इंटरनेट मानक

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Mazdoor Kisan Shakti Sangathan
"The Right to Information, The Right to Live"

"पुराने को छोड नये के तरफ"
Jawaharlal Nehru
"Step Out From the Old to the New"

IS/IEC 62271-1 (2007): High-Voltage Switchgear and Controlgear, Part 1: Common Specifications [ETD 8: High Voltage Switchgear and Controlgear]

"ज्ञान से एक नये भारत का निर्माण"
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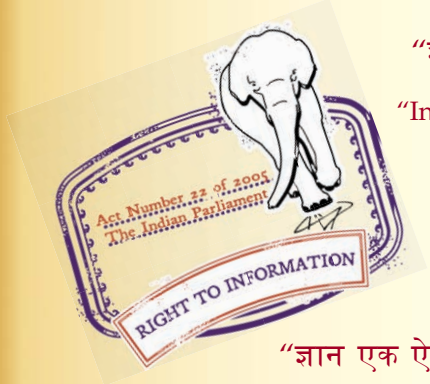

"ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है"
Bhartṛhari—Nītiśatakam
"Knowledge is such a treasure which cannot be stolen"

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IS/IEC 62271-1 : 2007
(Superseding IS 12729 : 2004/IEC 60694 : 1996)

भारतीय मानक

उच्च-वोल्टता के स्विचगियर और नियंत्रणगियर

भाग 1 सामान्य विशिष्टियाँ

Indian Standard

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR

PART 1 COMMON SPECIFICATIONS

ICS 29.130.10; 29.130.99

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

November 2012 **Price Group 20**

CONTENTS

High-Voltage Switchgear and Controlgear Sectional Committee, ETD 08

NATIONAL FOREWORD

This Indian Standard (Part 1) which is identical with IEC 62271-1 : 2007 'High-voltage switchgear and controlgear — Part 1: Common specifications' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the High-Voltage Switchgear and Controlgear Sectional Committee and approval of the Electrotechnical Division Council.

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

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.
b) Comma (,) has been used as a decimal marker, while in Indian Standards the current practice is to use a point (.) as the decimal marker.

This standard supersedes IS 12729 : 2004/IEC 60694 : 1996 'Common specification for high-voltage switchgear and controlgear standards (*first revision*)'.

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

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60034-1 Rotating electrical machines — Part 1: Rating and performance	IS/IEC 60034 (Part 1) : 2004 Rotating electrical machines: Part 1 Rating and performance	Identical to IEC 60034 (Part 1) : 2004
IEC 60038 : 1983 IEC standard voltages	IS 12360 : 1988 Voltage bands for electrical installations including preferred voltages and frequency	Technically Equivalent
IEC 60050-151 : 2001 International Electrotechnical Vocabulary (IEV) — Part 151: Electrical and magnetic devices	IS 1885 (Part 74) : 1993 Electrotechnical vocabulary: Part 74 Electrical and magnetic devices	Identical to IEC 60050-151 : 1978
IEC 60050-191 International Electrotechnical Vocabulary (IEV) — Chapter 191: Dependability and quality of service	IS 1885 (Part 39) : 1999 Electrotechnical vocabulary: Part 39 Dependability of electronic and electrical items	Technically Equivalent
IEC 60050-351 International Electrotechnical Vocabulary (IEV) — Part 351: Control technology	IS 1885 (Part 75) : 1993 Electrotechnical vocabulary: Part 75 Automatic control	Identical to IEC 60050-351 : 1975
IEC 60050-441 : 1984 International Electrotechnical Vocabulary (IEV) — Chapter 441: Switchgear, controlgear and fuses	IS 1885 (Part 17) : 1979 Electrotechnical vocabulary: Part 17 Switchgear and controlgear (*first revision*)	Technically Equivalent
IEC 60050-446 International Electrotechnical Vocabulary (IEV) — Chapter 446: Electrical relays	IS 1885 (Part 9) : 1992 Electrotechnical vocabulary: Part 9 Electrical relays (*second revision*)	Identical to IEC 60050-446 : 1983
IEC 60050-551 International Electrotechnical Vocabulary (IEV) — Power electronics	IS 1885 (Part 27) : 2008 Electrotechnical vocabulary: Part 27 Power electronics (*third revision*)	Technically Equivalent

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60050-601 International Electrotechnical Vocabulary (IEV) — Chapter 601: Generation, transmission and distribution of electricity — General	IS 1885 (Part 78) : 1993 Electrotechnical vocabulary: Part 78 Generation, transmission and distribution of electricity — General	Identical to IEC 60050-601 : 1985
IEC 60050-604 : 1987 International Electrotechnical Vocabulary (IEV) — Chapter 604: Generation, transmission and distribution of electricity — Operation	IS 1885 (Part 70) : 1993 Electrotechnical vocabulary: Part 70 Generation, transmission and distribution of electricity — Operation	Identical
IEC 60050-605 International Electrotechnical Vocabulary (IEV) — Chapter 605: Generation, transmission and distribution of electricity — Substations	IS 1885 (Part 71) : 1993 Electrotechnical vocabulary: Part 71 Generation, transmission and distribution of electricity — Substations	Identical to IEC 60050-605 : 1983
IEC 60051-1 Direct acting indicating analogue electrical measuring instruments and their accessories — Part 1: Definitions and general requirements common to all parts	IS 1248 (Part 1) : 2003 Direct acting indicating analogue electrical measuring instruments and their accessories: Part 1 General requirements (*fourth revision*)	Technically Equivalent
IEC 60051-2 Direct acting indicating analogue electrical measuring instruments and their accessories — Part 2: Special requirements for ammeters and voltmeters	IS 1248 (Part 2) : 2003 Direct acting indicating analogue electrical measuring instruments and their accessories: Part 2 Ammeters and voltmeters (*third revision*)	do
IEC 60051-4 Direct acting indicating analogue electrical measuring instruments and their accessories — Part 4: Special requirements for frequency meters	IS 1248 (Part 4) : 2003 Direct acting indicating analogue electrical measuring instruments and their accessories: Part 4 Frequency meters (*third revision*)	do
IEC 60051-5 Direct acting indicating analogue electrical measuring instruments and their accessories — Part 5: Special requirements for phase meters, power factor meters and synchroscopes	IS 1248 (Part 5) : 2003 Direct acting indicating analogue electrical measuring instruments and their accessories: Part 5 Phase meters, power factor meters and synchroscope (*third revision*)	do
IEC 60059 IEC standard current ratings	IS 11955 : 1987 Preferred current ratings	do
IEC 60060-1 : 1989 High-voltage test techniques — Part 1: General definitions and test requirements	IS 2071 (Part 1) : 1993 High-voltage test techniques: Part 1 General definitions and test requirements	do
IEC 60064 Tungsten filament lamps for domestic and similar general lighting purposes — Performance requirements	IS 418 : 2004 Tungsten filament lamps for domestic and similar general lighting purposes (*fourth revision*)	do
IEC 60068-2 (All parts) Environmental testing — Part 2: Tests	IS 9000 (All parts) Basic environmental testing procedures for electronic and electrical items	do

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60071-1 : 2006 Insulation co-ordination — Part 1: Definitions, principles and rules	IS 2165 (Part 1) : 1977 Insulation coordination: Part 1 Phase to earth insulation coordination principles and rules (*second revision*) IS 2165 (Part 2) : 1983 Insulation coordination: Part 2 Phase to phase insulation coordination principles and rules	Technically Equivalent
IEC 60071-2 : 1996 Insulation co-ordination — Part 2: Application guide	IS 3716 : 1978 Application guide for insulation coordination	do
IEC 60081 Double-capped fluorescent lamps — Performance specifications	IS 1248 (Part 1) : 2003 Direct acting indicating analogue electrical measuring instruments and their accessories: Part 1 General requirements (*fourth revision*)	do
IEC 60085 Electrical insulation — Thermal classification	IS 1271 : 1985 Thermal evaluation and classification of electrical insulation	do
IEC 60115-4 (All parts) Fixed resistors for use in electronic equipment — Part 4: Sectional specification: Fixed power resistors	IS QC 400200 : 1992/IEC QC 400200 : 1982 Fixed resistors for use in electronic equipment sectional specification : Fixed power resistors	do
IEC 60130 (All parts) Connectors for frequencies below 3 MHz	IS 3826 (Part 2) : 1970 Specification for connectors for frequencies below 3 Mhz: Part 2 Battery connectors for electronic equipment	do
IEC 60227 (All parts) Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V	IS 694 : 2010 Polyvinyl chloride insulated unsheathed and sheathed cables/cords with rigid and flexible conductor for rated voltages up to and including 450/750 V (*fourth revision*)	do
IEC 60228 Conductors of insulated cables	IS 8130 : 1984 Conductors for insulated electric cables and flexible cords (*first revision*)	do
IEC 60245 (All parts) Rubber insulated cables — Rated voltages up to and including 450/750 V	IS 9968 (Part 1) : 1988 Elastomer insulated cables: Part 1 For working voltages up to and including 1 100 V (*first revision*)	do
IEC 60255-8 Electrical relays — Part 8: Thermal electrical relays	IS 3231(Part 2/Sec 3):1987 Electrical relays for power system protection: Part 2 Requirements for principal families, Section 3 General requirements for thermal relays	do
IEC 60269-2 Low-voltage fuses — Part 2: Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application) — Examples of standardized systems of fuses A to I	IS 13703 (Part 2/Sec 1) : 1993 Low-voltage fuses for voltages not exceeding 1 000 V ac or 1 500 V dc: Part 2 Fuses for use by authorized persons, Section 1 Supplementary requirements	Identical to IEC 60269-2 : 1986
IEC 60270 High-voltage test techniques — Partial discharge measurements	IS/IEC 60270 : 2000 High-voltage test techniques — Partial discharge measurements	Identical to IEC 60270 : 2000

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60296 Fluids for electrotechnical applications — Unused mineral insulating oils for transformers and switchgear	IS 335 : 1993 New insulating oils (*fourth revision*)	Technically Equivalent
IEC 60376 Specification of technical grade sulphur hexafluoride (SF_6) for use in electrical equipment	IS 13072 : 1991 Sulphur hexafluoride for electrical purposes	Identical to IEC 60376 : 1971
IEC 60445 Basic and safety principles for man-machine interface, marking and identification — Identification of equipment terminals and conductors terminations	IS 11353 : 1985 Guide for uniform system of marking and identification of conductors and apparatus terminals	Technically Equivalent
IEC 60502-1 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)	IS 1554 (Part 1) : 1988 PVC insulated (heavy duty) electric cables: Part 1 For working voltages up to and including 1 100 V (*third revision*)	do
IEC 60507 Artificial pollution tests on high-voltage insulators to be used on a.c. systems	IS 8704 : 1995 Artificial pollution test on high-voltage insulators to be used on ac systems	do
IEC 60512-2 (All parts) Connectors for electronic equipment — Tests and measurements — Part 2: Electrical continuity and contact resistance tests	IS 12448 (Part 2) (All parts) General examination, electrical continuity and contact resistance tests, insulation tests and voltage stress tests	do
IEC 60529 : 1989[1)] Degrees of protection provided by enclosures (IP code)	IS/IEC 60529 : 2001 Degrees of protection provided by enclosures (IP Code)	Identical to IEC 60529 : 2001
IEC 60617 Graphical symbols for diagrams	IS 12032 (All parts) Graphical symbols for diagrams in the field of electrotechnology	Technically Equivalent
IEC 60669-1 Switches for household and similar fixed-electrical installations — Part 1:General requirements	IS 3854 : 1997 Switches for domestic and similar purposes	do
IEC 60695-1 (All parts) Fire hazard testing — Part 1: Guidance for assessing the fire hazard of electrotechnical products	IS 11000 (Part 1) (All parts) Fire hazard testing: Part 1 Guidance for the preparation of requirements and test specifications for assessing fire hazard of electronic and electrical items	do
IEC 60721-1 Classification of environmental conditions — Part 1: Environmental parameters and their severities	13736 (Part 1) : 1993 Classification of environmental conditions: Part 1 Classification of environmental parameters and their severities	do
IEC 60721-2 (All parts) Classification of environmental conditions — Part 2: Environmental conditions appearing in nature — Temperature and humidity	IS 13736 (Part 2) (All parts) Classification of environmental conditions: Part 2 Environmental conditions appearing in nature	do

[1)] Since revised in 2001.

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60721-3 (All parts) Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities	IS 13736 (Part 3) (All parts) Classification of environmental conditions: Part 3 Classification of groups of environmental parameters and their severities	Technically Equivalent
IEC 60815 : 1986 Guide for the selection of insulators in respect of polluted conditions	IS 13134 : 1992 Guide for the selection of insulators in respect of pollution conditions	do
IEC 60909-0 Short-circuit currents in three-phase a.c. systems — Part 0: Calculation of currents IEC 60909-1 Short-circuit currents in three-phase a.c. systems — Part 1: Factors for the calculations of short-circuit currents according to IEC 60909-0	IS 13234 : 1992 Guide for short-circuit current calculation in three-phase a.c. systems	do
IEC 60947-2 Low-voltage switchgear and controlgear — Part 2: Circuit-breakers	IS/IEC 60947-2 : 2003 Low-voltage switchgear and controlgear: Part 2 Circuit-breakers	Identical to IEC 60947-2 : 2003
IEC 60947-3 Low-voltage switchgear and controlgear — Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units	IS/IEC 60947-3 : 1999 Low-voltage switchgear and controlgear: Part 3 Switches, disconnectors, switch-disconnectors and fuse-combination units	Identical to IEC 60947-3 : 1999
IEC 60947-4-1 Low-voltage switchgear and controlgear — Part 4-1: Contactors and motor-starters — Electromechanical contactors and motor-starters	IS/IEC 60947-4-1 : 2000 Low-voltage switchgear and controlgear: Part 4 Contactors and motor-starters, Section 1 Electromechanical contactors and motor-starters	Identical to IEC 60947-4-1 : 2000
IEC 60947-4-2 Low-voltage switchgear and controlgear — Part 4-2: Contactors and motor-starters — AC semiconductor motor controllers and starters	IS/IEC 60947-4-2 : 1999 Low-voltage switchgear and controlgear: Part 4 Contactors and motor-starters, Section 2 AC semiconductor motor controllers and starters	Identical to IEC 60947-4-2 : 1999
IEC 60947-5-1 Low-voltage switchgear and controlgear — Part 5-1: Control circuit devices and switching elements — Electromechanical control circuit devices	IS/IEC 60947-5-1 : 2003 Low-voltage switchgear and controlgear: Part 5 Control circuit devices and switching elements, Section 1 Electromechanical control circuit devices	Identical to IEC 60947-5-1 : 2003
IEC 61000-4-1 Electromagnetic compatibility (EMC) — Part 4-1: Testing and measurement techniques — Overview of IEC 61000-4 series	IS 14700 (Part 4/Sec 1) : 2008 Electromagnetic compatibility (EMC): Part 4 Testing and measurement techniques, Section 1 : Overview of IEC 61000-4 series	Identical to IEC 61000-4-1 : 2006
IEC 61000-4-4 Electromagnetic compatibility (EMC) — Part 4-4: Testing and measurement techniques Electrical fast transient/ burst immunity test	IS 14700 (Part 4/Sec 4) : 2008 Electromagnetic compatibility (EMC): Part 4 Testing and measurement techniques, Section 4 Electrical fast transient/burst immunity test	Identical to IEC 61000-4-4 : 2004

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 62271-2[1)] High-voltage switchgear and controlgear — Part 2: Seismic qualification for rated voltages of 72,5 kV and above	IS/IEC 62271-207 : 2007 High-voltage switchgear and controlgear: Part 207 Seismic qualification for gas-insulated switchgear assemblies for rated voltages above 52 kV	Identical to IEC 62271-207 : 2007
CISPR 11 Industrial, scientific and medical (ISM) radio-frequency equipment — Electromagnetic disturbance characteristics — Limits and methods of measurement	IS 6873 (Part 4) : 1999 Limits and methods of measurement of radio disturbance characteristics: Part 4 Industrial, scientific and medical (ISM) radio-frequency equipment	Identical to CISPR 11 : 1997
CISPR 16-1 (All parts) Specification for radio disturbance and immunity measuring apparatus and methods — Part 1: Radio disturbance and immunity measuring apparatus	IS 10052 (All parts) Specification for radio disturbance and immunity measuring apparatus and methods	Technically Equivalent
CISPR 18-2 Radio interference characteristics of overhead power lines and high-voltage equipment — Part 2: Methods of measurement and procedure for determining limits	IS 12233 (Part 1/ Sec 2) : 1987 Electromagnetic interference characteristics of overhead power lines and high-voltage equipment: Part 1 Description of phenomena, Section 2 Effects of corona from conductors	do

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

International Standard	*Title*
IEC 60050-131	International Electrotechnical Vocabulary (IEV) — Part 131: Circuit theory
IEC 60050-581	International Electrotechnical Vocabulary (IEV) — Chapter 581: Electromechanical components for electronic equipment
IEC 60050-811	International Electrotechnical Vocabulary (IEV) — Chapter 811: Electric traction
IEC 60050-826	International Electrotechnical Vocabulary (IEV) — Part 826: Electrical installations
IEC 60073	Basic and safety principles for man-machine interface marking and identification — Coding principles for indicators and actuators
IEC/TR 60083	Plugs and socket-outlets for domestic and similar general use standardized in member countries of IEC
IEC 60255-21-1	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	Electrical relays — Part 21: Vibration, shock, bump and seismic tests on measuring relays and protection equipment — Section 3: Seismic tests
IEC 60309-1	Plugs, socket-outlets and couplers for industrial purposes — Part 1: General requirements
IEC 60309-2	Plugs, socket-outlets and couplers for industrial purposes — Part 2: Dimensional interchangeability requirements for pin and contact-tube accessories
IEC 60417	Graphical symbols for use on equipment
IEC 60480	Guidelines for the checking and treatment of sulfur hexafluoride (SF_6) taken from electrical equipment and specification for its re-use

[1)] Withdrawn and replaced by IEC 62271-207 : 2007.

