Induction Motors

- Widely used power drive.
- Run at **constant speed**.
- Working principle –**electromagnetic induction**. Hence the name induction motor.

Induction Motors - Classification

Based on type of ac supply,

- **Three Phase Induction Motors**

    - Self starting

    - Extensively used in industries and hence known as ‘work horse’ of modern industry

- **Single Phase Induction Motors**

    - not self starting

    - applications restricted to small power ratings.

Three Phase Induction Motors

Advantages

- Simple design
- Rugged construction
- Reliable operation
- Low cost
- Minimum maintenance
- High efficiency and good pf at full load

Construction

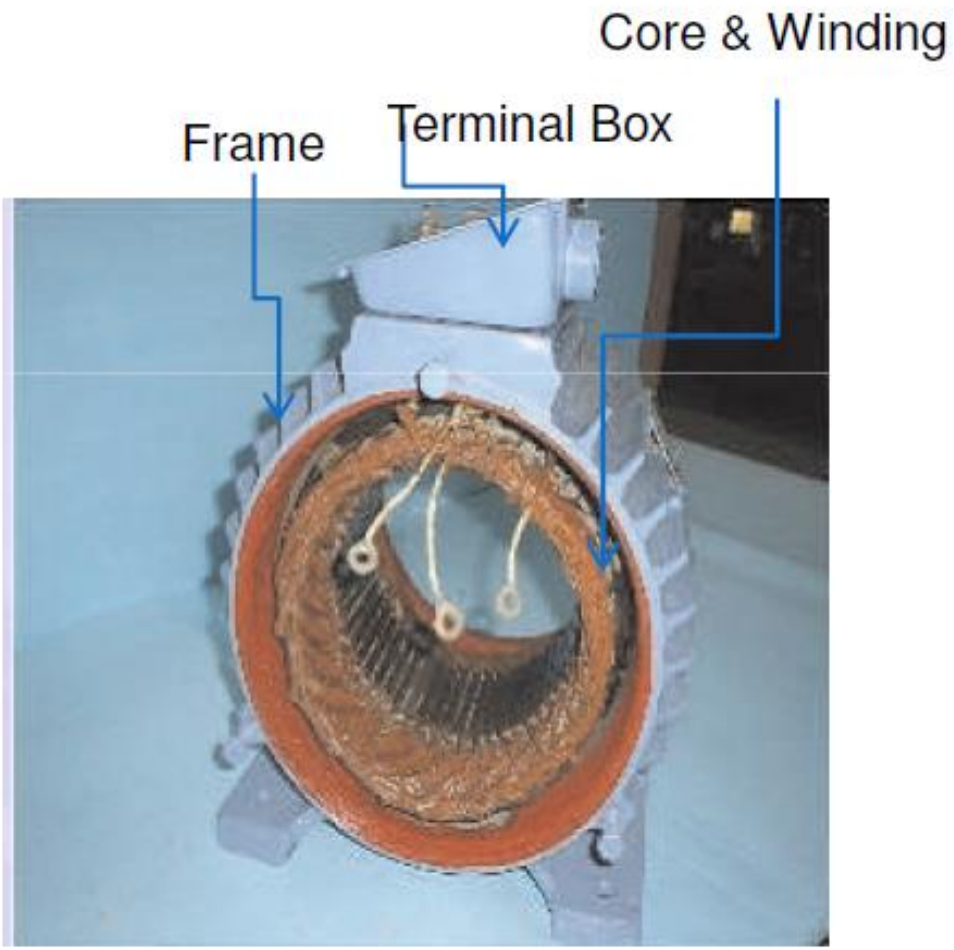
- Consists of **Stator** and **Rotor**.
- Rotor is separated from stator by a small airgap (0.4 mm to 4mm)
- Depending on **rotor construction**, induction motors are classified as

1. Squirrel Cage Induction Motor (SCIM)
2. Slip Ring Induction Motor (SRIM)

Construction - Stator

Main Parts

- Frame
- Stator Core
- 3ϕ distributed winding



Construction - Stator

Frame

- Cylindrical in shape and made of cast iron
- Provides support and act as protective cover.
- Provided with fins to increase heat dissipation.

