As Generator The current I_a flows in the same direction as the generated emf E, and the terminal voltage V is less than the emf E due to the armature-circuit voltage-drop. Thus, we have

$$V = E - I_a R_a \tag{16.3}$$

As Motor The current I_a flows in the opposite direction to that of the generated emf E, and the terminal voltage V is more than the emf E due to the armature-circuit voltage-drop. Thus, we have

$$V = E + I_a R_a \tag{16.4}$$

- I_a= Armature current
- R_a= resistance of the armature circuit

Types of DC Motors

- DC motors are classified according to electrical connections of armature windings and field windings.
- Armature windings: A winding which a voltage is induced
- Field windings: A winding that produces the main flux in machines
- Five major types of DC motors:-
  - Separately excited DC motor
  - Shunt DC motor
  - Permanent Magnet DC motor
  - Series DC motor
  - Compounded DC motor

Types of DC Machines

Self-excited DC machine: when a machine supplies its own excitation of the field windings. In this machine, residual magnetism must be present in the ferromagnetic circuit of the machine in order to start the self-excitation process.

Separately-excited DC machine: The field windings may be separately excited from an eternal DC source.

Shunt Machine: armature and field circuits are connected in parallel. Shunt generator can be separately-excited or self-excited.

Series Machine: armature and field circuits are connected in series.

Applications of DC Motors

<u>Shunt Motor</u>:

- Blowers and fans
- Centrifugal and reciprocating pumps
- Lathe machines
- Machine tools
- Milling machines
- Drilling machines

Applications of DC Motors

Series Motor:

- Cranes
- Elevators
- Trolleys
- Conveyors

Applications of DC Motors

Cumulative compound Motor:

- Rolling mills
- Shears
- Heavy planers
- Elevators

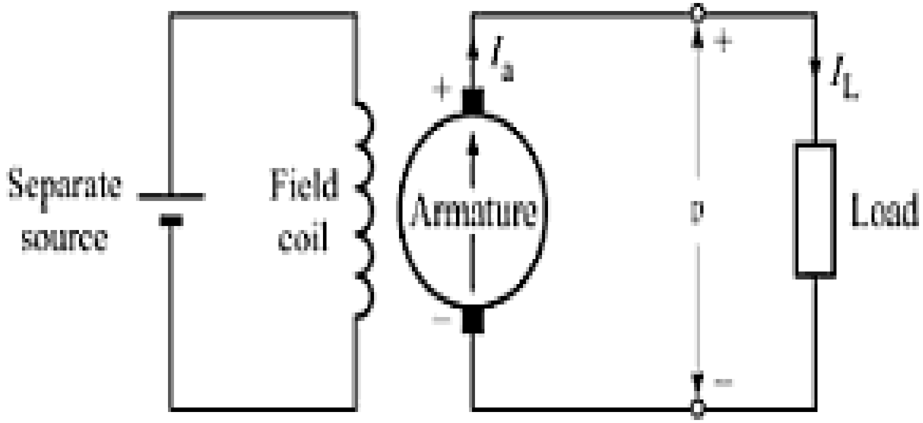
DC Generators

DC generators are dc machines used as generator. There are five major types of dc generators, classified according to the manner in which their field flux is produced:

- Using permanent magnet: <u>called permanent magnet generators</u>
- Using some external source to excite the field coils: called <u>separately excited generators</u>
- Using the armature supply to excite the field coils: <u>called self-excited generators</u>

DC Generators

- ***Separately excited generator:*** In separately excited generator, the field flux is derived from a separately power source independent of the generator itself.
- ***Shunt generator:*** In a shunt generator, the field flux is derived by connecting the field circuit directly across the terminals of the generators.
- ***Series generator:*** In a series generator, the field flux is produced by connecting the field circuit in series with the armature of the generator.
- ***Cumulatively compounded generator:*** In a cumulatively compounded generator, both a shunt and series field is present, and their effects are additive.
- ***Differentially compounded generator:*** In differentially compounded generator: In a differentially compounded generator, both a shunt and a series field are present, but their effects are subtractive.



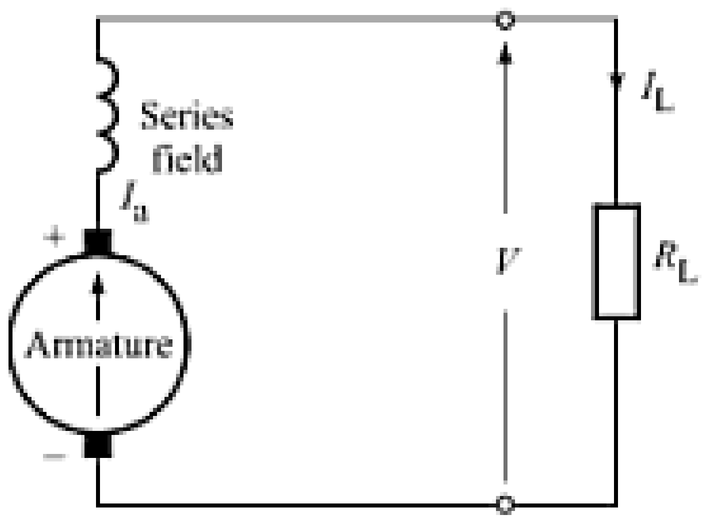
(i) $I_a = I_L = I$

(ii) $V = E - IR_a$

(iii) Power developed = EI

(iv) Power delivered = VI

Fig. 16.8 *Separately excited dc generator.*



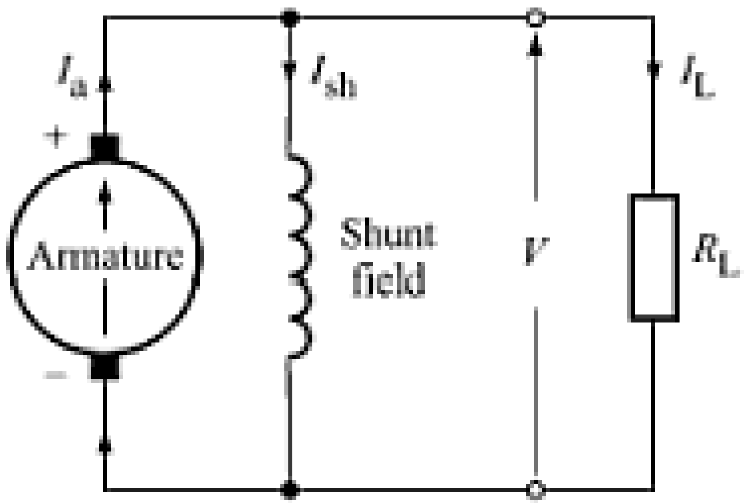
(ii) $I_a = I_{se} = I_L = I$ (say)

(iii) $V = E - I(R_a + R_{se})$

(iv) Power delivered = EI

(v) Power delivered = VI

(*a*) Series wound.



