A Review On Analysis Of Different Types Of Induction Motors And Their Performance

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Abstract

An induction motor is a common type of electric motor widely used in various industrial and domestic applications. It operates based on the principles of electromagnetic induction, discovered by Michael Faraday in the early 19th century. This technology forms the backbone of the modern electrical industry, powering everything from fans and pumps to conveyor belts and manufacturing equipment.

Introduction:

Induction motors are the most commonly used motors. Induction motors are also known as asynchronous motors because they always run slower than synchronous speed.

Based on the type of rotor construction, they are divided into two types as follows:

- **Squirrel Cage Motor**
- **Slip Ring Motor**

A 3 phase squirrel cage induction motor is a type of three phase induction motor which functions based on the principle of electromagnetism. It is called a 'squirrel cage' motor because the rotor inside of it – known as a 'squirrel cage rotor' – looks like a squirrel cage. This rotor is a cylinder of steel laminations, with highly conductive metal (typically aluminium or copper) embedded into its surface. When an alternating current is run through the stator windings, a rotating magnetic field is produced.

Squirrel cage induction motor is the simplest and most widely used type of asynchronous motor. Its rotor coil is cast aluminium and shaped like a squirrel cage, so it is called a "squirrel cage motor". These motors are a specific kind of induction motor, which uses the electromagnetic induction effect to transform electrical current into rotational energy. This article will explain the principles of squirrel cage motors, their specifications, and what kinds of applications they are used for. This way, we can make informed choices when choosing the right motor.

Squirrel Cage Induction Motor

A 3 phase squirrel cage induction motor is a type of 3-phase induction motor which functions based on the principle of electromagnetism. It is called a "squirrel cage" motor because the rotor inside of it looks like a squirrel cage.

This rotor is a cylinder of steel laminations, with highly conductive metal (typically aluminium or copper) embedded into its surface. When an alternating current is run through the stator windings, a rotating magnetic field is produced.

This induces a current in the rotor winding, which produces its own magnetic field. The interaction of the magnetic fields produced by the stator and rotor windings produces torque on the squirrel cage rotor.

One big advantage of a squirrel cage motor is how easily you can change its speed-torque characteristics. This can be done by simply adjusting the shape of the bars in the rotor. Squirrel cage induction motors are used a lot in the industry – as they are reliable, self-starting, and easy to adjust.

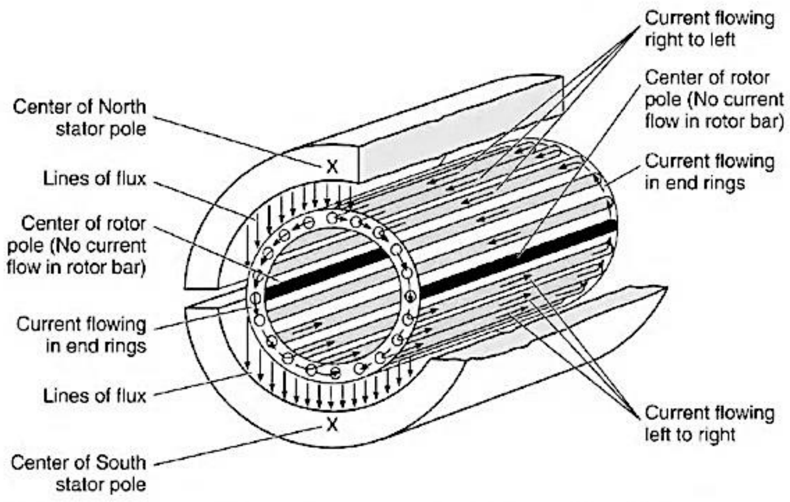

Fig 1: Squrriel Cage Induction Motor

Squirrel Cage Induction Motor Working Principle

In essence, squirrel cage motors work no differently than most other induction motors and only differ in the specific interaction between rotor and stator. Our article all about induction motors contains a discussion of the principal laws behind all induction motors and gives an understanding of how motion is created from magnetism.

