1 Types of Single-Phase Induction Motors

The single-phase induction motors are made self-starting by providing an additional flux by some additional means. Now depending upon these additional means the single-phase induction motors are classified as:

1. Split phase induction motor.
2. Capacitor starts induction motor.
3. Capacitor start capacitors run induction motor (two value capacitor method).
4. Permanent split capacitor (PSC) motor.
5. Shaded pole induction motor.

1.1 Split-Phase Induction Motor

A split-phase induction motor is a type of single-phase induction motor in which the stator is provided with a starting or auxiliary winding (S) and a main or running winding (M). The starting winding is displaced by 90° from the main winding as shown in the figure 1.

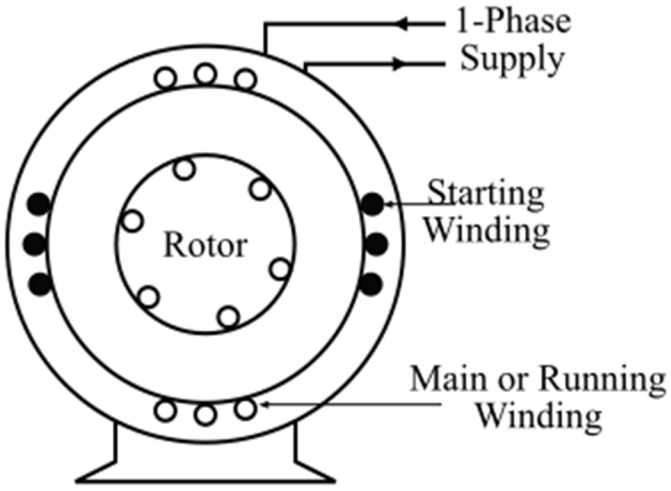

Fig. 1

The starting winding operates only during the brief period when the motor starts up. The starting and the main windings are so designed that the starting winding (S) has a high resistance and relatively low reactance while the main winding (M) has relatively low resistance and high reactance so that the currents flowing in the two windings have reasonable phase difference (α) of about 25° to 30° as shown in the phasor diagram.

