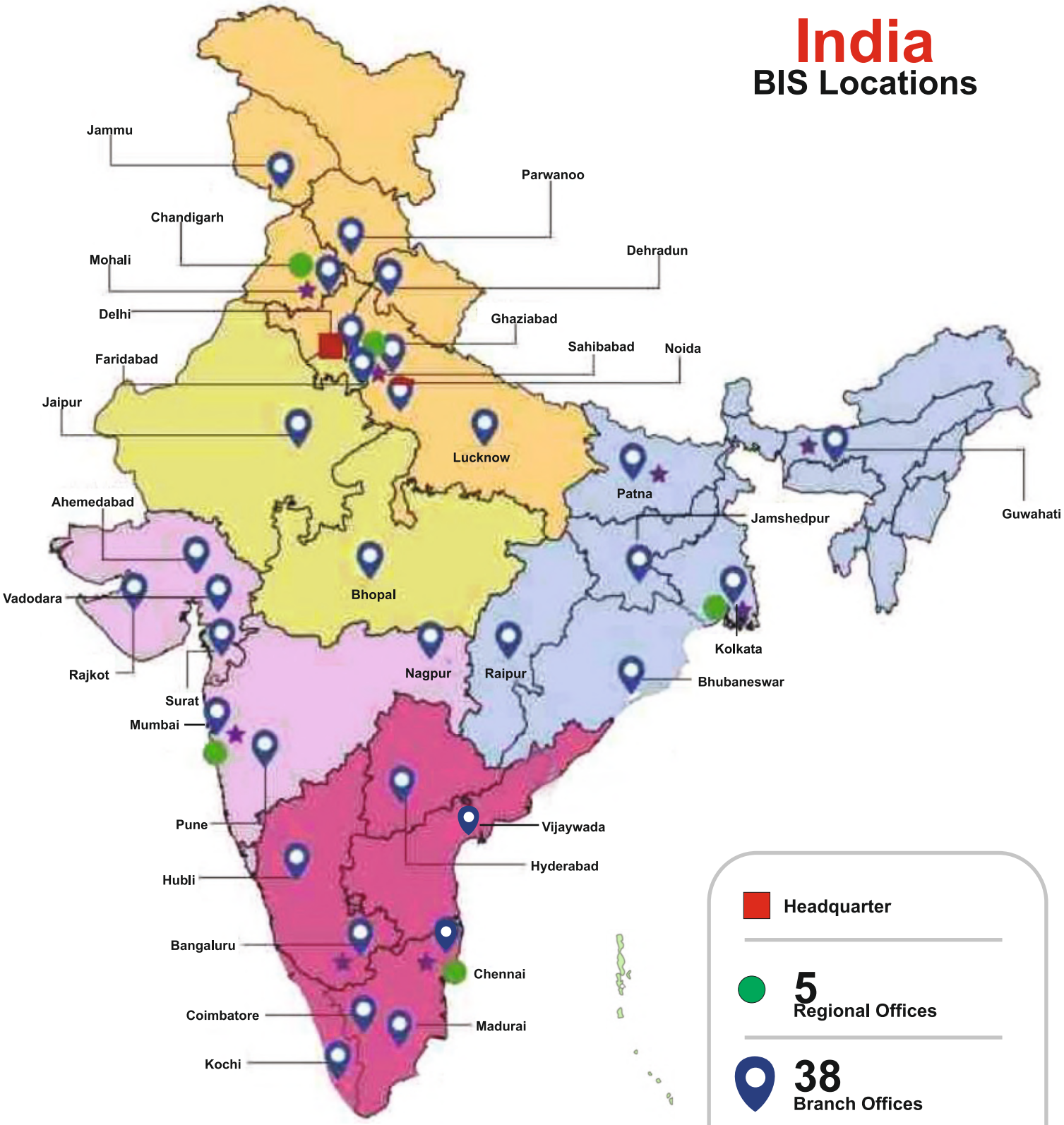
INDIAN STANDARDS ON ROTATING ELECTRICAL MACHINES

BUREAU OF INDIAN STANDARDS
Ministry of Consumer Affairs,
Food and Public Distribution
Government of India

भारतीय मानक ब्यूरो
उपभोक्ता मामले, खाद्य और
सार्वजनिक वितरण मंत्रालय
भारत सरकार

India
BIS Locations



Headquarter

5 Regional Offices

38 Branch Offices

8 Laboratories

— Training Institute (NITS)

सत्यमेव जयते

मानकः पथप्रदर्शकः

Azadi Ka Amrit Mahotsav

ABOUT BIS

Bureau of Indian Standards (BIS), the National Standards Body (NSB) of India was established under the *BIS Act*, 1986 and came into existence on 1 April 1987 assuming the functions of the erstwhile Indian Standards Institution (ISI). The ISI was established on 6 January 1947. *The BIS Act*, 2016 came into force on 12 October 2017 superseding BIS Act 1986. *The BIS Act*, 2016 provides for the establishment of a national standards body for the harmonious development of the activities of standardization, conformity assessment and quality assurance of goods, articles, processes, systems and services and for matters connected therewith or incidental thereto.

BIS through its core activities of standardization and conformity assessment, has been benefiting the national economy by providing safe, reliable and quality goods; minimizing health hazards to consumers; protecting the environment; controlling over proliferation of varieties; promoting exports and imports substitutes, etc. The standardization and conformity assessment schemes of BIS apart from benefitting the consumers and industry also support various public policies especially in areas of product safety, consumer protection, food safety, environment protection, building and infrastructure development, etc.

