are required. The indicators shall be evenly distributed, arranged in a checkerboard pattern, covering 40 % to 50 % of the area (refer to Figures AA.3 and AA.4).

Special accessibility conditions:

where normal operation requires persons to stand or walk upon the equipment, horizontal indicators shall be placed above the upper accessible surface, whatever the height of the switchgear and controlgear;

black cotton-interlining lawn (approximately 40 g/m^2) shall be used for the indicators.

NOTE Black cretonne (cotton fabric approximately 150 g/m^2) is considered to represent workman's clothes, whereas cotton-interlining lawn (approximately 40 g/m^2) is considered to represent light summer wear of the general public.

AA.3 Tolerances for geometrical dimensions of test arrangements

Summary of tolerances for geometrical dimensions of test arrangements as given in the text (the values given there in brackets are tolerances only for the actual test arrangement and do not extend the required values):

Distance between test specimen and ceiling:	± 50 mm
Distance between test specimen and lateral wall:	± 30 mm
Distance between test specimen and rear wall (non-accessible):	± 30 mm
Distance between test specimen and rear wall (accessible):	0/+100 mm
Indicator dimensions:	0/+15 mm
Depth of the steel frame for indicators:	-3/0 mm
Height of indicators	± 50 mm
Distance between test specimen and indicators for Accessibility type A	± 30 mm

AA.4 Test parameters

AA.4.1 General

A test performed at a given voltage, current and duration is generally valid for all lower values of current, voltage and duration.

Lower current level may influence the behaviour of the pressure-relief devices and the burn-through performance. For lower short-circuit current level than tested, care should be taken in the interpretation of the results.

AA.4.2 Voltage

The test shall be performed at any suitable voltage up to and including the rated voltage U_r. If a voltage lower than U_r.is chosen, the following conditions shall be met:

a) the average r.m.s. current value during the test as computed by a digital recording device complies with current requirements of AA.4.3.1;

b) the arc is not extinguished prematurely in any of the phases in which it has been initiated. Temporary single-phase extinguishing is permitted, as long as the cumulated duration of the intervals without current does not exceed 2 % of the test duration and the single events last not longer than to the next prospective current zero, provided that the integral of the a.c. component of the current equals at least the value specified in AA.4.3.1 in the relevant phase.

AA.4.3 Current

AA.4.3.1 AC component

The test current shall be set within a ±5 % tolerance of the rated arc fault current (I_A or I_{Ae}). If the applied voltage is equal to U_r , this tolerance applies only to the prospective current.

The current should remain constant. If the capability of the test plant does not permit this, the test shall be extended until the integral of the a.c. component of the current ($I \times t$) equals the value specified within a tolerance of ($^{+10}_{0}$ %). In this case, the current shall be equal to the specified value at least during the first three half-cycles and shall not be less than 50 % of the specified value at the end of the test.

NOTE Information about the relationship between type of neutral earthing and the single phase-to-earth arc fault current is provided in 8.104.6

AA.4.3.2 Peak current

The instant of closing shall be chosen so that the peak current is flowing in one of the outer, phases and a major loop also occurs in the other outer phase.

If the applied voltage is equal to U_r, the peak value of the prospective current shall be set to 2,5 times (for frequencies up to 50 Hz) or 2,6 times (for 60 Hz) the r.m.s. value of the a.c. component defined in AA.4.3.1 with a tolerance of $^{+5}_{0}$ %.

If the voltage is lower than U_r, the peak value of the prospective current is irrelevant, but the peak value of the short-circuit current for the solid-insulation enclosed switchgear and controlgear under test shall not drop below 90 % of the rated peak value.

For higher d.c. time constants than the standard defined 45 ms of the feeding network, a uniform value of 2,7 times the r.m.s. value of the a.c. component should be used as a rated value for both 50 Hz and 60 Hz applications.

In the case of two-phase initiating of the arc, the instant of closing shall be chosen to provide the maximum possible d.c. component.

AA.4.4 Frequency

At a rated frequency of 50 Hz or 60 Hz, the frequency at the beginning of the test shall be between 48 Hz and 62 Hz. At other frequencies it shall not deviate from the rated value by more than ±10 %.

AA.5 Test procedure

AA.5.1 Supply circuit

AA.5.1.1 Three phase tests

The supply circuit shall be three-phase and all three phases of the switchgear and controlgear shall be energised. The neutral point of the supply circuit may be either isolated or earthed through an impedance, in such a way that the maximum earth current is less than 100 A. In this situation, the arrangement covers all situations of neutral treatment.

AA.5.1.2 Single phase tests

One terminal of the supply circuit shall be connected to the earthing point provided on the switchgear and controlgear, the other to the phase under test.

The two remaining phases of the test specimen shall be energised at U_r, unless mutual influence between the phases is unlikely.

If one of the remaining phases ignites, the test shall be repeated as a three-phase test.

AA.5.1.3 Feeding arrangements

The feeding direction shall be as follows:

– for a connection compartment: supply from the busbar, through the main switching device;

– for a busbar compartment: the supply connections shall not introduce any opening in the compartment under test. Supply shall be made through one barrier or through a suitable feeder unit, from the opposite end of the switchgear and controlgear;

In case of non-symmetrical designs of a busbar compartment, the most onerous internal arc initiation shall be considered, with respect to arc energy and burn-through.

– for the main switching device compartment: supply from the busbar, with the device in the closed position;

– for a compartment with several main circuit components inside: supply through one available set of incoming bushings, with all switching devices in the closed position, except for earthing switches, if any, which shall be in the open position.

AA.5.2 Arc initiation

AA.5.2.1 General

The arc shall be initiated between all the phases under test by means of a metal wire of about 0,5 mm diameter or, in the case of a single phase-to earth arc fault current, between one phase and earth.

The point of initiation shall be located at the furthest point, downstream in the current path from the supply, within the compartment under test. If the main circuit of the compartment under test includes current limiting devices (e.g. fuses), the point of initiation shall be chosen upstream from the limiting device.

The number of phases to be tested, the connection arrangements, and the action to be taken if other phases are affected, shall be in accordance with Table AA.1, according to the construction of the compartment under test.

If a value of I_{Ae} is assigned to the switchgear and controlgear at least one compartment shall be tested single phase to earth. If this value is greater than 87 % of I_A any two phase tests shall use the value of I_{Ae} for the test current.

In the case of single phase- to earth ignition, the arc shall be initiated between the middle phase and closest earth.

