इंटरनेट मानक

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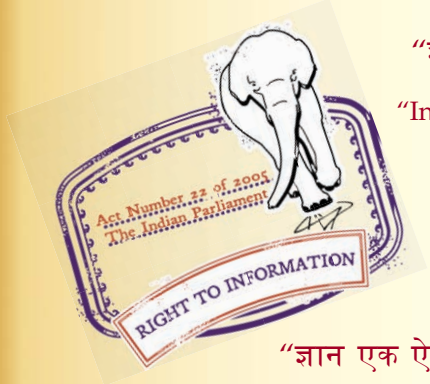
IS/IEC 62271-201 (2006): High-voltage switchgear and controlgear, Part 201: AC insulation-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV [ETD 8: High Voltage Switchgear and Controlgear]



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Bhartṛhari—Nītiśatakam
"Knowledge is such a treasure which cannot be stolen"

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भारतीय मानक

उच्च-वोल्टता के स्विचगियर और नियंत्रणगियर

भाग 201 1 कि वो से 52 कि वो तक की रेटित वोल्टता के लिए
ए सी विद्युतरोधित खोलबंद स्विचगियर और नियंत्रणगियर

Indian Standard

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR

PART 201 AC INSULATION-ENCLOSED SWITCHGEAR AND CONTROLGEAR FOR RATED VOLTAGES ABOVE 1 kV AND UP TO AND INCLUDING 52 kV

ICS 29.130.10

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
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NATIONAL FOREWORD

This Indian Standard (Part 201) which is identical with IEC 62271-201 : 2006 'High-voltage switchgear and controlgear — Part 201 : AC insulation-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the High-Voltage Switchgear and Controlgear Sectional Committee and approval of the Electrotechnical Division Council.

The text of IEC Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker in the International Standard while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

This standard is to be read in conjunction with IS 12729 : 2004 'Common specifications for high-voltage switchgear and controlgear standards'. In order to simplify the indication of corresponding requirements the same numbering of clauses and subclauses is used as in IS 12729 : 2004. Amendments to these clauses and subclauses are given under the same numbering, whilst additional subclauses are numbered from 101.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards, which are to be substituted in their respective places are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60050 151 : 1978 International Electrotechnical Vocabulary (IEV) — Electrical and magnetic devices	IS 1885 (Part 74) : 1993 Electrotechnical vocabulary: Part 74 Electrical and magnetic devices	Identical
IEC 60050 441 : 1984 International Electrotechnical Vocabulary (IEV) — Switchgear, controlgear and fuses	IS 1885 (Part 17) : 1979 Electrotechnical vocabulary: Part 17 Switchgear and controlgear (*first revision*)	Technically Equivalent
IEC 60060-1 : 1989 High-voltage test techniques — Part 1: General definitions and test requirements	IS 2071 (Part 1) : 1993 High-voltage test techniques: Part 1 General definitions and test requirements (*second revision*)	Identical
IEC 60243-1 : 1998 Electrical strength of insulating materials — Test methods — Part 1: Tests at power frequencies	IS 2584 : 1963 Method of test for electric strength of solid insulating materials at power frequencies	Technically Equivalent
IEC 60265-1 : 1998 High-voltage switches — Part 1: Switches for rated voltages above 1 kV and less than 52 kV	IS/IEC 60265-1 : 1998 High-voltage switches: Part 1 Switches for rated voltages above 1 kV and less than 52 kV	Identical
IEC 60270 : 2000 Partial discharge measurements	IS 6209 : 1982 Methods for partial discharge measurements (*first revision*)	Technically Equivalent

(*Continued on third cover*)

Indian Standard

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR

PART 201 AC 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 factory-assembled 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.

Insulation-enclosed switchgear and controlgear complying with this standard can, in principle, be safely touched.

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 insulation-enclosed switchgear and controlgear should be 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 Switchgear and controlgear assemblies having a metal enclosure are covered by IEC 62271-200.

1.2 Normative references

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

IEC 60050-151:1978, *International Electrotechnical Vocabulary (IEV) – Electrical and magnetic devices*

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

IEC 60060-1:1989, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60243-1:1998, *Electrical strength of insulating materials – Test methods – Part 1: Tests at power frequencies*

IEC 60265-1:1998, *High-voltage switches – Part 1: Switches for rated voltages above 1 kV and less than 52 kV*

IEC 60270:2000, *Partial discharge measurements*

IEC 60470:2000, *High-voltage alternating current contactors and contactor-based motor-starters*

IEC 60480:2004, *Guidelines for the checking and treatment of sulfur hexafluoride (SF6) taken from electrical equipment and specification for its re-use*

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

IEC 60694:1996, *Common specifications for high-voltage switchgear and controlgear* [1] *standards*
Amendment 1 (2000)
Amendment 2 (2001)

IEC 60909-0:2001, *Short-circuit currents in three-phase a.c. systems - Part 0: Calculation of currents*

IEC 60932:1988, *Additional requirements for enclosed switchgear and controlgear from 1 kV to 72, 5 kV to be used in severe climatic conditions*

IEC 62271-100:2001, *High-voltage switchgear and controlgear – Part 100: High-voltage alternating-current circuit-breakers* (formerly IEC 60056)

IEC 62271-102:2002, *High-voltage switchgear and controlgear – Part 102: Alternating current disconnectors and earthing switches* (formerly IEC 60129)

IEC 62271-105:2002, *High-voltage switchgear and controlgear – Part 105: Alternating current switch-fuse combinations* (formerly IEC 60420)

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

2 Normal and special service conditions

Clause 2 of IEC 60694 is applicable with the following addition:

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

NOTE If the ambient temperature exceeds the value for normal service conditions, derating may be necessary, and testing conditions may be considered.

3 Terms and definitions

For the purposes of this document, the following terms and definitions, as well as the definitions of IEC 60050(441), IEC 60050(151) and IEC 60694 apply, except where indicated. Some standard definitions are recalled here for ease of reference.

Additional definitions are classified so as to be aligned with the classification system used in IEC 60050(441)

[1] A consolidated edition is available (2002)

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

[IEV 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

[IEV 441-12-01]

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

[IEV 441-12-06, modified]

NOTE The external insulation may be supplied with a (semi-)conducting layer

3.104
functional unit (of an assembly)
part of 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

[IEV 441-13-04, modified]

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

3.105
transport unit
part of insulation-enclosed switchgear and controlgear suitable for shipment without being dismantled

3.106
insulation enclosure
part of 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.

The main material of the enclosure is of insulating type, and, in the case of added conductive layers, the resistance between any point of the conductive layer to the earthing point provided may be more than 100 mΩ

[IEV 441-13-01, modified]

NOTE 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

3.107
compartment
part of insulation-enclosed switchgear and controlgear enclosed except for openings necessary for interconnection, control or ventilation

[IEV 441-13-05, modified]

NOTE 1 Four types of compartments are distinguished: three that can be opened, called accessible (see 3.107.1/2/3), and one that cannot be opened, called non-accessible (see 3.107.4).

NOTE 2 Compartments are identified according to the main component(s) contained therein, refer to 5.103.1.

3.107.1
interlock-controlled accessible compartment
compartment containing high-voltage parts, 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 Installation, extension, repairing, etc. are not considered as normal maintenance.

3.107.2
procedure-based accessible compartment
compartment containing high-voltage parts, 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 Installation, extension, repairing, etc. are not considered as normal maintenance.

3.107.3
tool-based accessible compartment
compartment containing high-voltage parts that may be opened, but not for normal operation and maintenance. Special procedures are required. Tools are necessary for opening

3.107.4
non-accessible compartment
compartment containing high-voltage parts, that must not be opened. Opening may destroy the integrity of the compartment. Clear indication not to open is provided on/by the compartment

NOTE An insulation embedded component, as defined in 3.114, can generally be qualified as a 'non-accessible compartment'

3.108
partition
part of insulation-enclosed switchgear and controlgear separating one compartment from other compartments

[IEV 441-13-06, modified]

3.109
partition class PI
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

3.110
shutter
part of 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 insulation enclosure or partition shielding the fixed contacts

[IEV 441-13-07, modified]

3.111
segregation (of conductors)
arrangement of conductors with earthed metal interposed between them in such a manner that disruptive discharges can only occur to earth

[IEV 441-11-11]

NOTE A segregation may be established between the conductors as well as between the open contacts of a switching device or disconnector.

3.112
bushing
structure carrying one or more conductors through an enclosure or partition and insulating it therefrom, including the means of attachment

3.113
component
essential part of the main or earthing circuits of insulation-enclosed switchgear and controlgear which serves a specific function (for example, circuit-breaker, disconnector, switch, fuse, instrument transformer, bushing, busbar)

3.114
insulation-embedded component
component, the live parts of which are integrally surrounded by solid insulation, with the exception of the terminals, interfaces for driving mechanisms and secondary wiring

NOTE The insulation may form part of the insulation enclosure.

3.115
main circuit (of an assembly)
all the conductive parts of insulation-enclosed switchgear and controlgear included in a circuit which is intended to transmit electrical energy

[IEV 441-13-02, modified]

NOTE Connections to voltage transformers are not considered part of the main circuit

3.116
earthing circuit
connection of each earthing device, or points provided for earthing purposes, to the terminal intended to be connected to the earthing system of the installation

3.117
auxiliary circuit (of an assembly)
all the conductive parts of insulation-enclosed switchgear and controlgear included in a circuit (other than the main circuit) intended to control, measure, signal and regulate

[IEV 441-13-03, modified]

NOTE The auxiliary circuits of insulation-enclosed switchgear and controlgear include the control and auxiliary circuits of the switching devices.

3.118
pressure-relief device
device intended to limit the pressure in a fluid-filled compartment

3.119
fluid-filled compartment
compartment of insulation-enclosed switchgear and controlgear filled with a fluid, either gas, other than ambient air, or liquid, for insulation purposes

3.119.1
gas-filled compartment

NOTE Refer to 3.6.5.1 of IEC 60694.

3.119.2
liquid-filled compartment
compartment of 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 For pressure systems, refer to 3.6.4 of IEC 60694.

3.120
relative pressure
pressure, referred to the standard atmospheric pressure of 101,3 kPa

3.121
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 insulation-enclosed switchgear and controlgear are maintained

3.122
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

3.123
design temperature (of fluid-filled compartments)
highest temperature which can be reached by the gas or liquid under service conditions

3.124
ambient air temperature (of insulation-enclosed switchgear and controlgear)
temperature, determined under prescribed conditions, of the air surrounding the enclosure of insulation-enclosed switchgear and controlgear

3.125
removable part
part of insulation-enclosed switchgear and controlgear connected to the main circuit and that may be removed entirely from the insulation-enclosed switchgear and controlgear and replaced, even though the main circuit of the functional unit is energized

[IEV 441-13-08, modified]

3.126
withdrawable part
removable part of 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

[IEV 441-13-09, modified]

3.127
service position (connected position) (of a removable part)
position of a removable part in which it is fully connected for its intended function

[IEV 441-16-25]

3.128
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

[IEV 441-16-26, modified]

3.129
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

[IEV 441-16-27]

3.130
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

[IEV 441-16-28, modified]

NOTE In high-voltage insulation-enclosed switchgear and controlgear, the auxiliary circuits may not be disconnected.

3.131
removed position (of a removable part)
position of a removable part when it is outside and mechanically and electrically separated from the enclosure

[IEV 441-16-29, modified]

3.132
loss of service continuity category
LSC
category defining the possibility to keep other compartments and/or functional units energized when opening a main circuit compartment

NOTE 1 The LSC category describes the extent to which the switchgear and controlgear are intended to remain operational in case access to a main-circuit compartment is necessary. The extent to which it is considered necessary to open main-circuit compartments with a live installation might be dependent on several aspects (refer to 8.2).

NOTE 2 The LSC category does not describe ranks of reliability of switchgear and controlgear (refer to 8.2)

3.132.1
category LSC2 switchgear and controlgear
switchgear and controlgear having accessible compartments other than the busbar compartment of a single busbar switchgear and controlgear

For insulation-enclosed switchgear and controlgear, when any accessible compartment in a functional unit is open, all other functional units are intended to remain energized and operated normally. An exception applies in the case of the busbar compartment of single-busbar switchgear and controlgear which, when opened, prevents service continuity

Two subdivisions are recognized:

LSC2B: switchgear and controlgear of category LSC2 where the cable compartment is also intended to remain energized when any other accessible compartment of the corresponding functional unit is open.