BIS also represents India in international standards bodies like International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) and participates actively in the international standardization work undertaken by these bodies. BIS presents the national viewpoints on new areas taken up for international standardization and on various draft international standards during the process of development of these standards so that the country's interest is protected and reflected in these standards. This also enables the BIS technical committees to consider adoption of the international standards as Indian Standards, with or without modifications, in order to enable our products and services to integrate with global trade and commerce.

What are Standards?

Standard is a document, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context.

Importance of Standardization

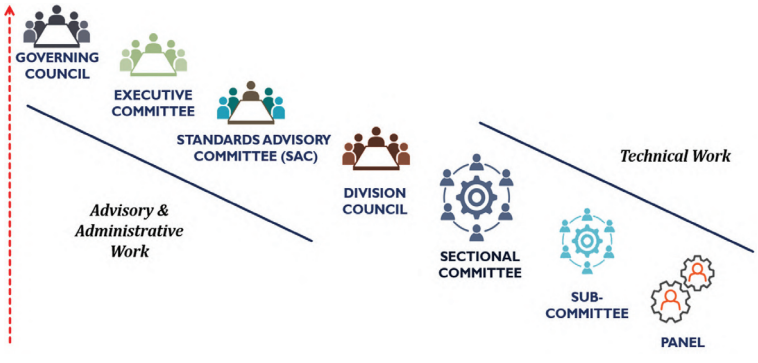
Standardization is the process of developing technical standards through consensus of different parties.This standardization aims to address one or all of compatibility, interchangeability, variety control, safety, environment protection, product protection and fitness for purpose. Standards provide numerable benefits to the technologists, producers, consumers and traders besides defining purpose for each of these entities.

Standards can be formulated at various levels ranging from an individual through National (IS) to International level (ISO). Also, depending on the subject in hand, standards can be made on various aspects such as terminology, specification, sampling, testing, code of good practice, systemes and services.

STANDARDIZATION ACTIVITY OF BIS

Standardization Structure

There are 16 Technical Departments formulating standards in various subject areas. Corresponding to these departments, 16 division councils exist. Each division council has several sectional committees working under it. The standards cover important segments of economy and help the industry in upgrading the quality of their goods and services.

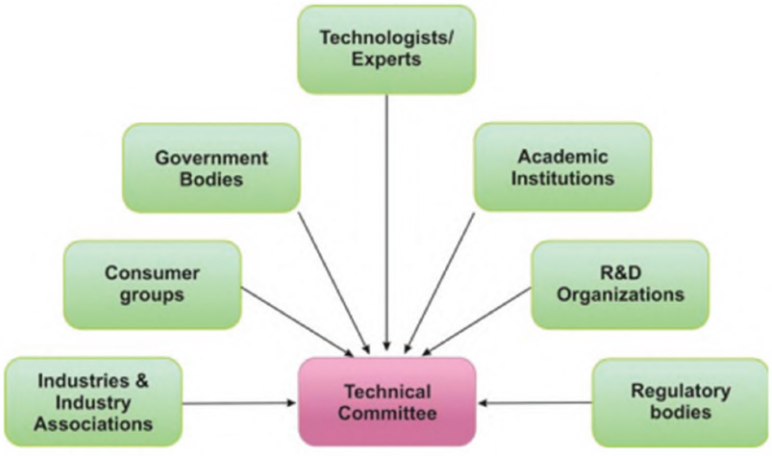


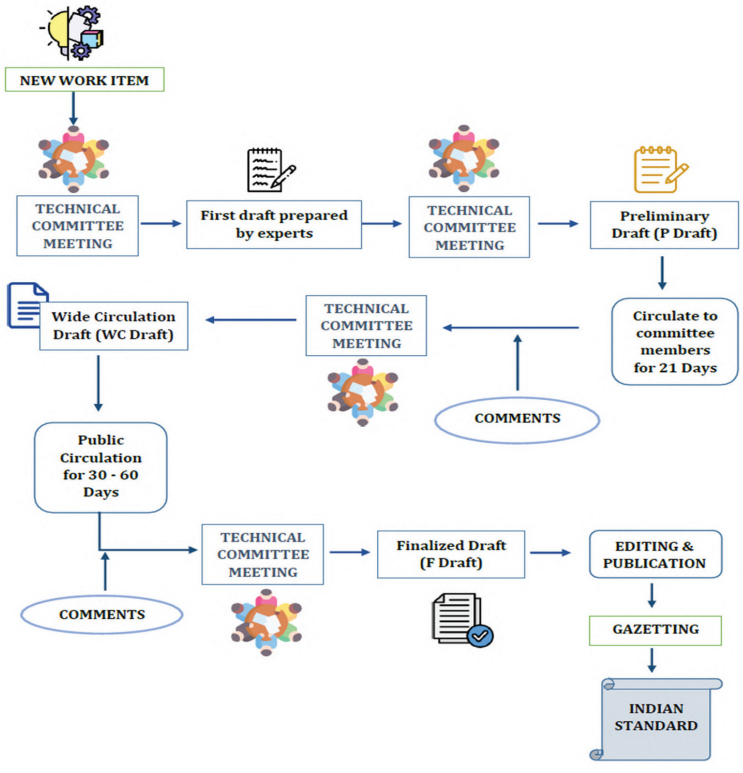
Ayush Division Council (AYDC)	Chemical Division Council (CHDC)	Civil Engineering Division Council (CEDC)	Electro-Technical Division Council (ETDC)
Electronics & Telecommunication Division Council (LITDC)	Food and Agriculture Division Council (FADC)	Mechanical Engineering Division Council (MEDC)	Management and Systems Division Council (MSDC)
Metallurgical Engineering Division Council (MTDC)	Medical Equipment & Hospital Planning Division Council (MHDC)	Petroleum, Coal & Related Products Division Council (PCDC)	Production and General Engineering Division Council (PGDC)
Transport Engineering Division Council (TEDC)	Textile Division Council (TXDC)	Water Resources Division Council (WRDC)	Service Sector Division Council (SSDC)

