Single-Phase Induction Motor

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Single-Phase Induction Motor

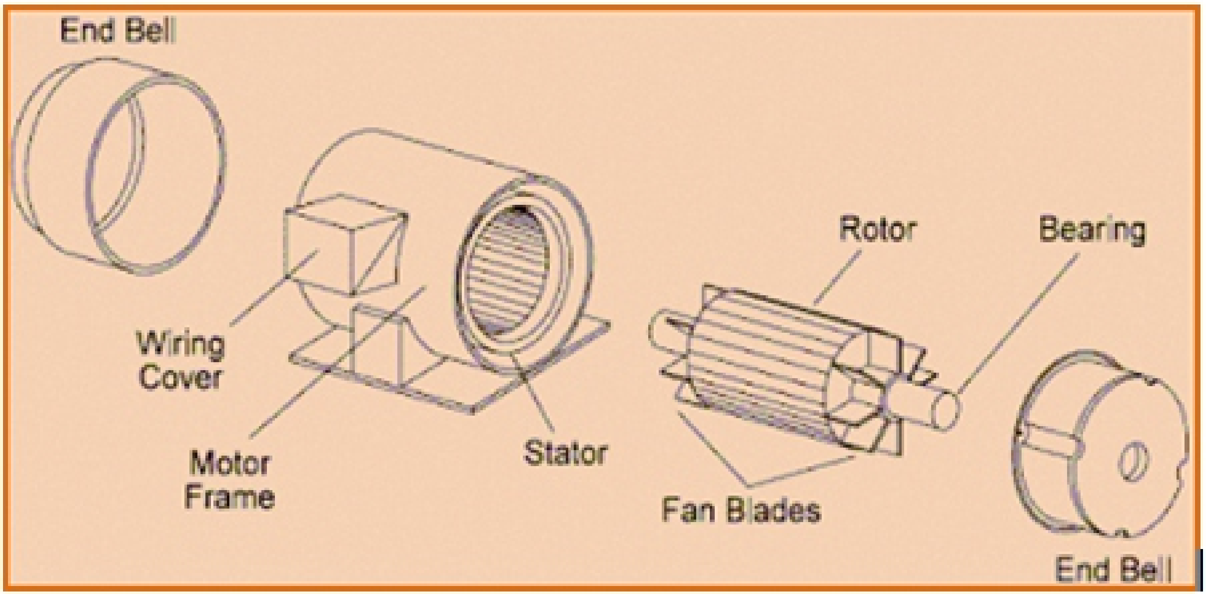
An electrical machine that is used for converting electrical energy into mechanical energy is called as an electric motor. Electric motors are classified into different types based on different criteria. Primarily, electric motors are categorized as AC motors powered by AC powersources (single phase motor poweredbya single phase supplysource and three phase motor powered by three phase supply source), and DC motors powered by DC power sources. Again, AC motors are classified as induction motors, synchronous motors, asynchronous motors, repulsion motor, universal motor, and so on. DC motors are classified as series motor, shunt motor, permanent magnet DC motor, brushed DC motor, brushless DC motor or BLDC motor and so on. Here, let us discuss in brief about single phase induction motor.

Introduction

Single phase induction motor is the most commonly used driving systems in domestic, commercial, agricultural, industrial and other low power applications. These motors are available in different ratings from fractional horsepower to hundreds of horsepower. Due to the rugged design, low maintenance, reliable operation and cheaper cost, single phase motors are most familiar over all other electric motors. Most of the domestic appliance like fans, washing machines, hair driers, mixers, blowers, refrigerators, etc uses this motor for their functioning which are mostly rated inthe fractional horsepower range.

