Preface

In the dynamic field of electrical engineering, the integration of academic curriculum with industry standards is crucial for fostering innovation and ensuring practical applicability. This book, “Electrical Motors: Bridging Academia and Industry Standards,” aims to seamlessly blend the comprehensive electrical engineering course curriculum of IITs, NITs and other premier engineering colleges in India with the stringent Indian Standards (IS) published by the Bureau of Indian Standards (BIS).

Electric motors are the workhorses of modern industry, powering a vast array of machines and processes. From the whirring fans in our homes to the colossal pumps in water treatment plants, motors play a vital role in our daily lives. As the demand for energy efficiency and environmental sustainability increases, optimizing motor performance and selecting the right motor for the job becomes crucial.

Our goal is to provide a comprehensive resource that not only educates but also empowers students, educators, and professionals to design, analyze, and innovate within the realm of electrical motors, while adhering to the highest standards of quality and efficiency. By bridging the gap between theoretical knowledge and practical standards, we aspire to contribute to the advancement of electrical engineering practices in India and beyond.

This book provides an overview of motors, with a particular focus on the Indian context. We will explore the different types of motors, their operating principles, and key considerations for selection and application. Furthermore, we will delve into the published standards in India that govern motor design, performance, and efficiency. Understanding these standards empowers engineers, procurement specialists, and facility managers to make informed decisions when selecting and using motors. By adhering to these standards, stakeholders can ensure the efficient operation of motors, leading to significant energy savings, reduced carbon footprint, and overall cost optimization.

This book serves as a valuable resource for anyone seeking to gain a comprehensive understanding of motors and their associated standards in India. We aim to bridge the gap between theoretical knowledge and practical application, providing insights that can be readily implemented in real-world scenarios. We trust that this book will serve as a valuable tool for those who are eager to excel in the field of electrical engineering, ensuring that they are well-equipped to meet the challenges of the industry with confidence and competence.

Let us embark on this journey to explore the fascinating world of motors and empower ourselves to leverage their potential for a more sustainable future. Welcome to a journey of learning, integration, and application

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CHAPTER I
KNOW THE LANDSCAPE

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KNOW THE LANDSCAPE

Industrial Motors:

1. ***Three-Phase Induction Motors:*** Used in high-power applications like pumps, compressors, and conveyor systems.
2. ***Single-Phase Induction Motors:*** Used in low-power applications like fans, blowers, and small pumps.
3. ***Synchronous Motors:*** Used in high-precision applications like textile mills, paper mills, and chemical plants.
4. ***DC Motors:*** Used in applications requiring high torque and speed control like cranes, hoists, and conveyor systems.
5. ***Stepper Motors:*** Used in applications requiring precise positioning and control like CNC machines, robotics, and automation.
6. ***Servo Motors:*** Used in applications requiring high precision and control like robotics, automation, and CNC machines.

Domestic Motors:

1. ***Ceiling Fan Motors:*** Used in ceiling fans for air circulation.
2. ***BLDC (Brushless DC) Motors:*** Used in energy-efficient appliances like air conditioners, refrigerators, and washing machines.
3. ***Induction Cooktop Motors:*** Used in induction cooktops for heating.
4. ***Mixer Grinder Motors:*** Used in mixer grinders for food processing.
5. ***Pump Motors:*** Used in water pumps for domestic water supply.
6. ***Refrigerator Compressor Motors:*** Used in refrigerators for cooling.
7. ***Air Conditioner Compressor Motors:*** Used in air conditioners for cooling.
8. ***Washing Machine Motors:*** Used in washing machines for washing and spinning.

These motors are used in various applications across industries and households in India, driving efficiency, productivity, and convenience.

CHAPTER II

KNOW THE FACTS & FIGURES

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KNOW THE FACTS & FIGURES

Three-phase induction motors are the workhorses of industrial processes, driving pumps, fans, compressors, and conveyor systems. However, they are also the largest consumers of electrical energy, accounting for a significant percentage of industrial power consumption. In this article, we'll explore why three-phase induction motors dominate energy usage and why improving their efficiency is crucial.

Energy Consumption:

- Three-phase induction motors consume approximately 70% of industrial electrical energy.
- They are used in various applications, including:
  - o Pumps (20-30%)
  - o Fans and blowers (15-25%)
  - o Compressors (10-20%)
  - o Conveyor systems (5-15%)

Why High Energy Consumption?

- High starting currents and torque requirements
- Inefficient design and outdated technology
- Poor maintenance and operating practices
- Inadequate control and monitoring systems

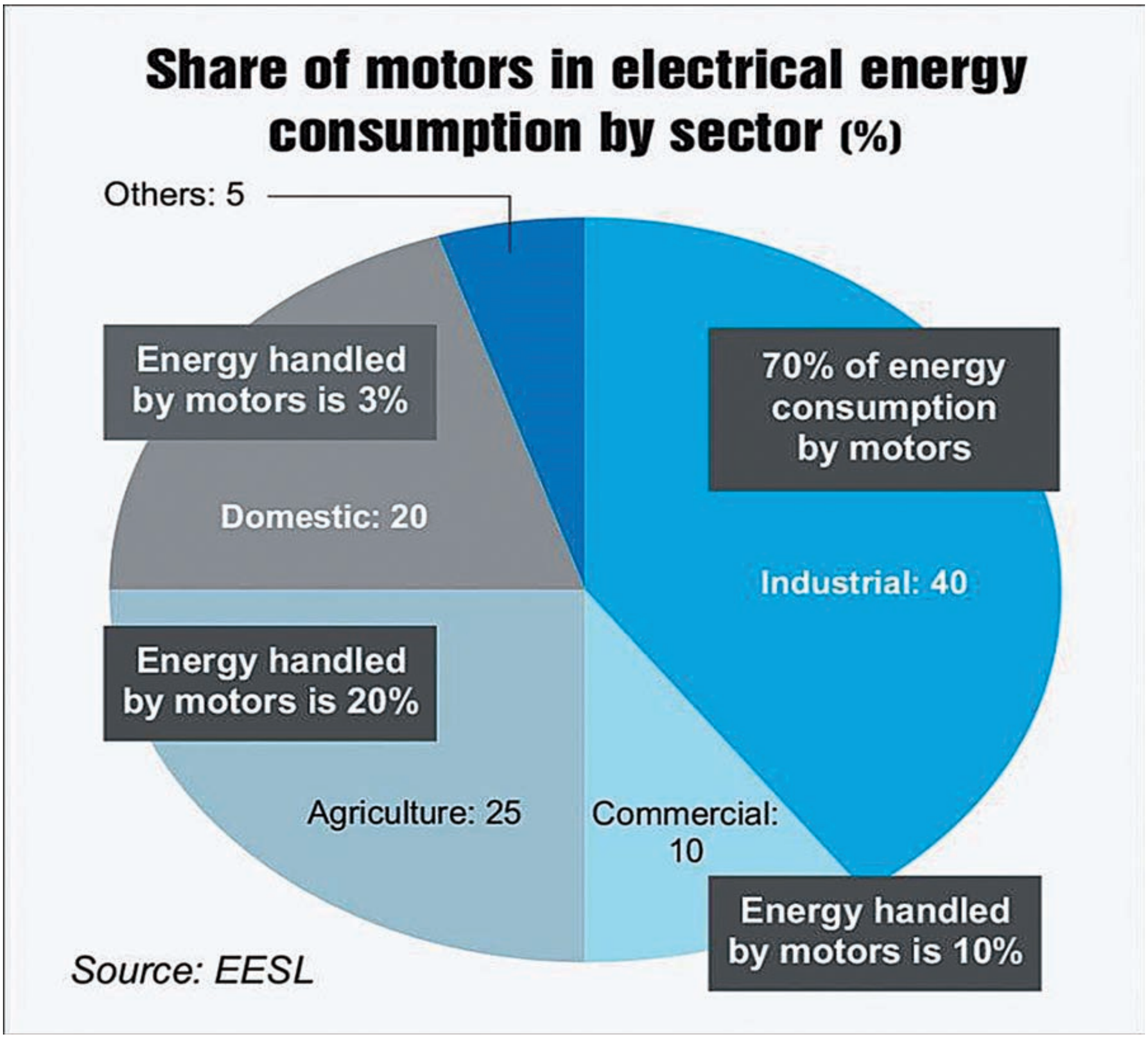
Importance of Energy Efficiency Improvement:

- Reduces energy costs and greenhouse gas emissions
- Increases productivity and competitiveness
- Supports sustainability and environmental goals
- Enhances motor reliability and lifespan

Improvement Strategies:

- High-efficiency motor designs (e.g., IE3, IE4)
- Variable speed drives (VSDs) and soft starters
- Regular maintenance and monitoring
- Energy audits and optimization studies
- Retrofitting and upgrading existing motors

Three-phase induction motors are the largest consumers of electrical energy in industry, making their efficiency improvement crucial. By adopting high-efficiency designs, optimizing operating practices, and implementing advanced technologies, industries can reduce energy consumption, costs, and environmental impact. The time to act is now, and the benefits are substantial.



CHAPTER III

KNOW THE ENVIRONMENTAL IMPACT

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KNOW THE ENVIRONMENTAL IMPACT

Increasing demand for motors in various industries has raised concerns about their environmental impact. Traditional motors, characterized by inefficiencies and energy losses, contribute significantly to carbon emissions and resource depletion. In contrast, highefficiency motors minimize energy wastage, reducing greenhouse gas emissions and alleviating strain on finite resources. Indian standards on motors play a crucial role in addressing sustainability concerns, ensuring energy efficiency, and reducing environmental footprint.

Importance of Indian Standards on Motors:

1. ***Energy Efficiency:*** Indian standards ensure motors meet energy efficiency requirements, reducing energy consumption and greenhouse gas emissions.

2. ***Waste Reduction:*** Standards encourage recycling and responsible disposal of motor waste.

3. ***Climate Change Mitigation:*** By improving energy efficiency, Indian standards contribute to climate change mitigation efforts.

4. ***Resource Conservation:*** Standards help conserve natural resources by promoting efficient motor design and operation.

5. ***Economic Benefits:*** Compliance with Indian standards can reduce energy costs and extend motor lifespan, resulting in economic benefits.

The adoption of efficient motors resonates deeply with the United Nations' Sustainable Development Goals. Here's how efficient motors contribute to key SDGs:

- ***SDG 7:*** Affordable and Clean Energy: Efficient motors promote the use of clean energy by optimizing electricity consumption.

- ***SDG 11:*** Sustainable Cities and Communities: From efficient HVAC systems to electric transportation, energy efficient motors contribute to building resilient, sustainable cities that prioritize energy conservation and environmental stewardship.

- ***SDG 13:*** Climate Action: By minimizing energy consumption and greenhouse gas emissions, energy efficient motors play a crucial role in realizing the targets set forth in SDG 13, fostering a low-carbon future.

Indian standards on motors are crucial for addressing sustainability concerns, ensuring energy efficiency, and reducing environmental impact. By implementing these standards, India can promote sustainable development, reduce greenhouse gas emissions, and conserve natural resources.

CHAPTER IV
KNOW THE STRATEGY

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KNOW THE STRATEGY

The design of motors plays a crucial role in their efficiency, performance, and reliability. A well-planned design improvement strategy can significantly enhance motor performance, reduce energy consumption, and increase lifespan.

Design Improvement Strategy:

1. ***Define Objectives:*** Identify specific goals, such as increasing efficiency, reducing weight, or improving reliability.
2. ***Analyse Existing Design:*** Evaluate current motor design, identifying areas for improvement.
3. ***Material Selection:*** Optimize material selection for improved performance, efficiency, and durability.
4. ***Electromagnetic Design:*** Enhance electromagnetic design for better flux distribution, reduced losses, and increased torque.
5. ***Thermal Management:*** Improve heat dissipation and cooling systems to reduce temperature-related losses.
6. ***Mechanical Design:*** Optimize mechanical components for reduced vibration, noise, and wear.
7. ***Simulation and Modelling:*** Utilize simulation tools to test and validate design improvements.
8. ***Prototyping and Testing:*** Build prototypes and conduct rigorous testing to ensure design improvements meet objectives.
9. ***Continual Improvement:*** Regularly review and refine design improvements to stay competitive.

Key Design Improvement Techniques:

- ➢ Optimization of Magnetic Circuit
- ➢ Improved Winding Techniques
- ➢ Enhanced Cooling Systems
- ➢ Advanced Bearing Designs
- ➢ Lightweight Materials
- ➢ Aerodynamic Improvements
- ➢ Electromagnetic Interference (EMI) Reduction

Best Practices:

1. ***Collaborative Approach:*** Involve multidisciplinary teams in design improvement efforts.

2. ***Customer Feedback:*** Incorporate customer insights and feedback into design improvements.

3. ***Technology Advancements:*** Leverage emerging technologies and innovations.

4. ***Sustainability Considerations:*** Incorporate eco-friendly design principles and materials.

A structured design improvement strategy can significantly enhance motor performance, efficiency, and reliability. By following a systematic approach and leveraging advanced techniques and technologies, motor designers can create innovative solutions that meet evolving customer needs and stay competitive in the market.

Indian Standards are developed by technical experts who represent all stakeholders' interests, incorporating the global best practices and design improvement techniques and provide optimum performance for industrial/ domestic applications in India.

CHAPTER V
MIND THE GAP

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MIND THE GAP

Indian Standards play a crucial role in bridging the gap between academia and industry skill set:

1. Defining industry requirements: Standards outline specific skills and knowledge required by industry, helping academia tailor curricula to meet these needs.

2. Ensuring consistency: Standards ensure consistency in skills and knowledge across academia and industry, reducing the skills gap.

3. Facilitating collaboration: Standards provide a common language and framework for academia and industry to collaborate on research, projects, and workforce development.

4. Staying up-to-date: Standards keep pace with industry developments, ensuring academia teaches relevant and current skills.

5. Curriculum development: Standards inform curriculum development, ensuring students learn industry-relevant skills and knowledge.

6. Assessment and evaluation: Standards-based assessments evaluate student learning, identifying areas for improvement.

7. Professional development: Standards-based training programs upskill professionals, enhancing their industry relevance.

By adopting industry-recognized standards, academia can:

- Align curricula with industry needs
- Enhance graduate employability
- Foster collaboration with industry
- Stay current with industry developments
- Validate skills and knowledge
- Support continuous professional development

Standards bridge the gap between academia and industry, ensuring students acquire relevant skills and knowledge, and industry gets skilled professionals.

CHAPTER VI

STANDARDS - BRIDGING THE GAP

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STANDARDS - BRIDGING THE GAP

Role of standards is crucial in following aspects:

1. ***Relevance:*** Academic research may not always address industry-specific challenges. By collaborating with industry, researchers can focus on practical problems.

Example: Developing more efficient motor designs for specific industrial applications, like high-torque motors for heavy machinery.