(i) $I_{sh} = V/R_{sh}$

(ii) $I_a = I_{sh} + I_L$

(iii) $V = E - I_a R_a$

(iv) Power delivered $= EI_a$

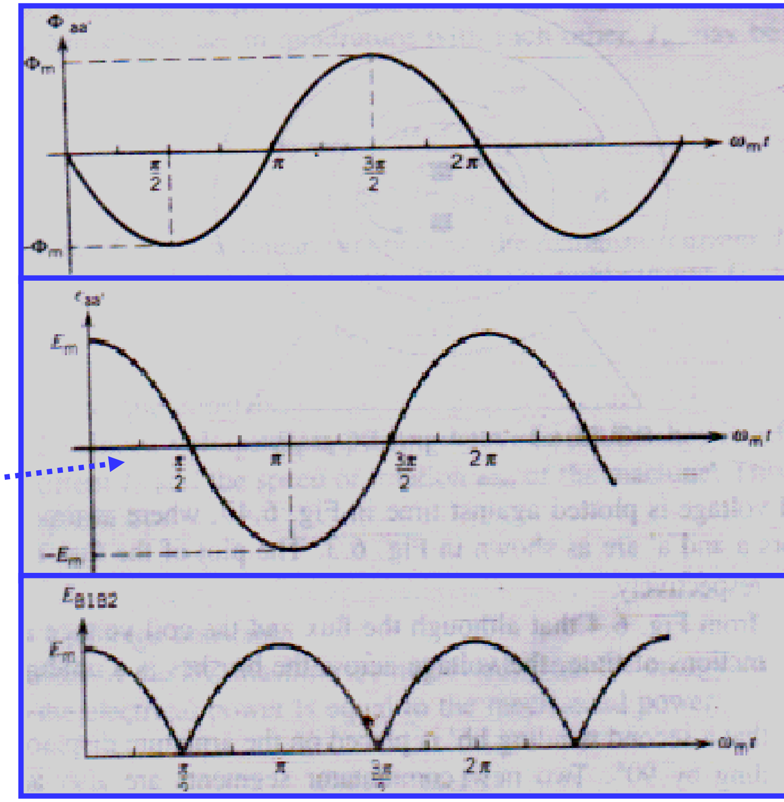
(v) Power delivered $= VI_L$

(*b*) Shunt wound.

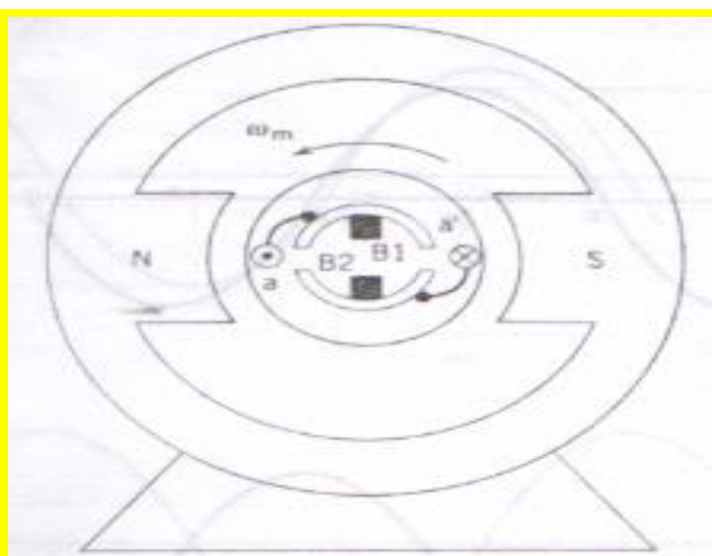
DC GENERATOR: Generation of Unidirectional Voltage

As the rotor is rotated at an angular velocity (ω), the armature flux linkage (Φ) change and a voltage e_{aa}' is induced between terminal a and a'. The expression for the voltage induced is given by Faraday's Law

$$e_{aa'} = -\frac{d\Phi}{dt}$$



a) Flux linkage of coil aa'; b) induced voltage; c) rectified voltage



Two pole DC generator

Applications of DC Generator

Shunt Generators:

a. in electro plating

b. for battery recharging

c. as exciters for AC generators.

Series Generators :

A. As boosters

B. As lighting arc lamps

Losses in DC machine

- **Copper losses:**

a) Aramature copper loss: this loss amounts about 30-40% of the full-load loss

b) Field copper loss: It is $I^2_{sh} R_{sh}$ (shunt) and $I^2_{se}R_{se}$ (series)

c) Brush contact loss: due to resistance of brush contact with the commutator

- **Magnetic losses:** mainly occurs in armature core. This loss amounts to about 20-30% of the full load losses.

a. Hysterises loss
b. Eddy current loss

- **Mechanical losses: two types**

a. Air friction: due to rotation of armature

b. Bearing friction loss: occurs at the ball-bearings fixed on the rotor

They are about 10-20% of the full load losses also called stray losses

Speed Control of DC motors

According to the speed equation of a dc motor

$$N \propto E_b/\phi$$

$$\propto V- Ia\ Ra/\ \phi$$

Thus speed can be controlled by:

Flux control method: By Changing the flux by controlling the current through the field winding.

Armature control method: By Changing the armature resistance which in turn changes the voltage applied across the armature.

Flux Control Method

Advantages:

- It provides relatively smooth and easy control
- Speed control above rated speed is possible
- As the field winding resistance is high the field current is small. Power loss in the external resistance is small . Hence this method is economical

Disadvantages:

- Flux can be increased only upto its rated value
- High speed affects the commutation, motor operation becomes unstable

Armature Voltage Control Method

- The speed is directly proportional to the voltage applied across the armature .

- Voltage across armature can be controlled by adding a variable resistance in series with the armature A rheostat is a *variable resistor* which is used to control current.