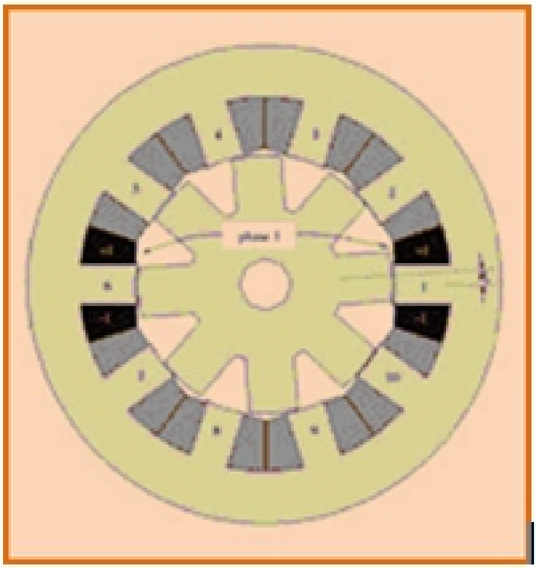
Construction

As the name indicates, these motors utilize single-phase-power supply for their operations.A single phase induction motor construction is similar to a 3-phase squirrel cage induction motor consists of single-phase winding on the stator and a squirrel-cage rotor identical to a 3-phase motor.



Stator

The stator consists of set of stacked lamination stampings which are slotted on its periphery.These stampings carries the single phase winding which is excited by single phase AC supply. These stampings are made up of silicon steel to reduce the hysteresis losses and laminated construction to reduce the eddy current losses. The stator winding is wound for a certain number of poles, which decides the synchronous speed of the motor.



Rotor

It is of squirrel cage type construction similar to three phase induction motor consisting of uninsulated aluminum or copper bars on cylindrical shaped slots in rotor periphery. These slots are placed at certain angle not made parallel to each other to avoid magnetic locking. The copper or aluminium bars are placed on slots, stacked and shorted at both ends with end rings on rotor core.

Working Principle

Whenever single phase AC supply is given to the stator, current flows through the stator conductors and a magnetic field is built up around it. Depends on the coil winding like reversing the direction in which one coil is wound in the stator relative to the adjacent coil causes the current flow becomes reversed, which in turn causes to change the magnetic field polarity such as creating an alternate north and south poles in the stator.

If we consider a three-phase motor usually operating with a three-phase-power supply, then a rotating magnetic field is produced due to the phase shift of 1200 between any two phases of the available three phases. Due to this, the current is induced in the rotor and causes an interaction between the stator and rotor which results in the rotor rotation.

Why Single-Phase Induction Motor is Not-Self-Start?

If we consider the double field revolving theory, then every alternating quantity is resolved into two components. The magnitude of each of these two components is equal to the half of the maximum magnitude of the main alternating quantity. The direction of rotation of these two components is opposite to each other.

Thus, the flux $Ø_m$ can be resolved into two components as shown below:

$$\frac{Ø_m}{2} \text{ and } -\frac{Ø_m}{2}$$

Hence, one component rotates in clockwise direction and the other component rotates in the anti clockwise direction.

If we give single phase AC supply to the single phase induction motor, then a flux is produced with magnitude $Ø_m$. As we discussed earlier, this flux is resolved into two components of equal magnitude of $\frac{Ø_m}{2}$. These components rotate in the opposite direction with each other with the synchronous speed of Ns. If we consider the flux of these two components as $Ø_f$ as the flux of the forward component and $Ø_b$ as the flux of the backward component.

Thus, the resultant of these two fluxes at any instant of time is equal to the instantaneous stator flux at that particular instant and is given as:

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$$\phi_r = \frac{\phi_m}{2} + \frac{\phi_m}{2} \text{ or } \phi_r = \phi_f + \phi_b$$

Now, in the starting condition of the single phase induction motor, these two fluxes are equal in magnitude and opposite in direction. Hence, these two cancel each other and no net torque is produced, so the single-phase induction motors are not self-starting.

When the motor is connected to a single-phase power supply, the main winding carries an alternating current. It is logical that the least expensive, most reduced upkeep sort engine ought to be utilized most regularly. These are of different types based on their way of starting since these are of not self-starting. Those are split phase, shaded pole and capacitor motors. Again capacitor motors are capacitor start, capacitor run and permanent capacitor motors. Permanent capacitor motor is shown below.

