INTERNATIONAL STANDARD

IEC 60694

Edition 2.2
2002-01

Edition 2:1996 consolidated with amendments 1:2000 and 2:2001

Common specifications for high-voltage switchgear and controlgear standards

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMON SPECIFICATIONS FOR HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR STANDARDS

FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of the IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested National Committees.
3) The documents produced have the form of recommendations for international use and are published in the form of standards, technical specifications, technical reports or guides and they are accepted by the National Committees in that sense.
4) In order to promote international unification, IEC National Committees undertake to apply IEC International Standards transparently to the maximum extent possible in their national and regional standards. Any divergence between the IEC Standard and the corresponding national or regional standard shall be clearly indicated in the latter.
5) The IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with one of its standards.
6) Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. The IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 60694 has been prepared by subcommittee 17A: High-voltage switchgear and controlgear, and subcommittee 17C: High-voltage enclosed switchgear and controlgear, of IEC technical committee 17: Switchgear and controlgear.

This consolidated version of IEC 60694 is based on the second edition (1996) [documents 17A/458/FDIS and 17A/479/RVD, its amendment 1 (2000) [documents 17A/579/FDIS and 17A/588/RVD], its corrigendum of January 2001, its amendment 2 (2001) [documents 17A/599/FDIS and 17A/609/RVD] and its corrigendum of December 2001.

It bears the edition number 2.2.

A vertical line in the margin shows where the base publication has been modified by amendment 1, amendment 2 and the corrigenda.

Annexes A, B and C form an integral part of this standard.

Annexes D to H are for information only.

The following differences exist in some countries:

6.2.11 The required test voltage for disconnectors and switch-disconnectors of all rated voltages is 100 % of the tabulated voltage in columns 3 of tables 1a or 1b and 2a or 2b (Canada, France, Italy).

The committee has decided that the contents of the base publication and its amendments will remain unchanged until 2007. At this date, the publication will be

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

COMMON SPECIFICATIONS FOR HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR STANDARDS

1 General

1.1 Scope

This International Standard applies to a.c. switchgear and controlgear, designed for indoor and outdoor installation and for operation at service frequencies up to and including 60 Hz on systems having voltages above 1 000 V.

This standard applies to all high-voltage switchgear and controlgear except as otherwise specified in the relevant IEC standards for the particular type of switchgear and controlgear.

1.2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60034-1:1996, *Rotating electrical machines – Part 1: Rating and performance*

IEC 60038:1983, *IEC standard voltages*

IEC 60050(131):1978, *International Electrotechnical Vocabulary (IEV) – Chapter 131: Electric and magnetic circuits*

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

IEC 60050(191):1990, *International Electrotechnical Vocabulary (IEV) – Chapter 191: Dependability and quality of service*

IEC 60050(301):1983, *International Electrotechnical Vocabulary (IEV) – Chapter 301: General terms on measurements in electricity*

IEC 60050-351:1998, *International Electrotechnical Vocabulary (IEV) – Part 351: Automatic control*

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

IEC 60050(446):1983, *International Electrotechnical Vocabulary (IEV) – Chapter 446: Electrical relays*

IEC 60050(581):1978, *International Electrotechnical Vocabulary (IEV) – Chapter 581: Electromechanical components for electronic equipment*

IEC 60050(604):1987, *International Electrotechnical Vocabulary (IEV) – Chapter 604: Generation, transmission and distribution of electricity – Operation*

IEC 60050(811):1991, *International Electrotechnical Vocabulary (IEV) – Chapter 811: Electric traction*

IEC 60050(826):1982, *International Electrotechnical Vocabulary (IEV) – Chapter 826: Electrical installations of buildings*

IEC 60051-2:1984, *Direct acting indicating analogue electrical measuring instruments and their accessories – Part 2: Special requirements for ammeters and voltmeters*

IEC 60051-4:1984, *Direct acting indicating analogue electrical measuring instruments and their accessories – Part 4: Special requirements for frequency meters*

IEC 60051-5:1985, *Direct acting indicating analogue electrical measuring instruments and their accessories – Part 5: Special requirements for phase meters, power factor meters and synchroscopes*

IEC 60056:1987, *High-voltage alternating-current circuit-breakers*

IEC 60059:1938, *IEC standard current ratings*

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

IEC 60064:1993, *Tungsten filament lamps for domestic and similar general lighting purposes – Performance requirements*

IEC 60068-2 (all parts), *Environmental testing – Part 2: Tests*

IEC 60068-2-1:1990, *Environmental testing – Part 2: Tests. Tests A: Cold*

IEC 60068-2-2:1974, *Environmental testing – Part 2: Tests. Tests B: Dry heat*

IEC 60068-2-3:1969, *Environmental testing – Part 2: Tests. Test Ca: Damp heat, steady state*

IEC 60068-2-17:1994, *Environmental testing – Part 2: Tests – Test Q: Sealing*

IEC 60068-2-30:1980, *Environmental testing – Part 2: Tests. Test Db and guidance: Damp heat, cyclic (12 + 12-hour cycle)*

IEC 60068-2-63:1991, *Environmental testing – Part 2: Tests – Test Eg: Impact, spring hammer*

IEC 60071-1:1993, *Insulation co-ordination – Part 1: Definitions, principles and rules*

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

IEC 60073:1996, *Basic and safety principles for man-machine interface, marking and identification – Coding principles for indication devices and actuators*

IEC 60081:1997, *Double-capped fluorescent lamps – Performance specifications*

IEC 60083:1997, *Plugs and socket-outlets for domestic and similar general use standardized in member countries of IEC*

IEC 60085:1984, *Thermal evaluation and classification of electrical insulation*

IEC 60115-4:1982, *Fixed resistors for use in electronic equipment – Part 4: Sectional specification: Fixed power resistors*

IEC 60130 (all parts), *Connectors for frequencies below 3 MHz*

IEC 60227 (all parts), *Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V*

IEC 60228:1978, *Conductors of insulated cables*

IEC 60245 (all parts), *Rubber insulated cables – Rated voltages up to and including 450/750 V*

IEC 60255-5:1977, *Electrical relays – Part 5: Insulation tests for electrical relays*

IEC 60255-8:1990, *Electrical relays – Part 8: Thermal electrical relays*

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

IEC 60255-21-3:1993, *Electrical relays – Part 21: Vibration, shock, bump and seismic tests on measuring relays and protection equipment – Section 3: Seismic tests*

IEC 60255-23:1994, *Electrical relays – Part 23: Contact performance*

IEC 60269-1:1998, *Low-voltage fuses – Part 1: General requirements*

IEC 60269-2:1986, *Low-voltage fuses – Part 2: Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application)*

IEC 60269-2-1:1998, *Low-voltage fuses – Part 2-1: Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application) – Sections I to V: Examples of types of standardized fuses*

IEC 60270:1981, *Partial discharge measurements*

IEC 60296:1982, *Specification for unused mineral insulating oils for transformers and switchgear*

IEC 60309-1:1999, *Plugs, socket-outlets and couplers for industrial purposes – Part 1: General requirements*

IEC 60309-2:1999, *Plugs, socket-outlets and couplers for industrial purposes – Part 2: Dimensional interchangeability requirements for pin and contact-tube accessories*

IEC 60326 (all parts), *Printed boards*

IEC 60376:1971, *Specification and acceptance of new sulphur hexafluoride*

IEC 60393-1:1989, *Potentiometers for use in electronic equipment – Part 1: Generic specification*

IEC 60417 (all parts), *Graphical symbols for use on equipment*

IEC 60445:1999, *Basic and safety principles for man-machine interface, marking and identification – Identification of equipment terminals and of terminations of certain designated conductors, including general rules for an alphanumeric system*

IEC 60480:1974, *Guide to the checking of sulphur hexafluoride (SF_6) taken from electrical equipment*

IEC 60485:1974, *Digital electronic d.c. voltmeters and d.c. electronic analogue-to-digital converters*

IEC 60502-1:1997, *Power cables with extruded insulation and their accessories for rated voltages from 1 kV (U_m = 1,2 kV) up to 30 kV (U_m = 36 kV) – Part 1: Cables for rated voltages of 1 kV (U_m = 1,2 kV) and 3 kV (U_m = 3,6 kV)*

IEC 60507:1991, *Artificial pollution tests on high-voltage insulators to be used on a.c. systems*

IEC 60512-2:1985, *Electromechanical components for electronic equipment; basic testing procedures and measuring methods – Part 2: General examination, electrical continuity and contact resistance tests, insulation tests and voltage stress tests*

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

IEC 60617, *Graphical symbols for diagrams*

IEC 60669-1:1998, *Switches for household and similar fixed-electrical installations – Part 1: General requirements*

IEC 60721, *Classification of environmental conditions*

IEC 60730-2-9:1992, *Automatic electrical controls for household and similar use – Part 2: Particular requirements for temperature sensing controls*

IEC 60730-2-13:1995, *Automatic electrical controls for household and similar use – Part 2: Particular requirements for humidity sensing controls*

IEC 60815:1986, *Guide for the selection of insulators in respect of polluted conditions*

IEC 60816:1984, *Guide on methods of measurement of short-duration transients on low-voltage power and signal lines*

IEC 60947-2:1995, *Low-voltage switchgear and controlgear – Part 2: Circuit-breakers*

IEC 60947-3:1999, *Low-voltage switchgear and controlgear – Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units*

IEC 60947-4-1:1990, *Low-voltage switchgear and controlgear – Part 4: Contactors and motor-starters – Section One: Electromechanical contactors and motor-starters*

IEC 60947-4-2:1995, *Low-voltage switchgear and controlgear – Part 4: Contactors and motor-starters – Section 2: AC semiconductor motor controllers and starters*

IEC 60947-5-1:1997, *Low-voltage switchgear and controlgear – Part 5: Control circuit devices and switching elements – Section One: Electromechanical control circuit devices*

IEC 60947-7-1:1989, *Low-voltage switchgear and controlgear – Part 7: Ancillary equipment – Section One: Terminal blocks for copper conductors*

IEC 60947-7-2:1995, *Low-voltage switchgear and controlgear – Part 7: Ancillary equipment – Section 2: Protective conductor terminal blocks for copper conductors*

IEC 61000-4-1:1992, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 1: Overview of immunity tests* – Basic EMC publication

IEC 61000-4-4:1995, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 4: Electrical fast transient/burst immunity test* – Basic EMC Publication

IEC 61000-4-12:1995, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 12: Oscillatory waves immunity test* – Basic EMC Publication

IEC 61000-4-17:1999, *Electromagnetic compatibility (EMC) – Part 4-17: Testing and measurement techniques – Ripple on d.c. input power port immunity test*

IEC 61000-4-29:—, *Electromagnetic compatibility (EMC) – Part 4-29: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations on d.c. input power ports, immunity tests* [1)]

IEC 61000-5 (all parts), *Electromagnetic compatibility (EMC) – Part 5: Installation and mitigation guidelines*

IEC 61000-5-1:1996, *Electromagnetic compatibility (EMC) – Part 5: Installation and mitigation guidelines – Section 1: General considerations* – Basic EMC publication

IEC 61000-5-2:1997, *Electromagnetic compatibility (EMC) – Part 5: Installation and mitigation guidelines – Section 2: Earthing and cabling*

IEC 61000-6-5:—, *Electromagnetic compatibility (EMC) – Part 6-5: Generic standards – Immunity for power station and substation environments* [1)]

[1)] To be published.

IEC 61020-4:1991, *Electromechanical switches for use in electronic equipment – Part 4: Sectional specification for lever (toggle) switches*

IEC 61166:1993, *High-voltage alternating current circuit-breakers – Guide for seismic qualification of high-voltage alternating current circuit-breakers*

IEC 61180-1:1992, *High-voltage test techniques for low-voltage equipment – Part 1: Definitions, test and procedure requirements*

IEC 61634:1995, *High-voltage switchgear and controlgear – Use and handling of sulphur hexafluoride (SF_6) in high-voltage switchgear and controlgear*

IEC 61810 (all parts), *Electromechanical non-specified time all-or-nothing relays*

IEC 61810-1:1998, *Electromechanical non-specified time all-or-nothing relays – Part 1: General requirements*

IEC 61810-7:1997, *Electromechanical all-or-nothing relays – Part 7: Tests and measurement procedures*

CISPR 11:1990, *Limits and methods of measurement of electromagnetic disturbance characteristics of industrial, scientific and medical (ISM) radio-frequency equipment*

CISPR 16-1:1993, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1: Radio disturbance and immunity measuring apparatus*

CISPR 18-2:1986, *Radio interference characteristics of overhead power lines and high-voltage equipment – Part 2: Methods of measurement and procedure for determining limits* Amendment 1 (1993)

Other International Standards are referred to for information in this standard. They are listed in annex G.

2 Normal and special service conditions

Unless otherwise specified, high-voltage switchgear and controlgear, including the operating devices and the auxiliary equipment which form an integral part of them, are intended to be used in accordance with their rated characteristics and the normal service conditions listed in 2.1.

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

NOTE 1 Appropriate action should also be taken to ensure proper operation under such conditions of other components, such as relays.

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

2.1 Normal service conditions

2.1.1 Indoor switchgear and controlgear

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

The minimum ambient air temperature is –5 °C for class "minus 5 indoor", –15 °C for class "minus 15 indoor" and –25 °C for class "minus 25 indoor".

b) The influence of solar radiation may be neglected.

c) The altitude does not exceed 1 000 m.

d) The ambient air is not significantly polluted by dust, smoke, corrosive and/or flammable gases, vapours or salt.

e) The conditions of humidity are as follows:

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

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

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

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

For these conditions, condensation may occasionally occur.

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

NOTE 2 To withstand the effects of high humidity and condensation, such as breakdown of insulation or corrosion of metallic parts, switchgear designed for such conditions and tested accordingly should be used.

NOTE 3 Condensation may be prevented by special design of the building or housing, by suitable ventilation and heating of the station or by the use of dehumidifying equipment.

f) Vibration due to causes external to the switchgear and controlgear or earth tremors are negligible.

g) Induced electromagnetic disturbances at interfaces of the secondary system, as a result of switching in the high-voltage system, do not exceed 1,6 kV common mode for normal EMC severity class, and 0,8 kV common mode for reduced EMC severity class.

NOTE 4 The maximum induced voltage values may be exceeded at interfaces to instrument transformers. Refer to instrument transformer standards for adequate performances of these devices.

2.1.2 Outdoor switchgear and controlgear

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

The minimum ambient air temperature is –10 °C for class "minus 10 outdoor", –25 °C for class "minus 25 outdoor" and –40 °C for class "minus 40 outdoor".

Rapid temperature changes should be taken into account.

b) Solar radiation up to a level of 1 000 W/m^2 (on a clear day at noon) should be considered.

NOTE 1 Under certain conditions of solar radiation appropriate measures, e.g. roofing, forced ventilation, etc. may be necessary, or derating may be used, in order not to exceed the specified temperature rises.

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

c) The altitude does not exceed 1 000 m.

d) The ambient air may be polluted by dust, smoke, corrosive gas, vapours or salt. The pollution does not exceed the pollution level II – Medium according to table 1 of IEC 60815.

e) The ice coating does not exceed 1 mm for class 1, 10 mm for class 10 and 20 mm for class 20.

f) The wind speed does not exceed 34 m/s (corresponding to 700 Pa on cylindrical surfaces).

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

g) Account should be taken of the presence of condensation or precipitations.

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

h) Vibration due to causes external to the switchgear and controlgear or to earth tremors are negligible.

i) Induced electromagnetic disturbances at interfaces of the secondary system, as a result of switching in the high-voltage system, do not exceed 1,6 kV common mode for normal EMC severity class, and 0,8 kV common mode for reduced EMC severity class.

NOTE 5 The maximum induced voltage values may be exceeded at interfaces to instrument transformers. Refer to instrument transformer standards for adequate performances of these devices.

2.2 Special service conditions

When high-voltage switchgear and controlgear may be used under conditions different from the normal service conditions given in 2.1, the user's requirements should refer to standardized steps as follows.

2.2.1 Altitude

For installation at an altitude higher than 1 000 m, the insulation level of external insulation under the standardized reference atmospheric conditions shall be determined by multiplying the insulation withstand voltages required at the service location by a factor K_a in accordance with figure 1.

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

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

2.2.2 Pollution

For installation in polluted ambient air, a pollution level III – Heavy, or IV – Very heavy of IEC 60815 should be specified.

2.2.3 Temperature and humidity

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

–50 °C and +40 °C for very cold climates;

–5 °C and +50 °C for very hot climates.

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

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

2.2.4 Vibrations

For installations where earthquakes are likely to occur, severity level in accordance with IEC 61166 should be specified by the user.

2.2.5 Other parameters

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

3 Definitions

For the purpose of this International Standard, the definitions in IEC 60050(151); IEC 60050(191); IEC 60050(441); IEC 60050(604) and IEC 60050(826) apply.

Some of them are recalled hereunder for easier use.

The definitions given below are also applicable. They are classified in accordance with IEC 60050(441). The definitions of IEC 60050(441) are not repeated but reference is made to their specific sub-clause number. References from other than IEC 60050(441) are classified so as to be aligned with the classification used in International Electrotechnical Vocabulary IEC 60050(441).

3.1 General terms

3.1.1
switchgear and controlgear
[IEV 441-11-01]

3.1.2
external insulation
the distances in atmosphere and the surfaces in contact with open air of solid insulation of the equipment which are subject to dielectric stresses and to the effects of atmospheric and other external conditions such as pollution, humidity, vermin etc.
[IEV 604-03-02]

3.1.3
IP code
a coding system to indicate the degrees of protection provided by an enclosure against access to hazardous parts, ingress of solid foreign objects, ingress of water and to give additional information in connection with such protection [3.4 of IEC 60529]

3.1.4
protection provided by an enclosure against access to hazardous parts
the protection of persons against:

– contact with hazardous mechanical parts;

– contact with hazardous low-voltage live parts;

– approach to hazardous high-voltage live parts below adequate clearance inside an enclosure [3.6 of IEC 60529]

3.1.5
maintenance
the combination of all technical and administrative actions, including supervision actions, intended to retain an item in, or restore it to, a state in which it can perform a required function [IEV 191-07-01]

3.1.6
scheduled maintenance
the preventive maintenance carried out in accordance with an established time schedule
[IEV 191-07-10]

3.1.7
inspection
periodic visual investigation of the principal features of the switchgear and controlgear in service without dismantling. This investigation is generally directed toward pressures and/or levels of fluids, tightness, position of relays, pollution of insulating parts, but actions such as lubricating, cleaning, washing, etc. which can be carried out with the switchgear and controlgear in service are also included

NOTE Observations resulting from inspection can lead to the decision to carry out overhaul.

3.1.8
diagnostic tests
comparative tests of the characteristic parameters of switchgear and controlgear to verify that it performs its functions, by measuring one or more of these parameters

NOTE The result from diagnostic tests can lead to the decision to carry out overhaul.

3.1.9
examination
inspection with the addition of partial dismantling, as required, supplemented by means such as measurements and non-destructive tests in order to reliably evaluate the condition of the switchgear and controlgear

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

3.1.11
down time
the time interval during which an item is in a down state
[IEV 191-09-08]

3.1.12
failure
the termination of the ability of an item to perform a required function
[IEV 191-04-01]

NOTE 1 After failure the item has a fault.

NOTE 2 "Failure" is an event, as distinguished from "fault", which is a state.

NOTE 3 This concept as defined does not apply to items consisting of software only.

3.1.13
major failure (of switchgear and controlgear)

failure of a switchgear and controlgear which causes the cessation of one or more of its fundamental functions

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

3.1.14
minor failure (of switchgear and controlgear)
any failure of a constructional element or a sub-assembly which does not cause a major failure of the switchgear and controlgear

3.1.15
defect
an imperfection in the state of an item (or inherent weakness) which can result in one or more failures of the item itself, or of another item under the specific service or environmental or maintenance conditions, for a stated period of time

3.1.16
ambient air temperature
[IEV 441-11-13]

3.1.17
servicing level
ground level or fixed permanent floor level from which an authorized person can operate a device

3.1.18
non-exposed type
type of component of which no live part can readily be touched

3.1.19
monitoring
observation of the operation of a system or part of a system to verify correct functioning by detecting incorrect functioning; this being done by measuring one or more variables of the system and comparing the measured values with the specified values
[IEV 351-18-24, modified]

NOTE Several definitions are given for this term in the IEV. They are related to different cases of application. The reference given above is to be applied in the present case.

3.1.20
supervision
activity, performed either manually or automatically, intended to observe the state of an item
[IEV 191-07-26]

NOTE Several definitions are given for this term in the IEV. They are related to different cases of application. The reference given above is to be applied in the present case.

3.2 Assemblies of switchgear and controlgear

3.2.1
self-protected switchgear
switchgear and controlgear incorporating integral voltage-limiting devices

3.2.2
test specimen
a test specimen is a complete switchgear and controlgear when the poles are mechanically linked (i.e. one operating mechanism) or when the type tests are mainly three-pole type tests. If this is not the case, a test specimen is one pole of the complete switchgear and controlgear. Where permitted in the relevant IEC standard, a test specimen may be a representative sub-assembly

3.3 Parts of assemblies

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

3.4 Switching devices

No particular definitions.

3.5 Parts of switchgear and controlgear

3.5.1
enclosure
a part providing protection of equipment against certain external influences and, in any direction, protection against direct contact
[IEV 826-03-12]

NOTES This definition taken from IEC 60050(826) needs the following explanations under the scope of this standard:

1 Enclosures provide protection of persons or livestock against access to hazardous parts.

2 Barriers, shapes of openings or any other means – whether attached to the enclosure or formed by the enclosed equipment suitable to prevent or limit the penetration of the specified test probes are considered as a part of the enclosure, except when they can be removed without the use of a key or tool. [3.1 of IEC 60529]

3.5.2
hazardous part
a part that is hazardous to approach or touch [3.5 of IEC 60529]

3.5.3
contact
[IEV 441-15-05]

3.5.4
auxiliary circuit
[IEV 441-15-04]

3.5.5
control circuit
[IEV 441-15-03]

3.5.6
auxiliary switch
[IEV 441-15-11]

3.5.7
control switch
[IEV 441-14-46]

3.5.8
auxiliary contact
[IEV 441-15-10]

3.5.9
control contact
[IEV 441-15-09]

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

3.5.11
position indicating device
[IEV 441-15-25]

3.5.12
monitoring device
device intended to observe automatically the state of an item
[from IEV 191-07-26]

3.5.13
pilot switch
[IEV 441-14-48]

3.5.14
low energy contact
contact designed to be used in very low energy circuits, e.g. for monitoring or information technology

NOTE Typical applications are contacts inserted into a load circuit through which flows a current of some milliamperes at a voltage not exceeding 10 V at the terminals.

3.5.15
cable entry
part with openings, which permit the passage of cables into the enclosure

3.5.16
cover plate
part of an enclosure which is used for closing an opening and designed to be held in place by screws or similar means. It is not normally removed after the equipment is put in service

3.5.17
partition
part of an assembly separating one compartment from other compartments
[IEV 441-13-06]

3.5.18
actuator
part of the actuating system to which an external actuating force is applied

NOTE The actuator may take the form of a handle, knob, push-button, roller, plunger, etc.
[IEV 441-15-22]

3.5.19
indicating device (of a measuring instrument)
ensemble of components of a measuring instrument intended to indicate the value of the measured quantity

NOTE By extension, the indicating means or setting device of any instrument such as a material measure or a signal generator.
[IEV 301-07-01]

3.5.20
splice
connecting device with barrel(s) accommodating electrical conductor(s) with or without additional provision to accommodate and secure the insulation
[IEV 581-05-11]

3.5.21
terminal
point of an electric circuit, intended for making a connection
[IEV 131-01-02]

3.5.22
terminal block
assembly of terminals in a housing or body of insulating material to facilitate interconnection between multiple conductors
[IEV 581-06-36]

3.5.23
neutral conductor (symbol N)
conductor connected to the neutral point of a system and capable of contributing to the transmission of electrical energy
[IEV 826-01-03]

3.5.24
protective conductor (symbol PE)
conductor required by some measures for protection against electric shock for electrically connecting any of the following parts:

– exposed conductive parts;

– extraneous conductive parts;

– main earthing terminal;

– earth electrode;

– earthed point of the source or artificial neutral
[IEV 826-04-05]

3.5.25
PEN conductor
earthed conductor combining the functions of both protective conductor and neutral conductor

NOTE The acronym PEN results of the combination of both symbols PE for the protective conductor and N for the neutral conductor.
[IEV 826-04-06]

3.5.26
all-or-nothing relay
electrical relay which is intended to be energized by a quantity whose value is either within its operative range or effectively zero
[IEV 446-11-02]

3.5.27
thermal electrical relay
dependant-time measuring relay which is intended to protect an equipment from electrical thermal damage by measurement of the current flowing in the protected equipment and by a characteristic curve simulating its thermal behaviour
[IEV 446-15-16]

3.5.28
(mechanical) contactor
mechanical switching device having only one position of rest, operated otherwise than by hand, capable of making, carrying and breaking currents under normal circuit conditions including operating overload conditions

NOTE Contactors may be designated according to the method by which the force for closing the main contacts is provided.
[IEV 441-14-33]

3.5.29
starter
combination of all the switching means necessary to start and stop a motor in combination with suitable overload protection

NOTE Starters may be designated according to the method by which the force for closing the main contacts is provided.
[IEV 441-14-38]

3.5.30
shunt release
release energized by a source of voltage

NOTE The source of voltage may be independent of the voltage of the main circuit.
[IEV 441-16-41]

3.5.31
switch
component fitted with an actuator and contacts to make and break a connection
[IEV 581-10-01]

3.5.32
distribution circuit (of buildings)
circuit supplying a distribution board
[IEV 826-05-02]

3.5.33
final circuit (of buildings)
circuit connected directly to current using equipment or to socket-outlets
[IEV 826-05-03]

3.5.34
toggle switch
switch having a lever (toggle), the movement of which results either directly or indirectly in the connection or disconnection of the switch terminations in a specified manner. Any indirect action through an actuating mechanism shall be such that the speed of connection and/or disconnection is independent of the speed of lever movement
[IEV 581-10-11]

3.5.35
disconnector
mechanical switching device which provides, in the open position, an isolating distance in accordance with specified requirements

NOTE A disconnector is capable of opening and closing a circuit when either negligible current is broken or made, or when no significant change in the voltage across the terminals of each of the poles of the disconnector occurs. It is also capable of carrying currents under normal circuit conditions and carrying currents for a specified time under abnormal conditions such as those of short-circuit.
[IEV 441-14-05]

3.5.36
counter
device indicating the number of operating cycles a mechanical switching device has accomplished

3.5.37
indicator light
lamp used as an indicator
[IEV 811-31-06]

3.5.38
plug and socket-outlet
means enabling the connection at will of a flexible cable to fixed wiring

NOTE The application of the means is shown in figure 1 of IEC 60309-1.

