MODULE IV

AC MACHINES

Baiju.G.S
Lecturer in Electronics engineering
Central Polytechnic College

CO4 : Illustrate the principle and operations of AC machines.

Module Outcomes	Description	Duration	Cognitive Level
M4.01	Explain the principles and operations of alternator	3	Understanding
M4.02	Explain the principle and operations of AC motor	3	Understanding
M4.03	List the applications of various AC motors.	1	Understanding
M4.04	Explain the principle of three phase motors.	3	Understanding

Contents:

AC Machines

- **Alternators** - working principle of an alternator- emf equation of an alternator - synchronous speed and frequency - the open circuit characteristics of an alternator
- **AC motors** - working principle and classification of AC motors - working principle and applications of stepper motor, universal motor, servo motor - working principle and applications of single phase and three phase induction motor

Synchronous machines

- Machines generating AC EMF are called **alternators** or **synchronous generators**.
- While the machines accepting input from a.c supply to produce a mechanical output are called **synchronous motors**. Both these machines work at a specific constant speed called synchronous speed and hence is general called **synchronous machines**.

Difference between DC Generator and Alternator

It is seen that in the case of a DC generator, basically, the nature of the induced e.m.f in the armature conductors is of alternating type. By using commutator and brush assembly it is converted to d.c and made available to the external circuit.

If commutator is dropped from a d.c generator and induced e.m.f is tapped from an armature directly outside, the nature of such emf will be alternating. Such a machine without a commutator, providing an a.c emf to the external circuit is called an **alternator.**

Alternator

- • An alternator is an electrical generator that converts mechanical energy to electrical energy in the form of alternating current. Most alternators use a rotating magnetic field with stationary armature.
- • It is also known as synchronous generator.
- The working of an alternator is based on the principle that when the flux linking a conductor changes, an emf is induced in the conductor.
- Alternators are the primary source of all the electrical energy we consume. These machines are the largest energy converters found in the world.
- They convert mechanical energy into AC energy.

TYPES OF ALTERNATOR

According to application

- Automotive type - used in modern automobile.
- Diesel electric locomotive type - used in diesel electric multiple unit.
- Marine type - used in marine.
- Brush less type - used in electrical power generation plant as main source of power.
- Radio alternators - used for low brand radio
- frequency transmission.