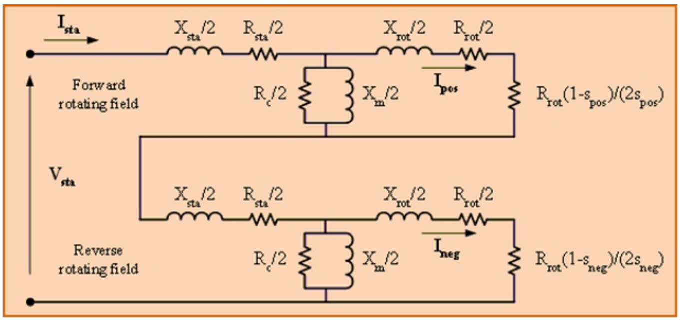
In these types of motors the start winding can have a series capacitor and/or a centrifugal switch. When the supply voltage is applied, current in the main winding lags the supply voltage because of the main winding impedance. And current in the start winding leads/lags the supply voltage depending on the starting mechanism impedance. The angle between the two windings is sufficient phase difference to provide a rotating magnitude field to produce a starting torque. The point when the motor reaches 70% to 80% of synchronous speed, a centrifugal switch on the motor shaft opens and disconnects the starting winding.

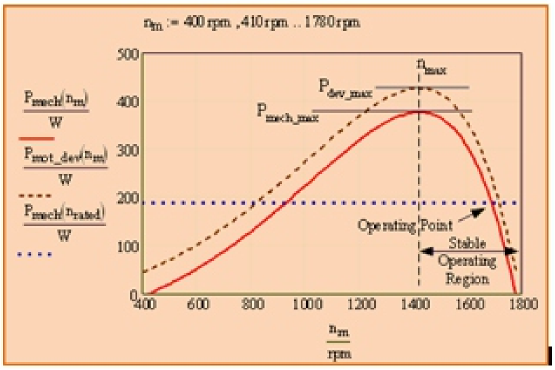
Single-Phase Induction Motor

But, in single-phase motors, which are running with only single-phase-power supply – there are different ways to start these motors – one such way is by using the single-phase-motor starter. In all these methods, mostly a second phase, called as an auxiliary phase or start phase, is produced to create a rotating magnetic field in the stator.

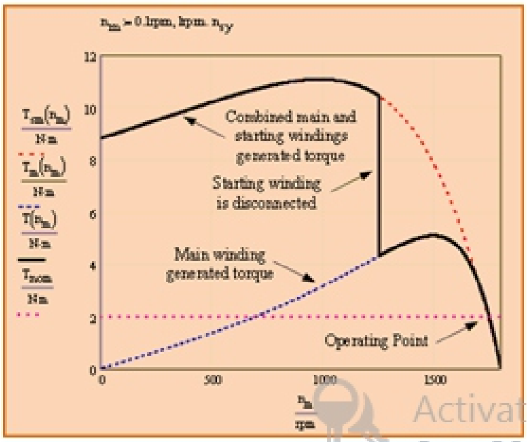
Single Phase Induction Motor-Equivalent Circuit

The above figure shows the equivalent circuit diagram of the single phase induction motor. As we discussed earlier, the total flux is divided into two equal components (and are opposite in direction). Here, the total reactance is divided into two components as represented in the above equivalent circuit diagram.





The above figure indicates the speed vs power (mechanical and electrical power) characteristics of a single phase induction motor.



The above figure represents the torque vs speed characteristics of a single-phase induction motor.