AA.5.2.2 Compartments with solid-insulation embedded live parts

In compartments where the live parts are covered by solid insulating material, the arc shall be initiated at the following locations:

a) at gaps or joining surfaces between the insulation of solid-insulation embedded parts;

b) by perforation at solid insulating joints made on site when prefabricated solid insulating parts are not used;

c) when a) and b) are not applicable, by perforation or partial removal of solid insulating material from the conductors.

AA.5.2.3 Connection compartments

AA.5.2.3.1 Cable compartments with plug-in solid insulating connections

For outer-cone plug-in connections, the phase(s) to be ignited shall be fitted with lugs without solid insulation.

For inner cone connections, the initiation shall be made by perforating or partly removing their solid insulation directly below the cable plug(s) of the phase(s) to be ignited.

The other phase(s) shall be provided with a plug-in connector as can be used in service, able to be energized.

NOTE Experience shows that the fault generally does not evolve towards a three-phase fault; therefore, the choice of the fitting for the third phase is not critical.

AA.5.2.3.2 Compartments with site-made solid insulating connections

For connection compartments in which connections are made with site-made solid insulating connections, the phase(s) to be ignited shall be fitted with lugs without solid insulation.

AA.5.2.3.3 Compartments without plug in or site-made solid insulating connections

Cable connections without plug-in or site-made solid insulating connections shall be tested without cables. The ignition shall be made three-phase.

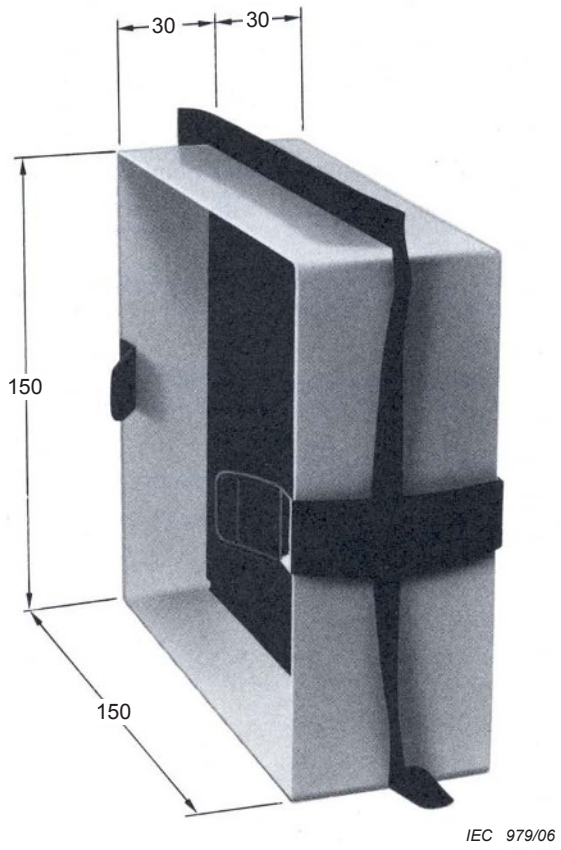
Cable lugs shall be fitted in their service configuration.

AA.5.2.4 Single phase compartments without any earthed metallic parts

For single phase compartments without any earthed metallic parts, a path shall be created through the insulation to the closest earthed metallic part.

Table AA.1 – Parameters for internal arc fault test according to compartment construction

		Test current	Number of phases/earth for arc initiation	Action if other phase affected
Three phase compartments, other than connection compartments:	with bare conductors	I_A	Three	N/A
	conductors with site-made solid insulation	I_A	Three	N/A
	conductors with non site-made solid insulation	87 % I_A	Two	Repeat as 3 phase test
		I_{Ae}	One phase and earth	
Single phase compartments:		I_{Ae}	One phase and earth.	Repeat as 3 phase test
Connection compartments:	Connections uninsulated or fitted with site-made solid insulation	I_A	Three	N/A
	Connections using outer cone plugs (screened or unscreened)	87 % I_A	Two	Repeat as 3 phase test
		I_{Ae}	One phase and earth	
	Connections using inner cone plugs	87 % I_A	Two	Repeat as 3 phase test
		I_{Ae}	One phase and earth	



Dimensions in millimetres

Figure AA.1 – Mounting frame for vertical indicators

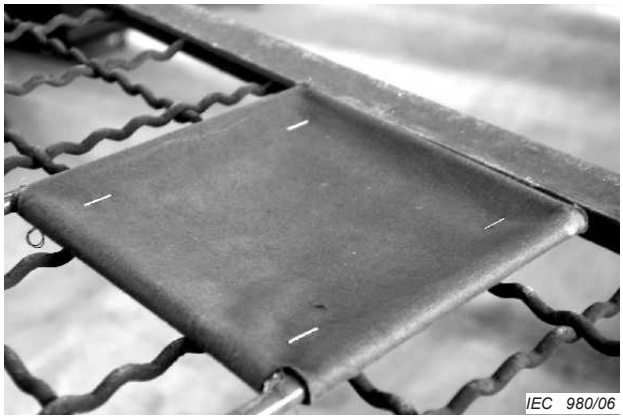
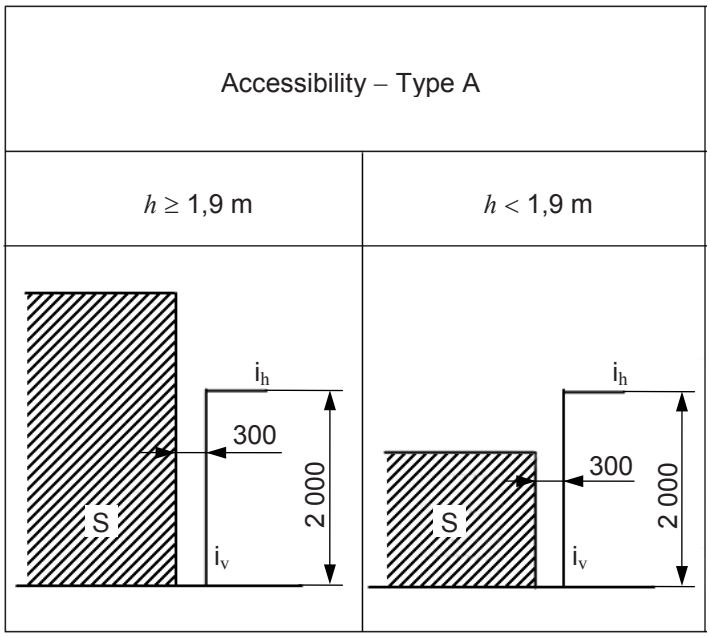