According to their design

- Salient pole type.
- Cylindrical rotor type

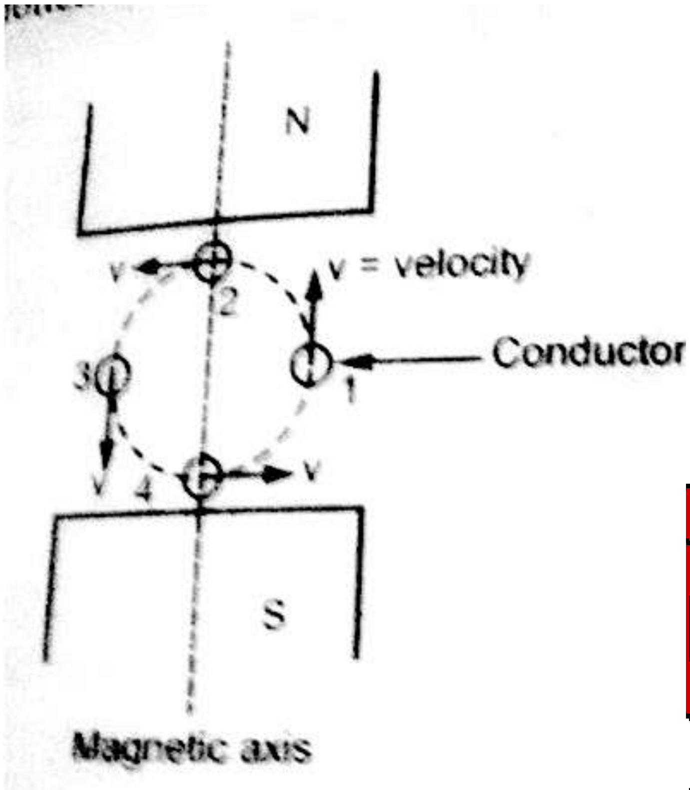
Working principle

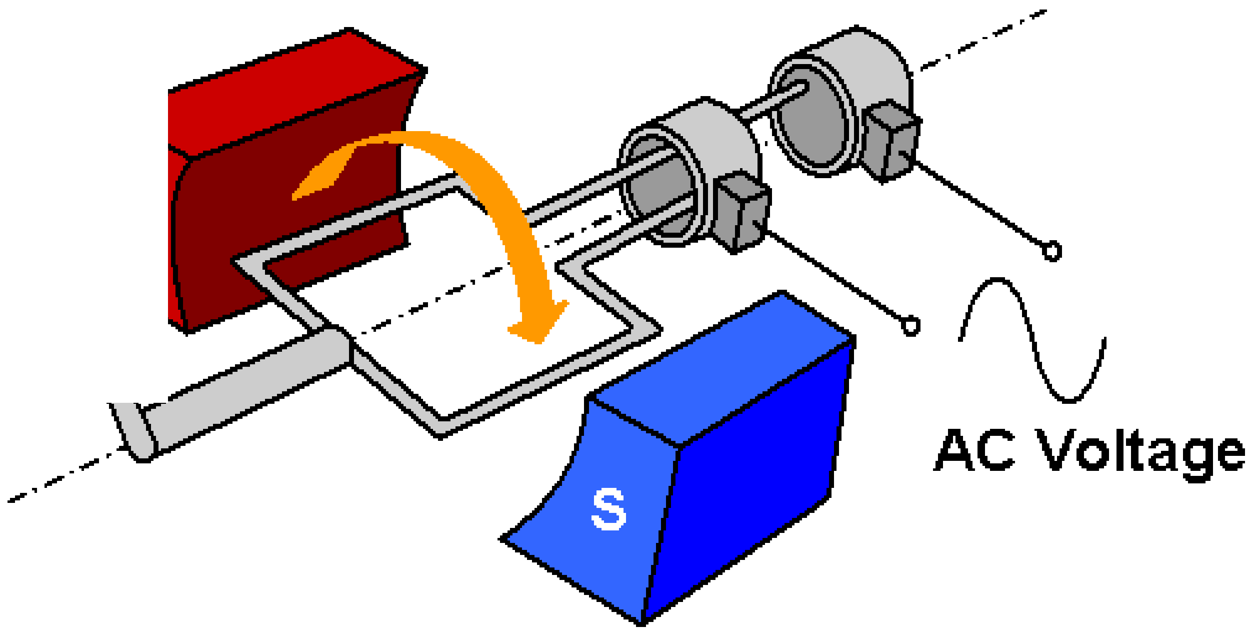
- Alternator operates on the same fundamental principle of **Faradays Laws of Electromagnetic Induction** as a DC generator. The working of an alternator is based on the principle that when the flux linking a conductor changes, an emf is induced in the conductor.
- Like a DC generator, an alternator also has an armature winding and a field winding. **But there is one important difference between the two.**
- In a DC generator, the armature winding is placed on the rotor in order to provide a way of converting alternating voltage generated in the winding to a direct voltage at the terminals through the use of a rotating commutator. The field poles are placed on the stationary part of the machine

- . Since no commutator is required in an alternator, it is usually more convenient and advantageous to place the field winding on the rotating part (i.e., rotor) and armature winding on the stationary part (i.e., stator).
- An alternator has 3,-phase winding on the stator and a DC field winding on the rotor. This DC source (called exciter) is generally a small DC shunt or compound generator mounted on the shaft of the alternator.
- The only difference in the practical **Synchronous Generator** and a dc generator is that in an alternator the conductors are stationary and field is rotating. But for understanding, the purpose we can always consider relative motion of conductors w.r.t the flux produced by the field winding.

