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## From the Author

Our Nation is on the threshold of becoming a Developed Nation. We will be able to achieve this only through ensuring high quality of goods and services which comply to expected norms. Bureau of Indian Standards has developed Indian Standards covering most of the technological area which cover terminology, product specifications, test methods, codes of practice etc. which set the benchmark on the expected quality of the goods and services. Indian Standards published by BIS form the basis of Conformity Assessment Schemes, thus providing a third-party assurance of quality, safety and reliability to consumer.

BIS has also undertaken in earnest, the task of building a quality conscious nation through sensitizing all segments of society on the role of quality and standards in everyday life. One such segment is the student community of technical institutions. Text books referred by the students address the technical aspects of the topic but often Indian Standards are not referred, or reference may have been made to standards of other countries. This Handbook is tailored specifically to aid the students in their journey into the world of electrical engineering. This Handbook is designed to introduce students to Indian Standards and the essential concepts that govern both low-voltage and high-voltage switchgear, providing a solid foundation for studies and future career. It is also intended to be a ready reference for engineers and professionals that are involved in the study, designing, installation and testing of Power Systems.

In the case of the switchgear, the industry in India is well established and has closely followed Indian Standards, which are harmonized with international standards. Indian Standards form the basis of designing of a switchgear product or system, its detailed testing, installation and maintenance practices.

This Handbook is based on the latest Indian Standards available on the subject. I hope that this Handbook will provide students pursuing electrical engineering degree and engineering professionals with the relevant tools not only to look up available Indian Standards and use them extensively, but also to provide feedback and inputs on Indian Standards.

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# CHAPTER I

# INTRODUCTION

# Chapter I

# INTRODUCTION

## 1.1 Introduction

With the increased use of electricity and associated automation in today's world, it is necessary that the delivery and usage of power is safe and reliable. Bureau of Indian Standards (BIS), the National Standard Body of India established under the BIS Act 2016, has the responsibility of Formulation, Promotion and Implementation of National Standards, also known as Indian Standards. Standards in the electrotechnical field ensure that the entire gamut of generation, transmission, distribution, conversion and utilization of electricity is safe, reliable, and efficient.

Applications based on electricity are an integral part of our day-to-day life. Be it lighting, ambient temperature control, processing of food, transportation, entertainment or communication – all rely on electrical power as a primary source of energy, due to ease in generation, transmission, conversion or utilization of electrical power. In view of extensive use of electricity, it is essential to manage the electrical systems for controlling its various components, as per our need and ensure that the equipment of the power systems are protected at all times. Equipment need to be protected from a variety of faults and electrical overload. At other times, parts of the power system need to be isolated in order to carry out maintenance activities.

## 1.2 Indian Standards in Action

As per the National Electrical Code (SP 30:2023), protective devices shall be provided to disconnect any overcurrent in the circuit conductors before such a current could cause danger due to thermal or mechanical effects detrimental to insulation, joints, terminations or material surrounding the conductors. Switchgear and controlgear fulfil this requirements and form an essential component of power systems to perform a variety of tasks such as switching, control and protection. Low-Voltage Switchgear and controlgear are mainly used in industry, commercial establishments, buildings etc. High-Voltage switchgear and controlgear are essential in generation, transmission, distribution and utilization of power at high-Voltages. To have an assurance of dependability of their operation, it is imperative that benchmarks for their safe and reliable performance are established and the products are developed, tested and certified in accordance to the established norms.

Indian Standards on Switchgears meticulosly lay down requirements for the design, performance and safety features of switchgear, with corresponding verification and validation through appropriate testing.

Switchgear standards are harmonized with international standards and have acted as an important building block in the country’s industrial and technological infrastructure. These harmonized standards also helped the technological evolutionary process and at the attainment of international competitiveness in the shortest possible time frame by facilitating technical upgradation and technology transfer.

There are several Indian Standards on low-voltage and high-voltage switchgear which cover terminology, basics of design, operation and maintenance of switchgear systems, safety protocols and testing. Though this Guidebook, students would be able to understand the important role of switchgear standards in ensuring safety of power systems. Some important low-voltage switchgear products have also been notified under Quality Control Orders.

## 1.3 Standardization at National Level

The Indian Standards are formulated by Technical Committees, having representation of experts from industry, testing laboratories, R&D institutions, users, government bodies and regulators. India also participates in development of international standards and has liaison with corresponding international technical committees. Standardization in the field of switchgears is undertaken by the following Technical Committees:

**i. ETD 07 Low-Voltage Switchgears and Controlgears**

This committee prepares standards for switchgear and controlgear such as circuit breakers, switches, contactors, starters, disconnectors, bus bars, fuse combination units and semiconductors connectors and for switchgear assemblies for voltages upto and including 1000 V ac or 1200 V dc. In view of impact on safety of persons and power systems, a number of standards of this committee have been brought in the ambit of mandatory BIS certification.

ETD 07 has liaison with IEC TC-23 SC-23E : Circuit-breakers and similar equipment for household use; IEC TC-121 : Switchgear and controlgear and their assemblies for low-voltage; IEC TC-121 SC-121A : Low-voltage switchgear and controlgear; and IEC TC-121 SC-121B : Low-voltage switchgear and controlgear assemblies.

**ii. ETD 08 High-Voltage Switchgears and Controlgears**

The scope of the committee is to prepare standards for switchgear and controlgear; such as circuit breakers, switches contactors, starters, disconnectors, busbars and any switchgear assemblies for voltages more than 1000 V ac.

ETD 08 has liaison with IEC TC-17 : High-voltage switchgear and controlgear; IEC TC-17 SC-17A : Switching devices and IEC TC-17 SC-17C : Assemblies.

**iii. ETD 39 Fuses**

The scope of the committee is to prepare standards regarding specification for all types of fuses, with the object of determining: a) The characteristics which are essential in specifying the conditions for installation and operation of the fuses b) The requirements to be met by the fuses and the tests designed to ascertain their compliance with such requirements as well as the procedures to be followed for these tests c) Markings To prepare for these fuses standards, standard values of: 1) Characteristics, rated voltages, currents and breaking capacities: 2) Dimensions in connections with the fixing and interchangeability of high-voltage and low-voltage fuses.

ETD 39 has liaison with IEC TC-32 : Fuses; IEC TC-32 SC-32A : High-voltage fuses; IEC TC-32 SC-32B : Low-voltage fuses; and IEC TC-32 SC-32C : Miniature fuses.

The role of BIS is to act as a facilitator in the development of national standards, to act as an agent for building national consensus by balancing the variety of interests to ensure transparency in the development of standards, to disseminate information and promote trade. BIS is committed to take care of national interests and enhance competitiveness.

## 1.4 Standardization at International Level

At the international level, standardization in the field of switchgears is undertaken by the International Electrotechnical Commission. India is represented on the IEC through the Indian National Committee (INC). India is a participating member in the following technical committees and subcommittees:

**IEC TC-23 SC-23E :** Circuit-breakers and similar equipment for household use

**IEC TC-121 :** Switchgear and controlgear and their assemblies for low-voltage

**IEC TC-121 SC-121A :** Low-voltage switchgear and controlgear

**IEC TC-121 SC-121B :** Low-voltage switchgear and controlgear assemblies,

**IEC TC-17 :** High-voltage switchgear and controlgear

**IEC TC-17 SC-17A :** Switching devices

**IEC TC-17 SC-17C :** Assemblies

**IEC TC-32 :** Fuses

**IEC TC-32 SC-32A :** High-voltage fuses

**IEC TC-32 SC-32B :** Low-voltage fuses

India is observer member in IEC TC-32 SC-32C : Miniature fuses.

Before a standard is finalized by IEC it proceeds through certain stages of consultation. These stages are mainly the Committee Draft (CD), Committee Draft for Voting (CDV) and Final Draft International Standards (FDIS). These documents are circulated by BIS to the members of corresponding National Mirror Committees to obtain their views in order to form India's position on these documents. Indian experts also represent in Working Groups of IEC committees and participate in their work. Consistent participation in the activities of international standardization work is desirable to project our views to derive the maximum benefit from standardization, especially as most of the Indian Standards on switchgear are harmonized with international standards.

## 1.5 Understanding Switchgears

As per the Indian Standard IS 1885 (Part 17) : 2024/IEC 60050-441 : 1984 International Electrotechnical Vocabulary (IEV): Part 441 Switchgear, controlgear and fuses, the term 'Switchgear and Controlgear' is defined as a comprehensive term encompassing

switching devices in combination with associated control, measuring, protective, and regulating equipment. It also includes assemblies of such devices and equipment with associated interconnections, accessories, enclosures, and supporting structures primarily intended for use in connection with the generation, transmission, distribution, and conversion of electric energy.

Switchgear may include circuit breakers, contactors, relays, fuses, disconnect switches, and other protective devices. Instrument transformers, surge arresters, and other devices capable of interrupting and controlling high-voltages and currents are part of high-voltage switchgear. These components are typically housed in metal enclosures to provide protection against environmental factors and ensure operator safety.

## 1.6 Role of Switchgear in Electrical Systems

i. Protection: Switchgear provides essential protection for electrical equipment and systems against various faults such as overloads, short-circuits, and earth faults. By detecting abnormal conditions and isolating faulty components, switchgear helps prevent damage to equipment, minimize downtime, and ensure the safety of personnel.

ii. Control: Switchgear enables operators to control the flow of electricity within a power system. By selectively opening or closing switches, circuit breakers, and other devices, switchgear facilitates the safe and efficient operation of electrical networks, allowing for the distribution of power to different loads as needed.

iii. Isolation: Switchgear allows for the isolation of electrical circuits or equipment for maintenance, repair, or troubleshooting purposes. By disconnecting specific components from the rest of the system, switchgear ensures the safety of personnel working on electrical installations and prevents the propagation of faults to other parts of the network.

iv. Distribution: Switchgear is used to distribute electrical power from sources such as generators or substations to various loads, including industrial machinery, commercial buildings, residential areas, and infrastructure. By incorporating switches, fuses, and circuit breakers into distribution networks, switchgear facilitates the efficient transfer of electricity to different consumers while maintaining system stability and reliability.

v. Fault Management: In the event of a fault or disturbance in the electrical system, switchgear helps manage and mitigate the impact of such events. By quickly detecting faults and isolating affected components, switchgear minimizes the extent of disruptions, reduces downtime, and enhances the overall resilience of the power infrastructure.

vi. Safety: Switchgear enhances the safety of electrical installations and operations by providing reliable protection mechanisms, isolating hazardous conditions, and enabling controlled access to electrical equipment. Properly designed and

maintained switchgear systems help prevent electrical accidents, fires, and other safety hazards in both industrial and commercial settings.

vii. Automation and Monitoring: Modern switchgear systems incorporate advanced automation and monitoring capabilities, allowing for remote operation, real-time condition monitoring, and predictive maintenance. By leveraging digital technologies such as programmable logic controllers (PLCs) and supervisory control and data acquisition (SCADA) systems, switchgear can optimize energy efficiency, improve asset management, and enhance system reliability.