Standards Formulation Process

The Indian Standards are developed by technical committees that are representative of various stakeholders having interest in the relevant subject of standardization under the scope of such committees through a process of consultation so that views of all are given due consideration and a consensus is evolved in formulating a standard. The stakeholders involved in national standardization can broadly be categorized as industry, consumers/ users, technologists (R&D and scientific institutions, academia, individual subject experts, etc) and government departments/regulators.

The process of standards development of BIS is aligned with accepted international best practices that are based on the core principles of openness, transparency, impartiality and consensus. The process begins with the identification of the standardization needs of the given sector or subject following which the development of the standard is taken up and planned bythe relevant technical committee. Apart from consultation within the technical committees, draft standards are also open for public views/comments.





Standards Development Process Flow

STANDARDIZATION IN THE FIELD OFELECTRICAL ENGINEERING DEPARTMENT (ETD)

Electrotechnical Department(ETD) is one of the 16 technical departments of BIS with the scope "Standardization of electrotechnical aspects of generation, transmission, distribution, storage and utilization of electrical energy, including renewable energy. It includes all aspects of electrotechnology such as electrical products and installations, insulation, power electronics, industrial/process automation, measuring instruments, electrotechnical aspects of e-mobility, and system level standardization addressing safety, security, sustainability, efficiency while delivering societal value."

ETDC is division council of ETD department.

The aspect wise breakup of the standards formulated by ETDC as on 15 September 2023 is given below:

Aspect	No. of Standards
Product Standards	726
Methods of Test	511
Codes of Practice	264
Terminology	56
Dimensions	47
System Standard	4
Safety Standard	6
Others	95
Total	1709

List of Technical Committees working under ETD

Under ETD, there are 44 Sectional Technical Committees working in various subject areas. List of committees with their scope is as follows:

Technical Committee No.	Technical Committee Name	Scope
ETD 1	Basic Electrotechnical Standards And Power Quality	To prepare standards of general and common nature in the field of electrotechnology, such as voltages, current ratings, power quality and frequency, quantities and units, nomenclature, graphical symbols, basic marking and general requirements for enclosures of equipment.
ETD 02	Solid Electrical Insulating Materials And Insulating Systems	To prepare standards: on solid electrical insulating materials on guiding principles and on the philosophy of evaluation of insulation systems in general for functional test programmes and methods

		intended for evaluation of possible insulation systems and their suitability for use in electrical equipment. for classification of insulation systems based upon their capability to withstand the complex of the most important service determined by the conditions of the use of insulation in equipment.
ETD 03	Fluids For Electrotechnical Applications	To prepare product specifications, test methods as well as maintenance and use guides for liquid and gaseous dielectric. Also to prepare specifications and maintenance and use guides for lubricants and control fluids for turbines, generators and control systems as well as to assist in the preparations of test methods for such fluids.
ETD 06	ElectricalInsulators And Accessories	To prepare standards regarding insulated bushing, insulators for overhead lines, insulators for sub-stations and jointing accessories which are integral parts of insulators
ETD 7	Low VoltageSwitchgear & Control Gear	To prepare standards for switchgear and controlgear such as circuit breakers, switches, contactors, starters, disconnectors, bus bars, fuse combination units and semiconductors connectors and any switchgear assemblies for voltages upto and including 1 000 V ac or 1 200 V dc
ETD 8	High Voltage Switchgear And Controlgear	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 9	Power Cables	To prepare standards for electric cables and their accessories, without limitations of voltage, current or form of construction but excluding cables for telecommunications and electronic equipment and such other cables as fall within the scope of other committees
ETD 10	Primary Cells AndBatteries	To prepare Indian standards for primary cells andbatteries, particularly those relating to specifications, dimensions, performance, along with guidance on environmental and safety matters
ETD 11	Secondary Cells And Batteries	To prepare standards for all rechargeable cells and batteries (starter batteries, stationary batteries, traction batteries etc.)
ETD 12	MeasuringEquipment For Basic Electrical Quantities	To prepare standards for direct and indirect acting analogue and digital indicating and recording instruments and their accessories, also transducers having electrical inputs and outputs for measuring electrical quantities by any method on direct current and alternating current at distribution system frequencies and their harmonics To prepare standards for primary reference apparatus, operating on direct current and alternating current at distribution frequencies and their harmonics for the purpose of measurement, traceability and intercomparison