Figure AA.2 – Horizontal indicator



IEC 0932/14

Dimensions in millimetres,
unless otherwise stated

Key

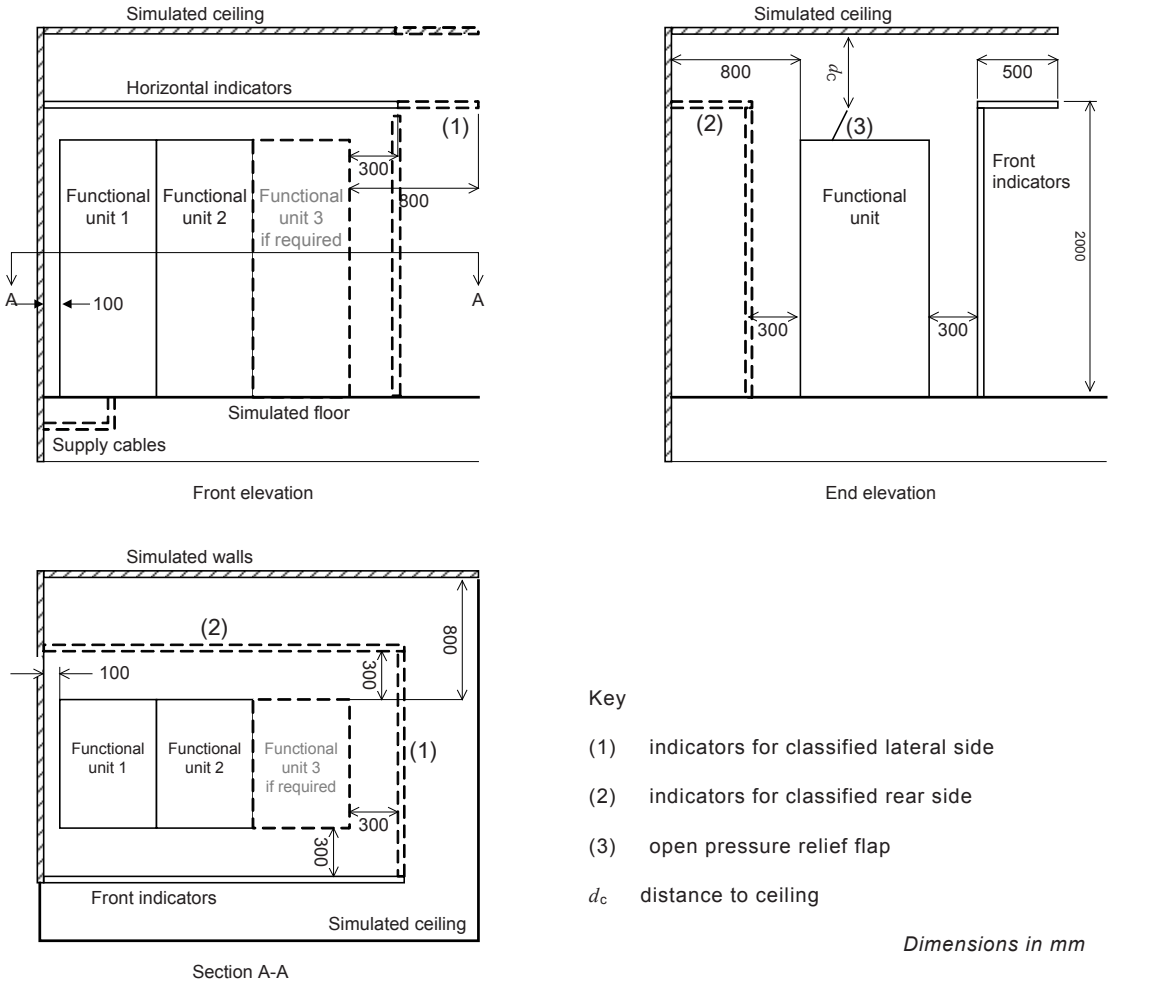
S switchgear and controlgear

h height of switchgear and controlgear

i_h horizontal indicators

i_v vertical indicators

Figure AA.3 – Position of the indicators



Key

(1) indicators for classified lateral side

(2) indicators for classified rear side

(3) open pressure relief flap

d_c distance to ceiling

Dimensions in mm

IEC 0933/14

Figure AA.4 – Room simulation and indicator positioning for accessibility A, classified rear side, functional unit of any height