3.5.39
cable coupler
means enabling the connection at will of two flexible cables

NOTE The application of the means is shown in figure 1 of IEC 60309-1.

3.5.40
appliance coupler
means enabling the connection at will of a flexible cable to the equipment

NOTE The application of the means is shown in figure 1 of IEC 60309-1.

3.5.41
connector
component which terminates conductors for the purpose of providing connection and disconnection to a suitable mating component
[IEV 581-06-01]

3.5.42
coil
set of series-connected turns, usually coaxial
[IEV 151-01-21]

3.5.43
static switching component
device in which the switching action is developed by electronic, magnetic, optical or other components without mechanical motion

3.5.44
secondary system
entity of

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

3.5.45
subassembly (of a secondary system)
part of a secondary system, with regard to function or position. A subassembly is normally placed in a separate enclosure, and shall have its own interface

3.5.46
interchangeable subassembly (of a secondary system)
subassembly which is intended to be placed in various positions within a secondary system, or intended to be replaced by other similar subassemblies. An interchangeable subassembly has an accessible interface

3.6 Operation

3.6.1
dependent power operation
[IEV 441-16-14]

3.6.2
stored energy operation
[IEV 441-16-15]

3.6.3
positively driven operation
operation which, in accordance with specified requirements, is designed to ensure that auxiliary contacts of a mechanical switching device are in the respective positions corresponding to the open or closed position of the main contacts
[IEV 441-16-12, modified]

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

3.6.4 Definitions relative to pressure (or density)

3.6.4.1
rated filling pressure for insulation p_{re} (or density ρ_{re})
the pressure in Pascals (Pa), for insulation and/or for switching, referred to the standard atmospheric air conditions of +20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, to which the assembly is filled before being put into service, or automatically replenished

3.6.4.2
rated filling pressure for operation p_{rm} (or density ρ_{rm})
the pressure (Pa), referred to the standard atmospheric air conditions of +20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, to which the control device is filled before being put into service or automatically replenished

3.6.4.3
alarm pressure for insulation p_{ae} (or density ρ_{ae})
the pressure (Pa), for insulation and/or for switching, referred to the standard atmospheric air conditions of +20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, at which a monitoring signal may be provided to indicate that replenishment is necessary in a relatively short time

3.6.4.4
alarm pressure for operation p_{am} (or density ρ_{am})
the pressure (Pa), referred to the standard atmospheric air conditions of +20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, at which a monitoring signal may be provided to indicate that replenishment of the control device is necessary in a relatively short time

3.6.4.5
minimum functional pressure for insulation p_{me} (or density ρ_{me})
the pressure (Pa), for insulation and/or for switching, referred to the standard atmospheric air conditions of +20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, at which and above which rated characteristics of switchgear and controlgear are maintained and at which a replenishment becomes necessary

3.6.4.6
minimum functional pressure for operation p_{mm} (or density ρ_{mm})
the pressure (Pa), referred to the standard atmospheric air conditions of +20 °C and 101,3 kPa (or density), which may be expressed in relative or absolute terms, at which and above which rated characteristics of switchgear and controlgear are maintained and at which a replenishment of the control device becomes necessary. This pressure is often designated as interlocking pressure

3.6.5 Definitions relating to gas and vacuum tightness

These definitions apply to all switchgear and controlgear which use vacuum or gas, other than air at atmospheric pressure, as insulating or combined insulating and interrupting or operating medium.

3.6.5.1
gas-filled compartment
a compartment of switchgear and controlgear in which the gas pressure is maintained by one of the following systems:

a) controlled pressure system;

b) closed pressure system;

c) sealed pressure system.

NOTE Several gas-filled compartments may be permanently interconnected to form a common gas-system (gas-tight assembly).

3.6.5.2
controlled pressure system for gas
a volume which is automatically replenished from an external or internal gas source

NOTE 1 Examples of controlled pressure systems are air-blast circuit-breakers or pneumatic operating mechanisms.

NOTE 2 A volume may consist of several permanently connected gas-filled compartments.

3.6.5.3
closed pressure system for gas
a volume which is replenished only periodically by manual connection to an external gas source

NOTE Example of closed pressure systems are SF_6 single pressure circuit-breakers.

3.6.5.4
sealed pressure system
a volume for which no further gas or vacuum processing is required during its expected operating life

NOTE 1 Examples of sealed pressure systems are tubes of vacuum circuit-breakers or some SF_6 circuit-breakers.

NOTE 2 Sealed pressure systems are completely assembled and tested in the factory.

3.6.5.5
absolute leakage rate, *F*
the amount of gas escaped by time unit, expressed in $Pa.m^3/s$

3.6.5.6
permissible leakage rate, F_p
the maximum permissible absolute leakage rate of gas specified by the manufacturer for a part, a component or a sub-assembly, or by using the tightness coordination chart (TC), for an arrangement of parts, components or sub-assemblies connected together in one pressure system

3.6.5.7
relative leakage rate, F_{rel}
the absolute leakage rate related to the total amount of gas in the system at rated filling pressure (or density). It is expressed in percentage per year or per day

3.6.5.8
time between replenishments, *T*
the time elapsed between two replenishments performed either manually or automatically when the pressure (density) reaches the alarm level, to compensate the leakage rate *F*

3.6.5.9
number of replenishments per day, *N*
the number of replenishments to compensate the leakage rate *F*. This value is applicable to controlled pressure systems

3.6.5.10
pressure drop, Δp
the drop of pressure in a given time caused by the leakage rate *F*, without replenishment

3.6.5.11
tightness coordination chart, TC
a survey document supplied by the manufacturer, used when testing parts, components or sub-assemblies, to demonstrate the relationship between the tightness of a complete system and that of the parts, components and/or sub-assemblies

3.6.5.12
cumulative leakage measurement
a measurement which takes into account all the leaks from a given assembly to determine the leakage rate

3.6.5.13
sniffing
the action of slowly moving a leak meter sensing probe around an assembly to locate a gas leak

3.6.6 Definitions relating to liquid tightness

These definitions apply to all switchgear and controlgear which use liquids as insulating, combined insulating and interrupting, or control medium with or without permanent pressure.

3.6.6.1
controlled pressure system for liquid
a volume which is automatically replenished with liquid

3.6.6.2
closed pressure system for liquid
a volume which is manually replenished only periodically with liquid

3.6.6.3
absolute leakage rate, F_{liq}
the amount of liquid escaped by time unit, expressed in cm^3/s

3.6.6.4
permissible leakage rate, $F_{p(liq)}$
the maximum permissible leakage rate specified by the manufacturer for a liquid pressure system

3.6.6.5
number of replenishments per day, N_{liq}
the number of replenishments to compensate the leakage rate F_{liq}. This value is applicable to controlled pressure systems

3.6.6.6
pressure drop, ΔP_{liq}
the drop in pressure in a given time caused by the leakage rate F_{liq} without replenishment

3.7 Characteristic quantities

3.7.1
isolating distance
[IEV 441-17-35]

3.7.2
degree of protection
the extent of protection provided by an enclosure against access to hazardous parts, against ingress of solid foreign objects and/or ingress of water and verified by standardized test methods [3.3 of IEC 60529]

3.7.3
rated value
a quantity value assigned, generally by a manufacturer, for a specified operating condition of a component device or equipment
[IEV 151-04-03]

3.8 Index of definitions

A

C

D

E

F

G – I

L – M

N – O

P

4 Ratings

The common ratings of switchgear and controlgear, including their operating devices and auxiliary equipment, should be selected from the following:

a) rated voltage (U_r)

b) rated insulation level

c) rated frequency (f_r)

d) rated normal current (I_r)

e) rated short-time withstand current (I_k)

f) rated peak withstand current (I_p)

g) rated duration of short circuit (t_k)

h) rated supply voltage of closing and opening devices and of auxiliary circuits (U_a)

i) rated supply frequency of closing and opening devices and of auxiliary circuits

j) rated pressure of compressed gas supply for insulation or operation.

NOTE Other rated characteristics may be necessary and will be specified in the relevant IEC standards.

4.1 Rated voltage (U_r)

The rated voltage indicates the upper limit of the highest voltage of systems for which the switchgear and controlgear is intended. Standard values of rated voltages are given below:

NOTE For editorial reasons, mainly due to the characteristics of the transient recovery voltages, the subdivision in voltage ranges differs from that in IEC 60038.

4.1.1 Range I for rated voltages of 245 kV and below

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

Series II (based on the current practice in North America): 4,76 kV – 8,25 kV – 15 kV – 25,8 kV – 38 kV – 48,3 kV – 72,5 kV.

4.1.2 Range II for rated voltages above 245 kV

300 kV – 362 kV – 420 kV – 550 kV – 800 kV.

4.2 Rated insulation level

The rated insulation level of switchgear and controlgear shall be selected from the values given in tables 1 and 2.

In these tables, the withstand voltage applies at the standardized reference atmosphere (temperature, pressure and humidity) specified in IEC 60071-1. For special service conditions, see 2.2.

The rated withstand voltage values for lightning impulse voltage (U_p), switching impulse voltage (U_s) (when applicable), and power-frequency voltage (U_d) shall be selected without crossing the horizontal marked lines. The rated insulation level is specified by the rated lightning impulse withstand voltage phase to earth.

For most of the rated voltages, several rated insulation levels exist to allow for application of different performance criteria or overvoltage patterns. The choice should be made considering the degree of exposure to fast-front and slow-front overvoltages, the type of neutral earthing of the system and the type of overvoltage limiting devices (see IEC 60071-2).

The "common values" as used in tables 1a and 1b apply to phase-to-earth, between phases and across the open switching device, if not otherwise specified in this standard. The withstand voltage values "across the isolating distance" are valid only for the switching devices where the clearance between open contacts is designed to meet the safety requirements specified for disconnectors.

For further information about insulation levels, see annex D.

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

Rated voltage U_r kV (r.m.s. value)	Rated short-duration power-frequency withstand voltage U_d kV (r.m.s. value)		Rated lightning impulse withstand voltage U_p kV (peak value)	
	Common value	Across the isolating distance	Common value	Across the isolating distance
(1)	(2)	(3)	(4)	(5)
3,6	10	12	20	23
			40	46
7,2	20	23	40	46
			60	70
12	28	32	60	70
			75	85
17,5	38	45	75	85
			95	110
24	50	60	95	110
			125	145
36	70	80	145	165
			170	195
52	95	110	250	290
72,5	140	160	325	375
100	150	175	380	440
	185	210	450	520
123	185	210	450	520
	230	265	550	630
145	230	265	550	630
	275	315	650	750
170	275	315	650	750
	325	375	750	860
245	360	415	850	950
	395	460	950	1 050
	460	530	1 050	1 200

Table 1b – Rated insulation levels for rated voltages of range I, series II (used in North America)*

Rated voltage U_r kV (r.m.s. value)	Rated short-duration power-frequency withstand voltage U_d kV (r.m.s. value)				Rated lightning impulse withstand voltage U_p kV (peak value)	
	Common value		Across the isolating distance		Common value	Across isolating distance
	Dry	Wet**	Dry	Wet**		
(1)	(2)	(2 a)	(3)	(3 a)	(4)	(5)
4,76	19	–	21	–	60	70
8,25	26	24	29	27	75	80
	35	30	39	33	95	105
15	35	30	39	33	95	105
	50	45	55	50	110	125
25,8	50	45	55	50	125	140
	70	60	77	66	150	165
38	70	60	77	66	150	165
	95	80	105	88	200	220
48,3	120	100	132	110	250	275
72,5	160	140	176	154	350	385

* For rated voltages higher than 72,5 kV up to and including 245 kV, the values of table 1a are applicable.

** Wet values are a 10 s withstand for equipment used outdoors. See 9.2 of IEC 60060-1.

Table 2a – Rated insulation levels for rated voltages of range II

Rated voltage U_r kV (r.m.s. value)	**Rated short-duration power-frequency withstand voltage** U_d kV (r.m.s. value)		**Rated switching impulse withstand voltage** U_s kV (peak value)			**Rated lightning impulse withstand voltage** U_p kV (peak value)	
	Phase-to-earth and between phases (note 3)	**Across open switching device and/or isolating distance** (note 3)	**Phase-to-earth and across open switching device**	**Between phases** (notes 3 and 4)	**Across isolating distance** (notes 1, 2 and 3)	**Phase-to-earth and between phases**	**Across open switching device and/or isolating distance** (notes 2 and 3)
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
300	380	435	750	1 125	700 (+ 245)	950	950 (+ 170)
			850	1 275		1 050	1 050 (+ 170)
362	450	520	850	1 275	800 (+ 295)	1 050	1 050 (+ 205)
			950	1 425		1 175	1 175 (+ 205)
420	520	610	950	1 425	900 (+ 345)	1 300	1 300 (+ 240)
			1 050	1 575		1 425	1 425 (+ 240)
550	620	800	1 050	1 680	900 (+ 450)	1 425	1 425 (+ 315)
			1 175	1 760		1 550	1 550 (+ 315)
800	830	1 150	1 300	2 210	1 100 (+ 650)	1 800	1 800 (+ 455)
			1 425	2 420		2 100	2 100 (+ 455)

NOTE 1 Column (6) is also applicable to some circuit-breakers, see IEC 60056.

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

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

NOTE 3 Values of column (2) are applicable:

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

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

Values of columns (3), (5), (6) and (8) are applicable for type tests only.

NOTE 4 These values are derived using the multiplying factors stated in table 3 of IEC 60071-1.

Table 2b – Additional rated insulation levels in North America for range II

Rated voltage U_r kV (r.m.s. value)	**Rated short-duration power-frequency withstand voltage** U_d kV (r.m.s. value)		**Rated switching impulse withstand voltage** U_s kV (peak value)			**Rated lightning impulse withstand voltage** U_p kV (peak value)	
	Phase-to-earth and between phases (note 3)	**Across open switching device and/or isolating distance** (note 3)	**Phase-to-earth and across open switching device**	**Between phases** (notes 3 and 4)	**Across isolating distance** (notes 1, 2 and 3)	**Phase-to-earth and between phases**	**Across open switching device and/or isolating distance** (notes 2 and 3)
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
362	520	610	950	1 425	800 (+ 295)	1300	1 300 (+ 205)
550	710	890	1 175	2 210	900 (+ 450)	1800	1 800 (+ 315)
The notes are the same as those to table 2a.							

4.3 Rated frequency (f_r)

The standard values of the rated frequency are 16 2/3 Hz, 25 Hz, 50 Hz and 60 Hz.

4.4 Rated normal current and temperature rise

4.4.1 Rated normal current (I_r)

The rated normal current of switchgear and controlgear is the r.m.s. value of the current which switchgear and controlgear shall be able to carry continuously under specified conditions of use and behaviour.

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

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

NOTE 2 Rated currents for temporary or for intermittent duty are subject to agreement between manufacturer and user.

4.4.2 Temperature rise

The temperature rise of any part of switchgear and controlgear at an ambient air temperature not exceeding 40 °C shall not exceed the temperature-rise limits specified in table 3 under the conditions specified in the test clauses.

Table 3 – Limits of temperature and temperature rise for various parts, materials and dielectrics of high-voltage switchgear and controlgear

Nature of the part, of the material and of the dielectric (See points 1, 2 and 3) (See note)	Maximum value	
	Temperature °C	Temperature rise at ambient air temperature not exceeding 40 °C K
1 Contacts (see point 4)		
Bare-copper or bare-copper alloy		
– in air	75	35
– in SF_6 (sulphur hexafluoride) (see point 5)	105	65
– in oil	80	40
Silver-coated or nickel-coated (see point 6)		
– in air	105	65
– in SF_6 (see point 5)	105	65
– in oil	90	50
Tin-coated (see point 6)		
– in air	90	50
– in SF_6 (see point 5)	90	50
– in oil	90	50
2 Connection, bolted or the equivalent (see point 4)		
Bare-copper, bare-copper alloy or bare-aluminium alloy		
– in air	90	50
– in SF_6 (see point 5)	115	75
– in oil	100	60
Silver-coated or nickel-coated see point 6)		
– in air	115	75
– in SF_6 (see point 5)	115	75
– in oil	100	60
Tin-coated		
in air	105	65
– in SF_6 (see point 5)	105	65
– in oil	100	60
3 All other contacts or connections made of bare metals or coated with other materials	(see point 7)	(see point 7)
4 Terminals for the connection to external conductors by screws or bolts (see point 8)		
– bare	90	50
– silver, nickel or tin-coated	105	65
– other coatings	(see point 7)	(see point 7)
5 Oil for oil switching devices (see points 9 and 10)	90	50
6 Metal parts acting as springs	(see point 11)	(see point 11)
7 Materials used as insulation and metal parts in contact with insulation of the following classes (see point 12)		
– Y	90	50
– A	105	65
– E	120	80
– B	130	90
– F	155	115
– Enamel: oil base	100	60
synthetic	120	80
– H	180	140
– C other insulating material	(see point 13)	(see point 13)
8 Any part of metal or of insulating material in contact with oil, except contacts	100	60
9 Accessible parts		
– expected to be touched in normal operation	70	30
– which need not to be touched in normal operation	80	40

NOTE The points referred to in this table are those of 4.4.3.

4.4.3 Particular points of table 3

The following points are referred to in table 3 and complete it.

Point 1 According to its function, the same part may belong to several categories as listed in table 3.

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

Point 2 For vacuum switching devices, the values of temperature and temperature-rise limits are not applicable for parts in vacuum. The remaining parts shall not exceed the values of temperature and temperature rise given in table 3.

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

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

a) for contacts, those of the surface material having the lowest value permitted in item 1 of table 3;

b) for connections, those of the surface material having the highest value permitted in item 2 of table 3.

Point 5 SF_6 means pure SF_6 or a mixture of SF_6 and other oxygen-free gases.

NOTE 1 Due to the absence of oxygen, a harmonization of the limits of temperature for different contact and connection parts in the case of SF_6 switchgear appears appropriate. In accordance with IEC 60943, which gives guidance for the specification of permissible temperatures, the permissible temperature limits for bare copper and bare copper alloy parts can be equalized to the values for silver-coated or nickel-coated parts in the case of SF_6 atmospheres.

In the particular case of tin-coated parts, due to fretting corrosion effects (refer to IEC 60943) an increase of the permissible temperatures is not applicable, even under the oxygen-free conditions of SF_6. Therefore the initial values for tin-coated parts are kept.

NOTE 2 Temperature rises for bare copper and silver-coated contacts in SF_6 are under consideration.

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

a) after making and breaking test (if any):

b) after short-time withstand current test:

c) after the mechanical endurance test:

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

Point 7 When materials other than those given in table 3 are used, their properties shall be considered, notably in order to determine the maximum permissible temperature rises.

Point 8 The values of temperature and temperature rise are valid even if the conductor connected to the terminals is bare.

Point 9 At the upper part of the oil.

Point 10 Special consideration should be given when low flash-point oil is used in regard to vaporization and oxidation.

Point 11 The temperature shall not reach a value where the elasticity of the material is impaired.

Point 12 Classes of insulating materials are those given in IEC 60085.

Point 13 Limited only by the requirement not to cause any damage to surrounding parts.

4.5 Rated short-time withstand current (I_k)

The r.m.s. value of the current which the switchgear and controlgear can carry in the closed position during a specified short time under prescribed conditions of use and behaviour.

The standard value of rated short-time withstand current should be selected from the R 10 series specified in IEC 60059, and shall be equal to the short-circuit rating assigned to switchgear and controlgear.

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

4.6 Rated peak withstand current (I_p)

The peak current associated with the first major loop of the rated short-time withstand current which switchgear and controlgear can carry in the closed position under prescribed conditions of use and behaviour.

The rated peak withstand current shall correspond to the rated frequency. For a rated frequency of 50 Hz and below it is equal to 2,5 times the rated short-time withstand current, and for a rated frequency of 60 Hz it is equal to 2,6 times the rated short-time withstand current.

NOTE Values higher than 2,5 or 2,6 times the rated short-time withstand current may be required according to the characteristics of the system.

4.7 Rated duration of short circuit (t_k)

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

The standard value of rated duration of short circuit is 1 s.

If it is necessary, a value lower or higher than 1 s may be chosen. The recommended values are 0,5 s, 2 s and 3 s.

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

4.8.1 General

The supply voltage of closing and opening devices and auxiliary and control circuits shall be understood to mean the voltage measured at the circuit terminals of the apparatus itself during its operation, including, if necessary, the auxiliary resistors or accessories supplied or required by the manufacturer to be installed in series with it, but not including the conductors for the connection to the electricity supply.

The supply system should preferably be referenced to earth (i.e. not completely floating) in order to avoid the accumulation of dangerous static voltages. The location of the earthing point should be defined according to good practice.

It should be noted that normal operation of equipment is to be assured when the supply voltage is within the tolerances described in 4.8.3.

4.8.2 Rated voltage (U_a)

The rated supply voltage should be selected from the standard values given in tables 14 and 15. The values marked with an asterisk are preferred values for electronic auxiliary equipment.

Table 14 – Direct current voltage

U_a V
24
48*
60
110* or 125
220 or 250

Table 15 – Alternating current voltage

Three-phase, three-wire or four-wire systems V	Single-phase, three-wire systems V	Single-phase, two-wire systems V
–	120/240	120
120/208	–	120
(220/380)	–	(220)
230/400*	–	230*
(240/415)	–	(240)
277/480	–	277
347/600	–	347

NOTE 1 The lower values in the first column of this table are voltages to neutral and the higher values are voltages between phases. The lower value in the second column is the voltage to neutral and the higher value is the voltage between lines.

NOTE 2 The value 230/400 V indicated in this table should be, in the future, the only IEC standard voltage and its adoption is recommended in new systems. The voltage variations of existing systems at 220/380 V and 240/415 V should be brought within the range 230/400 V ± 10 %. The reduction of this range will be considered at a later stage of standardization.

4.8.3 Tolerances

The relative tolerance of a.c. and d.c. power supply in normal duty measured at the input of the auxiliary equipment (electronic controls, supervision, monitoring and communication) is 85 % to 110 %.

For supply voltages less than the minimum stated for power supply, precautions shall be taken to prevent any damage to electronic equipment and/or unsafe operation due to its unpredictable behaviour.

For operation of shunt opening releases, the relative tolerance shall comply with the requirements of 5.8.

4.8.4 Ripple voltage

In case of d.c. supply, the ripple voltage, that is the peak-to-peak value of the a.c. component of the supply voltage at the rated load, shall be limited to a value not greater than 5 % of the d.c. component. The voltage is measured at the supply terminals of the auxiliary equipment. IEC 61000-4-17 applies.

4.8.5 Voltage drop and supply interruption

IEC 61000-4-29 should apply to electrical and electronic components.

As far as supply interruptions are concerned, the system is considered to perform correctly if

– there are no false operations;
– there are no false alarms or false remote signalling;
– any pending action is correctly completed, even with a short delay.

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

The standard values of rated supply frequency are DC, 50 Hz and 60 Hz.

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

The standard values of rated pressure are:

0,5 MPa – 1 MPa – 1,6 MPa – 2 MPa – 3 MPa – 4 MPa,

unless otherwise specified by the manufacturer.

5 Design and construction

5.1 Requirements for liquids in switchgear and controlgear

The manufacturer shall specify the type and the required quantity and quality of the liquid to be used in switchgear and controlgear and provide the user with necessary instructions for renewing the liquid and maintaining its required quantity and quality (see 10.4.1 item d)).

5.1.1 Liquid level

A device for checking the liquid level, preferably during service, with indication of minimum and maximum limits admissible for correct operation, shall be provided.

NOTE This is not applicable to dash-pots.

5.1.2 Liquid quality

Liquids for use in switchgear and controlgear shall comply with the instructions of the manufacturer.

For oil-filled switchgear and controlgear, new insulating oil shall comply with IEC 60296.

5.2 Requirements for gases in switchgear and controlgear

The manufacturer shall specify the type and the required quantity, quality and density of the gas to be used in switchgear and controlgear and provide the user with necessary instructions for renewing the gas and maintaining its required quantity and quality (see 10.4.1 a)), except for sealed pressure systems.