- Consider a relative motion of a single conductor under the magnetic field produced by two stationary poles. The magnetic axis of two poles produced by field is vertical, shown dotted in below figure.
- Let conductor starts rotating from position 1.at this instant, the entire velocity component is parallel to the flux lines. Hence there is no cutting of flux lines by the conductor. So $d\Phi /dt$ at this instant is zero and hence induced emf in the conductor is also zero. As the conductor moves from position 1 to position 2, the part of the velocity component becomes perpendicular to the flux lines and proportional to that, emf gets induced in the conductor. The magnitude of such an induced emf increases as conductor moves from position 1 to 2.

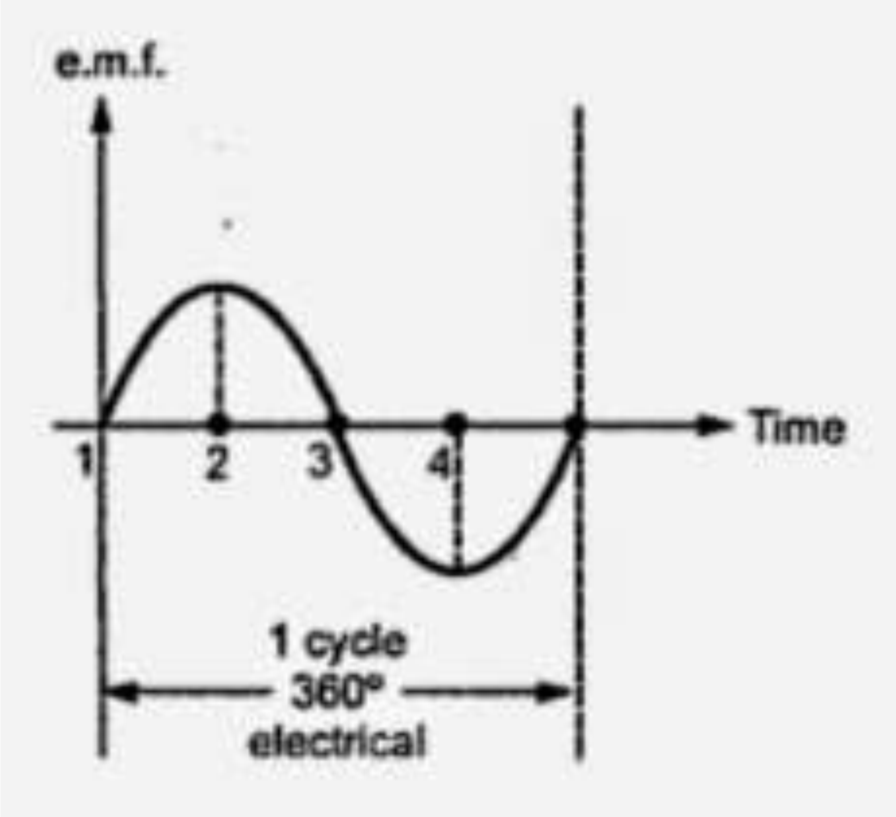
Generation of AC Waveform





- At position 2, the entire velocity component is perpendicular to the flux lines. Hence there exists cutting of the flux lines. And at this instant, the induced emf in the conductor is at its maximum. As the position of conductor changes from 2 to 3, the velocity component perpendicular to the flux starts decreasing and hence induced emf magnitude also starts decreasing.At position 3, again the entire velocity component is parallel to the flux lines and hence at this instant induced emf in the conductor is zero.
- As the conductor moves from 3 to 4, velocity component perpendicular to the flux lines again starts increasing. But the direction of velocity component now is opposite to the direction of velocity component existing during the movement of the conductor from position 1 to 2.Hence an induced emf in the conductor increase but in the opposite direction.
-

- In position 4, it achieves maxima in the opposite direction, as the entire velocity component becomes perpendicular to flux lines. Again from position 4 to 1, induced emf decreases and finally at the position again becomes zero. This cycle continues as conductor rotates at a certain speed. So if we plot the magnitudes of the induced emf against the
- time, we get an alternating shown figure below .
- This is the **working principle**
- **of Synchronous generator or**
- **Alternator**.



