Single - Phase Induction Motors.

Introduction

* It is not always convenient to have 3ϕ supply. Generally shops, offices, schools, hospitals, houses etc. use 1ϕ supply. In such cases 3ϕ motors cannot be used. Hence 1ϕ induction motors were developed.

* 1ϕ induction motors are mostly used in fractional horse power ranges.

* Applications based on rating
  a) In 1/8 HP to 1/4 HP range, these motors are widely used in fans, washing machines, blowers, centrifugal pumps, refrigerators etc.
  b) In 1/300 HP to 1/20 HP range they are used in toys, hair dryers, vending machines, etc.

* Applications with reference to types
  a) Capacitor start capacitor run type motors are used in ceiling fans, blowers and air circulators
  b) AC series motors, also known as universal motors are used in portable tools, vacuum cleaners, & kitchen equipments.

Construction

* A 1ϕ induction motor has

  a) Stator, the stationary part

  b) Rotor, the rotating part

* The stator has a laminated construction, made up of stampings. The stampings are slotted on its periphery to carry the stator winding or main winding. This is excited by a 1ϕ supply.

* The laminated construction keeps iron losses to the minimum. The stampings are made up of material like silicon steel which minimizes hysteresis loss.

* The stator winding is wound for a certain number of poles. This means that when the stator winding is excited by 1ϕ ac source, stator produces the magnetic flux which creates the effect of a certain number of poles. The number of poles decides the synchronous speed. It is given by

$$N_s = \frac{120f}{p}$$

where

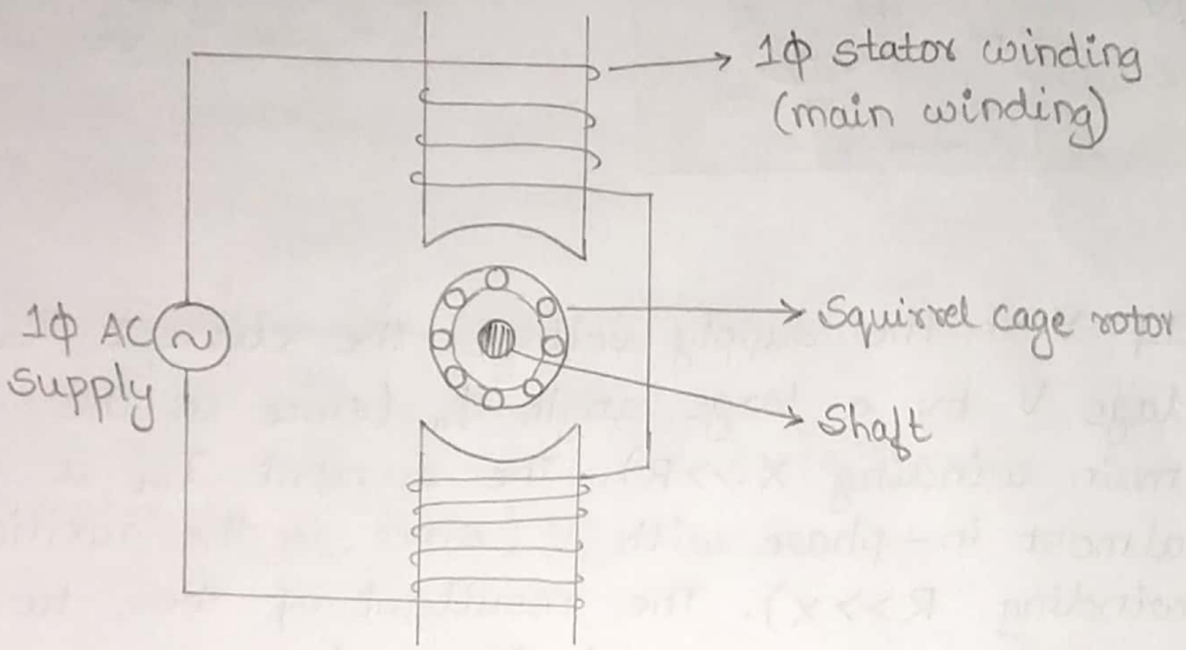
f = supply frequency

p = no. of poles

* The induction motor never rotates at synchronous speed but rotates at a speed slightly less than synchronous speed.

