

UNIT III

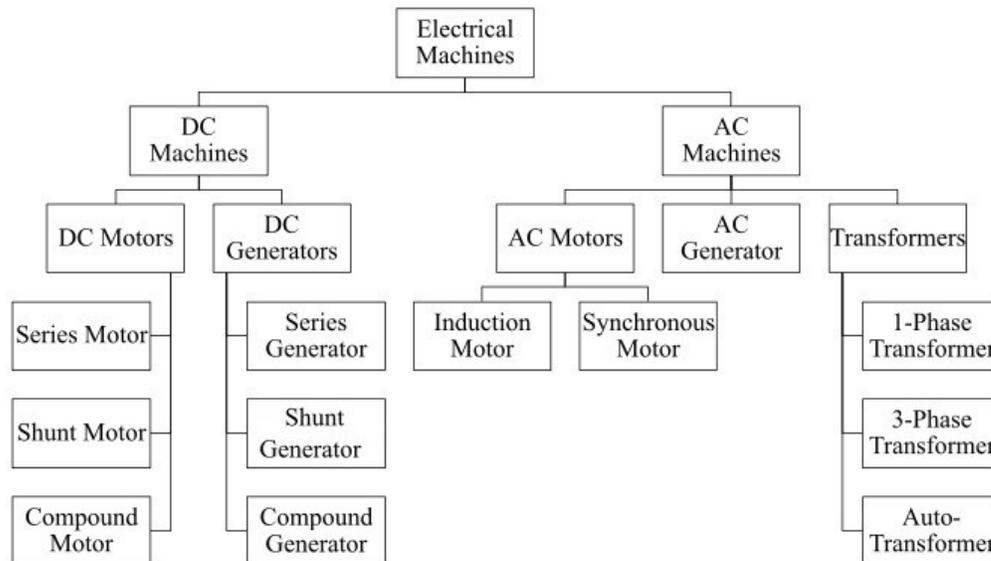
Electrical Machines

Definition of Electrical Machine

An electrical machine is a device that converts energy from one form to another:

- Electrical energy → Mechanical energy (Motor)
- Mechanical energy → Electrical energy (Generator)

These machines play a vital role in power generation, transmission, distribution, and utilization.



Basic Functions of Electrical Machines

Electrical machines are mainly used for:

- Converting electrical energy into mechanical motion
- Generating electrical power from mechanical input
- Controlling speed, torque, and power in industrial applications

Classification of Electrical Machines

Electrical machines can be classified based on different criteria such as type of supply, construction, and working principle.

Classification Based on Type of Supply

a) DC Machines

- Operate on Direct Current (DC) supply
- Can function as:
 - ❖ DC Generator – converts mechanical energy into DC electrical energy
 - ❖ DC Motor – converts DC electrical energy into mechanical energy
- Widely used where variable speed control is required
- Examples: electric traction, cranes, elevators

b) AC Machines

- Operate on Alternating Current (AC) supply
- More rugged and require less maintenance than DC machines
- Used extensively in domestic and industrial applications

Classification of AC Machines

a) Induction Machines

- Also called asynchronous machines
- Rotor speed is always less than synchronous speed
- Types:
 - ❖ Induction Motor – most commonly used motor
 - ❖ Induction Generator – used in wind energy systems
- Advantages:
 - ❖ Simple construction
 - ❖ Low cost
 - ❖ High reliability

b) Synchronous Machines

- Rotor rotates at synchronous speed
- Speed remains constant irrespective of load
- Types:
 - ❖ Synchronous Generator (Alternator) – used in power plants
 - ❖ Synchronous Motor – used for power factor improvement
- Require external excitation

Classification Based on Working Principle

a) Electromagnetic Induction

- Energy conversion takes place due to induced EMF
- Used in:
 - ❖ Induction motors
 - ❖ Transformers

b) Lorentz Force Principle

- A current-carrying conductor placed in a magnetic field experiences force
- Used in:
 - ❖ DC motors
 - ❖ AC motors

Classification Based on Construction

- Rotating Machines
 - ❖ DC motors
 - ❖ AC motors
 - ❖ Generators
- Static Machines
 - ❖ Transformers (no moving parts)

Applications of Electrical Machines

- Power generation stations
- Industrial drives and automation
- Domestic appliances (fans, mixers, pumps)
- Electric vehicles
- Renewable energy systems

Importance of Electrical Machines

- Backbone of modern electrical and industrial systems

- Enable efficient energy conversion and utilization

Definition of DC Machine

A DC machine (Direct Current machine) is an electrical machine that operates using direct current (DC) supply. It converts energy from one form to another based on its mode of operation:

- Electrical energy to mechanical energy, or
- Mechanical energy to electrical energy

DC machines are widely used where speed control and high starting torque are required.