For sulphur hexafluoride-filled switchgear and controlgear, new sulphur hexafluoride shall comply with IEC 60376.

In order to prevent condensation, the maximum allowable moisture content within gas-filled switchgear and controlgear filled with gas at rated filling density for insulation ρ_{re} shall be such that the dew-point is not higher than –5 °C for a measurement at 20 °C. Adequate correction shall be made for measurement made at other temperatures. For the measurement and determination of the dew-point, refer to IEC 60376B and IEC 60480.

Parts of high-voltage switchgear and controlgear housing compressed gas shall comply with the requirements laid down in the relevant IEC standards.

NOTE Attention is drawn to the need to comply with local regulation relevant to pressure vessels.

5.3 Earthing of switchgear and controlgear

The frame of each switching device shall be provided with a reliable earthing terminal having a clamping screw or bolt for connection to an earthing conductor suitable for specified fault conditions. The diameter of the clamping screw or bolt shall be at least 12 mm. The connecting point shall be marked with the "protective earth" symbol, as indicated by symbol No. 5019 of IEC 60417. Parts of metallic enclosures connected to the earthing system may be considered as an earthing conductor.

5.4 Auxiliary and control equipment

5.4.1 Enclosures

5.4.1.1 General

The enclosures for low-voltage control and auxiliary circuits shall be constructed of materials capable of withstanding the mechanical, electrical and thermal stresses, as well as the effects of humidity which are likely to be encountered in normal service.

5.4.1.2 Protection against corrosion

Protection against corrosion shall be ensured by the use of suitable materials or by the application of suitable protective coatings to the exposed surfaces, taking into account the intended conditions of use in accordance with the service conditions stated in clause 2.

5.4.1.3 Degrees of protection

The degree of protection provided by an enclosure for low-voltage auxiliary and control circuits shall be in accordance with 5.13.

Openings in cable entries, cover plates, etc. shall be so designed that, when the cables are properly installed, the stated degree of protection of an enclosure for low-voltage auxiliary and control circuits, as defined in 5.13, shall be obtained. This implies that a means of entry, suitable for the application stated by the manufacturer, should be selected.

Any ventilation openings shall be shielded or arranged so that the same degree of protection as that specified for the enclosure is obtained.

5.4.2 Protection against electric shock

5.4.2.1 Protection by segregation of auxiliary and control circuits from the main circuit

Auxiliary and control equipment which is installed on the frame of switching devices shall be suitably protected against disruptive discharge from the main circuit.

The wiring of auxiliary and control circuits, with the exception of short lengths of wire at terminals of instrument transformers, tripping coils, auxiliary contacts, etc. shall be either segregated from the main circuit by earthed metallic partitions (for example, tubes) or separated by partitions (for example, tubes) made of insulating material.

5.4.2.2 Accessibility of auxiliary and control equipment

Auxiliary and control equipment requiring attention during service shall be accessible without danger of direct contact with high-voltage parts.

Where the reduction of safety distances above the servicing level due to abnormal environmental conditions (for example accumulation of snow, sand, etc.) needs to be considered, the minimum height of live parts above it shall be increased.

5.4.3 Fire hazard

5.4.3.1 General

As the risk of fire is present in auxiliary and control circuits, the likelihood of fire shall be reduced under conditions of normal use, and even in the event of foreseeable abnormal use, malfunction or failure.

The first objective is to prevent ignition due to an electrically energized part. The second objective is to limit the fire impact, if fire or ignition occurs inside the enclosure.

5.4.3.2 Components and circuit design

In normal operation, heat dissipation of components is generally small. However, a component may, when faulty or in an overload condition resulting from an external fault, generate excess heat such that fire may be initiated.

The manufacturer should take every care so that, by appropriate circuit design and protections, internal faults or overload conditions will not give rise to fire hazard. The manufacturer should design or choose components which have a power rating higher than necessary under normal conditions and self-ignition characteristics determined with respect to the maximum fault power of the circuit. Special attention should be given to resistors.

Consideration should be given to the assembly of components and the relative arrangement of those that may dissipate excessive heat by providing around them sufficient space.

5.4.3.3 Managing fire impact

Provisions should be taken in order to manage fire impact. Enclosures should be constructed, insulated, made watertight, etc. with materials sufficiently resistant to probable ignition and heat sources situated within. The manufacturer should consider that, if it ignites, a component may emit melted flaming material and/or glowing particles.

5.4.4 Components installed in enclosures

5.4.4.1 Selection of components

Components installed in enclosures shall comply with the requirements of the relevant IEC standards. Where an IEC standard does not exist, or the component is qualified with reference to another standard (issued by a country or another organization), the criteria for selection should be agreed between the manufacturer and the user.

All components used in the auxiliary and control circuits shall be designed or selected to be operational with their rated characteristics over the whole actual service conditions inside auxiliary and control circuits enclosures that can differ from the external service conditions specified in clause 2.

Suitable precautions (insulation, heating, ventilation, etc.) shall be taken to ensure that those service conditions essential for proper functioning are maintained, for example, heaters to maintain the required minimum temperature for the correct operation of relays, contactors, low-voltage switches, meters, counters, push-buttons, etc. according to the relevant specifications.

The loss of those precaution means shall not cause failures of the components nor untimely operation of switchgear and controlgear. The operation of switchgear and controlgear shall be possible during 2 h after the loss of those means. After this period, a non-operation of the switchgear and controlgear with its associated auxiliary and control circuit is acceptable provided that the functionality resets to its original characteristics when environmental conditions inside the enclosure for auxiliary and control circuits are back to the specified service conditions.

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

In the case of switchgear and controlgear designed for outdoor installation, suitable arrangements (ventilation and/or internal heating, etc.) shall be made to prevent harmful condensation in low-voltage control and auxiliary circuits enclosures.

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

5.4.4.2 Installation of components

Components shall be installed in accordance with the instructions of their manufacturer.

5.4.4.3 Accessibility

Closing and opening actuators and emergency shut-down system actuators should be located between 0,4 m and 2 m above servicing level. Other actuators should be located at such a height that they can be easily operated, and indicating devices should be located at such a height that they can be easily readable.

Structure-mounted or floor-mounted enclosures for low-voltage auxiliary and control circuits should be installed at such a height, with respect to the servicing level, that the above requirements for accessibility, operating and reading heights are met.

Components in enclosures should be so arranged as to be accessible for mounting, wiring, maintenance and replacement. Where a component may need adjustment during its service life, easy access should be considered without danger of electrical shock.

5.4.4.4 Identification

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

Where mixing of components or voltages could cause confusion, consideration should be given to more explicit marking.

5.4.4.5 Requirements for auxiliary and control circuit components

5.4.4.5.1 Cables and wiring

The nominal cross-sectional area and characteristics of conductors and electric cables shall comply with the requirements of IEC 60228.

The insulation on cables shall comply with applicable IEC standards (for example, polyvinyl chloride insulated cables shall comply with the requirements of IEC 60227 or IEC 60502-1, rubber insulated cables shall comply with the requirements of IEC 60245, etc.).

The choice of cables to connect together control and auxiliary circuit enclosures is the responsibility of the manufacturer. The choice is governed by the current that must be carried, by the voltage drop and the current transformer burden, by the mechanical stresses to which the cable is subjected and by the type of insulation. The choice of conductors in enclosures is also the responsibility of the manufacturer.

Suitable means shall be provided for the connection of external wiring, for example terminal blocks, plug-in terminations, etc.

Cables between two terminal blocks shall have no intermediate splices or soldered joints. Connections shall be made at fixed terminals.

Insulated conductors shall be adequately supported and shall not rest against sharp edges.

Wiring should take into account the proximity of heating elements.

The available wiring space shall permit spreading of the cores of multi-core cables and the proper termination of the conductors. The conductors shall not be subjected to stresses that reduce their normal life.

Conductors connected to apparatus and indicating devices in covers or doors shall be so installed that no mechanical damage can occur to the conductors as a result of movement of these covers or doors.

Only one conductor should be connected to a terminal; the connection of two or more conductors to one terminal is permissible only in those cases where the terminal is designed for this purpose.

The method and extent of identification of conductors, for example by numbers, colours or symbols, is the responsibility of the manufacturer. Identification of conductors shall be in agreement with the wiring diagrams and drawings, and the specification of the user, if applicable. This identification may be limited to the ends of the conductors. Where appropriate, identification of wiring according to IEC 60445 may be applied.

5.4.4.5.2 Terminals

Terminal blocks intended to connect round copper conductors shall comply with the requirements of IEC 60947-7-1.

Protective conductor terminal blocks intended to connect round copper conductors shall comply with the requirements of IEC 60947-7-2.

Terminals shall maintain the necessary contact pressure, corresponding to the current rating and the short-circuit current of circuits.

Terminal blocks for wiring components inside the enclosure shall be chosen according to the cross-section of the conductors used.

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

Identification of terminals shall comply with the requirements of IEC 60445 and shall be in agreement with the indications on the wiring diagrams and drawings, and the specification of the user, if applicable.

5.4.4.5.3 Auxiliary switches

Auxiliary switches shall be suitable for the number of electrical and mechanical operating cycles specified for the switching device.

Auxiliary switches, which are operated in conjunction with the main contacts, shall be positively driven in both directions. However, in some cases where the speed of the operating mechanism is not very fast and by agreement between the manufacturer and the user, a set of two one-way positively driven auxiliary contacts (one for each direction) can be used, provided that dependability constraints are satisfied.

5.4.4.5.4 Auxiliary and control contacts

Auxiliary and control contacts shall be suitable for their intended duty in terms of environmental conditions (see 5.4.3.1), making and breaking capacity and timing of the operation of the auxiliary and control contacts in relation to the operation of the main equipment.

Auxiliary and control contacts shall be suitable for the number of electrical and mechanical operating cycles specified for the switching device.

Where an auxiliary contact is made available to the user, the technical documents provided by the manufacturer should contain information regarding the class of this contact.

The operational characteristics of the auxiliary contacts should comply with one of the classes shown in table 16.

Table 16 – Auxiliary contacts classes

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

NOTE 1 This table refers to auxiliary contacts [IEV 441-15-10] which are included in an auxiliary circuit and mechanically operated by the switching device. Control contacts [IEV 441-15-09] which are included in a control circuit of a mechanical switching device may be concerned by this table.

NOTE 2 If no sufficient current is flowing through the contact, oxidation may increase the resistance. Therefore, a minimum value of current may be required for class 1 contact.

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

NOTE 4 For all classes, breaking capacity is based on a circuit time constant of not less than 20 ms with a relative tolerance of $^{+20}_{0}$ %.

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

NOTE 6 Class 3 contacts are not intended to be subjected to full substation auxiliary supply short-circuit current. Class 1 and 2 contacts are intended to be subjected to full substation auxiliary supply short-circuit current.

NOTE 7 Breaking current at a defined voltage value between 110 V and 250 V may be deduced from the indicated power value for class 1 and class 2 contacts (for example 2 A at 220 V d.c. for a class 1 contact).

The number of free auxiliary contacts and the class of each one shall be specified to the manufacturer in accordance with clause 9 of the relevant equipment standard. For particular applications, different values may be specified to the manufacturer in accordance with clause 9 of the relevant equipment standard.

Examples of the three contact classes are shown in figure 4.

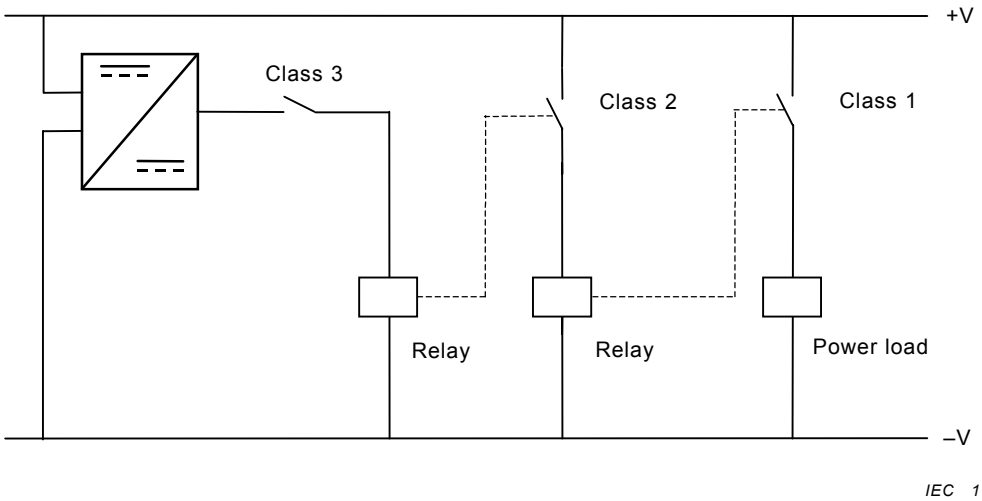


Figure 4 – Examples of classes of contacts

5.4.4.5.5 Contacts other than auxiliary and control contacts

A contact other than an auxiliary or control contact is a contact driven by a component (relay, contactor, low-voltage switch, etc.) used in the auxiliary and control circuits.

Where a contact other than an auxiliary or control contact is made available to the user, the technical documents provided by the manufacturer should include the rated continuous current and making and breaking capacity of this contact.

The user is responsible for ensuring that the contact performance is adequate for the task.

The number of contacts provided shall be specified to the manufacturer in accordance with clause 9 of the relevant equipment standard.

5.4.4.5.6 Relays

All-or-nothing relays shall comply with the requirements of the applicable parts of IEC 61810.

IEC 61810-1 sets the recommended rated voltages for relays and the recommended limits of the operating range for these voltages. For all relays chosen for the rated supply voltage of the auxiliary and control circuits, the limits of the operating range in IEC 61810-1 allow the relays to meet the limits required in 4.8.

Where a relay is chosen and used at a voltage different from the rated voltage of auxiliary and control circuits, suitable means shall be provided to allow it to operate correctly within the limits of the operating range required in 4.8 (for example, provision of a series resistor).

Thermal electrical relays for motor protection shall comply with the requirements of IEC 60255-8.

Performance of relay contacts shall comply with the requirements of IEC 60255-23.

Requirements for relay contacts available to the user, if any, are contained in 5.4.4.5.5.

5.4.4.5.7 Contactors and motor-starters

AC and d.c. electromechanical contactors intended for closing and opening electric circuits shall comply with the requirements of IEC 60947-4-1. Where an electromechanical contactor is combined with suitable relays, to provide short-circuit protection, it shall also satisfy the relevant conditions for LV circuit-breakers, as specified in IEC 60947-2.

AC motor-starters intended to start and accelerate motors to normal speed, to ensure continuous operation of motors, to switch off the supply from the motor and to provide means for the protection of motors and associated circuits against operating overloads shall comply with the requirements of IEC 60947-4-1. Overload relays for starters shall also meet the requirements of IEC 60947-4-1.

AC semiconductor motor controllers and starters shall comply with the requirements of IEC 60947-4-2.

Requirements for contactor and motor-starter contacts available to the user, if any, are contained in 5.4.4.5.5.

5.4.4.5.8 Shunt releases

Shunt releases are designed for specific purposes. As no IEC standard exists for shunt releases, they should satisfy the requirements of the relevant equipment standard.

The electrical power of the shunt releases shall be stated by the manufacturer.

5.4.4.5.9 Low-voltage switches

Switches to be used in motor circuits shall comply with the requirements of IEC 60947-3.

Switches to be used in distribution circuits or in final circuits shall comply with the requirements of IEC 60947-3.

Where household switches are applied in final circuits, they shall comply with the requirements of IEC 60669-1.

Manual control switches, for example push-buttons, rotary switches, etc. shall comply with the requirements of IEC 60947-5-1. Suggested colours for these switches are given in IEC 60073. Suggested graphical symbols for use on equipment are given in IEC 60417. Where a user has no specific local requirements, it is recommended that the colouring and labelling of manual control switches be in accordance with these two publications.

Requirements for any contacts of manual control switches that are made available to the user are contained in 5.4.4.5.5.

Pilot switches, for example pressure switches, temperature switches, etc. shall comply with the requirements of IEC 60947-5-1. Where household thermostats are applied, they shall comply with the requirements of IEC 60730-2-9 that sets the particular requirements for automatic electrical temperature sensing controls for household and similar use. Where household humidity sensing controls are applied, they shall comply with the requirements of IEC 60730-2-13, which sets the particular requirements for automatic electrical humidity sensing controls for household and similar use. Requirements for any pilot switch contacts that are made available to the user are contained in 5.4.4.5.5.

Lever (toggle) switches shall comply with the requirements of IEC 61020-4. Requirements for any lever switch contacts that are made available to the user are contained in 5.4.4.5.5.

5.4.4.5.10 Low-voltage circuit-breakers

Low-voltage circuit-breakers shall comply with the requirements of IEC 60947-2.

Low-voltage circuit-breakers incorporating residual current protection shall also comply with IEC 60947-2.

5.4.4.5.11 Low-voltage fuses

Low-voltage fuses shall comply with the requirements of IEC 60269-1.

Supplementary requirements concerning fuses mainly for industrial application are covered by IEC 60269-2. IEC 60269-2-1 gives three examples of fuse systems as standardized systems with respect to their safety aspects.

5.4.4.5.12 Low-voltage disconnectors

Low-voltage disconnectors shall comply with IEC 60947-3.

5.4.4.5.13 Motors

Rotating electrical machines shall comply with the requirements of the applicable subclauses of IEC 60034-1.

5.4.4.5.14 Heating elements

All heating elements shall be of the non-exposed type. Heaters shall be situated so that they do not cause any deterioration in the wiring or in the operation of the components.

Where contact with a heater or shield can occur accidentally, the surface temperature shall not exceed the temperature-rise limits for accessible parts which need not be touched in normal operation, as specified in table 3.

5.4.4.5.15 Meters

Direct-acting indicating analogue electrical measuring instruments and their accessories shall comply with the requirements of the applicable parts of IEC 60051. Ammeters and voltmeters shall comply with the requirements of IEC 60051-2. Frequency meters shall comply with the requirements of IEC 60051-4. Phase meters, power factor meters and synchroscopes shall comply with the requirements of IEC 60051-5.

Digital electronic d.c. voltmeters and d.c. electronic analogue-to-digital converters shall comply with the requirements of IEC 60485.

5.4.4.5.16 Counters

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

5.4.4.5.17 Indicator lights

Indicator lights are associated with the control circuit equipment. Therefore, they shall meet the requirements of IEC 60947-5-1.

Suggested colours for indicator lights are given in IEC 60073. Suggested graphical symbols for use on equipment are given in IEC 60417. Where a user has no specific local requirements, it is recommended that the colouring and labelling of any indicator lights be in accordance with these two publications.

5.4.4.5.18 Plugs, socket-outlets and couplers

Plugs and socket-outlets primarily intended for industrial use, either indoors or outdoors, shall comply with the requirements of IEC 60309-1 and IEC 60309-2.

Where a household socket-outlet is installed, it shall comply with the requirements of IEC 60083 that sets the particular requirements for plugs and socket-outlets for domestic and similar use.

Cable couplers primarily intended for industrial use, either indoors or outdoors, shall comply with the requirements of IEC 60309-1 and IEC 60309-2.

Appliance couplers primarily intended for industrial use, either indoors or outdoors, shall comply with the requirements of IEC 60309-1 and IEC 60309-2.

Other connectors shall comply with the requirements of the applicable parts of IEC 60130.

5.4.4.5.19 Printed boards

Printed boards used to connect conventional components (for example, relays) are considered to be conventional equipment. Printed boards shall comply with the requirements of the applicable parts of IEC 60326.

5.4.4.5.20 Resistors

Fixed power resistors, rated over 1 W and under 1 000 W, shall comply with the requirements of IEC 60115-4.

Potentiometers shall comply with the requirements of IEC 60393-1.

5.4.4.5.21 Illumination

In some enclosures, for example enclosures containing manual operating means (handles, push-buttons, etc.), lighting should be considered. Where lighting is installed, consideration should be given to the heat and electromagnetic noise produced by the lighting on the auxiliary and control-circuit components.

Tungsten filament lamps shall comply with the requirements of IEC 60064.

Fluorescent illumination shall comply with requirements of IEC 60081.

5.4.4.5.22 Coils

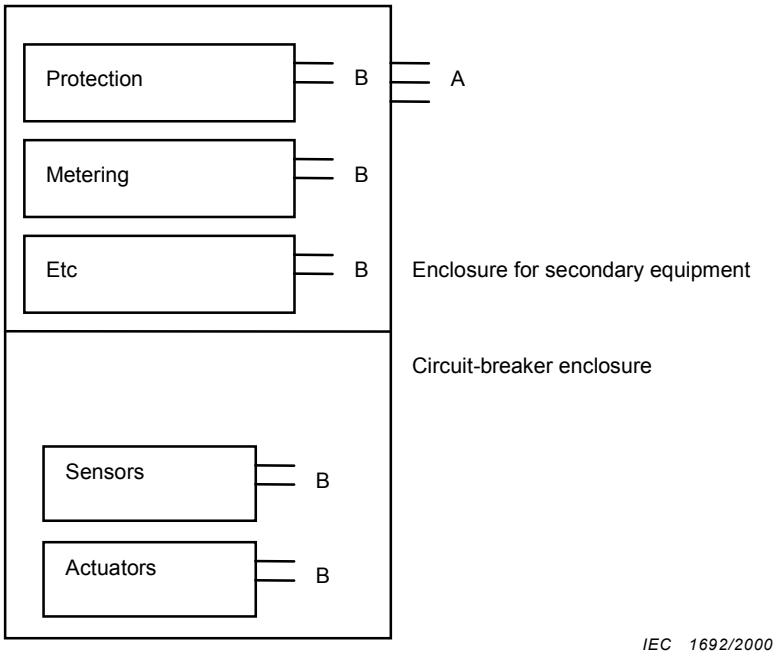
Coils not covered by a component standard shall be suitable for their intended duty (for example, with respect to temperature rise, dielectric withstand, etc.).

5.4.5 Secondary systems

In many cases, the secondary system may be divided into a number of subassemblies, such as the central control cubicle of a circuit-breaker, or the complete control cubicle of a circuit-breaker in a gas-insulated substation (GIS) bay. Examples are shown in figures 5, 6, 7 and 8.

Interchangeable subassemblies may be placed in different position within the secondary system or replaced by other similar subassemblies.

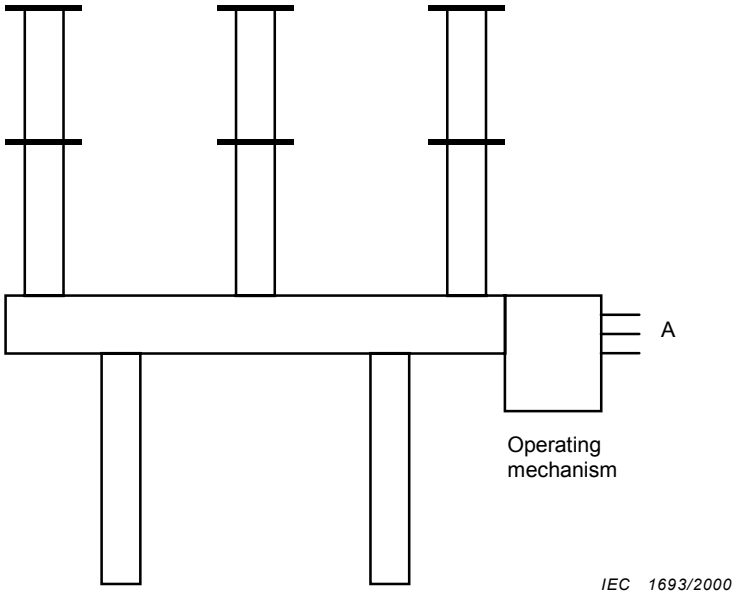
NOTE In practice, there is a wide variation in the complexity of equipment within the secondary system. In some cases the system may consist of only some auxiliary all-or-nothing relays, signal cabling and terminal blocks. In other cases, complete equipment for protection, control and measurement is included.



A External interface, for total secondary system

B Internal interface, for subassembly

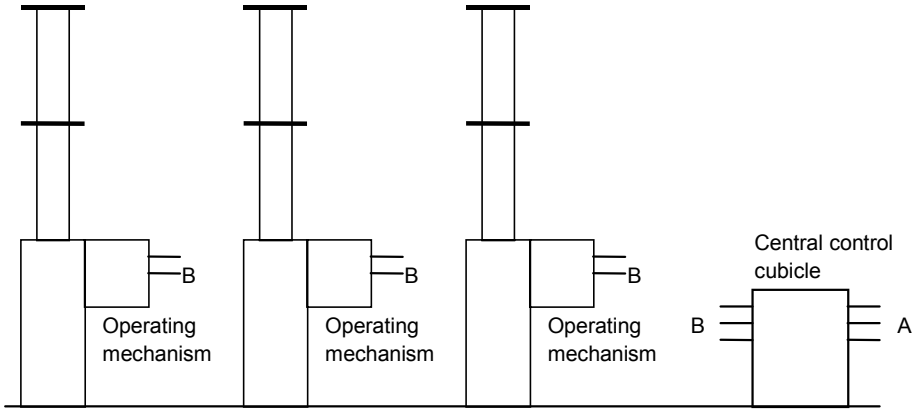
Figure 5 – Example of secondary system in medium voltage cubicle



A External interface, for total secondary system

NOTE Subassemblies may be defined within the cubicle in line with figure 5.