International Standard	*Title*
IEC 60695-7 (All parts)	Fire hazard testing — Part 7:Toxicity of fire effluent
IEC 60730-2-9	Automatic electrical controls for household and similar use — Part 2-9: Particular requirements for temperature sensing controls
IEC 60730-2-13	Automatic electrical controls for household and similar use — Part 2-13: Particular requirements for humidity sensing controls
IEC 60932	Additional requirements for enclosed switchgear and controlgear from 1 kV to 72,5 kV to be used in severe climatic conditions
IEC 60947-7-1	Low-voltage switchgear and controlgear — Part 7-1: Ancillary equipment — Terminal blocks for copper conductors
IEC 60947-7-2	Low-voltage switchgear and controlgear — Part 7-2: Ancillary equipment — Protective conductor terminal blocks for copper conductors
IEC 61000-4-11	Electromagnetic compatibility (EMC) — Part 4-11: Testing and measurement techniques — Voltage dips, short interruptions and voltage variations immunity tests
IEC 61000-4-17	Electromagnetic compatibility (EMC) — Part 4-17: Testing and measurement techniques — Ripple on d.c. input power port immunity test
IEC 61000-4-18	Electromagnetic compatibility (EMC) — Part 4-18: Testing and measurement techniques — Damped oscillatory wave immunity test
IEC 61000-4-29	Electromagnetic compatibility (EMC) — Part 4-29: Testing and measurement techniques — Voltage dips, short interruptions and voltage variations on d.c. input power port immunity tests
IEC 61000-5 (All parts)	Electromagnetic compatibility (EMC) — Part 5: Installation and mitigation guidelines
IEC 61000-6-2	Eletromagnetic compatibility (EMC) — Part 6-2: Generic standards — Immunity for industrial environments
IEC 61000-6-5	Electromagnetic compatibility (EMC) — Part 6-5: Generic standards — Immunity for power station and substation environments
IEC 61020-4	Electromechanical switches for use in electronic equipment — Part 4: Sectional specification for lever (toggle) switches
IEC 61180-1	High-voltage test techniques for low-voltage equipment — Part 1: Definitions, test and procedure requirements
IEC 61634	High-voltage switchgear and controlgear — Use and handling of sulphur hexafluoride (SF_6) in high-voltage switchgear and controlgear
IEC 61810 (All parts)	Electromechanical elementary relays
IEC 62063	High-voltage switchgear and controlgear — The use of electronic and associated technologies in auxiliary equipment of switchgear and controlgear
IEC 62262	Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)
IEC/TR 62271-300	High-voltage switchgear and controlgear — Part 300: Seismic qualification of alternating current circuit-breakers
IEC 62326-1	Printed boards — Part 1: Generic specification

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

Indian Standard

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR

PART 1 COMMON SPECIFICATIONS

1 General

1.1 Scope

This part of IEC 62271 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.

NOTE For the use of this standard, high voltage (see IEV 601-01-27) is the rated voltage above 1 000 V. However, the term medium voltage (see IEV 601-01-28) is commonly used for distribution systems with voltages above 1 kV and generally applied up to and including 52 kV.

1.2 Normative references

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

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

IEC 60038:1983, *IEC standard voltages*

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

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

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

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

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

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

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

IEC 60050-581, *International Electrotechnical Vocabulary (IEV) – Chapter 581: Electro-mechanical components for electronic equipment*

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

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

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

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

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

IEC 60051-1, *Direct acting indicating analogue electrical measuring instruments and their accessories – Part 1: Definitions and general requirements common to all parts*

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

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

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

IEC 60059, *IEC standard current ratings*

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

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

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

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

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

IEC 60073, *Basic and safety principles for man-machine interface, marking and identification – Coding principles for indicators and actuators*

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

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

IEC 60085, *Electrical insulation – Thermal classification*

IEC 60115-4 (all parts), *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, *Conductors of insulated cables*

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

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

IEC 60255-21-1, *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, *Electrical relays – Part 21: Vibration, shock, bump and seismic tests on measuring relays and protection equipment – Section 3: Seismic tests*

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

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

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

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

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

IEC 60376, *Specification of technical grade sulfur hexafluoride (SF_6) for use in electrical equipment*

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

IEC 60417, *Graphical symbols for use on equipment*

IEC 60445, *Basic and safety principles for man-machine interface, marking and identification – Identification of equipment terminals and conductors terminations*

IEC 60480, *Guidelines for the checking and treatment of sulfur hexafluoride (SF_6) taken from electrical equipment and specification for its re-use*

IEC 60502-1, *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, *Artificial pollution tests on high-voltage insulators to be used on a.c. systems*

IEC 60512-2 (all parts), *Connectors for electronic equipment – Tests and measurements – Part 2: Electrical continuity and contact resistance tests*

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

IEC 60617, *Graphical symbols for diagrams*

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

IEC 60695-1 (all parts), *Fire hazard testing – Part 1: Guidance for assessing the fire hazard of electrotechnical products*

IEC 60695-7 (all parts), Fire hazard testing – *Part 7:Toxicity of fire effluent*

IEC 60721-1, *Classification of environmental conditions – Part 1: Environmental parameters*

and their severities

IEC 60721-2 (all parts), *Classification of environmental conditions – Part 2: Environmental conditions appearing in nature – Temperature and humidity*

IEC 60721-3 (all parts), *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities*

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

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

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

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

IEC 60909-1, *Short-circuit currents in three-phase a.c. systems – Part 1: Factors for the calculations of short-circuit currents according to IEC 60909-0*

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

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

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

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

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

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

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

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

IEC 61000-4-1, *Electromagnetic compatibility (EMC) – Part 4-1: Testing and measurement techniques – Overview of IEC 61000-4 series*

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

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

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

IEC 61000-4-17, *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 port immunity tests*

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

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

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

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

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

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

IEC 61810 (all parts), *Electromechanical elementary relays*

IEC 62063, *High-voltage switchgear and controlgear – The use of electronic and associated technologies in auxiliary equipment of switchgear and controlgear*

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

IEC 62271-2, *High-voltage switchgear and controlgear – Part 2: Seismic qualification for rated voltages of 72,5 kV and above*

IEC/TR 62271-300, *High-voltage switchgear and controlgear – Part 300: Seismic qualification of alternating current circuit-breakers*

IEC 62326-1, *Printed boards – Part 1:Generic specification*

CISPR 11, *Industrial, scientific and medical (ISM) radio-frequency equipment – Electromagnetic disturbance characteristics – Limits and methods of measurement*

CISPR 16-1 (all parts), *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1: Radio disturbance and immunity measuring apparatus*

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

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 (refer to 2.2).

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

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

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

b) The influence of solar radiation may be neglected.

c) The altitude does not exceed 1 000 m.

d) The ambient air is not significantly polluted by dust, smoke, corrosive and/or flammable gases, vapours or salt. The manufacturer will assume that, in the absence of specific requirements from the user, there are none.

e) The conditions of humidity are as follows:

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

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

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

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

   For these conditions, condensation may occasionally occur.

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

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

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

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

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

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

   Rapid temperature changes should be taken into account.

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

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

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

c) The altitude does not exceed 1 000 m.

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

e) The ice coating shall be considered in the range from 1 mm up to, but not exceeding, 20 mm.

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

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

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

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

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

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

2.2 Special service conditions

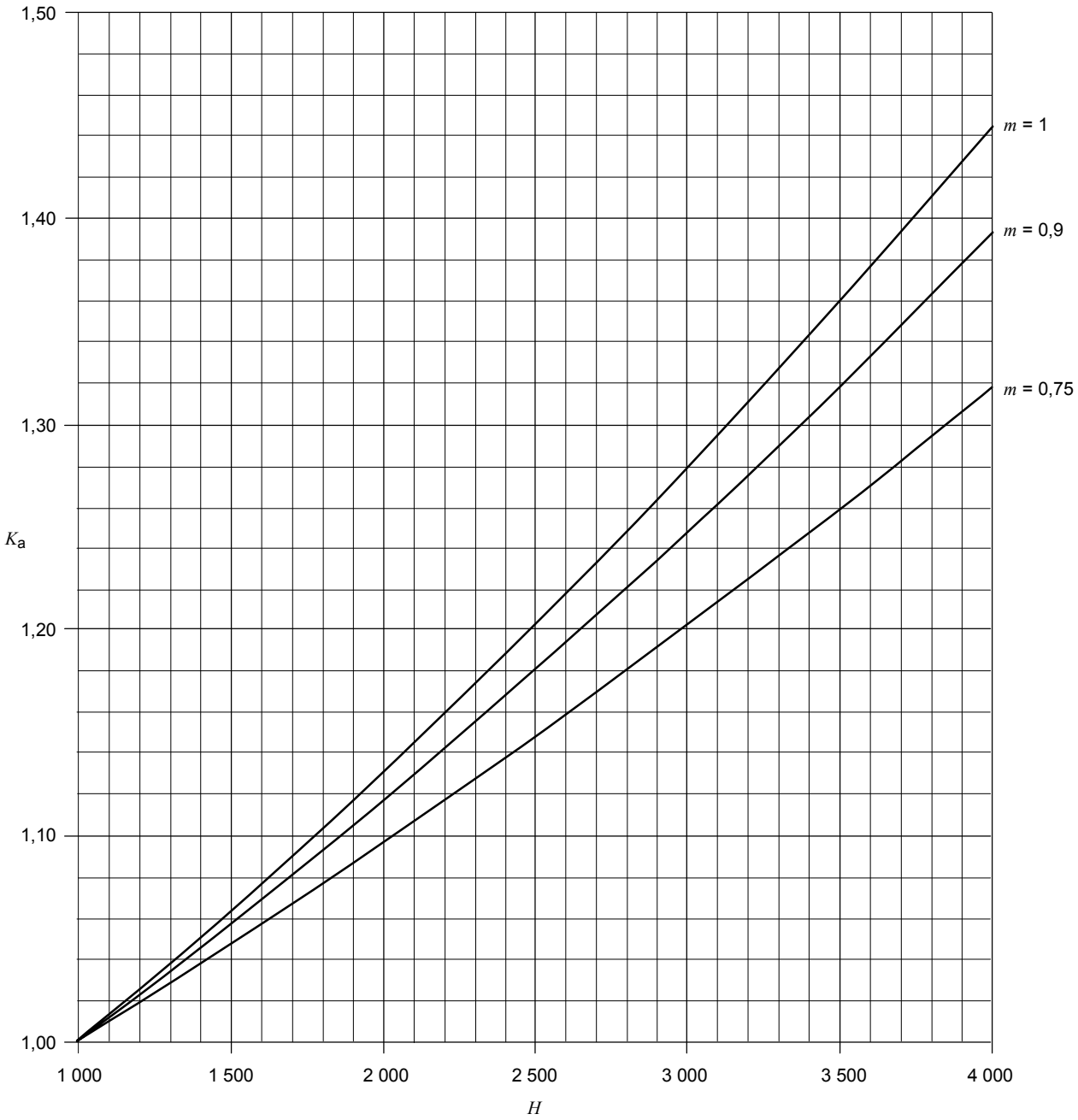
When high-voltage switchgear and controlgear is used under conditions different from the normal service conditions given in 2.1, the user's requirements should refer to standardized steps as follows.

2.2.1 Altitude

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

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

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



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

$$K_a = e^{m\,(H-1\,000)/8150}$$

where

H is the altitude, in metres;

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

- m = 1 for power-frequency, lightning impulse and phase-to-phase switching impulse voltages;
- m = 0,9 for longitudinal switching impulse voltage;
- m = 0,75 for phase-to-earth switching impulse voltage.

Figure 1 – Altitude correction factor

2.2.2 Pollution

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

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

2.2.3 Temperature and humidity

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

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

b) –5 °C and +55 °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, shock or tilting

Standard switchgear and controlgear is designed for mounting on substantially level structures, free from excessive vibration, shock, or tilting. Where any of these abnormal conditions exists, requirements for the particular application should be specified by the user.

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

2.2.5 Wind speed

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

2.2.6 Other parameters

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050(131), IEC 60050(151), IEC 60050(191), IEC 60050(351), IEC 60050(441), IEC 60050(446), IEC 60050(551), IEC 60050(581), IEC 60050(601), IEC 60050(604), IEC 60050(605), IEC 60050(811), and IEC 60050(826), some of which are recalled hereunder, as well as the following, apply.

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

3.1 General terms

3.1.1
switchgear and controlgear
general term covering switching devices and their combination with associated control,

measuring, protective and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, enclosures and supporting structures

[IEV 441-11-01]

3.1.2
external insulation
distances in atmosphere and 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
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
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

NOTE This protection may be provided
– by means of the enclosure itself;
– by means of barriers as part of the enclosure or distances inside the enclosure.

[3.6 of IEC 60529]

3.1.5
IK code
coding system to indicate the degree of protection provided by an enclosure against harmful external mechanical impacts

[3.3 of IEC 62262]

3.1.6
maintenance
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]

3.1.7
scheduled maintenance
preventive maintenance carried out in accordance with an established time schedule

[IEV 191-07-10]

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

without dismantling

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

NOTE 2 Observations resulting from inspection can lead to the decision to carry out overhaul.

3.1.9
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.

3.1.10
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

3.1.11
overhaul
work performed 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 (within tolerance)

3.1.12
down time
time interval during which an item is in a down state

[IEV 191-09-08]

3.1.13
failure
termination of the ability of an item to perform a required function

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.

[IEV 191-04-01]

3.1.14
major failure (of switchgear and controlgear)
failure of 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, for example, the backup protective equipment will be required to remove the fault or will result in mandatory removal from service within 30 min for unscheduled maintenance

3.1.15
minor failure (of switchgear and controlgear)
any failure of a constructional element or a subassembly which does not cause a major failure of the switchgear and controlgear

3.1.16
defect
imperfection in the state of an item (or inherent weakness) which can result in one or more failures of the item itself, or of another item under the specific service or environmental or maintenance conditions, for a stated period of time

3.1.17
ambient air temperature
temperature, determined under prescribed conditions, of the air surrounding the complete switching device or fuse

NOTE For switching devices or fuses installed inside an enclosure, it is the temperature of the air outside the enclosure.
[IEV 441-11-13]

3.1.18
servicing level
ground level or fixed permanent floor level from which an authorized person can operate a device

3.1.19
non-exposed type
type of component of which no live part can readily be touched

3.1.20
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.