LSC2A: LSC2 switchgear and controlgear, other than LSC2B.

3.132.2
category LSC1 switchgear and controlgear
insulation-enclosed switchgear and controlgear other than category LSC2

3.133
internal arc classified switchgear and controlgear
IAC
insulation-enclosed switchgear and controlgear for which prescribed criteria for protection of persons are met in the event of internal arc as demonstrated by the appropriate tests

NOTE Refer to Annex A for additional information.

3.134
degree of protection
extent of protection provided by an insulation 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.

[IEC 60529:1989, definition 3.3, modified]

3.135
rated value
quantity value assigned, generally by a manufacturer, for a specified operating condition of a component device or equipment

[IEV 151-16-08, modified]

NOTE Refer to Clause 4 for individual rated values.

3.136
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 The term applies to discharges in solid, liquid and gaseous dielectrics and to combinations of these.

NOTE 2 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 The term "sparkover" is use 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.

3.137
electric shock
physiological effect resulting from an electric current through a human or animal body

[IEV 195-01-04]

3.138
protection grade against electric shock
grade of protection of the insulation enclosure against electric shock

3.138.1
protection grade PA
for protection grade PA the insulation is generally sufficient for those parts of the enclosure which are touched by persons only accidentally or inadvertently

3.138.2
protection grade PB
protection grade PB is considered as suitable for parts which are liable to be touched Two different designs for class PB are recognized

- PB1 with an extra insulation in addition to the grade PA insulation, as a safeguard in case the protection grade PA insulation is damaged,
- PB2 with an earthed conductive cover/layer in addition to the grade PA insulation The resistance between the points of this conductive layer that are liable to be touched, to the earthing point provided shall be less than 100 mΩ (refer to 3 106)

4 Ratings

The ratings of 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) (for main and earthing circuits);
f) rated peak withstand current (I_p), if applicable (for main and earthing circuits);
g) rated duration of short circuit (t_k) (for main and earthing circuits);
h) rated values of the components forming part of the insulation-enclosed switchgear and controlgear including their operating devices and auxiliary equipment
i) rated filling level (of fluid-filled compartments)

4.1 Rated voltage (U_r)

Subclauses 4.1 and 4.1.1 of IEC 60694 are applicable

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

4.2 Rated insulation level

Subclause 4.2 of IEC 60694 is applicable

4.3 Rated frequency (f_r)

Subclause 4.3 of IEC 60694 is applicable

4.4 Rated normal current and temperature rise

4.4.1 Rated normal current (I_r)

Subclause 4.4.1 of IEC 60694 is applicable with the following addition:

Some main circuits of 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 60694 is applicable with the following addition:

The temperature rise of components contained in the insulation-enclosed switchgear and controlgear which are subject to individual specifications not covered by the scope of IEC 60694 shall not exceed the temperature-rise limits permitted in the relevant standard for that component.

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 insulation 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, if not accessible to public.

4.5 Rated short-time withstand current (I_k)

Subclause 4.5 of IEC 60694 is applicable with the following addition:

A rated short-time withstand current shall also be assigned to the earthing circuit. This value may differ from that of the main circuit.

4.6 Rated peak withstand current (I_p)

Subclause 4.6 of IEC 60694 is applicable with the following addition:

A rated peak withstand current shall also be assigned to the earthing circuit. This value may differ from that of the main circuit.

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

4.7 Rated duration of short circuit (t_k)

Subclause 4.7 of IEC 60694 is applicable with the following addition:

A rated duration of short circuit shall also be assigned to the earthing circuit. 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 60694 is applicable.

4.9 Rated supply frequency of operating devices and of auxiliary and control circuits

Subclause 4.9 of IEC 60694 is applicable.

4.10 Rated pressure of compressed gas supply for insulation and/or operation

Subclause 4.10 of IEC 60694 is applicable

4.10.1 Rated filling level (of fluid-filled compartments)

The pressure (relative pressure) in Pa (or density) or liquid mass assigned by the manufacturer referred to atmospheric air conditions of 20 °C at which the gas- or liquid-filled compartment is filled before being put into service.

5 Design and construction

Insulation-enclosed switchgear and controlgear shall be designed so that normal service, inspection and maintenance operations, determination of the energized or de-energized state of the main circuit, including the usual checking of phase sequence, earthing of connected cables, locating of cable faults, voltage tests on connected cables or other apparatus and the elimination of electrostatic charges that may result in electric shock, can be carried out safely

For 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 insulation 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 interchangeability. 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 insulation 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 fused short-circuit current.

5.1 Requirements for liquids in switchgear and controlgear

Subclause 5.1 of IEC 60694 is applicable.

5.2 Requirements for gases in switchgear and controlgear

Subclause 5.2 of IEC 60694 is applicable with the following addition:

Sulphur hexafluoride (SF6) complying with IEC 60480 may be used.

NOTE For handling of SF6, refer to IEC 61634.

5.3 Earthing of switchgear and controlgear

Subclause 5.3. of IEC 60694 is applicable with the following addition:

All accessible metal parts, which do not belong to a main or auxiliary circuit and which can collect electric charges that may result in electrical shock, shall be connected to the earthing terminal direct or through metallic structural parts. Thereupon, metallic frames and conductive layers shall always be connected to the earthing terminal direct or through metallic structural parts.

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

NOTE 1 For systems with 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.

NOTE 2 For systems with other than solidly earthed neutral the maximum short-time current of the earthing circuit may reach levels up to 87 % of the rated short-time withstand current of the main circuit (short circuit under conditions of double-earth fault).

The earthing circuit is normally designed for a single short-circuit withstand.

5.3.1 Earthing of the main circuit

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

5.3.2 Earthing conductor

An earthing conductor shall be provided extending the whole length of the insulation-enclosed switchgear and controlgear. The current density in the earthing conductor, if of copper, shall 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. However, its cross-section shall be not less than 30 mm^2. It shall be terminated by an adequate terminal intended for connection to the earth system of the installation.

If the earthing conductor is not made of copper, equivalent thermal and mechanical requirements shall be met.

NOTE As guidance, reference is made to a method of calculating cross-sectional areas of conductors given in IEC 60724, Clause 3.

5.3.3 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

5.3.4 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.

NOTE This demand on resistance does not apply to field steering conductive layers where grade PA is applicable (refer to 3.138.1).

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).

5.4 Auxiliary and control equipment

Subclause 5.4 of IEC 60694 is applicable.

5.5 Dependent power closing

Subclause 5.5 of IEC 60694 is applicable.

5.6 Stored energy closing

Subclause 5.6 of IEC 60694 is applicable.

5.7 Independent manual operation

Subclause 5.7 of IEC 60694 is applicable.

5.8 Operation of releases

Subclause 5.8 of IEC 60694 is applicable.

5.9 Low- and high-pressure interlocking and monitoring devices

Subclause 5.9 of IEC 60694 is applicable.

5.10 Nameplates

Subclause 5.10 of IEC 60694 is applicable with the following additions:

Insulation-enclosed switchgear and controlgear shall be provided with durable and clearly legible nameplates which shall contain the information in accordance with Table 1.

Table 1 – Nameplate information

	Abbreviation	Unit	**	Condition: Marking only required if
(1)	(2)	(3)	(4)	(5)
Manufacturer			X	
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 normal current	I_r	A	X	
Rated short-time withstand current (for main and earthing circuits)	I_k	kA	X	
Rated peak withstand current (for main and earthing circuits)	I_p	kA	Y	Different from 2,5 for 50 Hz and 2,6 for 60 Hz
Rated duration of short circuit (for main and earthing circuits)	t_k	s	X	
Mass of main insulating material		kg	X	
Rated filling level for insulation	p_{re}	Pa or kg	(X)	
Alarm level for insulation	p_{ae}	Pa or kg	(X)	
Minimum functional level for insulation	p_{me}	Pa or kg	(X)	
Mass of insulating fluid		kg	(X)	
Internal arc classification	IAC		(X)	
Accessibility type (code)		A(F,L,R), B(F,L,R) or C	(X)	
Arc test current		kA	(X)	
Arc test current duration		s	(X)	

(**) 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 abbreviation in column (2) may be used instead of the terms in column (1).

NOTE 2 When terms in column (1) are used, the word "rated" need not appear.

The nameplates of each functional unit shall be legible during normal service. The removable parts, if any, shall have a separate nameplate with the data relating to the functional units they belong to, but this nameplate need only be legible when the removable part is in the removed position.

5.11 Interlocking devices

Subclause 5.11 of IEC 60694 is applicable with the following additions:

Interlocks between different components of the equipment are provided for reasons of protection and for convenience of operation. The following provisions are mandatory for main circuits:

a) 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 only 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 any auxiliary circuits associated with the automatic opening of these devices are connected. Conversely, it shall prevent the disconnection of the auxiliary circuits with the circuit-breaker closed in the service position.

b) 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 may 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 disconnectors.

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 the 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, also a disconnector in the 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 60694 is applicable.

5.13 Degrees of protection by enclosures

Subclause 5.13 of IEC 60694 is applicable. However for 5.13.3, the impact energy is limited to 1 J.

5.14 Creepage distances

Subclause 5.14 of IEC 60694 is applicable.

5.15 Gas and vacuum tightness

Subclause 5.15 of IEC 60694 is applicable with the following addition:

Refer to 5.103.2.3.

5.16 Liquid tightness

Subclause 5.16 of IEC 60694 is applicable with the following addition:

Refer to 5.103.2.3.

5.17 Flammability

Subclause 5.17 of IEC 60694 is applicable.

5.18 Electromagnetic compatibility (EMC)

Subclause 5.18 of IEC 60694 is applicable.

5.101 Internal fault

Insulation-enclosed switchgear and controlgear that satisfies the requirements of this standard, is designed and manufactured, in principle, to prevent the occurrence of internal faults.

The user shall make a proper selection, according to the characteristics of the network, operating procedures and service conditions, refer to 8.3.

If the switchgear and controlgear is installed, operated and maintained following the instructions of the manufacturer, there should be little probability that an internal arc occurs during its entire service life, but it cannot be completely disregarded.

Failure within the enclosure of insulation-enclosed switchgear and controlgear due either to a defect or an exceptional service condition or mal-operation may initiate an internal arc, which constitutes a hazard, if persons are present.

Experience has shown that faults are more likely to occur in some locations inside an enclosure than in others. Table 8.1 in Clause 8 gives a list of such locations, causes of failure and possible measures to decrease the probability of internal faults.

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 control.
- Pressure relief device.
- Transfer of a withdrawable part to or from the service position only when the front door is closed.

The effectiveness of the design for providing the prescribed level of protection of persons in case of an internal arc, occurring entirely in air within the enclosure of the insulation-enclosed switchgear and controlgear, can be verified by testing according to Annex A. Designs which have been successfully tested qualify as IAC classified.

5.102 Insulation enclosure

5.102.1 General

The complete insulation 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 and ageing which are likely to be encountered in normal service conditions.

The main parts of the insulation enclosure may be considered as consisting of non-self-restoring insulation.

When the insulation-enclosed switchgear and controlgear is installed, the enclosure shall provide at least the degree of protection IP 2X, according IEC 60529. The walls and the floor of a room shall not be considered as parts of the enclosure.

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

The complete insulation enclosure shall also ensure protection in accordance with the following conditions.

5.102.2 Protection grade of the insulation enclosure against electric shock

The insulation enclosure shall provide protection of persons against electric shock when touching the enclosure or operating insulation-enclosed switchgear and controlgear. The following two grades of protection are distinguished.

Protection grade 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.

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

- PB1 with an insulation which meets, in addition to those of protection grade PA, the requirements given in item e) or f) of 5.102.3 as a safeguard in case the protection grade PA insulation is damaged.

- PB2 with an insulation of protection grade PA, supplied with an earthed conductive cover or layer. This earthed conductive cover or layer shall meet the requirements given in item g) of 5.102.3, as a safeguard to demonstrate that the protection grade PA insulation is sufficient.

5.102.3 Requirements for protection grades

Reference is made to the informative Annex D for clarification.