ETD 13	Equipment For Electrical Energy Measurement And Load Control	To prepare international standards for equipment for electrical energy measurement, tariff - and load control, customer information, payment, local and/or remote data exchange, using electromechanical and/or electronic, technologies for applications ranging from electrical energy generation to residential. The standards may include requirements and test methods to cover mechanical, environmental, electrical, safety, metrology dependability aspects as well as functional requirements and data models
ETD 14	Electrical Wiring Accessories	To prepare standards for electrical wiring accessories ; such as lamp holders, switches, plugs and socket- outlets, connecting devices and conduits and their accessories for electrical installations
ETD 15	RotatingMachinery	To prepare standards on rotating electrical machines like induction, synchronous, motors, generators, dc machines and turbines including carbon brushes for electrical machines (with the exception of traction machines and rotating machinery coming under the purview of other Committees)
ETD 16	Transformers	To prepare standards on power and distribution transformers, reactors, onload tap changers, etc. , without limitation on voltage or power. Transformer accessories and voltage stablizers, testing transformers and furnace transformers are included. (Instrument transformers, welding transformers and traction transformers are excluded)
ETD 18	Industrial Process Measurement And Control	To prepare standards for systems and elements used for industrial process measurement and control concerning continuous and batch processes.To coordinate the standardization of those features of related elements which affect suitability for integration into such systems operating with electrical, pneumatic, hydraulics mechanical or other systems of measurements and/or control
ETD 19	High VoltageEngineering	To prepare standards for high voltage testing techniques and for different types of tests belonging there to such as high voltage ac, dc and impulse tests and high current impulse tests, definitions and basic principles of insulation coordination and insulation levels.To prepare application guides recommending the insulation levels in relation to possibilities of over-voltage protection devices. The work also includes formulation of standards for clearances and creepage distances.
ETD 20	ElectricalInstallations	To prepare standards for safety and related matters in designing, erection and maintenance of electrical installations from the point of view of safety and good practice that would, amongst other things, promote compatibility between such standards and those

		concerning the equipment installed The work includes electrical installations in buildings for different occupancies and outdoor sites of temporary or permanent nature and also installations in the ships
ETD 21	Electric Welding Equipment	To prepare standards on the construction, performance, testing and safety requirements for electric welding equipment and accessories for both arc and resistance type.
ETD 22	ElectricalApparatus For Explosive Atmospheres	To prepare guidelines and requirements for electrical apparatus for use where there is a hazard due to the possible presence of ignitable gas, vapour liquid particles or dust in the atmosphere.
ETD 23	Lamps And Related Equipments	To prepare Indian Standards for all types of electric lamps (including LED), caps, controlgear and their auxillaries (luminaires excluded)
ETD 25	Lifts, EscalatorsAnd Moving	To prepare standards and codes of practice for electrically Walks operated lifts and escalators, including equipment and components. continuous mechanical handling equipment and lifts in mines is excluded
ETD 28	Solar Photovoltaic Energy Systems	To prepare standards for systems of photovoltaic conversion of solar energy into electrical energy and for all the elements in the entire photovoltaic energy systems in this context, the concept photovoltaic energy systems include the entire field from light input to solar cell and including the interface with the electrical system(s) towhich energy is supplied
ETD 29	Power Capacitors	To prepare standards for power capacitors such as series and shunt capacitors for power systems, self-healing and non-self-healing power capacitors with metallized dielectric, ac motor capacitors, capacitors for inductive heating plants,voltage grading capacitors, coupling capacitors, energy storage capacitors etc.
ETD 30	Surge Arresters	To prepare standards on surge arresters and their accessories, application guide for surge arrestors for different locations
ETD 31	Power Electronics	To prepare standards regarding equipment and their components for electronic power switching. To prepare standards for electrical appliances for household and similar purposes, including associated controls.
ETD 32	ElectricalAppliances	To prepare standards for electrical appliances for household and similar purposes, including associated controls
ETD 33	Winding Wires	To prepare standards for wires for electrical winding irrespective of conductor material, shape or type of covering taking into account the needs in the fields of electrotechnology
ETD34	InstrumentTransformers	To prepare standards and application guides for instrument transformers

ETD 35	Power SystemsRelays	To prepare standards for power systems relays including those incorporating solid state devices, also taking into account combination of relays and devices to form schemes for power systems including control equipment associated with thatprotection
ETD 36	Tools AndEquipment For Live Working	To prepare standard on electrical and mechanical characteristics as well as reliability requirements for tools and equipment used in connections with work on energized electrical systems
ETD 37	Conductors And Accessories For Overhead Lines	To prepare standards for conductors and accessories for overhead power lines and codes of practice for the design, installation and maintenance of overhead power lines
ETD 39	Fuses	To prepare standards regarding specification for all types of fuses, with the object of determining The characteristics which are essential inspecifying the conditions for installation and operation of the fuses 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 testsMarkingsTo prepare for these fuses standards, standard values of:Characteristics, rated voltages, currents and breaking capacities:Dimensions in connections with the fixing and interchangeability of high voltage and low voltage fuses
ETD 40	HVDC PowerSystems	To prepare standards and guidelines on equipment and performance of high- voltage d.c. (HVDC) Transmission Systems
ETD 42	Wind Turbines	To prepare Indian standards for wind turbines that convert wind energy into electrical energy. These standards address design requirements, engineering integrity, measurement techniques and test procedures. Their purpose is to provide a basis for design, quality assurance and certification. The standards are concerned with all subsystems of wind turbines, such as mechanical and internal electrical systems, support structures and control and protection systems. They are intended to be used together with appropriate Indian Stanfdards.
ETD 43	Standardization of Environmental Aspects For Electrical And Electronic Products	To prepare the necessary guidelines, basic standards, in the environmental area, in close cooperation with product committees, which remain autonomous in dealing with the environmental aspects relevant to their products;To liaise with product committees in the elaboration of environmental requirements of product standards in order to foster common technical approaches and solutions for similar problems and thus assure consistency in standards.
ETD 44	Safety of Machinery - Electrical Aspects	Standardization in the field of the application of electro-technical equipment and systems to machinery (including a group of