Squirrel cage motors maximize electromagnetic induction by utilizing rotor bars to interact with the stator's EMF. The stator usually contains windings of wire which carry an AC current; this current change in sync with a sinusoidal curve which changes the current direction in the wire windings. When the current oscillates, the generated EMF will follow suit, and in certain arrangements will cause it to "rotate" with a frequency similar to the AC frequency. This rotating EMF produces an opposing voltage and EMF in the rotor bars, thus pushing the rotor around, generating rotational motion.

This rotor does not spin at the exact frequency of the AC current and is why squirrel cage motors (as well as other induction motors) are considered asynchronous. There is always some loss, or "slip", between the AC frequency and the rotational frequency of the shaft, and this is a consequence of why the rotor rotates in the first place. If the rotor were to spin at the same frequency, then the magnitude of the force on the rotor bars would equal zero, thus creating no motion. The rotor must always be slower to feel the electromagnetic induction effect as if the rotor is playing a constant game of magnetic "catch-up".

Squirrel Cage Motor Specifications

This paper explains the specifications for all types of induction motors and is a good place to see all the different induction motor characteristics. This paper will focus on what needs to be specified for squirrel cage induction motors, which mainly involve phase. Since these motors are massively popular, NEMA and the IEC have made standardized classes of squirrel cage motors based on their speed-torque characteristics.

Phase type

Induction motors can be driven by a single-phase (one AC frequency) or poly phases (multiple AC frequencies) depending upon the input power supply. Some of the most common types of squirrel cage motor use three phases, meaning the input current is three identical AC frequencies, split by 120 degrees of phase. Three-phase motors are self-starting, meaning the only necessary input is a starting voltage and makes these motors essentially plug-and-play. Single-phase motors are also common, but they are not self-starting and require some initial "shove". This is because one AC frequency is not enough to create a truly "rotating" EMF, and some compensation must be done to simulate the rotating field. This can be done with starters, which can be capacitors, split phases, or other components.

Application of Squirrel Cage Induction Motor

Squirrel cage induction motors are commonly used in many industrial applications. They are particularly suited for applications where the motor must maintain a constant speed is self-starting, or there is a desire for low maintenance.

These motors are commonly used in:

- Centrifugal pumps
- Industrial drives (e.g. to run conveyor belts)
- Large blowers and fans
- Machine tools
- Lathes and other turning equipment

Slip Ring Induction Motor

A slip ring induction motor is referred to as an asynchronous motor as the speed at which it operates is not equal to the synchronous speed of a rotor. The rotor of this type of motor is wound type. It comprises of a cylindrical laminated steel core and a semi-closed groove at the outer boundary to accommodate a 3-phase insulated winding circuit.