EMF equation of an Alternator

- Lets,
- **P** = No. of poles
- **Z** = No. of Conductors or Coil sides in series/phase i.e. **Z = 2T**…Where T is the number of coils or turns per phase (Note that one turn or coil has two ends or sides)
- ***f*** = frequency of induced EMF in Hz = NP/120
- **Φ** = Flux per pole (Weber)
- **N** = rotor speed (RPM)

- Time taken for one revolution = 60/Ns seconds.

- Total flux cut in one revolution , i.e. in **60/N** seconds =s Φ x P. Webers.

- ie **dΦ = P Φ**
  - **dt = 60/N**
- The average value of emf induced in a conductor = Flux cut in one revolution**/**Time taken for one revolution)

- ie Eavg per conductor = dΦ/dt ,

- Substituting the value of dΦ and dt in above equation

- Average emf /conductor = PΦ / (60/N) = PNΦ/60
- Frequency f = NP/120

- :. Eavg per conductor = 2 f Φ volts

- Average emf / phase = Eph = $2\Phi fz$ volt
  or $4\varphi fT$ volts (where Z=2T)

Form factor Kf = 1.1 (for Sine wave)

Also we know that;

- **Form Factor= RMS Value / Average Value**

RMS value= Form factor x Average Value,

- RMS value of emf / ph = Eph = $1.11*2\varphi fz$
- ie = $4.44\ \varphi f\ T$, where Z=2T

Kp and Kd reduces the actual voltage .

- Hence $E_{ph} = 4.44\ KpKdf\varphi T$ volts.

where

- ***Kp*** is called ***pitch factor***

The ratio of phasor (vector) sum of induced emfs per coil to the arithmetic sum of induced emfs per coil is known as ***pitch factor (Kp)***or ***coil span factor (Kc)*** which is always less than unity.

- **Kd = Distribution Factor**

Te ratio of the phasor sum of the emfs induced in all the coils distributed in a number of slots under one pole to the arithmetic sum of the emfs induced

= the ratio of the actual voltage obtained to the possible voltage

- known as ***breadth factor (Kb)*** or ***distribution factor (Kd)***

Synchronous speeds

- One cycle of alternating current is produced each time a pair of field poles passes over a point on the stationary winding.
- The relation between speed and frequency is
- **$N = 120\ f\ /\ P$**
- where f is the frequency in Hz (cycles per second). P is the number of poles (2, 4, 6, …) and N is the rotational speed in revolutions per minute (RPM).
- The output frequency of an alternator depends on the number of poles and the rotational speed.

The speed corresponding to a particular frequency is called the *synchronous speed* for that frequency

- If a two-pole **alternator** creates one cycle of voltage in one second (or one hertz of **frequency**), a four pole **alternator** will create two cycles of voltage in one second (or two hertz). The **frequency** of an **alternator** is directly proportional to the number of poles in the **alternator**. (f= NP/120)

- he **output frequency of an alternator** can be **determined** by the following **two factors**. The number of stator poles is constant for a particular machine. Thus the **output frequency** is controlled by adjusting the speed of the **alternator**.

- The frequency of any AC generator in hertz (Hz), which is the number of cycles per second, is related to the number of poles and the speed of rotation, as expressed by the equation f= NP/120

- where P is the number of poles N is the speed of rotation in revolutions per minute (rpm), and 120 is a constant to allow for the conversion of minutes to seconds and from poles to pairs of poles.
- For example, a 2-pole, 3600-rpm alternator has a frequency of 60 Hz; determined as follows:
- 2*36000/120 = 60Hz

- A 4-pole, 1800-rpm generator also has a frequency of 4* 1800 ‘ 120 = 60 Hz.

- A 6-pole, 500-rpm generator has a frequency of
- 6*500/120 = 25Hz

- 12-pole, 4000-rpm generator has a frequency of
- 12*4000/120 = 400hz
- What is the frequency of the output voltage of an alternator with four poles that is rotated at 3600 rpm?