3.1.21
supervision
activity, performed either manually or automatically, intended to observe the state of an item

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

[IEV 191-07-26]

NOTE 2 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
test specimen
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
part of switchgear and controlgear intended for transportation without being dismantled

3.3.2

busbar
[IEV 605-02-02]

3.4 Switching devices

Definitions of particular switching devices will be found in the specific product standards.

3.4.1
vacuum interrupter
switching component in which high-voltage electrical contacts operate in a highly evacuated, hermetically sealed environment

3.5 Parts of switchgear and controlgear

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

[IEV 826-12-20]

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

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

b) Barriers, shapes of openings or any other means (whether attached to the enclosure or formed by the enclosed equipment) suitable to prevent or limit the penetration of the specified test probes, are considered as a part of the enclosure, when they are secured in position either by means of interlocks, keys, or by hardware requiring a tool to be removed.

3.5.2
hazardous part
part that is hazardous to approach or touch

[3.5 of IEC 60529]

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

[IEV 441-15-05]

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

NOTE Some auxiliary circuits fulfil supplementary functions such as signaling, interlocking, etc., and, as such, they may be part of the control circuit of another switching device.

[IEV 441-15-04]

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

[IEV 441-15-03]

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

[IEV 441-15-11]

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

NOTE A control switch consists of one or more contact elements with a common actuating system.

[IEV 441-14-46]

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

[IEV 441-15-10]

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

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

[IEV 441-15-25]

3.5.12

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

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

NOTE The actuating quantity may be pressure, temperature, velocity, liquid level, elapsed time, etc.

[IEV 441-14-48]

3.5.14
low-energy contact
contact designed to be used in very low-energy circuits, for example, for monitoring or information technology

NOTE Typical applications are contacts inserted into a load circuit through which flows a current of some mA 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 normally not removed after the equipment is put in service

3.5.17
partition (of an assembly)
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)
set of components of a measuring instrument intended to indicate the value of the measurand

NOTE By extension, the indicating means or setting device of any instrument such as a material measure or a signal generator.

[IEV 311-05-02]

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

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

NOTE 2 The term “terminal” has a related meaning in IEC 60050-151.

[IEV 131-11-11]

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
conductor electrically connected to the neutral point and capable of contributing to the distribution of electrical energy

[IEV 826-14-07]

3.5.24
protective conductor
(symbol PE)
conductor provided for purposes of safety, for example protection aginst electric shock

NOTE In an electrical installation, the conductor identified PE is normally also considered as protective earthing conductor.

[IEV 826-13-22]

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

[IEV 826-13-25, modified]

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
dependent-time measuring relay which is intended to protect an equipment from electrical thermal damage by the 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
electric circuit supplying one or more distribution boards

[IEV 826-14-02]

3.5.33
final circuit (of buildings)
electric circuit intended to supply directly electric current using equipment or socket-outlets

[IEV 826-14-03]

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
operations 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 151-13-15]

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
auxiliary and control circuits
entity of

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

3.5.45
subassembly (of auxiliary and control circuits)
part of auxiliary and control circuits, with regard to function or position. A subassembly has its own interface and is normally placed in a separate enclosure

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

3.5.47
electronic device
device the function of which is based on charge carriers moving through a semiconductor, a high vacuum or a gas discharge

[IEV 551-14-01]

3.5.48
interlocking device
device which makes the operation of a switching device dependent upon the position or operation of one or more other pieces of equipment

[IEV 441-16-49]

3.6 Operation

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

[IEV 441-16-14]

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

NOTE This kind of operation may be subdivided according to:

1 the manner of storing the energy (spring, weight, etc.);

2 the origin of the energy (manual, electric, etc.);

3 the manner of releasing the energy (manual, electric, etc.).

[IEV 441-16-15]

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

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

[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.

3.6.5 Definitions relative to pressure (or density)

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

3.6.5.2
rated filling pressure for operation p_{rm} (or density ρ_{rm})
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

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

3.6.5.4
alarm pressure for operation p_{am} (or density ρ_{am})
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

3.6.5.5
minimum functional pressure p_{me} (or density ρ_{me}) for insulation and/or switching
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

3.6.5.6
minimum functional pressure for operation p_{mm} (or density ρ_{mm})
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. This pressure is often designated as interlocking pressure

3.6.6 Definitions relating to gas and vacuum tightness

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

3.6.6.1
gas-filled compartment
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).

3.6.6.2
controlled pressure system for gas
volume which is automatically replenished from an external compressed gas supply 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.

3.6.6.3
closed pressure system for gas
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.

3.6.6.4
sealed pressure system
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.

3.6.6.5
absolute leakage rate
F
amount of gas escaped by time unit, expressed in Pa $\times$ m^3/s

3.6.6.6
permissible leakage rate
F_p
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 subassemblies connected together in one pressure system

3.6.6.7
relative leakage rate
F_{rel}
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

3.6.6.8
time between replenishments
t_r
time elapsed between two replenishments performed either manually or automatically when the pressure (density) reaches the alarm level, to compensate the leakage rate F. This value is applicable to closed pressure systems

3.6.6.9
number of replenishments per day
N
number of replenishments to compensate the leakage rate F. This value is applicable to controlled pressure systems

3.6.6.10
pressure drop
Δp
drop of pressure in a given time caused by the leakage rate F, without replenishment

3.6.6.11
tightness coordination chart
TC
survey document supplied by the manufacturer, used when testing parts, components or sub-assemblies, to demonstrate the relationship between the tightness of a complete system and that of the parts, components and/or sub-assemblies

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

3.6.6.13
sniffing
action of slowly moving a leak meter sensing probe around an assembly to locate a gas leak

3.6.7 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.

3.6.7.1
controlled pressure system for liquid
volume which is automatically replenished with liquid

3.6.7.2
closed pressure system for liquid
volume which is manually replenished only periodically with liquid

3.6.7.3
absolute leakage rate
F_{liq}
amount of liquid escaped by time unit, expressed in cm^3/s

3.6.7.4
permissible leakage rate
$F_{p(liq)}$
maximum permissible leakage rate specified by the manufacturer for a liquid pressure system

3.6.7.5
number of replenishments per day
N_{liq}
number of replenishments to compensate the leakage rate F_{liq}. This value is applicable to controlled pressure systems

3.6.7.6
pressure drop
ΔP_{liq}
drop in pressure in a given time caused by the leakage rate F_{liq} without replenishment

3.7 Characteristic quantities

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

[IEV 441-17-35, modified]

3.7.2
degree of protection
extent of protection provided by an enclosure against access to hazardous parts, against ingress of solid foreign objects and/or ingress of water and against mechanical impact (refer to IEC 60529 and IEC 62262)

3.7.3
rated value
value of a quantity used for specification purposes, established for a specified set of operating conditions of a component, device, equipment or system

[IEV 151-16-08]

3.7.4
non-sustained disruptive discharge
NSDD
disruptive discharge associated with current interruption, that does not result in the resumption of power frequency current or, in the case of capacitive current interruption, does not result in current in the main load circuit

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4 Ratings

The common ratings of switchgear and controlgear assigned by the manufacturer, including their operating devices and auxiliary equipment, should be selected from the following (as applicable):

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 controlled pressure systems;

k) rated filling levels for insulation and/or operation.

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

4.1 Rated voltage (U_r)

The rated voltage is equal to the maximum system voltage for which the equipment is designed. It indicates the maximum value of the "highest system voltage" of networks for which the equipment may be used (refer to Clause 9 of IEC 60038). Standard values of rated voltages are given below.

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 (Voltages based on the current practice in some areas, like North America): – 4,76 kV – 8,25 kV – 15 kV – 15,5 kV – 25,8 kV – 27 kV – 38 kV – 48,3 kV – 72,5 kV – 123 kV – 145 kV – 170 kV – 245 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 (20 °C), pressure(101,3 kPa) and humidity (11 g/m^3)) specified in IEC 60071-1.

These withstand voltages include the altitude correction to a maximum altitude of 1 000 m specified for the normal operating conditions (see 2.1). For special service conditions, refer to 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" 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 functional requirements specified for disconnectors.

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 (based on current practice in some areas, including North America)[a]

Rated voltage U_r kV (rms value)	Rated power frequency withstand voltage U_d kV (rms value)			Rated lightning impulse withstand voltage U_p kV (peak value)	
	Common value		Across the isolating distance[b]	Common value	Across isolating distance[b]
	Dry 1 min	Wet[e] 10 sec	Dry 1 min		
(1)	(2)	(2a)	(3)	(4)	(5)
4,76[c]	19	- -	21	60	66
8,25[c]	36	- -	40	95	105
8,25[d]	38	30	42		
15[c]	36	30	40	95	105
15,5[d]	50	45	55	110	121
25,8[c]	60	50	66	125	- -
				150	- -
27,0[c]	60	50	66	125	- -
27,0[d]	70	60	77	150	165
38[c]	70	60	- -	150	- -
	80	75	- -	200	- -
38[d]	95	80	105	200	220
48,3[c]	105	95	- -	250	- -
48,3[d]	120	100	132	250	275
72,5[c]	160	140	- -	350	- -
72,5[d]	175	145	193	350	385
123[c]	260	230	- -	550	- -
123[d]	280	230	308	550	605
145[c]	310	275	- -	650	- -
145[d]	335	275	369	650	715
170[c]	365	315	- -	750	- -
170[d]	385	315	424	750	825
245[c]	425	350	- -	900	- -
245[d]	465	385	512	900	990

a For rated voltages higher than 72,5 kV up to and including 245 kV, the values in Table 1a are also applicable.

b Isolation of indoor circuits is normally achieved by withdrawing the removable switching device. Refer to relevant equipment standards for testing methods and requirements where this method of isolation is applicable.

c These ratings are generally applicable to switchgear equipment that is not used for isolation, for example high voltage circuit-breakers and reclosers. Refer to relevant equipment standards.

d These ratings are generally applicable to switchgear equipment that is used for circuit isolation, for example high voltage switches. Refer to relevant equipment standards.

e The power frequency withstand test under wet conditions is only required for outdoor switchgear

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 2)	**Across open switching device and/or isolating distance** (Note 2)	**Phase-to-earth and across open switching device**	**Between phases** (Notes 2 and 3)	**Across isolating distance** (Notes 1 and 2)	**Phase-to-earth and between phases**	**Across open switching device and/or isolating distance** (Notes 1 and 2)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
300	395	435	750	1 125	700(+245)	950	950(+170)
			850	1 275		1 050	1 050(+170)
362	450	520	850	1 275	800(+295)	1 050	1 050(+205)
			950	1 425		1 175	1 175(+205)
420	520	610	950	1 425	900(+345)	1 300	1 300(+240)
			1 050	1 575		1 425	1 425(+240)
550	620	800	1 050	1 680	900(+450)	1 425	1 425(+315)
			1 175	1 760		1 550	1 550(+315)
800	830	1150	1 425	2 420	1 175(+650)	2 100	2 100(+455)
			1 550	2 480			

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

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

NOTE 2 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.

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

NOTE 3 These values are derived using the multiplying factors given in Table 3 of IEC 60071-1.

Table 2b – Additional rated insulation levels, based on current practice in some areas, including 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)	Across open switching device and/or isolating distance (Note)	Phase-to-earth switching device closed	terminal to terminal, switching device open	Phase-to-earth and between phases	Across open switching device and/or isolating distance (Note)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
362 [c]	520	610	950	900	1 300	1 300
362 [d]	610	671	- -	- -	1 300	1 430
550 [c]	710	890	1 175	1300	1800	1 800
550 [d]	810	891	- -	- -	1 800	1 980
800 [c]	960	1 056	1425	1500	2 050	2 050
800 [d]	940	1 034	- -	- -	2 050	2 255

NOTE 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 (7) are applicable for type tests only.

[c] These ratings are generally applicable to switchgear equipment that is not used for isolation, for example, high-voltage circuit-breakers and reclosers. Refer to relevant equipment standards.

[d] These ratings are generally applicable to switchgear equipment that is used for circuit isolation, for example high-voltage switches. Refer to relevant equipment standards.

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 the 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 (Refer to points 1, 2 and 3) (Refer to note)	Maximum value	
	Temperature °C	Temperature rise at ambient air temperature not exceeding 40 °C K
1 Contacts (refer to point 4)		
Bare-copper or bare-copper alloy		
– in air	75	35
– in SF_6 (sulphur hexafluoride) (refer to point 5)	105	65
– in oil	80	40
Silver-coated or nickel-coated (refer to point 6)		
– in air	105	65
– in SF_6 (refer to point 5)	105	65
– in oil	90	50
Tin-coated (refer to point 6)		
– in air	90	50
– in SF_6 (refer to point 5)	90	50
– in oil	90	50
2 Connection, bolted or the equivalent (refer to point 4)		
Bare-copper, bare-copper alloy or bare-aluminium alloy		
– in air	90	50
– in SF_6 (refer to point 5)	115	75
– in oil	100	60
Silver-coated or nickel-coated refer to point 6)		
– in air	115	75
– in SF_6 (refer to point 5)	115	75
– in oil	100	60
Tin-coated		
in air	105	65
– in SF_6 (refer to point 5)	105	65
– in oil	100	60
3 All other contacts or connections made of bare metals or coated with other materials	(Refer to point 7)	(Refer to point 7)
4 Terminals for the connection to external conductors by screws or bolts (refer to point 8)		
– bare	90	50
– silver, nickel or tin-coated	105	65
– other coatings	(Refer to point 7)	(Refer to point 7)

Table 3 *(continued)*

Nature of the part, of the material and of the dielectric (Refer to points 1, 2 and 3) (Refer to note)	Maximum value	
	Temperature °C	**Temperature rise at ambient air temperature not exceeding 40 °C** K
5 Oil for oil switching devices (refer to points 9 and 10)	90	50
6 Metal parts acting as springs	(Refer to point 11)	(Refer to point 11)
7 Materials used as insulation and metal parts in contact with insulation of the following classes (refer to point 12)		
– Y	90	50
– A	105	65
– E	120	80
– B	130	90
– F	155	115
– Enamel: oil base	100	60
synthetic	120	80
– H	180	140
– C other insulating material	(Refer to point 13)	(Refer to point 13)
8 Any part of metal or of insulating material in contact with oil, except contacts	100	60
9 Accessible 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 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 [1][1], 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.

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

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

b) after the short-time withstand current test;

c) after the mechanical endurance test;

according to the relevant 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.

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 be defined according to the d.c. time constant which is a system characteristic. A d.c. time constant of 45 ms covers the majority of cases and corresponds to a rated peak withstand current equal to 2,5 times the rated short-time

[1] Numbers in square brackets refer to the Bibliography.

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

For some applications, system characteristics are such that the d.c. time constant is higher than 45 ms. Other values generally suitable for special systems are 60 ms, 75 ms and 120 ms depending on the rated voltage. For those cases, the preferred value is 2,7 times the rated short-time withstand current.

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.

NOTE 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.

4.8.2 Rated supply voltage (U_a)

The rated supply voltage should be selected from the standard values given in Tables 4 and 5. The values marked with an asterisk are preferred values for electronic auxiliary equipment.

Table 4 – Direct current voltage

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

Table 5 – 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 the 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 (d.c. supply voltage) and IEC 61000-4-11 (a.c. supply voltage) 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 signaling;
– 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 d.c., 50 Hz and 60 Hz.

4.10 Rated pressure of compressed gas supply for controlled pressure systems

The preferred values of rated pressure (relative pressure) are:

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

4.11 Rated filling levels for insulation and/or operation

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

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 (refer to item a) of 10.4.1), except for sealed pressure systems.