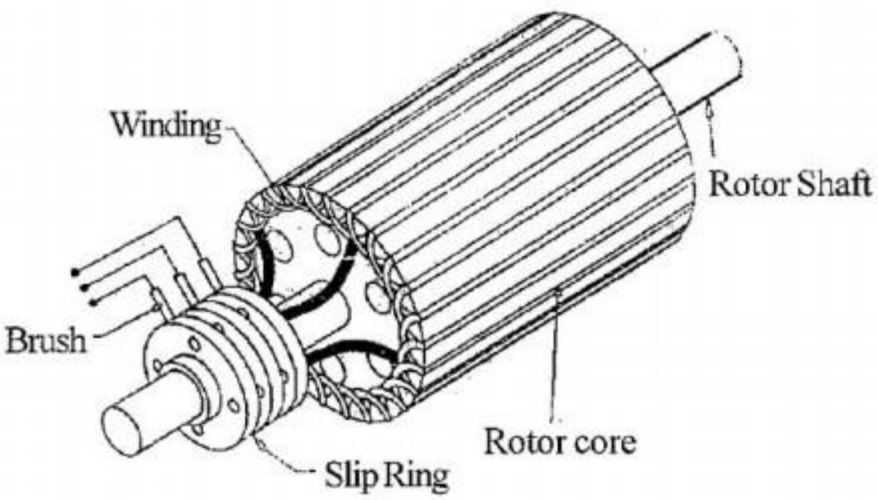

Fig 2: Slip Ring in Induction Motor

As seen in the figure above, the rotor is wound to match the number of poles on the stator. The three terminals of a rotor and three start terminals connecting through slip rings are connected to a shaft. The aim of the shaft is to transmit mechanical power.

Construction

The construction includes two parts:

Stator

- Rotor

Stator

The stator of this motor comprises of various slots that are arranged to support the construction of a 3-phase winding circuit connecting to a 3-phase AC source.

Rotor

The rotor of this motor consists of a cylindrical core with steel laminations. Besides this, the rotor has parallel slots to accommodate 3-phase windings. The windings in these slots are arranged at 120 degrees to each other. This arrangement can reduce noise and avoid irregular pausing of a motor.

Working of Slip Ring Induction Motor

This motor runs on the principle of Faraday's law of electromagnetic induction. When a stator winding is excited with an AC supply, the stator winding produces magnetic flux. Based on faraday's law of electromagnetic induction, the rotor winding gets induced and generates a current of magnetic flux. This induced EMF develops torque that enables the rotor to rotate.

However, the phase difference between the voltage and current do not meet the requirements to generate high starting torque as torque developed is not unidirectional. The external resistance of high value is connected with the circuit to improve the phase difference of a motor. As a result, inductive reactance and phase difference between I and V is reduced. Consequently, this reduction helps the motor to generate high stating torque. The slip ring induction motor diagram is shown below.

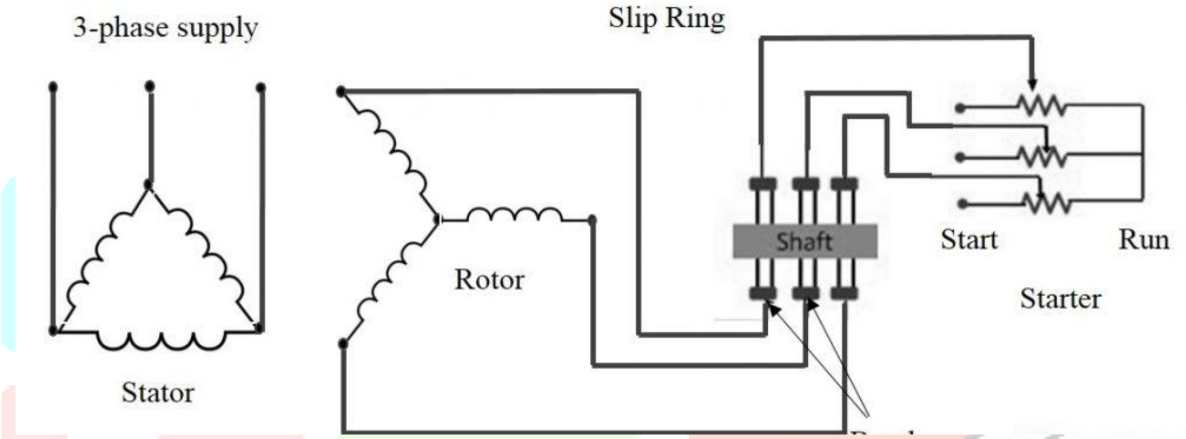

Fig 3: Slip Ring Induction Motor Connection Diagram

Use of Slip Rings

It is defined as the difference between the flux speed and the rotor speed. For an induction motor to produce torque, at least some difference should be there between stator field speed and rotor speed. This difference is called 'slip'. The Slip Ring" is an electromechanical device that aids in transmitting power and electrical signals from stationary to a rotating component.