* The rotor of a 1ϕ induction motor is always of squirrel-cage type. The rotor consists of solid uninsulated bars of copper or aluminium, placed in slots. The bars are permanently short circuited at both ends with the help of conducting rings called end rings.

* The schematic representation of a 1ϕ induction motor is shown below.



Split - Phase induction motor

* For 1ϕ induction motor to work, it needs to be converted into a two-phase motor. The 1ϕ stator winding is called the main winding. In addition to this, stator carries one more winding called auxiliary winding or starting winding.

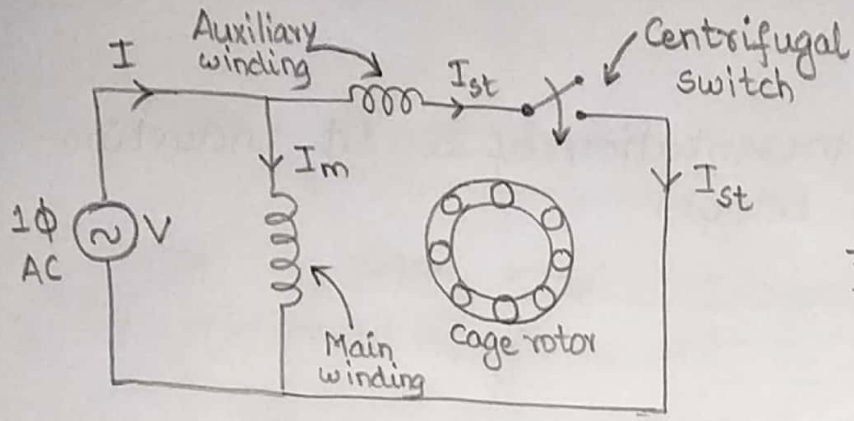
* The auxiliary winding is such that its resistance is very high when compared to its reactance. i.e., its impedance is highly resistive in nature.

* The main winding is inductive in nature.

* Let,

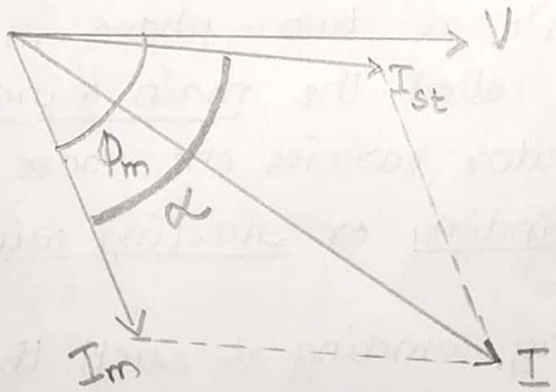
  I_m = current through main winding

  I_{st} = current through the auxiliary (starting) winding.



$$\bar{I} = \bar{I}_m + \bar{I}_{st}$$

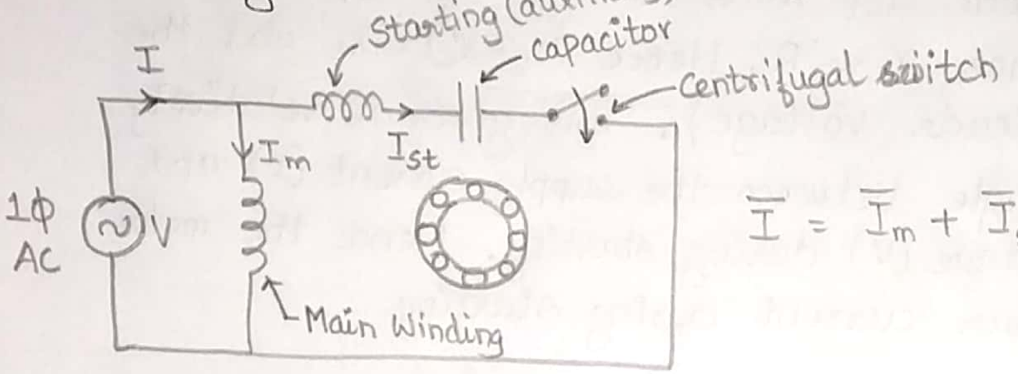
* If V is the supply voltage, the current I_m lags V by a large angle ϕ_m (since in the main winding $X >> R$). The current I_{st} is almost in-phase with V (since in the auxiliary winding $R >> X$). The resultant of these two currents is the current drawn from the supply. The fluxes due to these two currents produces a rotating field.