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

5.1.1 Liquid level

A device for checking the liquid level, preferably during service, with indication of minimum and maximum limits permissible 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.

NOTE For sealed pressure systems, instructions for maintaining the liquid quality are not applicable.

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 (refer to item a) of 10.4.1), except for sealed pressure systems.

For sulphur hexafluoride (SF_6) filled switchgear and controlgear, SF_6 in accordance with either IEC 60376 or IEC 60480 can be used. In order to prevent condensation, the maximum allowable moisture content within gas-filled switchgear and controlgear filled with gas at the 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 60376 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.

5.3 Earthing of switchgear and controlgear

Switchgear and controlgear shall be provided with a reliable earthing terminal having a clamping screw or bolt for connection of an earthing conductor suitable for specified fault conditions. The connecting point shall be marked with the "protective earth" symbol, as indicated by symbol 5019 of IEC 60417. Parts of metallic enclosures connected to the earthing system may be considered as an earthing conductor.

All metallic components and enclosures that may be touched during normal operating conditions and are intended to be earthed shall be connected to an earthing terminal.

NOTE For connection of the earthing terminal of the switchgear and controlgear to the main station earth, refer to Clause 10 of IEC 61936-1 [2].

5.4 Auxiliary and control equipment

Auxiliary and control equipment is considered to be of conventional or non-conventional (electronic) design components. For non-conventional design components refer to IEC 62063..

For electronic devices, electro-magnetic (EM) susceptibility shall be considered (refer to IEC 61000-5).

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 (reference is made to Annex H).

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. 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

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

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

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 malfunction or failure.

The first objective is to prevent ignition due to an electrically energized part of auxiliary and control circuits. 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 design or choose components taking into account normal conditions and self-ignition characteristics due to the effects of the maximum fault power. 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 and/or ventilation.

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 applicable. Where an IEC standard does not exist the component should be qualified with reference to another standard (issued by a country or another organization).

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. These internal conditions can differ from the external service conditions specified in Clause 2.

Suitable precautions (insulation, heating, ventilation, etc.) should 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, operation counters, push-buttons, etc. according to the relevant specifications.

The loss of those precautional means should 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, 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

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

5.4.4.5.1 Cables and wiring

The specification of cables to connect auxiliary and control circuits of the switchgear and controlgear 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.

Where a facility for external wiring is required, an appropriate connecting device shall be provided 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.

Wire routing 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.

The number of connections made to a terminal shall not exceed its designed maximum.

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

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.

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, a set of two one-way positively driven auxiliary contacts (one for each direction) can be used.

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 (refer to 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 6.

Table 6 – Auxiliary contact classes

D.c. 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 covered by this table.

NOTE 2 If insufficient 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).

Examples of the use of the three contact classes are shown in Figure 2.

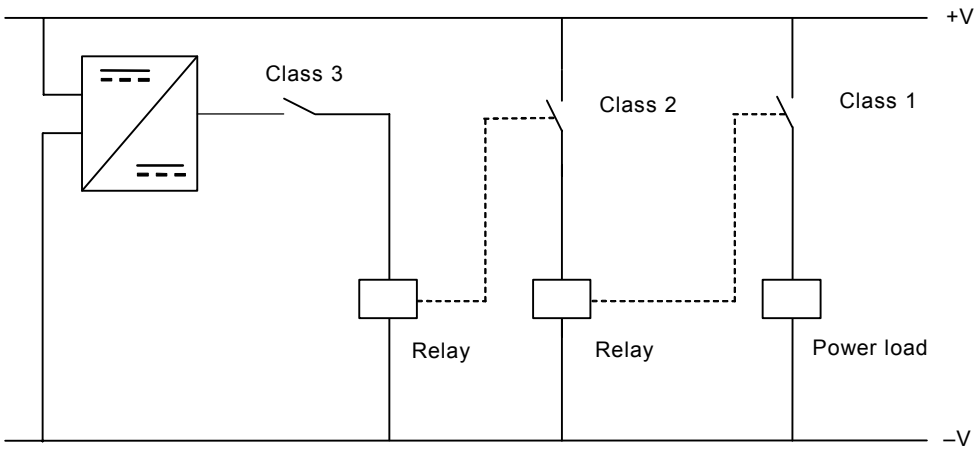


Figure 2 – Examples of classes of contacts

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 (see Annex G). 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 or the relevant equipment standard.

5.4.4.5.6 Relays

Where a relay is chosen and used at a voltage different from the rated voltage of auxiliary and control circuits, an appropriate device shall be provided to allow it to operate correctly under the conditions specified in 4.8 (for example, provision of a series resistor).

5.4.4.5.7 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.

5.4.4.5.8 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.

5.4.4.5.9 Operation counters

Operation 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.

5.4.4.5.10 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 disturbance produced by the lighting on the auxiliary and control-circuit components.

5.4.4.5.11 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.).

5.5 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 all currents up to its rated values when the energy storage device is suitably charged. 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.

A device indicating when the energy storage device is charged shall be mounted on the switching device except in the case of an independent unlatched operation.

It shall not be possible for the moving contacts to move from one position to the other, unless the stored energy is sufficient for satisfactory completion of the opening or closing operation. Stored energy devices shall be able to be discharged to a safe level prior to access.

5.6.1 Energy storage in gas receivers or hydraulic accumulators

When the energy storage device 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 85 % and 110 % of the 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 storage device is a spring (or weight), the requirements of 5.6 apply when the spring is charged (or the weight lifted).

5.6.3 Manual charging

If a spring (or weight) is charged by hand, the direction of motion of the handle shall be marked.

The manual charging facility shall be designed such that the handle is not driven by the operation of the switching device.

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 (refer to 4.8), the frequency, in the case of a.c., being the rated supply frequency (refer to 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.

5.6.5 Energy storage in capacitors

When the energy store is a charged capacitor, the requirements of 5.6 apply when the capacitor is charged.

5.7 Independent manual or power operation (independent unlatched operation)

The mechanism shall not reach the energy release point of a close operation if the switching device is in the closed state or of an open operation if it is open. This is to prevent the inadvertent, and potentially damaging, discharge of stored energy against an already closed or already open switching device.

It shall not be possible to progressively store energy by incomplete operations against an interlock, if supplied. During the operation, any movement of the contacts prior to release of the energy shall not reduce any electrically stressed gap to below that which will withstand rated insulation levels.

For a switching device with a short-circuit making capacity but no short-circuit current breaking capacity, a time delay (anti-reflex) shall be introduced between the closing and opening operation. This time delay shall be not less than the rated duration of the short circuit (refer to 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 (refer to 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 or the auxiliary supply, 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 (refer to 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 standards.

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 nameplates 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 or equivalent, the rated characteristics etc. as specified in the relevant IEC standards.

If applicable, the type and mass of insulating fluid shall be noted on the nameplate.

NOTE It should be stated whether pressures (or densities) are absolute or relative values.

For outdoor switchgear and controlgear, the nameplates and their methods of attachment 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 [2)] U_p
– rated switching impulse withstand voltage [2)] U_s
– rated power-frequency withstand voltage[2)] 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})

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

5.11 Interlocking devices

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

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

[2)] The values to be used for nameplates are phase-to-earth values.

earthed position shall be in accordance with IEC 60073.

The closed position shall be marked, preferably with a I (as per symbol IEC 60417-5007 (2007-04)). The open position shall be marked, preferably with an O (as per symbol IEC 60417-5008 (2007-04)).

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 provided by enclosures

Degrees of protection according to IEC 60529 and IEC 62262 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 (IP coding)

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 7.

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 7.

Table 7 gives details of objects which will be "excluded" from the enclosure for each of the degrees of protection. The term "excluded" means that solid foreign objects will not enter the enclosure fully, 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.

Table 7 – 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 the 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.		

5.13.2 Protection against ingress of water (IP coding)

For equipment of indoor installation 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 (IK coding)

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

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

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

5.14 Creepage distances for outdoor insulators

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

NOTE For insulators other than outdoor external ceramic or glass insulator specific requirements are under consideration.

5.15 Gas and vacuum tightness

The following specifications apply to all switchgear and controlgear which use vacuum or gas, other than ambient air, 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 and the time between replenishment under normal service condition shall be stated by the manufacturer and shall be consistent with a minimum maintenance and inspection philosophy.

The tightness of closed pressure systems for gas is specified by the relative leakage rate F_{rel} of each compartment; standardized values are:

– for SF_6 and SF_6 mixtures, the standardized values are 0,5 % and 1 % per year;

– for other gases, the standardized values are 0,5 %, 1 % and 3 % per year.

The value for the time between replenishment shall be at least 10 years for SF_6 systems and for other gases should be consistent with the tightness values.

The possible leakages between subassemblies having different pressures shall also be taken into account. 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 expected operating life with regard to leakage performance shall be specified by the manufacturer. Preferred values are 20 years, 30 years and 40 years.

NOTE To fulfil the expected operating life requirement, the leakage rate for SF_6 systems is considered to be 0,1 % per year.

5.16 Liquid tightness

The following specifications apply to all switchgear and controlgear which use liquids as insulating, or combined insulating and interrupting, or operating 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 leakage rate of closed pressure systems for liquid, pressurized or not, shall be specified by the manufacturer.

5.16.3 Leakage rates for liquid

The permissible leakage rate 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 Fire hazard (flammability)

The materials should be chosen and the parts designed in such a way that they retard the propagation of any flame resulting from accidental overheating in the switchgear and controlgear and reduce harmful effects on the local environment. In cases where product performance requires the use of flammable materials, product design should take flame retardation into account, if applicable.

IEC 60695-1 provides guidance for assessing the fire hazard of electrotechnical products.

IEC 60695-7 on the minimization of toxic hazards due to fires involving electrotechnical products should be applied.

The information supplied by manufacturer should enable the user to evaluate fire hazards.

5.18 Electromagnetic compatibility (EMC)

For the 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 where applicable.

The EMC is defined for interfaces or ports of auxiliary and control circuits or subassemblies. The limit of permissible, induced interferences must correspond to the test levels defined in 6.9.2 to ensure a proper EMC coordination between disturbances and immunity.

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 auxiliary and control circuits depend both on the auxiliary and control circuits themselves and on conditions such as the earthing and rated voltage of the main circuit.

5.19 X-ray emission

When subjected to high test voltages with the contacts open, vacuum interrupters may emit X-rays. In order to ensure that these are of an acceptable level all vacuum interrupters shall comply with 6.11. Subclause 6.11 sets limits for X-ray emission and prescribes the test procedures to be carried out to verify this.

NOTE These requirements and test procedures are based on ANSI C37.85-2002 [3].

5.20 Corrosion

Caution has to be taken against corrosion of the equipment during the service life. Corrosion shall not affect the functionality of the equipment under defined service conditions. All bolted or screwed parts of the main circuit and of the enclosure should remain easy to disassemble, as applicable. In particular, galvanic corrosion of materials in contact shall be considered because, for example, it may lead to the loss of tightness or increased contact resistance, reference is made to Annex H.

NOTE Corrosion stresses are strongly dependant on the installation. The atmospheric conditions are important, but the installation should consider the solar and temperature variation, the air flow, etc.

6 Type tests

6.1 General

The type tests are for the purpose of proving the ratings and 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

Group	Type tests	Subclause
1	Dielectric tests on main circuits	6.2
	Radio interference voltage (r.i.v.) test	6.9.1.1
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	Refer to relevant IEC standard
4	Tests to verify the degrees of protection of enclosures	6.7
	Tightness tests (where applicable)	6.8
	Mechanical tests	Refer to relevant IEC standard
	Environmental tests	Refer to relevant IEC standard
	Dielectric tests on auxiliary and control circuits	6.10.6

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 refer to 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. A summary list of the drawings and data schedules shall be supplied by the manufacturer and shall be uniquely referenced and shall contain a statement to the effect that the manufacturer guarantees that the drawings or data schedules listed are the correct version and truly represent the switchgear and controlgear to be tested.

After completion of verification, the summary list shall be retained by the test laboratory. The detail drawings and other data should be returned to the manufacturer. 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.

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 ratings and the test clauses of the relevant standards 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;
– manufacturer, type, serial numbers and ratings of essential parts, where applicable (for example, 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 including revision number 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.

NOTE NSDDs may occur during the recovery voltage period following a breaking operation. Their number is of no significance to interpreting the performance of the device under test. They should only be reported in the test report in order to differentiate them from restrikes.

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.

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.

If K_t is above 1,0 then to fully test the external insulation system the internal insulation will be overstressed and steps may be necessary to prevent overstressing the internal insulation systems. If K_t is below 1,0 then to test the internal insulation system fully, the external insulation will be overstressed and steps may be necessary to prevent overstressing the external insulation systems. Some methods are discussed in 11.4 of IEC 60060-1.

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.

Tests are valid if the height above ground during the tests is less than or equal to the height used 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 A.1 and A.2 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 during high-voltage testing is within safe limits (see 5.19). 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 (as defined by 4.1 of IEC 60060-1) 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

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

– each series has at least 15 tests;

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

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

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

Procedure C of IEC 60060-1 may be used when all three poles are tested.

NOTE 1 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.

NOTE 2 The determination of the location of the observed disruptive discharges may be done by the laboratory using sufficient detection means, for example, photographs, video recordings, internal inspection, etc.

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 the first connected part. When this part has passed the test according to the above-mentioned criteria, its qualification is not impaired by possible disruptive discharges which could occur in it during further tests on other parts.

NOTE 3 When testing switchgear incorporating an open vacuum interrupter contact gap, some preliminary impulse tests may be performed at up to and including the rated withstand voltage. Breakdowns that are observed during these preliminary tests can be disregarded for the withstand statistics used to determine pass or fail performance of the equipment.

NOTE 4 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. Parts operating at increased pressure should be clearly identified in the test report(s).

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 3, which shows a diagram of connection of a three-pole switching device, the test voltage shall be applied according to 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

NOTE 1 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.

NOTE 2 Test conditions 2, 3, 5, 6, 8, 9 may be omitted if the arrangement of the poles is fully symmetrical with respect to each other and to the frame.

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

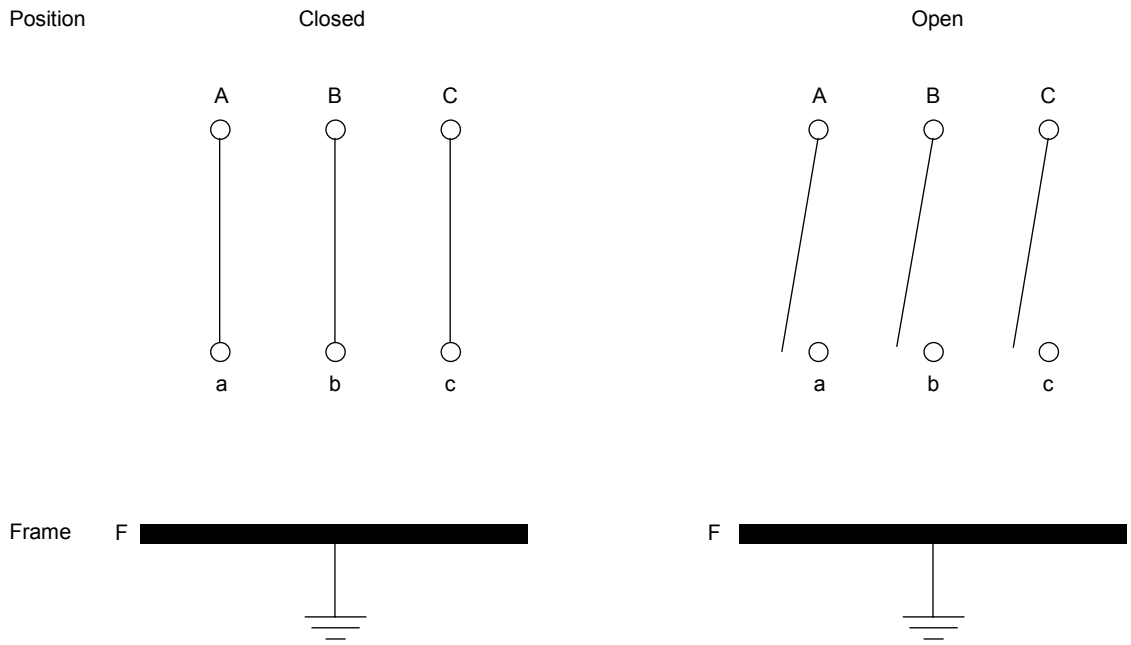


Figure 3 – Diagram of connections of a three-pole switching device

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 (refer to 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 Table 10.