		machines working together in a coordinated manner, excluding higher-level systems aspects) not portable by hand while working, but which may include mobile equipment. The equipment covered commences at the point of connection of the electrical supply to the machinery.Standardization of interfaces (excluding local area networks and field-bus) between control equipment and the electro-technical equipment of machinery. Standardization of electro- technical equipment and systems elating to the safeguarding of persons from hazards of the machinery, its associated equipment and the environment.To coordinate with ISO/IEC on all matters concerning the safety of machinery."
ETD 46	Grid Integration of Renewable Energy	To prepare standards in the field of Grid Integration comprising of LT (ON Grid, Off Grid and Hybrid with and without storage), HT and EHT for all capacities
ETD 47	Railway Electric Traction Equipment	To prepare Indian Standards for the railways field which includes rolling stock, fixed installations, management systems (including communication, signalling and processing systems) for railway operation, their interfaces and their ecological environment.These standards cover railway networks, metropolitan transport networks (including metros, tramways, trolleybuses and fully automated transport systems) and magnetic levitated transport systems.These standards relate to systems, components and software and they will deal with electrical, electronic and mechanical aspects, the latterbeing limited to items depending on electrical factors. These standards deal with electromechanical and electronic aspects of power components as well as with electronic hardware and software components
ETD 48	StandardizationIn The Field Of UHV AC Transmission Systems	Standardization in the field of AC transmission technology at 1000 kV and above, comprising systems-oriented guidance such as that for planning, design aspects, technical requirements, construction, commissioning, reliability, availability, operation and maintenance, processes for specifying requirements and demonstrating whether the required performance of UHV systems is assured.
ETD 49	Illumination Engineering And Luminaires	To prepare Indian Standards for luminaires (including luminaires for use in hazardous area, aviation lighting, emergency lighting etc.) and codes of practice for interior/exterior lighting
ETD 50	LVDC Power Distribution Systems	To prepare standards on:LVDC System Requirements, Safety and Installation Guidelines LVDC products including electrical wiring accessories and Applications Integration of DC Infrastructure Non Traditional Distribution Networks/ Microgrids

ETD 51	Electrotechnology In Mobility	To prepare Indian Standards for electrotechnical aspects of totally or partly electrically propelled road vehicles.
ETD 52	Electrical Energy Storage Systems	Standardization in the field of grid integrated Electrical Energy Storage Systems.
ETD 53	Standardization Of The Management Of Assets In Power Networks	Standardization in the field of standardized tools, technique and frameworks (common language and common metrics with consistent approach), for coordinated lifetime management of assets within which a wide variety of power system assets can be managed, working closely with asset management system committees and power system equipment committees.

TESTING OF ROTATING ELECTRICAL MACHINES

1) INTRODUCTION

Rotating electrical machine is an electrical apparatus which consists of a stationary part known as stator and a rotating part known as rotor. Depending upon the type of electromechanical energy conversion, these machines are classified into generators or motors. In generators, the machine converts mechanical energy into electrical energy and in motors electrical energy is converted into mechanical energy. Electric motors are the most important type of electric load in every industry. The motor driven systems account for about seventy percent of the energy consumed by industry. In this chapter, we consider various features of *'**Single phase ac induction motors for general purpose**' and '**Line operated three phase ac motors**'*.

2) INDIAN STANDARDS ON ROTATING ELECTRIC MACHINES

a) IS 996 - SINGLE PHASE AC INDUCTION MOTORS FOR GENERAL PURPOSE

Single phase ac induction motors of the capacitor types, split phase and shaded pole types for voltages up to and including 250 V and having windings with Class B, Class F and Class H insulation an output upto and including 2200 W are covered in IS 996.

The **torque characteristics** of various types of motors are given below:

- ***Capacitor Start - Induction Run**:* These motors have higher starting torques and lower starting currents than split-phase motors and are generally more suitable for loads of higher inertia and more frequent starting.
- ***Capacitor Start - Capacitor Run**:* These motors have characteristics similar to those covered by capacitor start – induction run motors, but are more applicable where a greater degree of quietness or a higher efficiency and power factor are desirable.
- ***Capacitor Start and Run**:* These motors are for use where low starting torques are acceptable. They are also generally quieter than split phase or capacitor start – induction run motors.
- ***Split Phase**:* Owing to their high starting currents, split-phase motors are generally used for loads of low inertia and infrequent starting. When higher starting currents can be tolerated, motors of the higher torque rating can be used.
- ***Shaded Poles**:* These motors are suitable for all applications where only a very low starting torque is required and motor efficiency is not important.

IMPORTANT TERMINOLOGIES

The following definitions are considered relevant:

***Rotor**:* The rotating portion of a machine.

***Stator**:* The portion of a machine which includes the stationary magnetic parts with their associated windings.

Universal motor: A motor which can be operated by either direct current or single-phase alternating current of normal supply frequencies.

Induction motor: An alternating current motor without a commutator, in which one part only, either the rotor or the stator, is connected to the supply network, the other working by induction.

Starting current: The rms current drawn.by the motor during the starting period.

Starting torque: The electromagnetic torque exerted by a motor during the starting period.