Open Circuit characteristics of an Alternator

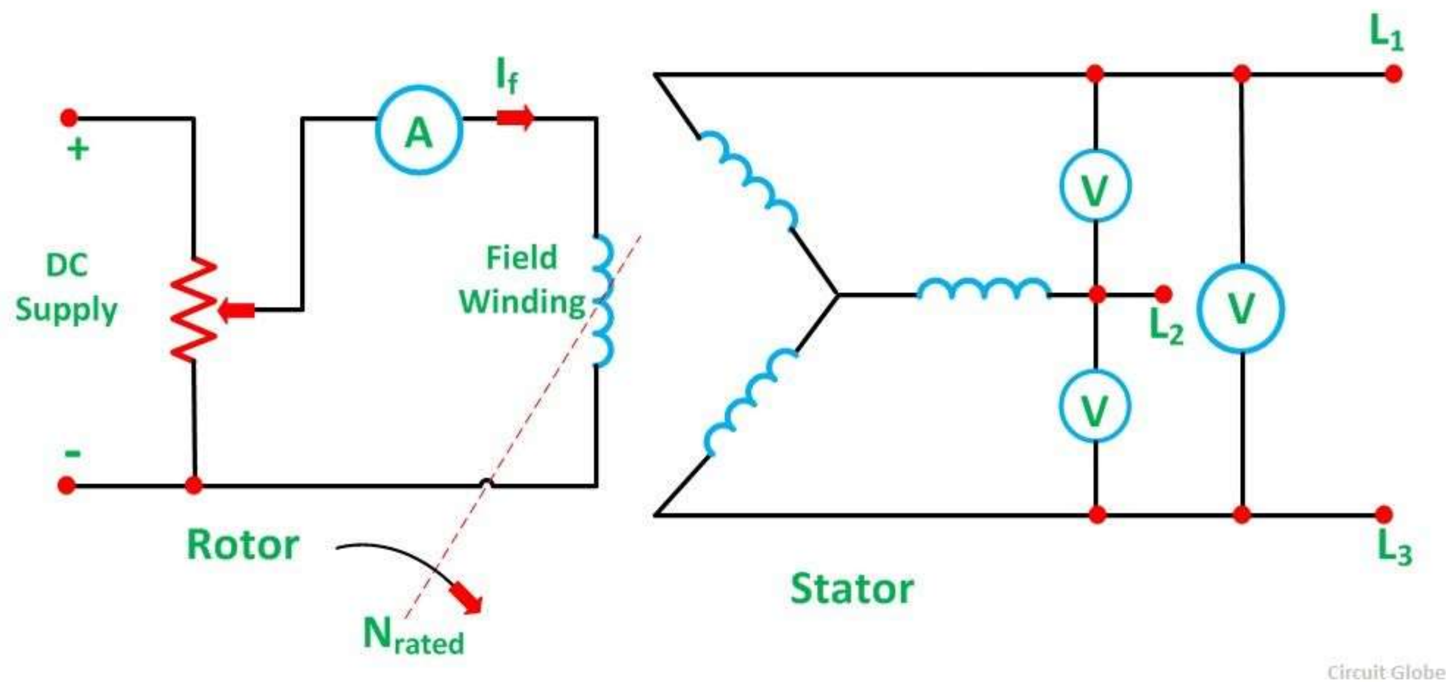


Figure (a)