## 1.7 Desirable Features of Switchgear:

**1.7.1 Switchgear are expected to have the following features:**

i. **Reliability:** Switchgear are used to protect and regulate equipment and power systems, hence it is important that they are completely reliable. When fault occurs on any part of the power system, the switchgear must operate to isolate the faulty section from the remainder circuit. In view of interconnection and the increasing capacity of generating stations, it is essential for switchgear to be fully reliable. Absence of such reliability would lead to highly unsafe and hazardous operations.

ii. **Discrimination:** Whenever a fault occurs in a power system, the switchgear must be able to discriminate between the faulty section and the healthy section and should be able to isolate the section having the fault from the system without affecting the healthy section. Discrimination ensures continuity of supply for sections which are not affected by the fault.

iii. **Quickness of operation:** A fault in electrical system has adverse impact on the connected equipment. It is necessary that when fault occurs on any part of the power system, the switching must be quick to safeguard generators, transformers and other equipment by the fault currents. If fault is not cleared by switchgear quickly, it is likely to spread into healthy parts, thus endangering safe operations and may lead to complete shutdown of the system.

iv. **Provision for manual control:** In case the electrical (or electronics) control fails, there should be provision that the switching operation can be carried out through manual control.

v. **Provision for instruments:** The switchgear must have provision for measuring instruments on the unit itself or in association with current and voltage transformers connected to the main switchboard or a separate instrument panel.

## 1.8 Indian Standards cater to the Product and Power System Requirements

**1.8.1** It is through Indian Standards that switchgear can be designed and tested so as to address all above requirements. The Indian Standards on switchgear specify:

i. the characteristics of switchgear;

ii. the conditions with which switchgear shall comply, with reference to:

a) their operation and behaviour in normal service;

b) their operation and behaviour in case of overload;

c) their operation and behaviour in case of short-circuits up to their rated short-circuit capacity;

d) their dielectric properties;

iii. the tests intended for confirming that these conditions have been met and the methods to be adopted for the tests;

iv. the data to be marked on the devices;

v. the test sequences to be carried out and the number of samples;

vi. the co-ordination under short-circuit conditions with another short-circuit protective device (SCPD) associated in the same circuit;

vii. the routine tests to be carried out on each circuit-breaker to reveal unacceptable variations in material or manufacture, likely to affect safety.

1.8.2 Special constructions are required for circuit-breakers for use in locations where arduous environmental conditions prevail (e.g. excessive humidity, heat or cold or deposition of dust) and in hazardous locations (e.g. where explosions are liable to occur), having a degree of protection higher than IP20 according to IS/IEC 60529.

# CHAPTER II
# LOW-VOLTAGE SWITCHGEAR

# CHAPTER II

# LOW-VOLTAGE SWITCHGEAR

2.1 An electrical power system is very complex. It needs switchgear in order that it may be safely and efficiently controlled or regulated under both normal and abnormal operating conditions. A circuit breaker in a power station serves exactly the same purpose as a tumbler switch with a fuse to control the light and other electrical equipment, but it has many added and much more complex features. Indian Standards give the detailed requirements for each of the type of switchgears. This chapter gives an overview of the types of low-voltage switchgear and available Indian Standards.

These Indian Standards contain all requirements necessary to ensure compliance with the operational characteristics required for these devices through type tests. They also contain the details relative to test requirements and methods of test necessary to ensure reproducibility of test results.

## 2.2 Types Of Low-Voltage Switchgear

### 2.2.1 Air-break circuit-breakers, also called as Miniature Circuit Breakers (MCBs)


MCBs are intended for the protection against overcurrents of wiring installations of buildings and similar applications; they are designed for use by uninstructed people and for not being maintained. These circuit-breakers are meant for operation at 50 Hz, having a rated voltage not exceeding 440 V (between phases), a rated current not exceeding 125 A and a rated short-circuit capacity not exceeding 25 000 A. They are intended for use in an environment with pollution degree 2. They are suitable for isolation.

Following Indian Standards exist for such circuit breakers:

i. **IS/IEC 60898-1 : 2015** *Electrical accessories - Circuit-breakers for overcurrent protection for household and similar installations: Part 1 Circuit-breakers for ac operation*

ii. **IS/IEC 60898-2 : 2016** *Electrical accessories - Circuit-breakers for overcurrent protection for household and similar installations Part 2: Circuit-breakers for ac and dc operation*

iii. **IS/IEC 60898-3 : 2019** *Electrical accessories - Circuit-breakers for overcurrent protection for household and similar installations - Part 3: Circuit-breakers for dc operation*

Circuit breakers covered by IS/IEC 60898 provide essential protection by automatically disconnecting circuits when an overload or short-circuit occurs. This prevents potential

damage to wiring and connected devices. These standards outline performance requirements, including tripping characteristics and breaking capacity, ensuring circuit breakers function correctly under various conditions.

### 2.2.2 Circuit-breakers incorporating residual current tripping devices (RCCBs)

Residual current operated circuit-breakers for household and similar uses, not incorporating overcurrent protection for rated voltages not exceeding 440 V a.c. with rated frequencies of 50 Hz and rated currents not exceeding 125 A, are intended principally for protection against shock hazard.

These devices are intended to protect persons against indirect contact, the exposed conductive parts of the installation being connected to an appropriate earth electrode. They may be used to provide protection against fire hazards due to a persistent earth fault current, without the operation of the overcurrent protective device. RCCBs having a rated residual operating current not exceeding 30 mA are also used as a means for additional protection in case of failure of the protective means against electric shock. Indian Standards on RCCBs apply to devices performing simultaneously the functions of detection of the residual current, of comparison of the value of this current with the residual operating value and of opening of the protected circuit when the residual current exceeds this value. RCCBs are essentially intended to be operated by uninstructed persons and designed not to require maintenance. They are intended for use in an environment with pollution degree 2. They are suitable for isolation. Following Indian Standards exist for RCCBs:

i. **IS 12640 (Part 1) : 2016/ IEC 61008-1 : 2012** *Residual current operated circuit Breakers without integral overcurrent protection for household and similar uses (RCCBS): Part 1 General rules*

ii. **IS 12640 (Part 2) : 2016/ IEC 61009-1 : 2012** *Residual current operated circuit - Breakers with integral overcurrent protection for household and similar uses (RCBOS): Part 2 General rules*

iii. **IS 12640 (Part 3) : 2018/ IEC 61008-2-1 : 1990** *Residual Current Operated Circuit - Breakers Without Integral Overcurrent Protection for Household and Similar Uses ( RCCB's) Part 3 Applicability of the General Rule to RCCB 's Functionally Independent of Line Voltage*

iv. **IS 12640 (Part 4) : 2018/ IEC 61008-2-2 : 1990** *Residual Current Operated Circuit Breakers Without Integral Overcurrent Protection for Household and Similar Uses (RCCB's) Part 4 Applicability of the General Rules to RCCB's Functionally Dependent on Line Voltage*

v. **IS 17119 : 2019/ IEC 62640 : 2015** *Residual current devices with or without overcurrent protection for socket - outlets for household and similar uses*

RCDs according to above Indian Standards are designed to detect leakage currents that may occur when there is a fault in the insulation or an unintended path to earth. They quickly disconnect the circuit to prevent electric shock, which is critical for user safety in both residential and commercial settings. The standards specify various sensitivity levels (such as 30 mA, 100 mA, etc.) to ensure the RCDs can protect against different types of electrical faults, enhancing overall safety.

### 2.2.3 Low-Voltage Switchgear for Commercial and Industrial Installations

A variety of low-voltage switchgear are used extensively in commercial and industrial installations comprising diverse electrical equipment to be operated by instructed persons, for switching and control functions. These low-voltage switchgear and controlgear are intended to be connected to circuits of rated voltage not exceeding 1000 V ac or 1500 V dc. The IS/IEC 60947 series of standards cover the entire range of low-voltage switchgear such as circuit breakers, switches, disconnectors, switch-disconnectors and fuse-combination units, contactors and motor starters, control circuit devices and switching elements and multiple function equipment. Switchgear assemblies are covered under the IS/IEC 61439 series of standards.

The IS/IEC 60947 series of standards is as follows:

i. **IS/IEC 60947-1 : 2020** *Low-voltage switchgear and controlgear: Part 1 General rules*

ii. **IS/IEC 60947-2 : 2016** *Low-voltage switchgear and controlgear: Part 2 Circuit - breakers*

iii. **IS/IEC 60947-3 : 2020** *Low-voltage switchgear and controlgear: Part 3 Switches, Disconnectors, Switch-Disconnectors and Fuse-Combination Units*

iv. **IS/IEC 60947-4-1 : 2018** *Low-voltage switchgear and controlgear: Part 4-1 Contactors and motor starters - Electromechanical contactors and motor-starters*

v. **IS/IEC 60947-4-2 : 2020** *Low-voltage switchgear and controlgear: Part 4-2 Contactors and motor starters - Semiconductor motor controllers, starters and soft starters*

vi. **IS/IEC 60947-4-3 : 2020** *Low-voltage switchgear and controlgear: Part 4-3 Contactors and motor-starters - Semiconductor Controllers and Semiconductor contactors for non-motor loads*

vii. **IS/IEC 60947-5-1 : 2016** *Low-voltage switchgear and controlgear: Part 5-1 Control circuit devices and switching elements - Electromechanical control circuit devices*

viii. **IS/IEC 60947-5-2 : 2019** *Low-voltage switchgear and controlgear: Part 5-2 Control circuit devices and switching elements - Proximity switches*

ix. **IS/IEC 60947-5-5 : 2016** *Low-voltage switchgear and controlgear: Part 5-3 Control circuit devices and switching elements - Electrical emergency stop devices with mechanical latching function*

x. **IS/IEC 60947-6-1 : 2021** *Low-voltage switchgear and controlgear: Part 6-1 Multiple function equipment - Transfer switching equipment*

xi. **IS/IEC 60947-6-2 : 2020** *Low-voltage switchgear and controlgear: Part 6-2 Multiple function equipment - Control and protective switching devices or equipment (CPS)*

IS/IEC 60947 is a crucial series of Indian Standards that define the requirements for low-voltage switchgear and controlgear. These standards cover a broad range of equipment essential for the safe and efficient operation of electrical systems.

## 2.3 Types of Fuses

A fuse is an electric / electronic or mechanical device, used to protect circuits from over current and overload.

### 2.3.1 Rewirable Fuses

The majority of the low-voltage switches being manufactured in India are metal-clad switches. Switches with insulated enclosures and fuse combination units, incorporating particularly rewirable type fuses, are being manufactured in the small-scale sector, intended for domestic and similar installations. This following Indian Standards were, therefore, brought out primarily to meet the requirements of the manufacturer and the users in respect of rewirable type switch-fuse units for current ratings not exceeding 100 A:

i. **IS 10027 : 2018** Composite units of air - Break switches and rewirable type fuses for voltages not exceeding 650 V a.c.

ii. **IS 2086 : 1993** Carriers and bases in rewirable type electric fuses for voltages up to 650 V

The above Indian Standards for rewirable type fuses are essential for protecting electrical circuits and equipment from overloads and short-circuits. These units combine the functions of switching and protection in a single assembly, facilitating simplified design and installation while maintaining operational safety.

### 2.3.2 Miniature fuses

Miniature fuses such as cartridge fuse-links, sub-miniature fuse -links and universal modular fuse-links are used for the protection of electric appliances, electronic equipment and component parts thereof normally intended to be used indoors.