For protection grade PA, the insulation enclosure shall meet the following requirements:

a) The insulation between parts of the main circuit and the accessible surface of the insulation 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 insulation enclosures shall be sufficient to withstand the test voltages specified in item a). The methods specified in IEC 60243 should be applied to the tests to meet the relevant requirements.

c) The insulation between live parts of the main circuit and the inner surface of insulating partitions and shutters facing these shall withstand at least 150 % of the rated voltage of the equipment.

d) Capacitive and leakage currents shall not be greater than 0,5 mA under the specified test conditions (refer to 6.104.2). Leakage currents may reach the accessible side of the insulation by a continuous path over insulating surfaces or by a path broken only by small gaps of gas or liquid.

For protection grade PB1, the requirements of protection grade PA and one of the following additional requirements shall be met by the insulation enclosure.

e) The insulation 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 the rated voltage. It shall not be possible to remove the additional insulation without the aid of a tool.

f) The insulation enclosure contains a fluid insulant or ambient air. In these cases, it shall be ensured that the insulation of the main circuit with respect to the internal surface of the insulation enclosure is capable of withstanding a 1 min power-frequency test voltage equal to 150 % of the rated voltage, even when the gaseous or liquid insulant 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 D.2b in Annex D.

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

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

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

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

5.102.4 Covers and doors

When covers and doors that are parts of the enclosure are closed, they shall provide the degree of protection specified for the insulation enclosure.

When ventilating openings, vent outlets or inspection windows are incorporated in the cover or door, reference is made to 5 102 6/7

Several categories of covers or doors are recognized with regard to the type of accessible compartments to which they provide access

a) Covers or doors that give access to tool-based accessible compartments They need not be opened for the normal purposes of operation or maintenance (fixed covers) It shall not be possible for them to be opened, dismantled or removed without the use of tools

NOTE 1 They should be opened only when precautions to ensure electrical safety have been taken

NOTE 2 Attention should be 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 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 disconnected position with corresponding shutters closed Procedures may be dictated by legislation of the country of installation or by user safety documentation

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 3.128 to 3.131, they shall provide the degree of protection specified for the enclosure In this case shutters also shall meet the requirements specified for protection grade PB, if liable to be touched

NOTE 1 A partition or shutter becomes a part of the enclosure, if it is accessible in any of the positions defined in 3.128 to 3.131 and if no door is provided which can be closed in the positions defined in 3.127 to 3.131

NOTE 2 If a door is provided which can be closed in the positions defined in 3.127 to 3.131 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 insulation enclosure. They shall meet at least the requirements of insulation enclosures specified for protection grade 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 insulation 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 Compartments

5.103.1 General

A compartment shall be designated by the main component contained therein, for example, circuit-breaker compartment, busbar compartment, cable 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 may be further identified according to the several components enclosed, for example, cable/CT compartment, etc.

Compartments may be of various types, for example:

- liquid-filled,
- gas-filled;
- solid-insulation.

Main components individually embedded in solid insulating material are considered as compartments.

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, separate compartments shall be provided for each set of busbars, for example, in double busbar systems and for sections of switchable or disconnectable busbars.

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 enclosure shall not be less than the upper limit of the pressure reached within the enclosure at the design temperature

Account shall be taken of the possibility of the occurrence of an internal fault (refer to 5.101) and the following for fluid-filled compartments.

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 60694)

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 3.121)

A partition, separating a compartment filled with insulating gas from a neighbouring compartment filled with liquid, such as a cable box or a voltage transformer, 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 an operator during the time that he is performing his 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 3.109

Partitions and shutters shall provide at least the degree of protection IP2X according to IEC 60529.

Partitions shall provide mechanical protection against the normal gas pressure still present in the adjacent compartment (if applicable).

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

Openings in the enclosure of 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 3.127 to 3.131. 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.

For removable parts that are not withdrawable, positions according to 3.128, 3.129 and 3.130 are not applicable. In this case a temporary inserted partition is also allowed.

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.

5.104 Removable parts

Removable parts for ensuring the isolating distance 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 1 In some countries regulations require that the isolating distance is visible.

NOTE 2 Refer to IEC 62271-102.

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 switchgear and controlgear IAC classified, the transfer of withdrawable parts to or from the service position shall be carried out without reduction of 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 The effectiveness of the adopted design shall be verified by testing (see Clause A 1)

Leakage currents across the isolating distance shall not exceed 0,5 mA The measurement of leakage currents shall be carried out in accordance with the method specified in 6 104 2

5.105 Provisions for dielectric tests on cables

When it is not practical to disconnect the cable from the insulation-enclosed switchgear and controlgear, those parts which remain connected to the cable shall be capable of withstanding the cable test voltages as stated by the manufacturer and based upon the relevant cable standards. That is, when one side of the isolating gap is energized at normal system voltage to earth and tests are being carried out on the cable connected to the other side of the isolating gap

Refer to the dielectric test defined in 6 2 101

NOTE Attention is drawn to the fact that practically no safety margin is left in some cases between the rated power-frequency test voltage for the isolating distance and the resulting voltage stress across the isolating distance due to the application of the cable test voltage, if the other side of the isolating distance of the switchgear and controlgear is still live.

6 Type tests

6.1 General

Subclause 6 1 of IEC 60694 is applicable with following additions

Components contained in insulation-enclosed switchgear and controlgear which are subject to individual specifications not covered by the scope of IEC 60694 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

NOTE 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

		Subclause
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 protection of persons against approach to hazardous parts and the protection of the equipment against solid foreign objects	6.7
g)	Tests to verify the protection of persons against electric shock	6.104
h)	Tests to detect certain defects in the solid insulation of the equipment by the measurement of partial discharges	6.2.9

Mandatory type tests, where applicable:

i)	Tests to verify the strength of gas-filled compartments	6.103
j)	Tightness tests of gas- or liquid-filled compartments	6.8
k)	Tests to assess the effects of arcing due to an internal fault (for switchgear and controlgear classification IAC)	6.105
l)	Electromagnetic compatibility tests (EMC)	6.9

Optional type tests (subject to agreement between manufacturer and user):

m)	Tests to verify the protection of the equipment against mechanical impact	6.7
n)	Tests to verify the thermal stability of insulating materials	6.106
o)	Tests to assess the effects of condensation on insulation surfaces	6.107
p)	Artificial pollution tests	6.2.8
q)	Dielectric tests on cable testing circuits	6.2.101

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 60694 is applicable with the following modification:

The mandatory type tests (not including items k) and l) 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 60694 is applicable.

6.1.3 Information to be included in type-test reports

Subclause 6.1.3 of IEC 60694 is applicable.

6.2 Dielectric tests

Subclause 6.2 of IEC 60694 is applicable

6.2.1 Ambient air conditions during tests

Subclause 6.2.1 of IEC 60694 is applicable.

6.2.2 Wet test procedure

IEC 60694 is not applicable as insulation-enclosed switchgear and controlgear is suitable only for indoor use.

6.2.3 Conditions of switchgear and controlgear during dielectric tests

Subclause 6.2.3 of IEC 60694 is applicable with the following addition.

For 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 60694 is applicable, with the following modifications:

- The second paragraph of item a) that refers to wet test is not applicable.
- The first paragraph of item b) is replaced by:

  The switchgear and controlgear has passed the impulse tests if the following conditions are fulfilled:

  a) the number of disruptive discharges does not exceed two for each series of 15 impulses;

  b) no disruptive discharges on non-self-restoring insulation occur.

  This is verified by at least five impulses without disruptive discharge following that impulse, which caused the last disruptive discharge. If this impulse is one of the last five out of the series of 15 impulses, additional impulses shall be applied, provided that the total number of discharges does not exceed two in the complete series. This can result in a maximum of 25 impulses per series.

  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 test voltages and test conditions

Subclause 6.2.5 of IEC 60694 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, they shall cover the following tests:

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.

   Areas of the insulation enclosure intended for resting on the floor or being fixed to the wall shall be covered by earthed metal foils.

In order to check compliance with the requirement of item a) of 5.102.3, the insulation enclosure as well as inspection windows, partitions and shutters of insulating material shall be covered, on the side 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 insulation-embedded components if these are used.

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. In case of doubt about the most unfavourable arrangement, tests shall be repeated with alternative configurations.

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 6.2.5.2 of IEC 60694.

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 withdrawn or removed switching device.

If, in the disconnected position, an earthed metallic shutter is interposed between the disengaged contacts to assure a segregation, the gap between the earthed metallic shutter and the live parts shall withstand only the test voltages required to earth.

If, in the disconnected position, there is no earthed metallic shutter or partition between the fixed part and the withdrawable part, the test voltages specified for the isolating distance shall be applied:

- between the fixed and moving contacts intended to engage, if conductive parts of the main circuit of the withdrawable part can inadvertently be touched;
- between the fixed contacts on one side and the fixed contacts on the other side, with the switching device of the withdrawable part in the closed position if possible, if they cannot inadvertently be touched. If it is not possible to have the switching device closed in the disconnected position, then this test shall be repeated in the test position with the switching device of the withdrawable part closed.

c) Complementary tests

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 the rated voltage for 1 min.

In the case of gaseous or liquid insulation, the insulation between the live parts of the main circuit and the inside surface of insulating partitions or shutters shall be subjected to a power-frequency test voltage of 150 % of the rated voltage for 1 min. For this test the inner surface of the partitions or shutters that face the live parts shall be covered by an earthed metal foil or conducting cloth as described under item a) above. The test voltage is applied on all parts of the main circuit connected together.

6.2.6 Tests of insulation-enclosed switchgear and controlgear

The tests shall be performed with the applicable test voltages given in Table 1a or 1b of 4.2 of IEC 60694. 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.

Overvoltage protective devices, not forming an integral part of the switchgear and controlgear, if any, shall be disconnected or removed.

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

Current transformer secondaries shall be short-circuited and earthed. Current transformers with a low ratio may have their primaries short-circuited too.

6.2.6.1 Power-frequency voltage tests

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.

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 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

Switchgear and controlgear shall be subjected to lightning impulse voltage tests in dry conditions only.

Procedure B of IEC 60060-1 shall be applied using the standard lightning impulse 1.2/50µs. Fifteen consecutive lightning impulses at the rated withstand voltage shall be applied for each test condition and each polarity. However, as an alternative in order to avoid possible damage to the solid insulation, procedure C of IEC 60060-1 may be applied, subject to agreement between manufacturer and user.

NOTE 1 This procedure C test is performed by applying three consecutive impulses for each polarity. If no disruptive discharge occurs, the switchgear is considered to have passed the test.

NOTE 2 It may be necessary for certain types of 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 metal-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 rated voltage above 245 kV

Not applicable.

6.2.8 Artificial pollution tests

Insulation-enclosed switchgear and controlgear 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 submitted to test according to IEC 60932, upon agreement between the manufacturer and user.

NOTE In general, this test may be considered as superfluous, as a specific test is already prescribed in 6.107.

6.2.9 Partial discharge tests

Refer to Annex B with the following additions:

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 1 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.

NOTE 2 This test may be carried out on assemblies or subassemblies. Care should be taken that external partial discharges do not affect the measurement.

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 B.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 60694 is applicable.

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

Voltage-limiting devices, if any, shall be disconnected.

6.2.11 Voltage test as condition check

Subclause 6.2.11 of IEC 60694 is applicable

6.2.101 Dielectric tests on cable testing circuits

To allow dielectric tests on cables while the switchgear and controlgear is in service (refer to 5.105), an additional power-frequency withstand-voltage type test may be applied to confirm the ability of the relevant isolating distances to withstand cable test voltage while the other side of the isolating distance is still live.

The test values are subject to agreement between the user and the manufacturer.

NOTE The test values agreed should be chosen to ensure a safety margin between the rated power-frequency test voltages for the isolating distance and the resulting voltage stress across the isolating distance due to the application of, for example, a d.c. cable test voltage while the other side of the isolating distance of insulation-enclosed switchgear and controlgear is still live.

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

Not applicable.

6.4 Measurement of the resistance of circuits

6.4.1 Main circuit

Subclause 6.4.1 of IEC 60694 is applicable with the following addition:

The measured resistance across the complete main circuit of an assembly of 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 60694 is applicable.