2. ***Applicability:*** Industry standards and requirements may not be fully incorporated into academic curricula. This can lead to a skills gap in graduates.

Example: Teaching students about industry-specific motor control algorithms and programming languages, like PLCs (Programmable Logic Controllers).

3. ***Innovation:*** Industry can benefit from academic research, while academia can gain from industry's practical expertise.

Example: Collaborative research on advanced motor materials, like superconducting materials, can lead to innovative motor designs.

4. ***Standardization:*** Indian Standards or IEC Standards, may not be widely taught in academia. This can lead to inconsistencies in motor design and testing.

Example: Ensuring students understand and apply industry standards for motor testing and validation.

5. ***Talent pipeline:*** Industry can influence academia to produce graduates with relevant skills, reducing the need for extensive training.

Example: Industry partnerships can lead to internships, capstone projects, or research collaborations, preparing students for industry-specific challenges.

By bridging the gap, we can:

- Enhance the relevance and applicability of academic research
- Ensure standards are incorporated into curricula
- Foster innovation through collaborative research
- Develop a talent pipeline with industry-specific skills

This collaboration with standards benefits both academia and industry, ultimately leading to more efficient, innovative, and practical solutions.

CHAPTER VII
KNOW THE VOCABULARY

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KNOW THE VOCABULARY

Standardization of terms and definitions is crucial in Indian standards to ensure clarity, consistency, and accuracy in communication. It enables stakeholders to understand and interpret standards correctly, facilitating effective implementation and compliance.

Importance of Standardizing Terms and Definitions:

1. ***Avoids Ambiguity:*** Standardized terms and definitions prevent ambiguity, ensuring that all stakeholders interpret standards consistently.

2. ***Enhances Clarity:*** Clear and concise language facilitates easy understanding of standards, reducing confusion and misinterpretation.

3. ***Ensures Consistency:*** Standardized terms and definitions maintain consistency across different standards and industries.

4. ***Facilitates Communication:*** Standardized language enables effective communication among stakeholders, including manufacturers, regulators, and consumers.

5. ***Supports International Trade:*** Standardized terms and definitions align with international standards, facilitating global trade and commerce.

6. ***Reduces Errors:*** Standardized terms and definitions minimize errors, ensuring accurate implementation and compliance.

7. ***Enhances Credibility:*** Standardized terms and definitions contribute to the credibility and reliability of Indian standards.

Best Practices for Standardizing Terms and Definitions:

1. Collaborative Approach: Involve stakeholders from various industries and sectors.

2. Clear and Concise Language: Use simple and unambiguous language.

3. Consistency: Ensure consistency across standards and industries.

4. Regular Review and Update: Periodically review and update standardized terms and definitions.

Standardizing terms and definitions is vital in Indian standards to ensure clarity, consistency, and accuracy. By adopting a collaborative approach and following best practices, Indian Standards establish a robust framework for standardized terms and definitions.

IS 1885 (Part 35): 2021 Electrotechnical Vocabulary: Part 35 Rotating Machinery	
GENERAL	➢ **Electrical Rotating Machine**— An electrical apparatus depending on electromagnetic induction for its operation and having components capable of relative rotary movement and intended for converting energy.

- **Homopolar Machine**—A machine in which the magnetic flux passes in the same direction from one member to the other over the whole of a single air-gap area.
- **Acyclic Machine**—A direct current homopolar machine.
- **Heteropolar Machine**—A machine having successive physical or effective poles of opposite polarity.
- **Direct Current Machine**—A machine incorporating an armature winding connected via a commutator to a direct current system and having magnetic poles which are excited from a source of direct or undulating current or which are permanent magnets.
- **Alternating Current Machine**—A machine which has an armature winding intended for connection to an alternating current system.
- **Synchronous Machine**—An alternating current machine in which the frequency of the generated voltages and the speed of the machine are in a constant ratio.
- **Asynchronous Machine**—An alternating current machine in which the speed on load and the frequency of the system to which it is connected are not in a constant ratio.
- **Induction Machine**—An asynchronous machine of which only one winding is energized.
- **Permanent Magnet Machine**—A machine in which the field system consists of one or more permanent magnets.
- **Single-Phase Machine**—A machine for the generation or utilization of single-phase alternating voltage and current.
- **Polyphase Machine**—A machine for the generation or utilization of polyphase alternating voltage and current.
- **Salient Pole Machine**—A machine in which the field poles project from the frame yoke or hub towards the air-gap.
- **Solid Pole Shoe Machine**—A salient pole machine having non-laminated pole shoes.
- **Cylindrical Rotor Machine**—A machine having a cylindrically shaped rotor the periphery of which may be provided with slots which accommodate the coil sides of a winding.
- **Turbine-Type Machine**—A cylindrical rotor machine designed for operation at high peripheral rotor speed.

MOTORS	➢ **Motor** —A machine which converts electrical energy into mechanical energy. ➢ **Universal Motor—**A motor which can be operated by either direct current or single-phase alternating current of normal supply frequencies. ➢ **Cage Synchronous Motor—**A salient pole synchronous motor having a cage winding embedded in the pole shoes for starting. ➢ **Synchronous Induction Motor —**A cylindrical rotor synchronous motor with a secondary coil winding, similar to that of a slip-ring induction motor, which is used for both starting and excitation. ➢ **Reluctance Motor—**A synchronous motor with an unexcited rotor carrying a number of regular projections which may or may not have a cage winding for starting. ➢ **Sub synchronous Reluctance Motor—**A reluctance motor in which the number of projections acting as salient poles is greater than the number of the poles formed by the primary winding, thus causing the motor to operate at a constant average speed which is a submultiple of its apparent synchronous speed. ➢ **Cage Induction Motor —**An induction motor with secondary cage (squirrel cage) winding(s). ➢ **Wound-Rotor Induction Motor—**An induction motor with secondary polyphase coil winding(s). ➢ **Slip-Ring Induction Motor—**A wound-rotor induction motor with secondary winding(s) connected to slip-rings. ➢ **Brushless Wound-Rotor Induction Motor—**A wound-rotor induction motor with the secondary winding(s) directly connected to an incorporated rotating starting device. ➢ **Hysteresis Motor—**A synchronous motor with a smooth cylindrically shaped member, of magnetic material without a field winding, which starts by virtue of hysteresis losses induced in that member and operates at synchronous speed due to the retentivity of that member. ➢ **Shaded Pole Motor—**A single-phase induction motor having one or more auxiliary short-circuited windings displaced in magnetic position from the main winding, all these windings being on the primary core, usually the stator.

	➢ **Split Phase Motor—**A single-phase induction motor with an auxiliary circuit which is connected in parallel with the main winding, including an auxiliary winding displaced in magnetic position from the main winding, a phase displacement between the currents in these two primary windings being arranged. ➢ **Capacitor Motor—**A split phase motor in which the phase displacement results from a capacitor in the auxiliary circuit. ➢ **Capacitor Start Motor—**A capacitor motor in which the auxiliary circuit is energized only during the starting period. ➢ **Capacitor start and run motor —**A capacitor motor in which the auxiliary circuit is energized during both starting and running. ➢ **General Purpose Motor —**A motor designed, listed and offered in standardized ratings with operating characteristics and mechanical construction suitable for use under usual operating conditions without restrictions to a particular application or type of application.
SPECIAL MACHINES	➢ **Electrical Dynamometer**—An electrical machine equipped with means for indicating torque and additionally with means for indicating speed when used for determining power. ➢ **Booster—**A machine connected in a circuit so that its voltage either adds to or substracts from the voltage furnished by another source. ➢ **Synchronous Compensator—**A synchronous machine running without mechanical load and supplying or absorbing reactive power. ➢ **Motor Generator Set —**A set which consists of one or more motors mechanically coupled to one or more generators. ➢ **Rotary Convertor—**A machine with a single armature winding connected to a commutator and to slip-rings and used for converting alternating current into direct current or vice versa. ➢ **Motor Convertor—**The combination of an induction motor and a rotary convertor on a common shaft system, the current produced in the rotor winding of the motor flowing through the armature winding of the rotary convertor.

QUALIFYING TERMS	➢ **(Rotating) Frequency Convertor —**A machine which converts electrical energy from one frequency to another. ➢ **Commutator Type Frequency Convertor —**A polyphase machine, the rotor of which has one or two windings connected to a set of slip-rings and to a commutator such that by feeding one set of brushes with a voltage of a given frequency, a voltage of another frequency may be obtained from the other set. ➢ **Frequency Changer Set—**A motor generator set which converts electrical energy from one frequency to another. ➢ **Separately Excited**—Qualifies a machine to denote that the excitation is obtained from a source other than the machine itself. ➢ **Self-Excited—**Qualifies a machine to denote that the excitation is supplied by the machine itself. ➢ **Shunt —**Qualifies a machine to denote that it is excited by a winding in parallel to the armature winding. ➢ **Series—**Qualifies a machine to denote that it is excited by a winding in series with the armature winding ➢ **Compound Excited —**Qualifies a machine to denote that it is excited by at least two windings, one of which is a series winding. ➢ **Cumulative Compounded—**Qualifies a compound excited machine to denote that the magnetomotive force of the series and shunt windings are in the same direction. ➢ **Differential Compounded —**Qualifies a compound excited machine to denote that the magnetomotive force of the series winding is opposed to that of the shunt winding. ➢ **Over-Compounded —**Qualifies a compound excited generator to denote that the series winding is so proportioned that the terminal voltage at rated output is greater than at no load. ➢ **Level Compounded—**Qualifies a compound excited generator to denote that the series winding is so proportioned that the terminal voltage at rated output is the same as at no load. ➢ **Under-Compounded—**Qualifies a compound excited generator to denote that the series winding is so proportioned that the terminal voltage at rated output is less than at no load.

WINDING ARRANGEMENTS	➢ **Winding—**An assembly of turns or coils having a defined function in an electrical rotating machine. ➢ **Armature Winding—**A winding in a synchronous, d.c. or single-phase commutator machine which, in service, receives active power from or delivers active power to the external electrical system. ➢ **Primary Winding—**A winding in an induction machine which, in service, receives active power from or delivers active power to the external electrical system. ➢ **Secondary Winding—**A winding in an induction machine which is not connected to the external electrical system. ➢ **Main Winding—**The primary winding of a split phase motor. ➢ **Starting Winding—**A winding for the purpose of starting a machine. ➢ **Auxiliary Starting Winding —**A starting winding of a split phase motor. ➢ **Excitation Winding—**A winding for the production of a magnetic field which is stationary with respect to that winding. ➢ **Field Winding —**An excitation winding contributing to the creation of the principal magnetic field of a machine. ➢ **Shunt Winding—**A field winding connected across the whole or part of the armature circuit. ➢ **Series Winding—**A field winding connected in series with the armature winding and carrying the whole or part of the armature current
MAGNETIC PARTS	➢ **Core—**The parts of a magnetic circuit in a machine, excluding the air-gap, which are intended to carry the magnetic flux. ➢ **Laminated Core —**A core consisting of laminations. ➢ **Core End Plate—**A plate or structure at the end of a laminated core to maintain pressure on the laminations. ➢ **Field Pole—**A part of a core which carries or in which is embedded an excitation winding, or which includes one or more permanent magnets. ➢ **Non-Salient Pole—**A part of a cylindrical core which acts as a pole by virtue of excitation by a distributed winding. ➢ **Salient Pole—**A type of field pole which projects from the yoke or hub towards the air-gap.

	➢ **Pole Body —**That part of a salient pole around which a field coil is fitted or which includes one or more permanent magnets. ➢ **Pole Shoe—**That part of a salient pole adjacent to the airgap. ➢ **Pole Tips—**The extremities of the pole shoe in the circumferential direction. ➢ **Pole Face—**The surface of a pole shoe forming one boundary of the air-gap.
BRUSHES,BRUSH-HOLDERS, COMMUTATORS, SLIP-RINGS, TERMINATIONS	➢ **Brush—**A conducting part, generally stationary, which provides electrical sliding contact with a commutator or slipring. ➢ **Brush Holder—**A structure which maintains one or more brushes in a definite position relative to a commutator or slip-ring and usually applies an approximately constant thrust on the brush or brushes. ➢ **Commutator—**An assembly of conducting members insulated from one another and from their supports, against which the brushes are maintained, enabling current to flow between a rotating winding and a generally stationary part of a circuit by sliding contact and also enabling commutation between the particular coils of the rotating winding.
	➢ **Slip-Ring—**A conducting ring against which the brushes are maintained enabling current to flow between a rotating and a stationary part of a circuit by sliding contact.
	➢ **Termination**—Any arrangement provided for making the connections between the machine internal leads and the external conductors.
BEARINGS AND LUBRICATION	➢ **Bearing**—A structure intended to support a rotating shaft and if necessary to limit its axial movement. ➢ **Ball Bearing —**A bearing incorporating a peripheral assembly of balls. ➢ **Journal Bearing—**A cylindrical or partly cylindrical bearing which supports the journal of a shaft. ➢ **Roller Bearing—**A bearing incorporating a peripheral assembly of rollers. ➢ **Thrust Bearing—**A bearing arranged to resist an axial movement of a shaft and to carry axial load. ➢ **Self-Lubricating Bearing—**A bearing lined with a

	material containing its own lubricant such that little or no additional lubricating fluid need be added subsequently to ensure satisfactory lubrication of the bearing. ➢ **Oil Ring Lubricated Bearing—**A bearing in which a ring, encircling the journal and rotated by it, raises oil to lubricate the bearing from a reservoir into which the ring dips. ➢ **Disc and Wiper Lubricated Bearing—**A bearing in which a disc mounted on and concentric with the shaft dips into a reservoir of oil. As the shaft rotates, the oil is diverted from the surface of the disc by a scraper action into the bearing. ➢ **Flood Lubricated Bearing—**A bearing in which a continuous flow of lubricant is poured over the top of the bearing or journal at about normal atmospheric pressure. ➢ **Forced Lubricated Bearing—**A bearing in which a continuous flow of lubricant is forced over the bearing or journal.
MECHANICAL STRUCTURE, MOUNTING ARRANGEMENT, DIRECTION OF ROTATION	➢ **Stator—**The stationary portion of a machine. ➢ **Rotor—**The rotating portion of a machine. ➢ **Armature—**The portion of a machine which carries the armature winding. ➢ **Field System—**The portion of a machine which carries the field winding. ➢ **Journal (of a Shaft)—**That part of a shaft which is intended to rotate inside a bearing. ➢ **Shaft Extension—**A portion of a shaft extending beyond an extreme bearing. ➢ **Shaft End—**A portion of the shaft which is used to transmit torque from or to the machine. ➢ **Jack Shaft—**A separate shaft carried in its own bearings and rigidly coupled to the shaft of a machine. ➢ **Stub Shaft—**A separate shaft without its own bearings and rigidly coupled to the shaft of a machine.
COOLING	➢ **Cooling**—A procedure by means of which heat resulting from losses occurring in a machine is given up to a primary coolant which may be continuously replaced or may itself be cooled by a secondary coolant in a heat exchanger. ➢ **Primary Coolant—**A medium, liquid or gas, which, being at a lower temperature than a part of a machine and in contact with it, removes heat from that part.