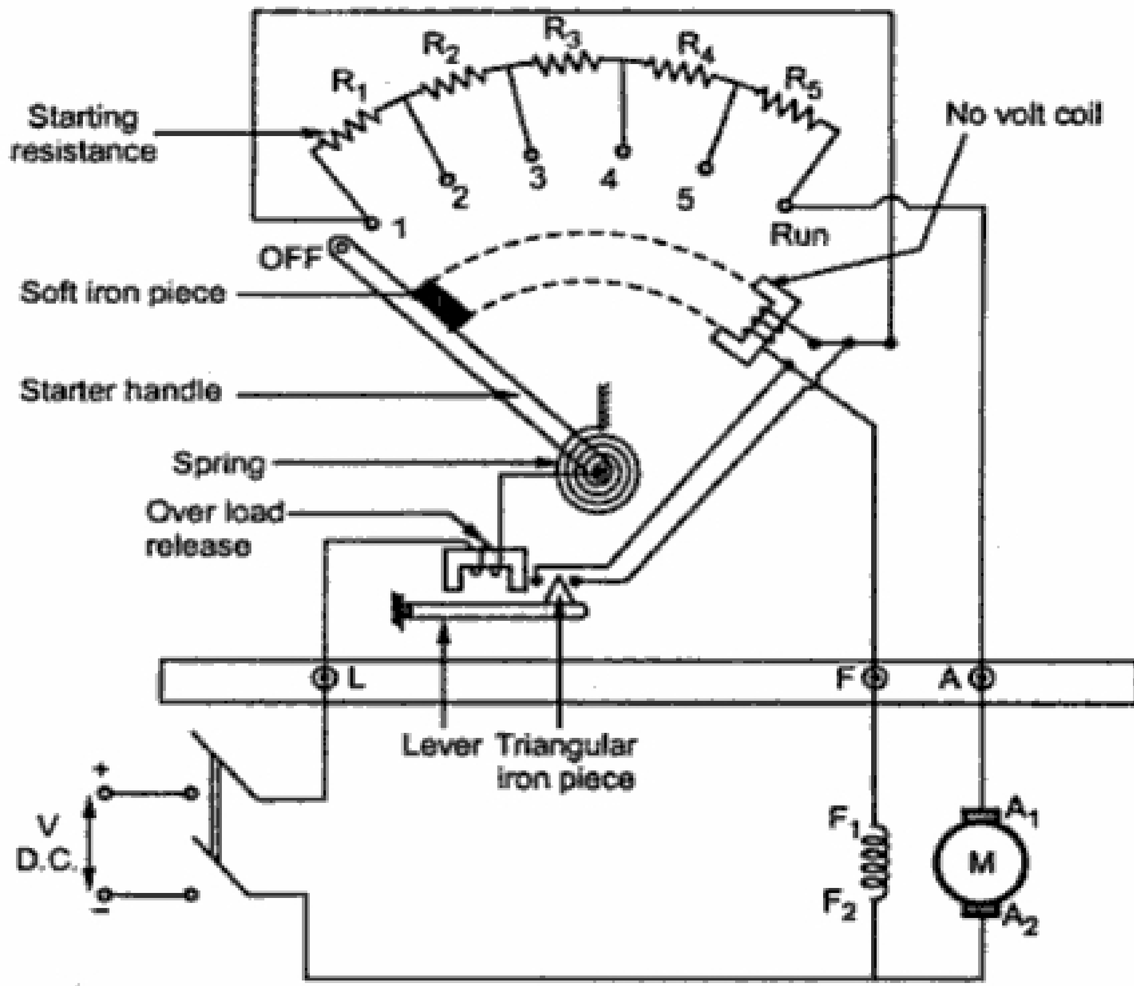
  Potential Divider Control : If the speed control from zero to the rated speed is required , by rheostatic method then the voltage across the armature can be varied by connecting rheostat in a potential divider arrangement .

Objective

- Starting of Dc motor
- Three point Starter
- INDUCTION MOTORS
- Squirrel cage rotor
- Wire-wound rotor
- Single phase and
- Three phase induction motor

Three point starter

- It consist of series starting resistance divided in several sections.
- Initially starter arm is in OFF position
- Switching ON DC supply starter arm moves towards right
- Field circuit direclty connected to supply
- At the same time entire resistance is inserted in the armature circuit.
- Some current flows in the armature, developing a torque
- The motor starts running and torque is developed

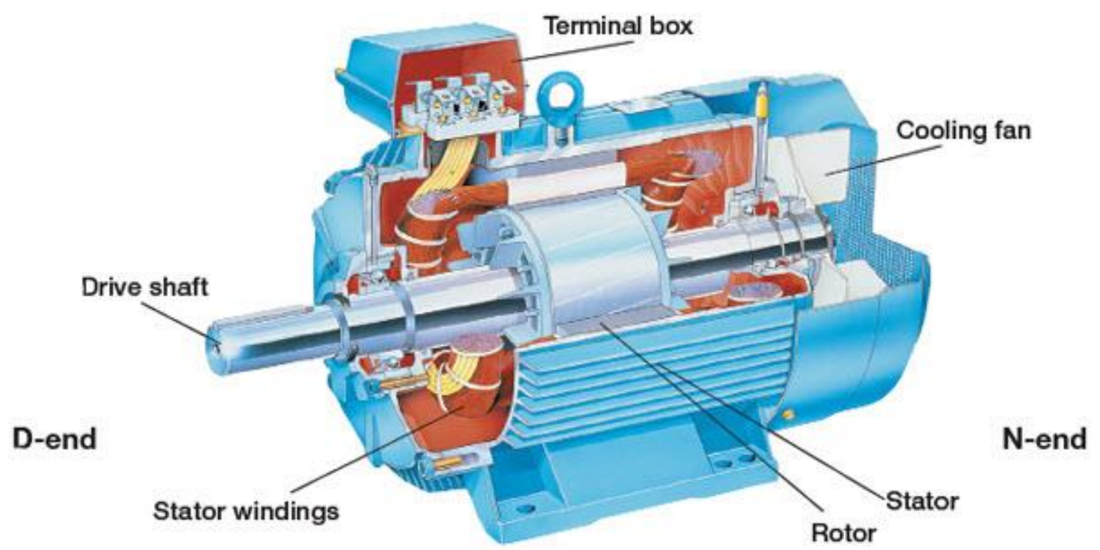


Three Point Starter

- <u>NO- Volt Release: </u>In ON position, The starter arm is held by no-volt release magnet energised by field current. Whenever pull of this magnet weakness arm is released to go back position . Without this arrangement armature gets directly connected to supply may cause heavy damage
- <u>Overload Release: </u>this is to protect the motor against the flow of excessive current due to overload. The coil is connected in series with motor. It carries full load current
- This short circuited the no volt release coil. The no volt coil is demagnetized and the handle is pulled to the OFF position by the spring. Thus the motor is automatically disconnected from the supply