Stator Core

- Cylindrical in shape and made of silicon steel laminations
- Provides space for accommodating 3ϕ balanced winding.

Stator Winding

- Made of copper wire.
- The 3 coils from 3 windings are distributed over slots
- Both λ/Δ connections are possible

Construction – Squirrel Cage Rotor

Main Parts

- Shaft
- Rotor Core
- Rotor Bars

Construction – Squirrel Cage Rotor

Rotor Core

- laminated cylindrical core .
- have slots on its outer periphery.

Rotor Core

- A thick copper or aluminum bar is placed in each slot.
- All these bars are joined together at both ends by metal rings called end rings. Rotor circuit is permanently closed circuit.
- Rotor bars and end rings together resembles the cage of squirrel and hence the name.

Squirrel Cage Rotor

Advantages

- Simple and robust construction

Disadvantages

- Low starting torque

Construction – Slip Ring Rotor

Main Parts

- Shaft
- Rotor Core
- Rotor windings
- Slip Rings

Construction – Slip Ring Rotor

Rotor Core

- laminated cylindrical core .
- have slots on its outer periphery. to accommodate balance 3ϕ windings

Rotor Windings and Slip Ring Arrangement

- Rotor winding is usually star connected.
- The open ends of rotor windings are brought out and connected to three slip rings mounted on rotor shaft.
- Brushes are used to take connection from these slip rings
- At starting high external resistances are usually included to improve starting torque and reduce starting current.
- When motor attains normal speed, three brushes are short circuited.

Squirrel Cage Rotor

Advantages

- Starting resistance can be included to improve starting torque
- Speed control is possible.

Working

- When 3ϕ stator winding is energized from a 3ϕ supply, a rotating magnetic field is produced.
- The speed at which magnetic field rotates is called synchronous speed Ns

$$N_s = \frac{120\,f}{P}$$

where, P – no. of poles

f – supply frequency

- This field passes through the air gap and cuts the stationary rotor conductors which induces emf in the rotor conductors.
- Since rotor circuit is short circuited current starts flowing through rotor conductors

Working

- Now the situation is like a current carrying conductor (rotor conductor) placed in a magnetic field (produced by stator)
- Thus mechanical force acts on all rotor conductors. The sum of mechanical forces on all rotor conductors produces a torque which tends to move rotor in the same direction as that of rotating magnetic field

Slip

- In practice rotor can never achieve the speed of stator field(Ns). If it did so, there would be no relative speed between two, hence no rotor emf, rotor current and torque to drive rotor.
- The difference between synchronous speed (Ns) and actual speed of rotor (N) is called slip.

$$\text{slip}, S = \frac{N_s - N}{N_s}$$

$$\%\text{slip} = \frac{N_s - N}{N_s} x100$$

- Rotor current frequency, $f_r = Sf$

Tutorials

1. A 3hp, three phase, 4-pole, 400V, 50Hz, induction motor runs at 1440rpm. Calculate slip and frequency of rotor-induced EMF?

   Ans : Slip = 0.04 and fr = 2Hz

2. The frequency of rotor induced EMF of 400V, three phase, six pole induction motor is 2Hz. Calculate the speed of motor.

   Ans : 960 rpm

3. A slip ring, three phase induction motor rotates at a speed of 1440rpm, when a supply of 400V, 50Hz is applied across the stator terminals. What will be the frequency of rotor induced EMF?

   Ans : 2 Hz

Applications

- Squirrel Cage Motor – Low rotor resistance – low starting torque – centrifugal pumps, wood working tools etc.
- Squirrel Cage Motor – High rotor resistance – High starting torque – compressors, crushers, reciprocating pumps etc.
- Squirrel Cage Motor – Higher rotor resistance – Higher starting torque – punching presses, hoists, elevators etc
- Slip Ring Motor –used for loads requiring severe starting conditions like hoists, cranes elevators etc

Single Phase Induction Motor

- widely used in commercial and domestic field, where single phase supply is available

Applications

- Washing machines, fans, refrigerators, grinders, centrifugal pumps, hair dryers, blowers etc.

Disadvantages – comparing with 3ϕ IM

- Not self starting.
- Low starting torque
- Operates at low efficiency and low pf.