6.4.101 Requirement for protection grade PB2

If the requirement of item g) of 5.102.3 is applicable, the resistance of the earthed conductive cover or 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.

NOTE 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 60694 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 may be taken under the same ambient conditions.

6.5.1 Conditions of the insulation-enclosed switchgear and controlgear to be tested.

Subclause 6.5.1 of IEC 60694 is applicable.

6.5.2 Arrangement of the equipment

Subclause 6.5.2 of IEC 60694 is applicable.

6.5.3 Measurement of the temperature and the temperature rise

Subclause 6.5.3 of IEC 60694 is applicable.

6.5.4 Ambient air temperature

Subclause 6.5.4 of IEC 60694 is applicable.

6.5.5 Temperature-rise test of the auxiliary and control equipment

Subclause 6.5.5 of IEC 60694 is applicable.

6.5.6 Interpretation of the temperature-rise test

Subclause 6.5.6 of IEC 60694 is applicable.

6.6 Short-time withstand current and peak withstand current tests

Subclause 6.6 of IEC 60694 is applicable, with the following addition:

a) Test on main circuits

Main circuits of 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 insulation-enclosed switchgear and controlgear with all associated components influencing the performance or modifying the short-circuit current.

For these tests, short 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 the rated voltage of the switchgear and controlgear. 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 rated voltage.

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 insulation enclosure shall in particular be unimpaired. It may be possible to detect the presence of cracks in the insulation of 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 insulation-enclosed switchgear and controlgear shall be tested to verify their capability to withstand the rated short-time and peak withstand current under the neutral earthing condition of the system. That is, they shall be tested as installed in the 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. Further single-phase tests may be necessary in order to verify the performance of 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 60694 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 double busbar systems and/or multi-tier designs, the tests shall be made with the most onerous position(s) 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 60694 is applicable.

6.6.3 Behaviour of switchgear and controlgear during test

Subclause 6.6.3 of IEC 60694 is applicable.

6.6.4 Condition of switchgear and controlgear after test

Subclause 6.6.4 of IEC 60694 is applicable.

6.7 Verification of the protection

6.7.1 Verification of the IP coding

Subclause 6.7.1 of IEC 60694 is applicable, with the following addition:

The minimum degree of protection of the enclosure of the insulation-enclosed switchgear and controlgear shall be IP2X in accordance with IEC 60529. A higher degree of protection may be specified in accordance with IEC 60529.

6.7.2 Mechanical impact test

Subclause 6.7.2 of IEC 60694 is applicable with the following addition:

Unless otherwise agreed between manufacturer and user, impacts of 1 J should be applied.

After the test the enclosure shall show no cracks. Superficial damage can be ignored.

6.8 Tightness tests

Subclause 6.8 of IEC 60694 is applicable

6.9 Electromagnetic compatibility tests (EMC)

Subclause 6.9 of IEC 60694 is applicable, with exception of the radio interference voltage test

6.10 Additional tests on auxiliary and control circuits

IEC 60694 is applicable for 6.10.1, 6.10.2, 6.10.4 to 6.10.7.

6.10.3 Tests on metallic parts of enclosures and compartments

IEC 60694 is not applicable.

6.101 Verification of making and breaking capacities

Switching devices forming part of the main circuit and earthing switches of 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 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 insulation-enclosed switchgear and controlgear with more onerous conditions.

NOTE 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

Where multi-tier compartments of a multi-tier design are not identical but are designed to accept the same switching device, the following tests/test-duties shall be repeated in each compartment as appropriate to the requirements of the relevant standard.

Where switching devices have previously been tested for short-circuit performance to their relevant standard within the enclosure of the insulation-enclosed switchgear and controlgear then no further tests may be required.

Switchgear and controlgear, incorporating single or multi-tier design and/or double busbar systems, requires special consideration for the test procedures applicable for the verification of their rated making and breaking capacities to cover combinations likely to be encountered in service.

As it is not possible to cover all possible configurations and designs of switching devices, the following procedures shall be followed, the precise combination of tests being determined by the characteristics and location of the particular switching device being considered.

a) The complete appropriate making and breaking current test series shall be made with the switching device in one of the compartments. If other compartments are similar in design, and also the switching device intended for use in the compartment is identical, then the tests referred to above are also valid for these compartments.

b) Where the compartments are not similar but are designed to accept the same switching device, the following tests/test duties are to be repeated in each of the other compartments, as appropriate to the requirements of the relevant standard:

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

IEC 62271-102: Short-circuit making operations according to class E1 or E2, as applicable.

IEC 60265-1: Ten CO operations with rated mainly active load-breaking current (Test duty 1) Test duty 5 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 TDI_{sc}, TDI_{Wmax} and $TDI_{transfer}$.

IEC 60470: Verification of coordination with SCPDs to 6.106 of IEC 60470.

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 a) and also, where appropriate b) above.

6.102 Mechanical operation tests

6.102.1 Switching devices and removable parts

Switching devices and withdrawable parts shall be operated 50 times, and removable parts inserted 25 times and removed 25 times to verify satisfactory operation of the equipment.

If a withdrawable or removable part is intended to be used as a disconnector, then testing shall be in accordance with IEC 62271-102.

6.102.2 Interlocks

The interlocks shall be set in the position intended to prevent the operation of the switching devices and the insertion or withdrawal of removable parts. Fifty attempts shall be made to operate the switching devices and 25 attempts shall be made to insert and 25 attempts to withdraw the removable parts. During these tests only normal operating forces shall be employed and no adjustment shall be made to the switching devices, removable parts or interlocks. In case of manually operated equipment, the normal manual operation handle shall be used to perform the tests.

The interlocks are considered satisfactory, if

a) the switching devices cannot be operated;

b) the insertion and withdrawal of the removable parts are prevented;

c) the switching devices, removable parts and the interlocks are in proper working order and the effort to operate them is practically the same before and after the tests.

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.

NOTE The relative withstand pressure of 3 times the design pressure may not be tested for the compartment because it is not always possible to test without the presence of the pressure relief device or a dedicated relief area of the compartment wall.

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.

6.104 Tests to prove the protection of persons against electric shock

This clause applies to the insulation enclosure and to partitions (and shutters) intended for protection from electric shock. 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 insulation enclosure and non-metallic partitions and shutters, made or partly made of insulating material shall be tested as follows.

6.104.1 Dielectric tests

a) The insulation between live parts of the main circuit and the accessible surface of the insulation enclosure and insulating partitions and shutters shall withstand the test voltages specified in 4.2 of IEC 60694 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 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.

NOTE In the case of moulded conductors, this test is already covered by test a) above

c) The insulation between live parts of the main circuit and the inner surface of insulating partitions and shutters facing these shall be tested at 150 % of the rated voltage of the equipment for 1 min. For the test, the inner surface of the partition or shutter shall be earthed by applying a conductive layer of at least 100 cm^2, at the most onerous point. The test setup shall be as specified in item c) of 6.2.5.

d) Complementary tests (for protection grade 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 the rated voltage for 1 min

In the case of a second insulation layer, this layer shall be subjected to a power-frequency test voltage of 150 % of the rated voltage for 1 min.

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.

6.104.2 Measurements of leakage currents

For insulation-enclosed switchgear and controlgear, containing insulating partitions or shutters as applicable, 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 the rated voltage of the insulation-enclosed switchgear and controlgear, with one phase connected to earth, or to a single-phase supply of a voltage equal to the rated voltage, 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 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. The leakage current flowing through the metal foil to earth shall be measured with the insulation dry and clean.

If the value of the leakage current measured is more than 0,5 mA, the insulation surface does not provide the protection required in this standard.

If, as indicated in item d) of 5.102.3, the continuous path over 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 insulating partitions and shutters, the gaps shall withstand the test voltages specified in 4.2 of IEC 60694 for voltage tests to earth and between poles.

NOTE This requirement can by its nature only apply to parts of the enclosure: it is essential that the remainder of the enclosure meets the first requirement if the measurement of leakage currents is to be dispensed with.

The leakage current shall also be measured in conditions representing condensation and light pollution on the accessible surfaces of the insulation enclosure after the humidity test according to 6.107, if such a test was agreed.

6.105 Internal arcing test

This test is applicable to insulation-enclosed switchgear and controlgear, intended to be qualified as IAC classified with respect to personnel protection in the event of an internal arc. The test shall be performed according to Annex A, in every compartment containing main circuit parts of representative functional units (refer to Clause A.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.

NOTE 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 may 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, unless they are intended to be tested. In that case the 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.

This test covers the case of a fault resulting in an arc occurring in air or in another insulating fluid (liquid or gas) within the enclosure or within components having housings which form part of the enclosure when the doors and covers are in the position required for normal operating conditions (refer to Clause A.1).

The test procedure also covers the particular case of a fault occurring in solid insulation where this insulation is applied during assembly on site of insulation-enclosed switchgear and controlgear and does not comprise prefabricated type-tested insulating parts (refer to A.5.2).

The validity of the results of a test carried out in a functional unit of a particular 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;
- partition's architecture;
- performance of the pressure relief device, if any;
- insulation system.

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 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 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 the rated voltage 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.

NOTE 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 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 cover/layer.

With conductive cover/layer it is meant that the resistance, measured from any point on the enclosure to the earthing point provided, is less than 96 kΩ to keep the maximum touch voltage below 48 V.

The test shall be performed according to Annex C.

7 Routine tests

The routine test shall be carried out on each transport unit and, whenever practicable, at the manufacturer's works 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 60694 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

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

7.1 Dielectric tests on the main circuit

Subclause 7.1 of IEC 60694 is applicable, with the following addition and exception:

There are two alternative procedures:

a) If the insulation-enclosed switchgear and controlgear is an assembly of components which have not been tested individually, all the tests according to 6.2.5 shall be carried out except for lightning impulse voltage tests.

b) If the insulation-enclosed switchgear and controlgear is an assembly of components which individually have been subjected to appropriate routine tests, the tests according to this subclause serve in principle to prove the interconnections and the insulation enclosure

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 60694 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 5.103.3 the insulation enclosure shall be covered, on the accessible side in the most unfavourable situation for the test, with a metal foil not exceeding 100 cm^2 connected to earth.

For gas-filled compartments the tests shall be performed at the rated filling pressure (or density) of the insulating gas (refer to 4.10.1).

7.2 Tests on auxiliary and control circuits

Subclause 7.2 of IEC 60694 is applicable.

7.3 Measurement of the resistance of the main circuit

IEC 60694 is not applicable. This test is subject to agreement between manufacturer and user.

The d.c. voltage drop or resistance of each phase of the main circuit shall be measured under conditions as close as possible to those under which the corresponding type test was carried out. The measured value of the type test can be used to determine the limit of resistance value for the routine test.

7.4 Tightness test

IEC 60694 is applicable.

7.5 Design and visual checks

IEC 60694 is applicable.

7.101 Partial discharge measurement

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

Partial discharge measurements shall be in accordance with 6.2.9.

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.

During these tests, which are performed without voltage on or current in the main circuits, it shall be verified, in particular, that the switching devices open and close correctly within the specified limits of the supply voltage and pressure of their operating devices.

Each switching device, and each removable part shall be tested as specified in 6.102, but substituting the 50 operations or attempts with 5 operations or attempts in each direction.

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, 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 it is recommended to carry out the following tests.

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 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 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.

NOTE Overvoltage protective devices should be disconnected during dielectric site tests. This also applies for voltage transformers, unless the test frequency used for site test is high enough to prevent core saturation.

b) Tightness tests: subclause 7.4 is applicable.

c) Measurement of fluid condition after filling on site: subclause 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 insulation-enclosed switchgear and controlgear for service

This standard provides for insulation-enclosed switchgear and controlgear which has either

- protection grade PB throughout for generally accessible installations (operating areas), or
- partly protection grade PA and partly protection grade PB for installations accessible to skilled operators only (closed electrical operating areas).

NOTE For the definitions of "operating area" and "closed electrical operating area" refer to IEC 60621-1

Insulation-enclosed switchgear and controlgear may be constructed in various forms that have evolved with changing technologies and functional requirements. The selection of 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 8.2 provides a summary of the considerations for specifying switchgear and controlgear.