INDUCTION MOTORS

An induction motor or asynchronous motor is an AC electric motor in which the electric current in the rotor needed to produce torque is obtained by electromagnetic induction from the magnetic field of the stator winding



Depending on the rotor construction, induction motor can be classified into two categories:

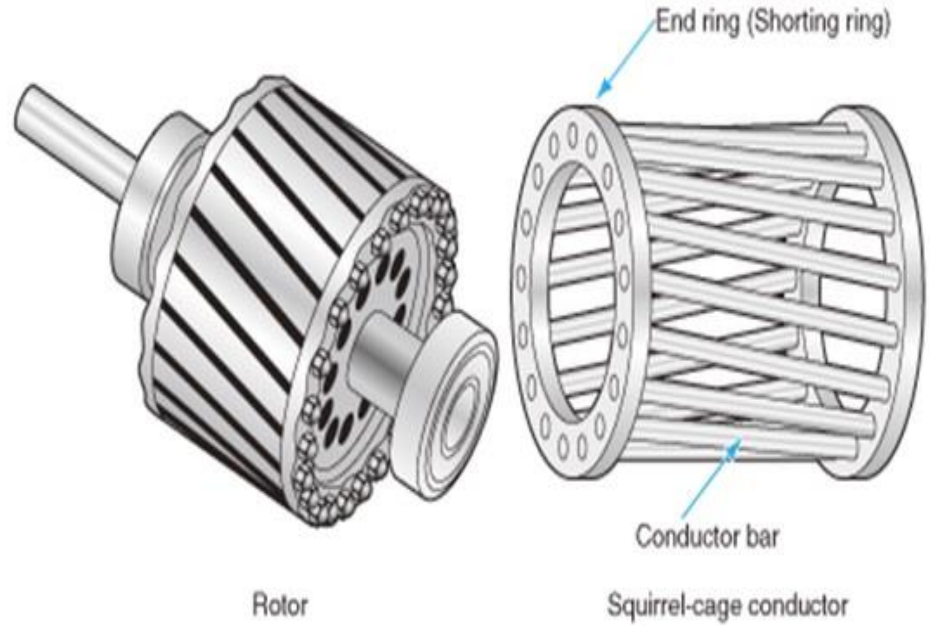
- Squirrel-cage induction motor.
- Slip-ring induction motor or wound rotor induction motor.

Depending on the number of phases it can be classified as:

- Single-phase induction motor
- Three-phase induction motor

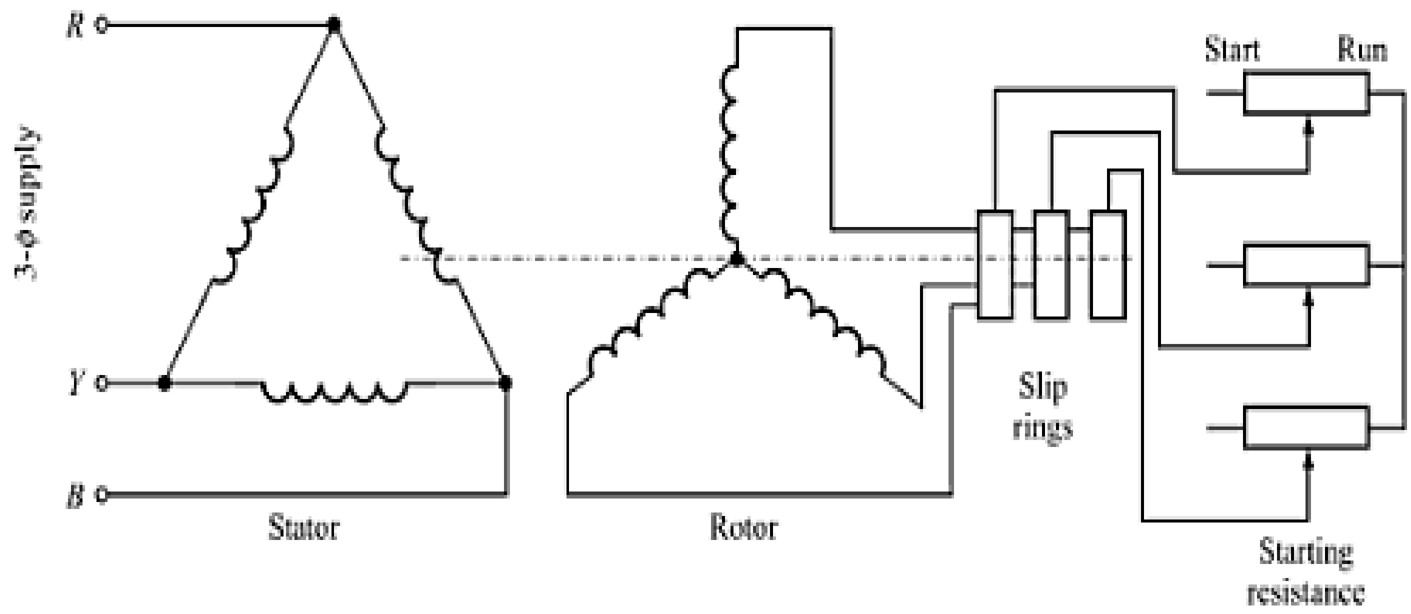
Squirrel cage rotor

- 90% of motor in use have this type of rotor
- Two main advantages
- Adaptable to any number of poles
- Simple in construction, has no slip-rings and brushers very economical in construction