	➢ **Secondary Coolant—**A medium, liquid or gas, which, being at a lower temperature than the primary coolant, removes the heat given up by this primary coolant by means of a heat exchanger or through the external surface of the machine. ➢ **Final Coolant—**The Last Coolant to Which the Heat Is Transferred. ➢ **Heat Exchanger—**A component intended to transfer heat from one coolant to another while keeping the two coolants separate. ➢ **Open Circuit (of a Cooling System)—**A circuit in which the coolant is drawn directly from the surrounding medium or from a remote medium, passes over or through the machine or through a heat exchanger and then returns directly to the surrounding medium or is discharged to a remote medium. ➢ **Closed Circuit (of a Cooling System)—**A circuit in which a coolant is circulated in closed loop(s) in or through the machine and possibly through a heat exchanger, the heat being transferred from the primary coolant to the next, secondary or final, coolant through the surface of the machine or in the heat exchanger. ➢ **Piped or Ducted Circuit (of a Cooling System)—**A circuit in which the coolant is guided either by inlet or outlet pipe or duct, or by both inlet and outlet pipe or duct, these serving as separators between the coolant and the surrounding medium. ➢ **Standby or Emergency Cooling System—**A cooling system which is provided in addition to the normal cooling system and which is intended to be used when the normal system is not available.

CHAPTER VIII

KNOW THE FUNDAMENTALS

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Maxwell's Equations

All electrical machines operate on the four Maxwell equations on electromagnetics. Here's a brief description of the four fundamental laws of electromagnetism known as Maxwell's equations:

Gauss's Law for Electricity

- **Key Idea** – Electric charges produce electric fields. The strength of the electric field is directly related to the amount of charge present.
- **Concept** – Imagine an electric charge enclosed within an imaginary surface. The electric flux (a measure of the field lines) passing through that closed surface is proportional to the enclosed charge.

Gauss's Law for Magnetism

- **Key Idea** – Isolated magnetic poles (monopoles) do not exist. Magnetic field lines always form closed loops.
- **Concept** – The net magnetic flux passing through any closed surface is always zero. Essentially, magnetic field lines entering any closed surface must also exit it.

Faraday's Law of Induction

- **Key Idea:** A changing magnetic field induces an electromotive force (EMF) and hence an electric field.
- **Concept:** Imagine a wire loop in a magnetic field. If the magnetic field strength or the loop's orientation changes, an electromotive force (EMF) is induced, potentially driving an electric current.

Ampère's Law with Maxwell's Addition

- **Key Idea** – Electric currents and changing electric fields generate magnetic fields.
- **Concept** – This law comes in two parts
- Ampère's original law – A magnetic field is generated around any closed loop of current.
- Maxwell's addition – Not only steady currents but also changing electric fields produce magnetic fields.

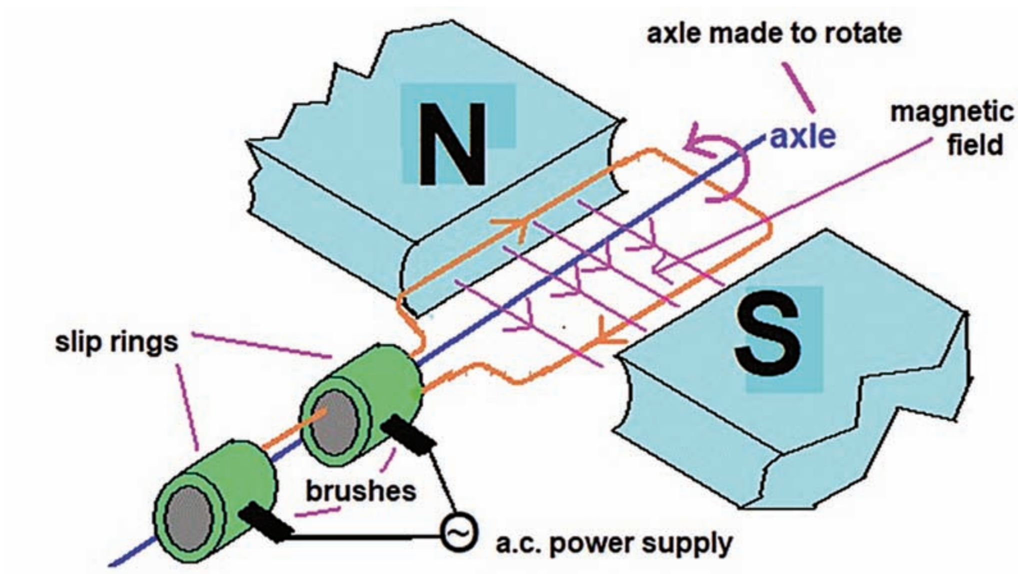
Electromagnetism

- The word "electromagnetism" in physics is used to describe one of the fundamental forces of nature. This force is between subatomic particles such as protons and electrons. It helps to hold matter together. Electromagnetism is also used to describe how a magnetic field is created by the flowing of electric current.

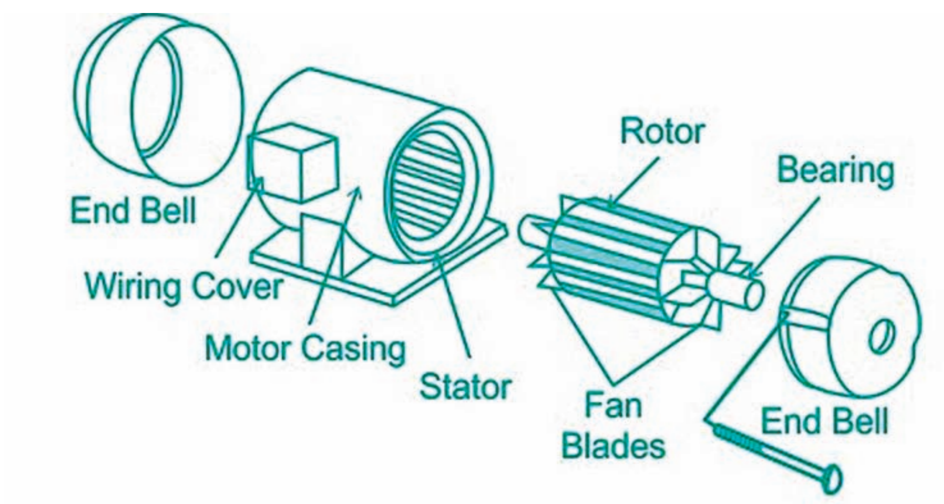
Electromagnet

- Electromagnetism plays a pivotal role in various technological applications, particularly evident in the functioning of electric motors. When an electrical current courses through a conductor like a wire, it induces a magnetic field. This fundamental principle underscores much of modern electricity. To amplify this effect, engineers often coil the wire, intensifying the magnetic field. This strategy enhances the efficiency of the system by allowing more current to traverse a shorter distance, thereby bolstering the magnetic field's strength.

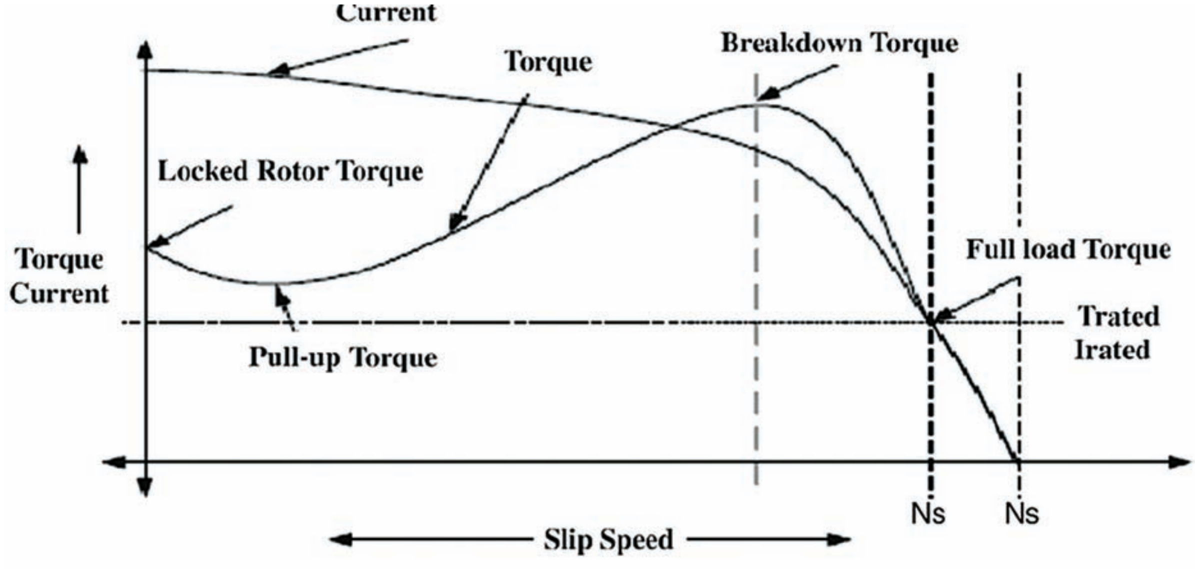
The electric motor exemplifies the practical manifestation of electromagnetism. By converting electrical energy into physical motion, electric motors power myriad devices. Within an electric motor, a coil carrying an electric current generates a magnetic field. This magnetic field, in turn, interacts with a permanent magnet, producing a force that impels movement or rotation, thereby driving the motor's operation.



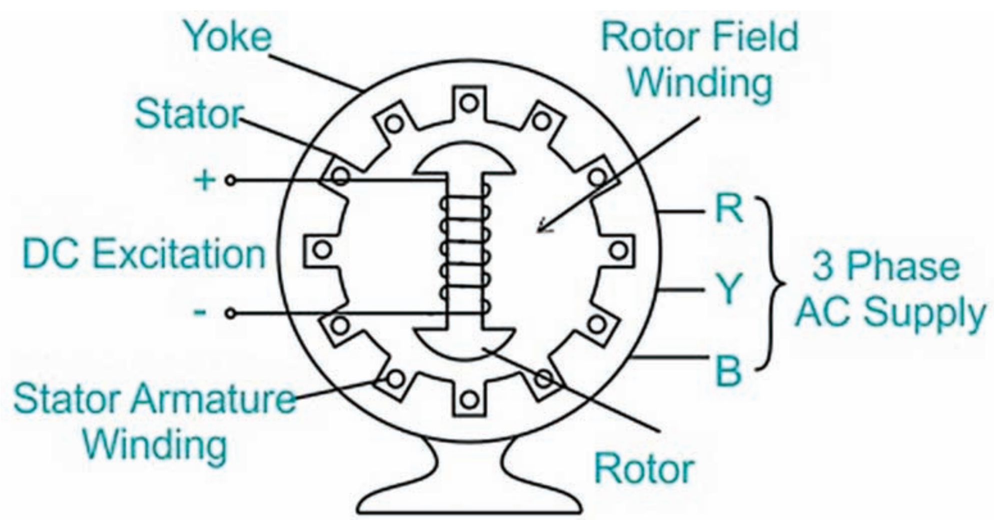
Working of A.C Motor



Parts of AC Motors



Torque slip characteristics



Parts of Synchronous Motor

CHAPTER IX

KNOW THE PROCEDURES

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Know the Procedures

Standardizing methods of testing is crucial in Indian Standards to ensure the quality, safety, and performance of products, services, and systems. It enables manufacturers, regulators, and consumers to rely on consistent and accurate test results, facilitating informed decisionmaking and compliance.

Importance of Standardizing Methods of Testing:

1. Ensures Accuracy and Reliability: Standardized test methods ensure accurate and reliable results, minimizing errors and variability.
2. Facilitates Comparability: Standardized test methods enable comparison of test results across different products, services, and systems.
3. Enhances Consistency: Standardized test methods maintain consistency in testing procedures, reducing confusion and misinterpretation.
4. Supports Quality Assurance: Standardized test methods contribute to quality assurance, ensuring products meet required standards.
5. Facilitates Regulatory Compliance: Standardized test methods support regulatory compliance, enabling manufacturers to demonstrate conformity to standards.
6. Reduces Costs: Standardized test methods reduce testing costs, minimizing duplication of efforts and resources.
7. Enhances International Trade: Standardized test methods align with international standards, facilitating global trade and commerce.
8. Supports Innovation: Standardized test methods enable innovation, allowing manufacturers to develop new products and services with confidence.

Best Practices for Standardizing Methods of Testing:

1. Collaborative Approach: Involve stakeholders from various industries and sectors.
2. Internationally Recognized Methods: Adopt internationally recognized test methods, ensuring global acceptance.
3. Regular Review and Update: Periodically review and update standardized test methods, reflecting technological advancements.
4. Training and Capacity Building: Provide training and capacity-building programs for testing personnel.
5. Accreditation and Certification: Establish accreditation and certification programs for Conformity Assessment

Standardizing methods of testing is vital in Indian standards to ensure accuracy, reliability, and consistency in testing. By adopting a collaborative approach and

following best practices, India can establish a robust framework for standardized test methods, enhancing the quality, safety, and performance of products, services, and systems, and supporting innovation and international trade.

IS 4029- Guide for Testing Three Phase Induction Motors	
This Guide Prescribes Methods for Conducting and Reporting Tests for Three Phase Induction Motor.	
Electrical Test Method	
Test Method	**Details**
Insulation Resistance Test	Insulation resistance shall be measured between winding and frame (earth). Insulation resistance may be measured by an instrument like hand operated insulation resistance tester having a dc voltage of about 500 V. For testing of insulation resistance for machines of output ratings 1 MW and above reference may be made to IS 7816.
High Voltage Test	The high voltage test shall be applied between the windings and the frame, with the core connected to the frame and to the windings not under test and shall be applied only to a new and completed motor with all its parts in place under conditions equivalent to normal working conditions. It is generally advisable that the high voltage test should be conducted, In the case of motors with nominal voltage above 1 kV, when both ends of each phase are individually accessible, the test voltage shall be applied between each phase and the frame, with the core connected to the frame and to other phases and windings not under test. The test voltage shall be of power frequency and shall be as near as possible to sine waveform. The test shall be commenced at the voltage of not more than one-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 percent of the full value, the time allowed for the increase of the voltage from half to full value not being less than 10 s. The full test voltage shall then be maintained for 1 min in accordance with the values. At the end of this period, the test voltage shall be rapidly diminished to one third of its full value before switching off.