Figure 6 – Example of secondary system of air insulated circuit-breaker with single mechanism

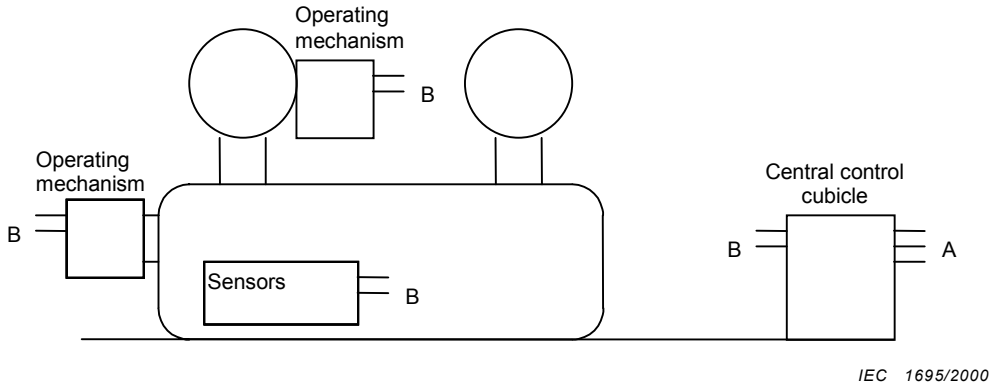


A External interface, for total secondary system

B Internal interface, for subassembly

NOTE Subassemblies may be defined within each cubicle in line with figure 5.

Figure 7 – Example of secondary system of air insulated circuit-breaker with separate control cubicle



A External interface, for total secondary system

B Internal interface, for subassembly

NOTE Subassemblies may be defined within each cubicle in line with figure 5.

Figure 8 – Example of secondary system for GIS bay

5.5 Dependent power operation

A switching device arranged for dependent power operation with external energy supply shall be capable of making and/or breaking its rated short-circuit current (if any) when the voltage or the pressure of the power supply of the operating device is at the lower of the limits specified under 4.8 and 4.10 (the term "operating device" here embraces intermediate control relays and contactors where provided). If maximum closing and opening times are stated by the manufacturer, these shall not be exceeded.

Except for slow operation during maintenance, the main contacts shall only move under the action of the drive mechanism and in the designed manner. The closed or open position of the main contacts shall not change as a result of loss of the energy supply or the re-application of the energy supply after a loss of energy, to the closing and/or opening device.

5.6 Stored energy operation

A switching device arranged for stored energy operation shall be capable of making and breaking its rated short-circuit current (if any), when the energy store is suitably charged in accordance with 5.6.1 or 5.6.2. If maximum closing and opening times are stated by the manufacturer, these shall not be exceeded.

Except for slow operation during maintenance, the main contacts shall only move under the action of the drive mechanism and in the designed manner, and not in the case of re-application of the energy supply after a loss of energy.

5.6.1 Energy storage in gas receivers or hydraulic accumulators

When the energy store is a gas receiver or hydraulic accumulator, the requirements of 5.6 apply at operating pressures between the limits specified in items a) and b):

a) External pneumatic or hydraulic supply

   Unless otherwise specified by the manufacturer, the limits of the operating pressure are between 85 % and 110 % of rated pressure.

   These limits do not apply where receivers also store compressed gas for interruption.

b) Compressor or pump integral with the switching device or the operating device

   The limits of operating pressure shall be stated by the manufacturer.

5.6.2 Energy storage in springs (or weights)

When the energy store is a spring (or weight), the requirements of 5.6 apply when the spring is charged (or the weight lifted). It shall not be possible for the moving contacts to move from the open position unless the charge is sufficient for satisfactory completion of the closing operation.

5.6.3 Manual charging

If a spring (or weight) is charged by hand, the direction of motion of the handle shall be marked. A device indicating when the spring (or weight) is charged shall be mounted on the switching device except in the case of an independent manual closing operation.

The maximum actuating force required for manually charging a spring (or weight) shall not exceed 250 N.

5.6.4 Motor charging

Motors, and their electrically operated auxiliary equipment for charging a spring (or weight) or for driving a compressor or pump, shall operate satisfactorily between 85 % and 110 % of the rated supply voltage (see 4.8), the frequency, in the case of a.c., being the rated supply frequency (see 4.9).

NOTE For electric motors the limits do not imply the use of non-standard motors, but only the selection of a motor which at these values provides the necessary effort, and the rated voltage of the motor need not coincide with the rated supply voltage of the closing device.

In addition a means of charging a spring or weight by hand shall be provided if specified to the manufacturer; such means shall comply with 5.6.3.

5.7 Independent manual operation

In the case of an independent manually operated switch or earthing switch – if stated by the manufacturer – to avoid the untimely reopening of the apparatus after closing on a short circuit, a defined time delay should be introduced between the closing and opening operation by suitable means. This time delay shall be not less than the rated duration of the short circuit (see 4.7).

5.8 Operation of releases

The operation limits of releases shall be as follows.

5.8.1 Shunt closing release

A shunt closing release shall operate correctly between 85 % and 110 % of the rated supply voltage of the closing device (see 4.8), the frequency, in the case of a.c., being the rated supply frequency of the closing device (see 4.9).

5.8.2 Shunt opening release

A shunt opening release shall operate correctly under all operating conditions of the switching device up to its rated short-circuit breaking current, and between 70 % in the case of d.c. – or 85 % in the case of a.c. – and 110 % of the rated supply voltage of the opening device (see 4.8), the frequency in the case of a.c. being the rated supply frequency of the opening device (see 4.9).

5.8.3 Capacitor operation of shunt releases

When, for stored energy operation of a shunt release, a rectifier-capacitor combination is provided as an integral part of the switching device, the charge of the capacitors to be derived from the voltage of the main circuit, the capacitors shall retain a charge sufficient for satisfactory operation of the release 5 s after the voltage supply has been disconnected from the terminals of the combination and replaced by a short-circuiting link. The voltages of the main circuit before disconnection shall be taken as the lowest voltage of the system associated with the rated voltage of the switching device (see IEC 60038 for the relation between "highest voltage for equipment" and system voltages).

5.8.4 Under-voltage release

An under-voltage release shall operate to open the switching device when the voltage at the terminals of the release falls below 35 % of its rated voltage, even if the fall is slow and gradual.

On the other hand, it shall not operate the switching device when the voltage at its terminals exceeds 70 % of its rated supply voltage.

The closing of the switching device shall be possible when the values of the voltage at the terminals of the release are equal to or higher than 85 % of its rated voltage. Its closing shall be impossible when the voltage at the terminals is lower than 35 % of its rated supply voltage.

5.9 Low- and high-pressure interlocking and monitoring devices

Where low-pressure or high-pressure interlocking devices are provided in operating mechanism systems, they shall be such that they can be set to operate at, or within, the appropriate limits of pressure stated by the manufacturer, in accordance with 5.6.1 and with relevant IEC specifications.

Closed pressure systems filled with compressed gas for insulation and/or operation and having a minimum functional pressure for insulation and/or operation above 0,2 MPa (absolute pressure), shall be provided with pressure (or density) monitoring devices, to be continuously, or at least periodically, checked as part of the maintenance programme, taking into account the relevant IEC standards. For switchgear and controlgear having a minimum functional pressure not higher than 0,2 MPa (absolute pressure), such means should be subject to agreement between manufacturer and user.

5.10 Nameplates

Switchgear and controlgear and their operating devices shall be provided with name-plates which contain the necessary information such as the name or mark of the manufacturer, the year of manufacture, the manufacturer's type designation, the serial number, the rated characteristics etc. as specified in the relevant IEC standards.

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

If the switchgear and controlgear consist of several poles with independent operating mechanisms, each pole shall be provided with a nameplate.

For an operating device combined with a switching device, it may be sufficient to use only one combined nameplate.

Technical characteristics on nameplates and/or in documents which are common to several kinds of high-voltage switchgear and controlgear shall be represented by the same symbols. Such characteristics and their symbols are:

– rated voltage U_r
– rated lightning impulse withstand voltage [1)] U_p
– rated switching impulse withstand voltage [1)] U_s
– rated power-frequency withstand voltage [1)] U_d
– rated normal current I_r
– rated short-time withstand current I_k
– rated peak withstand current I_p
– rated frequency f_r
– rated duration of short circuit t_k
– rated auxiliary voltage U_a
– rated filling pressure (density) for insulation p_{re} (ρ_{re})
– rated filling pressure (density) for operation p_{rm} (ρ_{rm})
– alarm pressure (density) for insulation p_{ae} (ρ_{ae})
– alarm pressure (density) for operation p_{am} (ρ_{am})
– minimum functional pressure (density) for insulation p_{me} (ρ_{me})
– minimum functional pressure (density) for operation p_{mm} (ρ_{mm}).

Other characteristics (such as type of gas or temperature class) being specialized shall be represented by the symbols which are used in the relevant standards.

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1) The values to be used for nameplates are phase-to-earth values.

5.11 Interlocking devices

Interlocking devices between different components of equipment may be required for reasons of safety and convenience of operation (for example between a switching device and the associated earthing switch).

These interlocking devices shall be provided subject to agreement between manufacturer and user.

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

An interlocking device is a system made of components (it may contain mechanical parts, cables, contactors, coils, etc.). Each component shall be considered as a part of auxiliary and control equipment (see 5.4).

5.12 Position indication

Clear and reliable indication shall be provided of the position of the contacts of the main circuit in case of non-visible contacts. It shall be possible to easily check the state of the position-indicating device when operating locally.

The colours of the position-indicating device in the open, closed, or, where appropriate, earthed position shall be in accordance with IEC 60073.

The closed position shall be marked, preferably with a I (as per symbol 417-IEC-5007-a of IEC 60417). The open position shall be marked, preferably with a O (as per symbol 417-IEC-5008-a of IEC 60417).

Alternatively, in the case of a multi-function device, the positions may be marked with graphical symbols for diagrams of IEC 60617.

5.13 Degrees of protection by enclosures

Degrees of protection according to IEC 60529, shall be specified for all enclosures of high-voltage switchgear and controlgear containing parts of the main circuit allowing penetration from outside as well as for enclosures for appropriate low-voltage control and/or auxiliary circuits and mechanical operating equipment of all high-voltage switchgear, controlgear and switching devices.

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

NOTE The degrees of protection may be different for other conditions such as maintenance, testing, etc.

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

The degree of protection of persons provided by an enclosure against access to hazardous parts of the main circuit, control and/or auxiliary circuits and to any hazardous moving parts (other than smooth rotating shafts and slowly moving linkages) shall be indicated by means of a designation specified in table 6.

The first characteristic numeral indicates the degree of protection provided by the enclosure with respect to persons, as well as of protection of the equipment inside the enclosure against ingress of solid foreign bodies.

If only the protection against access to hazardous parts is requested or if it is higher than that indicated by the first characteristic numeral, an additional letter may be used as in table 6.

Table 6 gives details of objects which will be "excluded" from the enclosure for each of the degrees of protection. The term "excluded" implies that solid foreign objects will not enter fully the enclosure and that a part of the body or an object held by a person, either will not enter the enclosure or, if it enters, that adequate clearance will be maintained and no hazardous moving part will be touched.

5.13.2 Protection against ingress of water

No degrees of protection against harmful ingress of water as per the second characteristic numeral of the IP-code is specified (second characteristic numeral X).

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

5.13.3 Protection of equipment against mechanical impact under normal service conditions

Enclosures of enclosed switchgear and controlgear shall be of sufficient mechanical strength (possible corresponding tests are specified in 6.7.2).

For indoor installation, the proposed impact level is 2 J.

For outdoor installation without additional mechanical protection, higher impact levels may be specified, subject to an agreement between manufacturer and user.

Table 6 – Degrees of protection

Degree of protection	Protection against ingress of solid foreign bodies	Protection against access to hazardous parts
IP1XB	Objects of 50 mm diameter and greater	Access with a finger (test-finger 12 mm diameter, 80 mm long)
IP2X	Objects of 12,5 mm diameter and greater	Access with a finger (test-finger 12 mm diameter, 80 mm long)
IP2XC	Objects of 12,5 mm diameter and greater	Access with a tool (test-rod 2,5 mm diameter, 100 mm long)
IP2XD	Objects of 12,5 mm diameter and greater	Access with a wire (test-wire 1,0 mm diameter, 100 mm long)
IP3X	Objects of 2,5 mm diameter and greater	Access with a tool (test-rod 2,5 mm diameter, 100 mm long)
IP3XD	Objects of 2,5 mm diameter and greater	Access with a wire (test-wire 1,0 mm diameter, 100 mm long)
IP4X	Objects of 1,0 mm diameter and greater	Access with a wire (test-wire 1,0 mm diameter, 100 mm long)
IP5X	Dust The ingress of dust is not totally prevented, but does not penetrate in a quantity or at a location such that it can interfere with satisfactory operation of apparatus or to impair safety.	Access with a wire (test-wire 1,0 mm diameter, 100 mm long)

NOTE 1 The designation of the degree of protection corresponds to IEC 60529.

NOTE 2 In the case of IP5X category 2 of 13.4 of IEC 60529, is applicable.

NOTE 3 If only the protection against access to hazardous parts is concerned, the additional letter is used and the first numeral is replaced by an X.

5.14 Creepage distances

IEC 60815 gives general rules that assist in choosing insulators which should give satisfactory performance under polluted conditions.

The minimum nominal creepage distance of an outdoor external ceramic or glass insulator situated between phase and earth, between phases or across the terminals of a pole of a circuit-breaker or a switch, is determined by the relation:

$$l_t = a \times l_f \times U_r \times k_D$$

where

l_t is the minimum nominal creepage distance (mm) (see note 1);

a is the application factor selected in relation to the type of insulation according to table 7;

l_f is the minimum nominal specific creepage distance according to table II of IEC 60815 (mm/kV) (see note 2);

U_r is the rated voltage of the switchgear and controlgear;

k_D is the correction factor due to diameter (see 5.3 of IEC 60815).

NOTE 1 For the actual creepage distance, the specified manufacturing tolerances are applicable (see IEC 60273 and IEC 60233).

NOTE 2 Ratio of the creepage distance measured between phase and earth divided by U_r.

Table 7 – Application factors for creepage distances

Application to insulation	Application factor *a*
Between phase and earth	1,0
Between phases	$\sqrt{3}$
Across open contacts of a circuit-breaker or a switch	1,0
NOTE 1 Switching devices that may be exposed to out-of-phase conditions may need a somewhat longer creepage distance across the open contacts. An application factor a = 1,15 has been suggested for such applications. NOTE 2 Non-vertical insulators liable to be covered with melting polluted snow may require a longer creepage distance.	

5.15 Gas and vacuum tightness

The following specifications apply to all switchgear and controlgear which use vacuum or gas, other than air at atmospheric pressure, as an insulating, combined insulating and interrupting, or operating medium. Annex E gives some information, examples and guidance for tightness.

5.15.1 Controlled pressure systems for gas

The tightness of controlled pressure systems for gas is specified by the number of replenishments per day (N) or by the pressure drop per day (Δp). The permissible values shall be given by the manufacturer.

5.15.2 Closed pressure systems for gas

The tightness characteristic of a closed pressure system stated by the manufacturer shall be consistent with a minimum maintenance and inspection philosophy.

The tightness of closed pressure systems for gas is specified by the relative leakage rate F_{rel} of each compartment; standardized values are 1 % and 3 % per year.

NOTE These values can be used to calculate times between replenishments, T, outside extreme conditions of temperature or frequency of operations.

The possible leakages between sub-assemblies having different pressures are also to be taken into account. In the particular case of maintenance in a compartment when adjacent compartments contain gas under pressure, the permissible gas leakage rate across partitions should also be stated by the manufacturer, and the time between replenishments shall be not less than one month.

Means shall be provided to enable gas systems to be safely replenished whilst the equipment is in service.

5.15.3 Sealed pressure systems

The tightness of sealed pressure systems is specified by their expected operating life.

The standard values are 20 years and 30 years.

5.16 Liquid tightness

The following specifications apply to all switchgear and controlgear which use liquids as insulating, or combined insulating and interrupting, or control medium with or without permanent pressure.

5.16.1 Controlled pressure systems for liquid

The tightness of controlled pressure systems for liquid is specified by the number of replenishments per day, N_{liq} or by the pressure drop, Δp_{liq} without replenishment, both caused by the leakage rate F_{liq}.

The permissible values shall be given by the manufacturer.

5.16.2 Closed pressure systems for liquid

The tightness level of closed pressure systems for liquid, pressurized or not, shall be specified by the manufacturer.

5.16.3 Tightness levels for liquid

The tightness level for liquid shall be indicated by the manufacturer. A clear distinction shall be made between internal and external tightness.

a) total tightness: no liquid loss can be detected;

b) relative tightness: slight loss is acceptable under the following conditions:
   - the leakage rate, F_{liq} shall be less than the permissible leakage rate, $F_{p(liq)}$;
   - the leakage rate, F_{liq} shall not continuously increase with time or in the case of switching devices, with number of operations;
   - the liquid leakage shall cause no malfunction of the switchgear or controlgear, nor cause any injury to operators in the normal course of their duty.

5.17 Flammability

The materials shall be chosen and the parts designed such that they retard the propagation of any flame resulting from accidental overheating in the switchgear and controlgear.

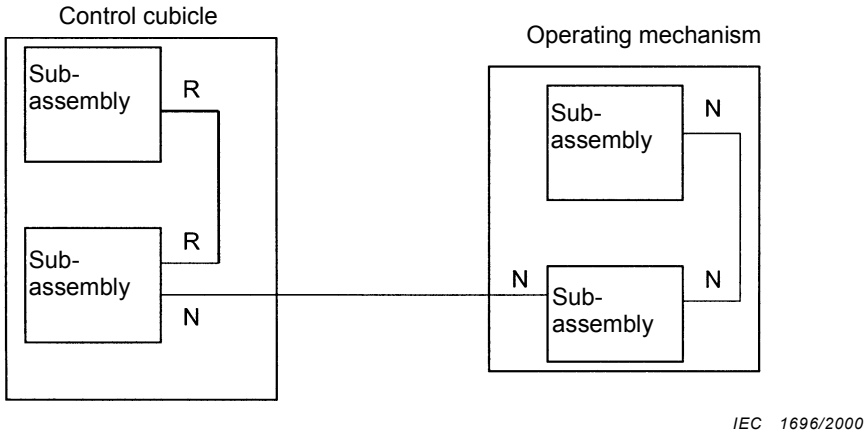
5.18 Electromagnetic compatibility (EMC)

The secondary system shall be able to withstand electromagnetic disturbances, stated in 2.1, without damage or malfunction. This applies both under normal operation and under switching conditions, including interruption of fault currents in the main circuit.

Two EMC severity classes are defined for interfaces or ports of secondary systems or subassemblies:

– normal EMC severity class:
  - interfaces or ports situated close to the primary, high-voltage system;
  - interfaces or ports intended for connection between cubicles within a secondary system;
– reduced EMC severity class: interfaces or ports intended for connection only within a cubicle, not situated close to the primary, high-voltage system.

A complete secondary system may consist of parts belonging to both classes. An example is shown in figure 9.



N Normal EMC severity class

R Reduced EMC severity class

Figure 9 – Example of choice of EMC severity class

NOTE General guidance regarding EMC and considerations to improve EMC are given in IEC 61000-5-1 and IEC 61000-5-2. The magnitude of induced voltages in a secondary system depends both on the secondary system itself and on conditions such as the earthing and rated voltage of the main circuit.

6 Type tests

6.1 General

The type tests are for the purpose of proving the characteristics of switchgear and controlgear, their operating devices and their auxiliary equipment.

6.1.1 Grouping of tests

The type tests shall be carried out on a maximum of four test specimens unless otherwise specified in the relevant IEC standards.

NOTE The rationale behind the specification of four test specimens is to give increased confidence to users that the switchgear and controlgear tested is representative of that which will be delivered (in the limit, this would require all tests to be carried out on a single specimen), whilst allowing manufacturers to carry out testing at separate laboratories for different groups of tests.

Each test specimen of switchgear and controlgear shall truly conform to drawings and be fully representative of its type and shall be subjected to one or more type tests.

For convenience of testing, the type tests may be grouped. An example of a possible grouping is shown in table 8 below.

Table 8 – Example of grouping of type tests

Group	Type tests	Subclause
1	Dielectric tests on main, auxiliary and control circuits	6.2
	Radio interference voltage (r.i.v.) test	6.3
2	Measurement of resistance of the main current path	6.4
	Temperature rise tests	6.5
3	Short-time withstand current and peak withstand current tests	6.6
	Making and breaking tests	See relevant IEC standard
4	Tests to verify the degrees of protection of enclosures	6.7
	Tightness tests (where applicable)	6.8
	Mechanical tests	} See relevant IEC standard
	Environmental tests	

Where additional type tests are necessary, these are specified in the relevant IEC standard.

Each individual type test shall be made in principle on complete switchgear and controlgear (but see 3.2.2) in the condition as required for service (filled with the specified types and quantities of liquid or gas at specified pressure and temperature), on their operating devices and auxiliary equipment, all of which in principle shall be in, or restored to, a new and clean condition at the beginning of each type test.

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

6.1.2 Information for identification of specimens

The manufacturer shall submit to the testing laboratory, drawings and other data containing sufficient information to unambiguously identify by type the essential details and parts of the switchgear and controlgear presented for test. Each drawing or data schedule shall be uniquely referenced and shall contain a statement to the effect that the manufacturer guarantees that the drawings or data schedules truly represent the switchgear and controlgear to be tested.

After completion of verification, detail drawings and other data shall be returned to the manufacturer for storage.

The manufacturer shall maintain detailed design records of all component parts of the switchgear and controlgear tested and shall ensure that these may be identified from information included in the drawings and data schedules.

NOTE Manufacturers whose production systems have been certified for compliance with ISO 9001 or ISO 9002 do satisfy the previously mentioned requirements.

The testing laboratory shall check that drawings and data schedules adequately represent the essential details and parts of the switchgear and controlgear to be tested, but shall not be responsible for the accuracy of the detailed information.

Particular drawings or data required to be submitted by the manufacturer to the test laboratory for identification of essential parts of switchgear and controlgear are specified in annex A.

NOTE An individual type test need not be repeated for a change of construction detail, if the manufacturer can demonstrate that this change does not influence the result of that individual type test.

6.1.3 Information to be included in type-test reports

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

– manufacturer;
– type designation and serial number of switchgear and controlgear tested;
– rated characteristics of switchgear and controlgear tested as specified in the relevant IEC standard;
– general description (by manufacturer) of switchgear and controlgear tested, including number of poles;
– make, type, serial numbers and ratings of essential parts, where applicable (e.g. operating-mechanisms, interrupters, shunt impedances);
– general details of the supporting structure of the switching device or enclosed switchgear of which the switching device forms an integral part;
– details of the operating-mechanism and devices employed during tests, where applicable;
– photographs to illustrate the condition of switchgear and controlgear before and after test;
– sufficient outline drawings and data schedules to represent the switchgear and controlgear tested;
– reference numbers of all drawings submitted to identify the essential parts of the switchgear and controlgear tested;
– details of the testing arrangements (including diagram of test circuit);
– statements of the behaviour of the switchgear and controlgear during tests, its condition after tests and any parts renewed or reconditioned during the tests;
– records of the test quantities during each test or test duty, as specified in the relevant IEC standard.

6.2 Dielectric tests

Dielectric tests of the switchgear and controlgear shall be performed in compliance with IEC 60060-1, unless otherwise specified in this standard.

Information about dielectric tests is given in annex F.

NOTE Where switchgear and controlgear incorporates voltage-limiting devices which cannot be separated from the switchgear and controlgear, then the complete equipment should be tested in accordance with annex F.

6.2.1 Ambient air conditions during tests

Reference shall be made to IEC 60060-1 regarding standard reference atmospheric conditions and atmospheric correction factors.

For switchgear and controlgear where external insulation in free air is of principal concern, the correction factor K_t shall be applied.

The humidity correction factor shall be applied only for the dry tests where insulation in free air is of principal concern.

For switchgear and controlgear of rated voltage of 52 kV and below, it can be assumed that:

- m = 1 and w = 0 when the absolute humidity is higher than that of the reference atmosphere, i.e. when $h > 11$ g/m^3;
- m = 1 and w = 1 when the absolute humidity is lower than that of the reference atmosphere, i.e. when $h < 11$ g/m^3.

For switchgear and controlgear having external and internal insulation, the correction factor K_t shall be applied if its value is between 0,95 and 1,05. However, in order to avoid over-stressing of internal insulation, the application of the correction factor K_t may be omitted where the satisfactory performance of external insulation has been established. When the correction factor is outside the range of 0,95 and 1,05, details of dielectric tests shall be subject to agreement between manufacturer and user.

For switchgear and controlgear having only internal insulation, the ambient air conditions are of no influence and the correction factor K_t shall not be applied.

For combined tests, parameter g shall be calculated considering the total test voltage value.

6.2.2 Wet test procedure

The external insulation of outdoor switchgear and controlgear shall be subjected to wet withstand tests under the standard wet test procedure given in IEC 60060-1.

6.2.3 Conditions of switchgear and controlgear during dielectric tests

Dielectric tests shall be made on switchgear and controlgear completely assembled, as in service; the outside surfaces of insulating parts shall be in clean condition.

The switchgear and controlgear shall be mounted for test with minimum clearances and height as specified by the manufacturer.

Equipment tested at one height above ground surface level will be deemed to be satisfactory if mounted at a greater height above ground surface level when in service.