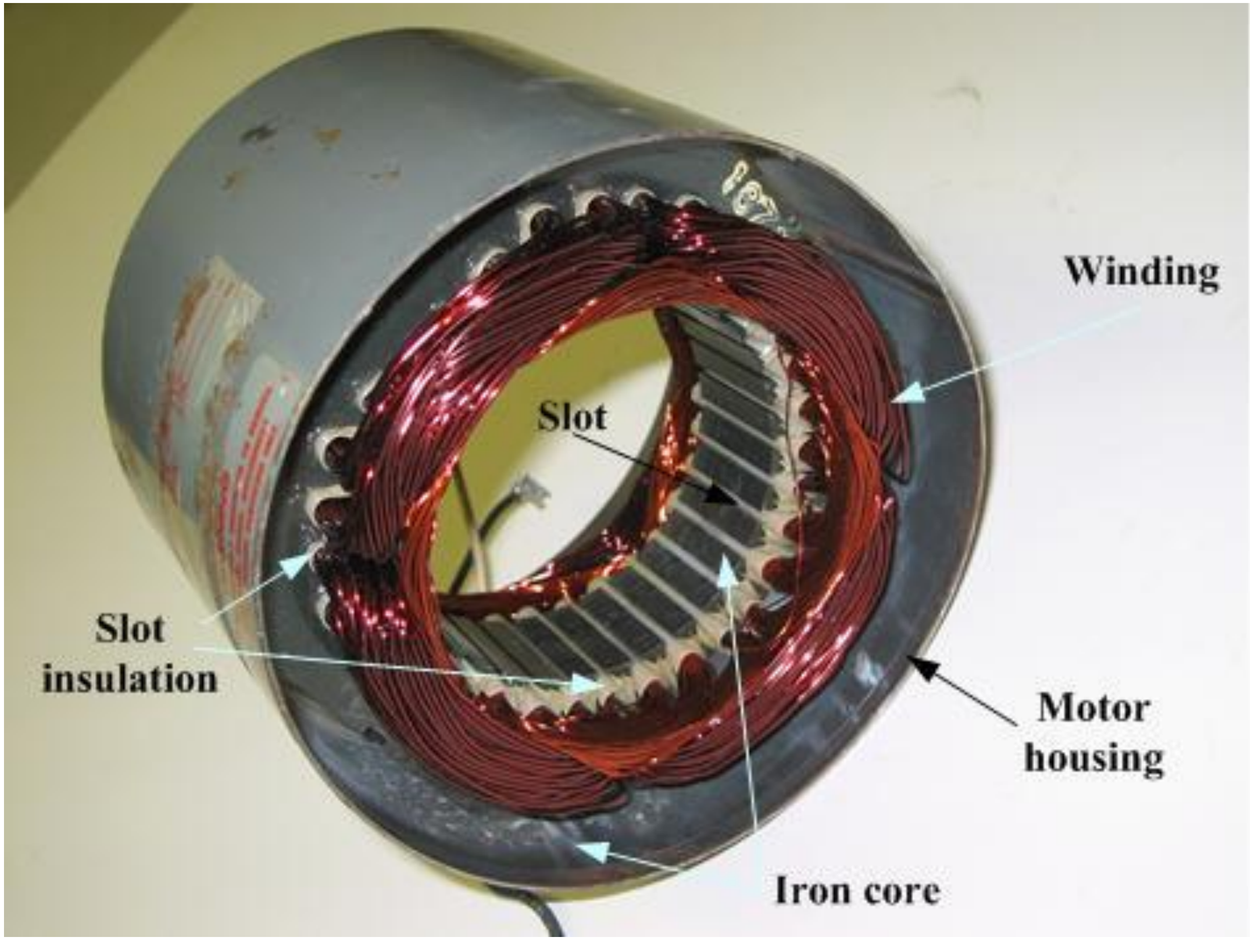


Wire-wound rotor

- The rotor windings are connected through slip rings to external resistance. Adjusting the resistance allows control of the speed/torque characteristic of the motor. Wound-rotor motors can be started with low inrush current, by inserting high resistance into the rotor circuit; as the motor accelerates, the resistance can be decreased

