**History of induction motor**

An induction motor (or asynchronous motor) is a type of alternating current motor where power is supplied to the rotor by means of electromagnetic induction.

An electric motor converts electrical power to mechanical power in its rotor (rotating part). There are several ways to supply power to the rotor. In a DC motor this power is supplied to the armature directly from a DC source, while in an induction motor this power is induced in the rotating device. An induction motor is sometimes called a rotating transformer because the stator (stationary part) is essentially the primary side of the transformer and the rotor (rotating part) is the secondary side. The primary side's currents evokes a magnetic field which interacts with the secondary sides EMF to produce a resultant torque, henceforth serving the purpose of producing mechanical energy. Induction motors are widely used, especially polyphase induction motors which are frequently used in industrial drives. Induction motors are now the preferred choice for industrial motors due to their rugged construction, absence of brushes (which are required in most DC motors) and — thanks to modern power electronics — the ability to control the speed of the motor. A 3-phase power supply provides a rotating magnetic field in an induction motor. The first induction motor was realized by Galileo Ferraris in 1885 in Italy. In 1888, Ferraris published his research in a paper to the Royal Academy of Sciences in Turin (later, in the same year, Tesla gained U.S. Patent 381,968) where he exposed the theoretical foundations for understanding the way the motor operates. The induction motor with a cage was invented by Mikhail Dolivo- Dobrovolsky about a year later. Technological development in the field has improved to where a 100 hp (74.6 kW) motor from 1976 takes the same volume as a 7.5 hp (5.5 kW) motor did in 1897. Currently, the most common induction motor is the cage rotor motor. The basic difference between an induction motor and a synchronous AC motor is that in the latter a current is supplied onto the rotor. This then creates a magnetic field which, through magnetic interaction, links to the rotating magnetic field in the stator which in turn causes the rotor to turn. It is called synchronous because at steady state the speed of the rotor is the same as the speed of the rotating magnetic field in the stator. By way of contrast, the induction motor does not have any direct supply onto the rotor; instead, a secondary current is induced in the rotor. To achieve this, stator windings are arranged around the rotor so that when energized with a polyphase supply they create a rotating magnetic field pattern which sweeps past the rotor. This changing magnetic field pattern induces current in the rotor conductors. These currents interact with the rotating magnetic field created by the stator and in effect cause a rotational motion on the rotor. However, for these currents to be induced, the speed of the physical rotor must be less than the speed of the rotating magnetic field in the stator, or else the magnetic field will not be moving relative to the rotor conductors and no currents will be induced. If by some chance this happens, the rotor typically slows slightly until a current is re-induced and then the rotor continues as before. This difference between the speed of the rotor and speed of the rotating magnetic field in the stator is called slip. It is unit less and is the ratio between the relative speeds of the magnetic field as seen by the rotor (the slip speed) to the speed of the rotating stator field. Due to this an induction motor is sometimes referred to as an asynchronous machine most frequently used in industries. The relationship between the supply frequency, f, the number of poles, p, and the synchronous speed (speed of rotating field), is given by: From this relationship:

Where

n = Revolutions per minute (rpm)

f = AC power frequency (hertz)

p = Number of poles per phase (an even number)

The rotor speed is: where s is the slip.

Slip is calculated using: A synchronous motor always runs at synchronous speed with 0% slip. Note on the use of p: Some texts refer to number of pole pairs per phase instead of number of poles per phase. For example a 6 pole motor would have 3 pole pairs. The equation of synchronous speed then becomes: where p is the number of pole pairs per phase. The stator consists of wound 'poles' that carry the supply current to induce a magnetic field that penetrates the rotor. In a very simple motor, there would be a single projecting piece of the stator (a salient pole) for each pole, with windings around it; in fact, to optimize the distribution of the magnetic field, the windings are distributed in many slots located around the stator, but the magnetic field still has the same number of north-south alternations. The number of 'poles' can vary between motor types but the poles are always in pairs (i.e. 2, 4, 6, etc.).

Induction motors are most commonly built to run on single-phase or three-phase power, but two-phase motors also exist. In theory, two-phase and more than three phase induction motors are possible; many single-phase motors having two windings and requiring a capacitor can actually be viewed as two-phase motors, since the capacitor generates a second power phase 90 degrees from the single-phase supply and feeds it to a separate motor winding. Single-phase power is more widely available in residential buildings, but cannot produce a rotating field in the motor (the field merely oscillates back and forth), so single-phase induction motors must incorporate some kind of starting mechanism to produce a rotating field. They would, using the simplified analogy of salient poles, have one salient pole per pole number; a four-pole motor would have four salient poles. Three-phase motors have three salient poles per pole number, so a four-pole motor would have twelve salient poles. This allows the motor to produce a rotating field, allowing the motor to start with no extra equipment and run more efficiently than a similar single-phase motor. There are three types of rotor:

**Squirrel-cage rotor**

The most common rotor is a squirrel-cage rotor. It is made up of bars of either solid copper (most common) or aluminum that span the length of the rotor, and those solid copper or aluminum strips can be shorted or connected by a ring or some times not, i.e. the rotor can be closed or semi-closed type. The rotor bars in squirrel-cage induction motors are not straight, but have some skew to reduce noise and harmonics.