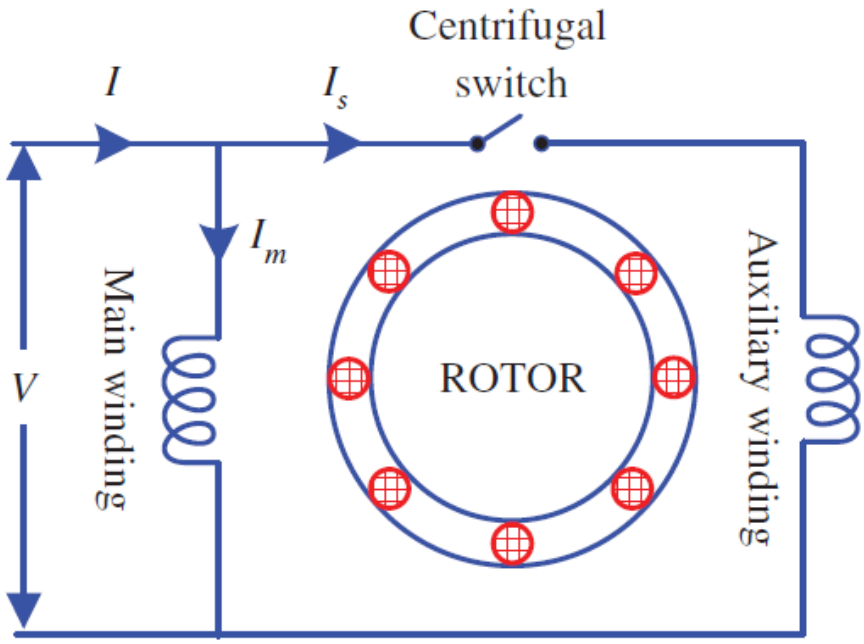

Fig. 2

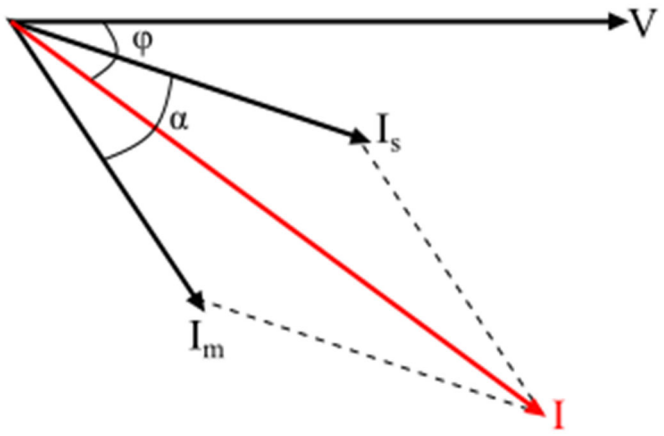

Fig. 3

1.1.1 Operation of Split-Phase Induction Motor

When the starting winding of the motor is connected to the source of single-phase AC supply, the starting winding carries a current I_s while the main winding carries a current I_m as shown in the connection diagram. As the starting winding is made highly resistive whereas the main winding highly inductive. Therefore, the currents I_s and I_m in the two windings have a reasonable phase difference of about 25° to 30° between them. As a result, a weak revolving field is produced which starts the motor. The starting torque of the split-phase motor is given by,

$$T_{st} = k\, I_s\, I_m \sin\alpha \qquad (1)$$

Where, k is a constant of proportionality whose value depends upon the design of the machine.

When the motor speed reaches about 80% of the synchronous speed, then the centrifugal switch isolates the starting winding from the circuit. Now, the motor operates as a single-phase induction motor and continues to accelerate till it reaches the normal speed. The normal speed of the motor is less than the synchronous speed and it depends upon the mechanical load on the shaft of the motor.

1.1.2 Characteristics of Split-Phase Induction Motor

The characteristics of split-phase induction motors are given as follows:

- The split-phase motor has the starting current about 7 to 8 times of the full load current.
- The starting torque of a split-phase induction motor is about 1.5 times of the full-load torque.
- The maximum or pull-out torque is about 2.5 times of the full-load torque at about 75% of synchronous speed.
- Split-phase induction motors are less expensive; thus, they are very popular motors in the market.
- Split-phase induction motors are suitable for the applications where the starting period is small. Since the starting winding of the split-phase motor has high resistance, it heats up quickly. If the starting period exceeds 5 seconds, the starting winding may burn out unless the motor is protected by a thermal relay.
- The power rating of split-phase induction motors lies between 60 W and 250 W.

1.2 Capacitor start induction motor

This motor is similar to the split-phase motor, but the capacitor is also connected to auxiliary winding in series. This is a modified version of the split-phase motor.