The following series of Indian Standards exists for miniature fuses:

i. **IS/IEC 60127-1 : 2006** *Miniature fuses Part 1 definitions for miniature fuses and general requirements for miniature fuse - links*

ii. **IS/IEC 60127-2 : 2003** *Miniature fuses Part 2 Cartridge fuse - links*

iii. **IS/IEC 60127-4 : 2005** *Miniature fuses Part 4 Universal modular fuse - links (UMF) - Through - hole and surface mount types*

iv. **IS/IEC 60127-5 : 1988** *Miniature fuses Part 5 Guidelines for quality assessment of miniature fuse - links*

v. **IS/IEC 60127-6 : 1994** *Miniature fuses Part 6 Fuse holders for miniature cartridge fuse links*

These standards establish uniform requirements for miniature fuses so as to protect appliances or parts of appliances in the most suitable way, define the performance of the fuses, so as to give guidance to designers of electrical appliances and electronic equipment and to ensure replacement of fuse-links by those of similar dimensions and characteristics. The standards also define methods of testing, the maximum sustained

dissipation of fuse -links to ensure good compatibility of stated power acceptance when used with fuse -holders according to IS/ IEC 60127-6.

### 2.3.3 Low-Voltage fuses

Fuses incorporating enclosed current-limiting fuse-links with rated breaking capacities of not less than 6 kA, are used for protecting power-frequency a.c. circuits of nominal voltages not exceeding 1000 V or d.c. circuits of nominal voltages not exceeding 1500 V. Such fuses are used for industrial and commercial applications, for residential applications and for protecting semiconductor devices. The following Indian Standards exist for low-voltage fuses:

**IS/IEC 60269-1 : 2014** *Low-voltage fuses Part 1 General requirements*

**IS/IEC 60269-2 : 2016** *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 K*

**IS 13703 (Part 4) : 1993 / IEC 269-4** *Specification for low-voltage fuses for voltages not exceeding 1000 v ac or 1500 v dc Part 4 Supplementary requirements for fuse links for the protection of semiconductor devices*

**IS/IEC/TR 60269-5 : 2014** *Low-voltage fuses Part 5 Guidance for the application of low-voltage fuses*

**IS/IEC 60269-6 : 2010** *Low-voltage fuses Part 6 Supplementary requirements for fuse-links for the protection of solar photovoltaic energy systems*

IS/ IEC 60269 series of standards for low-voltage power fuses gives the requirements of such fuses and unifies several national standards, thereby improving the interchangeability of fuses in international trade. All fuses of different technologies tested to meet IS/ IEC 60269 series of standards will have similar time-current characteristics, which simplifies design and maintenance. Any fuses built to the IEC 60269 standard and carrying the same application category will have similar electrical characteristics, time-current characteristics, and power dissipation as any other, even if the fuses are made in the packages standardized to the earlier national standards. Fuses of the same application category can be substituted for each other provided the voltage rating of the circuit does not exceed the fuse rating.

## 2.4 Switchgear for Electric Vehicles

Electric vehicles are a fast emerging technology, which have specialized switchgear requirements.

i. **IS 17040 : 2018/ IEC 62335 : 2008** *Circuit breakers switched protective earth portable residual current devices for Class I and battery powered vehicle applications*

ii. **IS 17120 : 2019/ IEC 62752 : 2016** *In - Cable control and protection device for mode 2 charging of electric road vehicles (IC - CPD)*

The standards specify the requirements for protective devices that integrate a circuit breaker and switched protective earth functionality. These devices are designed to

enhance safety by detecting and interrupting leakage currents to prevent electrical shock and other hazards in battery-powered vehicles.

## 2.5 Switchgear Assemblies

A switchgear assembly consists of switchgear as well as controlgear. It consists of equipment such as switches, circuit breakers, fuses, and lightning arrestors that are capable of conducting or interrupting the flow of electrical power, as well as equipment such as control panels, current transformers, potential transformers, protective relays, and associated circuitry that monitor, control, and protect the switchgear.

The following Indian Standards have been developed specifying the requirements for low-voltage switchgear assemblies:

i. **IS 5039 : 1983** *Specification for distribution pillars for voltages not exceeding 1000 V ac and 1200 V dc*

ii. **IS 13032 : 1991** *ac Miniature circuit - breaker boards for voltages not exceeding 1000 V*

iii. **IS/IEC 61439-0 : 2014** *Low-Voltage Switchgear and Controlgear Assemblies Part 0 Guidance to specifying assemblies*

iv. **IS/IEC 61439-1 : 2020** *Low-voltage switchgear and controlgear assemblies: Part 1 General rules*

v. **IS/IEC 61439-2 : 2020** *Low-voltage switchgear and con*trolgear assemblies: Part 2 Power switchgear and controlgear assemblies

vi. **IS/IEC 61439-3 : 2012** *Low-voltage switchgear and controlgear assemblies: Part 3 distribution boards intended to be operated by ordinary persons (DBO)*

vii. **IS/IEC 61439-4 : 2012** *Low-voltage switchgear and controlgear assemblies: Part 4 particular requirements for assemblies for construction sites (ACS)*

viii. **IS/IEC 61439-5 : 2014** *Low-voltage switchgear and controlgear assemblies: Part 5 Assemblies for power distribution in public networks*

ix. **IS/IEC 61439-6 : 2012** *Low-voltage switchgear and controlgear assemblies: Part 6 Busbar trunking systems (busways)*

x. **IS/IEC/TS 61439-7 : 2023** *Low-voltage switchgear and controlgear assemblies: Part 7 Assemblies for specific applications such as marinas camping sites market squares electric vehicle charging stations*

IS/IEC 61439 series of standards specify the general service conditions, construction requirements, technical characteristics and verification requirements for low-voltage switchgear and controlgear assemblies for which the rated voltage does not exceed 1000 V AC or 1500 V DC. These Indian Standards are intended for indoor and outdoor applications, stationary or movable assemblies with or without an enclosure, intended for use in connection with the generation, transmission, distribution and conversion of electric energy, and for the control of electrical energy consuming equipment.

The purpose of IS/IEC 61439 series is to harmonize as far as practicable all rules and

requirements of a general nature applicable to low-voltage switchgear and controlgear assemblies, in order to obtain uniformity of requirements and verification for assemblies and to avoid the need for verification in other standards. All those requirements for the various assembly standards which can be considered as general have therefore been compiles in these standards with specific requirements such as temperature-rise, dielectric properties, etc. to facilitate the supply of information on basic conditions and additional user specifications to enable proper design, application and utilization of the assembly. The various types of assemblies include the basic distribution pillars to more complex assemblies such as for distribution boards intended to be operated by ordinary persons for construction sites (ACS), for power distribution in public networks, Busbar Trunking Systems (Busways), and for electric vehicle charging stations.

# CHAPTER III
# HIGH-VOLTAGE SWITCHGEAR

# CHAPTER III

# HIGH-VOLTAGE SWITCHGEAR

## 3.1 High-Voltage Switchgear

Transmitting power at a higher voltage requires less current to distribute the same amount of energy. It is considered to be more efficient. High-voltage switchgears are indispensable components of high-voltage transmission systems, where they are tasked with the switching and isolation of high-voltage circuits, thereby providing the necessary means to control power flow, reroute electricity in case of contingencies, and maintain system stability. They are typically installed in close proximity to critical equipment and machinery, providing localized power distribution and protect against electrical faults, surges, lightning strikes, and other external factors.

These Indian Standards contain all requirements necessary to ensure compliance with the operational characteristics required for these devices through type tests. They also contain the details relative to test requirements and methods of test necessary to ensure reproducibility of test results.

## 3.2 Types of High-Voltage Switchgear

High-voltage switchgear are used for power systems operating above 1000 V. The switchgear are classified on the basis of operating voltage, which goes upto or beyond 52 kV. It is of paramount importance that such switchgear are designed, tested, and maintained to reliably meet desired safety and performance of power systems.

The Indian Standards for high-voltage switchgear ensure comprehensive coverage of design, functionality, testing, and operational safety of high-voltage switchgear. By following these standards, manufacturers and operators ensure that the high-voltage switchgear systems.

### 3.2.1 High-Voltage Circuit Breakers and Switches

Circuit Breakers and Switches used in high-voltage power systems with rated voltages above 1 kV need to safely interrupt fault currents and provide reliable protection. Important aspects include performance under short-circuit conditions, insulation levels, and operational reliability, aimed at enhancing system safety and efficiency. Following is the list of Indian Standards on high-voltage circuit breakers and switches:

i. **IS/IEC 62271-100:2021** *High-voltage switchgear and controlgear Part 100: Alternating-current circuit-breakers*

   The Indian Standard specifies requirements and tests for circuit-breakers to safely interrupt fault currents and provide reliable protection for electrical systems.

ii. **IS/IEC 62271-102:2018** *High-voltage switchgear and controlgear Part 102: Alternating current disconnectors and earthing switches*

The Indian Standard ensures that Alternating Current Disconnectors and Earthing Switches can safely handle operational stresses and provide reliable disconnection and grounding capabilities, crucial for maintenance and fault isolation in electrical installations.

iii. **IS/IEC 62271-103:2021** *High-voltage switchgear and controlgear Part 103: Alternating current switches for rated voltages above 1 kV up to and including 52 kV*

The Indian Standard ensures that switches meet specified operational criteria, such as contact performance and insulation integrity, contributing to the reliable control and switching of electrical circuits.

iv. **IS/IEC 62271-104:2023** *High-voltage switchgear and controlgear Part 104: Alternating current switches for rated voltages higher than 52 kV*

The Indian Standard ensures operational performance, insulation requirements, and mechanical durability to support the reliable control and switching of high-voltage systems.

v. **IS/IEC 62271-105:2021** *High-voltage switchgear and controlgear Part 105: Alternating current switch-fuse combinations for rated voltages above 1 kv up to and including 52 kV*

The Indian Standard specifies the requirements for switch-fuse combinations used in high-voltage switchgear. It integrates switching and protection functions into a single unit, providing both circuit interruption and protection capabilities.

vi. **IS/IEC 62271-106:2021** *High-voltage switchgear and controlgear Part 106: Alternating current contactors, contactor-based controllers, and motor starters*

The Indian Standard ensures that these devices can reliably control and start electrical motors and other loads.

vii. **IS/IEC 62271-109:2019** *High-voltage switchgear and controlgear Part 109: Alternating current series capacitor by-pass switches*

The Indian Standard specifies the requirements for alternating current series capacitor by-pass switches that are essential for bypassing series capacitors during maintenance or fault conditions.

viii. **IS/IEC 62271-110:2023** *High-voltage switchgear and controlgear Part 110: Inductive load switching*

The Indian Standard specifies the design, performance, and testing of equipment used to switch inductive loads, such as transformers and reactors. This Indian Standard ensures that equipment can handle the high currents and voltages associated with inductive load switching.

ix. **IS/IEC 62271-111:2019** *High-voltage switchgear and controlgear Part 111: Automatic circuit reclosers for alternating current systems up to and including 38 kV*

The Indian Standard specifies the requirements for automatic circuit reclosers that automatically reset and restore service after momentary faults.