Types of Single-Phase Induction Motors

Single phase induction motors are further classified into various types such as:

- Split-phase induction motors
- Capacitor-start induction motors
- Capacitor-start capacitor-run induction motors
- Shaded pole induction motors

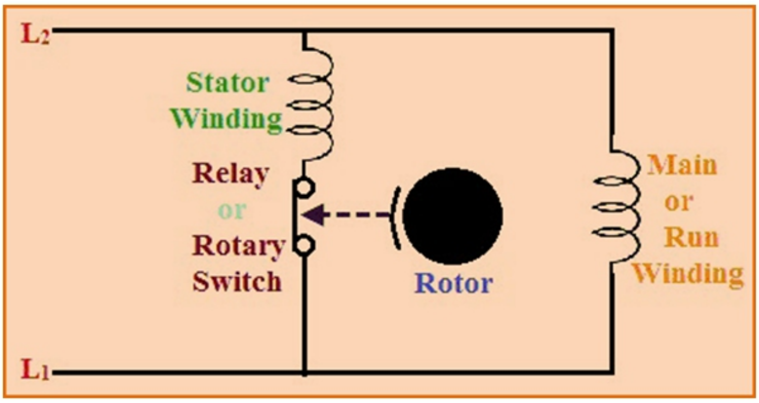
The single-phase induction motors are classified based on the starting methods used for starting the motor. Thus, it is easy to understand about the types of single phase motors by learning about the starting methods of single phase induction motors.

Starting Methods of Single-Phase Motor

There are different methods to start the 1-Ø motors, they are as follows:

- Split Phase or Resistance Start
- Capacitor Start
- Permanent Split Capacitor
- Capacitor Start Capacitor Run
- Electronic Starter for Single Phase Motor

Split Phase or Resistance Start Single-Phase Induction Motor

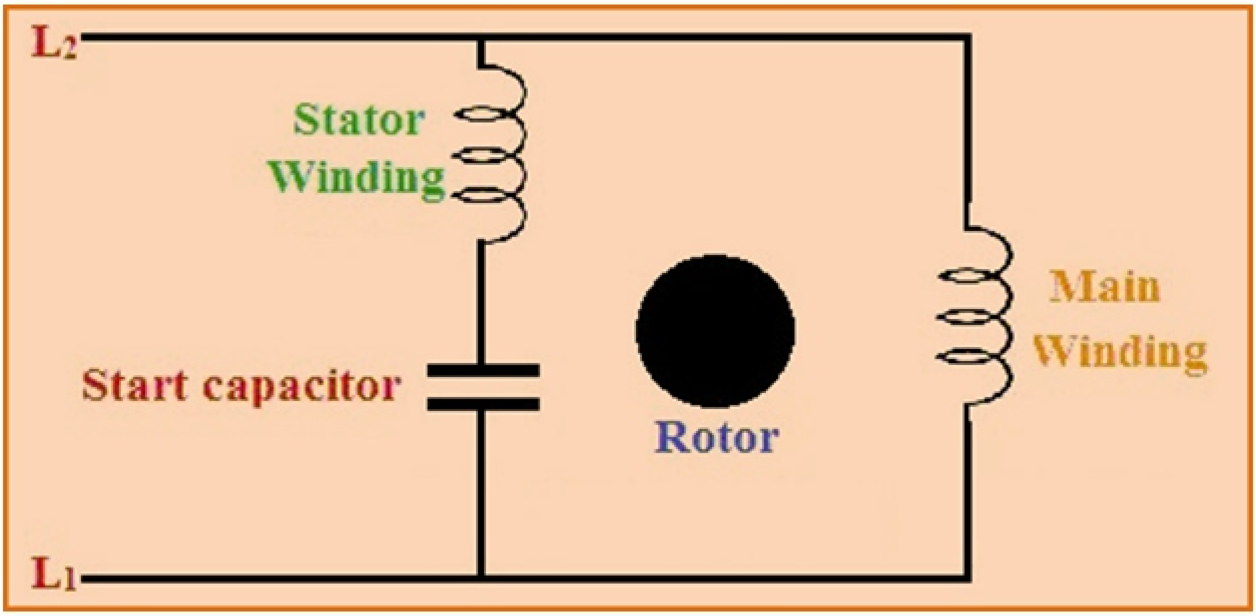


This method is majorly employed in simple industrial duty motors. These motors consist of two sets of windings, namely, start winding and main or run winding. The start winding is made from small wire with which it offers high resistance to electrical flow compared to run winding. Due to this high resistance, magnetic field is developed in start winding by the current earlier than the run winding magnetic field development.Thus, two fields are 300 apart, but this small angle itself is enough to start the motor.