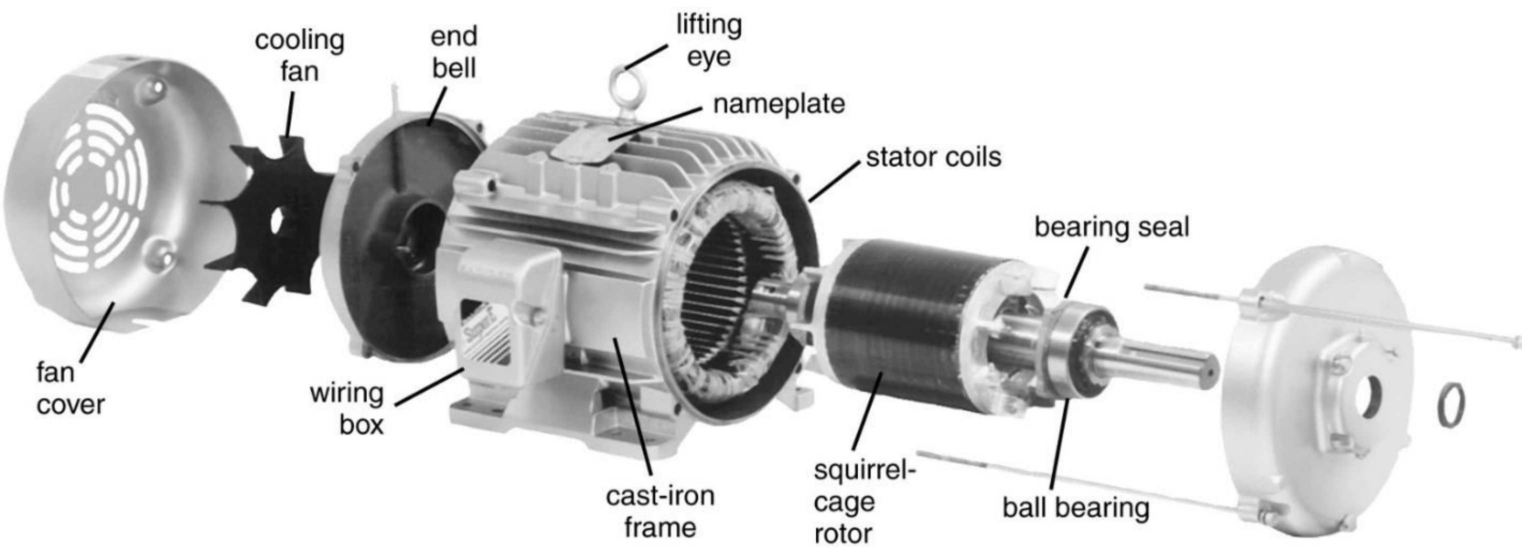


Construction of Single Phase Induction Motor



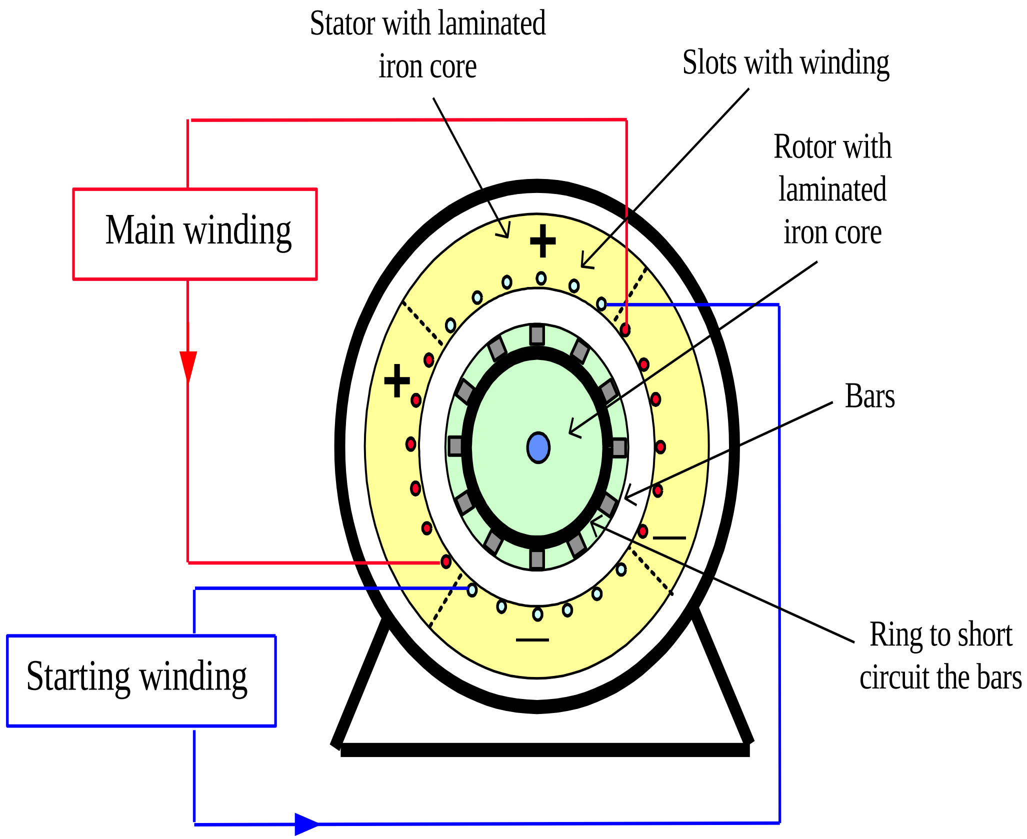
Single Phase Induction Motor

- The single-phase induction machine is the most frequently used motor for refrigerators, washing machines, drills, compressors, pumps, and so forth.
- The single-phase motor stator has a laminated iron core with two windings arranged perpendicularly.
  - One is the main and
  - The other is the auxiliary winding or *starting winding*



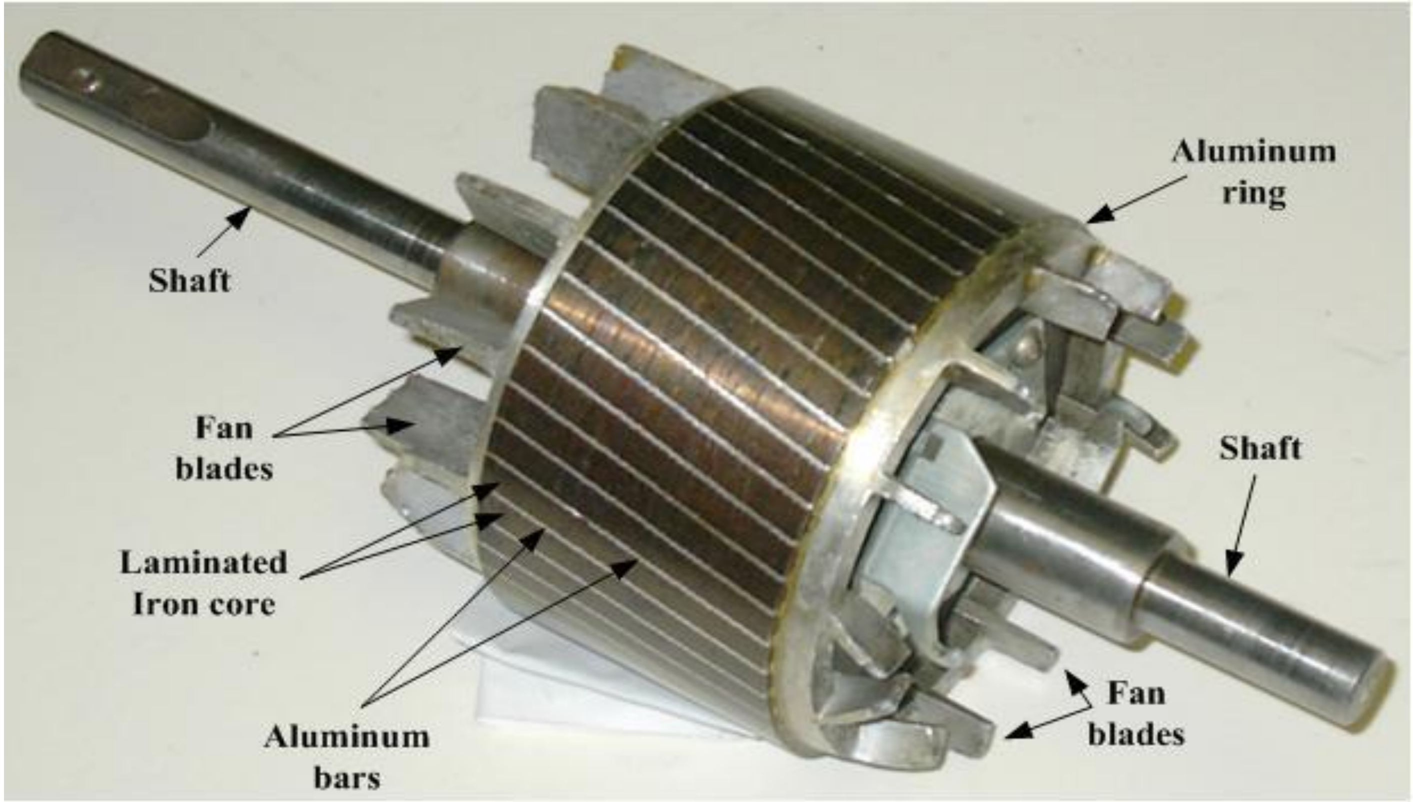
Single Phase Induction Motor

- This “single-phase” motors are truly two-phase machines.
- The motor uses a squirrel cage rotor, which has a laminated iron core with slots.
- Aluminum bars are molded on the slots and short-circuited at both ends with a ring.