### 3.2.2 Metal Enclosed High-Voltage Switchgear

Metal-enclosed switchgear comprises various components such as circuit breakers, disconnector switches, busbars, and associated control, monitoring and protection devices. These components are housed within a grounded metal enclosure, typically made of steel sheet. The following IS/IEC 62271 series of Indian Standards provide comprehensive guidelines on the design, construction, performance, and testing of metal-enclosed switchgear assemblies.

i. **IS/IEC 62271-200 : 2021** *High-voltage switchgear and controlgear: Part 200 ac metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

ii. **IS/IEC 62271-203 : 2022** *High-voltage switchgear and controlgear: Part 203: AC gas-insulated metal-enclosed switchgear for rated voltages above 52 kV*

iii. **IS/IEC 62271-201 : 2014** *High-voltage switchgear and controlgear: Part 201 AC solid-insulation enclosed switchgear and controlgear for rated voltages above 1 kV up to and including 52 kV*

iv. **IS/IEC 62271-202 : 2014** *High-voltage switchgear and controlgear: Part 202 High-voltage/ low-voltage prefabricated substation*

The standards outline the criteria for constructing metal-enclosed switchgear, including materials, insulation, and protection against environmental conditions. The standards specify tests to ensure that the switchgear is robust, reliable, and safe for use in various operational environments.

### 3.2.3 Connectors for High-Voltage switchgear

Electric power connectors and busbars are crucial components in electrical distribution systems, used to conduct electrical power between various equipment and components. Electric power connectors and busbars used in electrical systems for various applications shall meet safety, performance, and durability requirements. The connectors and busbars used for power transmission and distribution shall prevent electrical faults, ensure secure connections, and reduce the risk of electrical hazards. The following Indian Standards exist for connectors and busbars:

i. **IS 5561 : 2018** *Electric power connectors - Specification*

ii. **IS 8084 : 1976** *Specification for interconnecting bus - Bars for ac voltage above 1 kV up to and including 36 kV*

These Indian Standards define the design parameters for power connectors, including material specifications, dimensional requirements, and mechanical properties. Connectors must be designed to ensure reliable and secure connections in electrical systems. handle rated currents and voltages without degradation or failure.

## 3.3 Testing on High-Voltage Switchgear

i. **IS/IEC 62271-1 : 2017** *High-voltage switchgear and controlgear: Part 1 Common specifications for alternating current switchgear and controlgear*

The Indian Standard provides the general specifications for high-voltage AC

switchgear and controlgear, and covers definitions, ratings, design and construction requirements, and testing procedures. The focus is on ensuring that switchgear and controlgear systems meet a uniform standard of safety, performance, and reliability. This standard is crucial for ensuring compatibility and interoperability among different manufacturers' equipment.

ii. **IS/IEC 62271-101 : 2021** *High-voltage Switchgear and controlgear: Part 101: Synthetic testing*

The Indian Standard specifies the procedures for synthetic testing of high-voltage switchgear and controlgear. Synthetic testing involves creating test conditions that simulate real-world scenarios to assess the performance and reliability of switchgear and controlgear. It aims to establish methodologies for testing that ensure the equipment can perform safely and effectively under various conditions, including during and after extreme events or failures.

iii. **IS/IEC 62271-300 : 2006** *High-voltage Switchgear and controlgear: Part 300 seismic qualification of alternating current circuit-breakers*

The Indian Standard outlines the requirements and methods for seismic qualification of AC circuit-breakers used in high-voltage switchgear and controlgear systems. It provides guidelines for testing circuit-breakers to ensure they can withstand seismic events, maintaining operational reliability and safety during and after an earthquake. The focus is on ensuring that the equipment can endure seismic forces without failure.

iv. **IS/IEC 62271-207 : 2012** *High-voltage switchgear and controlgear: Part 207 Seismic qualification for gas - insulated switchgear assemblies for rated voltages above 52 kV*

The Indian Standard provides specific requirements for seismic qualification of gas-insulated switchgear (GIS) assemblies with rated voltages above 52 kV. It focuses on ensuring that GIS assemblies can withstand seismic activities, ensuring their operational integrity and reliability under earthquake conditions. It includes testing methodologies and performance criteria to verify the seismic resilience of GIS equipment.

## 3.4 High-Voltage Fuses

### 3.4.1 Current limiting fuses

Current limiting fuses interrupt high fault currents, protecting electrical equipment by limiting the duration and magnitude of fault currents. The following Indian Standards provide the specifications for such fuses:

i. **IS 9385 (Part 1) : 2018** *High-voltage fuses: Part 1 current - limiting fuses*

ii. **IS 9385 (Part 5) : 1983** *Specification for high-voltage fuses: Part 5 Types and dimensions of fuse - links for current - limiting fuses*

The Indian Standards specifies the requirements for current-limiting fuses designed for high-voltage applications. These fuses are crucial for protecting electrical circuits and equipment by limiting the amount of current that can flow through them during a fault condition. The standards outline the essential characteristics, performance

criteria, testing procedures, and other technical specifications necessary for ensuring the reliability and effectiveness of current-limiting fuses in high-voltage environments, and the dimensional requirements. It aims to provide a standardized approach to designing and testing these fuses to ensure they meet safety and performance standards while ensuring interchangeability.

### 3.4.2 Expulsion fuses

Expulsion fuses are designed to eject the fuse elements and extinguish the arc during a fault condition. The following Indian Standard provide the specifications for such fuses:

i. **IS 9385 (Part 2) : 2018** *High-voltage fuses: Part 2 Expulsion fuses*

This Indian Standard outlines the technical criteria for the design, construction, testing, and performance of expulsion fuses, including their ability to handle high-voltage conditions and effectively manage fault currents.

### 3.4.3 Fuses for external protection of shunt power capacitors

i. **IS 9402 : 1980** *Specification for high-voltage fuses for external protection of shunt power capacitors*

This Indian Standard specifies the technical criteria for high-voltage fuses used in electrical systems to protect shunt power capacitors, which are used to improve power factor and voltage regulation in AC power systems.

### 3.4.4 Fuse links for motor circuit applications

i. **IS 10624 : 1983** *Specification for high-voltage fuse links for motor circuit applications*

This Indian Standard provides the requirements and guidelines for high-voltage fuse links intended to protect electrical motors and their associated circuits. These fuse links are crucial for safeguarding motors from overcurrents, short-circuits, and other electrical faults.

## 3.5 Short-Circuit Power Factor for Testing on High-voltage Fuses

The following Indian Standard specifies the method for determining the short-circuit power factor used in testing high-voltage fuses:

i. **IS 9385 (Part 4) : 1983** *Specification for high-voltage fuses: Part 4 Determination of short-circuit power factor for testing high-voltage fuses*

The Indian Standard is crucial for evaluating the performance of fuses under short-circuit conditions by determining the short-circuit power factor used in testing high-voltage fuses.

## 3.6 Application Guide on High-Voltage Fuses

The following Indian Standard is an application guide for high-voltage fuses:

i. **IS/IEC/TR 62655 : 2013** *Tutorial and application guide for high-voltage fuses*

The Indian Standard is both a tutorial and an application guide which provides practical guidance on the use of high-voltage fuses so as to support users in selecting, installing, and applying high-voltage fuses effectively.

# CHAPTER IV

# CHARACTERISTICS OF SWITCHGEAR

# CHAPTER IV

# CHARACTERISTICS OF SWITCHGEAR

## 4.1 Introduction

Switchgear are designed to switch, protect, and control electrical circuits and equipment. Switchgear can include switches, circuit breakers, fuses, and other devices or their assemblies that manage electrical power systems. This chapter gives an overview of the common characteristics for switchgear, based on IS/IEC 60947-1 : 2020 Low-voltage switchgear and controlgear: Part 1 General rules. In addition to the listed characteristics, each switchgear has additional characteristics specific to its type, role and function for which relevant Indian Standard should be referred. Further, this Chapter covers switchgear only as per IS/IEC 60947 series. Do refer the relevant Indian Standards, as given in Chapter II and Chapter III of this Handbook to seek details for specific devices or assemblies.

## 4.2 Summary of characteristics

The characteristics of a switchgear are stated mainly in the following terms, in respective product standards, as applicable (refer clause 5.1 of IS/IEC 60947-1 : 2020):

i. type of equipment
ii. rated and limiting values for the main circuit
iii. utilization category
iv. control circuits
v. auxiliary circuits
vi. relay and releases
vii. co-ordination with short-circuit protective devices

Clause 3.10 of IS/IEC 60947-1 : 2020 provides the symbols and clause references for characteristics for circuit breakers. These characteristics determine the selection of particular type of switchgear as per the application and ratings required. In addition to the above listed characteristics, each switchgear and controlgear product has characteristics specific to its type, role and function for which reference should be made to the relevant Indian Standard.

## 4.3 Type of Equipment

The switchgear product standards state the following, where applicable (refer clause 5.2 of IS/IEC 60947-1 : 2020):

i. kind of equipment
ii. number of poles
iii. kind of current
iv. interrupting medium
v. operating conditions (method of operation, method of control, etc.)

## 4.4 Rated and limiting values for the main circuit

Rated value is the value of a quantity used for specification purposes, established for a specified set of operating conditions of a component, device, equipment, or system, and are specified for each of them. (refer clause 5.2 of IS/IEC 60947-1 : 2020)

### 4.4.1 Rated voltages

#### 4.4.1.1 Rated operational voltage (Ue)

The rated operational voltage (hereinafter referred to as rated voltage) of a circuit-breaker is the value of voltage, assigned by the manufacturer, to which its performance (particularly the short-circuit performance) is referred. For single-pole equipment, the rated operational voltage is generally stated as the voltage across the pole. For multipole equipment, it is generally stated as the voltage between phases.

#### 4.4.1.2 Rated insulation voltage (Ui)

The rated insulation voltage of an equipment is the voltage, assigned by the manufacturer, to which dielectric tests and creepage distances are referred. In no case shall the maximum value of the rated operational voltage exceed that of the rated insulation voltage.

#### 4.4.1.3 Rated impulse withstand voltage (Uimp)

The peak impulse voltage of prescribed form and polarity which the equipment is capable of withstanding without failure under specified conditions of test and to which the values of the clearances are referred. The rated impulse withstand voltage of an equipment shall be equal to or higher than the values stated for the transient overvoltages occurring in the circuit in which the equipment is fitted.

Preferred values of rated impulse withstand voltage are given in Table 1 (Refer clause 5.3.1.3 of IS/ IEC 60947-1 : 2020).

**Table 1– Impulse withstand test voltages**

| Rated impulse withstand voltage Uimp | Test voltages and corresponding altitudes | | | | |
|---|---|---|---|---|---|
| | U1.2/50 kV | | | | |
| kV | Sea level | 200 m | 500 m | 1 000 m | 2 000 m |
| 0.33 | 0.35 | 0.35 | 0.35 | 0.34 | 0.33 |
| 0.5 | 0.55 | 0.54 | 0.53 | 0.52 | 0.5 |
| 0.8 | 0.91 | 0.9 | 0.9 | 0.85 | 0.8 |
| 1.5 | 1.75 | 1.7 | 1.7 | 1.6 | 1.5 |
| 2.5 | 2.95 | 2.8 | 2.8 | 2.7 | 2.5 |
| 4.0 | 4.8 | 4.8 | 4.7 | 4.4 | 4.0 |
| 6.0 | 7.3 | 7.2 | 7.0 | 6.7 | 6.0 |
| 8.0 | 9.8 | 9.6 | 9.3 | 9.0 | 8.0 |
| 12 | 14.8 | 14.5 | 14 | 13.3 | 12 |

### 4.4.2 Currents

#### 4.4.2.1 Conventional free air thermal current (Ith)

The conventional free air thermal current is the maximum test current to be used for temperature-rise tests of unenclosed equipment in free air. The value of the conventional free air thermal current shall be at least equal to the maximum value of the rated operational current of the unenclosed equipment in eight-hour duty.