When the distance between the poles of switchgear and controlgear is not inherently fixed by the design, the distance between the poles for the test shall be the minimum value stated by the manufacturer. However, to obviate the necessity of erecting large three-pole switchgear and controlgear for test purposes alone, the artificial pollution and the radio interference voltage tests may be made on a single pole and, if the minimum clearance between poles is equal to or larger than those given in tables F.1 and F.3 of IEC 60071-2, all other dielectric tests may be made on a single pole.

When the manufacturer states that supplementary insulation such as tape or barriers is required to be used in service, such supplementary insulation shall also be used during the tests.

If arcing horns or rings are required for the purpose of system protection, they may be removed or their spacing increased for the purpose of the test. If they are required for gradient distribution, they shall remain in position for the test.

For switchgear and controlgear using compressed gas for insulation, dielectric tests shall be performed at minimum functional pressure (density) for insulation as specified by the manufacturer. The temperature and pressure of the gas during the tests shall be noted and recorded in the test report.

NOTE **Caution:** In the dielectric testing of switchgear and controlgear incorporating vacuum switching devices, precautions should be taken to ensure that the level of possible emitted X-radiation is within safe limits. National safety codes may influence the safety measures established.

6.2.4 Criteria to pass the test

a) Short-duration power-frequency withstand voltage tests

The switchgear and controlgear shall be considered to have passed the test if no disruptive discharge occurs.

If during a wet test a disruptive discharge on external self-restoring insulation occurs, this test shall be repeated in the same test condition and the switchgear and controlgear shall be considered to have passed this test successfully if no further disruptive discharge occurs.

b) Impulse tests

Procedure B of IEC 60060-1 shall be applied: 15 consecutive lightning or switching impulses at the rated withstand voltage shall be applied for each test condition and each polarity. The switchgear and controlgear shall be considered to have passed the test if the number of the disruptive discharges on self-restoring insulation does not exceed two for each series of 15 impulses and if no disruptive discharge on non-self-restoring insulation occurs.

Procedure C of IEC 60060-1 may be applied as an alternative to the 15 impulses withstand test. In this case, the test shall be performed by applying three consecutive impulses for each polarity. The switchgear and controlgear shall be considered to have passed the test if no disruptive discharge occurs. If one disruptive discharge occurs in the self-restoring part of the insulation, then 9 additional impulses shall be applied and if no disruptive discharges occur, the switchgear and controlgear shall be considered to have passed the test.

If it is proved that tests for one polarity give the most unfavourable results, it is permissible to perform the tests for this polarity only.

Some insulating materials retain a charge after an impulse test and for these cases care should be taken when reversing the polarity. To allow the discharge of insulating materials, the use of appropriate methods, such as the application of three impulses at about 80 % of the test voltage in the reverse polarity before the test, is recommended.

c) General comment

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

NOTE These discharges may have been generated by accumulation of discharge probability with the increased number of voltage applications or by reflected voltage after a disruptive discharge at a remote location within the equipment. To reduce the probability of occurrence of these discharges in gas-filled equipment, the pressure of the already-tested parts may be increased after passing their tests.

6.2.5 Application of the test voltage and test conditions

Distinction must be made between the general case, where the three test voltages (phase-to-earth, between phases and across open switching device) are the same, and the special cases of the isolating distance and of insulation between phases higher than phase to ground.

6.2.5.1 General case

With reference to figure 2, which shows a diagram of connection of a three-pole switching device, the test voltage shall be applied according to the following table 9:

Table 9 – Test conditions in general case

Test condition	Switching device	Voltage applied to	Earth connected to
1	Closed	Aa	BCbcF
2	Closed	Bb	ACacF
3	Closed	Cc	ABabF
4	Open	A	BCabcF
5	Open	B	ACabcF
6	Open	C	ABabcF
7	Open	a	ABCbcF
8	Open	b	ABCacF
9	Open	c	ABCabF

Test conditions 3, 6 and 9 may be omitted if the arrangement of the outer poles is symmetrical with respect to the centre pole and the frame. Test conditions 7, 8 and 9 may be omitted if the arrangement of the terminals of each pole is symmetrical with respect to the base.

6.2.5.2 Special case

When the test voltage across the open switching device is higher than the phase-to-earth withstand voltage, different test methods may be used.

a) Preferred method

Unless otherwise specified in this standard, the preferred method is the use of combined voltage tests (see clause 26 of IEC 60060-1).

– Power-frequency voltage tests

The tests shall be performed using two different voltage sources in out-of-phase conditions in order to obtain the specified test value. The voltage share is specified in 6.2.6.1 and in 6.2.7.1.

In this case, the test voltage across the open switching device (or isolating distance) shall be applied according to the following table 10.

Table 10 – Power-frequency test conditions for longitudinal insulation

Test condition	Voltages applied to	Earth connected to
1	A and a	BCbcF
2	B and b	ACacF
3	C and c	ABabF

Test conditions 3 may be omitted if the arrangement of the outer poles is symmetrical with respect to the centre pole and the frame.

– Impulse voltage tests

The rated impulse withstand voltage phase-to-earth constitutes the main part of the test voltage and is applied to one terminal; the complementary voltage is supplied by another voltage source of the opposite polarity and applied to the opposite terminal. This complementary voltage may be either another impulse voltage or the peak of a power-frequency voltage. The other poles and the frame are earthed.

To take into account the influence of the impulse on the power-frequency voltage wave, caused by capacitive coupling between the two voltage circuits, the following test requirements shall be fulfilled: the voltage drop on the power-frequency wave shall be limited so that the actual test voltage to ground, measured at the instant of the peak value of the impulse is not less than the value specified for the complementary voltage with a tolerance of 5 %. To achieve such a condition, the instantaneous power-frequency voltage may be increased up to, but no more than $U_r \sqrt{2}/\sqrt{3}$ for the lightning impulse tests, and not more than 1,2 $U_r \sqrt{2}/\sqrt{3}$ for the switching impulse tests. See D.2.3.1.

The voltage drop can be greatly reduced by using a capacitor of a convenient value connected in parallel to the terminal of the power-frequency side.

The test voltage shall be applied according to table 11.

Table 11 – Impulse test conditions for longitudinal insulation

Test condition	Main part	Complementary part	Earth connected to
	Voltage applied to		
1	A	a	BbCcF
2	B	b	AaCcF
3	C	c	AaBbF
4	a	A	BbCcF
5	b	B	AaCcF
6	c	C	AaBbF

Test conditions 3 and 6 may be omitted if the arrangement of the outer poles is symmetrical with respect to the centre pole and the frame.

Test conditions 4, 5 and 6 may be omitted if the arrangement of the terminals of each pole is symmetrical with respect to the frame.

b) Alternative method

When only one voltage source is used, the insulation across the open switching device (or isolating distance) may be tested as follows, for both power-frequency voltage tests and impulse voltage tests:

– the total test voltage U_t is applied between one terminal and earth; the opposite terminal is earthed:

– When the resulting voltage across the supporting insulation of the switching device would exceed the rated phase-to-earth withstand voltage, the frame is fixed at a partial voltage with respect to earth U_f, so that $U_t - U_f$ is between 90 % and 100 % of the rated withstand voltage phase-to-earth.

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

The tests shall be performed with the test voltages given in table 1a or 1b.

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 and also in wet conditions for outdoor switchgear and controlgear.

The isolating distance may be tested as follows:

– preferred method. In this case, neither of the two voltage values applied to the two terminals shall be less than one-third of the rated withstand voltage phase-to-earth;

– alternative method: for metal-enclosed gas-insulated switching device with a rated voltage of less than 72,5 kV and for conventional switching device of any rated voltage, the voltage to earth of the frame U_f need not be fixed so accurately and the frame may even be insulated.

NOTE Due to the large scatter of the results of power-frequency voltage wet tests for switchgear and controlgear of rated voltage equal to 170 kV and 245 kV, it is accepted to replace these tests by a wet 250/2 500 μs switching impulse voltage test, with a peak value equal to 1,55 times the r.m.s. value of the specified power-frequency test voltage.

6.2.6.2 Lightning impulse voltage tests

Switchgear and controlgear shall be subjected to lightning impulse voltage tests in dry conditions only. The tests shall be performed with voltages of both polarities using the standard lightning impulse 1,2/50 μs according to IEC 60060-1.

When the alternative method is used to test the isolating distance of metal-enclosed gas-insulated switching device with a rated voltage of less than 72,5 kV and of conventional switching device of any rated voltage, the voltage to earth of the frame U_f need not be fixed so accurately and the frame may even be insulated.

6.2.7 Tests of switchgear and controlgear of rated voltage above 245 kV

In the closed position, the tests shall be performed in conditions 1, 2 and 3 of table 9. In the open position, the tests shall be performed as stated below (but see 6.2.3). In addition, phase-to-phase switching impulse voltage tests shall be performed as stated below. The test voltages are given in table 2a or 2b.

6.2.7.1 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 only.

The insulation across the open switching device or isolating distance shall be tested with the preferred method a) of 6.2.5.2 above. Subject to agreement with the manufacturer, the alternative method b) of 6.2.5.2 may also be used. Whichever method is chosen, neither of the voltages applied between one terminal and the frame shall be higher than the rated voltage U_r.

6.2.7.2 Switching impulse voltage tests

Switchgear and controlgear shall be subjected to switching impulse voltage tests. The tests shall be performed with voltages of both polarities using the standardized switching impulse 250/2500 μs according to IEC 60060-1. Wet tests shall be performed for outdoor switchgear and controlgear only.

The isolating distance shall be tested with the preferred method a) of 6.2.5.2.

The insulation between poles shall be tested in dry conditions only with a total test voltage as per column 5 of tables 2, by the preferred method a) of 6.2.5.2 above in which the two voltage components should be equal to half the total test voltage.

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

6.2.7.3 Lightning impulse voltage tests

Switchgear and controlgear shall be subjected to lightning impulse voltage tests in dry conditions only. The tests shall be performed with voltages of both polarities using the standard lightning impulse 1,2/50 μs according to IEC 60060-1.

6.2.8 Artificial pollution tests

No artificial pollution tests are necessary when the creepage distances of the insulators comply with the requirements of 5.14.

If the creepage distances do not comply with the requirements of 5.14, artificial pollution tests should be performed according to IEC 60507, using the rated voltage and the application factors given in 5.14.

6.2.9 Partial discharge tests

When requested by the relevant product standard, partial discharge tests shall be performed and the measurements made according to IEC 60270.

6.2.10 Dielectric tests on auxiliary and control circuits

Auxiliary and control circuits of switchgear and controlgear shall be subjected to impulse voltage withstand tests as well as to short duration power frequency voltage withstand tests. Each test shall be performed:

a) between the auxiliary and control circuits connected together as a whole and the frame of the switching device;

b) if practicable, between each part of the auxiliary and control circuits, which in normal use may be insulated from the other parts, and the other parts connected together and to the frame.

The impulse voltage withstand tests shall be performed in accordance with IEC 60255-5. The impulse voltage peak value shall be 5 kV. The auxiliary and control circuits shall withstand the tests without permanent damage. After the tests, they shall still be fully operational.

The power frequency tests shall be performed according to IEC 61180-1. The test voltage shall be 2 kV with a duration of 1 min.

The auxiliary and control circuits of switchgear and controlgear shall be considered to have passed the tests if no disruptive discharge occurs during each test.

Normally, the test voltage of motors and other devices used in the auxiliary and control circuits shall be the same as the test voltage of those circuits. If such apparatus has already been tested in accordance with the appropriate specification, it may be disconnected for these tests. Lower test voltage values are under consideration for auxiliary components. If it can be verified that the dielectric stress permits it, lower voltage values may be used, by agreement between manufacturer and user.

NOTE Possible lower values are 2,5 kV for the impulse test and 1 kV for the power frequency test.

The selection criterion is based on the magnitude of the largest common mode voltage, at industrial frequency, expected to occur between two points of the earthing circuitry of the substation (for example, during a primary short circuit or due to the presence of a shunt reactor).

6.2.11 Voltage test as condition check

When the insulating properties across open contacts of a switching device after the making, breaking and/or mechanical/electrical endurance tests cannot be verified by visual inspection with sufficient reliability, a power-frequency withstand voltage test in dry condition according to 6.2.6.1 and 6.2.7.1 across the open switching device at the following value of power-frequency voltage may be appropriate.

For equipment with rated voltages up to and including 245 kV:

– 80 % of the value in table 1a or 1b, column 3 for disconnectors and switch-disconnectors (equipment with safety requirements) and column 2 for other equipment.

For equipment with rated voltages from 300 kV and above:

– 100 % of the value in table 2a or 2b, column 3 for disconnectors and switch-disconnectors (equipment with safety requirements):

– 80 % of the value in tables 2a or 2b, column 3 for other equipment.

NOTE 1 The reduction of the test voltage is motivated by the safety margin in the rated test voltage values, which takes ageing, wear and other normal deterioration into account, and by the statistical nature of the flashover voltage.

NOTE 2 Condition-checking tests of the insulation to earth may be required for enclosed devices of certain design. In such cases a power-frequency test with 80 % of the values in column 2, of tables 1 and 2, respectively, should be performed.

NOTE 3 The relevant apparatus standard can specify that this condition-checking test is mandatory for certain types of equipment.

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

These tests apply only to switchgear and controlgear having a rated voltage of 123 kV and above, and shall be made when specified in the relevant IEC standards. Switchgear and controlgear shall be installed as stated in 6.2.3.

The test voltage shall be applied as follows:

a) in closed position, between the terminals and the earthed frame;

b) in open position, between one terminal and the other terminals connected to the earthed frame and then with the connections reversed if the switching device is not symmetrical.

The case, tank, frame and other normally earthed parts shall be connected to earth. Care should be taken to avoid influencing the measurements by earthed or unearthed objects near to the switchgear and controlgear and to the test and measuring circuits.

The switchgear and controlgear shall be dry and clean and at approximately the same temperature as the room in which the test is made. It should not be subjected to other dielectric tests within 2 h prior to the present test.

The test connections and their ends shall not be a source of radio interference voltage of higher values than those indicated below.

The measuring circuit (see figure 3) shall comply with CISPR 18-2. The measuring circuit shall preferably be tuned to a frequency within 10 % of 0,5 MHz, but other frequencies in the range 0,5 MHz to 2 MHz may be used, the measuring frequency being recorded. The results shall be expressed in microvolts.

If measuring impedances different from those specified in CISPR publications are used, they shall be not more than 600 Ω nor less than 30 Ω, in any case the phase angle shall not exceed 20°. The equivalent radio interference voltage referred to 300 Ω can be calculated, assuming the measured voltage to be directly proportional to the resistance, except for test pieces of large capacitance, for which a correction made on this basis may be inaccurate. Therefore, a 300 Ω resistance is recommended for switchgear and controlgear with bushings with earthed flanges (e.g. dead tank switchgear and controlgear).

The filter F shall have a high impedance at the measuring frequency, so that the impedance between the high-voltage conductor and earth is not appreciably shunted as seen from the switchgear and controlgear under test. This filter also reduces circulating radio-frequency currents in the test circuit, generated by the high-voltage transformer or picked up from extraneous sources. A suitable value for its impedance has been found to be 10 000 Ω to 20 000 Ω at the measuring frequency.

It shall be ensured by suitable means that the radio interference background level (radio interference level caused by external field and by the high-voltage transformer when magnetized at the full test voltage) is at least 6 dB and preferably 10 dB below the specified radio interference level of the switchgear and controlgear to be tested. Calibration methods for the measuring instrument and for the measuring circuits are given in CISPR 16-1 and CISPR 18-2 respectively.

As the radio interference level may be affected by fibres or dust settling on the insulators, it is permitted to wipe the insulators with a clean cloth before taking a measurement. The atmospheric conditions during the test shall be recorded. It is not known what correction factors apply to radio interference testing but it is known that tests may be sensitive to high relative humidity and the results of the test may be open to doubt if the relative humidity exceeds 80 %.

The following test procedure shall be followed:

A voltage of 1,1 $U_r/\sqrt{3}$ shall be applied to the switchgear and controlgear and maintained for at least 5 min, U_r being the rated voltage of the switchgear and controlgear. The voltage shall then be decreased by steps down to 0,3 $U_r/\sqrt{3}$, raised again by steps to the initial value and finally decreased by steps to 0,3 $U_r/\sqrt{3}$. At each step a radio interference measurement shall be taken and the radio interference level, as recorded during the last series of voltage reductions, shall be plotted versus the applied voltage; the curve so obtained is the radio interference characteristic of the switchgear and controlgear. The amplitude of voltage steps shall be approximately 0,1 $U_r/\sqrt{3}$.

The switchgear and controlgear shall be considered to have passed the test if the radio interference level at 1,1 $U_r/\sqrt{3}$ does not exceed 2 500 μV.

6.4 Measurement of the resistance of circuits

6.4.1 Main circuit

A measurement of the resistance of the main circuit shall be made for comparison between the switchgear and controlgear type tested for temperature rise and all other switchgear and controlgear of the same type subjected to routine tests (see 7.3).

The measurement shall be made with d.c. by measuring the voltage drop or resistance across the terminals of each pole. Special consideration shall be given to enclosed switchgear and controlgear (see the relevant standards).

The current during the test shall have any convenient value between 50 A and the rated normal current.

NOTE Experience shows that an increase of the main circuit resistance cannot alone be considered as reliable evidence of bad contacts or connections. In such a case, the test should be repeated with a higher current, as close as possible to the rated normal current.

The measurement of the d.c. voltage drop or the resistance shall be made before the temperature-rise test, with the switchgear and controlgear at the ambient air temperature and after the temperature-rise test when the switchgear and controlgear has cooled to a temperature equal to the ambient air temperature. The measured resistances in these two tests shall not differ by more than 20 %.

The measured value of the d.c. voltage drop or the resistance shall be given in the type-test report, as well as the general conditions during the test (current, ambient air temperature, points of measurement, etc.).

6.4.2 Auxiliary circuits

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

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

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

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

6.4.2.2 Measurement of the resistance of auxiliary contacts class 3

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

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

6.5 Temperature-rise tests

6.5.1 Conditions of the switchgear and controlgear to be tested

Unless otherwise specified in the relevant standards, the temperature-rise test of the main circuits shall be made on a new switching device with clean contacts, and, if applicable, filled with the appropriate liquid or gas at the minimum functional pressure (or density) for insulation prior to the test.

6.5.2 Arrangement of the equipment

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

For temperature-rise tests of parts other than auxiliary equipment, the switchgear and controlgear and their accessories shall be mounted in all significant respects as in service, including all normal covers of any part of the switchgear and controlgear, and shall be protected against undue external heating or cooling.

When the switchgear and controlgear, according to the manufacturer's instructions, may be installed in different positions, the temperature-rise tests shall be made in the most unfavourable position.

These tests shall be made in principle on three-pole switchgear and controlgear but may be made on a single pole or on a single unit provided the influence of the other poles or units is negligible. This is the general case for non-enclosed switchgear. For three-pole switchgear and controlgear with a rated normal current not exceeding 630 A, the tests may be made with all poles connected in series.

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

Temporary connections to the main circuit shall be such that no significant amount of heat is conducted away from, or conveyed to, the switchgear and controlgear during the test. The temperature rise at the terminals of the main circuit, and at the temporary connections at a distance of 1 m from the terminals, shall be measured. The difference of temperature rise shall not exceed 5 K. The type and sizes of the temporary connections shall be recorded in the test report.

NOTE 1 To make the temperature-rise test more reproducible, the type and/or sizes of the temporary connections may be specified in relevant standards.

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

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

Switchgear and controlgear with the exception of d.c. auxiliary equipment shall be tested at rated frequency with a tolerance of $^{+2}_{-5}$ %. The test frequency shall be recorded in the test report.

NOTE 2 Tests performed at 50 Hz on switching devices of the open type having no ferrous components adjacent to the current-carrying parts should be deemed to prove the performance of the switching device when rated 60 Hz, provided that the temperature-rise values recorded during the tests at 50 Hz do not exceed 95 % of the maximum permissible values.

When tests are performed at 60 Hz, they should be considered valid for the same current rating with 50 Hz rated frequency.

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

The time for the whole test may be shortened by preheating the circuit with a higher value of current, except where the measurement of thermal time constant is required.

6.5.3 Measurement of the temperature and the temperature rise

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

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

The temperature of the various parts other than coils for which limits are specified shall be measured with thermometers or thermocouples, or other sensitive devices of any suitable type, placed at the hottest accessible point. The temperature rise shall be recorded at regular intervals throughout the test when the calculation of the thermal time constant is needed.

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

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

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

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

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

6.5.4 Ambient air temperature

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

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

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

The ambient air temperature during tests shall be more than +10 °C but less than +40 °C. No correction of the temperature-rise values shall be made for ambient air temperatures within this range.

6.5.5 Temperature-rise test of the auxiliary and control equipment

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

NOTE Tests performed at 50 Hz on switching devices of the open type having no ferrous components adjacent to the current-carrying parts should be deemed to prove the performance of the switching device when rated 60 Hz, provided that the temperature-rise values recorded during the tests at 50 Hz do not exceed 95 % of the maximum permissible values. When tests are performed at 60 Hz they should be considered valid for the same current rating with 50 Hz rated frequency.

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

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

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

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

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

6.5.6 Interpretation of the temperature-rise tests

The temperature rise of the various parts of the switchgear and controlgear or auxiliary equipment for which limits are specified, shall not exceed the values specified in table 3. Otherwise, the switchgear and controlgear shall be considered to have failed the test.

When the arcing contacts are bare copper contacts and are separate from but in parallel with the main contacts, the temperature rise of the main contacts and of the arcing contacts shall not exceed the values given in table 3.

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

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

6.6 Short-time withstand current and peak withstand current tests

Main circuits and, where applicable, the earthing circuits of the switchgear and controlgear shall be subjected to a test to prove their ability to carry the rated peak withstand current and the rated short-time withstand current.

The test shall be made at the rated frequency with a tolerance of ±10 % at any suitable voltage and starting at any convenient ambient temperature.

NOTE For convenience of testing, wider tolerances of the rated frequency may be necessary. If the deviations are appreciable, i.e. when switchgear and controlgear rated for 50 Hz are tested at 60 Hz and vice versa, care should be taken in the interpretation of results.

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

The switchgear and controlgear shall be mounted on its own support or on an equivalent support and installed with its own operating device as far as necessary to make the test representative. It shall be in the closed position and fitted with clean contacts in 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 may be made three-phase or single-phase. In the case of a single-phase test, the following shall apply:

– on a three-pole switchgear and controlgear, the test shall be made on two adjacent poles;
– in the case of switchgear and controlgear with separated poles, the test may be made either on two adjacent poles or on one pole with the return conductor at phase distance. If the distance between poles is not fixed by the design, the test shall be made at the minimum distance indicated by the manufacturer;
– above a rated voltage of 72,5 kV, unless otherwise specified in the relevant standards, the return conductor need not be taken into account, but in no case shall it be located closer to the tested pole than the minimum distance indicated for phase centres by the manufacturer.

The connections to the terminals of the switchgear and controlgear shall be arranged in such a way as to avoid unrealistic stressing of the terminals. The distance between the terminals and the nearest supports of the conductors on both sides of the switchgear and controlgear shall be in accordance with the instructions of the manufacturer.

The test arrangement shall be noted in the test report.

6.6.2 Test current and duration

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

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

The test current I_t shall in principle be applied for a time t_t equal to the rated duration t_k of short circuit.

If no other method to determine the value $I_t^2t_t$ is available, then it shall be determined from the oscillogram using the method of evaluating I_t given in annex B. The value of $I_t^2t_t$ on test shall be not less than the value of $I_k^2t_k$ calculated from the rated short-time current (I_k) and the rated duration of short circuit (t_k), and shall not exceed this value by more than 10 % without the consent of the manufacturer.

When, however, the characteristics of the test plant are such that the peak and r.m.s. values of test current specified above cannot be obtained in a test of the specified duration, the following deviations are permitted:

a) if the decrement of the short-circuit current of the test plant is such that the specified r.m.s. value, measured in accordance with annex B or by an equivalent cannot be obtained for the rated duration without applying initially an excessively high current, the r.m.s. value of the test current may be permitted to fall below the specified value during the test and the duration of the test may be increased appropriately, provided that the value of the peak current is not less than that specified and the time is not more than 5 s;

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

c) if neither a) nor b) is practicable, separation of the peak withstand current test and the short-time withstand current test is permissible. In this case two tests are made:

   – for the peak withstand current test, the time during which the short-circuit current is applied shall be not less than 0,3 s;

   – for the short-time withstand current test, the time during which the short-circuit current is applied shall be equal to the rated duration. However, deviation in time according to item a) is permitted.

6.6.3 Behaviour of switchgear and controlgear during test

All switchgear and controlgear shall be capable of carrying their rated peak withstand current and their rated short-time withstand current without causing mechanical damage to any part or separation of the contacts.

It is recognized that, during the test, the temperature rise of current-carrying and adjacent parts of the mechanical switching device may exceed the limits specified in table 3. No temperature-rise limits are specified for the short-time current withstand tests but the maximum temperature reached should not be sufficient to cause significant damage to adjacent parts.

6.6.4 Conditions of switchgear and controlgear after test

After the test, the switchgear and controlgear shall not show significant deterioration, shall be capable of operating normally, carrying its rated normal current continuously without exceeding the temperature-rise limits specified in table 3 and withstanding the voltage specified under dielectric tests.

If the mechanical switching device has a rated making and/or breaking capacity, then the condition of the contacts shall not be such as to affect the performance materially at any making and/or breaking current up to its rated value.