Resistance Measurement	Two methods are commonly used for the measurement of resistance: a) Drop of potential or voltmeter ammeter method, and b)Bridge method. If the resistance of winding is known at one temperature it may be calculated for any other temperature by using following formula: $R_2 = (235 + t_2) / (235 + t_1) X R_1$ **a) Drop of Potential or Voltmeter Ammeter Method** In this method, a dc ammeter and d c voltmeter shall be used. Simultaneous readings of both voltage at motor terminals and current shall be taken when their values become steady. The relationship between R, V and I is as follows: R = V I **b) Bridge Method** The resistance above 1 Ù may be determined with sufficient accuracy, if ordinary Wheatstone bridge is used. Resistance lower than 1 Ù shall be measured by Kelvin double bridge method also known as Kelvin Thompson double bridge method. **i) Wheatstone Bridge Method** In using Wheatstone bridge method the resistance of the ratio arms shall be so selected that the values correspond as closely as possible to the resistance to be measured; the use of one ohm ratio coil should be avoided. The values of resistance thus measured include the resistance of connecting leads. Therefore, the resistance of leads should be subtracted from total measured resistance. **ii) Kelvin-Thompson Double Bridge** The double bridge compensates for resistance of leads or other connections. It also enables low resistance to be compared accurately with a standard one of the same order. The rotor winding resistance shall be measured at the point of connection of the rotor windings to the slip rings so that slip ring resistance is eliminated from the measurement and true rotor winding resistance obtained.

Performance Characteristics	
Test Method	**Details**
No Load Test	This test is intended to find out the no load current, core loss and friction and windage losses. The motor is run at no load at rated voltage and frequency until the watts input is constant. Reading of voltage, current and power input should be taken. This test shall preferably be conducted immediately after the temperature rise test. The sum of friction and windage losses and core loss is obtained by subtracting the primary I 2 R loss at the temperature of the test from input watts. The separation of friction and windage losses and core loss may be made, if desired, by obtaining readings of voltage, current and watts input at rated frequency and voltage from 125 percent of the rated voltage to the point where further voltage reduction will increase the current; this point is usually at 15 percent of the rated voltage.
Open Circuit Test	On wound-rotor motors, the voltage between all rotor terminals should be measured with rotor locked, if necessary and its winding on open circuit, with rated or reduced voltage and rated frequency applied to the stator. If any rotor unbalance is detected, it is recommended that the readings be taken with several rotor positions and an average obtained.
Locked Rotor Test (for Motors Having Output Rating Up to 37 kW)	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. It should be recognized that testing of induction motors under locked rotor conditions involves unusual stresses and high rates of heating. Therefore, it is necessary that a) the direction of rotation be established prior to the test; b) the mechanical means of locking the rotor be of adequate strength to prevent possible injury to personnel or damage to equipment; and c) as the windings gets heated very rapidly, the test

	shall be carried out as rapidly as possible. The readings at any point shall be taken within 6s. The torque should be measured with the rotor in various positions wherever possible and the minimum value shall be taken as starting torque. For extrapolation of the test results at the rated voltage, the test shall be carried out at least at three test voltages. At each test voltage, the readings of voltage, current, torque, frequency and power input should be taken. Then a curve between values of the current and the applied test voltage should be drawn. Similarly another curve shall be drawn between the torque value and the square of the applied test voltage. The values of starting current and starting torque shall be extrapolated from these curves.
Locked Rotor Test (for motors above 37 kW)	The locked rotor torque in such a case is calculated by the following formula from readings taken at rated frequency: Locked rotor torque at test voltage: (TIr): (1-s)x Psi - Pcu / Pr
Motors Having Output R to 15 kW) ***Pull Up and Pull Out Torque (for ating Up***	**Pull up Torque** The motor shall be mounted with suitable loading arrangement and the rotor fully locked. The rated voltage at the rated frequency shall be applied to the motor terminals under locked rotor conditions. The loading on the motor shall then be reduced slowly when the rotor starts and picks up speed. The value of the torque at which the motor breaks away from the locked rotor condition and attains the speed corresponding to pull out torque condition shall be noted and reported as pull up torque. **Pull out Torque** The motor shall be mounted with a suitable loading arrangement and the rated voltage at the rated frequency applied to the motor terminals at no load conditions. The load on the motor may then gradually be increased and the maximum load at which the motor stalls may be noted. The torque calculated at this point is the pull out torque.
and Tests for Speed-Torque Speed-Current Curves	Speed-torque and speed-current tests may be carried out by the following methods: a) Dynamometer; b) Pony brake; c) Rope and pulley; and d) Calibrated machine.

Load Test	Load characteristics are obtained by taking readings at higher loads followed by those at lower loads. This is usually done at 125, 100, 75, 50 and 25 percent of the full load values. 4 different Methods are: i) Brake method ii) Dynamometer method iii) Calibrated machine iv) Uncalibrated machine
Determination of Efficiency	Input-output method Input-output tests are carried out by the following three methods: a) Dynamometer, b) Brake and pulley, and c) Calibrated machine
Slip Determination	For the range of load for which the efficiency is determined, the measurement of slip is very important. Determination of slip by subtracting the value of speed obtained by means of conventional contact type tachometer from synchronous speed is not recommended. However, readings from digital noncontact type accurate tachometers with ± 0.1 percent accuracy can be used with frequency measured by an instrument of same accuracy class. The slip can be measured by one of the following methods: a) Stroboscope. b) Slip-coil. c) Magnetic needle d) Measurement of speed and frequency method.
Measurement of Shaft Currents and Voltages ***Test of Motors for Operation with Frequency Converters***	The machine is run at no-load and at rated supply voltage and frequency. A rectifier type moving coil voltmeter of full scale deflection of 5 V (preferably of 1 V only) should be connected across the ends of the machine by means of solid copper prods firmly held in the shaft centers. When this is not feasible any smooth cylindrical surface outside the bearing may be used. Alternatively, this measurement may be done by inserting a voltmeter between the shaft and the pedestal (in case of sleeve bearing). The connecting leads used in this test should be of very low resistance. Motors for operation with frequency converter are tested with sinusoidal supply as mentioned in this standard. Additional tests with frequency converter are as follows: a) Temperature-rise test at rated load and speed;

	b) Efficiency measurement by loss segregation method; and c) Vibration level test at the highest speed. Suitable power analyzer shall be used for measurement of voltage, current and input power.
Thermal Test Method	
Temperature-Rise Test	This test is intended primarily to determine the temperaturerise on different parts of the motor while running at rated conditions. It can be done either by direct loading method or equivalent loading method. When loading to rated conditions is not possible due to limitations in facility. **Methods of Measuring Temperature-Rise** a) Embedded temperature detector method b) Resistance method c) Thermometer method
Superimposition Method of Loading for Temperature-Rise	The temperature-rise of an induction motor under rated conditions is conventionally evaluated by loading the motor to its rated load, with the supply maintained at rated voltage and rated frequency. The motor is run till thermally it reaches steady state, there-after the motor is switched off, the resistance of the stator winding is measured and compared with the winding resistance measured under cold conditions (before starting the test) to determine the temperature-rise of the motor. **Method of Testing** The motor is run at no load with air gap voltage and rated frequency till steady state conditions are reached and the temperature-rise of winding is measured (T1). The motor is now run at a reduced load, reduced voltage and rated frequency such that the rated input current is drawn by the motor till steady state conditions are reached and the temperature-rise of winding is measured (T2). The motor is now run at no load, with the same reduced voltage and rated frequency till steady state conditions are reached and temperature rise of winding is measured (T3).
	EVALUATION The temperature-rise of windings under rated conditions shall be: T = T1 + T2 – T3

Two Frequency Equivalent Loading Method for Determination of TemperatureRise of Induction Machines	Load tests are carried out primarily to obtain temperaturerise of the machine under test **Method of Testing** One of the following two methods listed below shall be selected by the manufacturer depending on load facilities: a) Two frequency— Primary superposition method; and b) Two frequency— Secondary superposition method.
Performance Determination of Induction Machines by Circle Diagram Method and Equivalent Circuit Method	when direct load tests are not carried out, it becomes necessary to determine the values by other methods. With the introduction of equivalent loading method in India, it has become necessary to have an acceptance standard for performance testing when induction machines are tested by these methods. a) Circle Diagram Method i) Circle Diagram Method (Standard L Type) ii) Circle Diagram Method (Special L Type)
Mechanical Test Method	
Test Method	**Details**
Measurement of Noise	See IS 12065

IS 7572- Guide for Testing Single-Phase AC and Universal Motors	
This guide covers methods for conducting the tests for single-phase AC and universal motors	
Electrical Test Method	
Test Method	***Details***
Insulation Resistance Test	Insulation resistance shall be measured between individual windings and frame (earth). The insulation resistance, when the high voltage test is applied, shall be not less than one megohm. The insulation resistance shall be measured with a dc voltage of about 500 volts applied for a sufficient time for the reading of the indicator to become practically steady, such voltage being taken from an independent source or generated in the measuring instrument.
High Voltage Test	A test voltage shall be applied between the windings and the frame of the motor with the core connected to the frame and the windings not under test. **Method of High voltage Test** The test voltage shall be of approximately sine-wave form and, duririg the

	application of voltage, the peak value, as would be determined by spark gap, by oscillograph or by any other approved method, shall be not more than 1.45 times the rms value. The rms value of the applied voltage shall be measured by means of a voltmeter used with a suitable calibrated potential transformer or by means of voltmeter used in connection with a special calibrated voltmeter winding or testing transformers, or by any other suitable voltmeter connected to the output side of the testing transformer.
Resistance Measurement	Two methods are commonly used for the measurements of resistance. a) The drop of potential or voltmeter-ammeter method, and b) The bridge method in which the unknown resistance is compared with the known resistance by using a suitable bridge.

Performance Characteristics	
Test Method	**Details**
No-Load Test	This test is intended to find out the no-load current, core loss and friction and windage losses The motor is run at no load with the running winding 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	It should be recognized that the testing of induction motors under locked rotor conditions involves unusual mechanical stresses and high rates of heating. Therefore, it is necessary that: a) the mechanical means of locking the rotor be of adequate strength to prevent possible injury to personnel or damage to equipment. b) the direction of rotation be determined prior to this test. c) the current and torque readings be taken at approximately rated voltage and at rated frequency and that the motor be at approximately ambient temperature. The voltage shall be within 5 percent of rated voltage. The ammeter reading, shall be corrected by multiplying it by the rated voltage and dividing the product by the voltage read when the ammeter was read. The ammeter shall be read after its pointer has

	stopped its periodic swinging but all readings shall be taken within 3 seconds after the line switch is closed. The temperature- at the start of every test shall be not less than 20°C nor more than 40°C.
Tests for Speed-Torque and Speed-Current Curves	The speed-torque and speed-current tests may be made with a dynamometer or by rope and pulley methods. Measurements of current, voltage and speed shall be made. Data for these characteristics shall be taken at or near rated voltage. **Pull Out Torque** This test may be made by allowing the motor to run light and then increasing the torque until the speed of the motor falls off abruptly. This test should be made as rapidly as is possible, consistent with accuracy, but not so rapidly as to introduce inertia errors into the readings. **Pull Up Torque** The pull-up torque of an alternating current motor is the minimum external torque developed by the motor during the period of acceleration from rest to the speed at which pull-out torque occurs. For motors which do not have a definite pullout torque, the pull-up torque is the minimum torque developed up to rated speed.
Load Test	Loading is done at least at five points spaced substantially equally from no load to full load and that additional reading of power input and power factor shall be taken to calculate efficiency. **Methods of Loading** a) Brake method b) Dynamometer Method c) Rope and Pulley Method
Determination of Efficiency	Input-output method Input-output tests are carried out by the following three methods: a) Dynamometer, b) Brake c) Rope and Pulley, and d) Calibrated Machine
Slip Measurement	For the range of load for which the efficiency is determined, the measurement of slip is very important. Determination of slip by subtracting the value of speed obtained by means of techometer from synchronous speed is not recommended. The slip should be directIy measured by one of the following method: a) Stroboscope, b) Slip coil, and c) Magnetic Needle

Temperature Rise Test	This test is intended primarily to determine the temperaturerise on different parts of the motor while running at rated conditions. **Methods of Measuring Temperature-Rise** a) Thermometer method b) Applied Thermocouple Method c) Resistance method

IS 9320- Guide for Testing Direct-Current (DC) Machines	
This standard covers method for conducting and reporting the tests for dc machines except traction machines, marine service, air transport and mill type motors. This standard applies to direct current generators and motors rated 0·3 kW and higher.	
Electrical Test Method	
Test Method	***Details***
Measurement of Winding Resistance	Resistance of all windings shall be measured in accordance with 6 of IS: 4029
Measurement of Insulation Resistance	Insulation resistance shall be measured between winding and frame (earth), and between winding and winding. The insulation resistance when the high voltage test is applied, shall be not less than one megohm. The insulation resistance shall be measured with dc voltage of about 500 V applied for a sufficient time for the reading of the indicator to become practically steady, such voltage being taken from an independent source or generated in the measuring instrument.
Determination of Open Circuit Characteristics,	No-load saturation curve is determined by the field excitation required to provide given voltages at rated base speed and noload. The data should be taken at properly spaced voltages to permit an accurate plot from zero field current up to approximately 125 percent of rated voltage.
Determination of Regulation Characteristics	Regulation characteristics of a dc generator represent the dependence of the terminal voltage on the load current at constant field current and shall be determined at winding temperature approximately equal to the working temperature. Regulation characteristics of a dc motor represents the dependence of the speed of motor on the load current at constant field current and shall be

	determined at temperature approximately equal to working temperature.
Determination of External Characteristics (for Generators Only)	The external characteristic curve of dc generators represents the dependence of the terminal voltage on the load current or output at constant speed and field current (for separately excited generators) or at constant setting of field rheostat (for self-excited machines) and is determined at a winding temperature approximately equal to the design working temperature. External characteristics shall be plotted at various loads from zero load to 150 % of rated value.
Temperature-Rise Test	Temperature-rise test shall specify the values of temperature-rise of different parts of the machine and rated data of the machine. The machine shall be running continuously under no-load condition, that is, at rated volts and zero current; and after that under short circuit condition, that is, at zero volts and rated current. The temperature-rise of the tested windings shall be considered. as equal to the sum of the winding temperature-rises measured directly after each of the runs.
Efficiency Test	Efficiency test shall be conducted in accordance with IS: 4889
Load Saturation Characteristics (for Exciters Only)	Load saturation characteristics represent the dependence of the armature voltage on the field current at rated speed and constant load resistance. The value of constant load resistance shall be equal to the field resistance at 75°C, of the machine while this exciter is feeding power.
Overspeed Test	All dc machines shall be tested for overspeed in accordance with IS : 4722
High Voltage Test	High voltage test shall be conducted in accordance with IS: 4722
Measurement of Inductance of Armature Winding and Mainpole Winding	**Armature Circuit Inductance Measurement** This test is done by applying single phase 50 Hz alternating current to the terminals of the machine and taking reading of the voltage across the armature, compensating interpole winding and terminals of the machine. In case of series and compound machines, the series field winding should be out of circuit to prevent the machine acting like a series motors. The series field should not be shorted.