**Slip ring rotor**

A slip ring rotor replaces the bars of the squirrel-cage rotor with windings that are connected to slip rings. When these slip rings are shorted, the rotor behaves similarly to a squirrel-cage rotor; they can also be connected to resistors to produce a high resistance rotor circuit, which can be beneficial in starting

**Solid core rotor**

A rotor can be made from solid mild steel. The induced current causes the rotation.

The synchronous rotational speed of the rotor (i.e. the theoretical unloaded speed with no slip) is controlled by the number of pole pairs (number of windings in the stator) and by the frequency of the supply voltage. Before the development of cheap power electronics, it was difficult to vary the frequency to the motor and therefore the uses for the induction motor were limited. R has no brushes and is easy to control, many older DC motors are being replaced with induction motors and accompanying inverters in industrial applications.

***Three Phase***

**Direct-on-line starting**

The simplest way to start a three-phase induction motor is to connect its terminals to the line. This method is often called "direct on line" and abbreviated DOL.

In an induction motor, the magnitude of the induced EMF in the rotor circuit is proportional to the stator field and the slip speed (the difference between synchronous and rotor speeds) of the motor, and the rotor current depends on this EMF. When the motor is started, the rotor speed is zero. The synchronous speed is constant, based on the frequency of the supplied AC voltage. So the slip speed is equal to the synchronous speed, the slip ratio is 1, and the induced EMF in the rotor is large. As a result, a very high current flows through the rotor. This is similar to a transformer with the secondary coil short circuited, which causes the primary coil to draw a high current from the mains. When an induction motor starts DOL, a very high current is drawn by the stator, in the order of 5 to 9 times the full load current. This high current can, in some motors, damage the windings; in addition, because it causes heavy line voltage drop, other appliances connected to the same line may be affected by the voltage fluctuation. To avoid such effects, several other strategies are employed for starting motors.

**Star-delta starters**

An induction motor's windings can be connected to a 3-phase AC line in two different ways:

Wye (star in Europe), where the windings are connected from phases of the supply to the neutral;

Delta (sometimes mesh in Europe), where the windings are connected between phases of the supply.

A delta connection of the machine winding results in a higher voltage at each winding compared to a wye connection (the factor is). A star-delta starter initially connects the motor in wye, which produces a lower starting current than delta, then switches to delta when the motor has reached a set speed. Disadvantages of this method over DOL starting are: Lower starting torque, which may be a serious issue with pumps or any devices with significant breakaway torque increased complexity, as more contactors and some sort of speed switch or timers are needed. Two shocks to the motor (one for the initial start and another when the motor switches from wye to delta)

**Variable-frequency drives**

Variable-frequency drives (VFD) can be of considerable use in starting as well as running motors. A VFD can easily start a motor at a lower frequency than the AC line, as well as a lower voltage, so that the motor starts with full rated torque and with no inrush of current. The rotor circuit's impedance increases with slip frequency, which is equal to supply frequency for a stationary rotor, so running at a lower frequency actually increases torque.

**Resistance starters**

This method is used with slip ring motors where the rotor poles can be accessed byway of the slip rings. Using brushes, variable power resistors are connected in series with the poles. During start-up the resistance is large and then reduced to zero at full speed. At start-up the resistance results in the stator's field strength being weakened less. As a result, the inrush current is reduced. Another important advantage is higher start-up torque. As well, the resistors generate a phase shift in the field resulting in the magnetic force acting on the rotor having a favorable angle [citation needed].

**Autotransformer starters**

Such starters are called as auto starters or compensators, consists of an auto-transformer.

**Series Reactor starters**

In series reactor starter technology, an impedance in the form of a reactor is introduced in series with the motor terminals, which as a result reduces the motor terminal voltage resulting in a reduction of the starting current; the impedance of the reactor, a function of the current passing through it, gradually reduces as the motor accelerates, and at 95 % speed the reactors are bypassed by a suitable bypass method which enables the motor to run at full voltage and full speed. Air core series reactor starters or a series reactor soft starter is the most common and recommended method for fixed speed motor starting.

***Single Phase***

In a single phase induction motor, it is necessary to provide a starting circuit to start rotation of the rotor. If this is not done, rotation may be commenced by manually giving a slight turn to the rotor. The single phase induction motor may rotate in either direction and it is only the starting circuit which determines rotational direction.

For small motors of a few watts the start rotation is done by means of a single turn of heavy copper wire around one corner of the pole. The current induced in the single turn is out of phase with the supply current and so causes an out-of-phase component in the magnetic field, which imparts to the field sufficient rotational character to start the motor. Starting torque is very low and efficiency is also reduced. Such shaded-pole motors are typically used in low-power applications with low or zero starting torque requirements, such as desk fans and record players. Larger motors are provided with a second stator winding which is fed with an out-of-phase current to create a rotating magnetic field. The out-of-phase current may be derived by feeding the winding through a capacitor, or it may derive from the winding having different values of inductance and resistance from the main winding. In some designs the second winding is disconnected once the motor is up to speed, usually either by means of a switch operated by centrifugal force acting on weights on the motor shaft, or by a positive temperature coefficient thermistor which after a few seconds of operation heats up and increases its resistance to a high value, reducing the current through the second winding to an insignificant level. Other designs keep the second winding continuously energized during running, which improves torque. Control of speed in induction motor can be obtained in 3 ways 1.scalar control 2.vector control 3.direct torque control.