Table 10 – Power-frequency test conditions

Test condition	Voltages applied to	Earth connected to
1	A and a	BCbcF
2	B and b	ACacF
3	C and c	ABabF
NOTE 1 Test conditions 3 may be omitted if the arrangement of the outer poles is symmetrical with respect to the centre pole and the frame.		
NOTE 2 Test conditions 2 and 3 may be omitted if the arrangement of the poles is fully symmetrical with respect to each other and to 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, the peak of a

power-frequency voltage or a d.c. 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 requirement shall be fulfilled: the sum of the impulse voltage peak and the complementary voltage at the instant of the peak of the impulse shall be equal to the total test voltage required with a tolerance of +3 %. To achieve such a condition, the instantaneous power-frequency voltage or, the impulse voltage might be increased. The instantaneous power-frequency voltage may be increased up to, but no more than $U_r \times \sqrt{2} / \sqrt{3}$ for the lightning impulse tests, and not more than $1{,}2 \times U_r \times \sqrt{2} / \sqrt{3}$ for the switching impulse tests.

The voltage drop on the power frequency wave 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

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

NOTE 1 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.

NOTE 2 Test conditions 2, 3, 5, 6 may be omitted if the arrangement of the poles is fully symmetrical with respect to each other and to the frame.

NOTE 3 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 and the two phases of the main circuit not under test are 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;

– If reference is made in 6.2.6 to this alternative method, all terminals not under test and the frame may be insulated from earth.

Table 12 shows how to apply the different voltages.

Table 12 – Test conditions for the alternative method

Test condition	Main part		Fixed at partial voltage U_f [a]
	Voltage U_t applied to	Earth connected to	
1	A	a	B, b, C, c, F
2	B	b	A, a, C, c, F
3	C	c	A, a, B, b, F
4	a	A	B, b, C, c, F
5	b	B	A, a, C, c, F
6	c	C	A, a, B, b, F

[a] If permitted. all terminals (not under test) and the frame may even be insulated from earth, considering reference is made in 6.2.6 to the alternative method of 6.2.5.2.

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 Tables 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 a 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 the power-frequency voltage wet tests for switchgear and controlgear of rated voltage equal to 170 kV and 245 kV, it is agreed 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 $U_r > 245$ 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 refer to 6.2.3). In addition,

phase-to-phase switching impulse voltage tests shall be performed as stated below. The test voltages are given in Tables 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 according to Table 12 with a test voltage as per column 5 of Tables 2, by the preferred method a) of 6.2.5.2 in which the main part shall be equal to or higher than 90 % of the value given in column 4 of Tables 2. This value shall not exceed 100 % of the value indicated in column 4 of Table 2 without the consent of the manufacturer. The complementary part shall be applied to the adjacent phase in phase opposition in order that the sum of both voltages (main part and complementary part) is equal to the value indicated in column 5 of Tables 2.

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 for outdoor insulators

No artificial pollution tests are necessary when the creepage distances of the insulators comply with the requirements of IEC 60815.

If the creepage distances do not comply with the requirements of IEC 60815, artificial pollution tests should be performed according to IEC 60507, using the rated voltage and the application factors given in IEC 60815.

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

The dielectric test on auxiliary and control circuits is covered under 6.10.6.

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, if not otherwise stated in the relevant product standards.

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

– 80 % of the value in Tables 1a or 1b, column 3, for isolating distance and 80 % of the value in column 2 for other equipment.

For equipment with rated voltages from 300 kV and above:

– 100 % of the value in Tables 2a or 2b, column 3, for isolating distance;
– 80 % of the value in Tables 2a or 2b, column 2, for other equipment.

NOTE 1 The reduction of the test voltage is motivated by the insulation coordination 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 product standard can specify that this condition-checking test is mandatory for certain types of equipment.

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

This test applies only to switchgear and controlgear having rated voltages of 123 kV and above and shall be made when specified in the relevant product standard. Radio interference voltage test is regarded as EMC emission test and covered under 6.9.1. Between 1 kV and less than 123 kV the r.i.v. effects are of a low level and are negligible.

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 (refer to the relevant standards).

The current during the measurement 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 measurement 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 after the test shall not be increased 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 energized 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 which decreases the effective current-carrying capabilities may occur. This results in an increased contact resistance or even no conduction at very low voltage while no problems are observed at higher voltage. This test is intended to verify the contact performance under these low-voltage conditions. The assessment criterion takes into account the non-linearity of the resistance. The 50 Ω value results from statistical considerations and has already been taken into account by users.

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 Condition 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 (including any extra cover for testing purpose, for example cover surrounding a busbar extension), and shall be protected against undue external heating or cooling.

When the 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 1 250 A, the tests may be made with all poles connected in series.

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

Where temporary connections to the main circuit are used, they shall be such that there is no significant difference in heat conducted away from, or conveyed to, the switchgear and controlgear during the test compared to the connections intended to be used for service. 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 in 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 at 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, provided that sufficient test data is recorded to enable calculation of thermal time constant.

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.

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

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 recorded during the tests 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 unfavorable 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 shall not exceed +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 at 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.

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 series.
– 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 the rated voltage of 52 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 $I_t^2 \times t_t$ is available, then it shall be determined from the oscillogram using the method of evaluating I_t given in Annex B. The value of $I_t^2 \times t_t$ during test shall be not less than the value of $I_k^2 \times t_k$ calculated from the rated short-time current (I_k) and the rated duration of short circuit (t_k), and shall not exceed this value by more than 10 % without the consent of the manufacturer.

When 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 Verification of the IK coding

In accordance with the requirements specified in IEC 62262, tests shall be performed on the enclosures of switchgear and controlgear fully assembled as under service conditions.

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

ribs or of similar parts, or depression of small dimension can be ignored.

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

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

6.8 Tightness tests

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.

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}.

Tightness test shall be performed with the same fluid and under the same conditions as used in service. If the fluid itself is not traceable additional traceable fluids might be added, for example helium.

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 subassemblies. In such cases, the leakage rate of the total system shall be determined by summation of the component leakage rates using the tightness coordination chart TC (refer to Annex E). The possible leakages between subassemblies of different pressures shall also be taken into account.

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

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.

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 13.

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

Table 13 – Permissible temporary leakage rates for gas systems

Temperature °C	Permissible temporary leakage rate
+40 and +50	$3F_p$
Ambient temperature	F_p
–5 /–10 /–15 /–25 /-30/–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.

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

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

where t is the test duration (in 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 D) may be used to measure the leakage rate F, which allows in combination with the tightness coordination chart TC, 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 (refer to IEC 60068-2-17) represents an adequate method to determine leakages in gas systems.

The tightness test is considered to be successful when the stated values of Table 13 are achieved within the limits of +10 %. This inaccuracy of the measurement shall be taken into account when calculating the period of time between replenishments.

NOTE A recommended test procedure is described in CIGRE brochure 304 [4].

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) Switchgear using vacuum interrupters

No specific tightness tests are required for vacuum interrupters since their tightness is verified during manufacturing process and because they are considered to have a zero leakage rate during their life. Nevertheless, instead of a tightness test, the vacuum integrity needs to be verified where specific standards ask for a tightness test (for example mechanical test, low and high temperature tests, etc.). The manufacturer shall state the expected shelf life of the interrupters or switches, together with the manufacture date (month, year) for each device.

The integrity of the vacuum is verified by the condition check test, refer to 6.2.11

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 $F_{\text{p(liq)}}$.

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)

6.9.1 Emission tests

6.9.1.1 Emission tests from the main circuits (radio interference voltage test, r.i.v.)

From 1 kV to 123 kV, the radio interference effects are negligible. 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 specific product standards.

Switchgear and controlgear shall be installed as stated in 6.2.3.

The test voltage shall be applied as follows.

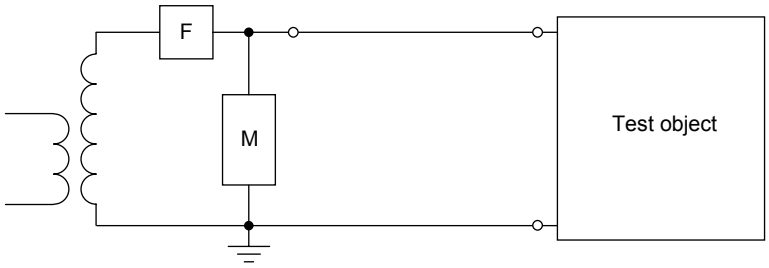
a) in closed position, between the terminals and the earthed frame;

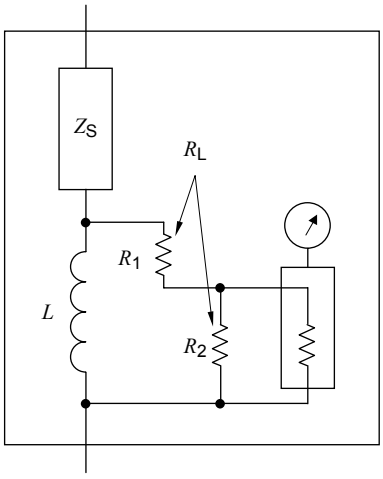
b) in open position, between one terminal and the other terminals connected to the earthed frame and then with the connections reversed if the switching device is not symmetrical.

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. During the tests the switchgear and controlgear shall be equipped with all accessories such as grading capacitors, corona rings, high-voltage connectors, etc. which may influence the radio interference voltage. 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 (refer to Figure 4) 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 μV.





Details of M

Key

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 inductance used to shunt power-frequency currents and to compensate for stray capacitance at the measuring frequency

Figure 4 – Diagram of a test circuit for the radio interference voltage test

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 (for example 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 radiofrequency 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 $1{,}1 \times U_r / \sqrt{3}$ 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 $0{,}3 \times U_r / \sqrt{3}$, raised again by steps to the initial value and finally decreased by steps to $0{,}3 \times U_r / \sqrt{3}$. 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 $0{,}1 \times U_r / \sqrt{3}$.

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

6.9.1.2 Emission tests from the auxiliary and control circuits

Auxiliary and control circuits of switchgear and controlgear shall be subjected to electromagnetic emission tests if they include electronic equipment or components. In other cases no tests are required.

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

The test shall be performed only on a representative auxiliary and control circuit, because the single components are tested according to the relevant standards.

Electronic equipment, which is part of the auxiliary and control circuits, shall fulfill the requirements with regard to radiated 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 auxiliary and control circuits

6.9.2.1 General

Auxiliary and control circuits 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 tests shall be performed only on a representative auxiliary and control circuit, because the variety of practical design is too big and also the single components are tested according to the relevant standards.

The following immunity tests are specified:

– electric fast transient/burst test (refer to 6.9.2.3). The test simulates the conditions caused by switching in the secondary circuit;
– oscillatory wave immunity test (refer to 6.9.2.4). 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 auxiliary and control circuits of switchgear and controlgear. These tests need not be repeated on complete auxiliary and control circuits. 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 auxiliary and control circuits to radio-frequency electromagnetic fields above the demonstrated value and should be avoided.

6.9.2.2 Guidelines for immunity tests

Electromagnetic immunity tests shall be made on complete auxiliary and control circuits or subassemblies. The tests may be made on

– the complete auxiliary and control circuits;
– 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 auxiliary and control circuits, without invalidating the type test of the complete system, provided that the overall wiring length and the number of individual wires connecting the subassembly to the auxiliary and control circuits is not greater than in the tested system.

Interchangeable subassemblies may be replaced by similar subassemblies, without invalidating the original type test, provided that

– rules for design and installation given in IEC 61000-6-5 are followed;

– type tests have been performed on the most complete subassembly applicable to the type of switchgear and controlgear;
– manufacturer's design rules are the same as for the type-tested subassembly.

The test voltage shall be applied to the interface of the auxiliary and control circuits 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.

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 with a repetition rate of 5 kHz. The ports and interfaces shall be chosen in accordance with IEC 61000-6-2.The test voltage and coupling shall be chosen according to Table 14.

Table 14 – Application of voltages at the fast transient/burst test

Interface	Relevance for equipment	Test voltage kV	Coupling
Power port	A.c. and d.c. power lines	2	CDN (NOTE 1)
Cabinet earth port		2	CDN (NOTE 1)
Signal port	Shielded and unshielded lines, carrying analogue and/or digital signals • control lines • communication lines (for example data buses) • measuring lines (for example CT, VT)	2	CCC or equivalent coupling methods (NOTE 2)
NOTE 1 CDN: Coupling decoupling network. NOTE 2 CCC: Capacitive coupling clamp.			

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 61000-4-18.

The ports and interfaces shall be chosen in accordance with IEC 61000-6-2.

Damped oscillatory wave tests shall be made at 100 kHz and 1 MHz, with a relative tolerance of ±30 %.

NOTE 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 30 MHz).

Tests shall be made for both common and differential mode. The test voltage and coupling method shall be chosen according to Table 15.

Table 15 – Application of voltage at the damped oscillatory wave test

Interface	Relevance for equipment	Test voltage kV	Coupling
Power port	A.c. and d.c. power lines	Differential mode: 1,0 Common mode: 2,5	CDN CDN (NOTE)
Signal port	Shielded and unshielded lines, carrying analogue and / or digital signals • control lines • communication lines (for example data buses) • measuring lines (for eaxample CT, VT)	Differential mode: 1,0 Common mode: 2,5	CDN CDN Or equivalent coupling method (NOTE)
NOTE CDN: coupling decoupling network.			

6.9.2.5 Behaviour of the secondary equipment during and after tests

The auxiliary and control circuits shall withstand each of the tests specified in 6.9.2.3 and 6.9.2.4 without permanent damage. After the tests it shall still be fully operative. Temporary loss of parts of the functionality is permitted according to Table 16.

Table 16 – Assessment criteria for transient disturbance immunity

Function	Criterion (NOTE)
Protection, teleprotection	A
Alarm	B
Supervision	B
Command and control	A
Measurement	B
Counting	A
Data processing – for high-speed protective system – for general use	 A B
Information	B
Data storage	A
Processing	B
Monitoring	B
Man-machine interface	B
Self-diagnostics	B
Processing, monitoring and self-diagnostic functions which are on-line connected, and are part of command and control circuits, shall fulfil criterion A.	
NOTE Criteria, according to IEC 61000-4-4 and IEC 61000-4-18: A: normal performance within the specification limits; B: temporary degradation or loss of function or performance which is self-recoverable.	

6.9.3 Additional EMC tests on auxiliary and control circuits

6.9.3.1 General

The objective of the tests described below is to qualify the whole assembly without repeating individual test on components. Therefore, tests on components which comply with their relevant IEC standards and with relevant rated values need not be repeated.

6.9.3.2 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 level 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).

6.9.3.3 Voltage dips, short interruptions and voltage variations on input power port immunity tests

Voltage dips, short interruptions and voltage variations tests on a.c. power ports shall be performed according to IEC 61000-4-11 and on d.c. power ports according to IEC 61000-4-29.

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 need 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

Generally no test is needed if adequate design is demonstrated.

However, in case of doubt, the metallic parts of the enclosures and/or metallic partitions and shutters or metallic parts of them shall be tested at 30 A (d.c.) to the earthing point provided.

The voltage drop shall be lower than 3 V.

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

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 6 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 6 for 30 ms, with a resistive load. 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 6, 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 Environmental tests

6.10.5.1 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.

If any other environmental tests are requested, due to special environmental conditions, then these tests shall be performed according to IEC 60068-2.

NOTE If the real service conditions deviate from the service conditions specified in Clause 2, other environmental tests may be requested and performed according to IEC 60068-2.

