ROHINI COLLEGE OF ENGINEERING AND TECHNOLOGY
AUTONOMOUS INSTITUTION
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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

VII Semester

AU3008 Sensors and Actuators

UNIT – 4 - AUTOMOTIVE ACTUATORS

4.3 Three Phase Machines

- Three Phase Linear Electric Actuators work to convert energy into linear motion. They are typically used in industrial applications where high loads are required.
- A three-phase electric motor uses a three-phase power supply to convert electric energy into mechanical energy. It contains four wires (three hot wires and one neutral wire) and uses three alternating currents of the same frequency. Since it generates a rotating magnetic field, it does not need a capacitor for startup.

Types of Three-Phase Electric Motors

These machines convert electrical energy into mechanical energy.

a. Induction Motors

- **Squirrel Cage Induction Motor**:
  - Simple and robust design.
  - Commonly used in industrial applications.
- **Wound Rotor Induction Motor**:
  - Equipped with slip rings and external resistors for speed control.
  - Used in applications requiring variable speed.

***b.* Synchronous Motors**

- Operate at a constant speed (synchronous speed).
- Require an external DC source for the rotor excitation.
- Used in high-precision applications and as power factor correction devices.

c. **Permanent Magnet Synchronous Motors (PMSM)**

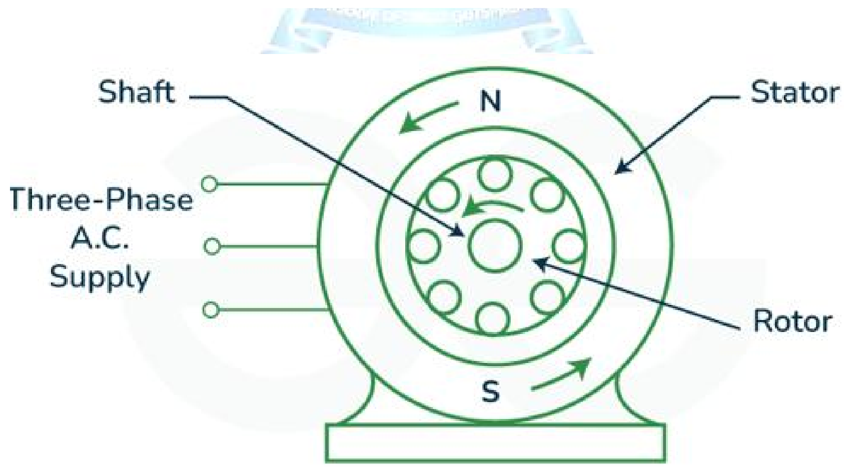
- Rotor uses permanent magnets instead of windings.
- High efficiency, often used in robotics and electric vehicles.

d. **Brushless DC Motors (BLDC)**

- Operate on three-phase AC but mimic DC motor characteristics.
- Used in applications requiring high reliability and efficiency, like drones and appliances.

4.3.1 Three Phase Induction Motors:

- The motor is used to convert an electrical form of energy into mechanical form. According to the type of supply, motors are classified as AC motors and DC motors. In today post, we will discuss the **different types of three phase induction motors** with working and applications.
- The **induction motor** especially **three phase induction motors** are widely used AC motor to produce mechanical power in industrial applications. Almost 80% of the motor is a three-phase induction motor among all motors used in industries. Therefore, the induction motor is the most important motor among all other types of motor.



The diagram represents a **three-phase induction motor**, a common type of electric machine. Let me explain its key components:

1. **Stator**:

   - The stationary part of the motor.
   - Houses the windings where the three-phase AC supply is connected.
   - Generates a rotating magnetic field when powered.
2. **Rotor**:
   - The rotating part of the motor, located inside the stator.
   - Induced currents in the rotor create torque, causing it to rotate.
3. **Shaft**:
   - Connected to the rotor, it transmits the mechanical output to the load.
4. **Three-Phase AC Supply**:
   - Provides electrical power to the stator windings to generate the magnetic field.
5. **Magnetic Poles (N and S)**:
   - Represent the North and South poles of the rotating magnetic field created by the stator.

Working:

1. Stator Winding and 3-Phase Supply:

- The stator has three sets of windings placed 120 degrees apart electrically.
- When a 3-phase AC supply is connected to these windings, it creates a rotating magnetic field. This field rotates at a constant speed called synchronous speed (Ns).

2. Rotating Magnetic Field (RMF):

- The 3-phase supply causes the current in each stator winding to vary sinusoidally.
- This creates a magnetic field that rotates around the stator core.
- The direction of rotation of this RMF depends on the phase sequence of the supply.

3. Rotor Construction:

- The rotor can be of two types:
  - **Squirrel Cage Rotor:** Consists of copper bars embedded in the rotor core, shorted at both ends.
  - **Wound Rotor:** Has 3-phase windings connected to slip rings, allowing external resistance to be added for starting and speed control.

4. Induction of EMF in Rotor:

- As the RMF cuts through the rotor conductors, it induces an electromotive force (EMF) in them according to Faraday's law of electromagnetic induction.
- This induced EMF causes a current to flow in the rotor conductors, since they are shorted in the case of a squirrel cage rotor or connected to an external resistance in the case of a wound rotor.

5. Torque Production:

- The current flowing in the rotor conductors creates its own magnetic field.
- The interaction between the rotor's magnetic field and the stator's RMF produces a torque on the rotor.
- This torque causes the rotor to start rotating.