Free air is understood to be air under normal indoor conditions reasonably free from draughts and external radiation.

#### 4.4.2.2 Conventional enclosed thermal current (Ithe)

The conventional enclosed thermal current is the current stated by the manufacturer to be used for the temperature-rise tests of the equipment when mounted in a specified enclosure.

The value of the conventional enclosed thermal current shall be at least equal to the maximum value of the rated operational current of the enclosed equipment in eight-hour duty.

The conventional enclosed thermal current value may be for unventilated equipment, in which case the enclosure used for the test shall be of the size stated by the manufacturer, being the smallest that is applicable in service. Alternatively, the value may be for a ventilated equipment according to the manufacturer's data.

#### 4.4.2.3 Rated operational current (Ie) or rated operational power

A rated operational current of an equipment is stated by the manufacturer and takes into account the rated operational voltage, the rated frequency, the rated duty, the utilization category and the type of protective enclosure, if appropriate.

In the case of equipment for direct switching of individual motors, the indication of a rated operational current may be replaced or supplemented by an indication of the maximum rated power output, at the rated operational voltage considered, of the motor for which the equipment is intended. The manufacturer shall be prepared to state the relationship assumed between the operational current and the operational power, if any.

#### 4.4.2.4 Rated uninterrupted current (Iu)

The rated uninterrupted current of an equipment is the current, stated by the manufacturer, which the equipment can carry in uninterrupted duty.

### 4.4.3 Rated frequency

The supply frequency for which an equipment is designed and to which the other characteristic values correspond. The same equipment may be assigned a number or a range of rated frequencies or be rated for both alternating current and direct current.

### 4.4.4 Rated duties

#### 4.4.4.1 Eight-hour duty

A duty in which the main contacts of an equipment remain closed, whilst carrying a steady current long enough for the equipment to reach thermal equilibrium but not for more than eight hours without interruption. This is the basic duty on which the conventional thermal currents Ith and Ithe of the equipment are determined.

#### 4.4.4.2 Uninterrupted duty

A duty without any off-load period in which the main contacts of an equipment remain closed, whilst carrying a steady current without interruption for periods of more than eight hours (weeks, months, or even years). This kind of service is set apart from the eight-hour duty because oxides and dirt can accumulate on the contacts and lead to progressive heating. Uninterrupted duty can be taken account of either by a derating factor, or by special design considerations (e.g. silver contacts).

#### 4.4.4.3 Intermittent periodic duty or intermittent duty

A duty with on-load periods, in which the main contacts of an equipment remain closed, having a definite relation to off-load periods, both periods being too short to allow the equipment to reach thermal equilibrium. Intermittent duty is characterized by the value of the current, the duration of the current flow and by the on-load factor which is the ratio of the in-service period to the entire period, often expressed as a percentage.

**Standardized values of the on-load factor are 15 %, 25 %, 40 % and 60 %.**

Equipment are divided into classes according to the number of operating cycles which they shall be capable of carrying out per hour. For details, refer IS/IEC 60947-1.

#### 4.4.4.4 Temporary duty

Duty in which the main contacts of an equipment remain closed for periods insufficient to allow the equipment to reach thermal equilibrium, the unload periods being separated by off- load periods of sufficient duration to restore equality of temperature with the cooling medium.

Standardized values of temporary duty are 3 min, 10 min, 30 min, 60 min and 90 min, with contacts closed.

#### 4.4.4.5 Periodic duty

A type of duty in which operation, whether at constant or variable load, is regularly repeated.

### 4.4.5 Characteristics under normal load and overload conditions

#### 4.4.5.1 Ability to withstand motor switching overload currents

An equipment intended for switching motors shall be capable of withstanding the thermal stresses due to starting and accelerating a motor to normal speed and due to operating overloads. The detailed requirements to meet these conditions are given in the relevant product standard.

#### 4.4.5.2 Rated making capacity

The rated making capacity of an equipment is the current, stated by the manufacturer, which the equipment can satisfactorily make under specified conditions. The making conditions which shall be specified are the applied voltage and the characteristics of the test circuit.

The rated making capacity is stated by reference to the rated operational voltage and rated operational current, according to the relevant product standard.

#### 4.4.5.3 Rated breaking capacity

The rated breaking capacity of all equipment is the current, stated by the manufacturer, which the equipment can satisfactorily break, under specified conditions. The breaking conditions which shall be specified are the characteristics of the test circuit and the power-frequency recovery voltage.

The rated breaking capacity is stated by reference to the rated operational voltage and rated operational current, according to the relevant product standard. An equipment shall be capable of breaking any value of current up to and including its rated breaking capacity.

### 4.4.6 Short-circuit characteristics

#### 4.4.6.1 Rated short-time withstand current (Icw)

The rated short-time withstand current of an equipment is the short-time current, assigned to the equipment by the manufacturer, that the equipment can carry without damage, under the test conditions specified in the relevant product standard.

#### 4.4.6.2 Rated short-circuit making capacity (Icm)

The rated short-circuit making capacity of an equipment is the short-circuit making capacity assigned to that equipment by the manufacturer for the rated operational voltage, at rated frequency, and at a specified power-factor for alternating current or time constant for direct current. lt is expressed as the maximum prospective peak current, under prescribed conditions.

#### 4.4.6.3 Rated short-circuit breaking capacity (Icn)

The rated short-circuit breaking capacity of an equipment is the short-circuit breaking capacity assigned to that equipment by the manufacturer for the rated operational voltage, at rated frequency, and at a specified power-factor for alternating current or time constant for direct current. It is expressed as the value of the prospective breaking current (RMS value of the AC component in the case of alternating current), under prescribed conditions.

#### 4.4.6.4 Rated conditional short-circuit current (Iq, alternatively Icc)

The rated conditional short-circuit current of an equipment is the prospective current, stated by the manufacturer, which the equipment, protected by a short-circuit protective device specified by the manufacturer, can withstand satisfactorily for the operating time of this device under the test conditions specified in the relevant product standard.

### 4.4.7 Pole impedance of the switching device (Z)

The pole impedance may be stated by the manufacturer and is determined by measuring the voltage drop resulting from the current flowing through the pole.

## 4.4 Utilization category

The utilization category of an equipment defines the intended application and shall be specified in the relevant product standard; it is characterized by one or more of the following service conditions:

i. current(s), expressed as multiple(s) of the rated operational current;

ii. voltage(s), expressed as multiple(s) of the rated operational voltage;

iii. power-factor or time-constant;

iv. short-circuit performance;

v. selectivity;

vi. other service conditions, as applicable.

IS/IEC 60947-1 provides assistance in the selection of equipment for specific applications by bringing all similar categories together under one common set of categories. The harmonisation framework for the low-voltage switchgear and controlgear is given in Table 2. A future objective is to specify a common set of requirements for testing of the products from different parts of the IS/IEC 60947 series.

**Table 2– Harmonisation Framework for Utilization Categories of Low-Voltage Switchgear and Controlgear**

| Nature of current | Relevant product standard | Utilization category | | Typical switched load |
|---|---|---|---|---|
| | | Specific | Present | |
| Alternating current | IS/ IEC 60947-3 | AC-20 | AC-20 | No-load condition |
| | | AC-21 | AC-21 | Resistive loads, including moderate overloads |
| | | AC-22 | AC-22 | Mixed resistive and inductive loads, including moderate overloads |
| | | AC-23 | AC-23 | Motor loads or other highly inductive loads |
| | IS/ IEC 60947-4-1 | AC-1 | AC-1 | Non-inductive or slightly inductive loads |
| | | AC-2 | AC-2 | Slip-ring motors or switching of mixed resistive and inductive loads, including moderate overloads |
| | | AC-3 | AC-3 | Squirrel-cage motors |
| | | AC-3e | AC-3e | Squirrel-cage motor with higher locked-rotor current |
| | | AC-4 | AC-4 | Squirrel-cage motors: plugging, inching |
| | | AC-5a | AC-5a | Discharge lamp ballasts |
| | | AC-5b | AC-5b | Incandescent lamps |
| | | AC-6a | AC-6a | Transformers |
| | | AC-6b | AC-6b | Capacitor banks |
| | | AC-8<br>AC-8 | AC-8a<br>AC-8b | Hermetic refrigerant compressor |
| | IS/ IEC | AC-2a | AC-52a | Slip ring motor stators: 8 h duty with |

| | | | | |
|---|---|---|---|---|
| | 60947-4-2 | | | on-load currents for start, acceleration, run |
| | | AC-2b | AC-52b | Slip ring motor stators: intermittent duty |
| | | AC-3a | AC-53a | Squirrel-cage motors: 8 h duty with on-load currents for start, acceleration, run |
| | | AC-3b | AC-53b | Squirrel-cage motors: intermittent duty |
| | | AC-8a | AC-58a | Hermetic refrigerant compressor motors with automatic resetting of overload releases: 8 h duty with on-load currents for start, acceleration, run |
| | | AC-8b | AC-58b | Hermetic refrigerant compressor motors with automatic resetting of overload releases: intermittent duty |
| | IS/ IEC 60947-4-3 | AC-1 | AC-51 | Non-inductive or slightly inductive loads |
| | | AC-5a | AC-55a | Discharge lamps ballast |
| | | AC-5b | AC-55b | Incandescent lamps |
| | | AC-6a | AC-56a | Transformers |
| | | AC-6b | AC-56b | Capacitor banks |
| | IS/ IEC 60947-5-1 | AC-12 | AC-12 | Resistive loads and solid-state loads with isolation by optocouplers |
| | | AC-13 | AC-13 | Solid-state loads with transformer isolation |
| | | AC-14 | AC-14 | Small electromagnetic loads |
| | | AC-15 | AC-15 | AC electromagnetic loads |
| | IS/ IEC 60947-5-2 | AC-12 | AC-12 | Resistive loads and solid state loads with optical isolation |
| | | AC-140 | AC-140 | Small electromagnetic loads with holding (closed) current ? 0,2 A, e.g. contactor relays |
| | IS/ IEC 60947-6-1 | AC-1 | AC-31 | Non inductive or slightly inductive loads |
| | | AC-2 | AC-32 | Slip-ring motors or switching of mixed resistive and inductive loads, including moderate overloads |
| | | AC-3 | AC-33 | Squirrel-cage motors |
| | | AC-5a | AC-35 | Discharge lamp ballast |
| | | AC-5b | AC-36 | Incandescent lamps |
| | IS/ IEC 60947-6-2 | AC-40 | AC-40 | Distribution circuits comprising mixed resistive and reactive loads having a resultant inductive reactance |
| | | AC-1 | AC-41 | Non-inductive or slightly inductive loads |