No-load: The state of a machine rotating at normal speed under rated conditions, but when no output is required of it.

Rated Output: The value of the output included in the rating.

Locked-rotor torque: The minimum measured torque which the motor will develop with the rotor locked and rated voltage applied at rated frequency.

Breakaway (Starting) torque: The lowest torque developed by the motor in the stand-still condition when the motor is supplied at the rated voltage and rated frequency.

Pull- up torque: The smallest torque developed by the motor between zero speed and the speed which corresponds to the pull-out torque when the motor is supplied at the rated voltage and rated frequency.

Pull-out torque: The highest torque that the motor can develop while running at rated voltage and rated frequency.

Locked-rotor current: The measured steady-state root mean square current taken from the line with the motor at rest, with rated voltage and frequency applied.

Breakaway starting current: The highest root mean square current absorbed by the motor when at rest, and when it is supplied at the rated voltage and frequency.

Duty: Statement of the loads, including no-load and rest and de-energized periods to which the machine is subjected, including their duration and sequence in time.

Intermittent duty: A duty in which the load changes regularly or irregularly with time.

Efficiency: The ratio of output to input, usually given as a percentage.

RATED CONDITIONS OF VOLTAGE, FREQUENCY, OUTPUT AND SPEED OF MOTORS

The preferred rated values are as given below:

a) ***Rated Voltage & Frequency***- The preferred rated voltage is 230V rated frequency is 50 Hz.

b) ***Rated Output***- The preferred output ratings are 2.5, 4, 7, 12, 18, 25, 40, 60, 90, 120, 180, 250, 370, 550, 750, 1100, 1500 and 2200 Watt.

c) ***Rated Speeds***- The preferred rated speeds are those corresponding to 2, 4, and 6 poles.

IMPORTANT PERFORMANCE PARAMETERS WITH TOLERANCE

Performance Parameter	Tolerance
Efficiency	-15 percent of (100 - η)
Power factor	*-1/5 (1-cos ϕ)*, Min *-0.02*, Max *-0.12*
Speed of motor at rated full load	±50 percent of rated slip at full load
Breakaway (starting) torque	-20 percent of the stated breakaway (starting) torque
Pull out torque	-10 percent of the stated pull-out torque
Pull up torque	-20 percent of the stated pull up torque
Breakaway (starting) current (lockedrotor)	+20 percent of the stated breakaway (starting) current

IMPORTANT TESTS

- **Temperature Rise**

This test is intended primarily to determine the temperature-rise on different parts of the motor while running at rated conditions. While preparing for temperature-rise test, the motor should be shielded from currents of air coming from adjacent pulleys, belts and other machines as incorrect results may be obtained if this is not done. A small current of air may cause great discrepancy in results obtained. Sufficient floor space should be left between machines to allow free circulation of air. Under ordinary conditions, a distance of two metres is sufficient.

At the end of the test, the specified temperature-rise limits should not be exceeded. The commonly used methods for measuring temperature are listed below:

a) Thermometer method (using liquid-in-glass thermometer, resistance thermometer or thermocouple).

b) Applied thermocouple method

c) Resistance method

- ***No-load Test***

This test is intended to find out the no-load current, power input and speed at rated voltage and frequency. The motor is run at no-load with the running windings excited at normal frequency and voltage until the power input is constant to assure that the temperature of the oil or grease and the bearings has become constant.

- ***Locked Rotor Test***

The testing of induction motors under locked rotor conditions involves unusual mechanical stresses and high rates of heating. Therefore, it is necessary that the mechanical means of locking the rotor be of adequate strength to prevent possible injury to personnel or damage to equipment. The current and torque readings shall be taken at approximately rated voltage and at rated frequency and that the motor shall be at approximately ambient temperature. The voltage shall be within 5 percent of the rated voltage.

- ***Insulation Resistance***

Insulation resistance shall be measured between individual windings and frame (earth). Insulation resistance between all the windings combined and the motor frame shall be not less than 5 MOhm at 500 V d.c.

- ***High voltage test***

The motor windings shall be capable of withstanding without failure, the test voltages of 500 V for motors having rated voltage of 50 V or less. The test voltage shall be 1500 V for motors having rated voltage above 50 V upto and including 250 V.

- ***Leakage current***

The leakage current shall not exceed 3.5 mA (rms) when a voltage equal to 1.1 times the rated voltage is applied to the motor and is measured between supply terminal of the system and the accessible metal parts, if any, and a metal foil covering the outer parts of the insulating material.

b) IS 12615- LINE OPERATED THREE PHASE AC MOTORS

IS 12615 specifies the efficiency classes (IE Code – International Energy Efficiency Class) and performance requirements of single-speed line operated three phase a.c. motors.

The motors specified here are rated for operation on a sinusoidal voltage supply and have rated power from 0.12 kW to 1 000 kW, covering 2, 4, 6 or 8 poles and having a rated voltage Un up to 1000 V with a rated frequency of 50 Hz.

TERMINOLOGY

The definitions given earlier are considered relevant.

RATED VOLTAGE AND FREQUENCY

- ***Rated Voltage*** – Design shall be for terminal voltages up to and including 1000 V.
- ***Rated Frequency*** - The rated frequency is 50 Hz. However, if 60 Hz motors are operated on a 50 Hz supply, they must meet the performance requirements as applicable to 50 Hz motors.