The following is sufficient to check these requirements:

a) a no-load operation of the mechanical switching device shall be performed immediately after the test, and the contacts shall open at the first attempt;
b) secondly, the resistance of the main circuit shall be measured according to 6.4.1 (except for earthing switches). If the resistance has increased by more than 20 %, and if it is not possible to confirm the condition of the contacts by visual inspection, it may be appropriate to perform an additional temperature-rise test.

6.7 Verification of the protection

6.7.1 Verification of the IP coding

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

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

When the supplementary letter W is used, a recommended test method is given in annex C.

6.7.2 Mechanical impact test

When agreed between manufacturer and user, enclosures for indoor installation shall be subjected to an impact test. Three blows are applied to points of the enclosure that are likely to be the weakest points of each enclosure. Devices such as relays, meters, etc., are excepted.

The hammer head with which the impact is applied has a hemispherical face with a radius of 25 mm of steel having a Rockwell hardness of R100. The use of a spring-operated impact test apparatus as defined in IEC 60068-2-63 is recommended.

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

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

For outdoor installation, the test should be agreed between manufacturer and user.

6.8 Tightness tests

The purpose of tightness tests is to demonstrate that the absolute leakage rate F does not exceed the specified value of the permissible leakage rate F_p.

Where possible, the tests should be performed on a complete system at p_{re} (or ρ_{re}). If this is not practical, the tests may be performed on parts, components or sub-assemblies. In such cases, the leakage rate of the total system shall be determined by summation of the component leakage rates using the tightness coordination chart TC (see annex E). The possible leakages between sub-assemblies of different pressures shall also be taken into account.

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

In general, only cumulative leakage measurements allow calculation of leakage rates.

The type test report should include such information as:

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

The tightness tests shall be performed in connection with the tests required in the relevant standards, typically before and after the mechanical operation test or during the operation tests at extreme temperatures.

An increased leakage rate at extreme temperatures (if such tests are required in the relevant standards) is acceptable, provided that this rate resets to a value not higher than the maximum permissible value at normal ambient air temperature. The increased temporary leakage rate shall not exceed the values given in table 12.

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

Table 12 – Permissible temporary leakage rates for gas systems

Temperature class °C	Permissible temporary leakage rate
+40 and +50	$3F_p$
ambient temperature	F_p
–5 /–10 /–15 /–25 /–40	$3F_p$
–50	$6F_p$

6.8.1 Controlled pressure systems for gas

The relative leakage rate F_{rel} shall be checked by measuring the pressure drop Δp over a time period, t that is of sufficient length to permit a determination of the pressure drop (within the filling and replenishing pressure range). A correction should be made to take into account the variation of ambient air temperature. During this period the replenishment device shall be inoperative.

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

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

where t is the test duration (hours).

NOTE In order to maintain the linearity of the formula, Δp should be of the same order of magnitude as $p_r - p_m$. Alternatively, the number of replenishment operations per day may be measured directly.

6.8.2 Closed pressure systems for gas

Due to comparatively small leakage rates of these systems, pressure drop measurements are not applicable. Other methods (examples are given in annex E) may be used to measure the leakage rate F, which allows in combination with the tightness coordination chart TC, allows one to calculate:

– the relative leakage rate F_{rel};

– the time between replenishments T (outside extreme conditions of temperature or frequency of operations).

In general the test Qm (see IEC 60068-2-17) represents an adequate method to determine leakages in gas systems.

If the test object is filled with a test gas different from the gas used in service and/or at a test pressure different from the normal operating pressure, corrective factors defined by the manufacturer shall be used for calculations.

Since metering difficulties occur during low and high temperature tests, the procedure used may be to perform the tightness test at ambient temperature before and after the low and high temperature tests to determine if there has been a change.

Since leakage rate measurements in practice may have an inaccuracy of ±50 %, the tightness test is considered to be successful when the stated values of table 12 are achieved within the limits of +50 %. This inaccuracy of measurement shall be taken into account when calculating the period of time between replenishments.

6.8.3 Sealed pressure systems

a) Switchgear using gas

Tightness tests on such switchgear and controlgear are performed in order to determine the expected operating life for the sealed pressure system.

The tests shall be performed according to 6.8.2.

b) Vacuum switchgear

The vacuum level shall be measured twice without operation of the vacuum tube, with a time interval such that the rate of vacuum pressure variation can be properly assessed.

This rate shall be such that the vacuum pressure level will not reach the maximum acceptable threshold during its expected operating life. The minimum time interval depends on the size of the vacuum tube and the sensitivity of the testing method.

NOTE Generally, a time interval of four weeks is considered acceptable.

The chosen method for measuring the vacuum shall be calibrated for each type of vacuum tube. This can be done by applying the test method simultaneously with a conventional vacuum pressure measurement before sealing a sample unit. The accuracy of the evaluation shall be established by repeating the measurements.

6.8.4 Liquid tightness tests

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

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

The tightness tests shall be performed in connection with the tests required in the relevant standards, typically before and after the mechanical operation test, during the operation tests at extreme temperatures or before and after the temperature-rise tests.

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

The switchgear shall be observed over a period sufficient to determine a possible leak or the pressure drop Δp. In this case, the calculations given in 6.8.1 are valid.

NOTE Using liquids different from those in service or gas for the test is possible but requires justification by the manufacturer.

The test report should include such information as:

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

6.9 Electromagnetic compatibility tests (EMC)

EMC requirements and tests are specified only for secondary systems.

For main circuit of switchgear and controlgear in normal operation, without switching operations, the emission level is verified by means of the radio interference voltage test, see 6.3.

Emission caused by switching operations, including interruption of fault currents, is incidental.

The frequency and level of such emission are considered to be part of the normal electromagnetic environment.

For secondary systems of switchgear and controlgear, the EMC requirements and tests specified in this standard have precedence over other EMC specifications.

6.9.1 Emission tests on secondary systems

Electronic equipment, which is part of the secondary system, shall fulfil the requirements with regard to emission, as defined in CISPR 11 for group 1, class A equipment. No other tests are specified.

A 10 m measuring distance may be used instead of 30 m, by increasing the limit values by 10 dB.

6.9.2 Immunity tests on secondary systems

6.9.2.1 General

Secondary systems of switchgear and controlgear shall be subjected to electromagnetic immunity tests if they include electronic equipment or components. In other cases no tests are required.

The following immunity tests are specified:

– electric fast transient/burst test (see 6.9.2.2). The test simulates the conditions caused by switching in the secondary circuit;
– oscillatory wave immunity test (see 6.9.2.3). The test simulates the conditions caused by switching in the main circuit.

Other EMC immunity tests do exist, but are not specified in this case. A compilation of EMC immunity tests is given in IEC 61000-4-1, and IEC 61000-6-5 deals with EMC immunity of apparatus in power generating stations and high-voltage substations.

Electrostatic discharge (ESD) tests are normally required on electronic equipment, and shall be performed on such equipment to be used in secondary systems of switchgear and controlgear. These tests need not be repeated on complete secondary systems. Radiated field and magnetic field tests are considered to be relevant only in special cases.

NOTE 1 Example of a special case: electronic devices, placed in the close vicinity of the busbars of metal-enclosed switchgear, may be influenced by magnetic fields. Supplementary arrangements may then be made in order to ensure electromagnetic compatibility.

NOTE 2 Use of radio-transmitters or cellular telephones close to a control cabinet with open door may subject the secondary system to considerable radio-frequency electromagnetic fields.

6.9.2.2 Guidelines for immunity tests

Electromagnetic immunity tests shall be made on complete secondary systems or sub-assemblies. Examples are given in figures 5, 6, 7, and 8. The tests may be made on

– the complete secondary system;
– subassemblies, such as central control cubicle, operating mechanism cubicle, etc.;
– subassemblies within a cubicle, such as metering or monitoring system.

Individual testing of subassemblies is strongly recommended in cases where long lengths of interconnections are needed, or where significant interference voltages are expected between the subassemblies. Individual testing is mandatory for each interchangeable subassembly.

Subassemblies may be positioned in different places within the secondary system, without invalidating the type test of the complete system, provided that the overall wiring length and the number of individual wires connecting the subassembly to the secondary system is not greater than in the tested system.

Interchangeable subassemblies may be replaced by similar subassemblies, without invalidating the original type test, provided that

– rules for design and installation given in IEC 61000-5 are followed;
– type tests have been performed on the most complete subassembly applicable to the type of switchgear and controlgear;
– manufacturer's design rules are the same as for the type-tested subassembly.

The test voltage shall be applied to the interface of the secondary system or tested subassembly. The interface shall be defined by the manufacturer.

The type test report shall clearly state what system or subassembly has been tested. See also annex A.

NOTE The immunity tests are intended to cover a majority of service conditions. There may be extreme situations where induced disturbances are more severe than those covered by the tests.

6.9.2.3 Electrical fast transient/burst test

An electrical fast transient/burst test shall be performed in accordance with IEC 61000-4-4. The test voltage and coupling shall be chosen according to table 17.

Table 17 – Application of voltage at the fast transient/burst test

Interface	**Normal EMC severity class** **Test voltage** kV	**Reduced EMC severity class** **Test voltage** kV	**Coupling**
Power lines	2	2	CDN[a]
Control lines	2	2	CDN
Communication and shielded lines	2	2	Capacitive coupling clamp
Earth terminal	2	2	CDN
[a] CDN: coupling decoupling network.			

6.9.2.4 Oscillatory wave immunity test

An oscillatory wave immunity test shall be performed, with shape and duration of the test voltage in accordance with IEC 61000-4-12.

Damped oscillatory wave tests shall be made at 100 kHz and 1 MHz, with a relative tolerance of ±30 %.

Disconnector operations in GIS may create surges with extremely steep wave fronts. For that reason, additional test frequencies are under consideration for equipment nearby GIS (10 MHz and 50 MHz).

Tests shall be made for both common and differential mode. The test voltage and coupling method shall be chosen according to table 18.

NOTE The increased test voltage values for instrument transformer secondaries reflect actual disturbance values recorded in field installations.

Table 18 – Application of voltage at the damped oscillatory wave test

Interface	Normal EMC severity class Test voltage kV	Reduced EMC severity class Test voltage kV	Coupling
Power lines	Differential mode: 1,0 (2,5[a]) Common mode: 2,5	Differential mode: 0,5 Common mode: 1,0	CDN[b] CDN
Control lines (measurement)	Differential mode: 1,0 (2,5[a]) Common mode: 2,5	Differential mode: 0,5 Common mode: 1,0	CDN CDN
Communication (unshielded)	Differential mode: 1,0 Common mode: 2,5	Differential mode: 0,5 Common mode: 1,0	CDN CDN
Shielded lines	2,5	1,0	Between cabinets

[a] For secondary circuits of instrument transformers only.

[b] CDN: coupling decoupling network.

6.9.2.5 Behaviour of the secondary equipment during and after tests

The secondary system shall withstand each of the tests specified in 6.9.2.2 and 6.9.2.3 without permanent damage. After the tests it shall still be fully operative. Temporary loss of parts of the functionality is permitted according to table 19.

Table 19 – Assessment criteria for transient disturbance immunity tests

Function	Criterion[a]
Protection, teleprotection	1
Alarm	2
Supervision	2
Command and control	1
Measurement	2
Counting	1
Data processing – for high-speed protective system – for general use	 1 2
Information	2
Data storage	1
Processing	2
Monitoring	2
Man-machine interface	2
Self-diagnostics	2
Processing, monitoring and self-diagnostic functions which are on-line connected, and are part of command and control circuits, shall fulfil criterion 1.	
[a] Criteria, according to IEC 61000-4-1: 1: normal performance within the specification limits; 2: temporary degradation or loss of function or performance which is self-recoverable.	

6.10 Additional tests on auxiliary and control circuits

6.10.1 General

The objective of the tests described below is to qualify the whole assembly without repeating individual tests on components. Therefore, tests on components which comply with their relevant IEC standards and with relevant rated values shall not be repeated.

6.10.2 Functional tests

A functional test of all low-voltage circuits shall be made to verify the proper functioning of auxiliary and control circuits in conjunction with the other parts of the switchgear and controlgear. The test procedures depend on the nature and the complexity of the low-voltage circuits of the device. These tests are specified in the relevant IEC standards for switchgear and controlgear. They shall be performed with the upper and lower value limits of the supply voltage defined in 4.8.3.

For low-voltage circuits, sub-assemblies and components, operation tests can be omitted if they have been fully performed during a test applied to the whole switchgear and controlgear or in relevant circumstances.

6.10.3 Electrical continuity of earthed metallic parts test

A test shall be performed on auxiliary and control circuit enclosures.

The test equipment comprises a d.c. power supply with a maximum open circuit voltage of 12 V d.c., an output current regulator, and voltage and current measuring instruments.

A minimum current of 2 A shall be circulated between the main earthing connections and each of the following mechanical masses, if applicable:

– doors;
– door handles;
– frames;
– metallic enclosures.

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

The auxiliary and control circuits enclosures of switchgear and controlgear shall be considered to have passed the test if the measured resistance is below 0,5 Ω.

6.10.4 Verification of the operational characteristics of auxiliary contacts

6.10.4.1 General

Auxiliary contacts, which are contacts included in auxiliary circuits, shall be submitted to the following tests unless the equipment has passed the whole type tests as a functional unit.

6.10.4.2 Auxiliary contact rated continuous current

This test verifies the rated value of current which a previously closed auxiliary contact is capable of carrying continuously.

The circuit shall be closed and opened by means independent from the contact under test. Test procedures are described in 6.5.5. The contact shall carry its class rated continuous current according to table 16 without exceeding the temperature rise in table 3 based on the contact material and the working environment.

6.10.4.3 Auxiliary contact rated short time withstand current

This test verifies the value of current which a previously closed auxiliary contact is capable of carrying for a specified short period.

The circuit shall be closed and opened by means independent from the contact under test. The contact shall carry its class rated short time withstand current according to table 16 for 30 ms, with a resistive load. This implies that the current value to be obtained shall be reached within 5 ms after current initiation. The relative tolerance on the test current amplitude is $^{+5}_{-0}$ % and the relative tolerance on the test current duration is $^{+10}_{-0}$ %.

This test shall be repeated 20 times with a 1 min interval between each test. The contact resistance value shall be taken before and after the tests, with the contacts at ambient temperature for both measurements. The resistance increase shall be less than 20 %.

6.10.4.4 Auxiliary contact breaking capacity

This test verifies the breaking capacity of an auxiliary contact.

The circuit shall be closed by means independent from the contact under test. The contact shall carry for 5 s and shall break the current associated with its class according to table 16, with an inductive load. The relative tolerance on the test voltage is $^{+10}_{-0}$ % and the relative tolerance on the test current amplitude is $^{+5}_{-0}$ %.

For all classes, the circuit time constant shall not be less than 20 ms with a relative tolerance of $^{+20}_{-0}$ %.

This test shall be repeated 20 times with a 1 min interval between each test. The recovery voltage shall be maintained during each 1 min interval and for 300 ms ± 30 ms after the last operation. The contact resistance value shall be taken before and after the tests, with the contacts at ambient temperature for both measurements. The resistance increase shall be less than 20 %.

6.10.5 Ripple on d.c. input power port immunity test

This test is performed according to IEC 61000-4-17 and applies to electrical and electronic components. The relevant IEC standards for switchgear and controlgear should state whether or not such a test is necessary on some components (for example, it does not apply to motors, motor-operated disconnectors, etc.).

The test level is class 2, and the frequency of the ripple is equal to three times the rated frequency.

The assessment criterion is: “normal performance within the specification limits” (criterion a).

6.10.6 Voltage dips, short interruptions and voltage variations on d.c. input power port immunity tests

Reference to IEC 61000-4-29 is under consideration.

6.10.7 Environmental tests

6.10.7.1 General

Tests on all parts of auxiliary and control equipment should be made under conditions fully representative of those that pertain when mounted, housed or operated as in the complete switchgear and controlgear. Such conditions are satisfied when the tests are made on complete switchgear and controlgear as stated in 6.1.1. Where this is not done, care shall be taken to ensure that tests are carried out under conditions relevant to operation in the complete switchgear and controlgear.

Environmental tests shall be made in order to assess:

– the efficiency of the precautions taken;
– the proper functioning of auxiliary and control circuits over the whole range of actual service conditions inside the enclosures.

All these tests shall be carried out on the same equipment assembly.

These tests may be carried out on the cubicle by itself, or associated with the switchgear and controlgear.

Each environmental test of the auxiliary and control circuits can be omitted, if covered by a test applied to the whole switchgear and controlgear.

Once an equipment has successfully passed the environmental tests, it may be attached to the switchgear and controlgear in several ways (directly mounted on the frame, located separately as a local control cubicle, etc.).

Environmental tests should preferably be made on complete auxiliary and control circuits. Such tests, made on a representative auxiliary and control circuits assembly, are considered to verify the proper functioning of similar auxiliary and control circuits assemblies belonging to the same range of switchgear and controlgear equipment.

Environmental tests do not need to be repeated if the rated voltage of the auxiliary and control circuits is changed.

The change of rated supply voltage of auxiliary and control circuits may have, for some designs, an impact on the results of environmental tests. In practice, unless otherwise justified by the manufacturer, it is desirable to perform the environmental tests on auxiliary and control circuits having the highest rated supply voltage in order to cover all other similar auxiliary and control circuits designed for lower rated supply voltages.

As environmental tests verify the proper functioning of auxiliary and control circuits over the whole range of service conditions in normal operation, heating elements shall be ready to operate except where otherwise stated. Actual service conditions will determine whether the heating elements are in circuit or not.

At the end of the test duration, except for the vibration response test, auxiliary and control circuits shall be checked to ascertain whether they are capable of functioning in accordance with the relevant specifications. These checks will be based on a relevant set of functions. Auxiliary and control circuits shall be energised, and shall remain in the operating condition during and after the test until the functional checks have been performed.

The manufacturer shall clearly state which functionalities are checked at the end of the tests.

6.10.7.2 Cold test

A cold test shall be performed according to test Ad of IEC 60068-2-1, under the service conditions specified in clause 2. The test duration shall be 16 h.

6.10.7.3 Dry heat test

A dry heat test shall be performed according to test Ba of IEC 60068-2-2, under the service conditions specified in clause 2. The test temperature shall be the maximum ambient air temperature and the test duration shall be 16 h.

6.10.7.4 Damp heat, steady state test

A steady state humidity test shall be performed according to test Ca of IEC 60068-2-3. The test duration shall be four days.

6.10.7.5 Cyclic humidity test

A cyclic humidity test shall be performed according to test Db of IEC 60068-2-30. The upper temperature shall be the maximum ambient air temperature specified in clause 2 and the number of temperature cycles shall be two. Variant 2 may be used for the temperature fall period and recovery shall take place under standard atmospheric conditions. No special precautions shall be taken regarding the removal of surface moisture.

6.10.7.6 Vibration response and seismic tests

As the vibration response test is not covered by IEC 60068-2-6, reference is made to IEC 60255-21-1.

This test aims to determine any mechanical weakness of the auxiliary and control equipment assembly. Damage may be caused by two different vibration sources:

– vibrations due to operation of the associated switchgear or controlgear which are highly dependent on site installation. The test shall be performed according to IEC 60255-21-1. Vibration response test parameters are those corresponding to severity class 1. This test can be omitted if the auxiliary and control equipment assembly was subjected to the relevant mechanical endurance tests in the complete switchgear and controlgear;

– vibrations due to special service conditions specified in 2.2.4. The test will be performed by agreement between manufacturer and user. In this case, an appropriate seismic test according to IEC 60255-21-3, test severity class 1, should be considered.

The secondary system shall withstand the vibration response test without permanent damage. After the test, it shall still be fully operational. Temporary loss of parts of the functionality is permitted during the test according to criteria stated in table 19.

6.10.7.7 Other environmental tests

By agreement between manufacturer and user (see 2.2.5), other environmental tests may be performed according to IEC 60068-2.

6.10.7.8 Final condition check

The power frequency voltage withstand tests according to 6.2.10 shall be repeated after all other type tests have been completed, to confirm that there has been no reduction of performance during testing.

7 Routine tests

The routine tests are for the purpose of revealing faults in material or construction. They do not impair the properties and reliability of a test object. The routine tests shall be made wherever reasonably practicable at the manufacturer's works on each apparatus manufactured, to ensure that the product is in accordance with the equipment on which the type tests have been passed. By agreement, any routine test may be made on site.

The routine tests given in this standard comprise:

a) dielectric test on the main circuit in accordance with 7.1;

b) tests on auxiliary and control circuits in accordance with 7.2;

c) measurement of the resistance of the main circuit in accordance with 7.3;

d) tightness test in accordance with 7.4;

e) design and visual checks in accordance with 7.5.

Additional routine tests may be necessary and will be specified in the relevant IEC standards.

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

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

7.1 Dielectric test on the main circuit

A dry, short-duration power-frequency voltage test shall be applied. The test shall be made according to IEC 60060-1, and to 6.2 on complete apparatus or on separate poles, or on transport units in new, clean and dry conditions.

The test voltage shall be that specified in column 2 of tables 1 or 2, according to the relevant IEC standards, or the applicable part of it.

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

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

7.2 Tests on auxiliary and control circuits

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

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

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

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

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

Furthermore, the identification of components and terminals and, if applicable, the identification of cables and wiring shall be verified. In addition, the conformity of auxiliary and control circuits to the circuit diagrams and wiring diagrams shall be checked and the technical data provided by the manufacturer (for example, number of free auxiliary contacts and the class of each one, number, type and capacity of contacts other than auxiliary and control contacts, electrical power of shunt releases, etc.).

7.2.2 Functional tests

A functional test of all low-voltage circuits shall be made to verify the proper functioning of auxiliary and control circuits in conjunction with the other parts of the switchgear and controlgear. The test procedures depend on the nature and the complexity of the low-voltage circuits of the device. These tests are specified in the relevant IEC standards for switchgear and controlgear. They shall be performed with the upper and lower limits values of the supply voltage defined in 4.8.3.

Operation tests on low-voltage circuits, sub-assemblies and components can be omitted if they have been fully tested during a test applied to the whole switchgear and controlgear.

7.2.3 Verification of protection against electrical shock

Protection against direct contact with the main circuit and safe accessibility to the auxiliary and control equipment parts liable to be touched during normal operation shall be checked. Where possible (for example, without removing any coating), the electrical continuity of earthed metallic parts shall be tested under the same conditions as those detailed in 6.10.3. Where not possible, a visual inspection shall be performed.

7.2.4 Dielectric tests

Only power frequency tests shall be performed. This test shall be made under the same conditions as those detailed in 6.2.10.

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

7.3 Measurement of the resistance of the main circuit

For the routine test, the d.c. voltage drop or resistance of each pole of the main circuit shall be measured under conditions as nearly as possible similar with regard to ambient air temperature and points of measurement to those under which the corresponding type test was made. The test current should be within the range stated in 6.4.1.

The measured resistance shall not exceed 1,2 R_u, where R_u is equal to the resistance measured before the temperature-rise test.

7.4 Tightness test

Routine tests shall be performed at normal ambient air temperature with the assembly filled at the pressure (or density) corresponding to the manufacturer's test practice. For gas-filled systems sniffing may be used.

7.4.1 Controlled pressure systems for gas

The test procedure corresponds to 6.8.1.

7.4.2 Closed pressure systems for gas

The test procedure corresponds to 6.8.2.

The test may be performed at different stages of the manufacturing process or of assembling on site, on parts, components and sub-assemblies, according to the tightness coordination chart TC.

7.4.3 Sealed pressure systems

a) Switchgear using gas

The test procedure corresponds to 6.8.3, item a).

b) Vacuum switchgear

Each vacuum tube shall be identified by its serial number. Its vacuum pressure level shall be tested by the manufacturer in accordance with 6.8.3, item b).

The test results shall be documented and, if asked for, certified.

After assembly of the switchgear device the vacuum pressure level of the vacuum tubes shall be tested by a significant routine dielectric test across the open contacts. The test voltage shall be stated by the manufacturer.

The dielectric test shall be carried out after the mechanical routine test.

7.4.4 Liquid tightness tests

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

The test methods correspond to those of the type tests (see 6.8.4).

7.5 Design and visual checks

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

8 Guide to the selection of switchgear and controlgear

To be specified in the relevant IEC standards for switchgear and controlgear.

9 Information to be given with enquiries, tenders and orders

To be specified in the relevant IEC standards for switchgear and controlgear.

10 Rules for transport, storage, installation, operation and maintenance

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

Consequently, the manufacturer should provide instructions for the transport, storage, installation, operation and maintenance of switchgear and controlgear. The instructions for the transport and storage should be given at a convenient time before delivery, and the instructions for the installation, operation and maintenance should be given by the time of delivery at the latest.

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

10.1 Conditions during transport, storage and installation

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

10.2 Installation

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

10.2.1 Unpacking and lifting

Required information for unpacking and lifting safely, including details of any special lifting and positioning devices which are necessary, should be given.

10.2.2 Assembly

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

10.2.3 Mounting

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

These instructions should also indicate:

– the total mass of the apparatus inclusive of extinguishing or insulating fluids;

– the mass of extinguishing or insulating fluids;

– the mass of the heaviest part of the apparatus to be lifted separately if it exceeds 100 kg.

10.2.4 Connections

Instructions should include information on:

a) connection of conductors, comprising the necessary advice to prevent overheating and unnecessary strain on the switchgear and controlgear and to provide adequate clearance distances;

b) connection of auxiliary circuits;

c) connection of liquid or gas systems, if any, including size and arrangement of piping;

d) connection for earthing.