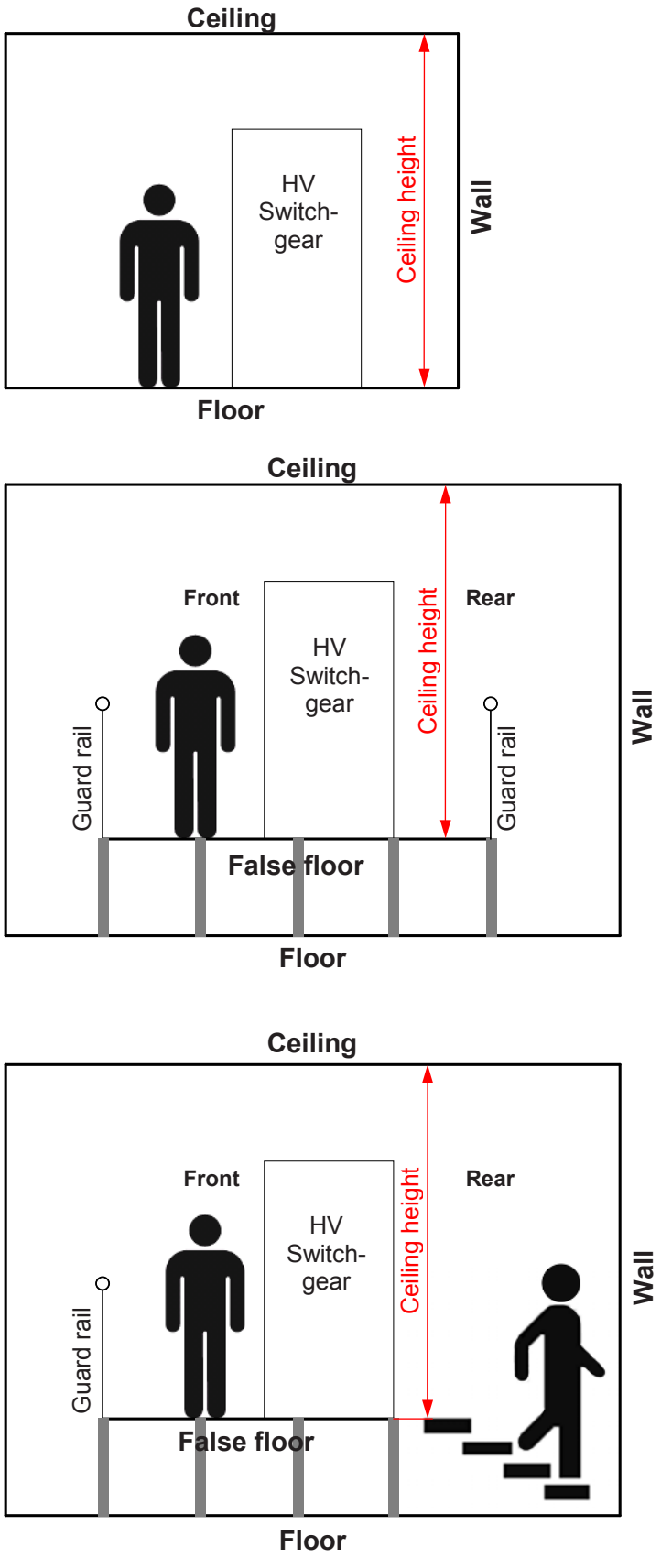


Figure AA.5 – Ceiling height stated from the floor or false floor level where the switchgear is actually placed

Annex BB
(normative)

Partial discharge measurement

BB.1 General

The measurement of partial discharges is a suitable means of detecting certain defects in the equipment under test and is a useful complement to the dielectric tests. Experience shows that partial discharges may lead in particular arrangements to a progressive degradation in the dielectric strength of the insulating material, especially of solid insulation, and fluid-filled compartments.

On the other hand, it is not yet possible to establish a reliable relationship between the results of partial discharge measurements and the life expectancy of the equipment owing to the complexity of the insulation systems used in solid-insulation enclosed switchgear and controlgear.

BB.2 Application

The measurement of partial discharges is in general appropriate for solid-insulation enclosed switchgear and controlgear.

Because of the design variations, a general specification for the test object cannot be given. In general, the test object should consist of assemblies or subassemblies with dielectric stresses which are identical to those which would occur in the complete assembly of the equipment.

NOTE 1 Test objects consisting of a complete assembly are to be preferred. In the case of integrated switchgear and controlgear design, especially where various live parts and connections are embedded in solid insulating material, tests are necessarily carried out on a complete assembly.

NOTE 2 In the case of designs consisting of a combination of conventional components (for instance, instrument transformers, bushings), which can be tested separately in accordance with their relevant standards, the purpose of this partial discharge test is to check the arrangement of the components in the assembly.

This test may be carried out on assemblies or subassemblies. Care should be taken that external partial discharges do not affect the measurement. To prevent these external partial discharges, shielding or grading electrodes may be applied.

BB.3 Test circuits and measuring instruments

The partial discharge tests shall be in accordance with IEC 60270.

NOTE The partial discharge quantity is apparent charge that is expressed usually in picocoulombs (pC).

Three-phase equipment is either tested in a single-phase test circuit or in a three-phase test circuit (refer to Table BB.1).

a) Single-phase test circuit

Procedure A:

To be used as a general method for equipment designed for use in systems with or without solidly earthed neutral.

For measuring the partial discharge quantities, each phase shall be connected to the test voltage source successively, the other two phases and all the parts earthed in service being earthed.

Procedure B:

To be used only for equipment exclusively designed for use in systems with solidly earthed neutral.

For measuring the partial discharge quantities, two test arrangements shall be used.

At first, measurements shall be made at a test voltage of 1,1 U_r. Each phase shall be connected to the test voltage source successively, the other two phases being earthed. It is allowed to insulate or to remove all the metallic parts normally earthed in service. Also any conductive layer that is normally earthed in service, may be isolated from earth for this test.

An additional measurement shall be made at a reduced test voltage of 1,1 $U_r/\sqrt{3}$ during which the parts being earthed in service are earthed and the three phases connected to the test voltage source are bridged.

b) Three-phase test circuit

When suitable test facilities are available, the partial discharge tests may be carried out in a three-phase arrangement.

In this case, it is recommended to use three coupling capacitors connected as shown in Figure BB.1. One discharge detector can be used which is connected successively to the three measuring impedances.

For calibration of the detector on one measuring position of the three-phase arrangement, short-duration current pulses of known charge are injected between each of the phases taken in turn on the one hand, and the earth and the other two phases, on the other hand. The calibration giving the lowest deflection is used for the determination of the discharge quantity.

In the case of equipment designed for use in systems without solidly earthed neutral, an additional test shall be made (as type test only). For this test, each phase of the test object and the corresponding phase of the voltage source shall be earthed successively, refer to Figure BB.2.

BB.4 Test procedure

The applied test-voltage is raised to a pre-stress value of at least 1,3 U_r or 1,3 $U_r/\sqrt{3}$ in accordance with the test circuit (refer to Table BB.1) and maintained at this value for at least 10 s.

Partial discharges occurring during this period shall be disregarded. The voltage is then decreased without interruption to 1,1 U_r or 1,1 $U_r/\sqrt{3}$ in accordance with the test circuit and the partial discharge quantity is measured at this test voltage (refer to Table BB.1).

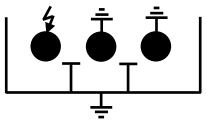
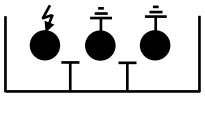
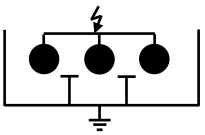
Alternatively, the partial discharge test may be performed while decreasing the voltage after the power- frequency voltage tests

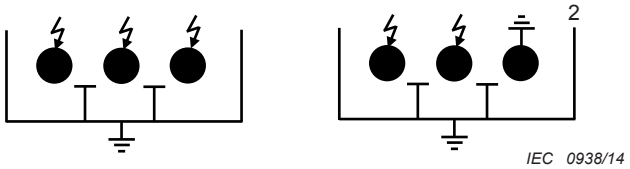
As far as possible with respect to the actual background noise level, the partial discharge inception and the partial discharge extinction voltages should be recorded for additional information.