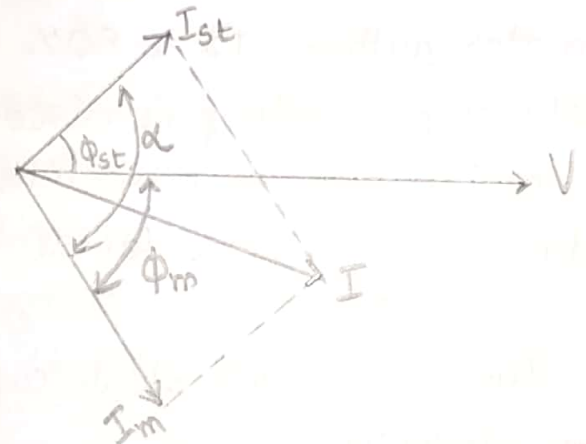
* The auxiliary winding has a centrifugal switch in series with it. When the motor reaches 75 to 80% of the synchronous speed, the centrifugal switch gets opened mechanically and in running condition only the main winding allows current.

Capacitor - start induction motor.

* In a capacitor - start induction motor, a capacitor and a centrifugal switch in series with the auxiliary winding.



$$\bar{I} = \bar{I}_m + \bar{I}_{st}$$



I = current drawn from the supply

I_m = current through main winding

I_{st} = current through aux winding

ϕ_m = angle between V and I_m

ϕ_{st} = angle between V and I_{st}

α = angle between I_m and I_{st}

* In a split-phase motor, the angle between the resultant current (I) and the supply voltage (V) is very large. This is because the motor winding is predominantly inductive. This causes low power-factor. This implies that the motor draws a very high current during running condition. In starting condition this current will be much higher. This ~~pro~~ will damage the motor windings. Hence, a capacitor is connected in series with the starting winding. Such a motor is called capacitor-start motor.

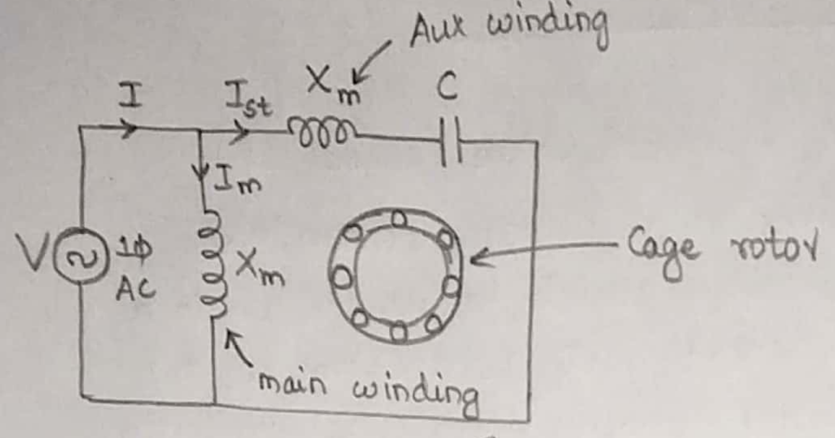
* The current I_m lags voltage by angle ϕ_m, while the current I_{st} leads Voltage by ϕ_{st} (the aux winding has $X_L << R$; Hence $(X_L - X_C) \simeq X_C$ and the current leads voltage). This gives a relatively smaller angle between the supply current (I) and supply voltage (V) during starting. Hence the motor draws lower current during starting.