VOLTAGE AND FREQUENCY VARIATION

- terminal voltage differing from its rated value by not more than ± 10 percent.
- frequency differing from its rated value by not more than ± 5 percent, or
- Combined variation-The sum of absolute percent variations of (i) and (ii) not exceeding 10 percent.

IMPORTANT TESTS

- **Temperature Rise**

The temperature rise test shall be continued until thermal equilibrium has been reached for motors with rating for continuous running duty. The temperature of windings and other parts can be measured by the methods given below:

a) Resistance method

b) Embedded temperature detector (ETD) method

c) Thermometer method

- **Determination of Efficiency**

The various methods for determining efficiency and losses are enumerated below:

a) Determination from direct measurement – In this method, efficiency is determined by measuring directly the input power and the output power as detailed in the tests given below:

i) ***Torque measurement test*** – This test can be performed by using torque meter or dynamometer. In torque meter test, the mechanical power output of a machine acting as a motor is determined by measurement of the shaft torque by means of a torque meter together with the rotational speed. The motor under test is coupled to a load machine or the generator under test is coupled to a motor with the torque meter. The machine is operated at the required load. In the dynamometer test, the shaft torque is measured by means of a dynamometer instead of torque meter.

Efficiency $\eta = P_2/P_1$, where

P_2 = Input Power and P_1 = Output Power

ii) ***Dual-supply back-to-back test*** – In this test, two identical machines are mechanically coupled together, and run at essentially the same rated conditions. The total losses of both machines are calculated from the difference between the electrical input to one machine and the electrical output of the other machine. The efficiency is calculated from half the total losses and the average input power of the motor and generator.

Efficiency $\eta = 1 - [P_T \div (P_1 + P_2)/2]$,

where Total losses $P_T = (P_1 - P_2)/2$

iii) ***Calibrated-machine test*** – In this test, the mechanical input or output of an electrical machine is calculated from the electrical output or input of a calibrated machine mechanically coupled to the machine on test. When the machine is running in this condition at rated speed, voltage and current, the efficiency is taken as the ratio of output to input.

b) Determination from indirect measurement – In this method, efficiency is determined by measuring the input power or the output power and determining the total losses. The details of the tests are given below:

i) ***Single-supply back-to-back test*** – In this test, two identical machines are mechanically coupled together, and both connected electrically to the same power system, and run at essentially rated conditions. The total losses of both machines are taken as the input power drawn from the system. The efficiency is calculated by assigning half the total losses to each machine.

Efficiency $\eta = 1 - (P_T \div P_M)$, where

P_M is the power absorbed at the terminals of the machine acting as motor, P_T is the total losses.

ii) ***Summation of separate losses*** – In this method, the separate losses are determined. The total loss is taken as the sum of constant losses, load losses and additional load losses.

iii) ***Calorimetric method*** – In this method, losses in a machine are deduced from the heat produced by them. The losses are calculated from the product of the amount of coolant and its temperature rise, and the heat dissipated in the surrounding media.

- **Reduced voltage running up test at no-load**

The test is conducted to check the ability of the motor to run up to its rated speed at no load. The motor shall be supplied with reduced voltage $1/\sqrt{3}$ of rated value for each direction of rotation. This test is applicable for squirrel cage motor up to 37 kW only.

- **High voltage test**

High voltage test is to be done at a test voltage as given in Table 16 of IS 15999 (Part 1). The test voltage shall be applied between the windings under test and the frame of the motor, with the core and the windings not under test connected to the frame. The test shall be commenced at a voltage not exceeding half of the full test voltage. The voltage shall then be increased to the full value, steadily or in steps of not more than 5 % of the full value, the time allowed for the voltage increase from half to full value being not less than 10 s. The full test voltage shall then be maintained for 1 min. There shall be no failure during this period. During the routine testing of motors up to 200 kW and rated for Un $\leq$1000 V, the 1 min test may be replaced by a test of 1 s at 120 % of the test voltage.

- **Dimensions**

The preferred dimensions of the motors shall be as specified in IS 1231 'Dimensions and Output Series of Foot Mounted Induction Motors - Frame Numbers 56 to 315 L', IS 2223 'Dimensions of Flange Mounted AC Induction Motors', IS 2254 'Dimensions of vertical shaft motors for pumps' and IS 8223 'Dimensions and output series for rotating electrical machines' as applicable. The dimensions can be special as agreed between manufacturer and buyer. However, the efficiency should be as per the relevant IE code.

- **Locked rotor test**

This test is carried out to determine the soundness of rotor in case of squirrel cage induction motors and their starting current, power factor, starting torque and impedance. This also enables a circle diagram to be drawn in case of squirrel cage induction motors and wound rotor motors. This test may be carried out at reduced voltage, one of the readings may be at a voltage that will produce rated current of the motor. The following mechanical arrangements may be used to measure the developed torque:

a) Dynamometer,

b) Rope and pulley,

c) Brake or beam clamped rigidly to motor shaft, and

d) Torque transducer.

- **Determination of Starting Characteristics - Locked Rotor Current**

The locked rotor current of induction machines shall be determined from the result of the locked rotor test by either of the methods given below. When the voltage for a constant current varies conspicuously depending on the rotor position at locked rotor test, the minimum value of the voltage shall be adopted.