| | | | | |
|---|---|---|---|---|
| | | AC-2 | AC-42 | Slip-ring motors or switching of mixed resistive and inductive loads, including moderate overloads |
| | | AC-3 | AC-43 | Squirrel-cage motors |
| | | AC-4 | AC-44 | Squirrel-cage motors: plugging, inching |
| | | AC-5a | AC-45a | Discharge lamp ballasts |
| | | AC-5b | AC-45b | Incandescent lamps |
| | IS/ IEC 61095 | AC-7a | AC-7a | Slightly inductive loads for household appliances and similar applications |
| | | AC-7b | AC-7b | Motor-loads for household applications |
| Direct current | IS/ IEC 60947-3 | DC-20 | DC-20 | Connecting and disconnecting under no-load conditions |
| | | DC-21 | DC-21 | Resistive loads, including moderate overloads |
| | | DC-22 | DC-22 | Mixed resistive and inductive loads, including moderate overloads (e.g. shunt motors) |
| | | DC-23 | DC-23 | Highly inductive loads (e.g. series motors) |
| | IS/ IEC 60947-4-1 | DC-1 | DC-1 | Non-inductive or slightly inductive loads |
| | | DC-3 | DC-3 | Shunt-motors |
| | | DC-5 | DC-5 | Series-motors |
| | | DC-6 | DC-6 | Incandescent lamps |
| | IS/ IEC 60947-5-1 | DC-12 | DC-12 | Control of resistive loads and solid-state loads with isolation by optocouplers |
| | | DC-13 | DC-13 | Control of electromagnets |
| | | DC-14 | DC-14 | Control of electromagnetic loads having economy resistors in circuit |
| | S/ IEC 60947-5-2 | DC-12 | DC-12 | Control of resistive loads and solid state loads with optical isolation |
| | | DC-13 | DC-13 | Control of electromagnets |
| | IS/ IEC 60947-6-1 | DC-1 | DC-31 | Non-inductive or slightly inductive loads |
| | | DC-3 | DC-33 | Shunt-motors |
| | | DC-6 | DC-36 | Incandescent lamps |
| | IS/ IEC 60947-6-2 | DC-40 | DC-40 | Distribution circuits comprising mixed resistive and reactive loads having a resultant inductive reactance |
| | | DC-1 | DC-41 | Non-inductive or slightly inductive loads |
| | | DC-3 | DC-43 | Shunt-motors |
| | | DC-5 | DC-45 | Series-motors |
| | | DC-6 | DC-46 | Incandescent lamps |

## 4.5 Ingress Protection

The main components of a switchgear are circuit breakers, switches, bus-bars, instruments and instrument transformers. For voltages beyond 66 kV, the clearances between conductors and the space required for switches, circuit breakers, transformers and others equipment become so great that it is not economical to install all such equipment indoor, hence such switchgear equipment is installed outdoor. For voltages below 66 kV, switchgear is generally installed indoor because of economic considerations.

It is necessary to house the switchgear and switchgear assemblies in such a way so as to safeguard personnel during operation and maintenance and to ensure that the effects of fault on any section of the gear are confined to a limited region.

Outdoor switchgear and controlgear is suitable for installation in the open air, and is expected to be capable of withstanding wind, rain, snow, dirt deposits, condensation, ice and hoar frost. Indoor switchgear and controlgear switchgear and controlgear is designed solely for installation within a building or other housing, where the switchgear and controlgear is protected against wind, rain, snow, abnormal dirt deposits, abnormal condensation, ice and hoar frost.

The equipment with its enclosure, if any, whether integral or not, shall be designed and constructed to withstand not only the stresses occurring during installation and normal use and provide a specified degree of resistance to abnormal heat and fire, but also provide ingress protection. The level of ingress protection of enclosures is designated by the IPXX ratings, as specified in IS/IEC 60529 'Degrees of protection provided by enclosures (IP Code)' which has been developed to rate and grade the resistance of enclosures of electric and electronic devices against the intrusion of dust and liquids.

An IP code is stated by the manufacturer for enclosed equipment and shall comply with the requirements of IS/ IEC 60529. If the IP Code is designated for one mounting position only, it shall be indicated by the symbol following placed next to the IP Code specifying this position of the equipment, e.g. vertical:

**Table 3 Ingress Protection – IP Codes**

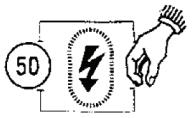
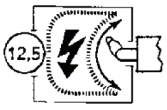
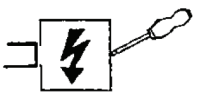
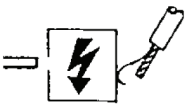
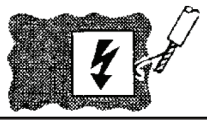
| FIRST NUMERAL | | | |
|---|---|---|---|
| **Protection against ingress of solid objects** | | | **Protection of persons against access to hazardous parts with:** |
| **IP** | **Requirements** | **Example** | |
| 0 | No protection |  | Non-protected |
| 1 | Full penetration of 50 mm diameter sphere not allowed. Contact with hazardous parts not permitted |   | Back of hand |
| 2 | Full penetration of 12,5 mm diameter sphere not allowed. The jointed test finger shall have adequate clearance from hazardous parts |   | Finger |
| 3 | The access probe of 2,5 mm diameter shall not penetrate |  | Tool |
| 4 | The access probe of 1,0 mm diameter shall not penetrate |  | Wire |
| 5 | Limited ingress of dust permitted (no harmful deposit) |  | Wire |
| 6 | Totally protected against ingress of dust |  | Wire |

**Table 4 Ingress Protection – IP Codes**

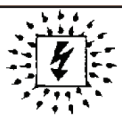
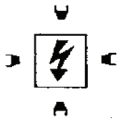
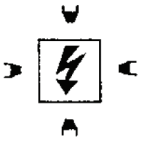
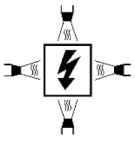
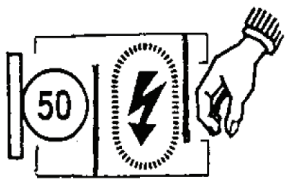
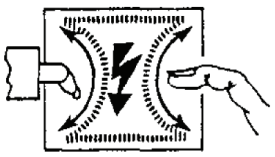
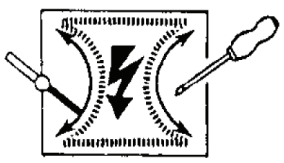
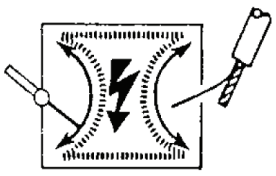
| SECOND NUMERAL | | | |
|---|---|---|---|
| **Protection against harmful ingress of water** | | | **Protection from water** |
| **IP** | **Prescriptions** | **Example** | |
| 0 | No protection |  | Non-protected |
| 1 | Protected against vertically falling drops of water. Limited ingress permitted |  | Vertically dripping |
| 2 | Protected against vertically falling drops of water with enclosure tilted 15° from the vertical. Limited ingress permitted |  | Dripping up to 15° from the vertical |
| 3 | Protected against sprays to 60° from the vertical. Limited ingress permitted |  | Limited spraying |
| 4 | Protected against water splashed from all directions. Limited ingress permitted |  | Splashing from all directions |
| 5 | Protected against jets of water. Limited ingress permitted |  | Hosing jets from all directions |
| 6 | Protected against strong jets of water. Limited ingress permitted |  | Strong hosing jets from all directions |
| 7 | Protected against the effects of immersion between 15 cm and 1 m |  | Temporary immersion |
| 8 | Protected against long periods of immersion under pressure |  | Continuous immersion |
| 9 | Protected against high pressure and temperature water jets |  | Strong hot water jets from all directions |

**Table 5 Ingress Protection – IP Codes**

| ADDITIONAL LETTER (optional) | | | |
|---|---|---|---|
| **IP** | **Requirements** | **Example** | **Protection of persons against access to hazardous parts with:** |
| A For use with first numeral 0 | Penetration of 50 mm diameter sphere up to barrier shall not contact hazardous parts |  | Back of hand |
| B For use with first numerals 0 and 1 | Test finger penetration to a maximum of 80 mm shall not contact hazardous parts |  | Finger |
| C For use with first numerals 1 and 2 | Wire of 2,5 mm diameter 100 mm long shall not contact hazardous parts when spherical stop face is partially entered |  | Tool |
| D For use with first numerals 2 and 3 | Wire of 1,0 mm diameter 100 mm long shall not contact hazardous parts when spherical stop face is partially entered |  | Wire |

# CHAPTER V
# SWITCHGEAR TESTING

# CHAPTER V

# SWITCHGEAR TESTING

## 5.1 Introduction

Tests are carried out on low-voltage and high-voltage switchgears to ensure that it meets the required standards for safety, reliability, and performance. The testing procedures are detailed and follow specific Indian Standards for particular type of switchgear. However, the basic principles of mechanical, electrical and environmental test procedures remain the same. IS/IEC 60947-1 Low-voltage switchgear and controlgear Part 1 General rules is referred extensively by the relevant product standards pertaining to low-voltage switchgear to verify their compliance. Accordingly, in this Chapter, this standard is used as a basis to provide an overview of testing for basic understanding of switchgear testing. For complete details on testing specific to low-voltage switchgear, low-voltage and high-voltage fuses and high-voltage switchgear, relevant product standards as mentioned in Chapter 2 and Chapter 3 of this Handbook may be referred.

The tests for switchgear are typically divided into Type tests, Routine tests, and Special tests.

### 5.1.1 Type Tests (Refer Clause 9.1.2 of IS/IEC 60947-1)

Type tests shall be made on representative samples of each switchgear to verify the design and ensure compliance with standards. It typically consists of the following tests:

i. Constructional requirements (9.2)
ii. Temperature Rise Test (9.3.3.3)
iii. Dielectric Test (9.3.3.4.1)
iv. Making and Breaking Capacity Test (9.3.3.5)
v. Short-Circuit Withstand Test (9.3.4)
vi. Critical load current performance (9.3.3)
vii. Operating limits (9.3.3.2)
viii. Operational performance (9.3.3.2.1)
ix. Degree of protection of enclosed equipment (Annex C)
x. Tests for EMC (9.4)
xi. Mechanical Operation Test (9.2.6.2.1)

### 5.1.2 Routine Tests (Refer Clause 9.1.3 of IS/IEC 60947-1)

Routine tests shall be made on each individual piece of switchgear manufactured before it leaves the factory, to ensure proper manufacturing and functionality. The following tests are routine tests for switchgear:

i. Insulation Resistance Test (IS/IEC 61557-2 : 2019)
ii. Dielectric Voltage Withstand Test (9.2)
iii. Functional Tests

### 5.1.3 Special Tests (Refer Clause 9.1.5 of IS/IEC 60947-1)

Special tests are performed based on specific customer requirements or conditions. They may consist of the following tests:

i. Reliability data tests (9.1.5.2)

ii. Environmental tests (9.1.5.3)

## 5.2 Tests on Switchgear

The major tests on switchgear as per IS/IEC 60947-1 : 2020 Low-voltage switchgear and controlgear Part 1 General rules, and their significance are elaborated under this clause. IS/IEC 60947-1 : 2020 should be referred for the complete list of tests, and for detailed procedure for carrying out these tests. Product-specific Indian Standards in the IS/IEC 60947 series may also consist of test sequences according to the requirements mentioned in the relevant product standard and should be referred as relevant.