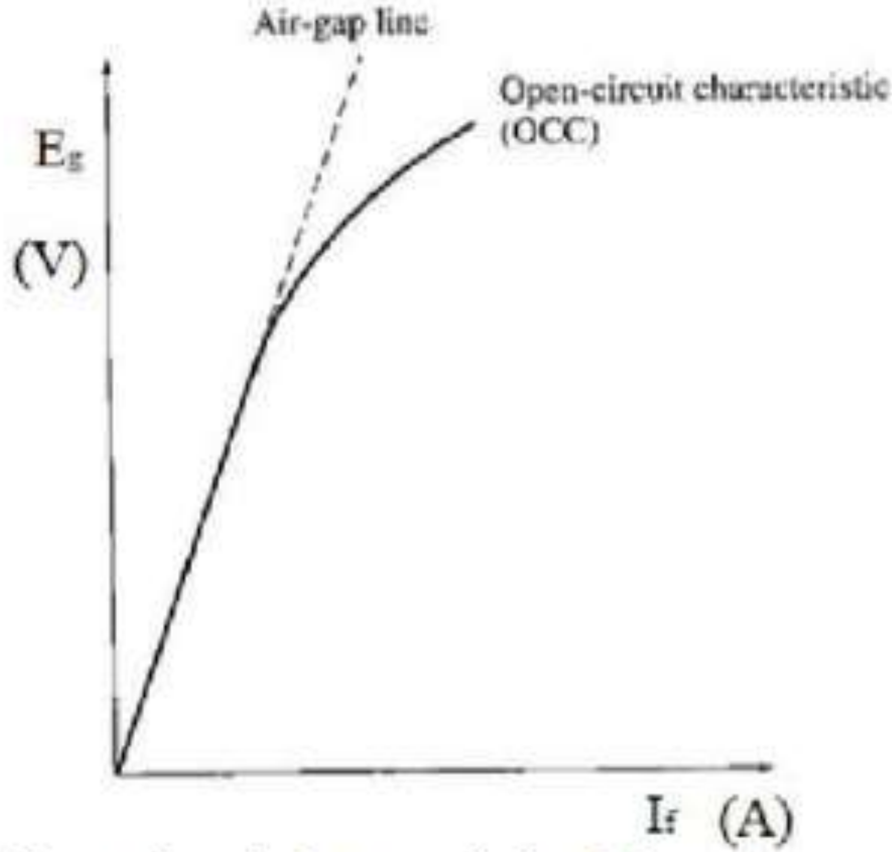


figure1(a), Open-circuit characteristic of alternator

- As clear from the figure (a), an Ammeter is connected in series with the field circuit to measure the field current and a Voltmeter is connected across the armature terminals to note down the voltage generated.
- Figure (b) shows the plot between I_f and E_g. It can be seen from the graph that the relationship between the field current I_f and no load generated voltage E_g is linear up to certain value of field current but as the field current increases the relationship no longer remains linear. The linear part of the relationship is because, at small value of field current the whole mmf is required by the air gap to create magnetic flux but as the value of mmf exceeds some certain value, the iron parts get saturated and hence the relationship between the flux (No load generated emf is proportional to flux) and field current no longer remain linear.

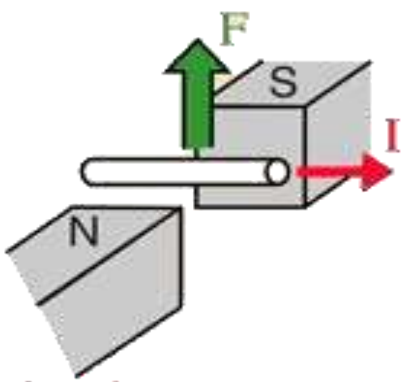
- Next assume that if there were no saturation (assuming no iron part is present rather only air gap is present), the relationship between the field current and no load voltage would have been a straight line and that is why the straight line ob in the figure is called Air Gap Line.
- Thus we observe that because of saturation in iron parts of machine, the no load generated voltage E_g does not increase in the same proportion as the increase in field current.