6.10.5.2 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.

6.10.5.3 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.

6.10.5.4 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.

6.10.5.5 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.

6.10.5.6 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 auxiliary and control circuits 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 16.

6.10.5.7 Final condition check

The power-frequency voltage withstand tests according to 6.10.6 shall be repeated after all other type tests have been completed, to confirm that there has been no reduction of performance during testing.

6.10.6 Dielectric test

Auxiliary and control circuits of switchgear and controlgear shall be subjected 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 power frequency tests shall be performed according to IEC 61180-1. The test voltage shall be 2 kV with 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.

The test voltage of motors and other devices such as electronic equipment 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 lower test voltages are used, the values shall be stated in the test document.

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).

6.11 X-radiation test procedure for vacuum interrupters

6.11.1 General requirements

6.11.1.1 Condition of interrupter to be tested

Tests on the X-radiation emission levels of vacuum interrupters shall be performed on new interrupters. The purpose of this type test is to verify that the X-radiation emitted from vacuum interrupters does not exceed the following:

a) 5 μSv per hour at 1 m distance at the maximum operating voltage U_r shown in Table 1a and Table 1b;
b) 150 μSv per hour at 1 m distance at the rated power-frequency withstand test voltage U_d shown in Table 1a and Table 1b.

6.11.1.2 Mounting of specimen

The interrupter shall be mounted in a test fixture, designed so that the open contact spacing may be set at the recommended minimum distance, and which will permit the application of a test voltage to one terminal of the interrupter while the other terminal is earthed. Interrupters designed for operation in an insulating medium other than air (such as oil or SF_6) may be tested in such a medium, if necessary, to withstand the test voltage.

The container for the insulating medium shall be of an insulating material having radiation attenuation no greater than that afforded by 9,5 mm thick methyl methacrylate. The insulating medium between the interrupter and radiation instrument shall be the minimum required for dielectric purposes.

6.11.1.3 Radiation instrument

A radiofrequency shielded radiation survey instrument having the following minimum specifications shall be used.

– Accuracy: Capable of measuring 150 μSv per hour with an accuracy of ± 25 % with a response time not to exceed 15 s.
– Energy response: 12 keV to 0,5 MeV ± 15 %.
– Sensitive area: 100 cm^2, maximum.

6.11.1.4 Location of radiation instrument

The sensing element of the radiation instrument shall be positioned in the plane of the separable contacts and pointed at the contacts from a distance of 1 metre from the nearest external surface of the interrupter (refer to Figure 5). When electrical safety requires the instrument to be located at a distance greater than 1 metre, the instrument reading shall be adjusted by applying the inverse square law as follows:

$$R(1\ \text{m}) = R(d) \times d^2$$

where $R(d)$ is the radiation level measured, at the distance d (in metres) from the external surface of the vacuum interrupter.

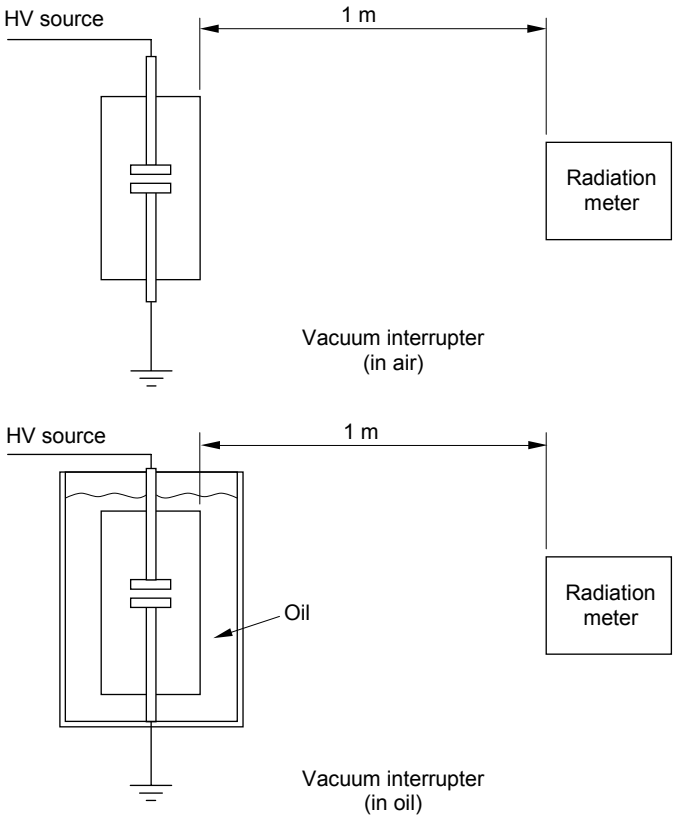


Figure 5 – Test location of radiation meter

6.11.2 Test voltage and measurement procedure

With the interrupter mounted in a test fixture, with the contacts blocked open at the minimum contact spacing specified, and with the radiation instrument in place (refer to Figure 5), a voltage shall be applied across the interrupter contacts equal to the maximum interrupter operating voltage equal to U_r shown in Table 1. After a minimum of 15 s, the X-radiation level on the radiation instrument shall be read.

Next, the voltage across the interrupter contacts shall be raised to a value equal to the power-

frequency insulation withstand test voltage equal to U_d shown in Table 1. After a minimum of 15 s, the X-radiation level on the radiation meter shall be read.

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 (for 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 the manufacturer and the user.

7.1 Dielectric test on the main circuit

A dry, short-duration power-frequency voltage test shall be applied. The test procedure shall be according to IEC 60060-1 and to 6.2, except that each pole or transport unit shall be tested 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 them.

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

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

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, subassemblies 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 by visual inspection.

Where visual inspection is not considered sufficient, the electrical continuity of earthed metallic parts should be checked as detailed in 6.10.3.

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

For gas-filled systems leakage detection by using a sniffing device may be used. The sensitivity of the sniffing device shall be at least 10^{-8} Pa $\times$ m^3/s.

Acceptance criteria shall be stated by the manufacturer to meet the specified time between replenishment.

In special cases the leak should be quantified by using a cumulative method as described in Annex E.

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 of the vacuum interrupter.

The test results shall be documented.

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 as required by the relevant product standard.

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 subassemblies is also permissible. In this case, a final check shall be performed at site.

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

Annex G provides a summary of the considerations for specifying the ratings of switchgear and controlgear.

8.1 Selection of rated values

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

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

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

8.2 Continuous or temporary overload due to changed service conditions

The temperature rise of any part of switchgear and controlgear shall not exceed the temperature-rise limits specified in Table 3 under the conditions specified in the test clauses.

Equipment may be assigned an overload capability for higher than rated normal current for a temporary period provided the temperature does not exceed the maximum temperature value specified in Table 3.

Equipment may be assigned an overload capability for higher than rated normal currents based on a lower ambient temperature provided the temperature does not exceed the maximum value temperature specified in Table 3.

NOTE 1 In the case of a switch, the overload capability may exceed its breaking capability.

NOTE 2 If such capability is assigned, it should be based on the results obtained from the temperature-rise test (refer to 6.5.2) by using the temperature rise, thermal time constant, actual current and actual ambient air temperature and maximum operating temperatures as defined in Table 3.

NOTE 3 When an overload capability is requested by users, the temporary or permanent overload requirements should be specified in accordance with this subclause.

Continuous or temporary overload should be established, on the basis of the results obtained from the temperature-rise test and test parameters: rated current, thermal time constant, temperature rise, ambient air temperature and maximum operating temperatures as defined in Table 3. Overload capability can be calculated with the following equations.

The overload current (I_s) for a given ambient temperature θ_a:

$$I_s = I_r \left[\frac{\theta_{max} - \theta_a}{\Delta\theta_r} \right]^{\frac{1}{n}} \quad (1)$$

The operating temperature during overload:

$$\theta_s = \Delta\theta_r \times \left(I_s / I_r \right)^n \times (1 - e^{-t/\tau}) + \theta_a \quad (2)$$

or the allowable duration (t_s) of overload current I_s after carrying a current I_i:

$$t_s = -\tau \ln\left[1 - \frac{(\theta_{max} - Y - \theta_a)}{Y\left(\left[\frac{I_s}{I_i}\right]^n - 1\right)}\right] \quad (3)$$

with

$$Y = (\theta_{max} - 40) \times \left[\frac{I_i}{I_r}\right]^n$$

where

θ_{max} is the maximum allowable total temperature (in °C) according to Table 3;

θ_a is the actual ambient temperature (in °C);

$\Delta\theta_r$ is the temperature rise at rated normal current I_r;

I_r is the rated normal current (in A);

τ is the thermal time constant (in h);

n is the overload exponent taking into account material, heat radiation, convection, etc.;

I_i is the initial current before application of the overload current (in A);

I_s is the overload current (in A);

t_s is the permissible time (in h) that the overload current (I_s) can be carried without exceeding the maximum temperature allowable (θ_{max}).

In general, no additional temperature-rise test is required if an exponent n = 2 (as a conservative estimate) is used for the determination of the operating temperature during overload or allowable overload duration. An exponent lower than n = 2 may be used for the calculation of the overload rating. It has to be demonstrated by calculation from test data.

NOTE 4 The time constant corresponds to the time to reach 63 % of the final temperature rise after stabilization.

9 Information to be given with enquiries, tenders and orders

The intention of this clause is to define information, which is necessary to enable the user to make an appropriate enquiry for equipment and to enable the supplier to give an adequate tender.

Furthermore, it enables the user to make a comparison and evaluation of offers from different suppliers.

NOTE 1 The supplier can either be a manufacturer or a contractor.

When enquiring about or ordering an installation of switchgear and controlgear the following information as a minimum should be supplied by the enquirer.

In addition to the list of type test reports (refer to Annex G) the first pages of the reports containing the results may be requested. On request the manufacturer shall supply the complete type test reports.

NOTE 2 The occurrence of abnormal environmental conditions should be specified by the user.

Annex G defines technical information in a tabular form to be exchanged between user and supplier.

9.1 Information with enquiries and orders

a) Particulars of the system

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

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

Any condition deviating from the normal or special service conditions or affecting the satisfactory operation of the equipment.

c) Particulars of the installation and its components

1) indoor or outdoor installation;
2) number of phases;
3) number of busbars, as shown in the single-line diagram;
4) rated voltage;
5) rated frequency;
6) rated insulation level;
7) rated normal currents of busbars and feeder circuits;
8) rated short-time withstand current (I_k);
9) rated duration of short circuit (if different from 1 s);
10) rated peak withstand current (if different from 2,5 I_k);
11) rated values of components;
12) degree of protection for the enclosure and partitions;
13) circuit diagrams.

d) Particulars of the operating devices

1) type of operating devices;
2) rated supply voltage (if any);
3) rated supply frequency (if any);
4) rated supply pressure (if any);
5) special interlocking requirements;
6) number of contacts other than an auxiliary or control contacts required (the user should state the contact performance needed).

In addition to these items the enquirer should indicate every condition which might influence the tender or the order, such as, for example, special mounting or installation conditions, the location of the external high-voltage connections or the rules for pressure vessels, requirements for cable testing.

Information should be supplied if type tests are requested.

9.2 Information with tenders

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

a) Rated values and characteristics as enumerated in item c) of 9.1.

Type test certificates or reports on request.

b) Constructional features, for example,

1) mass of the heaviest transport unit;
2) overall dimensions of the installation;
3) arrangement of the external connections;
4) future extensions if applicable;

5) facilities for transport and mounting;
6) mounting provisions;
7) accessible sides;
8) instructions for installation, operation and maintenance;
9) type of gas-pressure or liquid-pressure system;
10) rated filling level and minimum functional level;
11) volume or mass of fluid for the different compartments;
12) specification of fluid.

c) Particulars of the operating devices:
1) types and rated values as enumerated in item d) of 9.1;
2) current or power for operation;
3) operating times.

d) List of recommended spare parts that should be procured by the user.

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

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

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 include at least the items listed below.

10.2.1 Unpacking and lifting

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

Required information for unpacking should be given.

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

These instructions should also indicate

– the total mass of the apparatus inclusive of extinguishing or insulating fluids;
– the mass of extinguishing or insulating fluids;
– the mass of 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 J.

10.2.6 Basic input data by the user

a) Access limitations to the local site.
b) Local working conditions and any restrictions that may apply (for example, safety equipment, normal working hours, union requirements for supervisor, manufacturer's and local installation crew, etc.).
c) Availability and capacity of lifting and handling equipment.
d) Availability, number and experience of local personnel.

e) Specific pressure vessel rules and procedures that may apply during installation and commissioning tests.

f) Interface requirements for high-voltage cables and transformers.

g) In the case of extensions to existing switchgear and controlgear:

- provisions for the extension available within existing primary and secondary equipment;
- in-service conditions or operating restrictions that must be respected;
- safety regulations that must be adhered to.

10.2.7 Basic input data by the manufacturer

a) Space necessary for installation and assembly

b) Size and weight of components and testing equipment

c) Site conditions regarding cleanliness and temperature for clean installation and preparation area

d) Number and experience of local personnel required for installation

e) Time and activity schedules for installation and commissioning

f) Electric power, lighting, water and other needs for installation and commissioning

g) Proposed training of installation and service personnel

h) In case of extension to existing switchgear and controlgear

- out-of-service requirements of existing components related to the installation schedule;
- safety precautions.

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;

– as relevant, measures against corrosion should be given.

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's maintenance manual should include 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 (for example 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, subassemblies and significant parts.

   NOTE Expanded detail drawings which indicate the relative position of components in assemblies and subassemblies 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 (seeIEC 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 purchasers of a particular type of switchgear and controlgear about corrective actions required by systematic defects and failures detected in service.

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 perform maintenance, the maintenance manual of the manufacturer should be followed.

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 (for example 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 subassembly/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 to contribute 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;
   – cost of spare parts.

A failure report may include the following information:

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

11 Safety

High-voltage switchgear and controlgear can be considered safe when installed in accordance with the relevant installation rules including those provided by the manufacturers 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 switchgear and controlgear, additional safety features may be required.

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

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

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

11.1 Precautions by manufacturers

– Design and test of pressurized enclosures, pressure relief devices and relevant switchgear elements to international electrical standards such as IEC, ANSI, CENELEC, and JIS.

– Provide adequate and easy means to check interlocking systems (the most reasonable way to avoid human error).

– Explain safe operation of the switchgear clearly in instruction manuals. Explain precautions to prevent improper operation and the consequences of improper operation.

– Provide the user and/or contractor with appropriate information related to design of the surrounding area and, in the case of GIS in a building, ventilation and gas detection information, to minimize personnel risks in case a failure occurs.

11.2 Precautions by users

The following list is an example of precautions that may be taken by users.

– Limit access to the installation to people who are trained and authorized.

– Keep operators and other personnel instructed regarding risks and safety requirements including local regulations.

– Keep switchgear maintained and up to date in terms of technical standards, especially interlocking and protection devices.

– Use remote control and have the interlocking system working as intended.

– Select equipment that minimizes the risk to personnel from improper operation (for example, fast acting ground switches on lines, motor operators to allow remote operation).

– Coordinate the protection system with product properties (for example, do not reclose on internal faults).

– Prepare earthing procedures considering the difficulty of referring to and understanding the complex arrangement and operation of the switchgear and controlgear.

– Label equipment clearly for easy identification of individual devices and gas compartments.

Especially during maintenance, repair or extension work:

– Ensure that maintenance, repair and extension work is carried out only by qualified and trained personnel.

– Prepare a safety and protection plan for the work. Indicate who is responsible for planning, implementing and enforcing safety and protection measures.

– Check interlocking and protection devices before starting.

– Pay special attention to manual operations, especially when the switchgear and controlgear is energized.

– Inform personnel who may be near the switchgear and controlgear before operating the equipment (for example, a horn or flashing light).

– Mark emergency exits and keep passages clear of obstructions.

– Instruct the people involved how to work safely in a switchgear and controlgear environment and what to do in an emergency.

The following specifications of this standard provide personal safety measures for switchgear and controlgear against various hazards.