	Measurement of Inductance of Mainpole Windings The machine should be driven at rated speed. In the case of multispeed-rated machine, the machine should be driven at lowest rated speed. The test is taken with an oscillograph. The elements of the oscillograph should be connected to record as follows: a) Timing wave, b) Armature terminal voltage, c) Shunt-field current, and d) Shunt-field voltage.
Mechanical Test Method	
Test Method	**Details**
Measurement of Vibrations	The vibrations of the machines shall be measured in accordance with IS : 4729

IS 12998- Acoustics Test Code for the Measurement of Airborne Noise Emitted by Rotating Electrical Machines	
This International Standard specifies all the information necessary to carry out efficiently and under standardized conditions the determination, declaration, and verification of the noise emission characteristics of rotating electrical machines. It specifies noise measurement methods that can be used, and specifies the operating and mounting conditions required for the test. Noise emission characteristics include the sound power level and emission sound pressure level. The determination of these quantities is necessary: o for comparing the noise emitted by machines; o to enable manufacturers to declare the noise emitted; and o for the purposes of noise control. The use of this International Standard as a noise test code ensures the reproducibility of the determination of the noise emission characteristics within specified limits determined by the grade of accuracy of the basic noise measurement method used. Noise measurement methods allowed by this International Standard are precision methods (grade 1), engineering methods (grade 2) and survey methods (grade 3). Methods of engineering grade (grade 2) are to be preferred. This International Standard is applicable to rotating electrical machines of any length, width or height	
Electrical Test Method	
Test Method	***Details***
Load Test	The testing shall be performed under no-load conditions, unless otherwise specified
Variable Speed Devices	The machine under test shall be monitored over the whole range of operating speeds to determine the speed(s) generating the maximum noise level. To find this level, a low speed variation shall be applied. This condition shall be used for the noise test and the speed reported in the results.

IS 12065- Permissible Limits of Noise Level; For Rotating Electrical Machines	
This Indian Standard specifies methods of measuring and classifying the acoustic noise emitted by rotating electrical machines (excluding small power machines and machines for traction vehicles) on no-load.	
Test Method 1	
It describes the procedure to be used to establish the weighted sound power level of the machine.	
Test Method	**Details**
Operating Conditions of Machine on Test	For the purpose of the test, following conditions shall be observed: a) The machine shall be run on no-load. Synchronous machines shall be run at unity power factor; b) The machine shall be in its fully-assembled condition, and uncoupled; c) ac machines shall be supplied at rated voltage and frequency; d) Machines shall be run as nearly as possible at rated speed, or at the highest speed in the range, if there is a speed range; and e) Machines designed to operate at two or more discrete speeds shall be tested at each speed.
Method of Measurement	For all machines, measurements shall be made on the prescribed paths. For machines having a maximum linear dimension l (excluding shaft) equal to or exceeding 0.25 m these rectilinear paths are, at their nearest points, l m from the distance of the machine. For cases where l is less than 0.25 nr, these rectilinear paths are at their nearest points at a distance from the surface of the machine between 4l and 1 m but not less than 0.25 m. For all horizontal machines the prescribed path parallel to the reflecting ground plane should be at shaft height or 0.25 m, whichever is greater. For vertical machines, the prescribed path parallel to the reflecting ground plane shall be at half the height of the machine but not less than a height of 0.25 m . The prescribed path in the vertical plane may be in, or parallel to, the plane of the shaft.

Test Method 2	
These tests include detailed measurements based on frequency band analysis of sound radiation in a free field over a reflecting plane	
Test Method	***Details***
Operating Conditions of Machine on Test	Similar as Test Method 1
Method of Measurement	Similar as Test Method 1

IS 12075- Mechanical Vibration of Rotating Electrical Machines with Shaft Heights 56 mm and Higher — Measurement, Evaluation And Limits of Vibration Severity	
This standard specifies test and measurement conditions and fixes the limits for the level of vibration severity of an electrical machine when measurements are made on the machine alone, at a testing department under properly controlled conditions.	
Vibration Test Method	
Test Method	**Details**
Requirement	The vibration measuring equipment shall be in accordance with IS 11726.
Conditions of Measurement	Unless otherwise specified and agreed upon, the measurement of vibration shall be carried out with half key in its shaft extension key way. The shaft stick is attached to the accelerometer which is connected to the dynamic signal analyzer. A clean spot on the shaft is located where the shaft runout is known to be controlled to under 12.5 micron with the motor running, stick is manually pressed on to the shaft at the clean spot in the desired direction. The force is adjusted such as to only maintain a stick-to-shaft stable contact. It should be understood that shaft stick measures shaft absolute motion rather than shaft relative motion with respect to bearing housing as in the case with the contactless shaft probes.
Operating Conditions	Ac machines shall be fed with rated voltage and rated frequency supply having a virtually sinusoidal waveform according to IS 4722. DC machines shall be excited with nominal current and shall be fed with a such voltage so as to run at nominal speed. For machines with several speeds or variable speed, the test shall be carried out at lowest, middle and maximum of operational speed range. This test may

	be carried out using a converter supply or with sinusoidal ac supply as agreed between the manufacturer and the purchaser.
	For machines which are bi-directional, the vibration limits apply for both directions. Unless otherwise specified, measurement of the vibration severity shall be carried out under no-load and uncoupled operation at the temperature reached by the machine after a sufficient period of no-load operation.

IS 60034-5- Rotating Electrical Machines Degrees of Protection Provided by the Integral Design of Rotating Electrical Machines (IP Code) - Classification This Standard applies to the classification of degrees of protection provided by enclosures for rotating electrical machines. It defines the requirements for protective enclosures that are in all other respects suitable for their intended use and which, from the point of view of materials and workmanship, ensure that the properties dealt with in this standard are maintained under normal conditions of use.	
Test Method	
Test Method	***Details***
First Characteristic Numeral for Protection Against Solid Objects	**Test and acceptance conditions**
0	No test is required
1	The teat is made with a rigid sphere of 50 $^{+0.05}$ mm diameter applied against the opening(s) in the enclosure with a force of 45 N to 55 N The protection is satisfactory if the sphere does not pass through any opening and adequate clearance is maintained to parts which are normally live in service or moving parts inside the machine
2	a) Finger Test The test is made with a metallic test finger. Both joints of test finger may be bent through an angle of 90° with respect to the axis of the finger, but in one and the same direction only. The finger ls pushed without undue force (not more than 10 N) against any openings in the enclosure and, If it enters, It is placed in every possible position.

	The protection is satisfactory if adequate clearance is maintained between the test finger and live or moving parts inside the enclosure. However, It Is permissible to touch smooth rotating shafts and similar non dangerous parts. b) Sphere Test The test is made with a rigid sphere of $12.5^{+0.05}$ mm diameter applied to the openings of the enclosure with a force of 27 N to 33 N. The protection is satisfactory if the sphere does not pass through any opening and adequate clearance is maintained to live or moving parts inside the machine.
3	The test is made with a straight steel wire or rod of $2.5^{+0.05}$ mm diameter applied with a force of 2.7 N to 3.3 N. The end of the wire or rod shall be free from burns and at right angle to its length. The protection is satisfactory if the wire or rod cannot enter the enclosure.
4	The test is made with a straight rigid steel wire 01 mm diameter applied with a force of 0.9 N to 1.1 N. The end of the wire shall be free from burns and at right angles to its length. The protection is satisfactory if the wire cannot enter the enclosure.
5	a) Dust Test The test is made using equipment incorporating the basic principles, in which talcum powder is maintained in suspension in a suitable closed test chamber. The talcum powder used shall be able to pass through a square-meshed sieve having a nominal wire diameter of 50 ìm and a nominal width between wires of 75 ìm, The amount of talcum powder to be used is 2 kg/m^3 of the test chamber volume. It shall not be used for more than 20 tests. For this test the machine is supported inside the test chamber and the pressure inside the machine is maintained below atmospheric pressure by a vacuum pump. The object of the test is to draw into the machine, if possible, at least 80 times the volume of air in the enclosure without exceeding an extraction rate of 60 volumes per hour with a suitable depression. In no

	event shall the depression exceed 2 kPa (20 mbar) on the manometer. If an extraction rate of 40 to 60 volumes per hour is obtained, the test Is stopped after 2 h. If, with a maximum depression of 2 kPa (20 mbar), the extraction rate is less than 40 volumes per hour. the test is continued until 80 volumes have been drawn through, or a period of 8 h has elapsed. b) Wire Test If the machine is Intended to be run with open drain hole(s), these shall be tested in the same manner as the first characteristic numeral 4, that is using a 1 mm diameter wire.
6	Test in accordance with 5 a). The protection is satisfactory if. on inspection. there is no ingress of talcum powder.
Test Method	
Test Method	Details
Second Characteristic Numeral for Protection Against Liquid	**Test conditions**
0	No test is required
1	The test is made by means of an equipment. The rate of discharge shall be reasonably uniform over the whole area of the apparatus and shall produce a rainfall of between 3 mm and 5 mm of water minute. The machine under test is placed in its normal operating position under the dripping equipment, the base of which shall be larger than that of the machine. The machine normally fixed to a wall or ceiling is fixed in its normal position of use to a wooden board having dimensions which are equal to those of that surface of the machine which is in contact with the wall or ceiling when the machine is mounted as in normal use. The duration of the test shall be 10 min.
2	The dripping equipment is the same as that specified for the second characteristic numeral 1 and is adjusted to give the same rate of discharge. The machine is tested for 2,5 min in each of four fixed positions of tilt. These positions are 15° either side of the vertical in two mutually perpendicular planes. The total duration of the test shall be 10 min.

3	The test shall be made using equipment, provided that the dimensions and shape of the machine to be tested are such that the radius of the oscillating tube does not exceed 1 m. Where this condition cannot be fulfilled, a hand held spray device shall be used a) Method 1 The total flow rate shall be adjusted to an average rate of (0.067 to 0.074) 1/min per hole multiplied by the number of holes. The total flow rate shall be measured with a flowmeter. The tube is provided with spray holes over an arc of 60° either side of the centre point and shall be fixed in a vertical position. The test machine is mounted on a turntable with a vertlca1 axis and is located at approximately the centre point of the semicircle. The minimum duration of the test shall be 10 min. b) Method 2 The moving shield shall be in place for this test. The water pressure is adjusted to give a delivery rate of (10 ± 0.5) l/min (pressure approximately 80 kPa to 100 kPa (0.8 bar to 1.0 bar). The test duration shall be 1 min/m^2 calculated surface area of the machine with a minimum duration of 5 min.
4	The conditions for deciding whether the apparatus should be used are the same as stated for the second characteristic numeral 3. a) Method 1 The osscillating tube has holes drilled over the whole 180° of the semicircle. The test duration and the total water now rate are the same as for degree 3. The support for the machine under test shall be perforated so as to avoid acting as a baffle and the enclosure shall be sprayed from every direction by osscillating the tube at a rate of 60°s^{-1} to the limit of its travel in each direction. b) Method 2 The moving shield is removed from the spray nozzle and the machine is sprayed from all practicable directions. The rate of water delivery and the spraying time per unit area the same as for degree 3.

5	The test is made by spraying the machine from all practicable direction. with a steam of water from a standard test nozzle The condition. to be observed are as follows: a) Nozzle internal diameter: 6.3 mm; b) Delivery rate: 11.9 - 13.2 l/min; - c) Water pressure at the nozzle: approximately 30 kPa (0.3 bar) d) Test duration per m^2 of surface area of the machine: 1 min; e) Minimum test duration: 3 min; f) Distance from nozzle to machine surface: approximately 3 m.
6	The test is made by spraying the machine from all practicable direction. with a steam of water from a standard test nozzle The condition. to be observed are as follows: a) Nozzle internal diameter: 12.5 mm; b) Delivery rate: 95- 105 l/min; c) Water pressure at the nozzle: approximately 100 kPa (1 bar) d) Test duration per m^2 of surface area of the machine: 1 min; e) Minimum test duration: 3 min; f) Distance from nozzle to machine surface: approximately 3 m.
7	The test is made by completely immersing the machine in water and the following conditions are satisfied: a) the surface of the water shall be at least 150 mm above the highest point of the machine; b) the lowest portion of the machine shall be at least 1 m below the surface of the water; c) the duration of the test shall be at least 30 min; d) the water temperature shall not differ from that of the machine by more than 5°C.
8	The test conditions are subject to agreement between manufacturer and user, but they shall not be less severe than those prescribed for degree 7.

Ingress Protection Ratings Chart

0	Zero protection	0	Zero protection
1	Protected from solid objects bigger than 50 mm diameter (hands/large tools)	1	Protected against vertically falling water drops
2	Protected from solid objects no bigger than 12.5 mm diameter (hands/large tools)	2	Protected against vertically falling water drops when at a 15 degree angle
3	Protected from solid objects bigger than 2.5 mm diameter (small objects/wires)	3	Protected against water spraying up to 60 degrees on either side
4	Protected from solid objects bigger than 1.0 mm diameter (wires)	4	Protected against water spraying at any angle
5	Sufficient protection from entry of dust that could interfere with equipment	5	Protected from water jets from any direction (hose pipes)
6	Complete dust protection. (No ingress of dust.)	6	Protected against powerful water jets or heavy seas
		7	Protected against temporary submersion in water (up to 1 meter for 30 minutes)
		8	Protected against continuous submersion in water
		9	Complete protection from high pressure water in any direction

CHAPTER X

STANDARDS - OPTIMAL SOLUTIONS

Chapter X

STANDARDS - OPTIMAL SOLUTIONS

Knowledge of standards can boost the career prospects of engineering students in several ways:

1. ***Enhanced employability:*** Familiarity with industry-recognized standards makes students more attractive to potential employers.
2. ***Industry relevance:*** Understanding standards demonstrates a student's ability to apply theoretical knowledge to real-world industry scenarios.
3. ***Competitive advantage:*** Knowledge of standards sets students apart from peers, giving them a competitive edge in the job market.
4. ***Improved skills:*** Learning standards helps students develop practical skills, such as design, testing, and validation.
5. ***Networking opportunities:*** Participation in standards development and implementation provides opportunities to connect with industry professionals.
6. ***Staying up-to-date:*** Familiarity with standards keeps students current with industry developments and advancements.
7. ***Specialization:*** Expertise in specific standards can lead to specialization, opening up niche career paths.
8. ***Leadership roles:*** Understanding standards can prepare students for leadership roles, where they can drive innovation and compliance.
9. ***Global opportunities:*** Knowledge of international standards can lead to global career opportunities and collaborations.