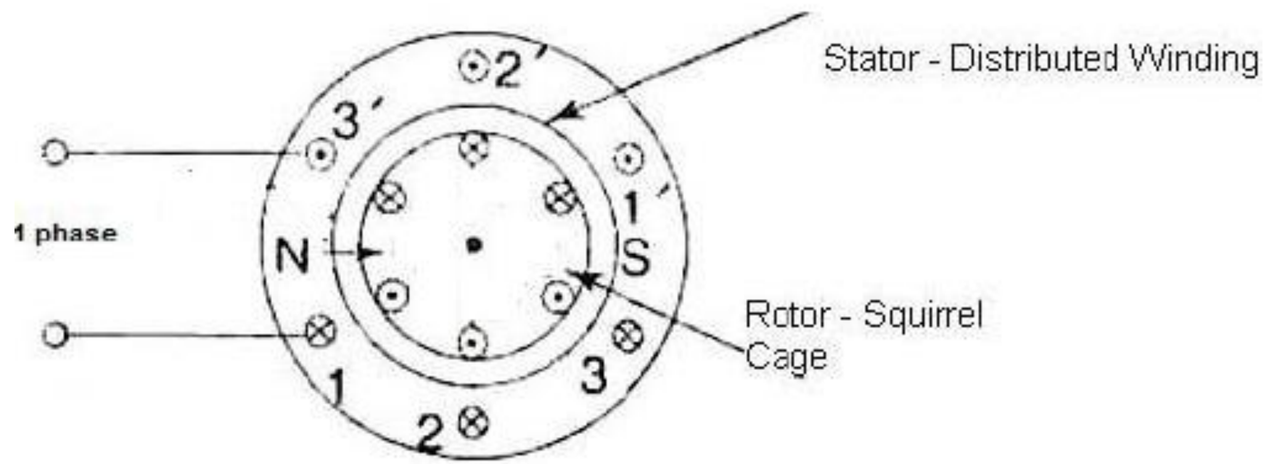
Single Phase Induction Motor - Construction

Parts

(1) Stator – contains a core which accommodates a 1ϕ distributed winding.

(2) Rotor – squirrel Cage rotor

Airgap between stator and rotor– 0.5mm to 1mm



Single Phase Induction Motor

Working

- When an alternating voltage is applied to the stator winding of single phase induction motor, an alternating magnetic field(pulsating) is produced. Such a magnetic field acting on squirrel cage rotor cannot produce starting torque needed for motor. Hence single phase induction motors are not self starting.
- Various method have been developed for obtaining starting torque in these motors.
- Stator winding is modified or split into two parts, to make it self start.