11.3 Electrical aspects

– insulation of the isolating distance (refer to 4.2);
– earthing (indirect contact) (refer to 5.3);
– separation of HV and LV circuits (refer to 5.4);

– IP coding (direct contact) (refer to 5.13.1).

11.4 Mechanical aspects

– pressurized components (refer to 5.2);
– manual actuating force (refer to 5.6.3);
– IP coding (moving parts) (refer to 5.13.1);
– mechanical impact protection (refer to 5.13.3).

11.5 Thermal aspects

– maximum temperature of accessible parts (refer to Table 3);
– flammability (refer to 5.17).

11.6 Operation aspects

– dependent power operation (refer to 5.5);
– manual charging (refer to 5.6.3);
– independent manual operation (refer to 5.7);
– interlocking devices (refer to 5.11);
– position indication (refer to 5.12).

12 Influence of the product on the environment

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

When fluids are used in switchgear and controlgear, as far as is practicable, instructions should be provided in order to allow the user to

– minimize the leakage rate;
– control the handling of the new and used fluids.

The manufacturer shall give guidance on request, concerning disassembly and end-of-life procedures for the different materials of the equipment and indicate the possibility to recycle.

Annex A
(normative)

Identification of test specimens

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 (for example, 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 and mounting points Enclosure(s) Pressure-relief devices Conducting parts of main circuit Earthing conductors and earthing connections Electrical clearances: – to earth, between open contacts – between poles Location and dimensions of barriers between poles Location of earthed metallic screens, shutters or partitions in relation to live parts Liquid insulation level Location and type designation of insulators Location and type designation of instrument transformers
Detailed drawings of insulators	Material Dimensions (including profile and creepage distances)
Arrangement drawings of cable boxes	Electrical clearances Principal dimensions Terminals Level or quantity and specifications of insulant in filled boxes Cable termination details

Drawings to be submitted	Drawing content (as applicable)
Detailed drawings of parts of the main circuit and associated components	Dimensions and material of principal parts Cross-sectional view through the axis of main and arcing contacts Travel of moving contacts Electrical clearance between open contacts Distance between point of contact separation and end of travel Assembly of fixed and moving contacts Details of terminals (dimensions, materials) Identity of springs Material and creepage distances of insulating parts
Detailed drawings of mechanisms (including coupling and 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 (refer to 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:

$$Z_0, Z_1 ... Z_{10}$$

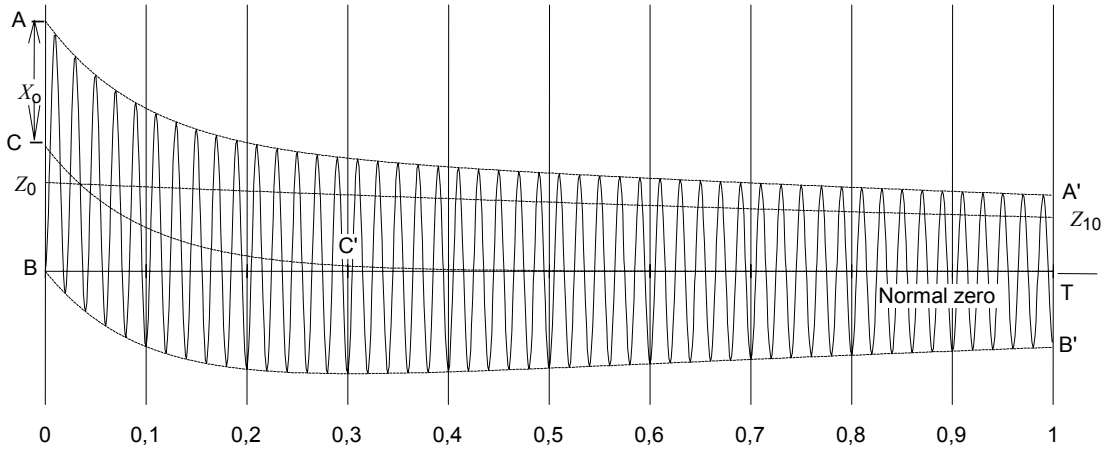
where

$Z = X / \sqrt{2}$ 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.



AA′ BB′	Envelopes of current wave
CC′	Displacement of current wave zero line from normal zero line at any instant
$Z_0 ... Z_{10}$	RMS value of a.c. component of current at any instant measured from normal zero; d.c. component is neglected
X_o	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.

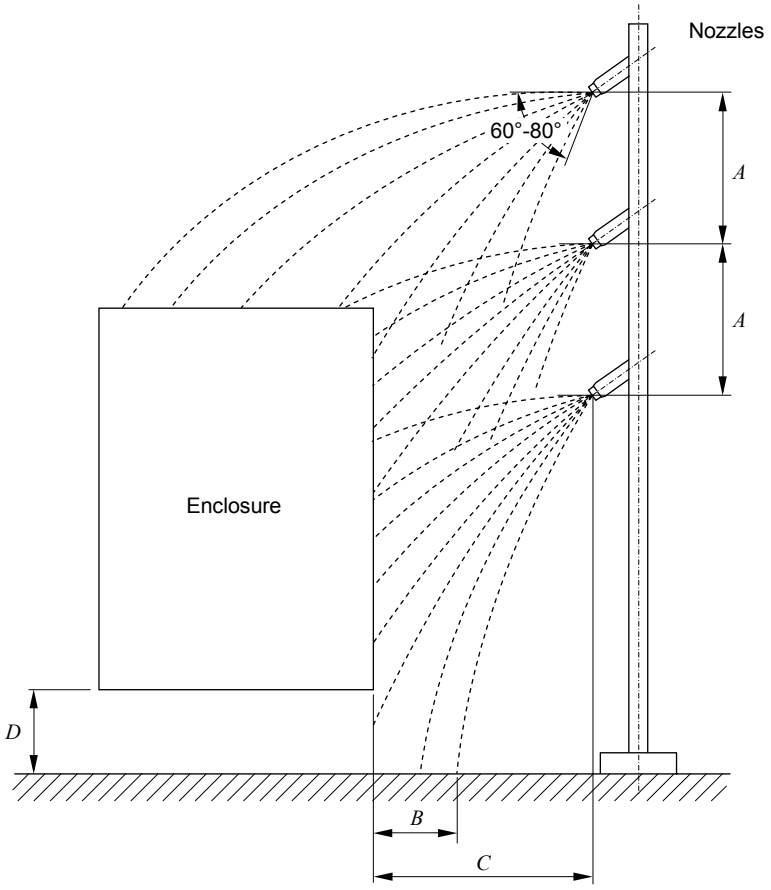
Each nozzle used for this test shall deliver a square-shaped spray pattern with uniform spray distribution and shall have a capacity of 30 l/min ± 10 % at a pressure of 460 kPa ± 10 % and a spray angle of 60° to 80°. The centre lines of the nozzles shall be inclined downwards so that the top of the spray 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 (refer to 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 %.

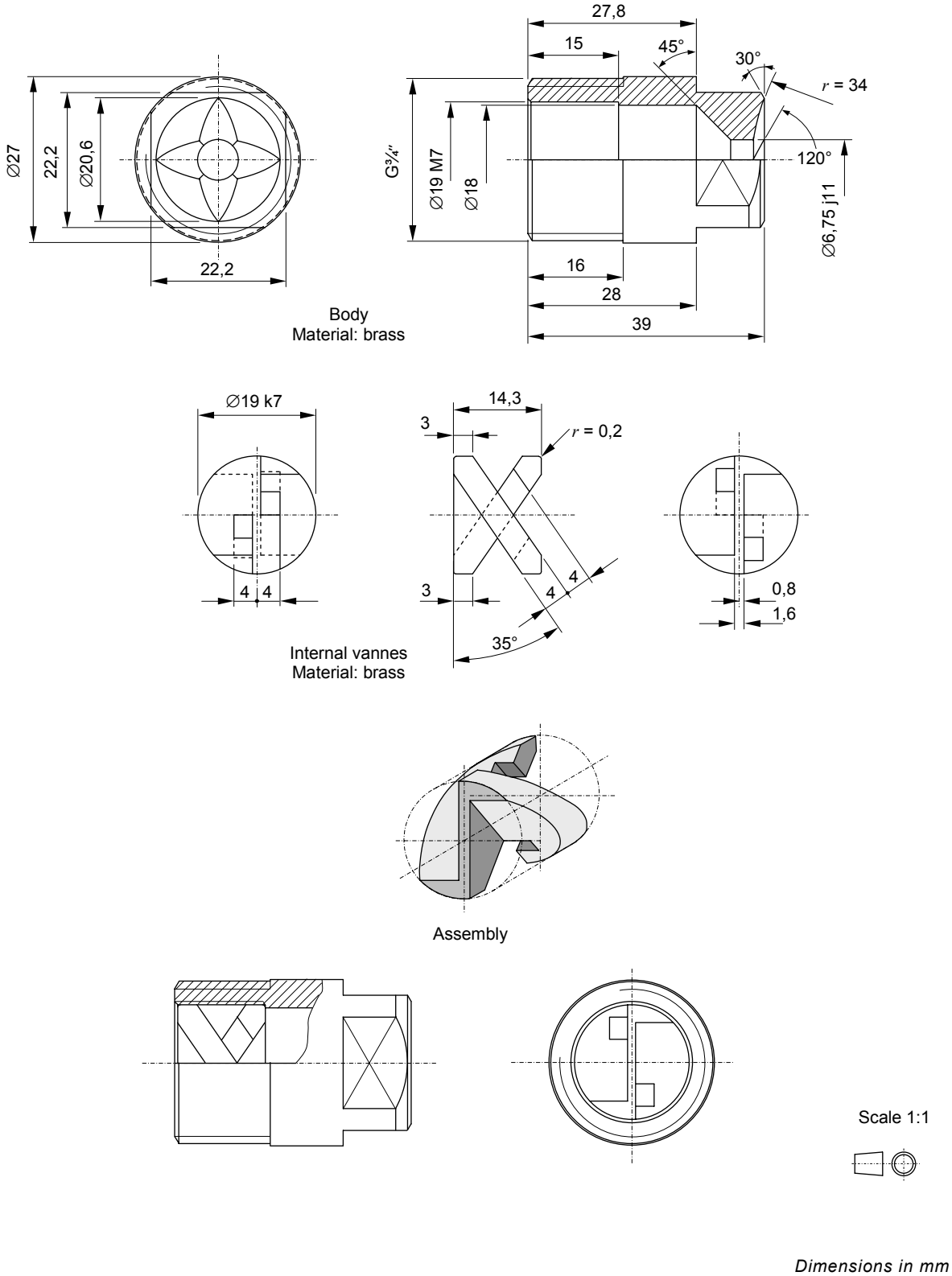
After the test is completed, the equipment shall be inspected promptly to determine whether the following requirements have been met:

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



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

Figure C.1 – Arrangement for weatherproofing test



Dimensions in mm

Figure C.2 – Nozzle for weatherproofing test

Annex D
(normative)

Requirements for auxiliary and control circuit components

The auxiliary and control circuit components shall comply with applicable IEC standards if one exists. Table D.1 is provided as a quick reference to many of the component standards.

Table D.1 – List of reference documents for auxiliary and control circuit components

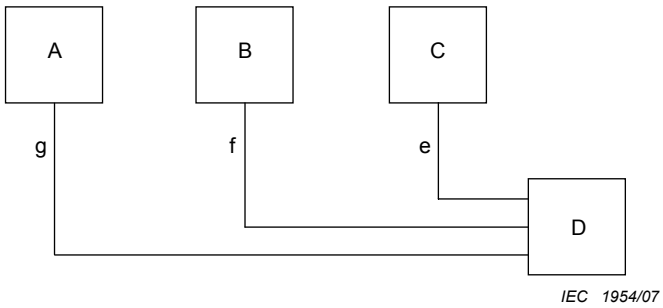
Device		IEC standard
Cables and wiring	Size and area of conductors	IEC 60228
	Insulation of PVC wiring	IEC 60227
	Insulation of extruded cable	IEC 60502-1
	Insulation of rubber cable	IEC 60245
	Identification	IEC 60445
Terminals	Terminal blocks for round wire	IEC 60947-7-1
	Protective terminal blocks for round wire	IEC 60947-7-2
	Identification	IEC 60445
Relays	All-or-nothing relays	IEC 61810
	Voltage ratings and operating range of all-or-nothing relays	IEC 61810-1
	Thermal electrical relays for motor protection	IEC 60255-8
	Performance of relay contacts	IEC 61810-2
Contactors and motor starters	Electromechanical contactors for closing and opening electrical circuit	IEC 60947-4-1
	Electromechanical contactors combined with relay for short-circuit protection	IEC 60947-2
	Motor starters (a.c.)	IEC 60947-4-1
	AC semiconductor motor controllers	IEC 60947-4-2
	Motor protective overload relays	IEC 60947-4-1
Low-voltage switches	Low-voltage switches for motor circuits and distribution circuits	IEC 60947-3
	Manual control switches and push-buttons	IEC 60947-5-1
	Pilot switches: pressure, temperature switches etc.	IEC 60947-5-1
	Household humidity sensing controls	IEC 60730-2-13
	Household switches	IEC 60669-1
	Household thermostats	IEC 60730-2-9
	Lever (toggle) switch	IEC 61020-4
	Graphical symbols for manual switches	IEC 60417
	Colours of lights for manual switches	IEC 60073
Low-voltage circuit-breakers and low-voltage circuit-breakers with residual current protection	Requirements	IEC 60947-2

Table D.1 *(continued)*

Device		IEC standard
Low-voltage fuses	Low-voltage fuse requirements	IEC 60269-2
	Low-voltage fuse systems	IEC 60269-2-1
Low-voltage disconnectors	Requirements	IEC 60947-3
Motors	Requirements	IEC 60034-1
Meters	Analogue meters	IEC 60051-1
	Ammeters and voltmeters	IEC 60051-2
	Frequency meters	IEC 60051-4
	Phase-angle and power-factor meters	IEC 60051-5
Indicator lights	Requirements	IEC 60947-5-1
	Graphical symbols	IEC 60417
	Colour lights	IEC 60073
Plugs, socket-outlets, and couplers	Requirements for plugs, sockets-outlet, industrial cable couplers, appliance couplers	IEC 60309-1
	Dimensional and interchangeability	IEC 60309-2
	Household plugs, socket-outlets and couplers	IEC 60083
	Other couplers and plugs	IEC 60130
Printed circuit-boards	Requirements	IEC 62326-1
Resistors	Potentiometers	IEC 60393-1
	Resistors 1 W to 1 000 W	IEC 60115-4
Illumination	Illumination fluorescents	IEC 60081
	Tungsten filament lamps	IEC 60064

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	19×10^{-6} Pa × m^3/s
Compartment B	19×10^{-6} Pa × m^3/s
Compartment C	19×10^{-6} Pa × m^3/s
Control box D (including valves, gauges, monitoring devices)	$2{,}3 \times 10^{-6}$ Pa × m^3/s
Piping e	$0{,}2 \times 10^{-6}$ Pa × m^3/s
Piping f	$0{,}2 \times 10^{-6}$ Pa × m^3/s
Piping g	$0{,}2 \times 10^{-6}$ Pa × m^3/s
Complete system	$59{,}9 \times 10^{-6}$ Pa × m^3/s

Filling pressure p_{re}: 700 kPa (absolute)

Alarm pressure p_{ae}: 640 kPa (absolute)