By acquiring knowledge of standards, engineering students can:

- Increase their industry relevance and employability
- Develop practical skills and certifications
- Enhance their career prospects and credibility
- Stay current with industry developments
- Pursue specialization and leadership roles

Standards knowledge is a valuable asset for engineering students, setting them up for success in their careers.

CHAPTER XI
KNOW YOUR STANDARDS

Chapter XI

KNOW YOUR STANDARDS

IS 12615 - Line Operated Three Phase a.c. Motors (IE CODE) "Efficiency Classes and Performance Specification"

This Indian Standard specifies the performance and efficiency requirements for single-speed, three-phase AC motors used in various industrial applications. It covers motors with power ratings from 0.12 kW to 1000 kW, various pole configurations (2, 4, 6, or 8), and rated voltages up to 1000V at 50Hz. IS 12615 plays a crucial role in promoting energy efficiency and performance standardization for three-phase AC motors in India

Salient Features:

a) ***Efficiency Classes (IE Code):*** The standard defines IE2, IE3, and IE4 efficiency classes, with IE2 being the minimum requirement for motors under this standard. Higher efficiency classes offer better energy savings and reduce operating costs.

b) ***Performance Specifications:*** The standard outlines specific performance parameters, including locked rotor torque, locked rotor current, full load speed, full load current, and frame size correlations to output power.

c) ***Site Conditions:*** Motors should be designed for specific site conditions, including altitude (up to 4000m) and ambient temperature (between -20°C and +60°C).

d) ***Electrical Operating Conditions***: Motors must operate on sinusoidal and balanced voltage conditions and withstand voltage and frequency variations within specified limits.

e) ***Type of Enclosures and Cooling Methods***: The standard recommends specific enclosure types (IP44 or better) and cooling methods (IC411 preferred) to ensure proper protection and performance.

f) ***Testing and Certification***: The standard details routine and type tests to verify motor performance and efficiency. Manufacturers should provide test certificates as evidence of compliance.

g) ***Marking and Labeling***: Motors must be marked with the rated efficiency, IE code, and other relevant information on the rating plate. ***Benefits of using motors compliant with IS 12615:***

a) ***Energy Savings***: Higher efficiency motors consume less energy, leading to reduced electricity bills and environmental impact.

b) ***Improved Performance***: The standard ensures that motors meet specific performance criteria, resulting in reliable and efficient operation.

c) ***Enhanced Durability***: Motors built to this standard are designed for specific environmental conditions, leading to increased lifespan and reduced maintenance costs.

d) ***Compliance with Regulations***: Adopting motors compliant with this standard can help industries meet energy efficiency regulations and avoid potential trade barriers.

Additional Information:

a) The standard does not cover certain types of motors, such as single-phase motors, multispeed motors, and motors integrated into machines.

b) The standard provides information on various motor technologies and their energy efficiency potential.

c) Users should be aware of the impact of motor speed on driven equipment, especially for applications with square law torque characteristics.

The standard prescribes several tests categorized as routine tests, type tests, and customerspecific tests. Here's a breakdown of the major ones:

1. Routine Tests (Performed on every motor):

a) ***Insulation Resistance Test***: Verifies the integrity of the motor's insulation system and ensures it can withstand electrical stresses without failure.

b) ***Winding Resistance Measurement***: Checks the resistance of the stator windings to detect any potential issues like shorted windings or manufacturing defects.

c) ***No-Load Test***: Measures the motor's performance without any load, determining parameters like no-load current and power losses.

d) ***Locked Rotor Test***: Evaluates the motor's starting characteristics, including locked rotor current and torque. This is typically done at a reduced voltage for safety.

e) ***High Voltage Test***: Assesses the dielectric strength of the motor's insulation system by applying a high voltage for a short duration.

2. Type Tests (Performed on representative sample motors):

a) ***Dimensions***: Checks if the motor's physical dimensions comply with relevant Indian Standards for frame size and mounting configurations.

b) ***Locked Rotor Test (up to 37 kW):*** Similar to the routine test but conducted at rated voltage and with more detailed measurements to determine starting characteristics and draw a circle diagram for analysis.

c) ***Full Load Test***: Evaluates the motor's performance at its rated power output, measuring efficiency, power factor, and slip.

d) ***Temperature Rise Test***: Measures the temperature rise of the motor's windings and other components under rated load conditions to ensure they remain within safe operating limits.

e) ***Momentary Overload Test***: Verifies the motor's ability to withstand a short duration overload (1.6 times rated torque for 15 seconds) without stalling or damage.

3. ***Customer-Specific Tests (Conducted upon agreement):***

a) ***Vibration Severity Test***: Measures the level of vibration produced by the motor during operation to ensure it meets acceptable limits and doesn't cause excessive noise or mechanical stress.

b) ***Noise Level Test***: Quantifies the noise emitted by the motor to ensure it complies with specified noise limits and doesn't create a nuisance in the operating environment.

c) ***Degree of Protection Test***: Confirms the motor's enclosure provides the designated level of protection against dust and water ingress as per the IP Code.

d) ***Over Speed Test***: Checks the motor's mechanical integrity and ability to withstand operation at speeds exceeding its rated speed for a specified duration.

e) ***Temperature Rise Test at Voltage and Frequency Variation***: Evaluates the motor's temperature rise under extreme voltage and frequency variations to ensure safe operation under fluctuating grid conditions.

These tests play a vital role in ensuring that motors meet the requirements of IS 12615 and deliver the expected performance, efficiency, and reliability in various industrial applications.

Essential information about motor performance characteristics, efficiency classifications, and interpolation coefficients is provided in a tabulated manner. Here's a list of the tables:

a) Table 1: Values of Performance Characteristics of 2 Pole Line Operated a.c. Motors

b) Table 2: Values of Performance Characteristics of 4 Pole Line Operated a.c. Motors

c) Table 3: Values of Performance Characteristics of 6 Pole Line Operated a.c. Motors

d) Table 4: Values of Performance Characteristics of 8 Pole Line Operated a.c. Motors

e) Table 5: Interpolation Coefficients for 0.12 kW up to 0.74 kW

f) Table 6: Interpolation Coefficients for 0.75 kW up to 200 kW

g) Table 7 (Annex A): Motor Technologies and Their Energy Efficiency Potential

These tables serve as a valuable reference for manufacturers, users, and regulators to understand the performance and efficiency expectations for three-phase AC motors under IS 12615.Tables 1 to 4 present the performance specifications for motors with different pole configurations (2, 4, 6, and 8 poles). Each table lists the rated output power, frame size, full-load speed, full-load current, locked rotor torque, locked rotor current, and nominal efficiency values for IE2, IE3, and IE4 efficiency classes. Tables 5 and 6 provide interpolation coefficients used to calculate the nominal efficiency limits for motors with intermediate rated power values not directly listed in Tables 1 to 4. Table 7 (Annex A) offers information on the energy efficiency potential of various motor technologies for different IE classes (IE1, IE2, IE3, and IE4).

IS 996 - Indian Standard for Single-Phase AC Induction Motors for General Purpose

This Indian Standard outlines the specifications for single-phase AC induction motors used for general purposes in India.

Salient Features:

a) ***Scope:*** Covers capacitor-type motors up to 250V and 2200W with Class A, E, B, F, or H insulation.

b) ***Terminology:*** Defines terms like overload, fan-duty motors, reversible motors, and more.

c) ***Rated Conditions:*** Specifies preferred voltage (230V), frequency (50Hz), output ratings, and speeds.

d) ***Site Conditions & Environment:*** Outlines acceptable altitude, temperature, voltage/frequency variations, and environmental factors.

e) ***Dimensions & Construction:*** Provides recommendations for motor dimensions and construction features, including mounting types, terminal boxes, materials, and thermal protection.

f) ***Types of Enclosures:*** Defines various enclosure types like open ventilated, drip-proof, totally enclosed, etc., as per IS 4691.

g) ***Methods of Cooling:*** Categorizes cooling methods according to origin and manner (natural, self, separate, open circuit, surface).

h) ***General Characteristics:*** Specifies requirements for torques (breakaway, pull-up, pullout), temperature rise limits, performance values (speed, current, efficiency), vibration severity, and insulation resistance.

i) ***High Voltage & Leakage Current:*** Details high voltage test values and methods, moisture proofness test procedures, and limits for leakage current.

j) ***Terminal Marking & Labeling:*** Specifies requirements for terminal markings and criteria for labeling environment-friendly products.

k) ***Marking & Diagram Connections:*** Requires a rating plate with specific information and a connection diagram.

l) ***Tests:*** Defines type tests, routine tests, and acceptance tests for ensuring motor compliance.

m) ***General Information:*** Lists information to be provided with inquiries and orders for motors.

n) ***Selection and Application:*** Offers guidance on selecting motors based on factors like the number of starts and specific applications.

o) ***Annexes:*** Provides additional information on types of motors, test report forms, information for inquiries/orders, selection/application guidance, and sampling procedures for quality control.

Additional Information:

a) Special requirements for specific applications like fans, pumps, and domestic appliances might require agreements between the user and manufacturer.

b) Fan-duty motors have specific requirements and guidelines detailed in Annex F.

c) The standard emphasizes compliance with relevant Indian Standards for materials and components.

d) Users are encouraged to follow IS 900 for proper installation and maintenance of induction motors.

The standard prescribes several tests categorized as type tests, routine tests, and acceptance tests. These tests collectively ensure that single-phase AC induction motors meet the safety and performance requirements outlined in the IS 996, providing reliable and efficient operation for various applications. Here's a breakdown of the major ones:

1. ***Type Tests (Performed on representative sample motors):***

   a) ***No-load Test***: Measures current, power input, and speed at rated voltage and frequency to assess basic performance and efficiency.

   b) ***Torque Tests***: Evaluates starting torque (breakaway), pull-up torque, and pull-out torque to determine the motor's ability to start and handle loads.

   c) ***Breakaway Starting Current Test***: Measures the current drawn by the motor at startup, ensuring it doesn't exceed acceptable limits.

   d) ***Full-Load Performance Test***: Assesses speed, current, efficiency, and power factor at rated load to verify performance under typical operating conditions.

   e) ***Temperature Rise Test***: Measures the increase in winding and core temperature during operation to ensure it stays within safe limits and avoid insulation damage.

   f) ***Momentary Overload Test***: Checks the motor's ability to withstand brief periods of excessive torque without damage, relevant for applications with fluctuating loads.

   g) ***Insulation Resistance Test***: Measures the resistance between windings and the frame to ensure proper insulation and prevent electrical hazards.

   h) ***High Voltage Test***: Applies a high voltage to the windings to check for insulation weaknesses and potential breakdown.

   i) ***Moisture Proofness Test***: Evaluates the motor's resistance to humidity and condensation to ensure reliable operation in various environments.

j) ***Leakage Current Test***: Measures current leakage to accessible metal parts to ensure safety and compliance with regulations.

k) ***Vibration Test***: Assesses vibration levels during operation to ensure they are within acceptable limits and avoid premature wear or damage to components.

l) ***Dimensions Test***: Verifies that the motor's physical dimensions comply with the standard or agreed-upon specifications.

2. Routine Tests (Performed on every motor):

a) ***No-load Test***: Same as in type tests.

b) ***Breakaway Starting Current Test***: Same as in type tests.

c) ***Insulation Resistance Test***: Same as in type tests.

d) ***High Voltage Test***: Same as in type tests.

e) ***Centrifugal Switch Operation Test (if applicable):*** Verifies proper functioning of the centrifugal switch for motors with starting windings.

3. Acceptance Tests (Performed on representative sample from a lot):

a) ***No-load Test:*** Same as in type tests.

b) ***Torque Tests:*** Same as in type tests.

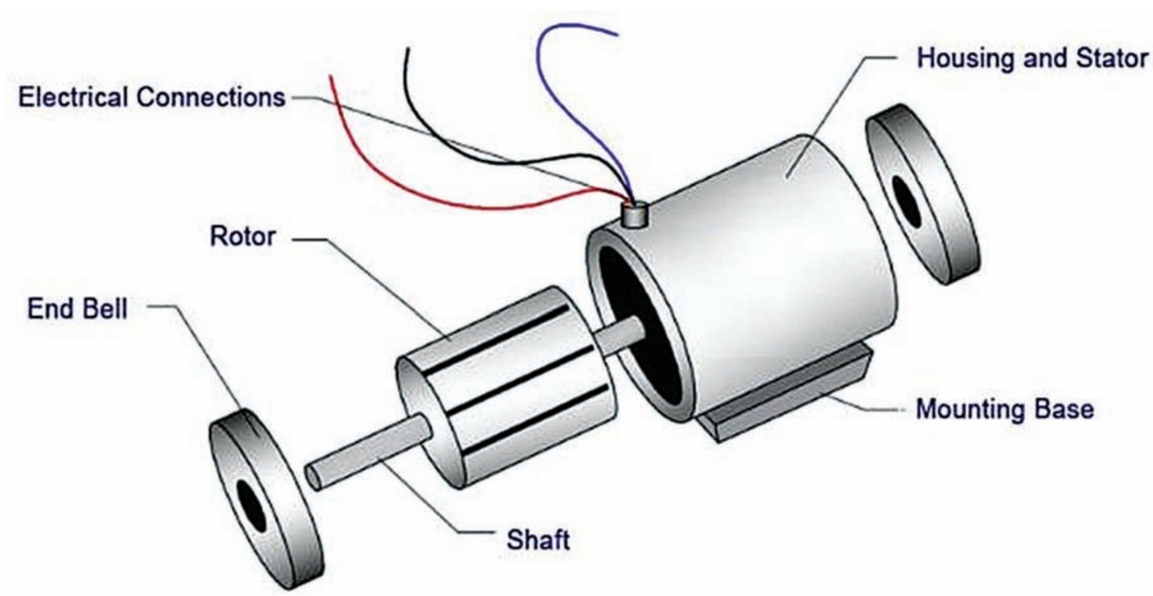
c) ***Breakaway Starting Current Test:*** Same as in type tests.

d) ***Temperature Rise Test:*** Same as in type tests.

e) ***Momentary Overload Test:*** Same as in type tests.

f) ***Insulation Resistance Test:*** Same as in type tests.

g) ***High Voltage Test:*** Same as in type tests.



Single Phase Induction Motor

IS 9283 - Motors for Submersible Pumpsets

This Indian Standard provides technical requirements for submersible motors used in:

a) ***Boreholes***: commonly known as bore-wells or tube wells.

b) ***Open wells***: for applications such as agriculture and water supply, handling clear, cold, and fresh water.