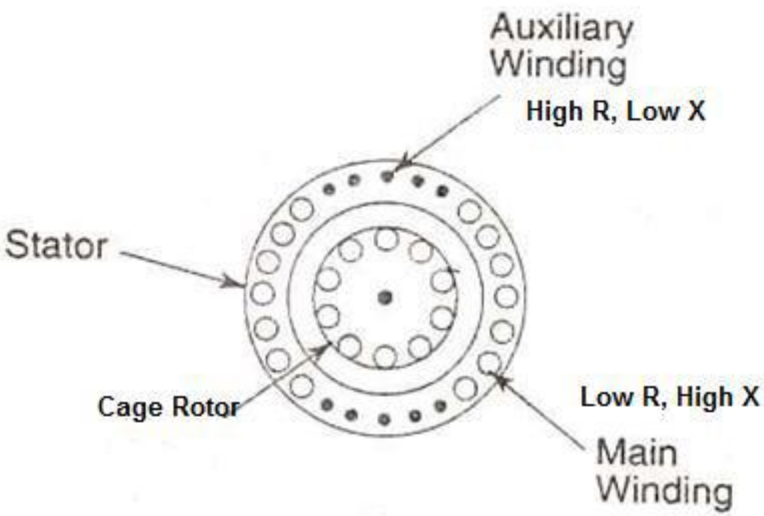
Classification

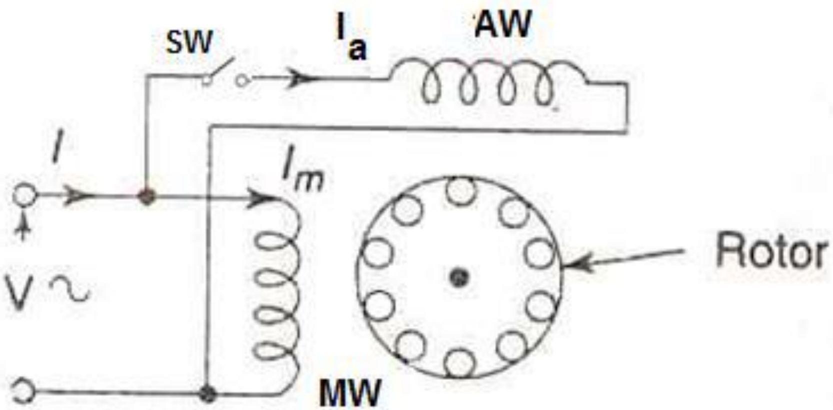
Based on starting method, single phase induction motors are classified into

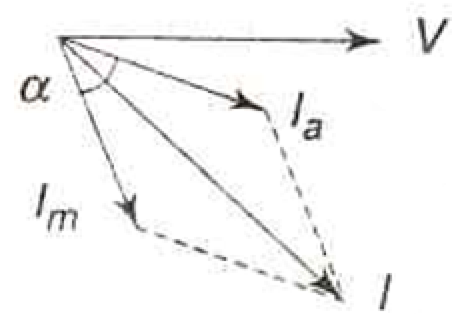
1. Split Phase Induction Motor
2. Capacitor Start Motor
3. Capacitor Start Capacitor Run Motor
4. Shaded Pole Induction Motor

Split Phase Induction Motor

- Contains an auxiliary winding and main winding on stator.
- Main winding - high reactance, low resistance
- Auxiliary winding – high resistance, low reactance







Split Phase Induction Motor

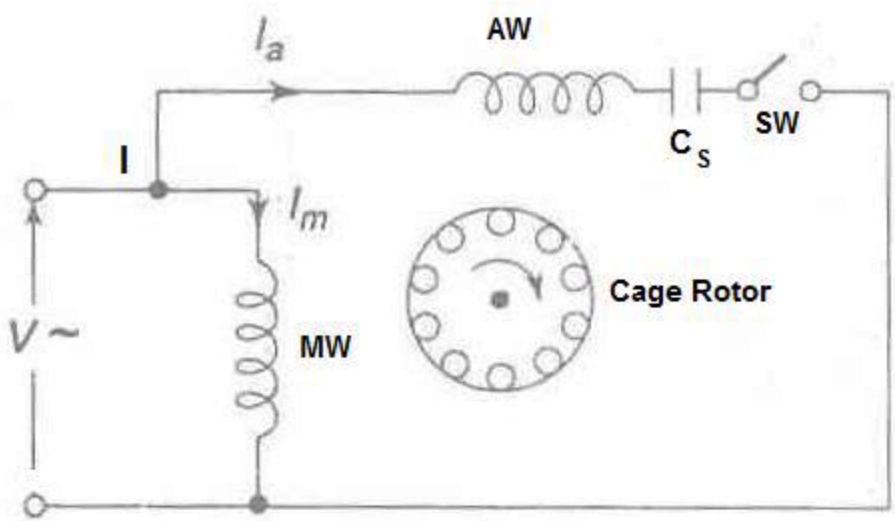
Working

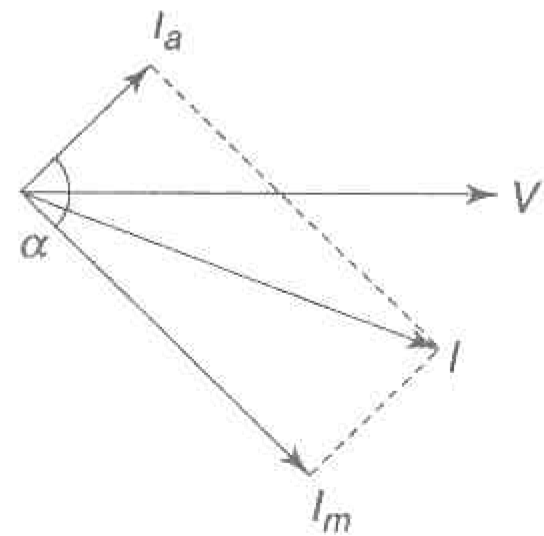
- displacement between the currents in stator winding, produces a rotating magnetic field.
- When motor attains sufficient speed, switch is opened.

$$T_d \;\alpha\; \sin\alpha$$

Capacitor Start Induction Motor

- Stator contains an auxiliary winding and main winding.
- A capacitor is included in the auxiliary winding to provide a proper displacement between the currents in stator winding.