In general, tests on assemblies or subassemblies should be made with the switching devices in the closed position. In the case of disconnectors where deterioration of the insulation between the open contacts by partial discharges is conceivable, additional partial discharge measurements should be made with the disconnector in the open position.

On fluid-filled equipment the tests shall be carried out at the minimum functional level or the rated filling level, whichever is most onerous. For routine tests the rated filling level shall be applied.

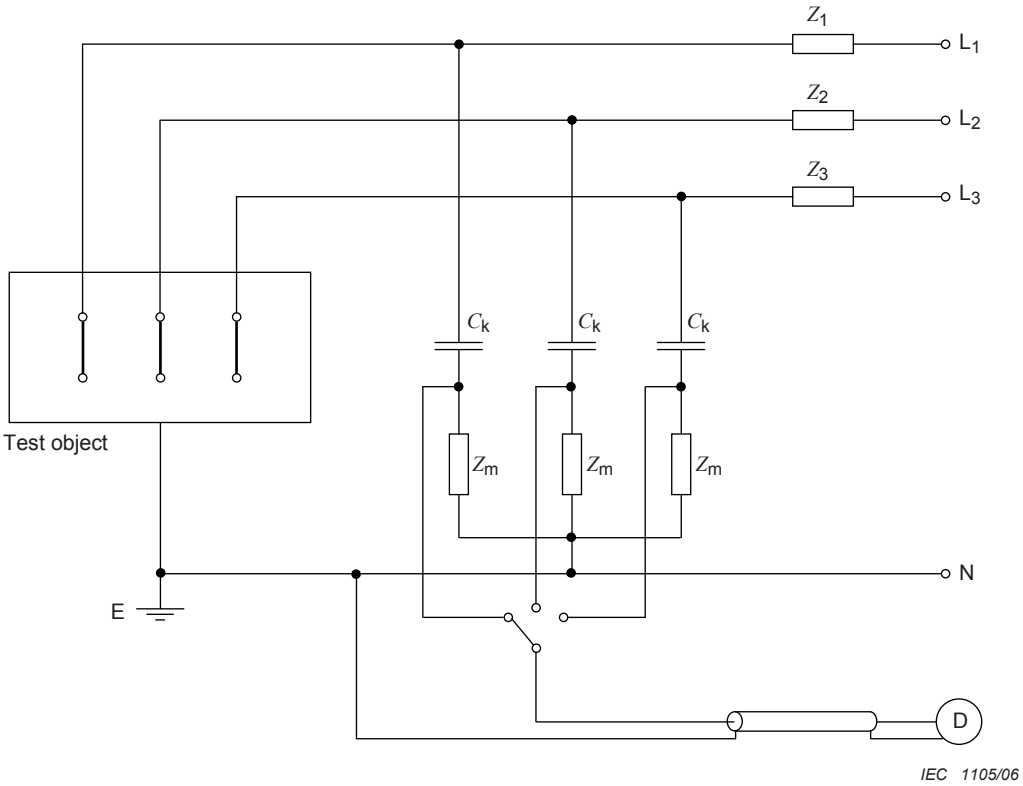
Table BB.1 – Test circuits and procedures

	Single-phase testing		
	Procedure A	**Procedure B**	
Voltage source connected to	Each phase successively	Each phase successively	Three phases simultaneously
Earth-connected elements	Both the other phases and all the parts earthed in service	Both the other phases	All the parts earthed in service
Minimum pre-stress voltage	1,3 U_r	1,3 U_r	1,3 $U_r/\sqrt{3}$
Test voltage	1,1 U_r	1,1 U_r	1,1 $U_r/\sqrt{3}$
Basic diagram	 IEC 0935/14	 IEC 0936/14	 IEC 0937/14

	Three-phase testing
Voltage source connected to	Three phases (Figures BB.1 and BB.2)
Earth-connected elements	All the parts earthed in service
Minimum pre-stress voltage	1,3 U_r [1]
Test voltage	1,1 U_r [1]
Basic diagram	
	 2 IEC 0938/14

[1] Voltage between phases

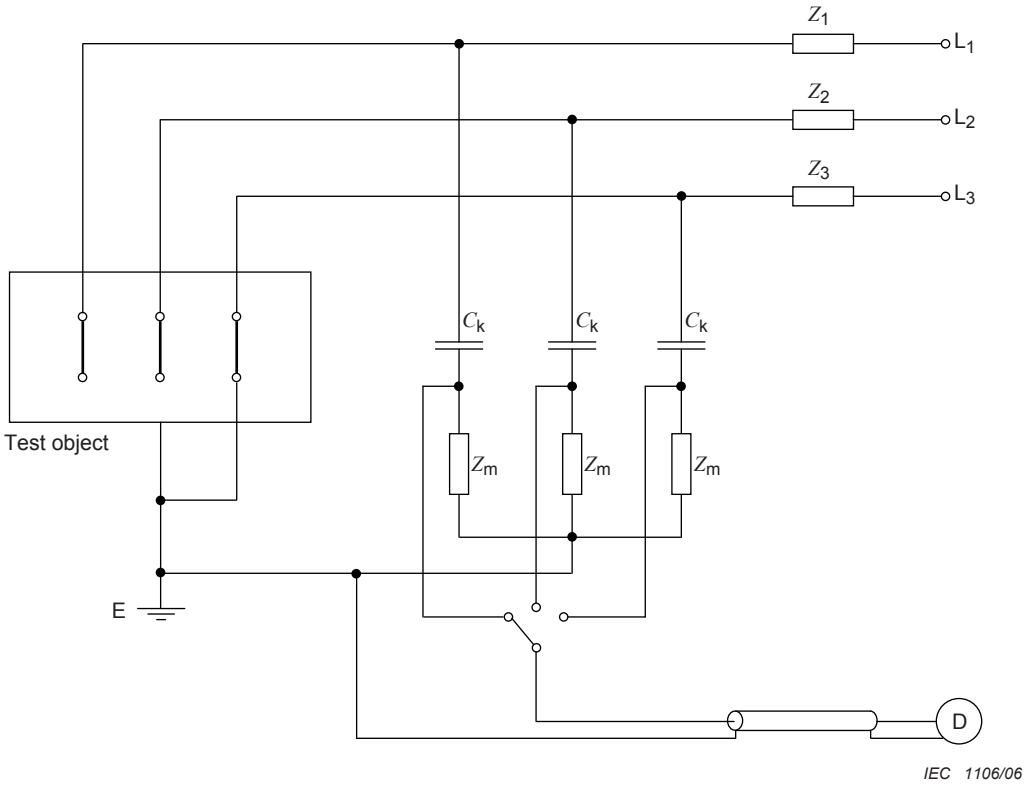
[2] Additional test in the case of a system without solidly earthed neutral (for type tests only).