### 5.2.1 Constructional Requirements

**5.2.1.1** Purpose: To ensure that the equipment is designed and constructed in accordance with safety standards and operational requirements. The verification of compliance includes the materials, components, dimensional requirements and actuator mechanism.

**5.2.1.2 Test Procedure:**

i. Visual Inspection: Check the equipment for obvious defects or deviations from design specifications.

ii. Material Verification: Confirm that the materials used comply with the specifications (e.g., insulation materials, conductive materials).

Test of materials to abnormal heat and fire is carried out through glow-wire test as per IS 11000 (Part 2/Sec 1) : 2018 Fire hazard testing: Part 2 Test methods, Section 1 Glow-wire apparatus and common test procedure, and IS/IEC 60695-2-11 : 2014 Fire hazard testing: Part 2-11 Glowing/ hot-wire based test methods glow-wire flammability test method for end-products (GWEPT).

Test on materials for flammability, hot wire ignition and arc ignition tests is carried out as per IS/IEC 60695-11-10 : 2013 Fire hazard testing: Part 11 Test flames, Section 10 50 w horizontal and vertical flame test methods.

iii. Component Checks: Ensure that all components are correctly assembled and secured. Mechanical properties of terminals are verified through tests using the appropriate type of conductor having the maximum cross-section.

The conductor shall be connected and disconnected five times using 110 % of the torque specified by the manufacturer.

Testing for damage to and accidental loosening of conductors (flexion test) is carried out by subjecting the connected conductor to circular motions according to the procedure prescribed in clause 9.2.5.3 of IS/IEC 60947-1.

iv. Dimensional Checks: Verify that the dimensions of the equipment parts are within tolerance limits.

**5.2.1.3 Significance:**

i. Safety and Compliance: Ensures that the equipment is designed and built according to safety standards and regulatory requirements.

ii. Reliability: Validates that materials and construction methods will support safe and effective operation over the equipment's expected lifespan.

iii. Prevention of Failures: Helps avoid potential mechanical and electrical failures caused by poor design or assembly.

**5.2.2 Temperature Rise Test**

**5.2.2.1 Purpose: To determine the temperature rise of the equipment under normal operating conditions.**

**5.2.2.2 Test Procedure:**

i. Setup: Connect the equipment to a load that represents its rated conditions.

ii. Initial Measurement: Measure the ambient temperature and the initial temperature of the equipment components.

iii. Operation: Operate the equipment continuously at rated load.

iv. Temperature Measurement: Record the temperature of critical components after a specified period (typically several hours).

v. Assessment: Compare the measured temperature rise against the maximum allowable temperature limits specified in IEC 60947.

**5.2.2.3 Significance:**

i. Safe Operation: Ensures that the equipment does not overheat under normal operating conditions, which could lead to safety hazards or premature failure.

ii. Efficiency: Verifies that the equipment maintains thermal performance within specified limits, preventing excessive energy loss or damage.

iii. Long-Term Reliability: Helps ensure the longevity of the equipment by confirming that it operates within safe temperature ranges.

**5.2.3 Dielectric Tests**

**5.2.3.1** Purpose: To ensure that the switchgear can withstand high-voltage stresses without insulation breakdown.

**5.2.3.2 Test Procedure:**

i. Preparation: Disconnect the equipment from the power supply and ensure it is in a safe condition for testing.

ii. Voltage Application: Apply the test voltage between live parts and earth (ground), or between live parts, as specified in the standard.

iii. Duration: Maintain the test voltage for a specified period (usually 1 minute).

iv. Observation: Observe and record any insulation breakdown or leakage current.

v. Evaluation: Check if the insulation withstands the test voltage without breakdown or excessive leakage.

vi. Criteria: No insulation breakdown or excessive leakage should occur.

**5.2.3.3 Significance:**

i. Insulation Integrity: Assesses the strength of the insulation to prevent electrical breakdown or leakage currents, which could lead to shock hazards or equipment failure. The lightning impulse withstand voltage test is a crucial test to verify the insulation strength of switchgear against high-voltage surges, simulating the effects of lightning strikes.

ii. Safety Assurance: Ensures that the insulation can withstand operational voltages and transient conditions, protecting both the equipment and users.

### 5.2.4 Making and Breaking Capacity Test

5.2.4.1 Purpose: To evaluate the equipment's ability to make and break electrical circuits under specified conditions.

**5.2.4.2 Test Procedure:**

i. Setup: Connect the equipment to a test circuit that simulates normal operational and fault conditions (e.g., short-circuit conditions).

ii. Making Test: Operate the equipment to make a connection under specified conditions and measure the performance.

iii. Breaking Test: Operate the equipment to break a circuit under specified conditions and measure its performance.

iv. Observation: Monitor for any excessive wear, arcing, or failure during the tests.

v. Assessment: Verify that the equipment can make and break the circuit without exceeding design limits or causing unsafe conditions.

**5.2.4.3 Significance:**

i. Operational Reliability: Confirms the equipment's ability to make (connect) and break (disconnect) electrical circuits effectively under normal and fault conditions.

ii. Safety: Ensures that the equipment can handle and isolate electrical faults, minimizing risks such as arcing and potential damage.

iii. Performance Assurance: Validates that the equipment performs reliably in real-world scenarios where switching operations are critical.

### 5.2.5 Short-Circuit Withstand Test

5.2.5.1 Purpose: To verify the equipment's ability to withstand and remain operational under short-circuit conditions.

**5.2.5.2 Test Procedure:**

i. Setup: Connect the equipment to a short-circuit test circuit.

ii. Short-Circuit Application: Apply a short-circuit current for a specified duration.

iii. Monitoring: Observe the equipment for deformation, damage, or failure.

iv. Assessment: Verify that the equipment remains operational and intact after the short-circuit test.

**5.2.4.3 Significance:**

i. Durability: Tests the equipment's ability to endure the thermal and mechanical stresses imposed by short-circuit conditions without significant damage.

ii. Safety: Ensures that the equipment can withstand short-circuit events without causing hazards or impairing performance.

iii. Structural Integrity: Verifies that the equipment's construction can handle extreme fault conditions without failing catastrophically

### 5.2.6 Critical Load Current Performance

**5.2.6.1** Purpose: To determine the performance of the equipment at its rated critical load current.

**5.2.6.2 Test Procedure:**

i. Setup: Connect the equipment to a test load equal to the critical load current.

ii. Operation: Run the equipment under the critical load conditions.

iii. Monitoring: Check for proper operation, including temperature rise, stability, and functionality.

iv. Assessment: Verify that the equipment operates correctly without excessive temperature rise or other issues.

**5.2.6.3 Significance:**

i. Performance Assurance: Ensures that the equipment performs reliably and safely under its maximum rated load conditions.

ii. Efficiency: Validates that the equipment can handle its rated load without excessive temperature rise or degradation in performance.

iii. Safety: Prevents potential overheating or failure during peak operating conditions.

### 5.2.7 Operating Limits

**5.2.7.1** Purpose: To establish the boundaries within which the equipment can safely operate.

**5.2.7.2 Test Procedure:**

i. Setup: Configure the equipment with varying loads and voltages within specified ranges.

ii. Operation: Test the equipment at the upper and lower limits of its operational parameters.

iii. Monitoring: Observe the performance and functionality at these limits.

iv. Assessment: Verify that the equipment operates correctly and safely within its specified operating limits.

**5.2.7.3 Significance:**

i. Operational Safety: Defines the boundaries within which the equipment can operate safely and effectively, preventing damage or unsafe conditions.

ii. Performance Assurance: Ensures that the equipment can handle variations in operational conditions without loss of functionality or safety.

iii. Design Validation: Confirms that the equipment operates within specified parameters, ensuring compliance with design and safety standards.

### 5.2.8 Operational Performance

5.2.8.1 Purpose: To assess the overall functionality and effectiveness of the equipment in real-world conditions.Test Procedure:

**5.2.8.2 Test Procedure:**

i. Setup: Install and connect the equipment in a manner similar to actual usage conditions.

ii. Operation: Test the equipment under normal operating conditions and scenarios.

iii. Monitoring: Evaluate the equipment's performance, including control functions, switching operations, and stability.

iv. Assessment: Ensure that the equipment performs as expected and meets all operational specifications.

**5.2.8.3 Significance:**

i. Functionality: Assesses whether the equipment performs its intended functions correctly and reliably in practical use scenarios.

ii. User Satisfaction: Ensures that the equipment meets performance expectations and user requirements under typical operating conditions.

iii. Safety and Efficiency: Validates that the equipment operates safely and efficiently during normal use, preventing unexpected issues.

### 5.2.9 Degree of Protection of Enclosed Equipment

**5.2.9.1** Purpose: To determine the level of protection provided by the enclosure against ingress of solid objects and liquids.

**5.2.9.2 Test Procedure:**

i. IP Code Testing: Conduct tests based on the IP (Ingress Protection) code requirements as per IS/IEC 60259, that is:

a. Solid Ingress: Test against dust ingress.

b. Water Ingress: Test against various water exposure conditions (e.g., water jets, immersion).

ii. Observation: Check for any ingress of dust or water that could affect the equipment's operation.

iii. Assessment: Verify that the equipment meets the specified IP rating for protection.

**5.2.9.3 Significance:**

i. Environmental Protection: Ensures that the equipment is adequately protected against ingress of dust, water, and other environmental factors that could impair performance or safety.

ii. Durability: Confirms that the enclosure can withstand environmental stresses, extending the equipment's operational life and reliability.

iii. Safety: Protects users from potential hazards related to environmental exposure.

### 5.2.10 Tests for EMC (Electromagnetic Compatibility)

**5.2.10.1** Purpose: To assess the equipment's ability to function correctly in the presence of electromagnetic interference and to limit its own emissions.

**5.2.10.2 Test Procedure:**

i. Emission Testing: Measure the electromagnetic emissions from the equipment to ensure they are within specified limits.

ii. Immunity Testing: Expose the equipment to electromagnetic interference (EMI) and verify it continues to operate correctly.

iii. Assessment: Ensure that the equipment meets EMC requirements for both emissions and immunity.

**5.2.10.3 Significance:**

i. Interference Prevention: Ensures that the equipment does not emit electromagnetic interference that could affect other devices and systems.

ii. Operational Reliability: Verifies that the equipment can operate correctly in the presence of electromagnetic disturbances, preventing malfunction or failure.

iii. Compliance: Confirms that the equipment meets regulatory requirements for electromagnetic compatibility, avoiding legal and performance issues.

### 5.2.11 Mechanical Operation Test

**5.2.11.1** Purpose: To evaluate the mechanical durability and reliability of the equipment's moving parts and mechanisms.

**5.2.11.2 Test Procedure:**

i. Setup: Configure the equipment to operate under typical mechanical loads and cycles.

ii. Operation: Perform repeated mechanical operations (e.g., switching cycles) to simulate long-term use.

iii. Monitoring: Inspect the equipment for wear, mechanical failures, or changes in performance.

iv. Assessment: Confirm that the equipment maintains its mechanical integrity and functionality after extensive operation.

**5.2.11.3 Significance:**

i. Durability: Assesses the mechanical robustness of the equipment, including its moving parts and mechanisms, to ensure long-term reliability.

ii. Performance: Validates that the mechanical components perform correctly over extended periods and under repeated operational cycles.

iii. Safety: Ensures that the equipment's mechanical systems do not fail or degrade in a way that could pose a risk to users or the equipment itself.