Capacitor Start Induction Motor

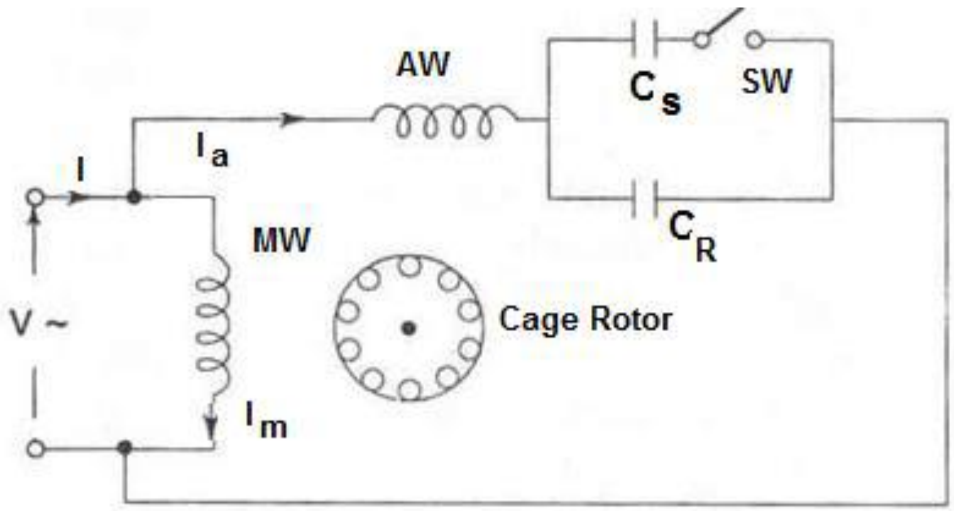
Working

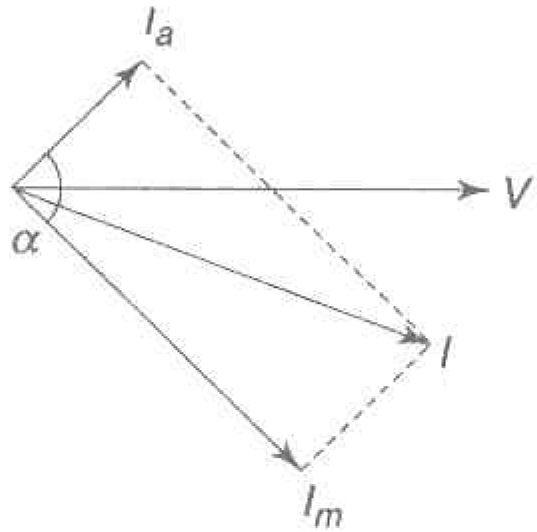
- displacement between the currents in stator winding, produces a rotating magnetic field.
- Capacitor is removed from the circuit during running condition by a centrifugal switch.

$$T_d \;\alpha\; \sin \alpha$$

Capacitor Start Capacitor Run Induction Motor

- Stator contains an auxiliary winding and main winding.
- Capacitors are included in the auxiliary winding to provide a proper displacement between the currents in stator winding.





Split Phase Induction Motor

Working

- displacement between the currents in stator winding, produces a rotating magnetic field.
- Starting capacitor is removed from the circuit during running condition by a centrifugal switch.

$$T_d \propto \sin\alpha$$

Shaded Pole Induction Motor

- A single turn of copper strap is wrapped around a portion of the main pole forming a closed circuit. This closed circuit is named as shading coil.
- The shading coil causes flux in that portion of pole surrounded by it, to lag behind flux in remaining portion of the pole.
- Hence two components of flux are displaced in time, which produce a revolving magnetic field which supplies the starting torque.