Main Parts of a DC Machine

- Field system (Stator) – produces the magnetic field
- Armature (Rotor) – carries current and rotates
- Commutator – converts AC induced in armature to DC
- Brushes – provide electrical connection between rotating and stationary parts
- Shaft and bearings – support smooth rotation

Types of DC Machines

Depending on the function performed, DC machines are classified into two main types:

DC Motor

Definition of DC Motor

A DC motor is a DC machine that converts direct current electrical energy into rotational mechanical energy.

Types of DC Motors

DC motors are classified based on the method of field winding connection:

a) DC Series Motor

- Field winding connected in series with armature
- Characteristics:
 - ❖ Very high starting torque
 - ❖ Speed varies widely with load
- Applications:
 - ❖ Electric traction
 - ❖ Cranes
 - ❖ Hoists

b) DC Shunt Motor

- Field winding connected in parallel with armature
- Characteristics:
 - ❖ Nearly constant speed
 - ❖ Moderate starting torque
- Applications:
 - ❖ Lathes
 - ❖ Fans
 - ❖ Pumps

c) DC Compound Motor

- Combination of series and shunt field windings
- Types:

- ❖ Cumulative compound motor
- ❖ Differential compound motor
- Characteristics:
 - ❖ Good starting torque
 - ❖ Fairly constant speed
- Applications:
 - ❖ Elevators
 - ❖ Press machines
 - ❖ Rolling mills

DC Generator

Definition of DC Generator

A DC generator is a DC machine that converts mechanical energy into direct current electrical energy.

Types of DC Generators

DC generators are classified based on field excitation:

a) DC Series Generator

- Field winding connected in series with armature
- Characteristics:
 - ❖ Voltage varies with load
- Applications:
 - ❖ Boosters
 - ❖ Special power supply applications

b) DC Shunt Generator

- Field winding connected in parallel with armature
- Characteristics:
 - ❖ Nearly constant terminal voltage
- Applications:
 - ❖ Battery charging
 - ❖ Lighting systems

c) DC Compound Generator

- Has both series and shunt field windings
- Types:
 - ❖ Cumulative compound generator
 - ❖ Differential compound generator
- Characteristics:
 - ❖ Better voltage regulation
- Applications:
 - ❖ Power supply systems
 - ❖ Industrial DC distribution

Advantages of DC Machines

- Easy speed control
- High starting torque
- Good overload capacity
- Simple control methods

Disadvantages of DC Machines

- Requires regular maintenance
- Brushes and commutator wear out
- More expensive compared to AC machines
- Sparking issues at high speeds

Applications of DC Machines

- Electric traction (locomotives, trams)
- Lifts and elevators
- Rolling mills
- Printing presses
- Battery charging systems

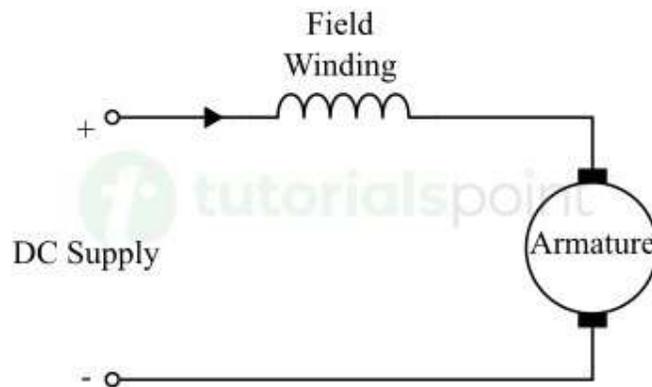
DC SERIES MOTOR

Definition

A DC series motor is a type of self-excited DC motor in which the field winding is connected in series with the armature winding. Therefore, the same current flows through both the armature and field windings.

Construction and Connection

- Field winding has few turns of thick wire to carry high current
- Armature and field windings are connected in series
- Suitable for applications requiring large current and high torque



Working Principle

➤ Basic Principle

A DC series motor works on the fundamental principle that when a current-carrying conductor is placed in a magnetic field, it experiences a mechanical force. This force produces rotational motion in the armature.

➤ Series Connection of Windings

In a DC series motor, the field winding is connected in series with the armature

winding. Hence, the same current flows through both the armature and the field winding.

➤ **Production of Magnetic Field**

When DC supply is applied, current flows through the series field winding. This current produces a magnetic flux around the field poles.

➤ **Current Flow in Armature Conductors**

The same current then flows through the armature conductors. These conductors are placed within the magnetic field produced by the field winding.

➤ **Force on Armature Conductors**

Due to the interaction between:

- ❖ Magnetic field produced by the field winding, and
 - ❖ Current flowing through the armature conductors,
- a force is exerted on each armature conductor according to Fleming's Left Hand Rule.