8.1 Selection of rated values

For a given duty in service, 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 insulation-enclosed switchgear and controlgear is to be located in the system. Reference is made to IEC 60909 in this regard.

8.2 Selection of design and construction

8.2.1 General

Insulation-enclosed switchgear and controlgear is normally identified by insulating technology (for example, solid 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 HV 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 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 that 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.

8.2.2 Architecture and accessibility to 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, if required 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.

Complete description of switchgear or controlgear shall include the list and type of 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 compartment; three are accessible to the user and one non-accessible.

Accessible compartments: Three methods of controlling the opening of an accessible compartment are defined:

- the first is by use of interlocks to ensure that all live parts inside are dead and earthed before opening, designated an "interlock-controlled accessible compartment";
- the second relies on user procedure and locking to ensure safety, the compartment being supplied with facilities for padlocking or equivalent, this is designated a "procedure-based accessible compartment";
- the third does not provide built-in feature to ensure electrical safety before opening. They need tools to be opened, this is designated a "tool-based accessible compartment".

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

If a 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, etc.

Non-accessible 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 of solid insulation

8.2.3 Service continuity of the switchgear and controlgear

The insulation-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 switchgear and controlgear the loss of service continuity category (LSC) describe the extend to which other compartments and/or functional units may remain energized when a main circuit compartment is opened.

Category **LSC1**: This form is not intended to provide service continuity during maintenance (if needed) and may require complete disconnection of the switchgear and controlgear from the system and making dead before accessing the interior of the enclosure

Category **LSC2**: This form is intended to allow maximum continuity of service of the network during access to the compartments inside the switchgear and controlgear

LSC2 has two recognized levels:

LSC2A: When accessing compartments of one functional unit, the other functional units of the switchgear and controlgear may be kept in service.

> **Example LSC2A for withdrawable designs**: In practical terms, this means that the incoming HV cables of that functional unit shall be made dead and earthed and the circuit shall be disconnected and separated (physically and electrically) from the busbars. Busbars may be kept live. The term separation is used here rather than segregation to avoid making a distinction at this stage between insulation and metallic partitions and shutters.

LSC2B: In addition to the above level of service continuity LSC2A, in this category LSC2B the incoming HV cables to the functional unit being accessed may be kept energized. This means that there is another point of disconnection and separation, i.e. between switching device and cables.

> **Example LSC2B for withdrawable designs**: If the main switching device of each functional unit of a LSC2B switchgear and controlgear is fitted in its own accessible compartment, maintenance may be performed on this main switching device without de-energizing the corresponding cable connection. As a consequence, a minimum of three compartments for each functional unit is necessary in this example of LSC2B switchgear and controlgear.
>
> a) For each main switching device.
> b) For components connected to one side of a main switching device, for example feeder circuit.
> c) For components connected to the other side of the main switching device, for example busbars, where more than one set of busbars is provided, each set being in a separate compartment.

8.3 Internal arc classification

When selecting an 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 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. This procedure is based on the assumption that the user has a role to play in the risk reduction.

For guidance, Table 8.1 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.

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 control.
- Pressure-relief device.
- Transfer of a withdrawable part to or from the service position only when the front door is closed.

Subclause 5.102.5 considers the practicality of the shutters becoming part of the enclosure when they are closed in positions defined in 3.128 to 3.131. The change of state when moving from the position defined in 3.127 to 3.129 (and vice versa) is not tested.

Failures can occur during the racking-in or racking-out of withdrawable parts. Such failures are not necessarily due to change of electrical field by the closing of the shutters, although this is one possibility. A more frequent failure is due to damage to, or distortion of, the plugging contacts and/or the shutters such that a flashover to earth is initiated during the racking process.

In defining classification IAC, the following points have to 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 3.127 to 3.129.

Table 8.1 – Locations, causes and examples of measures to decrease the probability of internal faults

Locations where internal faults are most likely to occur (1)	Possible causes of internal faults (2)	Examples of possible preventive measures (3)
Cable 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	Mis-operation	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
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, LV fuses
Circuit breakers	Insufficient maintenance	Regular programmed maintenance Instructions to personnel
All locations	Error by personnel	Limitation of access by compartmentation 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 gas-filled compartments
	Overvoltages	Surge protection Adequate insulation co-ordination Dielectric tests on site

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: Insulation-enclosed switchgear and controlgear which is IAC classified is not necessary.
- Where the risk is considered to be relevant: Only 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 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

Classification IAC gives a tested level of protection of persons under normal operating conditions as defined in Clause A 1 It is concerned with personnel protection under these conditions, it is not concerned with personnel protection under maintenance conditions nor with service continuity

Table 8.2 – Summary of technical requirements, ratings and optional tests for insulation-enclosed switchgear

Information	Subclause of this standard	User to indicate requirement as appropriate
Particulars of system (not equipment rating)		
Voltage kV		
Frequency Hz		
Number of phases		
Type of neutral earthing		
Switchgear characteristics		
Number of poles		
Class – indoor (or special service conditions)	2	
Name of compartment - Busbar Main device Cable CT VT (etc)	3 107 (refer to 5 103 1)	Busbar comp. = Main device comp = Cable comp = CT comp = VT comp.= Cable/CT comp = Main device/CT = Other comp (state)=
Type of compartment (specify type for each HV compartment) if applicable - interlock controlled access compartment procedure-based access compartment tool-based access compartment non-accessible compartment	 3 107 1 3 107 2 3 107 3 3 107 4	
Withdrawable/non-withdrawable (main device type)	3 125	(withdrawable/non-withdrawable) =

Information	Subclause of this standard	User to indicate requirement as appropriate
Loss of service continuity category (LSC) LSC2B LSC2A LSC1	 3.131.1 3.131.1 3.131.2	
Rated voltage U_r 3,6 kV; 7,2 kV; 12 kV; 17,5 kV; 24 kV; 36 kV; etc and number of phases 1 2 or 3	4.1	
Rated insulation level:- short-duration 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)
Rated short-time withstand current I_k Main circuit (incomer/busbar/feeder) Earth circuit	4.5	 a) b)
Rated peak withstand current I_p Main circuit (incomer/busbar/feeder) Earth circuit	4.6	 a) b)
Rated duration of short circuit t_k Main circuit (incomer/busbar/feeder) Earth circuit	4.7	 a) b)
Rated supply voltage of closing and opening devices and auxiliary and control circuits U_a a) Closing and tripping b) Indication c) Control	4.8	 a) b) c)
Rated supply frequency of closing and opening and of auxiliary circuits	4.9	
Low- and high-pressure interlocking and monitoring devices (state requirements, for example, lockout on low-pressure indication, etc.)	5.9	
Interlocking devices (state any additional requirements to 5.11)	5.11	

Information	Subclause of this standard	User to indicate requirement as appropriate
Degrees of protection by enclosures (if not IP2X) -	5.13 (see 5.102.1 and 5.102.3)	
With doors closed		a)
With doors open		b)
Artificial pollution tests	6.2.8	Additional condensation and pollution requirements:-
Dielectric tests on cable testing circuits	6.2.101	Agree with manufacturer the test values
Partial discharge measurement	7.101	
Internal fault IAC	6.106	Y/N
Types of accessibility to switchgear/controlgear (for A and B, specify for the side(s) that they are required)	Annex A, A.2	
A: restricted to authorized personnel only		F for front side =
B: unrestricted accessibility (includes public)		L for lateral side =
C: accessibility restricted by installation out of reach	See also examples in A.8	R for rear side =
Classification test value in kA and duration in s	Annex A, A.3	
Additional information for example, special requirements for cable testing		

9 Information to be given with enquiries, tenders and orders

9.101 Information to be given with enquiries and orders

When enquiring about or ordering an installation of 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 grade PA or PB to be provided by the insulation 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 current (Ik);
i) rated duration of short circuit (if different from 1 s);
j) rated peak withstand current (if different from 2,5 Ik);
k) rated values of components;
l) degree of protection for the insulation enclosure and partitions;
m) circuit diagrams;
n) type of insulation-enclosed switchgear and controlgear (LSC1 or LSC2);
o) description by name and category of the various compartments, if required;
p) classification IAC, if required, with corresponding Ik, Ip, t and FLR, ABC, 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, such 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.

Information should be supplied if special type tests are required.

9.102 Information to be given with tenders

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 9.101.
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) accessible sides;
   h) instructions for 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 9.101;

b) current or power for operation,

c) operating times;

d) quantity of free gas for operation.

5 List of recommended spare parts which should be procured by the user.

10 Rules for transport, storage, erection and maintenance

Refer to Clause 10 of IEC 60694.

10.1 Conditions during transport, storage and erection

Refer to 10.1 of IEC 60694.

10.2 Installation

Refer to 10.2 of IEC 60694 with the addition of a new paragraph after the first paragraph of 10.2.3

In case of classification IAC switchgear and controlgear, guidance on safe installation conditions for the case of an internal arc shall be provided as well. The hazards of the actual installation condition shall be assessed with respect to installation conditions of the test specimen during the internal arcing test (refer to Clause A.3). These conditions are considered as minimum permissible conditions. Any installation condition less stringent and/or providing more room is considered to be covered by the test.

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

Refer to 10.3 of IEC 60694.

10.4 Maintenance

Refer to 10.4 of IEC 60694 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 the partitions use,
- when installed according to the manufacturer's instructions, the requirements IP-2X (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 Partitions 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

Refer to Clause 11 of IEC 60694 with the following addition

11.101 Procedures

Suitable procedures should be put in place by the user to ensure that a procedure-based access 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.

11.102 Internal arc aspects

As far as the protection of persons is concerned, the correct performance of the 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 8.3.

Arcing due to an internal fault in the metal-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

The manufacturer shall be prepared to provide the following relevant information about the environmental impact of the switchgear.

When fluids are used in switchgear and controlgear, instructions shall be provided in order to

- minimize the leakage rate;
- control the handling of the new and used fluids;
- indicate the possibility to recycle.

The manufacturer shall give guidance, concerning disassembly and end-of-life procedures for the different materials of the equipment and disposal.

Annex A
(normative)

Internal fault – Method for testing the insulation-enclosed switchgear and controlgear under conditions of arcing due to an internal fault

A.1 Introduction

This annex applies to insulation-enclosed switchgear and controlgear of IAC classification. This classification is intended to offer a tested level of protection to persons in the vicinity of the equipment in normal operating conditions and with the switchgear and controlgear in normal service position, in the event of internal arc.

For the purpose of this annex, normal operating conditions means the conditions of insulation-enclosed switchgear and controlgear required to carry out operations such as opening or closing HV switching devices, connecting and disconnecting withdrawable parts, reading of measuring instruments and monitoring equipment, etc. Therefore, if, to perform any of such operations, any cover has to be removed and/or any door has to be opened, the test described below shall be carried out with the cover and/or door removed.

Removing or replacing active components (for example, HV fuses or any other removable component) are not considered to be normal operations, neither those required to carry out maintenance work.

Internal faults inside 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.

The internal arc IAC classification makes allowance for internal overpressure acting on covers, doors, inspection windows, ventilation openings, etc. It also takes into consideration the thermal effects of arc or its roots on the enclosure and of ejected hot gases and glowing particles, but not damage to internal partition and shutters not being accessible in normal operating conditions.

NOTE Influences of internal arc between compartments are not yet covered by this standard.

The internal arc test described below is intended to verify the effectiveness of the design in the protection of persons in case of an internal arc. It does not cover all effects which may constitute a hazard, such as the presence of gases with potential toxic characteristics that may be present after the fault. From this point of view, immediate evacuation and further ventilation of the switchgear room, before re-entering the site, is required.

Hazard of propagation of fire after an internal arc to combustible materials or equipment placed in the proximity of the insulation-enclosed switchgear and controlgear is not covered by this test.

A.2 Types of accessibility

A distinction is made between two types of accessibility to the insulation-enclosed switchgear and controlgear which are possible in the site of installation.

Accessibility Type A: restricted to authorised personnel only.

Accessibility Type B: unrestricted accessibility, including that of the general public

Corresponding to these two types of accessibility, two different test conditions are described in Clause A.3.

The insulation-enclosed switchgear and controlgear may have different types of accessibility on the various sides of its enclosure.