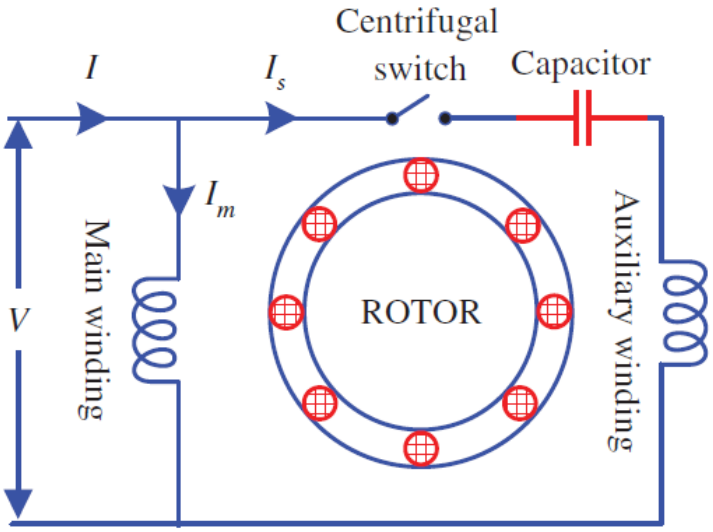

Fig. 4

1.2.1 Operation theory of Capacitor-start induction motor

A capacitor-start induction motor is a type of single-phase induction motor in which the starting torque is produced by using a starting capacitor and an auxiliary winding. The capacitor-start induction motor consists of a starting winding (S) and a main or running winding (M). Both the winding has the same number of turns. A starting capacitor (C) is connected in series with the starting winding as shown in the circuit diagram of the motor. The value of the starting capacitor is so chosen that the starting current I_s leads the main winding current $\boldsymbol{I_m}$ by an angle (α) of 90°. The starting torque of the capacitor-start induction motor is given by,

$$T_{st} = k\, I_s\, I_m \sin\alpha = k\, I_s\, I_m \qquad (2)$$

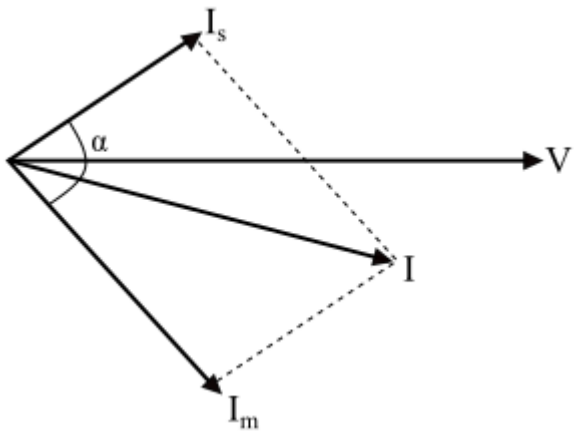

Fig. 5

As the value of phase angle (α) is very high (α = 90°), consequently, the capacitor-start induction motor has very high starting torque. As soon as the speed of the motor reaches about 75% of the synchronous speed, then the centrifugal switch isolates the starting winding from the motor circuit. Now, the motor operates as a 1-phase induction motor and continues to accelerate till it reaches the normal speed. The normal speed of the motor depends upon the load on the motor.

1.2.2 Characteristics of Capacitor-start Induction Motor

- The capacitor-start induction motor develops a very high starting torque about 3 to 4.5 times of the full-load torque.
- The value of the starting capacitor must be large and the starting winding resistance low to obtain a starting torque.
- The capacitor-start induction motor requires the starting capacitor of high VAR rating, thus, the electrostatic capacitors of the order of 250 F are used.
- The starting capacitor is a short-time rated capacitor.

- The capacitor-start induction motors possess good starting and running characteristics.
- For a capacitor-start induction motor, the starting current is small and the starting torque is high. Therefore, starting winding of a capacitor-start induction motor heats up less quickly and is well suited to the application where the starting period is either small or prolonged.

1.3 Capacitor-Start Capacitor-Run Induction Motor (Two-Value Capacitor Method)

The capacitor-start capacitor-run motor is a type of single-phase induction motor. The capacitor-start capacitor-run induction motor is also known as ***two value capacitor motor***. The schematic diagram of a capacitor-start capacitor run induction motor is shown in fig 6.