➤ **Development of Torque**

The forces acting on opposite sides of the armature form a couple, which produces a rotational torque. This torque causes the armature to rotate.

➤ **Relation Between Flux and Current**

Since the field winding and armature winding carry the same current, the magnetic flux (Φ) is directly proportional to the armature current (I_a), especially at low saturation levels.

➤ **High Starting Torque**

Torque (T) of a DC motor is given by:

$$T \propto \Phi \times I_a$$

In a DC series motor:

- ❖ $\Phi \propto I_a$
- ❖ Therefore, $T \propto I_a^2$

This results in very high starting torque, which makes the DC series motor suitable for heavy starting loads.

➤ **Effect of Load on Speed**

When load increases:

- ❖ Armature current increases
- ❖ Field flux increases
- ❖ Speed decreases

Hence, the motor speed reduces with increase in load.

➤ **No-Load Condition Warning**

At no load:

- ❖ Armature current is very small
- ❖ Field flux becomes weak
- ❖ Motor speed increases dangerously

Therefore, a DC series motor should never be operated without load.

Characteristics of DC Series Motor

- ❖ Very high starting torque
- ❖ Speed decreases as load increases

- ❖ Poor speed regulation
- ❖ Draws large current at starting
- ❖ Never operated at no-load condition (dangerously high speed)

Advantages of DC Series Motor

- ❖ Simple construction
- ❖ Less maintenance
- ❖ High overload capacity
- ❖ Economical compared to other DC motors

Applications of DC Series Motor

Used where high starting torque is essential:

- ❖ Electric cars and scooters
- ❖ Cranes and hoists
- ❖ Electric locomotives
- ❖ Grinders
- ❖ Elevators

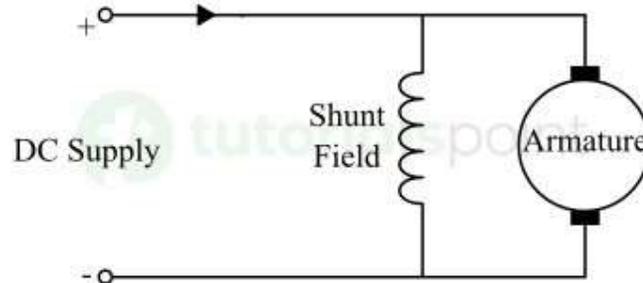
DC SHUNT MOTOR

Definition

A DC shunt motor is a self-excited DC motor in which the field winding is connected in parallel (shunt) with the armature winding.

Construction and Connection

- Shunt field winding has many turns of fine wire
- Field current is small and nearly constant
- Armature and field windings carry different currents



Working Principle

- Constant field flux due to shunt connection
- Motor speed remains almost constant even when load varies
- Provides smooth and steady operation

Characteristics of DC Shunt Motor

- Nearly constant speed
- Moderate starting torque
- Good speed regulation

- Self-regulating motor
- Simple speed control

Advantages of DC Shunt Motor

- Reliable operation
- Constant speed
- Low maintenance
- Suitable for continuous duty

Applications of DC Shunt Motor

Used where constant speed is required:

- Lathes and milling machines
- Woodworking machines
- Washing machines
- Metal cutting machines
- Small printing presses
- Elevators

DC COMPOUND MOTOR

Definition

A DC compound motor is a DC motor that has both series and shunt field windings. It combines the high starting torque of a series motor and the good speed regulation of a shunt motor.

Types of DC Compound Motors

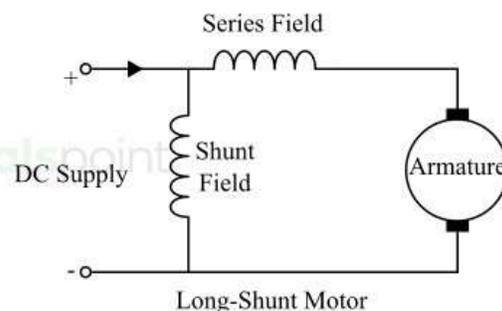
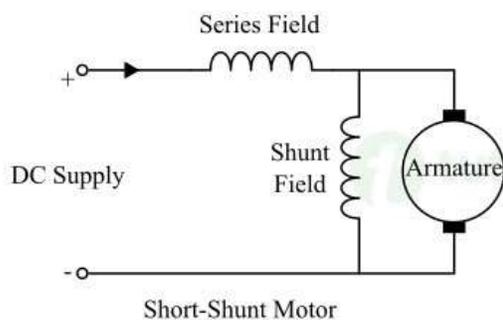
Based on winding connection, DC compound motors are classified into:

a) Long Shunt Compound Motor

- Shunt field winding connected in parallel with **armature + series field winding**

b) Short Shunt Compound Motor

- Series field winding connected in series with **armature only**
- Shunt field winding connected in parallel with armature