Slip rings are also known as rotary electrical interfaces, electric rotary joints, swivels, or collector rings. Sometimes, based on the application, the slip ring requires higher bandwidth to transmit data. Slip rings improve the efficiency and performance of a motor by improving system operation and eliminating wires that are dangling from motor joints.

Slip Ring Induction Motor Resistance Calculation

The peak torque occurs if

$r = S_{max}. X$ —— (I)

Where, S_{max} = Slip at pull-out torque

X = Inductance of a rotor

r = resistance of rotor winding

Adding external resistance R to equation (I),

$r+R= (S_{max})'. X$ —— (ii)
From equation (i) and (ii),

$R = r(S'_{max}/S_{max} - 1)$ —— (iii)
By definition of Smax, we get **$Smax = 1 - (N_{max}/N_s)$ —— (iv)**
Putting S'_{max} =1 in equation (iii), we get

$R = r. (1/S_{max}-1)$ —— (v)
Let's say, Ns = synchronous speed of 1000rpm and pull-out torque happens at 900 rpm, equation (iv) reduces to Smax = 0.1 (i.e., 10% slip)

Substitute in equation (v),

$$R = r. (1/0.1 - 1)$$
$$R = 9. r$$

'r' is measured using a multimeter. The resistance value of 9 times higher than of a slip ring rotor resistance is connected externally to experience maximum starting torque.

Slip Ring Induction Motor Speed Control

The speed control of this motor can be done using two methods which include the following.

Effect of Adding External Resistance

Generally, the initiation of these motors occurs when it draws full line voltage which is 6 to 7 times higher than the full load current. This high current can be controlled by external resistance connected in series with the rotor circuit. The external resistance acts as a variable rheostat during the motor kick-off and tweaks automatically to high resistance to get required starting current.

The external resistance reduces high resistance as soon as the motor obtains normal speed and increases the starting torque of a motor. The tweaking of external resistance also aids in decreasing of rotor and stator current but improves the power factor of a motor.

Using Thyristor Circuit

Thyristor On/Off circuit is another way to control the speed of a motor. In this method, rotor AC current is connected to a 3-phase bridge rectifier and connected to external resistance through a filter. The thyristor is connected across external resistance and is switched on/off at high frequency. The ratio of on-time to off-time estimates the actual value of rotor circuit resistance that helps in controlling the speed of a motor by controlling speed-torque characteristics.

Difference between Squirrel Cage and Slip Ring Induction Motor

The difference between these two motors is discussed below.

Slip Ring Motor	Squirrel Cage Motor
It has a rotor of wound type	Its rotor is of squirrel cage type
Rotor has cylindrical core has parallel slots, in which each slot has a bar	Slots are not parallel to each other
Construction is complicated because of slip rings and brushes	Construction is simple
External resistance circuit is connected with a motor	No external resistance circuit as bars of the rotor is completely slotted
Starting torque is high	Torque is low
Efficiency is low	Efficiency is high

Advantages and Disadvantages of Slip Ring Induction Motor

The advantages are

- High and excellent starting torque to support high inertia loads.
- It has a low starting current due to external resistance
- Can take full load current that is 6 to 7 times higher

The disadvantages are

- Includes higher maintenance costs due to brushes and slip rings compared to squirrel cage motor
- Intricate construction
- High copper loss
- Low efficiency and low power factor
- Expensive than 3 phase squirrel cage induction motor

Applications

Some of the **applications of slip ring induction motor** are

- These motors are used where higher torque and low starting current are required.
- Used in applications like elevators, compressors, cranes, conveyors, hoists, and many

Conclusion:

In conclusion, the study of induction motors emphasizes their indispensable role in our technologically driven world. Their efficiency, self-starting capability, and adaptability to various applications make them a cornerstone of electrical engineering. As we look to a future marked by sustainability and technological advancement, the enduring significance of induction motors is evident, driving further research and development in this field.

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