AC motor

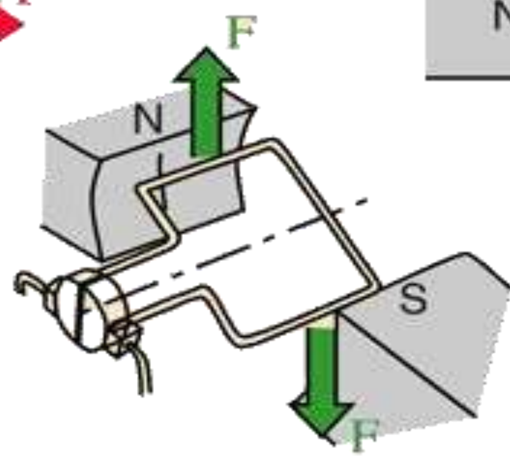
- n **AC motor** is an **electric motor** driven by an **alternating current** (**AC**).
- The **AC motor** commonly consists of two basic parts, an outside stator having coils supplied with **alternating current** to produce a rotating magnetic field, and an inside rotor attached to the output shaft producing a second rotating magnetic field.
- An **AC** Controller (Sometimes referred to as a Driver) is known as the device that controls the speed of the **AC Motor**.

Working principle of an AC Motor

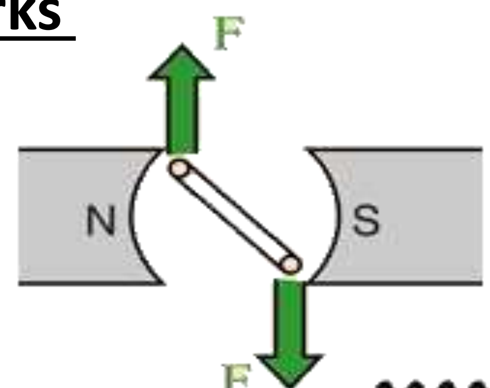
1. <u>Principle – How motor works</u>



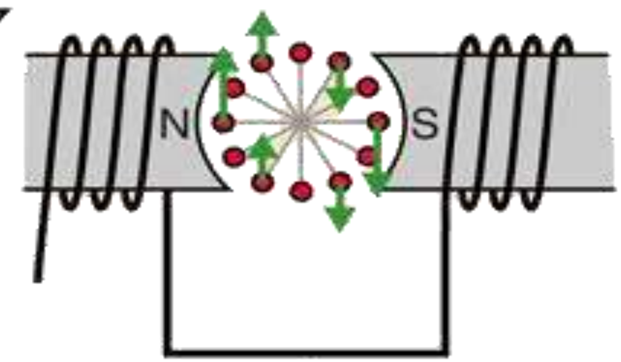
An electric current in a magnetic field will experience a force.



If the current-carrying wire is bent into a loop, then the two sides of the loop which are at right angles to the magnetic field will experience forces in opposite directions.



The pair of forces creates a turning influence or torque to rotate the coil.



Practical motors have several loops on an armature to provide a more uniform torque and the magnetic field is produced by an electromagnet arrangement called the field coils.