Working Principle

- Series field provides high starting torque
- Shunt field maintains nearly constant speed
- Suitable for varying load conditions

Characteristics of DC Compound Motor

- High starting torque

- Good speed regulation
- Stable operation
- Combines advantages of series and shunt motors

Advantages of DC Compound Motor

- Efficient under heavy load
- Smooth speed control
- Good overload capacity

Applications of DC Compound Motor

Widely used in industrial and mechanical applications:

- Industrial machinery
- Power tools
- Machine tools
- Shears and presses
- Reciprocating machines

Conclusion

- DC series motor → High starting torque applications
- DC shunt motor → Constant speed applications
- DC compound motor → Combination of high torque and good speed regulation

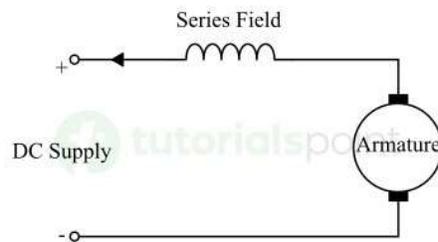
DC SERIES GENERATOR

Definition

A DC series generator is a type of DC generator in which the field winding is connected in series with the armature winding and the external load. Therefore, the same current flows through the armature, series field winding, and load.

Construction and Connection

- Series field winding consists of few turns of thick wire
- Designed to carry full load current
- Armature, field winding, and load are connected in series



Working Principle

1. When the DC supply is switched ON, current flows from the positive terminal of the supply.
2. The current first passes through the series field winding.
3. After flowing through the field winding, the same current enters the armature winding.

4. Due to current flowing through the series field winding, a strong magnetic field is produced.
5. Simultaneously, current flowing through the armature conductors produces another magnetic field around the conductors.
6. The interaction between:
 - The magnetic field produced by the field winding, and
 - The magnetic field produced by the armature conductors results in a mechanical force on the armature conductors.
7. According to Fleming's Left-Hand Rule, the direction of force determines the direction of rotation of the armature.
8. Due to this force, the armature starts rotating.
9. As the armature rotates, back EMF is induced in the armature winding, which opposes the applied voltage.
10. The motor reaches a steady speed when the developed torque balances the load torque.

Torque Characteristics

- In a DC series motor:
 - Torque (T) \propto Armature current (I_a)²
- Since both flux and armature current increase together:
 - The motor develops very high starting torque.
- This makes DC series motors suitable for heavy starting load applications.

Speed Characteristics

- At no load, the current drawn is very small.
- Hence, the flux is weak and speed becomes dangerously high.
- Therefore, a DC series motor should never be operated without load.

Important Features of Working Principle

- Same current flows through field and armature.
- High starting torque.
- Speed varies widely with load.
- Suitable for applications requiring high starting torque.

Applications Based on Working Principle

- Electric traction (locomotives, trams)
- Cranes and hoists
- Elevators
- Rolling mills
- Automobile starter motors

The DC series motor operates on the principle of force acting on a current-carrying conductor in a magnetic field. Due to its series connection, it develops very high starting torque, making it ideal for heavy-duty applications, but it must always be operated with load to prevent over speeding.

Characteristics of DC Series Generator

- Terminal voltage increases with increase in load current initially
- After magnetic saturation, terminal voltage decreases due to internal voltage drops

- Exhibits a rising voltage characteristic
- Poor voltage regulation at higher loads

Advantages of DC Series Generator

- Simple construction
- High current carrying capability
- Useful for special purpose applications

Applications of DC Series Generator

- Used in DC locomotives for field excitation during regenerative braking
- Used as a booster in distribution feeders to compensate voltage drop
- Used in series arc lighting systems
- Employed in special industrial applications

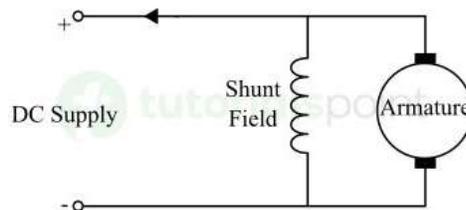
DC SHUNT GENERATOR

Definition

A DC shunt generator is a DC generator in which the field winding is connected in parallel (shunt) with the armature winding.

Construction and Connection

- Shunt field winding has many turns of fine wire
- Field current is small and nearly constant
- Armature current splits into:
 - ❖ Field current
 - ❖ Load current



Working Principle

1. When the DC supply is switched ON, voltage is applied across both:
 - ❖ The shunt field winding
 - ❖ The armature winding
2. The shunt field winding, having high resistance, draws a small but nearly constant current.
3. This current produces a steady and uniform magnetic flux in the air gap.
4. At the same time, current flows through the armature conductors.
5. The armature conductors carrying current are placed within the magnetic field produced by the shunt field winding.
6. Due to the interaction between:
 - ❖ The magnetic field (flux), and
 - ❖ The current carrying armature conductors, a force is produced on each conductor.