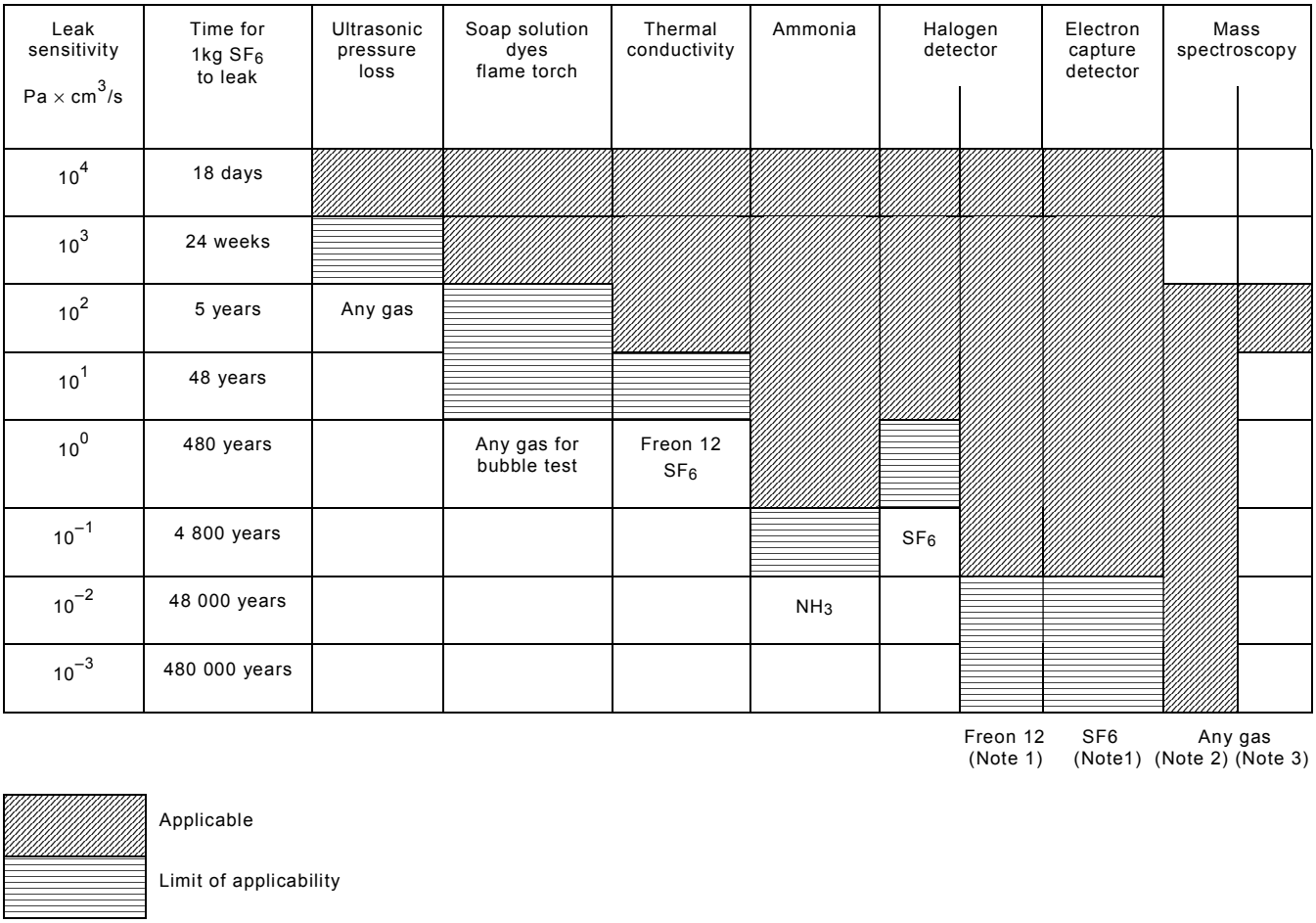
Total internal volume 270 dm^3

$$F_{rel} = \frac{59{,}9 \times 10^{-6} \times 60 \times 60 \times 24 \times 365}{700 \times 10^{3} \times 270 \times 10^{-3}} \times 100 = 1{,}0\ \%\ \text{per year}$$

$$T = \frac{(700 - 640) \times 10^{3} \times 270 \times 10^{-3}}{59{,}9 \times 10^{-6} \times 60 \times 60 \times 24 \times 365} = 8{,}5\ \text{years}$$

NOTE F_{rel} is the leakage rate and T is the time between replenishment.

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.

NOTE 4 Due to the environmental impact on the greenhouse effect, freon shall not longer be used for leakage detection.

Figure E.2 – Sensitivity and applicability of different leak-detection methods for tightness tests

Annex F
(normative)

Tolerances on test quantities during tests

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

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

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

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

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

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

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

Subclause	Description of the test	Test quantity	Specified test value	Test tolerances / limits of test values	Reference to
6.2 and 6.2.10	Dielectric tests				
6.2.6.1, 6.2.7.1, 6.2.11, 6.10.5.7	Power-frequency voltage tests	Test voltage (rms value)	Rated short-duration power frequency withstand voltage	±1 %	IEC 60060-1
		Frequency	–	45 Hz to 65 Hz	
		Wave shape	Peak value / rms value = √2	±5 %	
6.2.6.2 and 6.2.7.3	Lightning impulse voltage tests	Peak Value	Rated lightning impulse withstand voltage	±3 %	
		Front time	1,2 µs	±30 %	
		Time to half-value	50 µs	±20 %	
6.2.7.2	Switching Impulse Voltage tests	Peak Value	Rated switching impulse withstand voltage	±3 %	
		Front time	250 µs	±20 %	
		Time to half-value	2 500 µs	±60 %	
6.3 and 6.9.1	Radio Interference voltage tests	Test Voltage		±1 %	
		Tune frequency of measurement circuit		Within +10 % of 0,5 MHz or between 0,5 MHz to 2 MHz	
6.4	Measurement of the resistance of the main circuit	DC test current, I_{DC}	–	50 A ≤ I_{DC} ≤ rated current	
6.5	Temperature-rise tests	Ambient air velocity	–	≤ 0,5 m/s	
		Test current frequency	Rated frequency	-5 %, +2 %	
		Test current	Rated normal current	-0 %, +2 % These limits shall be kept only for the last two hours of testing period	
		Ambient air temperature T_a	--	+10 °C < T_a < 40 °C	
6.6	Short-time withstand current and	Test frequency	Rated frequency	±10 %	

Subclause	Description of the test	Test quantity	Specified test value	Test tolerances / limits of test values	Reference to
	peak withstand current tests	Peak current (in one of the outer phases)	Rated peak withstand current	-0 %, +5 %	
		Average of a.c. component of three-phase test current	Rated short-time withstand current	±5 %	
		A.c component of test current in any phase/average	1	±10 %	
		Short-circuit current duration	Rated short-circuit duration	See tolerance for I^2t	
		Value of I^2t	Rated value I^2t	-0 %, +10 %	
6.9	Electromagnetic compatibility tests (EMC)				
6.9.2.4	Oscillatory wave immunity test	Damped oscillatory wave tests	Test frequency 100 kHz, 1 MHz	±30 %	IEC 61000-4-18
6.10.4.3	Auxiliary contact rated short time withstand current	Test current amplitude		-0 %, +5 %	
		Test current duration		-0 %, +10 %	
6.10.4.4	Auxiliary contact breaking capability	Test voltage amplitude		-0 %,+10 %	
		Test current amplitude		-0 %, +5 %	
		Circuit time constant		-0 %, +20 %	
6.10.5	Environnemental tests		–	≤ 5 K	IEC 60068-2
6.10.5.2	Cold tests	Minimum and maximum ambient air temperature during tests	–	±3 K	IEC 60068-2-1
6.10.5.3	Dry heat test	Minimum and maximum ambient air temperature during tests	–	±3 K	IEC 60068-2-2
6.10.5.4	Damp heat, steady state	Minimum temperature of cycle		±3 K	IEC 60068-2-3
6.10.5.5	Cyclic humidity test	Minimum temperature of cycle		±3 K	IEC 60068-2-30
		Maximum temperature of cycle		± 2 K	
6.10.5.6	Vibration test				IEC 60255-21-1
6.11.1.3	Radiation instrument	Accuracy measurement of radiation (µSv)		±25 %	
	Energy response	Accuracy measurement of energy (MeV)		±15 %	

Annex G
(informative)

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

Annex G defines useful technical information in a tabular form to be exchanged between user and supplier.

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

G.1 Normal and special service conditions (refer to Clause 2)

		User requirements	Supplier proposals
Service condition	Indoor or Outdoor		
Ambient air temperature: Minimum Maximum	 °C °C		
Solar radiation	W/m²		
Altitude	m		
Pollution	Class		
Excessive dust or salt			
Ice coating	mm		
Wind	m/s		
Humidity	%		
Condensation or precipitation			
Vibration	Class		
Induced electromagnetic disturbance in auxiliary and control circuits	kV		

G.2 Ratings (refer to Clause 4)

		User requirements	Supplier proposals
Nominal voltage of system	kV		
Highest voltage of system	kV		
Rated voltage for equipment (U_r)	kV		
Rated insulation levels phase to earth and between phases Rated short-duration power-frequency withstand voltage (U_d) Rated switching impulse withstand voltage (U_s) – phase to earth – between phases Rated lightning impulse withstand voltage (U_p)	 kV kV kV kV kV		

		User requirements	Supplier proposals
Rated frequency (f_r)	Hz		
Rated normal current (I_r)	A	According single line	
Rated short-time withstand current (I_k)	kA		
Rated peak withstand current (I_p)	kA		
Rated duration of short circuit (t_k)	s		
Rated supply voltage of closing and opening devices and of auxiliary and control circuits (U_a)	V		
Rated supply frequency of closing and opening devices and of auxiliary circuits	Hz	d.c. or 50 or 60	
Type of system neutral earthing		Effectively or non-effectively	

G.3 Design and construction (refer to Clause 5)

To be specified by relevant standards.

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

G.4 Documentation for enquiries and tenders

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

Annex H
(informative)

Corrosion: Information regarding service conditions and recommended test requirements

H.1 Introduction

The minimum requirement for switchgear and controlgear with regard to corrosion is that the function of the equipment should not be affected by corrosion under the conditions specified by the user. Due to the many variables involved, for example, design of equipment, service conditions, user maintenance practices, and the expected life of the equipment; standardized requirements and verification testing is left to the relevant equipment standards or to agreement between the user and the manufacturer. In either case, however, the following guidelines should be followed.

NOTE When a surface becomes and remains wet, the two main factors involved in atmospheric corrosion are sodium chloride, mainly in marine environments, and sulphur dioxide, mainly in industrial environments. Occasionally, both of these factors apply at the same time.

H.2 Recommendation for minimum requirements

The basic function of switchgear and controlgear to be considered should include, but not be limited to, the following.

– The ability to withstand normal system voltage and carry rated normal current.
– The continuity of earthing circuits.
– The ability to access or disassemble equipment as required to perform routine inspection and maintenance.
– The ability to provide minimum security against unauthorized access.
– The ability to provide for the safety of the user or the public as appropriate.

H.3 Recommended test requirements

The tests and test methods are related to the material used in the equipment and are recommended when required by the relevant equipment standard or by agreement between the user and manufacturer.

Specific corrosion and humidity tests should be performed according to the relevant IEC standard, reference is made to IEC 60068-1 [5].

Annex I
(informative)

List of symbols and abbreviations used in IEC 62271-1

Description	Symbol	Clause
Absolute leakage rate	F	3.6.6.5
Absolute leakage rate	F_{liq}	3.6.7.3
Actual ambient temperature	θ_a	8.2
Alarm pressure for insulation (or density)	p_{ae}	3.6.5.3
Alarm pressure for operation (or density)	p_{am}	3.6.5.4
Ambient temperature	T_a	6.5.4
Initial current before application of overload current	I_i	8.2
Main circuit resistance measured before the temperature-rise test	R_u	6.4
Maximum allowable total temperature	θ_{max}	8.2
Measured filling pressure	p_m	6.8.1
Minimum functional pressure for insulation (or density)	p_{me}	3.6.5.5
Minimum functional pressure for operation (or density)	p_{mm}	3.6.5.6
Number of replenishments per day	N	3.6.6.9
Number of replenishments per day	N_{liq}	3.6.7.5
Overload current	I_s	8.2
Overload exponent	n	8.2
Partial voltage with respect to earth	U_f	6.2.5.2 b)
Permissible leakage rate	F_p	3.6.6.6
Permissible leakage rate	$F_{p(liq)}$	3.6.7.4
Permissible time for overload	t_s	8.2
Pressure drop	Δp	3.6.6.10
Pressure drop	ΔP_{liq}	3.6.7.6
Protection against ingress of water coding	IP	5.13.2
Protection of equipment against mechanical impact under normal service conditions coding	IK	5.13.3
Radio interference voltage test	$r.i.v.$	6.3
Rated duration of short circuit	t_k	4.7
Rated filling pressure	P_r	6.8.1
Rated filling pressure for insulation (or density)	p_{re}	3.6.5.1
Rated filling pressure for operation (or density)	p_{rm}	3.6.5.2
Rated frequency	f_r	4.3
Rated lightning impulse withstand voltage	U_p	Table 1
Rated normal current	I_r	4.4.1
Rated peak withstand current	I_p	4.6
Rated short-duration power-frequency withstand voltage	U_d	Table 1
Rated short-time withstand current	I_k	4.5
Rated supply voltage	U_a	4.8.2
Rated supply voltage of closing and opening devices and of auxiliary and control circuits	U_a	4.8
Rated switching impulse withstand voltage	U_s	Table 2

Description	Symbol	Clause
Rated voltage	U_r	4.1
Relative leakage rate	F_{rel}	3.6.6.7
Temperature rise at rated normal current	$\Delta\theta_r$	8.2
Thermal time constant	τ	8.2
Tightness coordination chart	TC	3.6.6.11
Time between replenishments	t_r	3.6.6.8
Total test voltage	U_t	6.2.5.2 b)

Annex J
(informative)

Electromagnetic compatibility on site

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

– where it is deemed necessary to verify that actual stresses are covered by the EMC severity class of the auxiliary and control circuits, or

– in order to evaluate the electromagnetic environment, in order to apply proper mitigation methods, if necessary,

– to record the electromagnetically induced voltages in auxiliary and control circuits, due to switching operations both in the main circuit and in the auxiliary and control circuits. It is not considered necessary to test all auxiliary and control circuits in a substation under consideration. A typical configuration should be chosen.

Measurement of the induced voltages should be made at representative ports in the interface between the auxiliary and control circuits and the surrounding network, for example, at the input terminals of control cubicles, without disconnection of the system. The extension of the auxiliary and control circuits is described in 5.18. Instrumentation for recording induced voltages should be connected as outlined in IEC 60816 [6].

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

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

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

– discharge the load side before the making operation, to assure that the trapped charge is zero;

– multiply recorded voltage values at the making operation by 2, in order to simulate the case with trapped charge on the load side.

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

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

NOTE 2 The most severe electromagnetic disturbances are expected to occur at disconnector switching, especially for GIS installations.

The recorded or calculated peak value of induced common-mode voltage, due to switching in the main circuit, should not exceed 1,6 kV for interfaces of the auxiliary and control circuits.

The note of 5.18 gives guidelines for improvement of electromagnetic compatibility.

Annex K
(informative)

List of notes concerning certain countries

Clause	Text
6.2.11	Add the following note at the end of the subclause: NOTE The required test voltage for disconnectors and switch disconnectors of all rated voltages is 100 % of the tabulated voltage in columns 3 of Tables 1a or 1b and 2a or 2b (Canada, France, Italy).

Bibliography

[1] IEC 60943:1998, *Guide concerning the permissible temperature rise for parts of electrical equipment, in particular for terminals*

[2] IEC 61936-1: *Power installations exceeding 1 kV a.c. – Part 1: Common rules*

[3] ANSI C37.85:2002, *Alternating-Current High-Voltage Power Vacuum Interrupters— Safety Requirements for X-Radiation Limits*

[4] CIGRE Technical Brochure 304: *Guide for application of IEC 62271-100 and IEC 62271-1 – Part 1: General subjects*

[5] IEC 60068-1, *Environmental testing – Part 1: General and guidance*

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

The following documents provide additional information

IEC 60099-4, *Surge-arresters – Part 4: Metal-oxide surge arresters without gaps for a.c. systems*

IEC 60273, *Characteristics of indoor and outdoor post insulators for systems with nominal voltages greater than 1 000 V*

IEC 60664-1, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

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

ISO 9001, Quality management systems – Requirements

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