Salient Features:

a) ***Types of motors covered***: Wet type water filled, Wet type oil filled, Resin filled

b) ***Water characteristics***: Defines the parameters of "clear, cold, and fresh water" for which the motors are suitable.

c) ***Construction***: Specifies materials for various components, including the cable, shaft, bearings, and casings. Also covers earthing requirements and protection against foreign matter.

d) ***Voltage and Frequency***: Preferred values are 415V (3-phase) and 240V (single-phase) at 50Hz. The standard also defines permissible variations.

e) ***Output Ratings***: Provides preferred output ratings in kW for both three-phase and singlephase motors.

f) ***Dimensions and Tolerances***: Defines maximum overall diameters for different bore sizes and provides recommended shaft dimensions. Tolerance limits for shaft extension runout, concentricity, and face runout are also specified.

g) ***Performance Characteristics***: Specifies minimum full load speed, maximum full load current, minimum starting torque, and nominal efficiency for 2-pole motors of different bore sizes and phases.

h) ***Overload Test***: Details the requirements for momentary and sustained overloads.

i) Temperature Rise Test: Defines the acceptable temperature rise limits for stator windings at rated and reduced voltage.

j) ***High Voltage Test***: Specifies the procedure and voltage levels for testing insulation strength.

k) ***Insulation Resistance Test***: Defines the minimum acceptable insulation resistance.

l) ***Leakage Current Test***: Sets the limit for maximum leakage current at rated voltage and no load.

m) ***Information with Enquiry and Order***: Provides a list of details to be furnished when enquiring about or ordering a submersible motor.

Additional notes:

a) This standard should be read in conjunction with IS 8034 (Submersible pumpsets) and IS 14220 (Openwell submersible pumpsets) as the motor and pump form a complete set.

b) The standard refers to several other Indian Standards for specific details and test procedures.

c) Information to be given with enquiry and order

d) Form for test report of motors for submersible pumpsets

IS 15999 (Part 1) Rotating Electrical Machines —Rating and Performance

IS 15999 (Part 1) provides a comprehensive framework for ensuring the proper rating, performance, and safety of rotating electrical machines in various applications.

This Indian Standard, identical to IEC 60034-1, provides guidelines for the rating and performance of rotating electrical machines. It is applicable to all rotating electrical machines except those with specific standards (e.g., IEC 60349 for traction vehicles). It may be subject to additional requirements in other standards for specific applications (e.g., IEC 60079 for explosive atmospheres).

Duty Types:

a) Defines various duty types (S1 to S10) based on load characteristics and operating conditions.

b) Purchaser is responsible for declaring the duty type; otherwise, S1 (continuous running duty) is assumed.

c) Each duty type has specific requirements and considerations for rating and performance.

Rating:

a) Manufacturer assigns the rating based on the chosen duty type.

b) Different classes of rating exist: Continuous running, Short-time, Periodic, Non-periodic, Discrete constant loads and speeds, and Equivalent loading.

c) The chosen rating class and its parameters should be clearly marked on the rating plate.

Site Conditions:

a) Defines standard site conditions for altitude, ambient temperature, and water coolant temperature.

b) Machines operating outside standard conditions require special considerations and adjustments to temperature rise limits.

Electrical Operating Conditions:

a) Defines requirements for electrical supply, voltage and frequency variations, and operation on unearthed systems.

b) Special considerations are needed for machines fed from or supplying static converters.

c) Defines withstand voltage test requirements for different machine types and components.

Thermal Performance and Tests:

a) Assigns thermal class to insulation systems according to IEC 60085.

b) Specifies reference coolants for different cooling methods.

c) Defines methods for measuring temperature: Resistance, Embedded temperature detector (ETD), and Thermometer.

d) Establishes limits for temperature rise and total temperature for windings, bearings, and other components.

e) Provides adjustments to temperature limits for different operating conditions and ratings.

Other Performance and Tests:

a) Defines minimum routine tests for machines assembled and tested in the factory.

b) Specifies requirements for occasional excess current and momentary excess torque.

c) Establishes safe operating speeds and overspeed withstand capabilities.

d) Defines requirements for short-circuit current and withstand tests for synchronous machines.

e) Specifies requirements for commutation tests for commutator machines.

f) Sets limits for total harmonic distortion (THD) for synchronous machines.

Rating Plates:

a) Requires all machines to have rating plates with specific information, including:

b) Manufacturer details, standards compliance, protection and cooling methods, thermal class, rating class, output, voltage, frequency, current, speed, and other relevant parameters.

c) Specific information required depends on the machine type and power rating.

d) Additional plates are needed for repaired or refurbished machines.

Miscellaneous Requirements:

- Defines requirements for protective earthing of machines and shaft-end keys. ***Tolerances:***
- Specifies tolerances for various quantities like efficiency, current, power factor, speed, slip, torque, etc.

Electromagnetic Compatibility (EMC):

a) Defines EMC requirements for machines with rated voltages up to 1000 V AC or 1500 V DC.

b) Sets emission limits for machines used in residential and industrial environments based on CISPR 11.

c) Immunity tests are not required for most machines.

Safety:

- Requires machines to comply with relevant safety standards like IEC 60204-1, IEC 6020411, or IEC 60335-1, as appropriate.

Annex A:

- Provides guidance for applying duty type S10 and establishing the relative thermal life expectancy (TL). ***Annex B:***
- Lists electromagnetic compatibility (EMC) limits for Class A and Class B equipment according to CISPR 11.

The standard outlines several tests to evaluate the performance and safety of rotating electrical machines. These tests play a crucial role in ensuring the performance, reliability, and safety of rotating electrical machines across various applications. Here's a breakdown of the major ones:

Routine Tests (9.1):

These are mandatory tests performed on all factory-assembled machines up to 20 MW (MVA). They ensure basic functionality and compliance with the standard. Examples include:

a) Resistance of windings (cold): Verifies the winding integrity and identifies potential issues like open circuits or short circuits.

b) No-load losses and current: Measures the power losses and current drawn by the machine at no-load, indicating core losses and magnetizing current.

c) No-load excitation current/losses: For synchronous machines (excluding permanent magnet types), measures the field current or losses needed to achieve rated voltage at no-load, providing insights into the excitation system performance.

d) Open circuit secondary induced voltage at standstill (wound rotor induction machines): Measures the voltage induced in the rotor windings at standstill with rated voltage applied to the stator, helping to determine the transformation ratio and winding connections.

e) Direction of rotation/Phase sequence: Verifies the correct direction of rotation for motors and phase sequence for three-phase machines, ensuring proper operation in the intended application.

Withstand Voltage Test (9.2):

This test assesses the insulation strength of the windings. A specified voltage is applied between the windings and the frame for a defined duration, ensuring the machine can withstand electrical stress without breakdown.

a) Different voltage levels and durations are specified depending on the machine type, voltage rating, and output power.

b) Rewound or repaired windings require specific test procedures and voltage levels.

Thermal Tests (8.3 - 8.8):

a) These tests evaluate the machine's thermal performance and verify that temperature rise limits are not exceeded under various operating conditions.

b) Methods of temperature measurement: The standard recognizes three methods: resistance, embedded temperature detector (ETD), and thermometer. The chosen method depends on the machine type and application.

c) Test duration: Varies depending on the chosen duty type. For continuous duty, the test runs until thermal equilibrium is reached. For other duty types, specific durations or equivalent loading conditions are applied.

d) Temperature limits: Tables within the standard specify the maximum allowable temperature rise and total temperature for windings, bearings, and other components based on the thermal class of the insulation and the cooling method.

e) Adjustments to temperature limits: Factors like ambient temperature, altitude, coolant temperature, and rated voltage can necessitate adjustments to the temperature limits.

Other Tests (9.3 - 9.11):

a) Occasional excess current: Verifies the machine's ability to handle short-term overcurrents without damage.

b) Momentary excess torque: Evaluates the motor's capability to withstand short duration torque overloads without stalling or experiencing abrupt speed changes.

c) Pull-up torque: Measures the minimum torque developed by an AC motor during starting, ensuring it can overcome the load's inertia.

d) Overspeed: Assesses the machine's mechanical integrity under overspeed conditions. While not always mandatory, it may be required for specific applications.

e) Short-circuit current/withstand test (synchronous machines): Evaluates the short-circuit current magnitude and the machine's ability to withstand short circuits without damage.

f) Commutation test (commutator machines): Verifies proper commutation performance under varying load conditions, ensuring smooth operation without excessive sparking or damage to the commutator and brushes.

g) Total harmonic distortion (THD): Measures the harmonic content in the output voltage of synchronous machines, ensuring compliance with limits to minimize interference with power networks.

IS 15999 (Part 2/Sec 1) - Standard Methods for Determining Losses and Efficiency from Tests Excluding Machines for Traction Vehicles

IS 15999 (Part 2/Sec 1) details methods for determining the losses and efficiency of rotating electrical machines through various testing procedures. It aligns with the IEC 60034-2-1 standard and applies to:

- DC machines: Covering various types and sizes.
- AC synchronous machines: Including those with electrical and permanent magnet excitation.

- AC induction machines: Including single-phase and three-phase configurations of all sizes. The document emphasizes the importance of considering the state of the machine and test categories to ensure reliable results. It provides detailed instructions on conducting various tests and calculating losses and efficiency. Annexes offer additional information on specific topics, such as calculations for the Eh-star method, types of excitation systems, and slip measurement in induction machines.

IS 15999 (Part 2/Sec 1) provides a comprehensive guide for determining the losses and efficiency of rotating electrical machines. By following the outlined methods and procedures, manufacturers and testing laboratories can obtain accurate and reliable results.

Salient Features:

a) ***Efficiency Determination***: The document outlines both direct and indirect methods for calculating efficiency. Direct methods involve measuring input and output power, while indirect methods involve calculating losses and then adding them to output power or subtracting them from input power.

b) ***Test Methods***: A variety of test methods are detailed, categorized as either preferred or for specific applications like field testing or routine checks.

c) ***Preferred Methods***: These methods offer low uncertainty and are recommended for specific machine types and sizes. They include:

d) ***Method 2-1-1A (Induction machines***): Direct measurement of input and output power using a dynamometer. Suitable for single-phase machines.

e) ***Method 2-1-1B (Induction machines)***: Summation of losses with additional load losses determined using the residual loss method. Applicable for three-phase machines up to 2 MW.

f) ***Method 2-1-1C (Induction machines)***: Summation of losses with additional load losses based on assigned values. Used for three-phase machines above 2 MW.

g) ***Method 2-1-2A (Synchronous machines):*** Direct measurement of input and output power using a dynamometer. Suitable for machines with frame sizes below 180 mm and permanent magnet excited machines.

h) ***Method 2-1-2B (Synchronous machines):*** Summation of losses with a rated load temperature test and a short circuit test. Applicable for machines with frame sizes above 180 mm and power ratings up to 2 MW.

i) ***Method 2-1-2C (Synchronous machines):*** Summation of losses without a full load test and additional load losses determined from a short circuit test. Used for machines above 2 MW.

j) ***Other Methods:*** These methods are suitable for various testing scenarios and include back-to-back tests, zero power factor tests, and equivalent circuit methods.

k) ***Loss Components:*** The document defines and explains different types of losses in detail, including:

l) ***Constant Losses:*** These include friction, windage, and iron losses.

m) ***Load Losses:*** These encompass winding (I2R) losses and electrical brush losses.

n) ***Additional Load Losses:*** These are losses caused by stray fluxes and eddy currents under load conditions.

o) ***Excitation Circuit Losses***: These are relevant for machines with electrical excitation and include losses in the field winding, exciter, and brushes.

p) ***Measurement and Instrumentation***: The document specifies requirements for accuracy and class of instruments used for measuring voltage, current, torque, speed, frequency, and temperature.

The Indian Standard IS 15999 (Part 2/Sec 1), aligned with IEC 60034-2-1, defines various test methods categorized as "preferred" and methods suitable for "field or routine testing". Here's a breakdown of the tests by category and machine type:

Induction Machines:

Preferred Methods:

Method 2-1-1A - Direct Measurement (Input-Output):

- Measures electrical input power and mechanical output power directly using a dynamometer.
- Best suited for single-phase induction machines. ***Method 2-1-1B - Summation of Losses (Residual Loss):***
- Determines efficiency by summing individual losses: iron loss, friction and windage losses, stator and rotor copper losses, and additional load losses.
- Additional load losses are calculated using the "residual loss method" which involves a load curve test and regression analysis.
- Applicable for three-phase machines up to 2 MW. ***Method 2-1-1C - Summation of Losses (Assigned Value):***
- Similar to Method 2-1-1B but uses an assigned value for additional load losses instead of the residual loss method.
- This method is more practical for large three-phase machines above 2 MW where full load testing is challenging.

Field or Routine Testing Methods:

Method 2-1-1D - Dual Supply Back-to-Back Test:

- Requires two identical machines mechanically coupled together.
- Losses are determined by comparing the electrical input to one machine and the electrical output of the other.

Method 2-1-1E - Single Supply Back-to-Back Test:

- Also requires two identical machines but both are connected to the same power supply.
- Total losses are calculated from the input power drawn from the supply.
- Applicable for wound-rotor induction machines.

Method 2-1-1F - Summation of Losses (Removed Rotor/Reverse Rotation):

- Similar to Method 2-1-1B but determines additional load losses using a combination of two tests: one with the rotor removed and another with the rotor running in reverse rotation.

Method 2-1-1G - Summation of Losses (Eh-star Method):

- Similar to Method 2-1-1B but utilizes the Eh-star test to determine additional load losses.
- This test involves running the motor with unbalanced voltage supply and requires specific calculations.

Method 2-1-1H - Equivalent Circuit Method:

- Employs an equivalent circuit model of the induction machine to calculate losses and efficiency.
- Requires design values and data from a no-load test and locked rotor tests. ? Can be used when load testing is not feasible.

Synchronous Machines:

Preferred Methods (Electrical Excitation):

Method 2-1-2A - Direct Measurement (Input-Output):

- Same as Method 2-1-1A for induction machines, measuring electrical input and mechanical output power directly.
- Applicable for machines with frame sizes below 180 mm.

Method 2-1-2B - Summation of Losses (Rated Load/Short Circuit):

- Similar to Method 2-1-1B but also considers excitation circuit losses.
- Additional load losses are determined using a short circuit test.
- Used for machines with frame size above 180 mm and power ratings up to 2 MW.

Method 2-1-2C - Summation of Losses (Without Full Load Test):

- Similar to Method 2-1-2B but does not require a full load test.

- Excitation current is determined using diagrams like the Potier, ASA, or Swedish diagram.
- Applicable for machines above 2 MW.

Preferred Method (Permanent Magnet Excitation):

Method 2-1-2A - Direct Measurement (Input-Output):

- Same as for electrically excited machines, measuring input and output power directly.
- Suitable for all sizes of permanent magnet synchronous machines.

Field or Routine Testing Methods:

Method 2-1-2D - Dual Supply Back-to-Back Test:

- Similar to Method 2-1-1D for induction machines, using two identical machines and comparing input and output power.

Method 2-1-2E - Single Supply Back-to-Back Test:

- Similar to Method 2-1-1E for induction machines, with two identical machines connected to the same supply.