7. According to Fleming's Left-Hand Rule, these forces act in a direction that produces a rotational torque.
8. As a result, the armature starts rotating.
9. During rotation, a back EMF is induced in the armature, which opposes the applied voltage.
10. The motor reaches steady speed when the developed torque equals the load torque.

Torque Characteristics

- In a DC shunt motor:

$$\text{Torque (T)} \propto \text{Flux } (\Phi) \times \text{Armature current (I}_a)$$

- Since the flux is almost constant, torque is directly proportional to armature current.
- This provides moderate starting torque.

Speed Characteristics

- Speed of a DC shunt motor remains almost constant under varying load conditions.
- This is because the field flux remains nearly constant.
- Hence, DC shunt motors are known as constant speed motors.

Important Features of Working Principle

- Field and armature are connected in parallel.
- Flux remains nearly constant.
- Speed remains almost constant with load.
- Moderate starting torque.
- Safe to operate at no load.

Applications Based on Working Principle

- Lathes
- Drilling machines
- Fans and blowers
- Centrifugal pumps
- Machine tools
- Conveyors

The DC shunt motor works on the principle of force acting on a current-carrying conductor placed in a magnetic field. Due to its constant flux and constant speed characteristics, it is widely used in applications where uniform speed is required.

Characteristics of DC Shunt Generator

- Provides nearly constant terminal voltage over a wide load range
- Good voltage regulation
- Terminal voltage slightly decreases due to:
 - ❖ Armature resistance drop
 - ❖ Armature reaction
- Requires low field excitation current at startup

Advantages of DC Shunt Generator

- Stable voltage output
- Reliable operation
- Simple control

- Suitable for continuous operation

Applications of DC Shunt Generator

- Battery charging systems
- General lighting schemes
- Power supply for electronic devices
- Laboratories and workshops

DC COMPOUND GENERATOR

Definition

A DC compound generator is a DC generator that has both series and shunt field windings. It combines the characteristics of DC series and DC shunt generators.

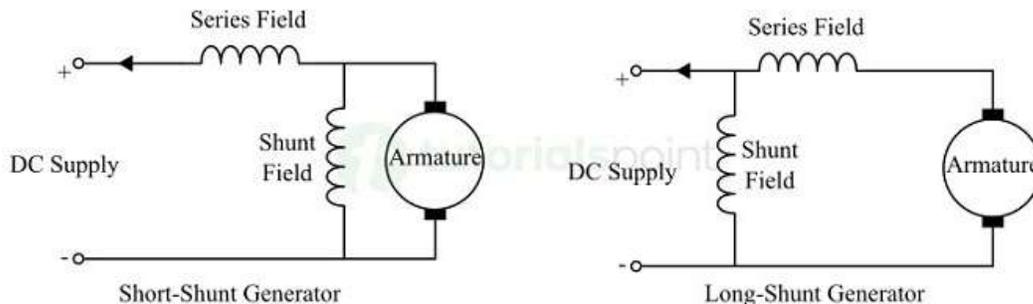
Types of DC Compound Generators

a) Long-Shunt DC Compound Generator

- Shunt field winding connected in parallel with armature + series field winding

b) Short-Shunt DC Compound Generator

- Shunt field winding connected in parallel with armature only
- Series field winding connected in series with load



Working Principle

- Shunt field provides base magnetic flux
- Series field strengthens or weakens flux depending on load
- Maintains better voltage regulation under varying loads

Characteristics of DC Compound Generator

- Better voltage regulation than series and shunt generators
- Can be:
 - ❖ Cumulatively compounded (series field aids shunt field)
 - ❖ Differentially compounded (series field opposes shunt field)
- Suitable for fluctuating loads

Advantages of DC Compound Generator

- Stable terminal voltage
- Handles heavy load variations
- Reliable performance

Applications of DC Compound Generator

- Power supply for lighting and heavy power services

- Used for driving DC motors
- Power supply in hotels, offices, and commercial buildings
- Differential compound generators used in arc welding

Conclusion

- DC series generator → Rising voltage applications
- DC shunt generator → Constant voltage applications
- DC compound generator → Combined advantages of both

AC MACHINES



- AC machines are electrical machines that operate with alternating current (AC).
- They are used either to:
 - Convert electrical energy into mechanical energy, or
 - Convert mechanical energy into electrical energy.
- In AC machines:
 - The armature winding is always placed on the stator.
 - The field winding is placed on the rotor.
- AC machines are widely used in:
 - Power generation
 - Industrial drives
 - Domestic and commercial applications