Key

N	Neutral connection
E	Earth connection
L_1, L_2, L_3	Terminals for the connection of the three-phase voltage source
Z_1, Z_2, Z_3	Impedances of the test circuit
C_k	Coupling capacitor
Z_m	Measuring impedance
D	Partial discharge detector

Figure BB.1 – Partial discharge test circuit (three-phase arrangement)



Key

E	Earth connection
L_1, L_2, L_3	Terminals for the connection of the three-phase voltage source
Z_1, Z_2, Z_3	Impedances of the test circuit
C_k	Coupling capacitor
Z_m	Measuring impedance
D	Partial discharge detector

Figure BB.2 – Partial discharge test circuit (system without earthed neutral)

Annex CC
(informative)

Regional deviations

5.104 In some countries, regulations require that the isolating distance is visible.

Annex DD
(normative)

Humidity test

DD.1 General

The object of the humidity test is to prove that the solid-insulation enclosed switchgear and controlgear is safe when touched on the accessible surface of the solid insulating enclosure, not only in a dry state but also with condensation and light pollution.

Under normal service conditions the ambient air is not materially polluted. This statement does not exclude, however, the possibility of a certain degree of pollution occurring in the course of time, depending on the frequency and quality of cleaning and reconditioning of the solid insulating surfaces.

This humidity test does not cover the security requirements relating to other influencing factors, although the philosophy of this test may serve as a base for an ageing test in connection with reliability in general.

The solid-insulation enclosed switchgear and controlgear is exposed to a certain number of identical humidity and temperature cycles in a test chamber, in which the humidity is generated by fog formed from conductive water. During this test an a.c. power-frequency voltage is continuously applied to the test object.

DD.2 Test procedure and test conditions

DD.2.1 Test cycle and its duration

The test cycle should be chosen so that all the surfaces of the test object are wet during about half of its duration and dry during the other half. To obtain this result the test cycle consists of a period with a low air temperature (T_{min}) and a period with a high air temperature (T_{max}) inside the test chamber. Both periods shall be equal in time and the generation of fog shall be maintained for the first half of the test cycle. The temperature variation between the two periods shall be (10 ± 2) K. The value of the low air temperature (T_{min}) shall be approximately equal to the ambient air temperature outside the test chamber (see Figure DD.1).

The beginning of fog generation (t_o) coincides in principle with the beginning of the low air temperature period. However, to wet the vertical surfaces of materials with a high thermal time constant, it may be necessary to start the fog generation later within the low air temperature period.

The duration of the test cycle depends on the thermal characteristics of the solid-insulation enclosed switchgear and controlgear and shall be sufficiently long both at high and low temperatures to cause wetting or drying of all the solid insulating surfaces.

Preliminary cycles shall be carried out with the test object placed in the test chamber in order to observe and to check these conditions.

The temperature and the relative humidity of the air in the test chamber shall be measured in the immediate vicinity of the solid insulating enclosure and shall be recorded for the whole duration of the test.

NOTE In order to achieve the required conditions, a duration of the test cycle of 8 h is generally satisfactory.

DD.2.2 Generation of fog

The fog is obtained by the continuous or periodical atomizing of 0,2 dm^3 to 0,5 dm^3 conductive water per hour and per cubic metre of test chamber volume. The resistivity of the water shall be 30 Ωm with a tolerance of ±10 % (equivalent to a conductivity of 0,033 S/m) at the lower value of the test-cycle temperature.

The diameter of the droplets shall be less than 10 μm. Such a fog may be achieved by mechanical atomizers situated at the bottom of the test chamber and directed upwards in such a manner that the solid insulating surfaces of the test object will not be sprayed direct. No water shall drop from the ceiling upon the test object.

During the fog generation the test chamber shall be closed and no additional forced air-circulation is permitted.

For the adjustment of the conductivity of the water, sodium chloride (NaCl) is added to distilled water. If a suitable supply of tap water is available, it may also be used.

NOTE 1 The relation between conductivity of the water and its temperature is given in IEC 60060-1.

NOTE 2 The method for measuring the conductivity is given in IEC 60507, refer to [14] of bibliography.

DD.2.3 High air temperature period

The high air temperature is achieved with the aid of a heater in combination with forced air-circulation inside the test chamber. This forced circulation shall not be directed at the test object.

DD.2.4 Test chamber

A proposal for an appropriate test chamber with thin walls is made in Figure DD.2.

The volume of the test chamber shall be at least five times the circumscribed volume of the test object. The test chamber shall not be higher than 2,5 m and the base dimensions shall ensure that the test object placed on the bottom will have a minimum distance from the wall of 0,15 m and from the atomizer of 0,5 m.

No special requirements are stated for the wall materials of the test chamber. However, materials having a high heat conductivity and a low thermal inertia are recommended because in this case the transition periods between wetting and drying and between drying and wetting will not significantly influence the time during which the solid insulating surfaces of the test object are wet.

If the walls do not meet these conditions, special measures should be taken to ensure that the period during which the solid insulating surfaces are wet is approximately equal to half the duration of one test cycle.

DD.2.5 Test object

The solid-insulation enclosed switchgear and controlgear to be tested shall be in a new condition with its outside solid insulating surfaces clean. It shall be mounted in the test chamber in its usual upright position, complete with all solid insulating parts and the continuity

of the main circuit ensured. Precautions shall be taken to ensure that no deposit of water accumulates inside the solid insulating enclosure during the test.

DD.2.6 Test voltage and voltage supply

During the humidity test the following power-frequency voltages shall be continuously applied to the main circuit of the solid-insulation enclosed switchgear and controlgear:

– U_r between phases;
– $U_r/\sqrt{3}$ between phase and earth.

DD.2.7 Total test duration

The total duration during which the surfaces are wet shall be 120 h. Normally, the period of fog generation equals the period of wet surfaces which shall be approximately equal to half the duration of one test cycle; thus the total duration of the humidity test will be a minimum of 240 h.