Capacitor Start Single-Phase Induction Motor

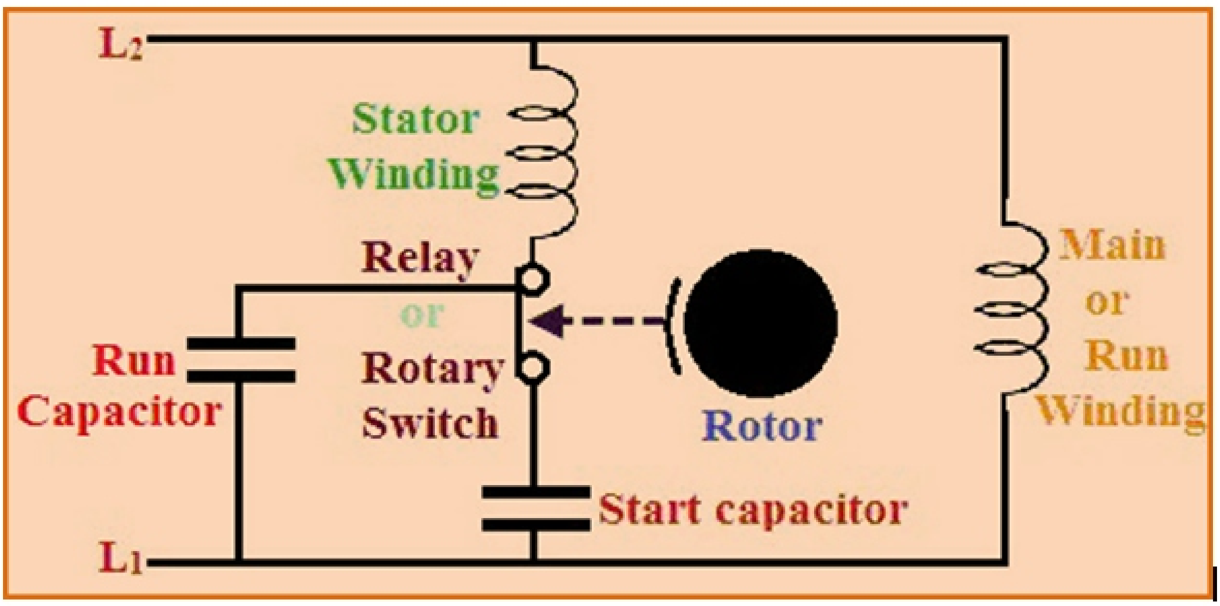
The windings of the capacitor start motor are almost similar to the split-phase motor. The poles of the stator are set apart by 900. To activate and deactivate the start windings, a normally closed switch is used and capacitor is placed in series with the start winding.

Due to this capacitor, current leads voltage, thus this capacitor is used to start the motor and it will be disconnected from the circuit after obtaining the 75% of the rated speed of the motor.



Capacitor Start Single-Phase Induction Motor

In a capacitor start method, a capacitor has to be disconnected after the motor reaches to a specific speed. But, in this method, a run-type capacitor is placed in series with the start winding or auxiliary winding. This capacitor is used continuously, and it doesn't require any switch to disconnect it as it is not used to start the motor only.The starting torque of the PSC is similar to the spilt-phase motors, but with a low starting current.



Capacitor-Start Capacitor-Run Single-Phase Induction Motor

The windings of the capacitor start motor are almost similar to the split-phase motor. The poles of the stator are set apart by 900. To activate and deactivate the start windings, a normally closed switch is used and capacitor is placed in series with the start winding.