Classification of AC Machines

Based on their function, AC machines are classified into the following types:

1. AC Motors
2. AC Generators
3. Transformers

AC Motor

- An AC motor is an electrical machine that converts alternating current electrical energy into mechanical (rotational) energy.
- The operation of AC motors is based on the principle of electromagnetic induction.
- AC motors are widely used due to:
 - Simple construction
 - Low cost
 - High efficiency
 - Minimum maintenance

Types of AC Motors

AC motors are mainly classified into:

a) Induction Motor

- An induction motor works on the principle of electromagnetic induction.
- The rotor current is induced due to the rotating magnetic field produced by the stator.
- The rotor does not run at synchronous speed; it always runs at a speed slightly less than synchronous speed.
- Induction motors are:
 - Simple in construction
 - Rugged and reliable
 - Widely used in industries

Applications:

- Fans
- Pumps
- Compressors
- Conveyors

b) Synchronous Motor

- A synchronous motor runs at a constant speed called synchronous speed.
- The rotor speed is exactly equal to the speed of the rotating magnetic field.
- It requires DC excitation for the rotor field winding.
- Synchronous motors are used where constant speed operation is required.

Applications:

- Power factor improvement
- Large industrial drives
- Precision speed applications

AC Generator (Alternator)

- An AC generator is an electrical machine that converts mechanical energy into alternating current electrical energy.
- It works on the principle of Faraday's law of electromagnetic induction.
- Since it generates AC power, it is also called an alternator.
- An AC generator is also known as a synchronous generator.

Construction Features

- The armature winding is placed on the stator.
- The field winding is placed on the rotor.
- This arrangement allows easy insulation and cooling.

Applications

- Power stations (thermal, hydro, nuclear)
- Wind power generation
- Diesel generator sets

Transformer

- A transformer is a static electrical machine.
- It has no moving parts.
- It is used to:
 - Increase voltage (step-up transformer)

- Decrease voltage (step-down transformer)
- The transformer works on the principle of mutual induction.

Important Characteristics

- There is no mechanical energy conversion.
- Frequency remains constant at input and output.
- Power remains approximately same, except for losses.
- Transformers are highly efficient machines.

Applications

- Power transmission and distribution
- Electrical substations
- Electronic devices
- Power supplies

- 🔌 **AC Motors** → Electrical energy to mechanical energy
- 🔌 **AC Generators** → Mechanical energy to electrical energy
- 🔌 **Transformers** → Change voltage/current level without changing frequency

INDUCTION MOTOR



- An induction motor is a type of AC electric motor.
- It converts alternating current electrical energy into mechanical energy.
- The working principle of an induction motor is electromagnetic induction.
- In this motor:
 - The stator produces a rotating magnetic field.
 - The rotor current is induced due to this rotating magnetic field.
- The rotor always rotates at a speed less than synchronous speed.
- Hence, the induction motor is also known as an asynchronous motor.

Types of Induction Motors

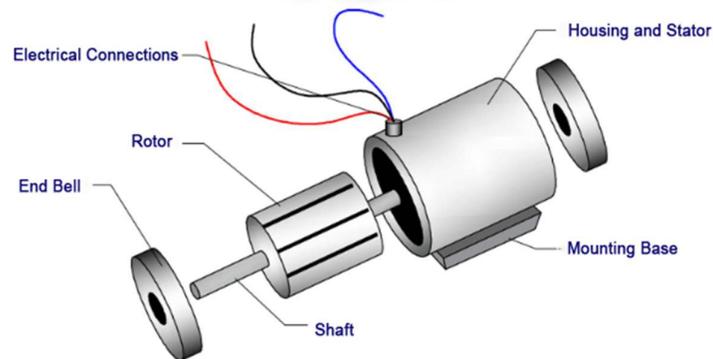
Based on the type of power supply used, induction motors are classified into:

1. Single-Phase Induction Motor

- Operates on single-phase AC supply.
- Used for light and domestic loads.
- Common applications include:
 - Fans
 - Coolers

- Air conditioners
- Washing machines

Construction of Single-Phase Induction Motor



1. Housing and Stator

- The housing forms the outer body of the motor.
- It provides:
 - Mechanical protection
 - Support to internal parts
- The stator is fixed inside the housing.
- It contains stator windings placed in slots.
- When supply is given, the stator produces a magnetic field.

2. Electrical Connections

- Electrical connections are provided at the terminal point on the stator.
- These terminals connect the stator windings to the power supply.
- Proper insulation is provided to avoid electrical faults.

3. Rotor

- The rotor is the rotating part of the motor.
- It is placed inside the stator with a small air gap.
- In induction motors, the rotor is usually:
 - Squirrel-cage type
- Rotor conductors are short-circuited by end rings.
- Rotor rotates due to interaction between stator flux and rotor current.