Single-phase induction motor.

Single Phase Induction Motor

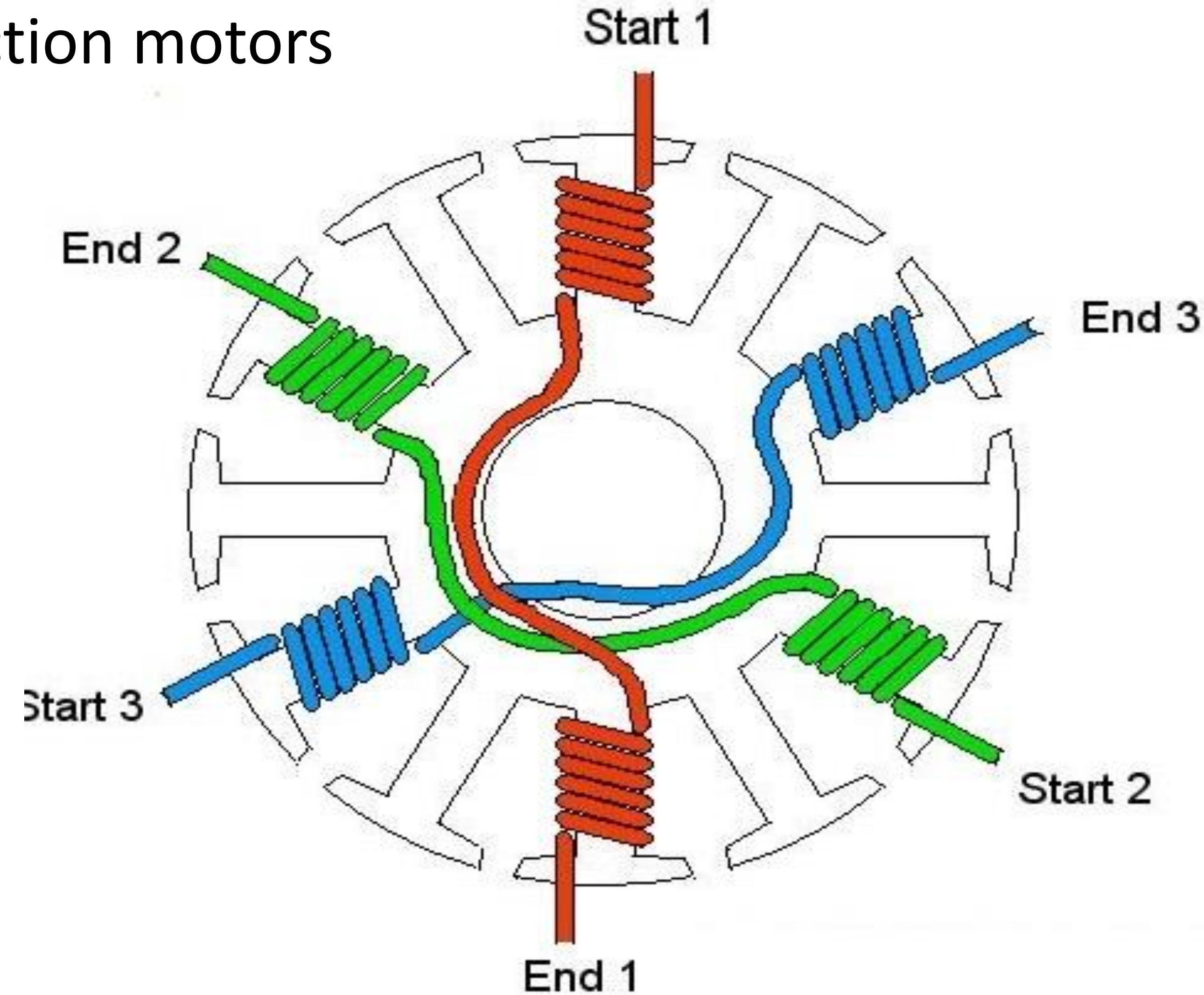


Squirrel cage rotor

Three Phase Induction Motor

- Three-phase induction motors are the most common and frequently encountered machines in industry
- It can be considered to be the cheapest motor.
- It is rugged and requires less maintenance.
- It is simple in design.
- It gives reliable operation.
- Its efficiency is very high.
- It is easy to control
- It runs at constant speed from zero to full load

Most widely used motor is **Three phase induction motor** as this type of motor does not require any starting device or we can say they are self-starting induction motors