For identification purposes of the different sides of the enclosure (refer to Clauses A.7 and A.8) the following code shall be used:

F for front side;

L for lateral side;

R for rear side.

The front side shall be clearly stated by the manufacturer.

A.3 Test arrangements

A.3.1 General

The following points shall be observed:

- 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 compartment of a functional unit, containing a main circuit component, shall be tested. This does not apply to compartments where the main component is individually embedded in solid insulating material (refer to 5.103.1). In the case of switchgear and controlgear consisting of extensible (modular) stand-alone units, the test specimen shall consist of two units connected together as in service. Testing shall be made at least in all compartments of the end of the switchgear and controlgear adjacent to the indicators. However, if there is a substantial difference (to be declared by the manufacturer) in strength between the joining sides of adjacent units and the side forming the end of a switchgear and controlgear, three units shall be used and the test of the different compartments repeated in the central unit.

  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 (tier).
- When the test specimen is earthed, it shall be at the 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 SF6), the test shall be made with the original fluid at its rated filling conditions (±10 %). It is permitted to replace SF6 with air at the rated filling conditions (±10 %).

  NOTE 2 If the test is carried out with air instead of SF6, the pressure rise will be different and care should be exercised in the interpretation of the test results.

A.3.2 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.

Ceiling:

Unless the manufacturer states a larger minimum clearance, the ceiling shall be located at a distance of 600 mm ± 100 mm from the upper part of the test specimen. However, the ceiling shall be located at a distance of 2 m, from the floor as a minimum. This provision is applicable when testing specimens of less than 1,5 m high.

The manufacturer may carry out an additional test with lower clearances to the ceiling in order to assess criteria for installation conditions.

Lateral wall:

The lateral wall shall be placed at 100 mm ± 30 mm from the lateral side of the test specimen. A lower clearance 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 manufacturer may carry out an additional test with higher clearances to the lateral wall, in order to assess criteria for installation conditions.

Rear wall:

The rear wall shall be placed as follows depending on the type of accessibility:

- **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 Clause A.6, 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^{0}_{+100} mm from the rear side of the test specimen.

  An additional test may be performed with lower clearances to prove the capability of the switchgear and controlgear to operate correctly when reduced room is available (for example, to justify the installation close to a wall, in a no rear-accessibility arrangement).

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.

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 m away from the switchgear and controlgear tested.

NOTE The possible effects of hot gases outside of the room containing the switchgear and controlgear are not covered by this standard.

A.3.3 Indicators (for assessing the thermal effects of the gases)

A.3.3.1 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 A.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 A.2.

The indicator dimensions shall be 150 mm × 150 mm ($^{+15}_{0}$ mm).

A.3.3.2 Arrangement of indicators

Indicators shall be placed at each accessible side, on a mounting rack, at distances depending on the type of accessibility.

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 100 mm longer than the unit under test in the case of accessibility type B, or 300 mm in the case of accessibility type A, provided that the position of the wall in the arrangement of the room simulation does not limit this extension.

NOTE In all cases the distance from the indicators fitted vertically to the switchgear and controlgear is measured from the surface of the enclosure, disregarding protruding elements (for example, handles, frame of apparatus and so on). 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) Accessibility type 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 accessible sides of the insulation-enclosed switchgear and controlgear up to a height of 2 m evenly distributed, arranged in a checkerboard pattern, covering 40 % to 50 % of the area (refer to Figures A.3 and A.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 m above the floor as described in Figures A.3 and A.4 and covering the whole area between 300 mm and 800 mm from the insulation-enclosed switchgear and controlgear. When the ceiling is placed at a height of 2 m above the floor (refer to A.3.2a)) 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 A.3 and A.4).

b) Accessibility type B (general public)

Black cotton-interlining lawn (approximately 40 g/m^2) shall be used for indicators.

Indicators shall be fitted vertically at all accessible sides for the insulation enclosed switchgear and controlgear up to 2 m above the floor. If the actual height of the specimen is lower than 1,9 m, vertical indicators shall be fitted up to a height 100 mm higher than the test specimen.

The indicators shall be evenly distributed, arranged in a checkerboard pattern, covering 40 % to 50 % of the area (refer to Figures A.3 and A.5).

The distance from the indicators to the switchgear and controlgear shall be 100 mm ± 5 mm.

Indicators shall also be arranged horizontally at a height above the floor, as described in Figure A.5, and covering the whole area between 100 mm and 800 mm from the insulation-enclosed switchgear and controlgear. If the test specimen is lower than 2 m, indicators shall be placed direct on the top covers as for accessible sides, at a distance of 100 mm ± 5 mm (refer to Figure A.6). They shall be evenly distributed, arranged in a checkerboard pattern, covering 40 % to 50 % of the area (refer to Figures A.5 and A.6).

c) Special accessibility condition

Black cotton-interlining lawn (approximately 40 g/m^2) shall be used for indicators.

Where normal operation requires persons to stand or walk upon the equipment, horizontal indicators shall be placed above the upper accessible surface, as described in Figure A.6, whatever the height of the switchgear and controlgear.

A.4 Current and voltage applied

A.4.1 General

The tests on insulation-enclosed switchgear and controlgear shall be carried out three-phase (for three-phase systems). The short-circuit current applied during the test corresponds to the rated short-time withstand current. It may be lower, if specified by the manufacturer.

A test performed at a given voltage, current and duration is generally valid for all lower values of current, voltage and duration.

NOTE 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.

A.4.2 Voltage

The applied voltage of the test circuit should be equal to the rated voltage of the insulation-enclosed switchgear and controlgear. If the capability of the test plant does not permit this, a lower voltage may be chosen provided the following conditions are met for the duration of the test:

a) the true r.m.s. current value as computed by a digital recording device complies with current requirements of A.4.3,

b) the arc is not extinguished prematurely in any of the phases in which it has been initiated.

A.4.3 Current

A.4.3.1 AC component

The short-circuit current for which the insulation-enclosed switchgear and controlgear is specified with respect to arcing shall be set within a $^{+5}_{0}$ % tolerance. If the applied voltage is equal to the rated voltage, this tolerance applies 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 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.

A.4.3.2 Peak current

The instant of closing shall be chosen so that the prospective value of the peak current, with a tolerance of $^{+5}_{0}$ %, flowing in one of the outer poles is 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 A.4.3.1, and so that a major loop also occurs in the other outer pole. If the voltage is lower than the rated voltage, the peak value of the short-circuit current for the insulation-enclosed switchgear and controlgear under test shall not drop below 90 % of the rated peak value.

NOTE 1 For other, higher, d.c. time constants 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.

NOTE 2 The major loop in the other outer pole generally has a lower peak value than the stated values above.

In case of two-phase initiating of the arc the instant of closing shall be chosen to provide the maximum possible d.c. component.

A.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 %.

Where the operation of fast-acting protective devices is dependent on the frequency, the test shall be performed with the rated frequency of these devices ±10 %.

A.4.5 Duration of the test

The test duration shall be stated by the manufacturer. Standard recommended values are 1 s, 0,5 s and 0,1 s.

NOTE 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.

A.5 Test procedure

A.5.1 Supply circuit

If applicable, the supply circuit shall be three-phase, except for tests on switchgear and controlgear with segregated phases, if no mutual influence between the segregated phase compartments is likely. 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.

NOTE 1 Internal arc faults with a directly grounded neutral are less severe.

When the test is made on part of the switchgear and controlgear where phases are segregated, the supply circuit shall be single-phase, one of the terminals earthed. The test current shall be equal to the three-phase value stated in A.4.3.1.

Care shall be taken in order that the connections do not alter the test conditions.

The feeding direction shall be as follows:

- for a cable 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, if barriers are fitted to create separated busbar compartments between functional units, or through the main switching device located at one end of the switchgear and controlgear, if the busbar compartment is common for the whole switchgear and controlgear;

  NOTE 2 In case of non-symmetrical designs of a busbar compartment, the most onerous internal arc initiation should 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.

A.5.2 Arc initiation

The arc shall be initiated between all the phases by means of a metal wire of about 0,5 mm diameter or, in the case of segregated phase conductors, between one phase and earth.

The point of initiation shall be located at the furthest accessible point from the supply within the compartment under test.

In functional units where the live parts are covered by solid insulating material, the arc shall be initiated between two adjacent phases with a current value of 87 % of the rated current or, in the case of segregated phase conductors, between one phase and earth at the following locations:

a) at gaps or joining surfaces between the insulation of insulation-embedded parts,

b) by perforation at insulated joints made on site when prefabricated insulating parts are not used.

Except for case b), solid insulation shall not be perforated. The supply circuit shall be three-phase to allow the fault to become three-phase (if applicable).

A.5.2.1 Cable compartments with plug-in or site-made solid insulation connections

For cable compartments in which connections are always made with plug-in connectors, screened or not, or site-made solid insulation, the two phases under test shall be fitted with plugs without insulation. The third phase 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.

In all these cases of phase-to-phase fault, the test current shall be the phase-to-phase fault current of the three-phase supply circuit defined according to A.4.3. That means the actual current value, unless the fault evolves towards a three-phase fault, is reduced to approximately 0,87 times the specified internal arc withstand current.

In solidly earthed networks (non-floating neutral), or in networks with earth-fault protection, the single phase-to-earth short-circuit current, which is generally lower than the possible two-phase fault current, will be switched off rapidly. For switchgear and controlgear only intended for this restricted use, it is acceptable to test accordingly, instead of the two-phase test described above. The arc will then be ignited as single phase to ground, provided that the other phases are energized to allow the arc to become three-phase. As the specified internal arc withstand current, the tested single-phase value applies.

A.6 Acceptance criteria

Insulation-enclosed switchgear and controlgear is qualified as classification IAC (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) in every side. The switchgear and controlgear does 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 (refer to A.3.2a)), 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 within the time specified for the test.
- Projections of small parts, up to a individual mass of 60 g, are accepted.

Criterion No. 3

Arcing does not cause holes in the accessible sides up to a height of 2 m.

Criterion No. 4

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

Should they start to burn during the test, 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 enclosure remains connected to its earthing point. Visual inspection is generally sufficient to assess compliance. In case of doubt, the continuity of the earthing connection shall be checked, refer to 6.6b).

A.7 Test report

The following information shall be given in the test report:

- Rating and 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 insulation-enclosed switchgear and controlgear to the floor and/or to the walls.
- Arrangement of the test connections.
- Point and method of initiation of the internal fault.
- Drawings of test arrangement (room simulation, test specimen and mounting frame of indicators) with respect to the type of accessibility (A or B), side (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 Clause A.6.
- Photographs of the object under test, before and after test.
- Other relevant remarks.

A.8 Designation of IAC classification

In the case where the IAC classification is proven by the tests, according to 6.106, the insulation enclosed switchgear and controlgear will be designated as follows:

- General: classification IAC (initials of internal arc classified)
- Accessibility: A or B (according to Clause A.2)
- Test values: test current in kA, and duration in seconds.

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

Example 1: an insulation-enclosed switchgear and controlgear tested for a fault current (r.m.s.) of 12,5 kA, for 0,5 s, intended to be installed in a site of public accessibility and tested with indicators placed in the front, lateral and rear sides, is designated as follows:

Classification IAC BFLR

Internal arc: 12,5 kA 0,5 s

Example 2: an insulation-enclosed switchgear and controlgear tested for a fault current (r.m.s.) of 16 kA, for 1 s, intended to be installed in the following conditions:

Front: public accessibility

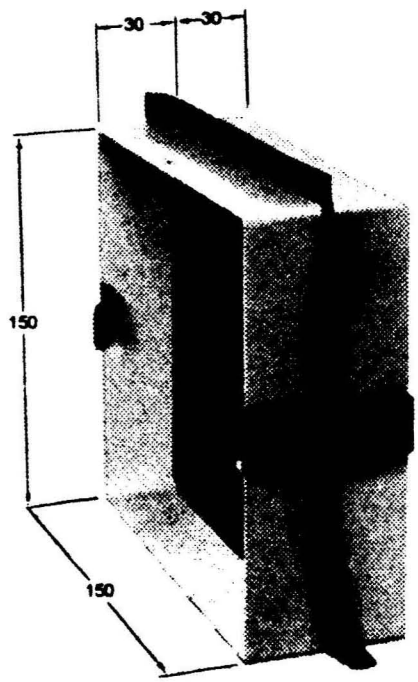
Rear: restricted to operators

Lateral: not accessible

is designated as follows:

Classification IAC BF-AR

Internal arc: 16 kA 1s.