* When the motor gathers 75 to 80% of synchronous speed, the starting winding is disconnected by operating the centrifugal switch. Thus, in running condition, the motor power factor is lower.

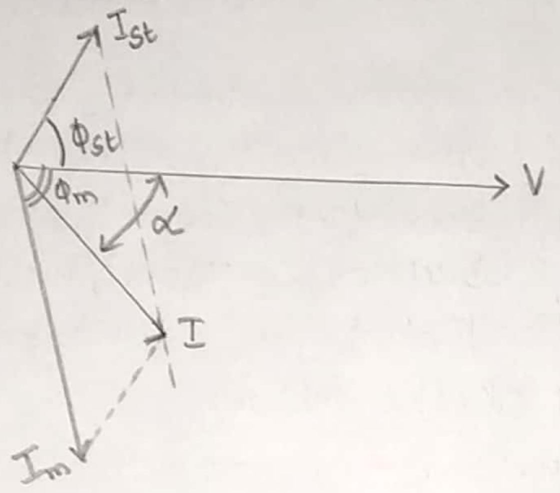
* To overcome this, capacitor start capacitor run motors were developed.

Capacitor - start capacitor - run motor

* In case of capacitor start capacitor run induction motor, there is no centrifugal switch.

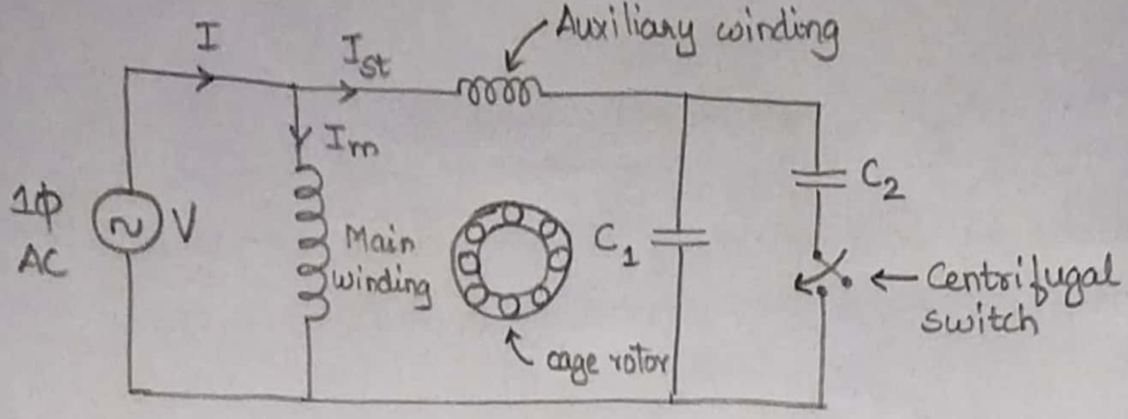


$$\bar{I} = \bar{I}_m + \bar{I}_{st}$$



* Since the capacitor is always connected, the motor has higher power factor during starting as well as running conditions. The capacitor has to be designed so as to compromise between best starting and best running conditions.

* Another version of a capacitor start capacitor run motor is also used.



* The capacitor C_1 is a small value (a few μF), continuous - duty (since it is always connected) capacitor while C_2 is a much larger ($50\mu F$ to a few hundred μF), short - duty (since the switch will be opened during running condition) capacitor.

* Initially when the motor is started, both the capacitors are connected in the circuit. After the motor has picked up enough speed, the centrifugal switch opens and disconnects capacitor C_2 from the circuit. The capacitor C_1 remains in the circuit even during normal running of the motor.

Applications

	Motor - Type	Characteristic	Rating	Applications
1.	Split - phase	moderate starting torque	1/20 HP to 1/2 HP	Washing machines blowers, centrifugal pumps, refrigerators, grinders
2.	Capacitor-start	High starting torque	1/8 HP to 5HP	Compressors, large fans, blowers, portable hoists
3.	Capacitor - start capacitor - run	Good power - factor, high starting torque	1/8HP to 5HP	compressors, conveyer pumps.