4. Shaft

- The shaft is mechanically coupled to the rotor.
- It transmits mechanical power from the motor to the load.
- The shaft is made of high-strength steel.
- It passes through the end bells.

5. End Bells (End Covers)

- End bells are fitted on both sides of the motor.
- They support the shaft and bearings.
- Help in maintaining correct rotor alignment.
- Protect internal parts from dust and damage.

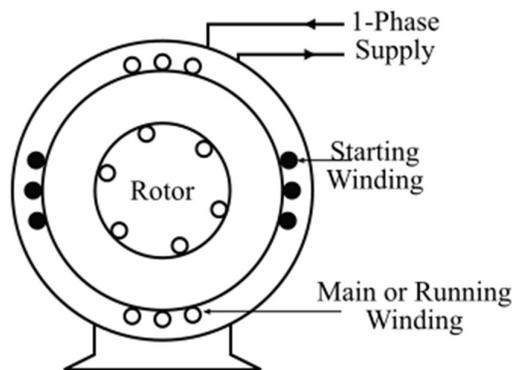
6. Mounting Base

- The mounting base is provided at the bottom of the motor.
- It is used to secure the motor on a foundation or machine frame.
- Ensures stability and reduces vibration during operation.

The motor construction shown in the diagram is simple, compact, and robust. Each component plays an important role in ensuring efficient operation, mechanical support, and safe electrical connection, making this type of motor widely used in domestic and industrial applications.

Working Principle of Single-Phase Induction Motor

- The working of a single-phase induction motor is based on the principle of electromagnetic induction.



Initial Condition

- When a single-phase AC supply is given only to the main winding:
 - It produces an alternating magnetic field.
 - This field does not rotate, it only pulsates.
- Hence, a single-phase induction motor is not self-starting.

Starting Operation

1. When the motor is switched ON:
 - Both main winding and starting winding are energized.
2. Due to difference in winding design:
 - Currents in both windings have a phase difference.
3. This phase difference produces a rotating magnetic field.
4. The rotating magnetic field induces current in the rotor conductors.
5. Interaction between stator flux and rotor current produces starting torque.
6. The rotor starts rotating.

Running Condition

7. Once the motor reaches about 70–80% of synchronous speed:
 - The starting winding is disconnected using a centrifugal switch.
8. The motor continues to run with only the main winding energized.

9. Rotor runs at a speed slightly less than synchronous speed.

Why Single-Phase Induction Motor is Not Self-Starting

- Single-phase supply produces only a pulsating magnetic field.
- Pulsating field produces equal forward and backward torques.
- Net starting torque is zero.
- Therefore, an auxiliary starting arrangement is required.

Applications of Single-Phase Induction Motor

- Ceiling fans
- Water pumps
- Refrigerators
- Washing machines
- Air conditioners
- Mixers and grinders

A single-phase induction motor is simple, rugged, and economical. Though it is not self-starting, the use of a starting winding enables it to produce starting torque, making it suitable for domestic and light industrial applications.

2. Three-Phase Induction Motor

- Operates on three-phase AC supply.
- Used for heavy and industrial loads.
- Common applications include:
 - Industrial machinery
 - Pumps
 - Compressors
 - Conveyors

Key Characteristics of Induction Motors

- Induction motors always operate at a speed slightly less than synchronous speed.
- Induction motors are self-starting.
- They have simple and rugged construction.
- Induction motors are highly reliable.
- Require less maintenance.
- Widely used in both domestic and industrial applications.

SYNCHRONOUS MOTOR



- A synchronous motor is a type of AC motor.
- It operates at a constant speed called synchronous speed.
- The rotor speed is exactly equal to the speed of the rotating magnetic field.
- The speed of the motor depends on the supply frequency.
- A synchronous motor is a doubly-excited machine because:
 - The stator is energized by AC supply.
 - The rotor is excited by DC supply.

Construction and Operation

- The stator produces a rotating magnetic field.
- The rotor produces a constant magnetic field using DC excitation.
- Both magnetic fields rotate at the same speed, resulting in synchronous operation.

Applications of Synchronous Motors

Small Synchronous Motors

- Used in timing and precision applications.
- Examples:
 - Synchronous clocks
 - Timers
 - Record players

Large Synchronous Motors

- Used in industrial applications.
- Examples:
 - Power factor improvement
 - Driving rolling mills
 - Ball mills
 - Large compressors

Key Features of Synchronous Motors

- Synchronous motors operate at a constant speed.
- They cannot be self-starting.
- Require external DC excitation for the rotor.
- Provide the ability to control and improve power factor.
- Suitable for applications requiring constant speed.