Method 2-1-2F - Zero Power Factor Test:

- Operates the machine as an overexcited motor at near zero power factor.
- Requires data from no-load, short circuit, and overexcitation tests.
- Excitation current is determined using diagrams like the Potier, ASA, or Swedish diagram. ***Method 2-1-2G - Summation of Losses (Without Additional Load Losses):***
- Similar to Method 2-1-2B but excludes the consideration of additional load losses, resulting in lower accuracy.

IS 15999 (Part 4/Sec 1) Electrically excited synchronous machine quantities- Test methods

This Indian Standard, identical to IEC 60034-4-1, outlines test methods for determining the quantities of electrically excited synchronous machines with a rating of 1 kVA or larger.

Applicability:

- Three-phase synchronous machines (1 kVA and larger)
- Machines with excitation windings supplied via sliprings and brushes (primarily)
- Limited applicability for brushless and permanent magnet machines ***Salient Features:***

a) Not all tests are mandatory: The specific tests to be performed are determined by agreement between the manufacturer and customer.

b) Testing conditions: Tests are conducted on complete machines with automatic regulation devices switched off (unless required by the test). Winding temperatures are monitored for safety and accuracy.

c) Per unit quantities: Calculations are done in SI units or per unit values based on rated voltage, apparent power, and derived current and impedance.

d) Magnetic saturation: Both saturated and unsaturated values of quantities are considered, depending on the specific test and application.

e) Two-axis theory: The document utilizes the two-axis theory of synchronous machines, with equivalent circuits representing the direct and quadrature axes.

f) Conventional machine model: Three reactances (synchronous, transient, and subtransient) and two-time constants (transient and sub-transient) are considered for each axis. Additional parameters might be required for more complex machines like turbogenerators.

Description of Tests in IS 15999 (Part 4/Sec 1)

Description of a few representative tests and a brief overview of the others is provided below. Users are encouraged to refer the Standards for getting the comprehensive information.

Detailed Descriptions:

1. No-load Saturation Test (6.4):

Objective: To determine the relationship between the open-circuit armature voltage and the excitation current at rated speed (frequency). This helps in understanding the machine's magnetization characteristics and finding unsaturated values of direct-axis synchronous reactance.

Procedure:

- The machine can be driven as a generator by a prime mover, run as a motor without shaft load, or tested during retardation.
- Excitation current is gradually changed in steps, and corresponding armature voltage, frequency (or speed), and potential armature current are recorded. ? For motor operation, the test is conducted at unity power factor.
- For retardation tests, specific deceleration rates and excitation conditions need to be maintained.

Analysis:

- The recorded data is used to plot the open-circuit armature voltage against the excitation current, creating the no-load saturation curve.
- Corrections may be necessary for high residual voltage.

- The curve helps determine the unsaturated value of direct-axis synchronous reactance and other machine parameters.

2. Sudden Three-Phase Short-Circuit Test (6.11):

Objective: To determine direct-axis transient and sub-transient reactance, and relevant time constants, under saturated and unsaturated conditions.

Procedure:

- The machine is run at rated speed and then suddenly short-circuited on the armature winding while operating at no-load with the desired voltage.
- The machine is typically excited from its own separately excited exciter or a separate one with sufficient rating.
- The short-circuit should be applied simultaneously to all three phases.
- Armature current in each phase and excitation current are recorded as time functions.
- The test may be performed at various armature voltages to obtain data for saturated and unsaturated conditions.

Analysis:

- The recorded data is analyzed to determine the time-varying components of armature current (aperiodic and periodic) and excitation current.
- The analysis involves finding the envelopes of the short-circuit currents, separating the aperiodic and periodic components, and then further separating the transient and subtransient components within the periodic component.
- Time constants are determined from the decay rates of these components.
- Reactance values are calculated based on the initial voltage before the short circuit and the initial values of the current components.

3. Direct Current Decay Test in the Armature Winding at Standstill (6.14):

Objective: To determine various reactances and time constants for both direct and quadrature axes. It is particularly useful for analyzing solid rotor machines and generating frequency response characteristics.

Procedure:

- The test is performed with the machine at standstill.
- DC voltage is applied to the armature winding through a resistor, and the winding is then short-circuited, causing the current to decay.
- The test is repeated with the rotor positioned along the direct axis and then the quadrature axis.
- The decaying currents in the armature winding and potentially the excitation winding is recorded as time functions.

Analysis:

- The recorded data is analyzed to extract the decaying exponential components of the currents.
- The initial values and time constants of these components are determined from their decay rates.
- These values are then used to calculate the relevant reactances and time constants for each axis.
- Frequency response characteristics can be generated by representing the reactances as functions of slip frequency.

Brief Overview of Other Tests:

a) ***Direct Measurement of Excitation Current (6.2):*** Directly measuring the excitation current under rated operating conditions.

b) ***Direct-Current Winding Resistance Measurement (6.3):*** Measuring the DC resistance of armature and excitation windings using standard methods.

c) ***Sustained Three-Phase Short-Circuit Test (6.5):*** Similar to the sudden short-circuit test, but with sustained short-circuit conditions to determine sustained short-circuit characteristics and unsaturated values of direct-axis synchronous reactance.

d) ***Motor No-Load Test (6.6):*** Running the machine as a motor without shaft load and zero excitation to determine unsaturated and saturated values of direct-axis synchronous reactance.

e) ***Over-excitation Test at Zero Power Factor (6.7):*** Operating the machine at zero power factor with over-excitation to determine excitation current at rated load.

f) ***Negative Excitation Test (6.8):*** Gradually reducing excitation, reversing polarity, and increasing it until the machine slips a pole pitch to determine unsaturated values of quadrature-axis synchronous reactance.

g) ***On-load Test Measuring the Load Angle (6.9):*** Measuring the load angle during on-load operation to determine direct-axis and quadrature-axis synchronous reactance.

h) ***Low Slip Test (6.10):*** Driving the rotor at a low slip with reduced voltage applied to the armature to determine unsaturated values of quadrature-axis synchronous reactance.

i) ***Voltage Recovery Test (6.12):*** Disconnecting a sustained short-circuit and observing the voltage recovery to determine direct-axis transient and sub-transient reactance and time constants.

j) ***Applied Voltage Tests (6.15, 6.16):*** Applying AC voltage to the armature windings with the rotor in specific positions to determine sub-transient reactance for both direct and quadrature axes.

k) ***Zero-Sequence and Negative-Sequence Tests (6.17-6.20):*** Applying single-phase or negative-phase sequence voltages to determine zero-sequence and negative-sequence reactances and resistances.

l) ***Field Current Decay Test (6.21):*** Observing the decay of field current after a sudden short circuit on the excitation winding to determine the direct-axis transient open-circuit time constant.

m) ***Applied Voltage Test with Rotor Removed (6.22):*** Applying voltage with the rotor removed and using a search coil to determine armature leakage reactance.

n) ***No-Load Retardation Test (6.23):*** Observing the machine's deceleration under no-load to determine unit acceleration time and stored energy constant.

o) ***Locked Rotor Test (6.24):*** Applying rated frequency voltage with the rotor locked to determine the initial starting impedance of synchronous motors.

p) ***Asynchronous Operation During Low-Voltage Test (6.25):*** Operating the machine asynchronously at reduced voltage to determine frequency response characteristics at low frequencies.

q) ***Over-excitation Test with Variable Armature Voltage (6.26):*** Varying armature voltage at zero power factor to determine excitation current at rated armature sustained shortcircuit current.

r) ***Applied Variable Frequency Voltage Test at Standstill (6.27):*** Applying variable frequency voltage with the rotor at standstill to determine frequency response characteristics.

IS 15999 (Part 20/Sec 1)- Control Motors Stepping Motors

This standard meticulously details the requirements for stepping motors, encompassing specifications, test methods, and information for manufacturers and users. Let's delve into the specifics:

Salient Features

- The standard zeroes in on stepping motors used for control applications.
- It explicitly excludes other motor types like induction, hydraulic, linear, etc.
- Two types are covered:
    - o Type 1: Based on metric dimensions (preferred for new designs).
    - o Type 2: Based on imperial dimensions (for existing designs only).

Terminology:

A comprehensive list of definitions clarifies key terms like:

a) ***Bipolar Drive:*** Where current direction reverses in motor windings.

b) ***Cogging Torque:*** Torque is present even when the motor is unenergized.

c) ***Detent Torque:*** Torque needed to move the rotor from its resting position.

d) ***Holding Torque:*** Torque applicable without causing rotation when energized.

e) ***Pull-Out Torque:*** Maximum torque applicable at a given speed without missing steps.

f) ***Step Angle:*** Rotation angle per energized step.

g) ***Step Angle Error:*** Deviation from the ideal step angle. ***Dimensional Specifications:***

a) Type 1 motors follow IEC standards for dimensions (IEC 60072-1 and IEC 60072-3).

b) Type 2 motors have specific dimension tables based on frame size and mounting type (IM B5 or IM B14).

c) Both types have detailed figures illustrating key dimensions like flange size, shaft diameter, etc.

Testing Procedures and Criteria:

A range of tests ensures motor conformity to specifications:

a) ***Shaft and Mounting:*** Checks for run-out, concentricity, and perpendicularity.

b) ***Moment of Inertia:*** Measures the rotor's resistance to rotational changes.

c) ***Voltage Withstand:*** Verifies insulation integrity in high voltage.

d) ***Thermal Properties:*** Determines the motor's heating and cooling characteristics.

e) ***Electrical Properties:*** Measures back EMF constant, inductance, and DC resistance.

f) ***Step Accuracy:*** Evaluates step angle error and detent torque.

g) ***Holding Torque:*** Measures the maximum torque the motor can hold without rotating.

Special Tests (Upon Request):

Additional tests provide further performance insights:

a) ***Winding Temperature Rise:*** Measures temperature increase under load.

b) ***Torque-Displacement Curve:*** Plots torque against rotor position.

c) ***Single Step Response:*** Analyzes the motor's behavior upon a single step command.

d) ***Dynamic Performance:*** Assesses maximum slew rate, pull-in/pull-out torque, reversing rate, and resonance.

Information and Documentation:

a) ***Rating Plate:*** Requires specific information like manufacturer details, voltage, current, phase, etc.

b) ***Modes of Operation:*** Defines typical excitation modes (A, B, AB, micro-stepping) and their sequences.

c) ***Manufacturer Declarations:*** Requires declaration of key parameters with tolerances.

d) ***Lead Identification:*** Standardizes lead colors and terminal numbering for clarity.

e) ***Catalog Presentation:*** Recommends information for easy comparison between motors.

f) ***Performance Curves:*** Suggests presenting basic performance curves for user reference.

Safety and EMC:

- Mandates compliance with relevant safety requirements and electromagnetic compatibility (EMC) regulations as per IEC 60034-1.

In essence, IS 15999 (Part 20/Sec 1) acts as a comprehensive guide for stepping motor specifications, testing, and documentation, ensuring quality, performance, and consistency within the Indian market while aligning with international standards.

IS 6362 (IEC Pub 34-6) - Designation of Methods of Cooling of Rotating Electrical Machines

This Indian Standard, identical to the IEC publication, provides a systematic way to designate the cooling methods employed in rotating electrical machines. The document outlines a comprehensive system using the "IC Code" to represent various cooling circuit arrangements, coolants, and methods of coolant movement.

IS 6362 (IEC Pub 34-6: 1991) plays a crucial role in establishing a clear and consistent method for designating cooling systems in rotating electrical machines, benefiting manufacturers, users, and maintenance personnel alike.

Salient Features:

- **Clear Communication:** Provides a standardized way to describe cooling methods, ensuring clarity and avoiding ambiguity.
- **Efficient Design and Selection:** Facilitates the design and selection of appropriate cooling systems for specific machine requirements.
- **Improved Maintenance and Troubleshooting:** Enables easier identification and understanding of cooling system configurations, aiding in maintenance and troubleshooting.
- **IC Code Structure:** The code begins with "IC" followed by a series of numerals and letters. Each element signifies a specific aspect of the cooling system. This code contains following numerals
- **Circuit Arrangement:** The first numeral indicates the cooling circuit arrangement (open or closed circuit, use of heat exchangers, etc.). Examples include:
  - o **IC0**: Free circulation (open circuit)
  - o **IC4**: Frame surface cooled (closed primary circuit, open secondary circuit)
  - o **IC7**: Integral heat exchanger with remote medium (closed primary circuit, open secondary circuit)
- **Primary Coolant:** A letter identifies the type of coolant used. Common examples are:
  - o **A**: Air (omitted in simplified designations)
  - o **W**: Water
  - o **H**: Hydrogen
  - o **S**: Other coolants (specified elsewhere)

- **Method of Movement of Primary Coolant:** A numeral specifies the method used to move the coolant. Examples include:
    - o **0**: Free convection
    - o **1**: Self-circulation (dependent on machine rotation)
    - o **5**: Integral independent component (e.g., motor-driven pump)
    - o **7**: Separate and independent component or coolant system pressure
- **Secondary Coolant**
- **Method of Movement of Secondary Coolant**
- **Complete vs. Simplified Designations:** The standard defines both complete and simplified designation systems. The simplified version omits certain elements under specific conditions, making it more concise for common scenarios.
- **Multiple Cooling Systems:** The document addresses situations with different coolants or methods of movement in various parts of a machine, or even different circuit arrangements for different parts. The designations are combined accordingly.
- **Direct Cooled Windings:** For machines with direct cooled windings (coolant flows through hollow conductors), the relevant part of the designation is enclosed in brackets.
- **Stand-by/Emergency Cooling:** The standard allows for designating stand-by or emergency cooling systems, which are indicated within brackets after the normal cooling method designation.

CHAPTER XII
CONCLUDING NOTE

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As we conclude this Reference Handbook, we emphasize the significance of Indian Standards in shaping the future of electric motors in India. We urge academia to:

- Stay updated on the latest Indian Standards related to electric motors
- Integrate these standards into curricula and research activities
- Encourage students to explore standardization as a career path
- Collaborate with industry and BIS to develop and implement new standards

By doing so, academia can:

- Bridge the gap between theory and practice
- Foster innovation and excellence in electric motor technology
- Contribute to the growth of the Indian economy
- Support the development of safe, efficient, and sustainable electric motors

We also encourage academia to actively participate in the standardization activities of the Bureau of Indian Standards (BIS). By doing so, they can:

- Provide expertise and insights to shape future standards
- Ensure that standards are relevant and effective
- Enhance the quality and credibility of Indian Standards

Together, let us work towards a future where electric motors in India are synonymous with excellence, safety, and sustainability.

Bureau of Indian Standards- The National Standards Body of India

We develop & publish Indian Standards, Implement Conformity Assessment Schemes, Recognise & run laboratories for Conformity Assessment, Implement Hallmarking, Work for Consumer empowerment, Conduct capacity building programs on quality assurance and represent the country in ISO & IEC.

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