10.2.5 Final installation inspection

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

These instructions should include:

– a schedule of recommended site tests to establish correct operation;
– procedures for carrying out any adjustment that may be necessary to obtain correct operation;
– recommendations for any relevant measurements that should be made and recorded to help with future maintenance decisions;
– instructions for final inspection and putting into service.

Guidance for electromagnetic compatibility site measurements is given in annex H.

10.3 Operation

The instructions given by the manufacturer should contain the following information:

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

10.4 Maintenance

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

10.4.1 Recommendations for the manufacturer

a) The manufacturer should issue a maintenance manual including the following information:
   1) Extent and frequency of maintenance. For this purpose the following factors should be considered;
      – switching operations (current and number);
      – total number of operations;
      – time in service (periodic intervals);
      – environmental conditions;
      – measurements and diagnostic tests, (if any).
   2) Detailed description of the maintenance work;
      – recommended place for the maintenance work (indoor, outdoor, in factory, on site, etc.);
      – procedures for inspection, diagnostic tests, examination, overhaul;
      – reference to drawings;
      – reference to part numbers;
      – use of special equipment or tools;
      – precautions to be observed (e.g. cleanliness and possible effects of harmful arcing by-products);
      – lubrication procedures.

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

NOTE Expanded detail drawings which indicate the relative position of components in assemblies and sub-assemblies are a recommended illustration method.

4) Limits of values and tolerances which, when exceeded, make corrective action necessary. For example:

- pressures, density levels;
- resistors and capacitors (of the main circuit);
- operating times;
- resistance of the main circuits;
- insulating liquid or gas characteristics;
- quantities and quality of liquid or gas (see IEC 60480 and IEC 61634 for SF_6);
- permissible erosion of parts subject to wear;
- torques;
- important dimensions.

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

- grease;
- oil;
- fluid;
- cleaning and degreasing agents.

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

7) Tests after the maintenance work.

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

9) Estimate of active scheduled maintenance time.

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

b) The manufacturer should inform the users of a particular type of switchgear and control-gear and about corrective actions required by possible systematic defects and failures.

c) Availability of spares:

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

10.4.2 Recommendations for the user

a) If the user wishes to do his own maintenance, he should ensure that his staff have sufficient qualification as well as a detailed knowledge of the respective switchgear and controlgear.

b) The user should record the following information:

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

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

10.4.3 Failure report

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

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

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

A failure report should include:

a) Identification of the switchgear which failed:
   – substation name;
   – identification of the switchgear (manufacturer, type, serial number, ratings);
   – switchgear family (air blast, minimum oil, SF_6, vacuum);
   – location (indoor, outdoor);
   – enclosure;
   – operating mechanism, if applicable (hydraulic, pneumatic, spring, motor, manual).
b) History of the switchgear:
   – date of commissioning of the equipment;
   – date of failure/defect;
   – total number of operating cycles, if applicable;
   – date of last maintenance;
   – details of any changes made to the equipment since manufacture;
   – total number of operating cycles since last maintenance;
   – condition of the switchgear when the failure/defect was discovered (in service, maintenance, etc.).
c) Identification of the sub-assembly/component responsible for the primary failure/defect
   – high-voltage stressed components;
   – electrical control and auxiliary circuits;
   – operating mechanism, if applicable;
   – other components.
d) Stresses presumed contributing to the failure/defect
   – Environmental conditions (temperature, wind, rain, snow, ice, pollution, lightning, etc.).
e) Classification of the failure/defect
   – major failure;
   – minor failure;
   – defect.
f) Origin and cause of the failure/defect
   – origin (mechanical, electrical, tightness if applicable);
   – cause (design, manufacture, inadequate instructions, incorrect mounting, incorrect maintenance, stresses beyond those specified, etc.).

g) Consequences of the failure or defect
   – switchgear down-time;
   – time consumption for repair;
   – labour cost;
   – spare parts cost.

A failure report may include the following information:

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

11 Safety

High-voltage switchgear and controlgear can be safe only when installed in accordance with the relevant installation rules, and used and maintained in accordance with the manufacturer's instructions (see clause 10).

High-voltage switchgear and controlgear is normally only accessible by instructed persons. It shall be operated and maintained by skilled persons. When unrestricted access is available to distribution switching and controlgear, additional safety features may be required.

The following specifications of this standard provide personal safety measures for switchgear and controlgear against various hazards:

11.1 Electrical aspects

– insulation of the isolating distance (see 4.2);
– earthing (indirect contact) (see 5.3);
– separation of HV and LV circuits (see 5.4);
– IP coding (direct contact) (see 5.13.1).

11.2 Mechanical aspects

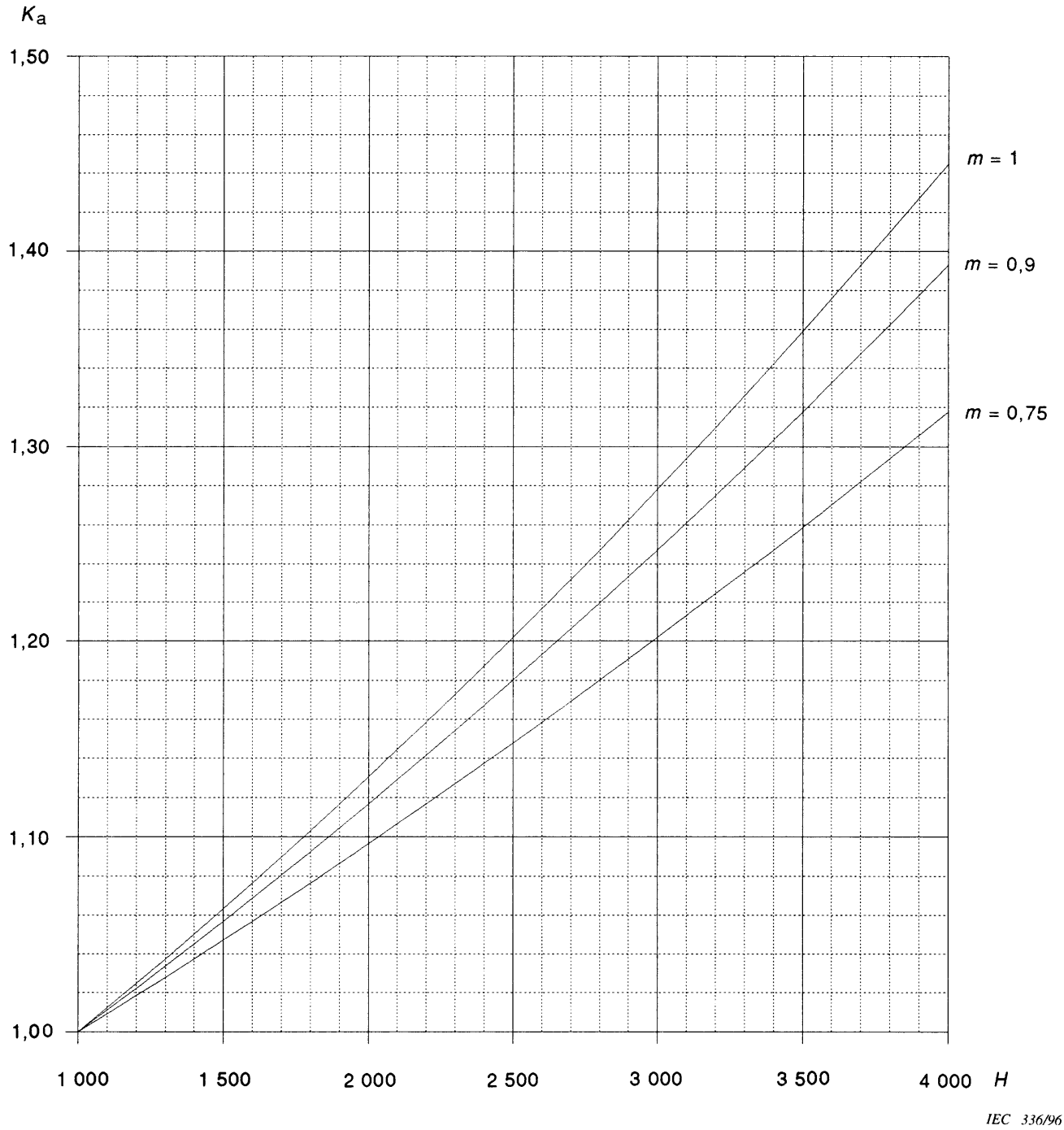
– pressurized components (see 5.2);
– manual actuating force (see 5.6.3);
– IP coding (moving parts) (see 5.13.1);
– mechanical impact protection (see 5.13.3).

11.3 Thermal aspects

– maximum temperature of accessible parts (see table 3);
– flammability (see 5.17).

11.4 Operation aspects

– dependent power operation (see 5.5);
– manual charging (see 5.6.3);
– independent manual operation (see 5.7);
– interlocking devices (see 5.11);
– position indication (see 5.12).



These factors can be calculated from 4.2.2 of IEC 60071-2 with the following equation:

$$K_a = e^{m\,(H-1\,000)/8150}$$

where

H is the altitude in metres;

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

m = 1 for power-frequency, lightning impulse and phase-to-phase switching impulse voltages

m = 0,9 for longitudinal switching impulse voltage

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

Figure 1 – Altitude correction factor (see 2.2.1)

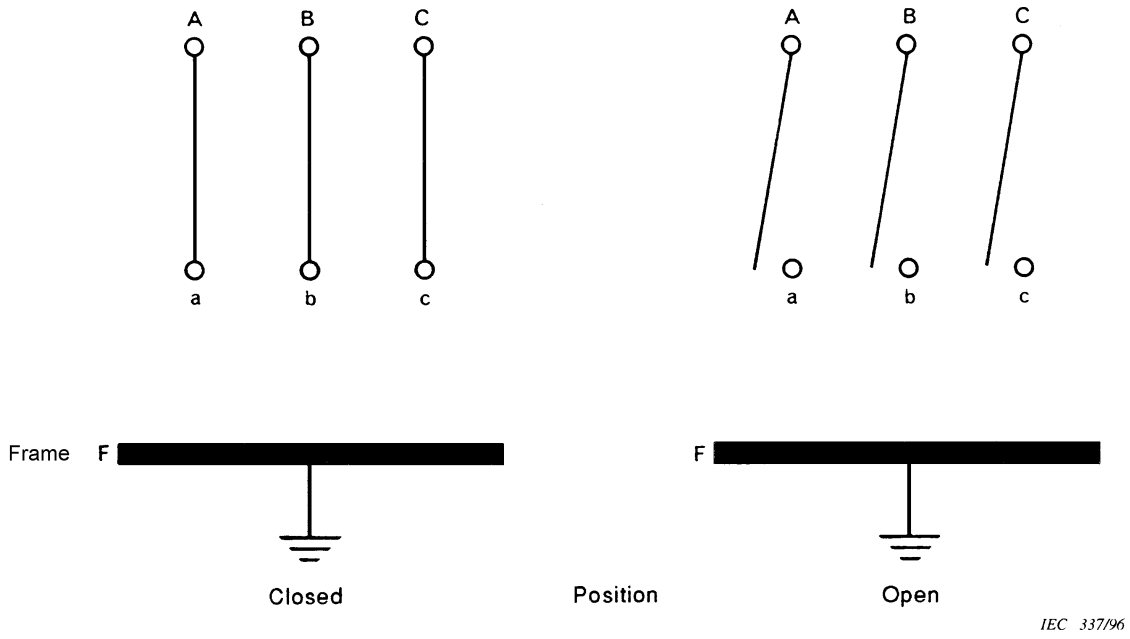
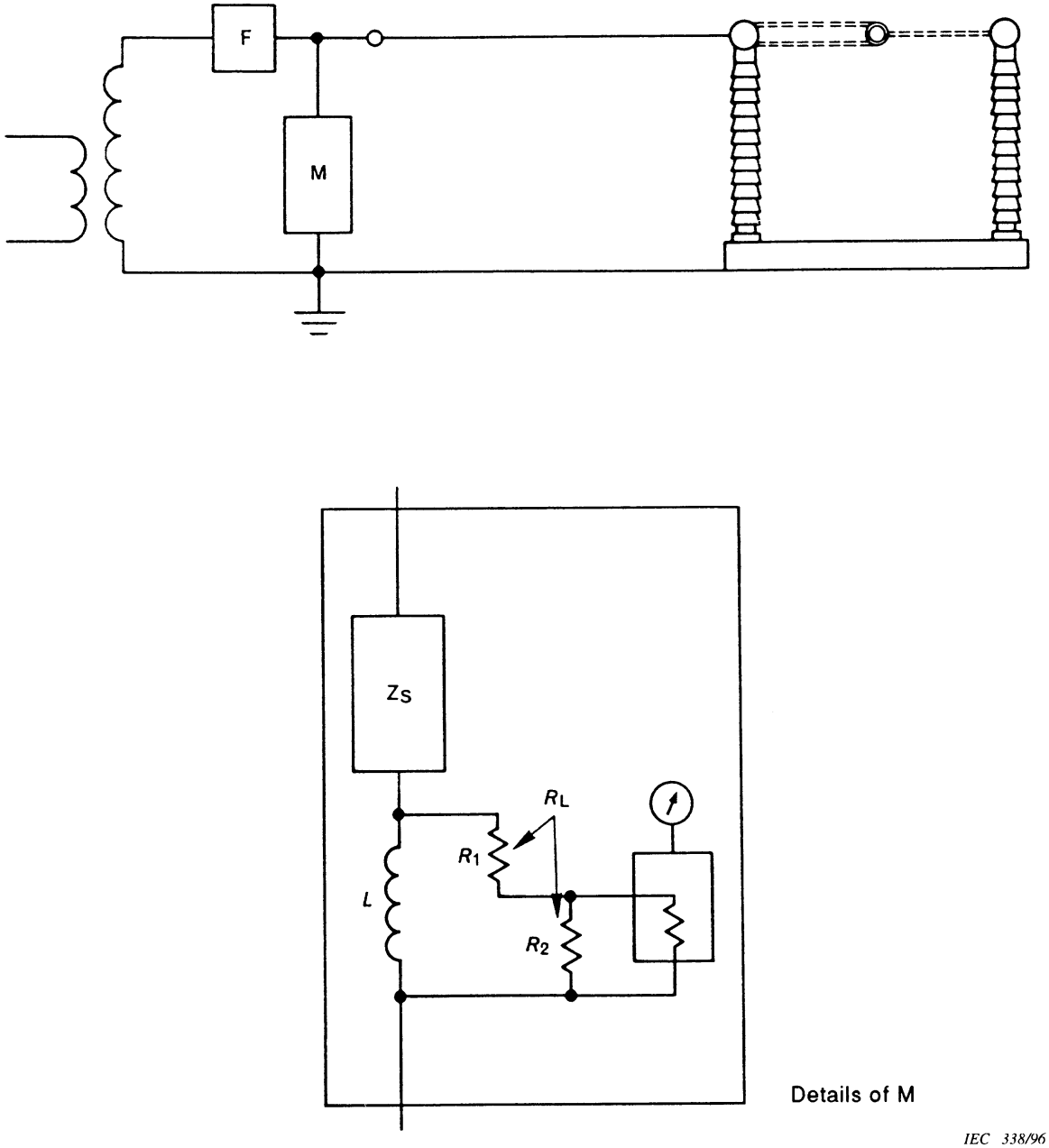


Figure 2 – Diagram of connections of a three-pole switching device (see 6.2.5.1)



F Filter

R_L The equivalent resistance of R_1 in series with the parallel combination of R_2 and the equivalent resistance of the measuring set.

Z_S May be either a capacitor or a circuit composed of a capacitor and an inductor in series

L The impedance used to shunt power-frequency currents and to compensate for stray capacitance at the measuring frequency

Figure 3 – Diagram of a test circuit for the radio interference voltage test of switching devices (see 6.3)

Annex A
(normative)

Identification of test specimens

The following data and drawings, as applicable, shall be submitted by the manufacturer to the testing laboratory, in respect of each test sample (but not necessarily included in the test report). Information to be included in the test report is given in 6.1.3.

A.1 Data

– Manufacturer's name;

– Type designation, ratings and serial number of apparatus;

– Outline description of apparatus (including number of poles, interlocking system, busbar system, earthing system, and the arc extinguishing process);

– Make, type, serial numbers, ratings of essential parts, where applicable (e.g. operating mechanisms, interrupters, shunt impedances, relays, fuse links, insulators);

– Rated characteristics of fuse links and protective devices;

– Whether the apparatus is intended for operation in the vertical and horizontal plane.

A.2 Drawings

Drawings to be submitted	Drawing content (as applicable)
Single-line diagram of main circuit	Type designation of principal components
General layout NOTE For an assembly it may be necessary to provide drawings of the complete assembly and of each switching device.	Overall dimensions Supporting structure Enclosure(s) Pressure-relief devices Conducting parts of main circuit Earthing conductors and earthing connections Electrical clearances: – to earth, between open contacts – between poles Location and dimensions of barriers between poles Location of earthed metallic screens, shutters or partitions in relation to live parts Liquid insulation level Location and type designation of insulators Location and type designation of instrument transformers
Detailed drawings of insulators	Material Dimensions (including profile and creepage distances)
Arrangement drawings of cable boxes	Electrical clearances Principal dimensions Terminals Level or quantity and specifications of insulant in filled boxes Cable termination details
Detailed drawings of parts of the main circuit and associated components	Dimensions and material of principal parts Cross-sectional view through the axis of main and arcing contacts Travel of moving contacts Electrical clearance between open contacts Distance between point of contact separation and end of travel Assembly of fixed and moving contacts Details of terminals (dimensions, materials) Identity of springs Material and creepage distances of insulating parts
Detailed drawings of mechanisms (including coupling and operating mechanisms)	Arrangement and identity of main components of the kinematic chains to: – main contacts – auxiliary switches – pilot switches – position indication Latching device Assembly of mechanism Interlocking devices Identity of springs Control and auxiliary devices
Electrical diagram of auxiliary and control circuits (if applicable)	Type designation of all components

Annex B
(normative)

Determination of the equivalent r.m.s. value of a short-time current during a short circuit of a given duration

The method illustrated in figure B.1 should be used to determine the short-time current (see 6.6.2).

The total time t_t of the test is divided into 10 equal parts by verticals 0 – 0,1 ... 1 and the r.m.s. value of the a.c. component of the current is measured at these verticals.

These values are designated:

$$Z_0, Z_1 \ldots Z_{10}$$

where:

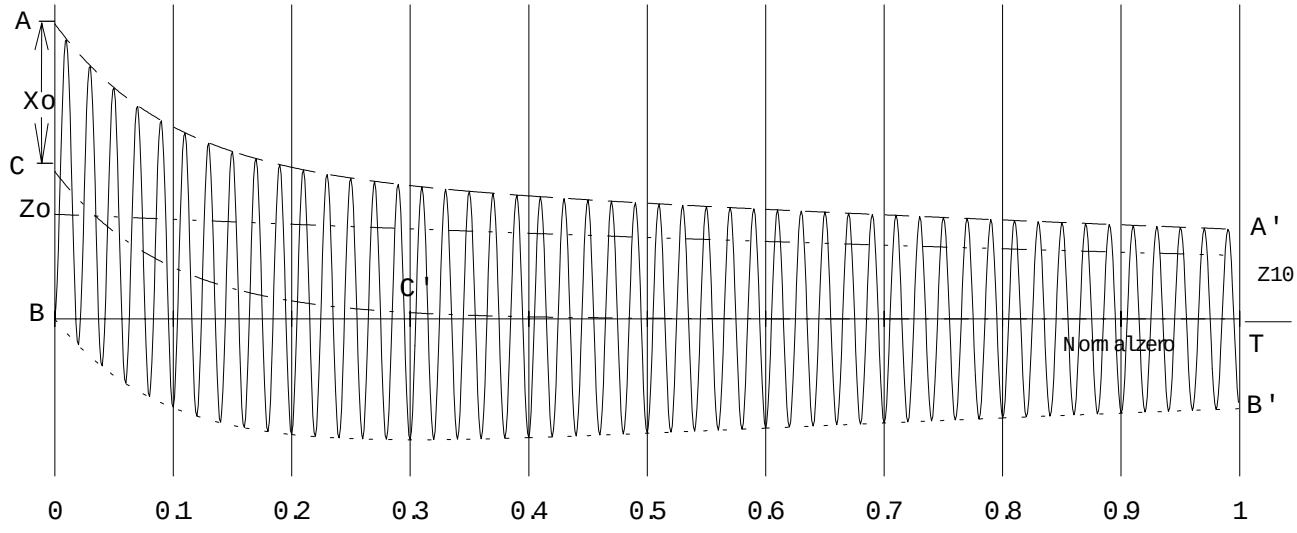
$Z = X/\sqrt{2}$

and X is the peak value of a.c. component of current.

The equivalent r.m.s. current during the time t_t is given by:

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

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



IEC 339/96

AA′ Envelopes of current wave.
BB′
CC′ Displacement of current wave zero line from normal zero line at any instant.
Z0...Z10 RMS value of a.c. component of current at any instant measured from normal zero; d.c. component is neglected.
Xo Peak value of a.c. component of current at instant of initiating short circuit.
BT Duration of short circuit, t_t.

Figure B.1 – Determination of short-time current

Annex C
(normative)

Method for the weatherproofing test for outdoor switchgear and controlgear

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

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

a) the top surfaces from nozzles located at a suitable height:

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

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

Each nozzle used for this test shall deliver a square-shaped spray pattern with uniform spray distribution and shall have a capacity of 30 l/min ± 10 % at a pressure of 460 kPa ± 10 % and a spray angle of 60° to 80°. The centre lines of the nozzles shall be inclined downwards so that the top of the spray is horizontal as it is directed towards the surfaces being tested. It is convenient to arrange the nozzles on a vertical stand-pipe and to space them about 2 m apart (see test arrangement in figure C.1).

The pressure in the feed pipe of the nozzles shall be 460 kPa ± 10 % under flow conditions. The rate at which water is applied to each surface under test shall be about 5 mm/min, and each surface so tested shall receive this rate of artificial precipitation for a duration of 5 min. The spray nozzles shall be at a distance between 2,5 m and 3 m from the nearest vertical surface under test.

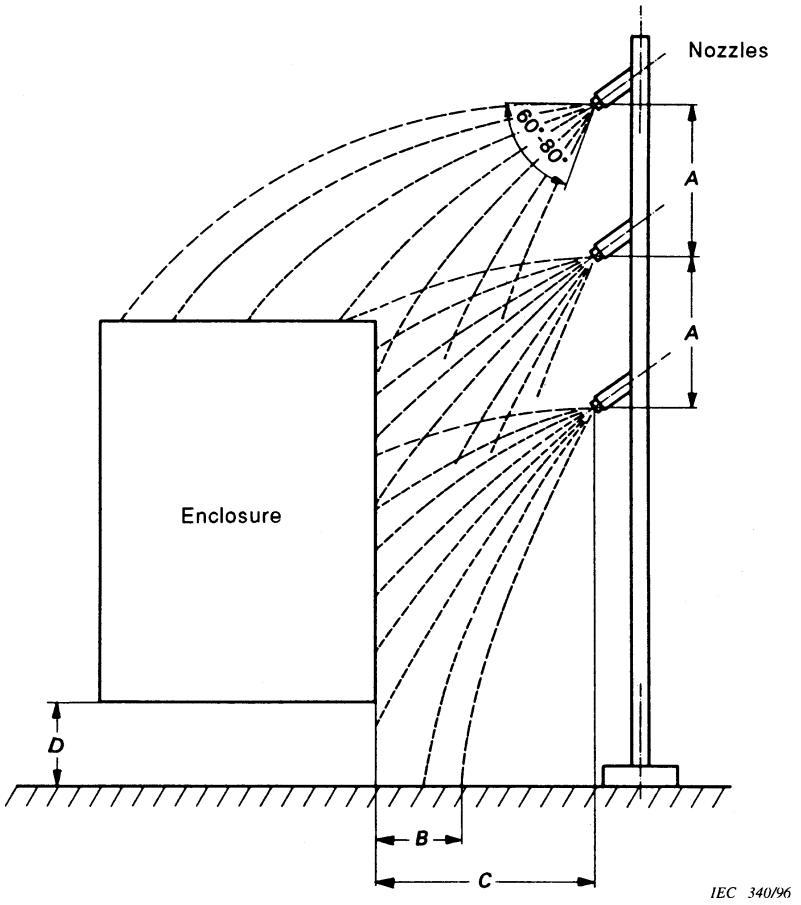
NOTE When a nozzle in accordance with figure C.2 is used, the quantity of water is considered to be in accordance with this standard when the pressure is 460 kPa ± 10 %.