Dimensions in millimetres

Figure A.1 – Mounting frame for vertical indicators

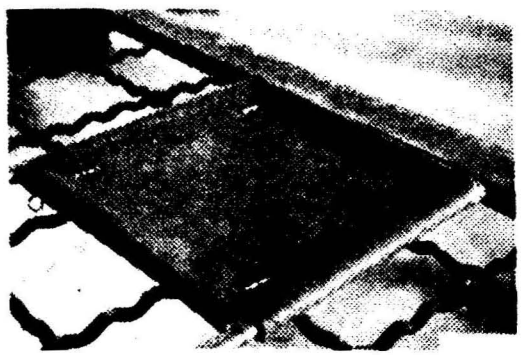


Figure A.2 – Horizontal indicator

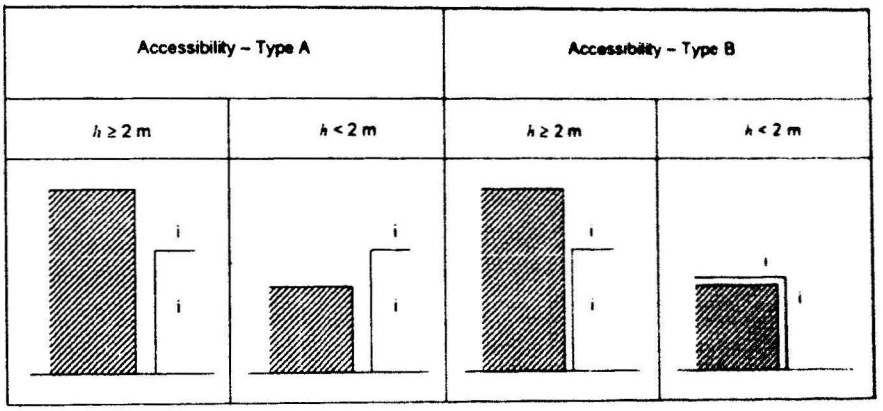
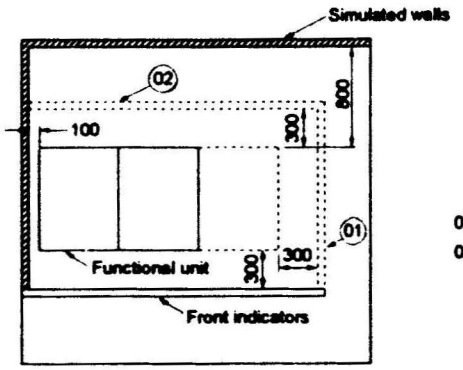
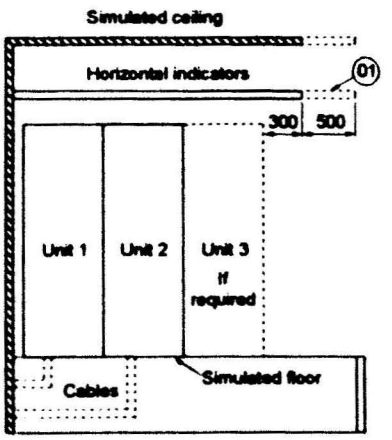


Figure A.3 – Position of indicators (*i*)
Height of equipment (*h*)

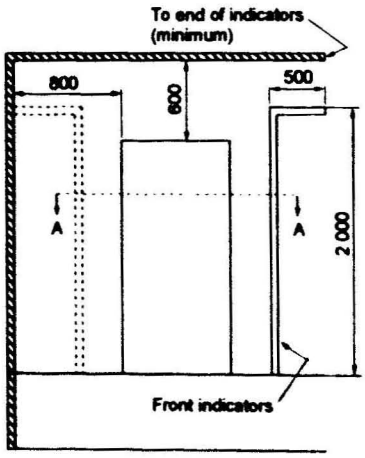


01 Indicators for lateral accessibility
02 Indicators for rear accessibility

Section A-A

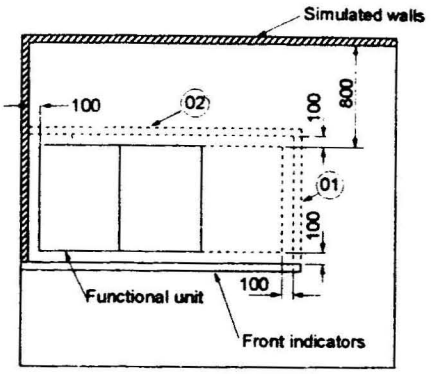


Front elevation



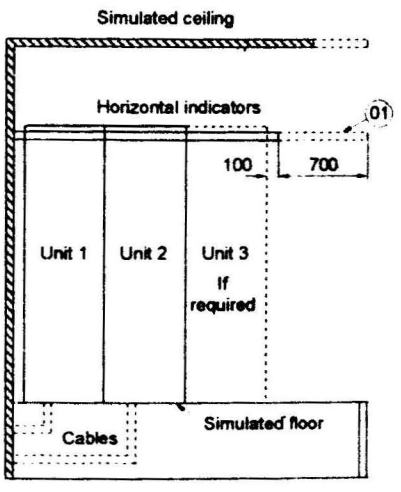
End elevation

Figure A.4 – Room simulation and indicator positioning for accessibility A, functional unit at or above 1,5 m

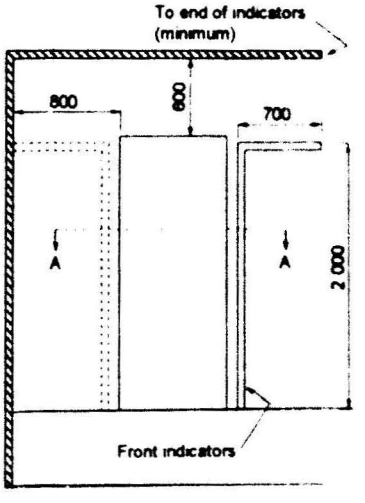


01 Indicators for lateral accessibility
02 Indicators for rear accessibility

Section A-A



Front elevation



End elevation

Figure A.5 – Room simulation and indicator positioning for accessibility B, functional unit above 2m high

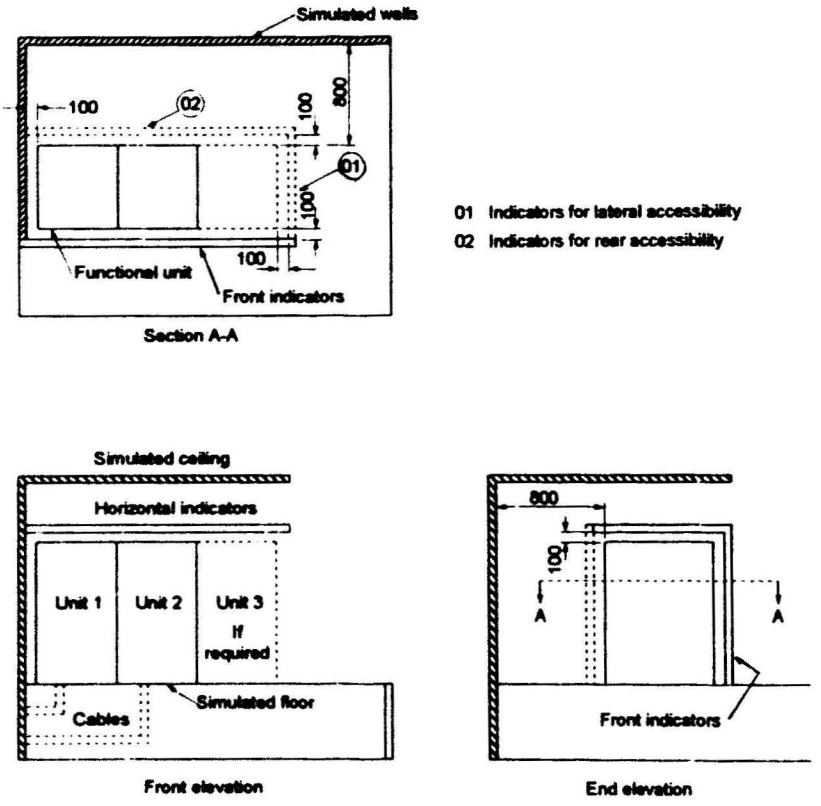


Figure A.6 – Room simulation and indicator positioning for accessibility B, functional unit below 2 m high

Annex B
(normative)

Partial discharge measurement

B.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 insulation, 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 insulation-enclosed switchgear and controlgear.

B.2 Application

The measurement of partial discharges is in general appropriate for 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 insulation, 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.

NOTE 3 This test may be carried out on assemblies or subassemblies. Care should be taken that external partial discharges do not affect the measurement.

B.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 B.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 (U_r is the rated voltage). Each phase shall be connected to the test voltage source successively, the other two phases being earthed. It is allowed to isolate 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 B.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 B.2.

B.4 Test procedure

The power-frequency voltage applied 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 B.1) and maintained at this value for at least 10 s [2]. 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 B.1).

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.

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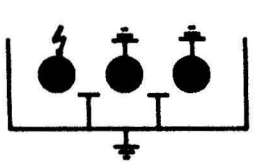
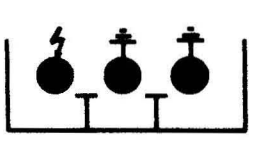
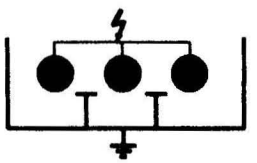
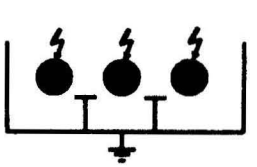
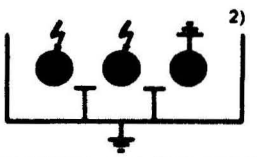
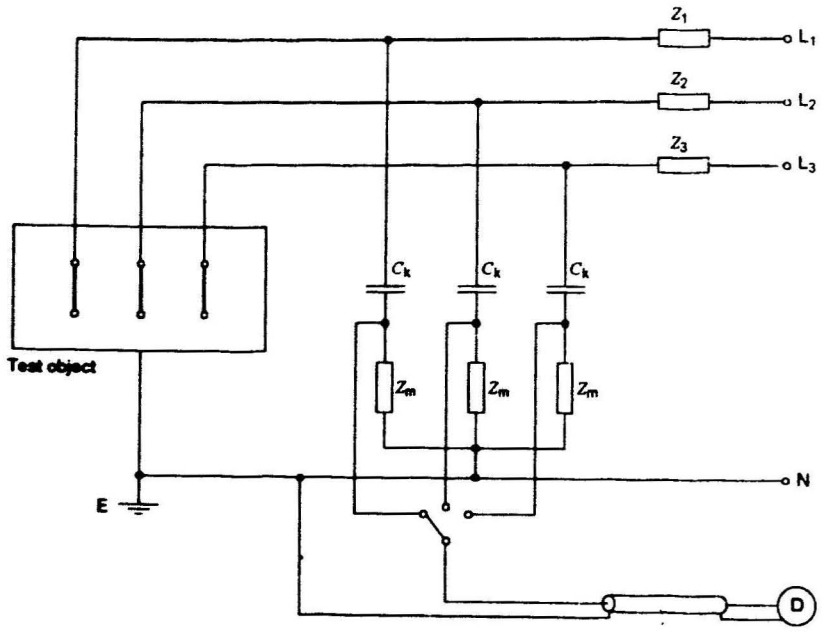
[2] Alternatively, the partial discharge test may be performed while decreasing the voltage after the power-frequency voltage tests.