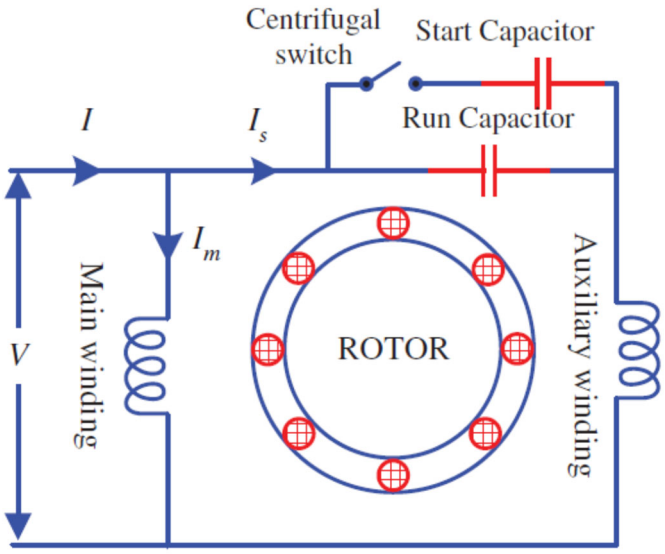

Fig. 6

1.3.1 Operation theory of Capacitor-start induction motor

The capacitor-start capacitor-run induction motor consists of a squirrel cage rotor and its stator has two windings, viz. the **starting** or **auxiliary winding** and the **main** or **running winding**. The two windings are displaced by an angle of 90° in the space.

This motor uses two capacitors − the **starting capacitor** *(C_S)* and the **running capacitor** *(C_R)*. The two capacitors are connected in parallel at the instant of starting. In order to obtain a high starting torque, a large starting current is required. For this, the capacitive reactance in the starting winding should be low.

Since the reactance of the starting capacitor is given by,

$$X_S = \frac{1}{\omega C_S} \tag{3}$$

Hence, for X_S to be small, the value of starting capacitor *(C_S)* should be large. The starting capacitor C_S is a short-time rated electrolytic capacitor. During the normal operation of the motor, the rated line current should be smaller than the starting current. Therefore, the capacitive reactance of the running capacitor should be high and is given by,

$$X_R = \frac{1}{\omega C_R} \tag{4}$$

Hence, for X_R to be high, the value of the running capacitor *(C_R)* should be small. The running capacitor is a long-time rated capacitor and is usually of oil-filled paper construction.

As the motor attains the normal speed, the starting capacitor *(C_S)* is disconnected from the motor circuit by a centrifugal switch (S) and the running

capacitor *(C_R)* remains permanently connected in the circuit. Since one capacitor *(C_S)* is used only at starting and the other capacitor *(C_R)* for continuous running, the motor is known as *capacitor-start capacitor-run motor*. The phasor diagram of the capacitor-start capacitor-run motor is shown below. At starting both the capacitors are in the circuit, therefore, the phase angle φ is greater than 90°. When the starting capacitor *(C_S)* is disconnected from the circuit, then the phase angle becomes 90° electrical.

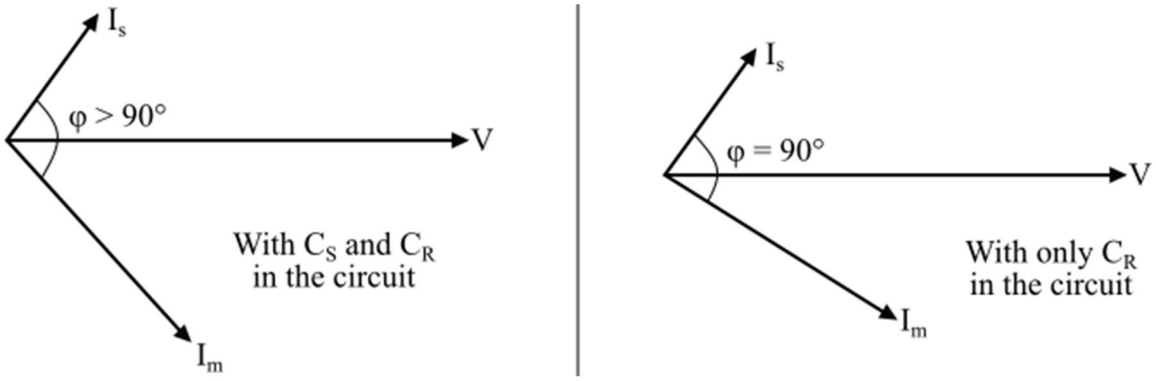

Fig. 7

1.3.2 Characteristics of Capacitor-Start Capacitor-Run Induction Motor

Following are the primary characteristics of a capacitor-start capacitor-run induction motor

- These motors have quiet and smooth-running operation.
- They have high efficiency.
- These motors produce constant torque and not a pulsating torque.
- Because of the constant torque, the motor is vibration free.