If during the preliminary cycles a considerable difference is observed between the period of fog generation and the corresponding period during which the surfaces are wet, the test shall be based on the total duration during which the solid insulating surfaces are wet.

DD.3 Test criteria and evaluation

DD.3.1 Criterion during the test

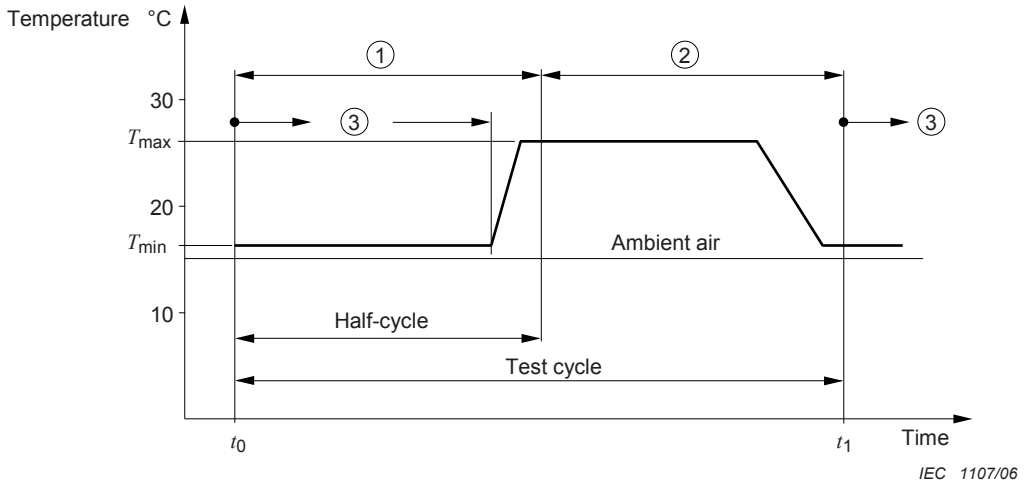
During the total duration of the humidity test, no flash-over shall occur either between phases or between phase and earth.

DD.3.2 Criterion after the test

The humidity test shall be followed, without any cleaning, by a supplementary test cycle. During the wet surface period, the leakage current shall be measured in accordance with 6.104.3. The leakage current to earth through the metal foil at any accessible place and at any time of this period shall not exceed 0,5 mA. Further supplementary test cycles may be carried out in order to verify the value of the leakage current with the metal foil attached to different places of the accessible surfaces.

DD.3.3 Evaluation of the test

If the criteria in DD.3.1 and DD.3.2 are met, the solid-insulation enclosed switchgear and controlgear shall be considered to have passed the humidity test.



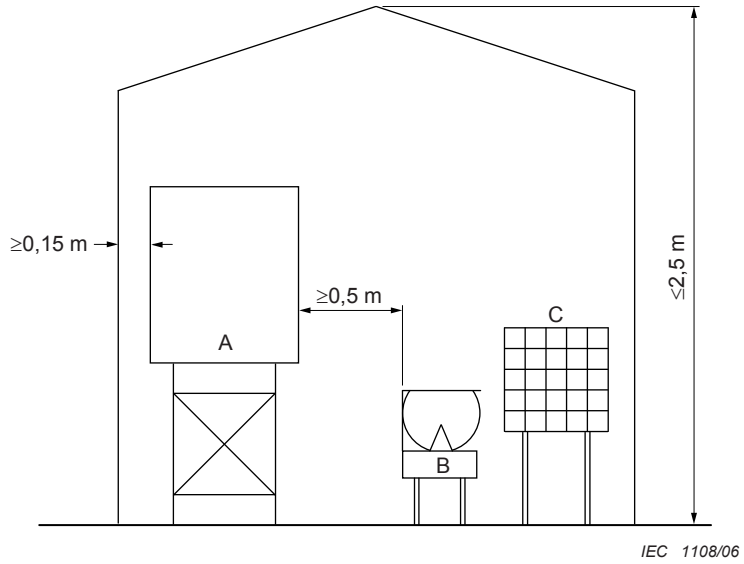
Key

1 wet surface period

2 dry surface period

3 fog generation

Figure DD.1 – Test cycle



Key

A test object

B atomizer

C radiator

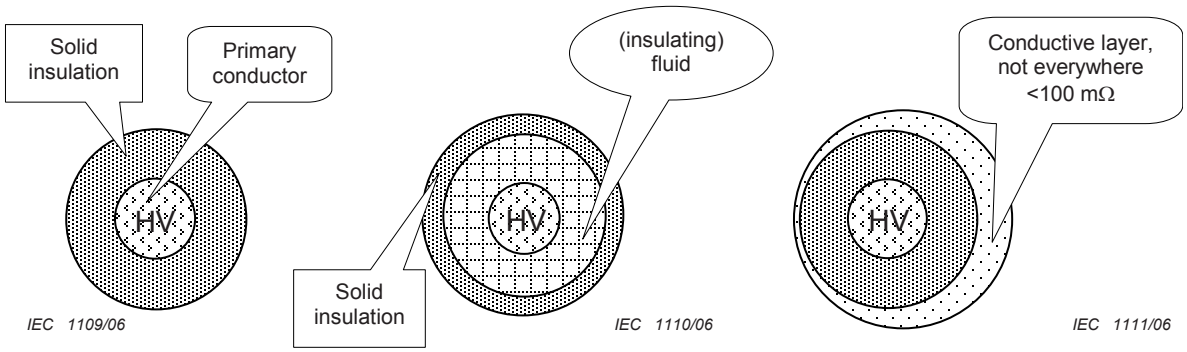
Figure DD.2 – Test chamber

Annex EE
(informative)

Protection categories

EE.1 Protection category PA

Protection category PA has the following three different basic arrangements:



a) b) c)

Figure EE.1 – Possible designs for protection category PA

Description of the different designs represented in Figure EE.1:

a) The solid insulation itself fulfils the requirements from items a), b), c) and d) of 5.102.3.

   To be tested with 100 cm^2 metal foil at most unfavourable places: power-frequency voltage test and lightning impulse voltage test (6.104.2a)).

b) The insulation fulfils the requirements from items a) and d) of 5.102.3.

   To be tested with 100 cm^2 metal foil at most unfavourable places: power-frequency voltage test and lightning impulse voltage test (6.104.2a)).