Table B.1 – Test circuits and procedures

	Single-phase testing			Three-phase testing
	Procedure A	Procedure B		
Voltage source connected to	Each phase successively	Each phase successively	Three phases simultaneously	Three phases (Figures B.1 and B.2)
Earth-connected elements	Both the other phases and all the parts earthed in service	Both the other phases	All the parts earthed in service	All the parts earthed in service
Minimum pre-stress voltage	1,3 U_r	1,3 U_r	1,3 $U_r/\sqrt{3}$	1,3 U_r [1]
Test voltage	1,1 U_r	1,1 U_r	1,1 $U_r/\sqrt{3}$	1,1 U_r [1]
Basic diagram				  [2]

[1] Voltage between phases

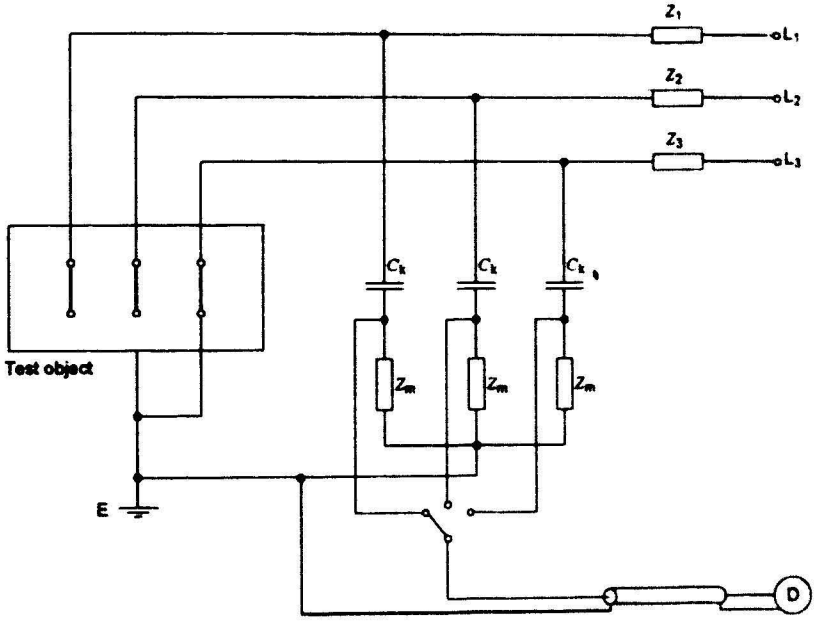
[2] Additional test in the case of a system without solidly earthed neutral (for type tests only)



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 B.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 B.2 – Partial discharge test circuit (system without earthed neutral)

Annex C
(normative)

Humidity test

C.1 General

The object of the humidity test is to prove that the insulation-enclosed switchgear and controlgear is safe when touched on the accessible surface of the insulation 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 insulation 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 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.

C.2 Test procedure and test conditions

C.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 C.1).

The beginning of fog generation (t_0) 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 insulation-enclosed switchgear and controlgear and shall be sufficiently long both at high and low temperatures to cause wetting or drying of all the insulation 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 insulation 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

C.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 insulation 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.

NOTE 1 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 2 The relation between conductivity of the water and its temperature is given in IEC 60060-1

C.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.

C.2.4 Test chamber

A proposal for an appropriate test chamber with thin walls is made in Figure C.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.

NOTE 1 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 insulation surfaces of the test object are wet.

NOTE 2 If the walls do not meet these conditions, special measures should be taken to ensure that the period during which the insulation surfaces are wet is approximately equal to half the duration of one test cycle

C.2.5 Test object

The insulation-enclosed switchgear and controlgear to be tested shall be in a new condition with its outside insulation surfaces clean. It shall be mounted in the test chamber in its usual upright position, complete with all insulating parts and the continuity of the main circuit ensured. Precautions shall be taken to ensure that no deposit of water accumulates inside the insulation enclosure during the test.

C.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 insulation-enclosed switchgear and controlgear:

- rated voltage U_r between phases;
- $U_r/\sqrt{3}$ between phase and earth,

C.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 insulation surfaces are wet.

C.3 Test criteria and evaluation

C.3.1 Criterion during the test

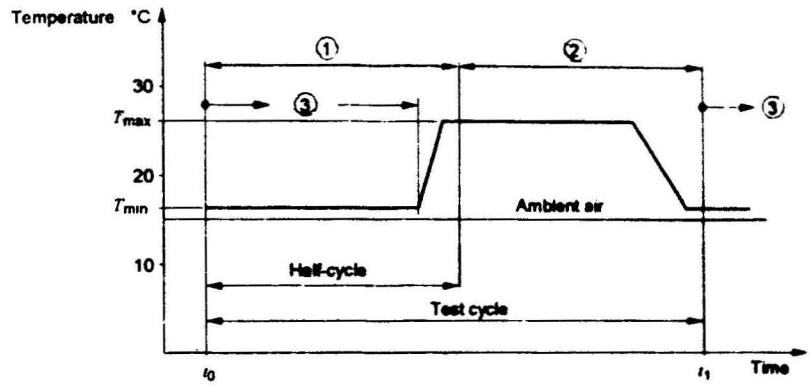
During the total duration of the humidity test, no flash-over shall occur either between phases or between phase and earth.

C.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. 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.

C.3.3 Evaluation of the test

If the criteria in C.3.1 and C.3.2 are met, the insulation-enclosed switchgear and controlgear shall be considered to have passed the humidity test.



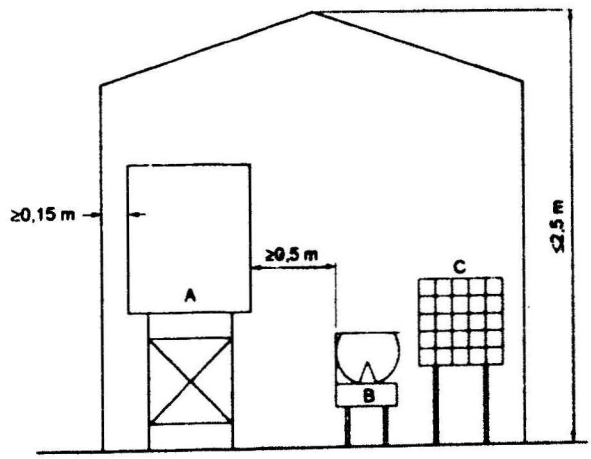
Key

1 wet surface period

2 dry surface period

3 for generation

Figure C.1 – Test cycle



Key

A test object

B atomizer

C radiator

Figure C.2 – Test chamber

Annex D
(informative)

Protection grades

D.1 Protection grade PA

Protection grade PA has the following three different basic arrangements:

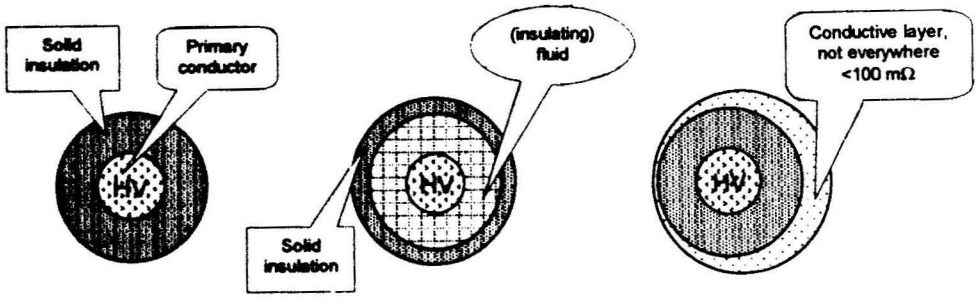


figure D.1.a figure D.1.b figure D.1.c.

Figure D.1a) 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 (6.104.1a)).

Figure D.1b) 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 (6.104.1a)).

The solid insulation fulfils the requirements of 5.102.3b).
Sample to be tested at power-frequency voltage test (6.104.1b)).

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 (6.104.1C)).

Figure D.1c) Same as for Figure D.1a)

Figure D.1 – Possible designs for protection grade PA

D.2 Protection grade PB

Protection grade PB, for those area's that are liable to be touched, has the following three different basic arrangements:

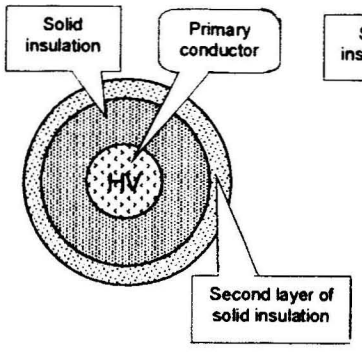


fig D.2.a (PB1)

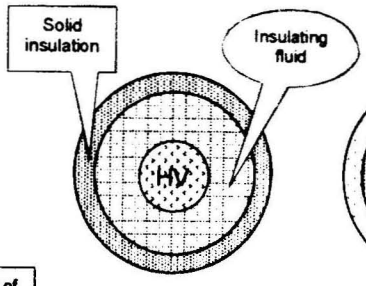


fig D.2 b (PB1)

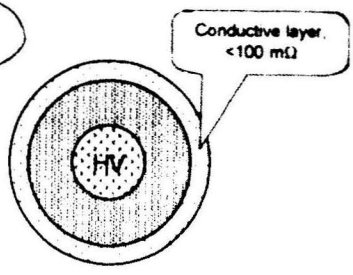


fig D.2 c (PB2)

Apart from the demands for protection grade PA, the following extra demands apply for the protection grade PB:

PB1:

Figure D.2 a) The second layer of insulating material fulfils the requirements of 5.102.3d) To be separately tested with 100 cm^2 metal foil at 150% U_r for 1 min (6.104.1d)).

Figure D.2 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 (6.104.1d))

PB2:

Figure D.2 c) The conductive layer fulfils the requirements in 5.102.3g) Resistance to be tested according to 6.4.101

Figure D.2 – Possible designs for protection grade PB

Bibliography

IEC 60621-1:1987, *Electrical installations for outdoor sites under heavy conditions (including open-cast mines and quarries) – Part 1: Scope and definitions*

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)*

IEC 61634:1995, *High-voltage switchgear and controlgear – Use and handling of sulphur hexafluoride (SF6) in high-voltage switchgear and controlgear*

IEC 62271-200:2003, *AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV* (formerly IEC 60298)

(*Continued from second cover*)

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60470 : 2000 High-voltage alternating current contactors and contactor-based motor-starters	IS/IEC 60470 : 2000 High-voltage alternating current contactors and contactor-based motor-starters	Identical
IEC 60529 : 1989 Degrees of protection provided by enclosures (IP Code)	IS 12063 : 1987 Classification of degrees of protection provided by enclosures of electrical equipment	Technically Equivalent
IEC 60694 : 1996 Common specification for high-voltage switchgear and controlgear standards	IS 12729 : 2004 Common specification for high voltage switchgear and controlgear standards (*first revision*)	Identical
IEC 60909-0 : 2001 Short-circuit currents in three-phase a.c. systems — Part 0: Calculation of currents	IS 13234 : 1992 Guide for short-circuit current calculation in three-phase a.c. systems	Technically Equivalent
IEC 62271-100 : 2001 High-voltage switchgear and controlgear — Part 100: High-voltage alternating-current circuit-breakers (formerly IEC 60056)	IS/IEC 62271-100 : 2001 High-voltage switchgear and controlgear: Part 100 High-voltage alternating-current circuit-breakers	Identical
IEC 62271-102 : 2001 High-voltage switchgear and controlgear — Part 102: Alternating current disconnectors and earthing switches	IS/IEC 62271-102 : 2001 High-voltage switchgear and controlgear: Part 102 Alternating current disconnectors and earthing switches	do
IEC 62271-105 : 2002 High-voltage switchgear and controlgear — Part 105: Alternating current switch-fuse combinations	IS/IEC 62271-105 : 2002 High-voltage switchgear and controlgear: Part 105 Alternating current switch-fuse combinations	do
ISO/IEC Guide 51 : 1999 Safety aspects — Guidelines for their inclusion in standards	IS/ISO/IEC Guide 51 : 2005 Safety aspects — Guidelines for their inclusion in standards	do

The technical committee has reviewed the provisions of the following International Standards referred in this adopted standard and has decided that they are acceptable for use in conjunction with this standard:

International Standard	*Title*
IEC 60480 : 2004	Guidelines for the checking and treatment of sulfur hexafluoride (SF6) taken from electrical equipment and specification for its re-use
IEC 60932 : 1988	Additional requirements for enclosed switchgear and controlgear from 1 kV to 72.5 kV to be used in severe climatic conditions

Only English language text has been retained while adopting it in this Indian Standard, and as such the page numbers given here are not the same as in the IEC Standard.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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This Indian Standard has been developed from Doc: No. ETD 08 (5784).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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