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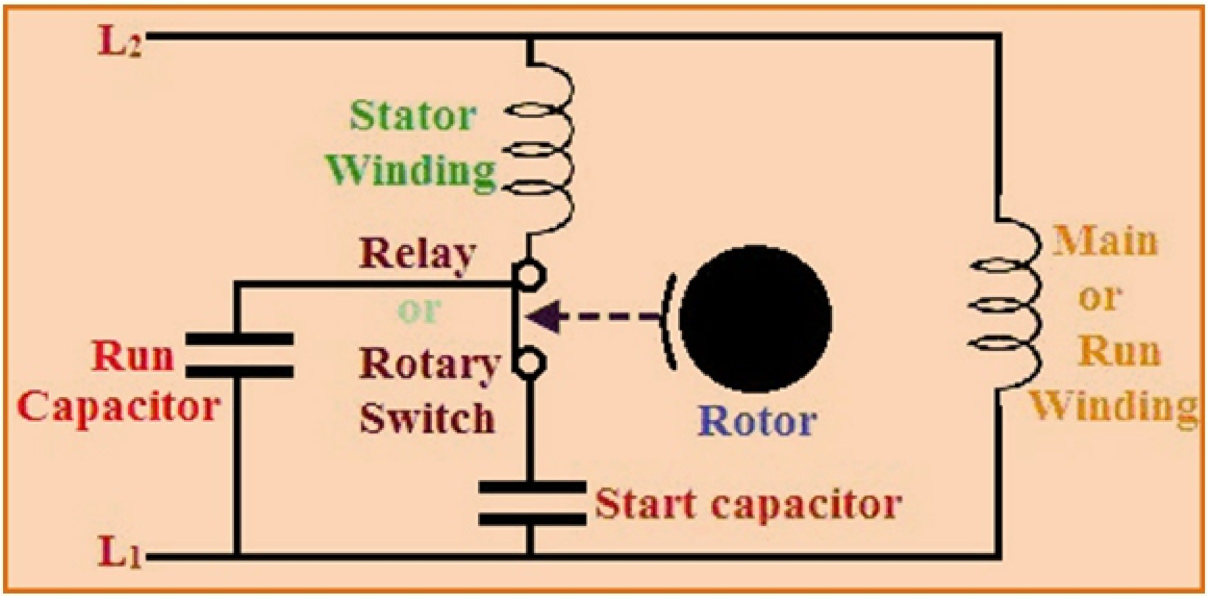

The features of the capacitor start and PSC methods can be combined with this method. Run capacitor is connected in series with the start winding or auxiliary winding, and a start capacitor is connected in the circuit using a normally closed switch while starting the motor. Start capacitor provides starting boost to motor and PSC provides high running to the motor. It is more costly, but still facilitates high starting and breakdown torque along with smooth running characteristics at high horsepower ratings.

Applications of Single-Phase Induction Motor

We learnt that single phase induction motors are classified into various types. Thus, each single phase motor is used for specific applications as discussed below:

- Split phase induction motors consists of low starting current and adequate starting torque. Thus, this type of single phase induction motors can be used in centrifugal pumps, fans, blowers, washing machines, mixer grinders, etc. this type of single phase induction motors are available in the range of 1/20 to ½ KW.
- Capacitor start single phase induction motors are generally available in the range up to 6KW. These capacitor start single phase induction motors are frequently used in grinders, conveyers, air conditioners, and so on.

- Shaded pole single phase induction motors are available in the range of 1/300 to 1/20 KW. These shaded pole single phase induction motors are having low starting torques, hence they are typically used in hair dryers, toys, electric clocks, record players, small instruments, etc.
- Capacitor-start capacitor-run single phase induction motors are having high starting torque and high power factor, hence, these are used in compressors, conveyors, pumps, and stokers.
- Permanent-slip capacitor motors are having low starting torque, hence, these are used in blowers and fans.

Comparison between Single-Phase and Three-Phase Induction Motors

- The single-phase induction motor construction is simple compared to the three-phase induction motor.
- The single phase induction motors are reliable and economical compared to the three phase induction motors.
- The single-phase induction motor's power factor is less compared to the three-phase induction motors.
- If we consider the efficiency, then the three-phase induction motors are better compared to the single-phase induction motors.

Hope, this white-paper given you a brief information about single-phase induction motors. Furthermore, technical assistance can be provided based on your queries posted in the comments section below.