   The solid insulation fulfils the requirements of 5.102.3b).

   Sample to be tested at power-frequency voltage test (6.104.2b)).

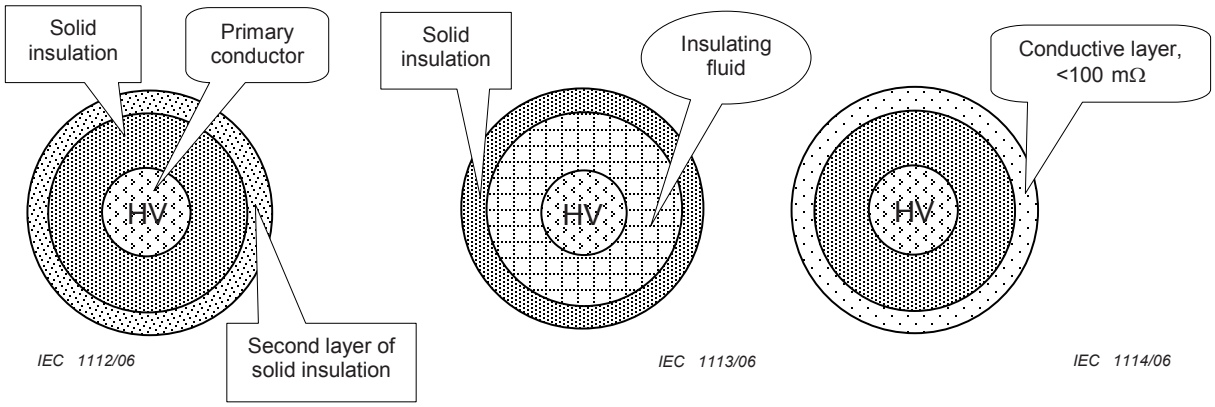
   The fluid insulation fulfils the requirements of 5.102.3c).

   To be tested with 150 % U_r for 1 min to the inside of the solid insulation (6.104.2c)).

c) Same as for a) in Figure EE.1

EE.2 Protection category PB

Protection category PB has the following three different basic arrangements:



a) (PB1) **b) (PB1)** **c) (PB2)**

Figure EE.2 – Possible designs for protection category PB

Apart from the demands for protection category PA, the following extra demands apply for the protection category PB defined in Figure EE.2:

PB1:

a) The second layer of solid insulating material fulfils the requirements of 5.102.3e).

   To be separately tested with 100 cm^2 metal foil at 150 % U_r for 1 min (6.104.2d)).

b) The insulation fulfils the requirements from 5.102.3f).

   To be tested with ambient air instead of insulating fluid, with 100 cm^2 metal foil at the inside at 150 % U_r for 1 min (6.104.2d)).

PB2:

c) The conductive layer fulfils the requirements in 5.102.3g).

   Resistance to be tested according to 6.4.101.

Annex FF
(informative)

List of symbols and abbreviations used in IEC 62271-201

Description	Symbol	Clause
Alarm level for insulation	p_{ae}	3.6.5.3*
Arc fault current and duration	I_A, t_A	4.101.4
Category LSC1 functional unit	LSC1	3.134.2
Category LSC2 functional units	LSC2	3.134.1
Functional unit of category LSC2A	LSC2A	3.134.1.1
Functional unit of category LSC2B	LSC2B	3.134.1.2
Internal arc classification	IAC	3.135
Loss of Service Continuity category	LSC	3.134
Minimum functional level for insulation	p_{me}	3.6.5.4*
Partition class	PI	3.111
Protection category PA	PA	3.140.1
Protection category PB	PB	3.140.2
Protection category PB1	PB1	3.140.2
Protection category PB2	PB2	3.140.2
Rated continuous current	I_r	4.4.1
Rated d.c. cable test voltage	U_{ct} (d.c.)	4.102.3
Rated duration of phase to earth short circuit	t_{ke}	4.7.102
Rated duration of short circuit	t_k	4.7.101
Rated filling level for insulation	p_{re}	4.10
Rated frequency	f_r	4.3
Rated lightning impulse withstand voltage	U_p	4.2
Rated peak phase to earth withstand current	I_{pe}	4.6.102
Rated peak withstand current	I_p	4.6.101
Rated power frequency withstand voltage	U_d	4.2
Rated power-frequency cable test voltage	U_{ct} (a.c.)	4.102.2
Rated short-time phase to earth withstand current	I_{ke}	4.5.102
Rated short-time withstand current	I_k	4.5.101
Rated supply frequency of operating devices and of auxiliary and control circuits	f_a	4.9
Rated supply voltage of closing and opening devices and of auxiliary and control circuits	U_a	4.8
Rated voltage	U_r	4.1
Single phase to earth arc fault current and duration	I_{Ae}, t_{Ae}	4.101.5

* Definition from IEC 62271-1

Bibliography

[1] IEC 60050-195:1998, *International Electrotechnical Vocabulary – Part 195: Earthing and protection against electric shock*

[2] IEC 60050-601:1985, *International Electrotechnical Vocabulary – Chapter 601: Generation, transmission and distribution of electricity – General*

[3] IEC 60059:1999, *IEC standard current ratings*

[4] IEC 60243-1:2013, *Electrical strength of insulating materials – Test methods – Part 1: Tests at power frequencies*

[5] IEC 60507:1991, *Artificial pollution tests on high-voltage insulators to be used on a.c. systems*

[6] IEC 60724:2000, *Short-circuit temperature limits of electric cables with rated voltages of 1 kV (U_m = 1,2 kV) and 3 kV (U_m = 3,6 kV)*

[7] IEC 60909-0:2001, *Short-circuit currents in three-phase a.c. systems – Part 0: Calculation of currents*

[8] IEC 61936-1:2010, *Power installations exceeding 1 kV a.c. – Part 1: Common rules*

[9] IEC 62271-200:2011, *High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

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

[11] IEC/TS 62271-304:2008, *High-voltage switchgear and controlgear – Part 304: Design classes for indoor enclosed switchgear and controlgear for rated voltages above 1 kV up to and including 52 kV to be used in severe climatic conditions*

[12] IEEE C37.20.7:2001, *IEEE Guide for Testing Medium-Voltage Metal-Enclosed Switchgear for Internal Arcing Faults*

[13] IEEE 400.2:2004, *IEEE Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF)*

[14] EN 50187:1996, *Gas-filled compartments for a.c. switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

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