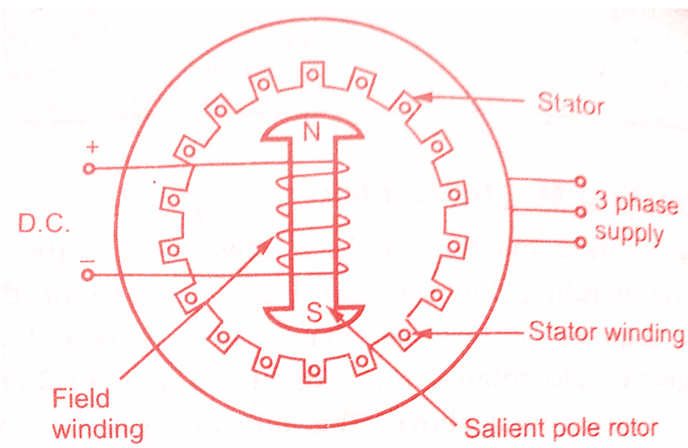
6. Rotor Speed and Slip:

- The rotor speed (Nr) will always be slightly less than the synchronous speed (Ns).
- The difference between these speeds is called slip (S).
- Slip is expressed as a percentage of synchronous speed: S = (Ns - Nr) / Ns * 100%.

7. Back EMF and Rotor Current:

- As the rotor starts rotating, it cuts the stator's magnetic field at a reduced relative speed (slip speed).
- This induces a back EMF in the rotor windings, which opposes the original induced EMF.
- The net EMF across the rotor windings decreases, reducing the rotor current and the torque.

4.3.2 Three Phase Synchronous Motor:



Construction:

Stator:

- The stationary part of the machine.
- Houses the **stator winding**, which is connected to a three-phase AC supply.

Rotor:

- The rotating part of the machine.
- Contains the **salient poles** (protruding poles) and the **field winding**.
- The field winding is energized by a DC source to create a magnetic field.

Field Winding:

- Wound around the rotor to produce a magnetic field when DC excitation is applied.

3-Phase Supply:

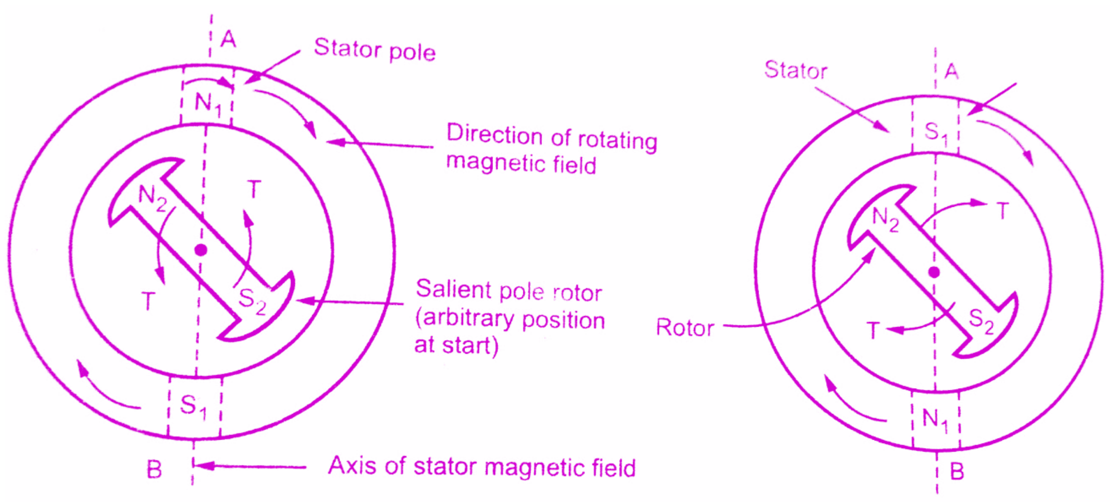
- Provides the three-phase current to the stator winding, which creates a rotating magnetic field.

Working Principle:

- The DC supply creates a magnetic field on the rotor.
- The stator's three-phase winding generates a rotating magnetic field when powered.
- The rotor locks with the rotating magnetic field due to magnetic attraction, and the machine runs at synchronous speed (the speed of the rotating magnetic field).
- If the frequency of the a.c supply is f Hz and stator is wound for P number of poles, then the speed of the rotating magnetic field is synchronous given by,

$$N_s = 120f/p \quad \text{r.p.m}$$

- The stator is wound for the similar number of poles as that of rotor, and fed with three phase AC supply. The 3 phase AC supply produces rotating magnetic field in stator. The rotor winding is fed with DC supply which magnetizes the rotor. Consider a two-pole synchronous machine as shown in figure below.



- Now, the stator poles are revolving with synchronous speed (let's say clockwise). If the rotor position is such that, N pole of the rotor is near the N pole of the stator (as shown in first schematic of above figure), then the poles of the stator and rotor will repel each other, and the torque produced will be anticlockwise.
- The stator poles are rotating with synchronous speed, and they rotate around very fast and interchange their position.
- But at this very soon, rotor cannot rotate with the same angle (due to inertia), and the next position will be likely the second schematic in above figure.
- In this case, poles of the stator will attract the poles of rotor, and the torque produced will be clockwise.
- Hence, the rotor will undergo to a rapidly reversing torque, and the motor will not start.
- But, if the rotor is rotated upto the synchronous speed of the stator by means of an external force (in the direction of revolving field of the stator), and the rotor field is excited near the synchronous speed, the poles of stator will keep attracting the opposite poles of the rotor (as the rotor is also, now, rotating with it and the position of the poles will be similar throughout the cycle).
- Now, the rotor will undergo unidirectional torque. The opposite poles of the stator and rotor will get locked with each other, and the rotor will rotate at the synchronous speed.

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