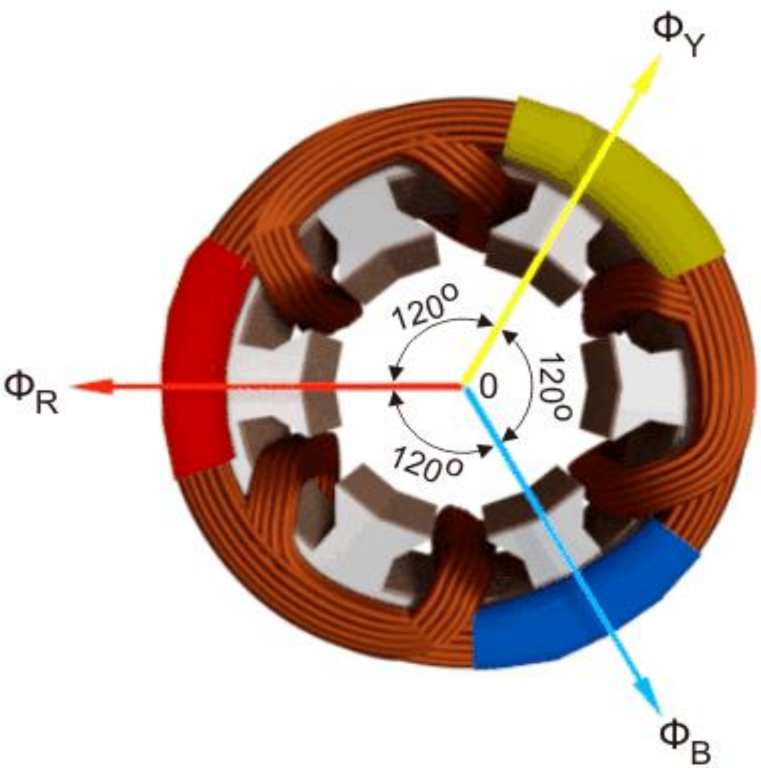


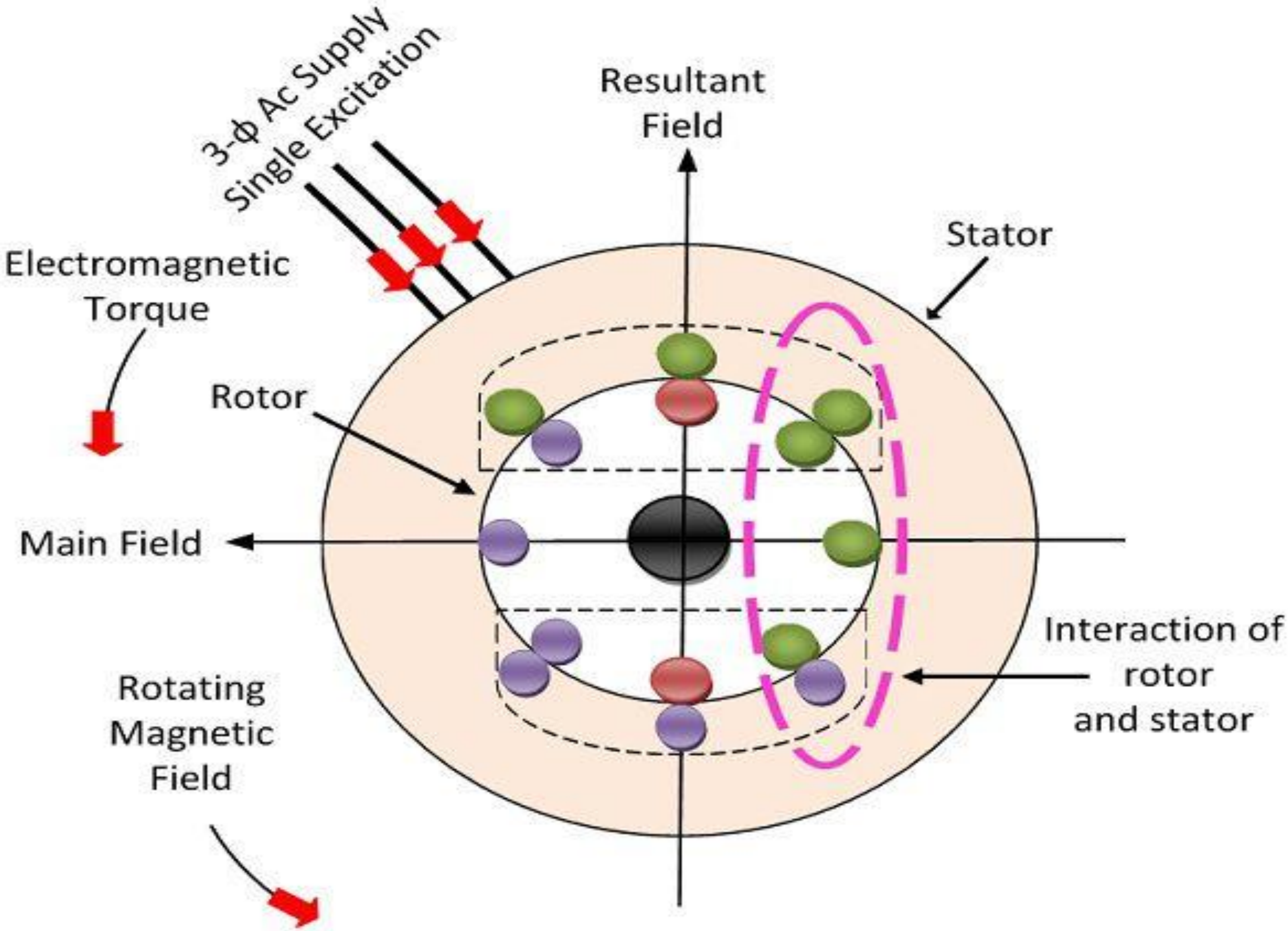
Principle of Operation

- A Rotating Magnetic field (RMF) is set up in the stator when a 3- Phase supply is given.
- The stationary rotor cut the revolving field and due to electromagnetic induction an e.m.f. is induced in the rotor conductor.
- As the rotor conductor is short circuited current flows through them.
- It becomes a current carrying conductor in magnetic field and start rotating.

Production of Rotating Magnetic Field

The stator of the motor consists of overlapping winding offset by an electrical angle of 120º. When we connect the primary winding, or the stator to a 3 phase AC source, it establishes rotating magnetic field which rotates at the synchronous speed.





Three Phase Induction Motor

1. The conductors of the rotor are short-circuited either by the end rings or by the help of the external resistance.

2. The relative motion between the rotating magnetic field and the rotor conductor induces the current in the rotor conductors.

3. As the current flows through the conductor, the flux induces on it. The direction of rotor flux is same as that of the rotor current.
4. Now we have two fluxes one because of the rotor and another because of the stator. These fluxes interact each other.

- Thus, the high-density flux tries to push the conductor of rotor towards the low-density flux region. This phenomenon induces the torque on the conductor, and this torque is known as the electromagnetic torque.

- The direction of electromagnetic torque and rotating magnetic field is same. Thus, the rotor starts rotating in the same direction as that of the rotating magnetic field

Single Phase Induction Motor

APPLICATIONS

- Fans, Compressor, Pumps, blowers, machine tools like lathe, drilling machine, lifts, conveyer belts etc.

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- **Advantages of Three-Phase Induction Motor**: These **motors** are self-starting and use no start winding or other starting device.

APPLICATIONS

- **Three-phase** AC **induction motors** are widely used in industrial and commercial **applications**.

APPLICATION OF three phase INDUCTION MOTOR

- **Squirrel cage induction motor**
- Squirrel cage induction motors are simple and rugged in construction, are relatively cheap and require little maintenance. Hence, squirrel cage induction motors are preferred in most of the industrial applications such as in
- Lathes
- Drilling machines
- Agricultural and industrial pumps
- Industrial drives.

Synchronous Motor	Induction Motor
1. Synchronous motors require DC excitation to be supplied to the rotor windings.	1. Induction Motors don't require DC excitation to be supplied to the rotor windings.
2. Synchronous motors require rotor windings.	2. Induction motors are most often constructed with conduction bars in the rotor that are shorted together at the ends to form a "squirrel cage."
3. Synchronous motors require a starting mechanism in addition to the mode of operation that is in effect once they reach synchronous speed.	3. Three phase induction motors can start by simply applying power, but single phase motors require an additional starting circuit.