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

1) no water shall be visible on the insulation of the main and auxiliary circuits;

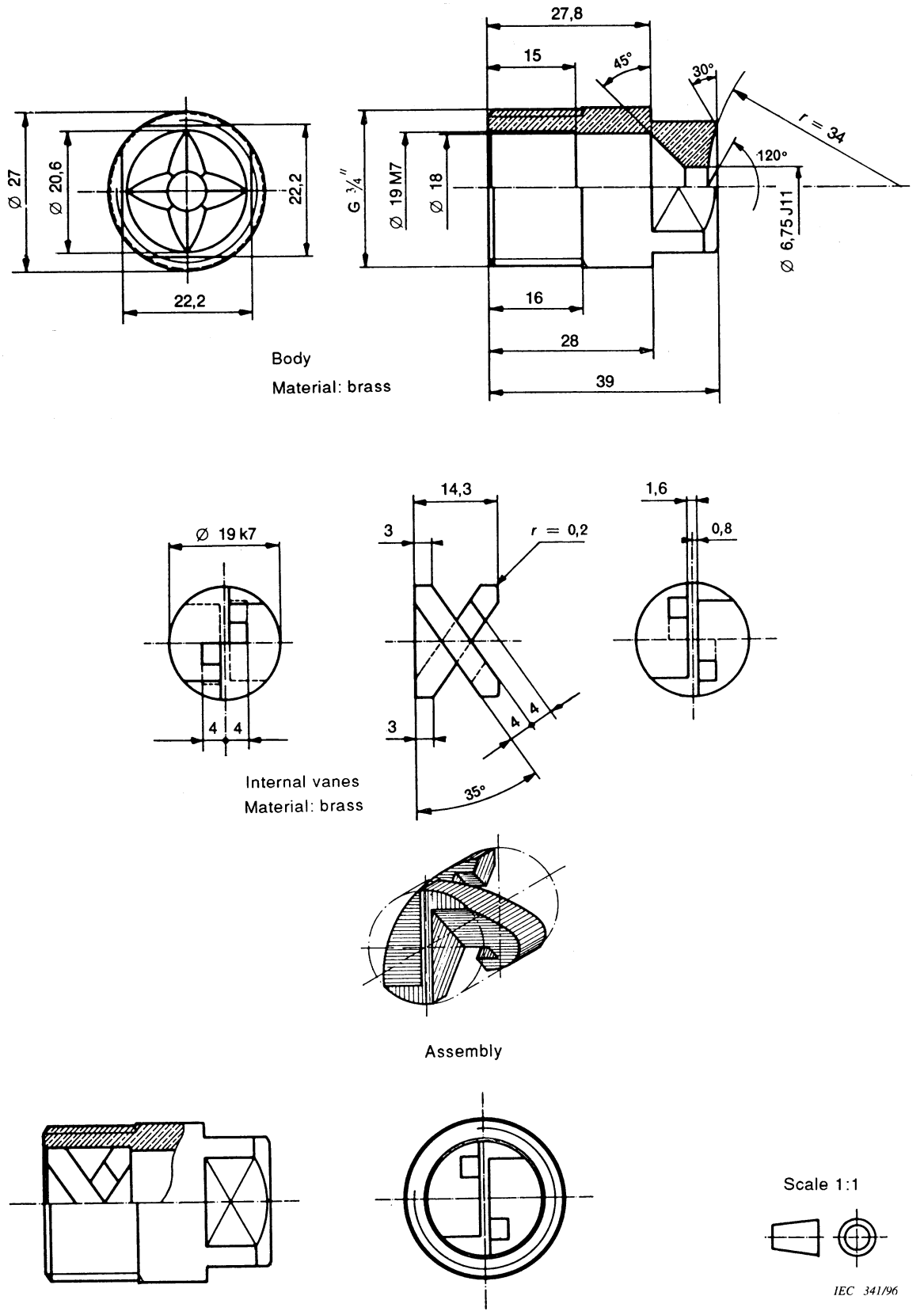
2) no water shall be visible on any internal electrical components and mechanisms of the equipment;

3) no significant accumulation of water shall be retained by the structure or other non-insulating parts (to minimize corrosion).



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

Figure C.1 – Arrangement for weatherproofing test



Dimensions in millimetres

Figure C.2 – Nozzle for weatherproofing test

Annex D
(informative)

Information about insulation levels and tests

The object of this annex is to give information about the insulation levels and tests specified in this standard.

D.1 Specification

The rated insulation levels are mainly based on the requirements of IEC 60071-1. The application guide IEC 60071-2 (future third edition) gives every explanation as to the relation between the system nominal voltage and the standardized insulation levels. But these standards are designed to be used by all sorts of equipment: insulators, cables, power transformers, etc. Therefore, some choices need to be made applying them to high-voltage switchgear and controlgear.

D.1.1 Phase-to-earth

The insulation levels have been selected taking into account the values most used for switchgear and controlgear.

In addition to IEC 60071-1, a rated short-duration power-frequency withstand voltage is added for rated voltages higher than 245 kV, in order to check the withstand of temporary overvoltages by internal insulation.

D.1.2 Phase-to-phase

No changes are made to the specifications of IEC 60071-1 for the insulation between poles.

D.1.3 Longitudinal insulation

Since no other IEC product standards specify longitudinal insulation, the rated withstand values need not be taken from the list of IEC 60071-1.

D.1.3.1 Isolating distance

In addition to the requirements of insulation coordination, the standard specifies insulation of the "isolating distance". This is to cover special conditions which are to be met by disconnectors to provide an additional safety factor (1,15) (see 5.102 of IEC 60129).

The intent is not to provide "auto-coordination" which would require that any disruptive discharge occurs phase-to-earth on the switching device rather than between its open contacts. It is generally recognized that when work has to be carried out on a high-voltage conductor, safety is insured only when the conductor is connected to earth. Local safety rules shall apply.

D.1.3.2 Combined voltage tests of tables 2

A combined voltage test is one in which two separate sources, generating voltages against earth, are connected to two terminals of the test object (see clause 26 of IEC 60060-1).

Such a test is required for switchgear and controlgear of 300 kV and above to account for out-of-phase conditions across the isolating distances or for coupling circuit-breakers. It may also be useful to perform any test where the test voltage between two live parts is specified higher than phase-to-earth.

The components of the combined voltage tests have been specified after the following considerations:

– *Short-duration power-frequency withstand voltage*

The specified power-frequency withstand voltage values correspond to the most severe situation of full load rejection after disconnection of a generator at full load. The over-voltage on the generator side of the switching device may reach up to 1,5 times the system voltage and may last up to 3 s with possible phase shift. At the same time, the network side of the switching device is energized at the normal operating voltage. The sum of the two voltages in phase opposition is 2,5 times the system voltage, extended here to 2,5 the rated voltage.

– *Switching impulse withstand voltage*

The switching impulse voltage value specified phase to earth in column 4 of table 2 is designed to cover the highest slow-front overvoltage likely to occur at the switching device terminal. This occurs at the remote end of a line after fast reclosing from the other end on a trapped charge. This highest overvoltage is of the same polarity as the power-frequency voltage of the network at this instant and therefore is not to be retained when the maximum stress across a switching device is looked for. The maximum stress takes place when an overvoltage occurs on the polarity opposite to the power-frequency voltage of the system. The maximum value in this case is the one occurring on closing from the remote end, which is lower than the one occurring on reclosing. Therefore, the values of switching impulse specified in column 6 are lower than those of column 4.

– *Lightning impulse*

In the process of designing insulation coordination, IEC 60071-1 takes into account the probability of occurrences of a situation to choose the performance criteria. The likelihood that the maximum fast-front overvoltage occurs on the terminal of a switching device at the instant when its opposite terminal is energized with the maximum system voltage at opposite polarity is small. Therefore, the specified lightning impulse to be considered in this particular case need not be as high as for the general case. A reduction of about 5 % has been proved more than adequate during the last decades. For convenient testing, this reduction of the total voltage across the switching device is applied to the power-frequency voltage component.

D.2 Testing

D.2.1 Test of the longitudinal insulation with the alternative method

To be strictly equivalent to the preferred method, the voltage between the energized terminal and the frame should be equal to the rated withstand voltage phase to earth. But it is difficult to adjust exactly this voltage simultaneously with the longitudinal test voltage. The value of U_f has been fixed considering the following facts:

– the test voltage between any terminal and the frame cannot exceed the rated phase to earth withstand voltage without risk;

– the electric field stress across open contacts is mainly dependant on the voltage across them, and to a lesser extent on the voltage to earth;

– the determination of the rated withstand voltage of the isolating distance is not so accurate;

– safety factor is included in the process of insulation coordination (see IEC 60071-1); to account for such testing difficulties.

D.2.2 Test between phases for rated voltages above 245 kV

D.2.2.1 Voltage share between the two switching impulse components of the phase-to-phase test

The actual ratio of the two components may have any value on the network. In order to simplify the tests IEC 60071-1 decided to specify balanced components (same amplitude with opposite polarities). Since this leads to a less severe condition, the total test voltage was increased to cover any realistic case (see annex C of IEC 60071-2). So if the same total test voltage is applied by an unbalanced share of the components, the test is more difficult than required.

But few laboratories have two impulse generators. So one component may be replaced by the peak of a power-frequency voltage. But this leads to power-frequency voltages higher than specified phase-to-earth, and for a rather long duration. Therefore, some compromise is necessary depending on the actual phase-to-earth withstand voltage of the switching device and on the laboratory's facilities.

D.2.2.2 Wet tests

No wet switching impulse tests are normally necessary between phases for the following reasons:

– enclosed insulation does not need wet tests;

– insulation between phases exposed to weather precipitations is only atmospheric air, the withstand voltage of which is not sensitive to this influence for switchgear and controlgear of rated voltage above 245 kV.

D.2.3 Combined voltage tests of longitudinal insulation

D.2.3.1 Tolerance on the power-frequency voltage component

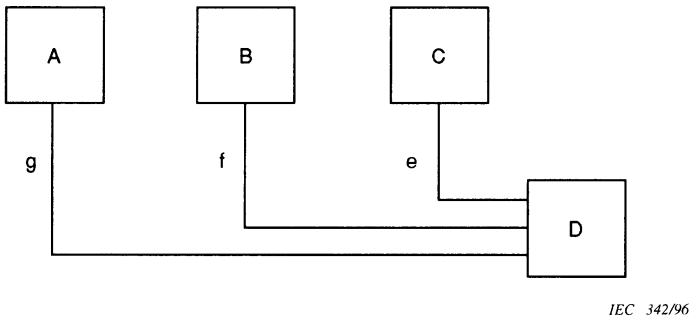
According to IEC 60060-1, the tolerance of the power-frequency component voltage should be maintained within 3 % of the specified level. This allows for some variations from the main voltage without permanent adjustment. But during a combined voltage test, the laboratory has also to monitor many other parameters from the impulse voltage source. Therefore a higher tolerance is acceptable for this component, but the test voltage to be considered is the actual total voltage across the open contacts or the isolating distance.

D.2.3.2 Atmospheric correction factor

The atmospheric correction factor should be calculated according to IEC 60060-1. In the case of combined voltage test, the atmospheric correction factor should be applied to the total test voltage, which is the sum of the two components.

Annex E
(informative)

Tightness (information, example and guidance)



Example:

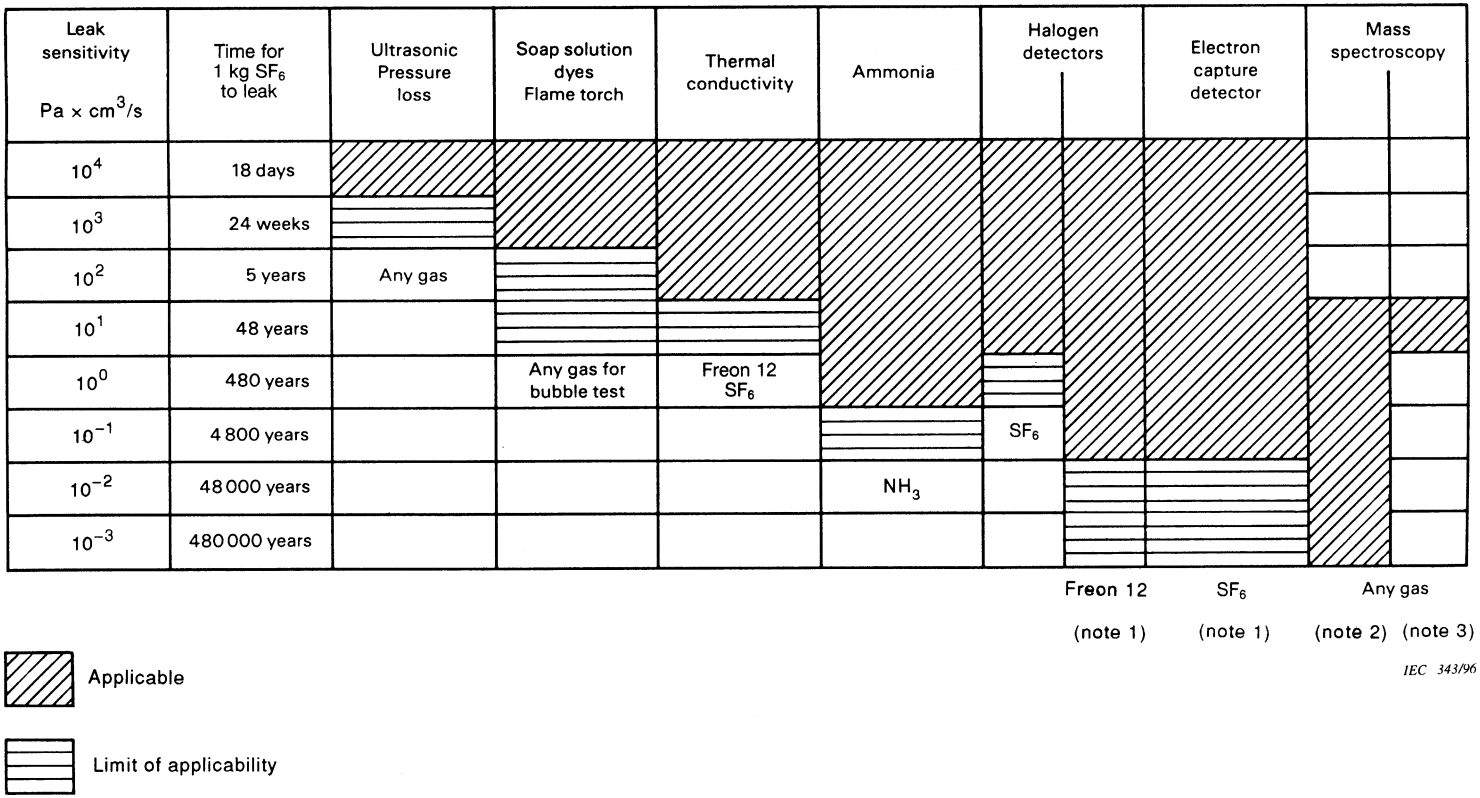
Gas-insulated metal-enclosed switchgear, single-phase encapsulated, circuit-breaker compartments of the three phases connected to the same gas-system.

Leakage rate of the system:	
Compartment A	$19 \cdot 10^{-6}$ Pa × m^3/s
Compartment B	$19 \cdot 10^{-6}$ Pa × m^3/s
Compartment C	$19 \cdot 10^{-6}$ Pa × m^3/s
Control box D (including valves, gauges, monitoring devices)	$2{,}3 \cdot 10^{-6}$ Pa × m^3/s
Piping e	$0{,}2 \cdot 10^{-6}$ Pa × m^3/s
Piping f	$0{,}2 \cdot 10^{-6}$ Pa × m^3/s
Piping g	$0{,}2 \cdot 10^{-6}$ Pa × m^3/s
Complete system	$59{,}9 \cdot 10^{-6}$ Pa × m^3/s
Filling pressure	p_{re}: 700 kPa (absolute)
Alarm pressure	p_{ae}: 640 kPa (absolute)
Total internal volume	270 dm^3

$$F_{rel} = \frac{59{,}9 \cdot 10^{-6} \times 60 \times 60 \times 24 \times 365}{700 \cdot 10^{3} \times 270 \times 10^{-3}} \times 100 = 1{,}0 \text{ \% per year}$$

$$T = \frac{(700 - 640) \times 10^{3} \times 270 \times 10^{-3}}{59{,}9 \cdot 10^{-6} \times 60 \times 60 \times 24 \times 365} = 8{,}5 \text{ years}$$

Figure E.1 – Example of a tightness coordination chart, TC, for closed pressure systems



NOTE 1 Sniffing in good conditions. By integrated leakage measurement, better sensitivity can be achieved.

NOTE 2 By integrated leakage measurement.

NOTE 3 By sniffing.

Figure E.2 – Sensitivity and applicability of different leak detection methods for tightness tests

Annex F
(informative)

Dielectric testing of self-protected switchgear and controlgear

F.1 General

F.1.1 When switchgear and controlgear include surge-arresters mixed with other pieces of equipment having withstand voltage rating without possible separation, some adaptations to the normal testing practices are needed.

Firstly, it is necessary to introduce a "prospective withstand voltage", the test voltage which would have been supplied by the impulse generator without the influence of the test object. It is to be measured before connecting the test object.

Then a failure criterion is to be defined: the "abnormal" discharge which is shown by a sudden step-down on the voltage-time recording, or which has a shape different from the shape of the voltage across the voltage-limiting device tested separately (see figure F.1).

F.1.2 The short-duration power-frequency withstand voltage has also to be considered, specially for switchgear and controlgear having a rated voltage of 245 kV and below.

For this range of equipment, the value of the power-frequency test voltage is high, not because of so high temporary overvoltages, but rather to cover also the withstand of slow-front class overvoltages.

Keeping this test voltage shape and duration at the levels specified in tables 1 and 2 would damage the surge-arresters without representing realistic service conditions. Therefore, power-frequency tests shall be performed at levels covering the actual possible temporary overvoltages and switching impulses shall be added to check the insulation against slow front overvoltages (see IEC 60071-2).

F.1.3 Voltage-limiting devices included in self-protected switchgear and controlgear shall be separately tested according to their relevant standard (IEC 60099).

The purpose of the tests of this annex is to check the coordination between voltage-limiting devices and other components of the switchgear and controlgear.

F.2 Power-frequency tests

Dry power-frequency tests shall be performed for 1 min at r.m.s. test voltages as below. No disruptive discharges shall occur. An earth-fault factor of 1,4 has been used in the following formulae as a general figure. Actual values should be used when these are known.

F.2.1 Phase-to-earth

– switchgear and controlgear to be used on solidly earthed systems shall be tested at $1{,}4 \times 1{,}15\ U_r/\sqrt{3} = 1{,}6\ U_r/\sqrt{3}$.

– switchgear and controlgear to be used on systems other than solidly earthed shall be tested at $1{,}15\ U_r = 2\ U_r/\sqrt{3}$.

F.2.2 Between phases

– switchgear and controlgear without conductive earthed partitions between phases shall be tested at 1,15 $U_r = 2\ U_r / \sqrt{3}$.

F.2.3 Across the open switching device

– switchgear and controlgear to be used on solidly earthed systems shall be tested at 1,15 (1+1,4) $U_r / \sqrt{3} = 2{,}75\ U_r / \sqrt{3}$

– switchgear and controlgear to be used on systems other than solidly earthed shall be tested at 1,15 $(1 + \sqrt{3})\ U_r / \sqrt{3} = 3{,}15\ U_r / \sqrt{3}$

– across the isolating distance, the test shall be 1,15 times the test voltage across the open switching device.

The test shall be performed with two voltage sources in opposition, one being set near the test voltage value phase-to-earth, and the other at a convenient value to give the total specified value.

As an alternative, a single voltage source may be used if the frame is insulated from earth. In that case, the voltage between the energized terminal and the frame should be fixed near the test voltage value phase-to-earth, as in alternative method of 6.2.5.2 b).

F.3 Switching impulse tests

Switchgear and controlgear of rated voltages 300 kV and above shall be tested with test voltages as in tables 2, as prospective voltages.

Switchgear and controlgear of rated voltage 245 kV and below shall be tested with 15 switching impulses, in each polarity and in each condition. No disruptive discharges shall occur. The prospective peak test voltage shall be 1,55 times the r.m.s. power frequency voltages specified in table 1 between phase and earth, between phases, between open switching devices and across the isolating distance respectively, if any.

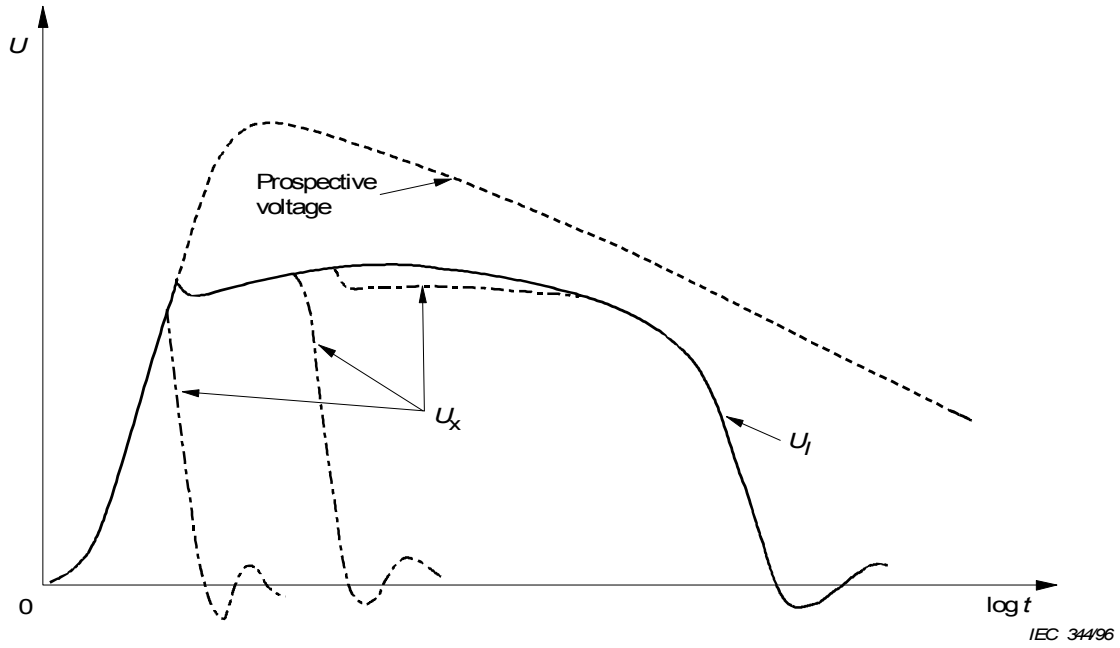
The actual voltage across the test object shall be recorded, at least phase-to-earth. The actual voltage shape may be very different from the prospective voltage shape, due to the respective characteristics of the test generator and of the voltage-limiting device (see figure F.1).

F.4 Lightning impulse tests

Switchgear and controlgear shall be tested with test voltages as in tables 1, and 2, as prospective voltages.

F.5 Routine tests

Components to be incorporated into self-protected switchgear and controlgear shall be tested for 1 min with a power-frequency voltage r.m.s. value equal to 1,15 × 0,7 of the value of the peak of the actual limited voltage U_I measured during the type test with switching impulses.



U_I Actual voltage

U_x Various shapes of disruptive voltage

Figure F.1 – Examples of impulse voltage shapes with incorporated voltage-limiting devices

Annex G
(informative)

Bibliography

The following International Standards are referred to in this standard for information.

IEC 60068-2-6:1995, *Environmental testing – Part 2: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60099-4:1991, *Surge-arresters – Part 4: Metal-oxide surge arresters without gaps for a.c. systems*

IEC 60129:1984, *Alternating current disconnectors (isolators) and earthing switches*

IEC 60233:1974, *Tests on hollow insulators for use in electrical equipment*

IEC 60273:1990, *Characteristics of indoor and outdoor post insulators for systems with nominal voltages greater than 1 000 V*

IEC 60664-1:1992, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60721-2-2:1988, *Classification of environmental conditions – Part 2: Environmental conditions appearing in nature – Precipitation and wind*

IEC 60721-2-4:1987, *Classification of environmental conditions – Part 2: Environmental conditions appearing in nature – Solar radiation and temperature*

IEC 60721-3-3:1994, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Section 3: Stationary use at weatherprotected locations*

IEC 60721-3-4:1995, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Section 4: Stationary use at non-weatherprotected locations*

IEC 60943:1989, *Guide for the specification of permissible temperature and temperature rise for parts of electrical equipment, in particular for terminals*

IEC 61000-4-1:1992, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 1: Overview of immunity tests – Basic EMC publication*

ISO 9001:1994, *Quality systems – Model for quality assurance in design, development, production, installation and servicing*

ISO 9002:1994, *Quality systems – Model for quality assurance in production, installation and servicing*

Annex H
(informative)

Electromagnetic compatibility site measurements

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

– where it is deemed necessary to verify that actual stresses are covered by the EMC severity class of the secondary system, or

– in order to evaluate the electromagnetic environment, in order to apply proper mitigation methods, if necessary,

– to record the electromagnetically induced voltages in a secondary system, due to switching operations both in the main circuit and in the secondary system. It is not considered necessary to test all secondary systems in a substation under consideration. A typical configuration should be chosen.

Measurement of the induced voltages are to be made at representative ports in the interface between the secondary system and the surrounding network, for example, at the input terminals of control cubicles, without disconnection of the system. The extension of the secondary system is described in 5.18. Instrumentation for recording induced voltages should be connected as outlined in IEC 60816.

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

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

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

– discharge the load side before the making operation, to assure that the trapped charge is zero;

– multiply recorded voltage values at the making operation by 2, in order to simulate the case with trapped charge on the load side.

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

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

NOTE 2 Especially for GIS installations, the most severe electromagnetic disturbances are expected to occur at disconnector switching.

The recorded or calculated peak value of induced common mode voltage, due to switching in the main circuit, should not exceed 1,6 kV for interfaces of normal EMC severity class, and 0,8 kV for interfaces of reduced EMC severity class.

The note of 5.18 gives guidelines for improvement of the electromagnetic compatibility.

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