Testing low-voltage switchgear according to Indian Standards is essential for ensuring its safety, reliability, and performance. Each testing procedure, from visual inspection to advanced functional and withstand tests, plays a critical role in verifying that the switchgear meets the required specifications and can operate effectively in real-world conditions. Adhering to these standards helps prevent equipment failures, ensures compliance with safety regulations, and maintains the integrity of electrical systems. Regular and thorough testing is crucial for the long-term reliability and safety of switchgear, protecting both equipment and personnel.

# CHAPTER VI

# FUTURE TRENDS IN STANDARDIZATION OF SWITCHGEAR

# CHAPTER VI

# FUTURE TRENDS IN STANDARDIZATION OF SWITCHGEAR

## 6.1 General

6.1.1 The field of switchgear is evolving rapidly due to technological advancements, regulatory changes, and shifting market demands. The future trends in standardization for switchgear will be influenced by use of IoT technology, cybersecurity, environmental impact and sustainability, scalability, and increased consumer expectations. Power systems and their components are expected to become more complex in the future, and standards have to lead the way.

## 6.2 Indian Standards under development

The following Indian Standards are under development:

i. Low-voltage switchgear and controlgear Part 7 Ancillary equipment Section 1 Terminal blocks for copper conductors

ii. Low-voltage switchgear and controlgear Part 7 Ancillary equipment Section 2 Protective conductor terminal blocks for copper Conductors

iii. Miniature Fuses Part 1 Definitions for Miniature Fuses and General Requirements for Miniature Fuse-Links

iv. Miniature Fuses Part 3 Sub-miniature fuse-links

v. Miniature fuses Part 7 Miniature fuse-links for special applications

vi. Miniature fuses Part 8 Fuse resistors with particular overcurrent protection

vii. Miniature fuses Part 10 User guide for miniature fuses

viii. Low-voltage Fuses Part 7 Supplementary Requirements for Fuse-Links for The Protection of Batteries and Battery Systems

## 6.3 International Standards under development

Some of the standards under development at international level are as follows:

i. Protective devices based on semiconductor technology for household and similar use - Part 1: Semiconductor Residual current operated Circuit-Breakers with integral Overcurrent protection for household and similar uses (SC-RCBOs)

ii. Low-voltage switchgear and controlgear – Part 10: Semiconductor Circuit-Breakers

iii. Low-voltage switchgear and controlgear - Controllers for drivers of stationary fire pumps

iv. Low-voltage switchgear and controlgear assemblies - Part 8: Assemblies for use in photovoltaic installations

v. Low-voltage switchgear and controlgear assemblies - Internal arc-fault protection of low-voltage switchgear and controlgear assemblies in accordance with the IEC 61439 series

vi. Supplementary requirements for intelligent assemblies

vii. High-voltage switchgear and controlgear - Part 3: Digital interfaces

viii. High-voltage switchgear and controlgear - Part 320: Environmental aspects and life cycle assessment rules

ix. High-voltage switchgear and controlgear data and properties for information exchange - Part 1: Catalogue data

x. High-voltage switchgear and controlgear - Part 322: Digital technologies – application and guidance

xi. Environmental Issues for/of fuses

xii. Energy efficiency issues for/of fuses

xiii. High-Voltage DC Fuses

xiv. Fuse-links for road vehicles - Fuse-links with a rated voltage up to 1000V AC and 1500V DC

# CHAPTER VII

# STANDARDS INFLUENCE TRADE & ECONOMY

# CHAPTER VII

## STANDARDS INFLUENCE TRADE & ECONOMY

### 7.1 Introduction

Standards facilitate trade and enable easier and faster market access. When products are tested as per defined norms in the Indian Standards, the purchaser, or consumer, is assured of the quality of the product. The Indian Standards established by BIS forms the basis for the Product Certification Schemes, which provides Third Party Assurance of Quality, Safety and Reliability of products to consumers. BIS encourages all procurement agencies to use Indian Standards as a benchmark in procurement of goods.

### 7.2 Thrust on Mandatory Certification through Technical Regulations

7.2.1 BIS certification scheme is basically voluntary in nature. However, for a number of products compliance to Indian Standards is made compulsory by the Central Government through technical regulations, under various considerations viz. public interest, protection of human, animal or plant health, safety of environment, prevention of unfair trade practices and national security. For such products, the Central Government directs mandatory use of Standard Mark under a Licence or Certificate of Conformity (CoC) from BIS through issuance of Quality Control Orders (QCOs).

### 7.3 Provisions of the BIS Act

7.3.1 The Central Government, after consulting BIS, publishes QCOs in exercise of the powers conferred by sub-sections (1) and (2) of section 16 read in conjunction with section 17 and sub-section (3) of section 25 of the BIS Act, 2016 thereby bringing the products under BIS Mandatory Certification.

### 7.4 Provisions of Quality Control Orders

7.4.1 The products notified under QCOs shall conform to corresponding Indian Standard(s) mentioned in the QCO and shall bear the Standard Mark under a Licence or CoC from BIS as per the relevant Scheme of BIS (Conformity Assessment) Regulations, 2018 as notified in the Order.

7.4.2 QCOs are issued by various Line Ministries (Regulators) under the Central Government depending upon the product(s)/ product categories being regulated through the Order, after having stakeholder consultations. The date of commencement of the QCO is clearly mentioned in the Order itself so that the stakeholders are well aware of the timelines for its implementation in terms of necessary manufacturing and testing infrastructure and compliance of the product to the requirements of the relevant Indian Standard.

7.4.3 After the date of commencement of the QCO, no person shall manufacture, import, distribute, sell, hire, lease, store or exhibit for sale any product(s) covered under the QCO without a Standard Mark except under a valid Licence or CoC from BIS.

7.4.4 Domestic Laws / Rules / Orders / Regulations applicable to domestically produced goods shall apply, mutatis mutandis, to imports, unless specifically exempted. If domestic

product(s) are subjected to mandatory compliance with Indian Standards, such product(s) if imported would also need to comply with Indian Standards compulsorily. Thus, for these products, the manufacturer in foreign country will be required to obtain a Licence or CoC from BIS under the Foreign Manufacturers Certification Scheme (FMCS) of BIS.

7.4.5 Any person who contravenes the provisions of the Order shall be punishable under the provisions of sub-section (3) of section 29 of the BIS Act, 2016 with imprisonment or with fine or with both.

7.4.6 Any exemptions like non-applicability of the Order on specific product(s), product(s) meant for export etc. come under the purview of the Line Ministry (Regulator) who has issued the QCO. Wherever exemptions are permitted, these are clearly brought out in respective QCO itself.

## 7.5 Clarifications on QCOs

7.5.1 If any person is having issues/queries/clarifications related to applicability of QCO on a particular product or implementation of QCO or any matters connected therewith or incidental thereto like extension in the date of implementation of QCO, exemptions, stock-in-hand as on the date of implementation of the Order etc., they may approach the concerned Line Ministry/Department of the Central Government that has issued the QCO. If any person is having queries/clarifications related to coverage of any product under Indian Standard covered under QCO, they may approach BIS. The information on QCOs is available on BIS website at BIS.GOV.IN » Product-certification » Products-under-compulsory-certification.

## 7.6 Role of BIS in implementation of QCOs

7.6.1 Indian Standards form the basis of for the notification of technical regulations purpose of facilitating the Central Government in issuance of QCOs, BIS regularly interacts with Line Ministries/ Departments and provides technical inputs related to Indian Standards, appropriate Conformity Assessment Scheme etc. and also participates in stakeholder's consultation meeting.

7.6.2 Further, for implementation of the provisions of QCO, BIS acts as the Certification Authority and grants Licence or CoC to manufacturers as per relevant Conformity Assessment Scheme. BIS also acts as the Enforcement Authority for the products specified in the QCO.

## 7.7 Information on QCOs

The information on QCOs issued by the Central Government can be obtained from BIS website under the following link 'Conformity Assessment' > 'Product Certification' > 'Products under Compulsory Certification'.

## 7.8 QCO on Switchgears

The following Indian Standards on Switchgear have been notified under QCOs:

7.8.1 Electrical Wires, Cables, Appliances and Protection Devices and Accessories (Quality Control) Order, 2003

i. IS 12640 (Part 1) Residual current operated circuit breakers for house hold and similar uses-Part 1 Circuit breakers without integral overcurrent protection (RCCBs)

ii. IS 12640 (Part 2) Residual current operated circuit breakers for household and similar uses–Part 2 Circuit breakers with integral overcurrent protection(RCVOs)

iii. IS/IEC 60898 Electrical Accessories-Circuit breakers for overcurrent protection for household and similar installations

7.8.2 Electrical Equipment (Quality Control) Order, 2020

i. IS/IEC 60947 (Part 2) : 2016 Low-Voltage switchgear and control gear: Part 2 Circuit- breaker

ii. IS/IEC 60947 (Part 3) : 2012 Low-Voltage switchgear and control gear: Part 3 switches, disconnectors, switch disconnectors and fuse – Combination units

iii. IS/IEC 60947: Part 4: Sec 1: 2012 Low-Voltage switchgear and control gear: Part 4 contactors and motor – Starters: Sec 1 electromechanical contactors and motor – Starters

iv. IS/IEC 60947 (Part 4/Sec 2) : 2011 Low-Voltage switchgear and control gear: Part 4 contactors and motor – Starters: Sec 2 AC semiconductor motor controllers and starters

v. IS/IEC 60947 (Part 4/Sec 3) : 2014 Low-Voltage switchgear and control gear: Part 4 Contactors and motor – Starters Sec 3 AC semiconductor motor controllers and contactors for non – Motor loads

vi. IS/IEC 60947 (Part 5/Sec 1) : 2009 Low-Voltage switchgear and control gear: Part 5 Control circuit devices and switching elements: Sec 1 Electromechanical control circuit devices

vii. IS/IEC 60947 (Part 5/Sec 2) : 2007 Low-Voltage switchgear and control gear: Part 5 Control circuit devices and switching elements: Sec 2 Proximity switches

viii. IS/IEC 60947 (Part 5/Sec 5) : 2016 Low-Voltage switchgear and control gear: Part 5 Control circuit devices and switching elements Sec 5 Electrical emergency stop devices with mechanical latching function

## Summary

Switchgear play a vital role in such management of isolation, switching and controlling of power systems and are thus an essential part of any electrical system. This Handbook provides a comprehensive overview of Indian Standards for low-voltage and high-voltage switchgear, essential for ensuring safe and reliable electrical installations. For detailed technical specifications and the latest updates, refer directly to the Indian Standards and BIS website.

The indigenous Indian Standards can be downloaded free of cost from BIS website www.bis.gov.in or using the link https://standardsbis.bsbedge.com. It is recommended to use Indian Standards extensively wherever they exist.

The 'Know You Standards' is a useful tab under BIS website www.bis.gov.in, or use the link https://www.services.bis.gov.in/php/BIS_2.0/bisconnect/knowyourstandards/indian_standards/isdetails to search for Indian Standards, download and comment on them.

## Acknowledgement

Reference has been taken extensively from Indian Standards. Images of Switchgear and products are generic and not intended to promote any specific company.