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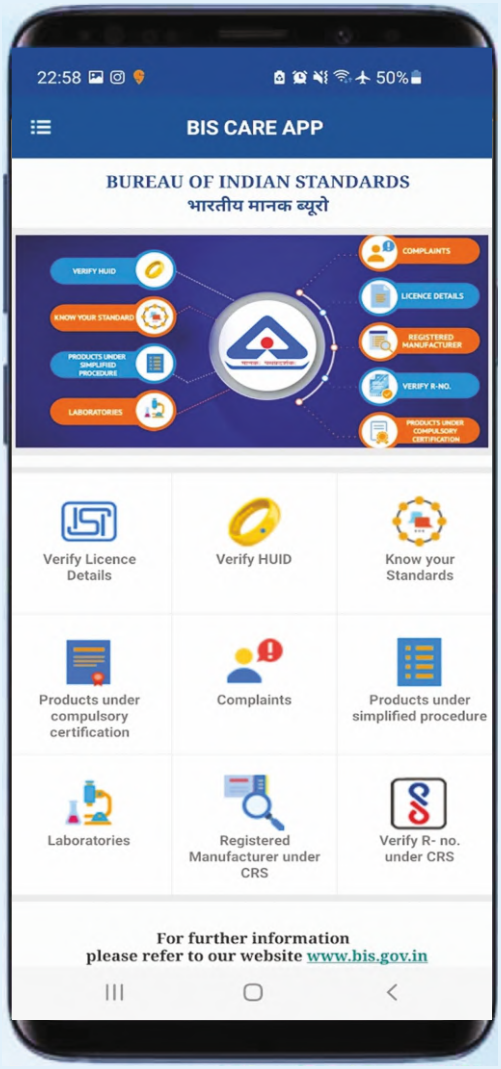

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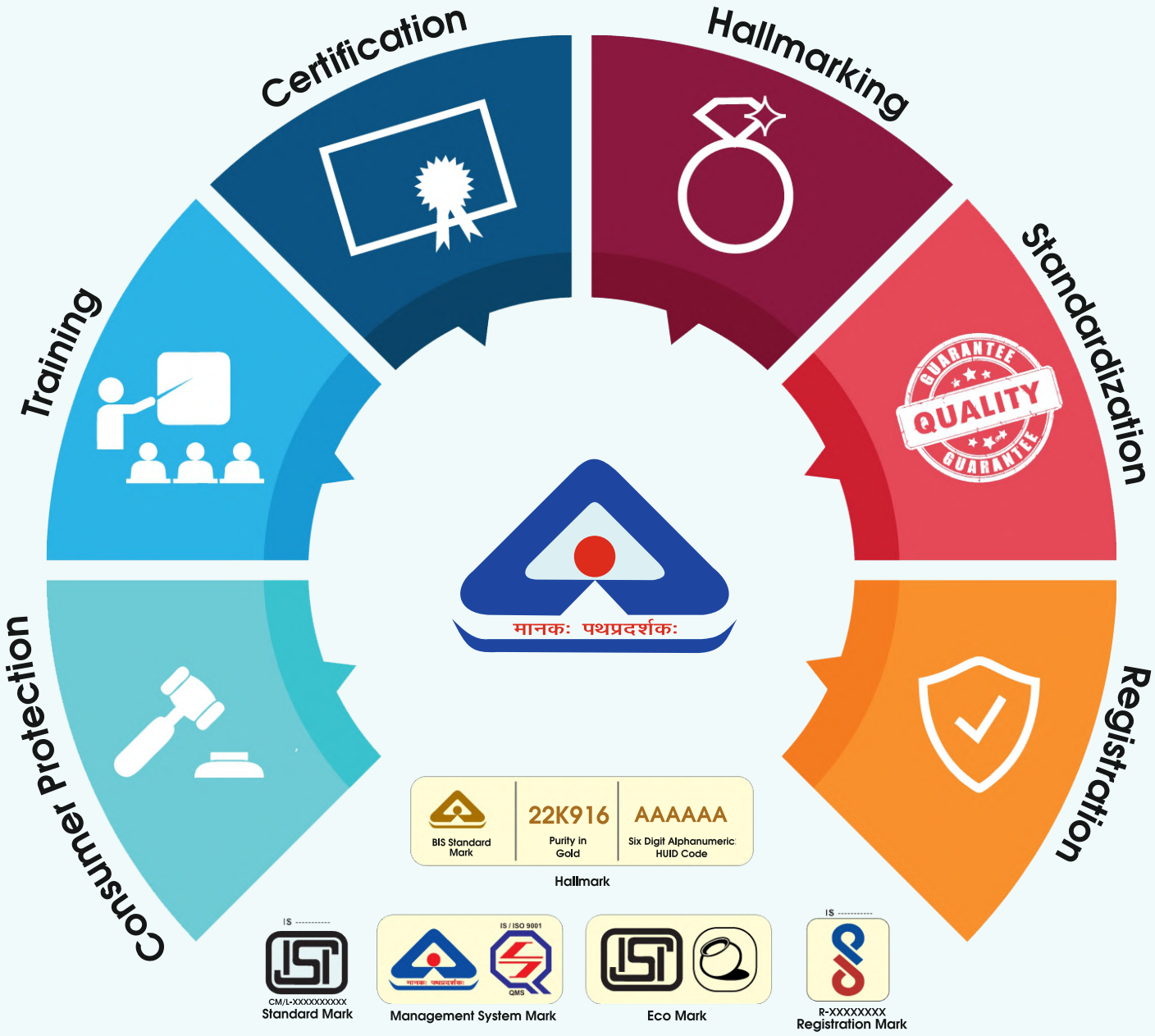

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