AC Generator (Alternator)

- An AC generator is an electromechanical device.
- It converts mechanical energy into alternating current electrical energy.
- It works on the principle of electromagnetic induction.
- Since it produces AC power, it is also called:
 - Alternator
 - Synchronous generator

Types of AC Generators

AC generators are classified based on the output supply as:

1. Single-Phase AC Generator

- Produces single-phase AC electricity.
- Used mainly in:
 - Domestic applications

- Commercial applications
- Examples:
 - Small generator sets
 - Home backup generators

2. Three-Phase AC Generator

- Produces three-phase AC electricity.
- Used in:
 - Industrial applications
 - Power stations
 - Large-scale power generation
- Three-phase generators are preferred due to:
 - Higher efficiency
 - Better power transmission

Applications of AC Generators

- Power stations (thermal, hydro, nuclear)
- Wind power plants
- Diesel generator sets
- Industrial power supply systems

⚡ **Induction Motor** → Electrical energy to mechanical energy (asynchronous)

⚡ **Synchronous Motor** → Electrical energy to mechanical energy (constant speed)

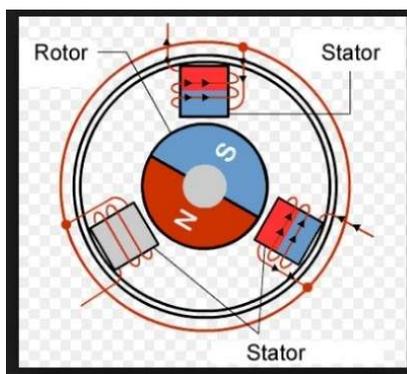
⚡ **AC Generator** → Mechanical energy to electrical energy

STEPPER MOTOR

Introduction

A stepper motor is an electromechanical device that converts electrical pulse signals into discrete mechanical motion. The motor rotates in fixed angular steps, and each input pulse causes one step of rotation. Hence, it is widely used for precise position and speed control.

WORKING OF STEPPER MOTOR



Principle of Operation

The working of a stepper motor is based on:

- Electromagnetic attraction and repulsion
- Sequential energization of stator windings

Constructional Features

1. Stator

- Consists of multiple poles with windings.
- Windings are grouped into phases.
- Produces a rotating magnetic field when energized in sequence.

2. Rotor

- May be:
 - Permanent magnet
 - Variable reluctance type
 - Hybrid type
- Aligns with stator magnetic field.

Working Mechanism

When the first stator winding is energized, it produces a magnetic field.

1. The rotor aligns itself with this magnetic field due to magnetic attraction.
2. When the next stator winding is energized:
 - The magnetic field shifts to the next position.
 - The rotor moves by a fixed angle called step angle.
3. This sequential energization of stator windings causes the rotor to rotate in discrete steps.
4. Each electrical pulse corresponds to one mechanical step.
5. The speed of rotation is directly proportional to the pulse frequency.
6. Direction of rotation is changed by reversing the sequence of excitation.
7. When power is applied continuously, the motor can hold its position due to holding torque.

Step Angle

$$\text{Step Angle} = \frac{360^\circ}{\text{Number of steps per revolution}}$$

Example:

- 200 steps per revolution → Step angle = 1.8°

Modes of Operation

1. Full-Step Mode

- One phase energized at a time.

2. Half-Step Mode

- Alternating single and dual phase excitation.

3. Micro-Stepping

- Produces very fine step movement.

Salient Features of Working

- Open-loop control system
- High positional accuracy
- Excellent repeatability
- No feedback device required

APPLICATIONS OF STEPPER MOTOR

Stepper motors are used in applications requiring accurate position control, controlled speed, and repeatable motion.

1. Computer and Office Equipment

- Printers
- Scanners
- Plotters
- Disk drives

2. Industrial Automation

- CNC machines
- Automated assembly lines
- Positioning of machine tools
- Robotic arm control

3. Robotics

- Joint movement in robots
- Pick-and-place robots
- Automated guided vehicles (AGVs)

4. Medical Equipment

- Infusion pumps
- Syringe pumps
- CT scanners
- MRI positioning systems

5. Consumer Electronics

- Digital cameras (zoom and focus)
- DVD and Blu-ray drives
- Smart home devices

6. Automotive Applications

- Speedometers
- Headlight positioning systems
- Dashboard instrumentation

7. 3D Printing and CNC

- X, Y, Z axis movement
- Precise layer positioning
- Tool head positioning

8. Instrumentation and Control Systems

- X-Y recorders
- Automatic valve control
- Antenna positioning systems
- Telescope positioning

Advantages Leading to Wide Applications

- Accurate angular movement
- Easy digital control
- High reliability
- Cost-effective for positioning tasks

Stepper motors play a vital role in modern automation and precision control systems due to their ability to move in exact steps with high accuracy and repeatability.