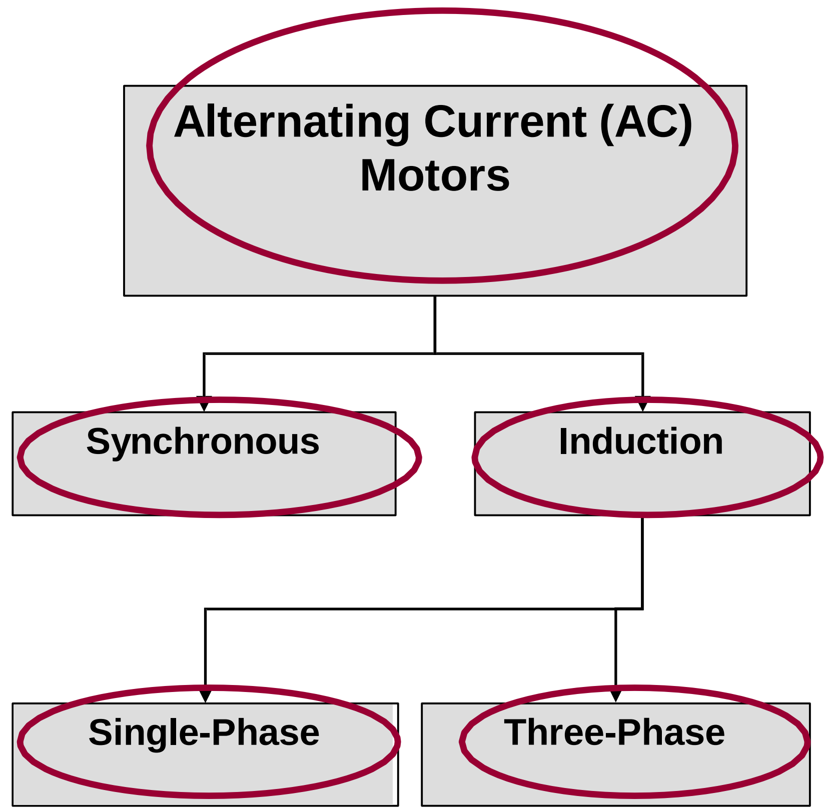
2. Working Principle – AC Motor

An **AC motor** is an **electric motor** driven by an alternating current (**AC**). The **AC motor** commonly consists of two basic parts, an outside stator having coils supplied with alternating current to produce a rotating magnetic field, and an inside rotor attached to the output shaft producing a second rotating magnetic field.

An **AC motor** works by applying **alternating current** to stator windings, which produce a rotating magnetic field. Because the magnetic field rotates in this way, an **AC motor** does not need power or mechanical aid to be applied to the rotor.

Classification of AC Motors

The two main **types** of **AC motors** are **induction motors** and synchronous **motors**. The **induction motor** (or asynchronous **motor**) always relies on a small difference in speed between the stator rotating magnetic field and the rotor shaft speed called slip to induce rotor current in the rotor **AC** winding.



Advantages and Disadvantages of AC motor

Advantages

- Low cost
- Speed variation
- High power factor
- Reliable operation

- **Disadvantages**
- Inability to operate at Low speeds
- Poor positioning control
- AC will produce eddy current due to the production of back emf

Application of AC motor

- **AC Motors** are primarily used in domestic **applications** due to their relatively low manufacturing costs, and durability, but are also widely used in industrial **applications**.

- General **uses** for **AC motors** include pumps, water heaters, lawn and garden equipment, ovens, and off-road motorized equipment. In fact, many of the appliances, equipment and tools you **use** on a daily basis are powered by an **AC motor**.

- hese **motors** are **used** in a wide array of applications like high-power engineering, railway traction, and commercial drill machines. They are most commonly found in blenders, vacuum cleaners, dryers, etc

Synchronous motors

- **Synchronous ac motors** are constant-speed electric motors and they operate in synchronism with line frequency. The speed of a synchronous motor is determined by the number of pairs of poles and is always a ratio of the line frequency.

- A **synchronous motor** is one in which the rotor normally rotates at the same speed as the revolving field in the **machine**. The stator is similar to that of an induction **machine** consisting of a cylindrical iron frame with windings, usually three-phase, located in slots around the inner periphery.

Working principle

- AC power is fed to the stator of the **synchronous motor**. The rotor is fed by DC from a separate source. The rotor magnetic field locks onto the stator rotating magnetic field and rotates at the same speed.
- The stator is provided with two simple coils, which can be directly connected to the mains.

- The rotor consists of a cylindrical permanent two-pole magnet, which is diametrically magnetized.

Induction Motor

- An **induction motor** or **asynchronous motor** is an **AC** electric **motor** in which the electric current in the rotor needed to produce torque is obtained by electromagnetic **induction** from the magnetic field of the stator winding.

- Induction motors can be classified intotwo main groups
- **Single-phase induction motors**
- **Three –phase induction motors**

Principle of operation

- The **motor** which works on the **principle** of electromagnetic **induction** is known as the **induction motor**. The electromagnetic **induction** is the phenomenon in which the electromotive force induces across the electrical conductor when it is placed in a rotating magnetic field.
- The basic difference between an induction motor and a synchronous AC motor is that in the Sychromous motor 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.

- 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 energised with a polyphase supply they create a rotating magnetic field pattern which sweeps past the rotor

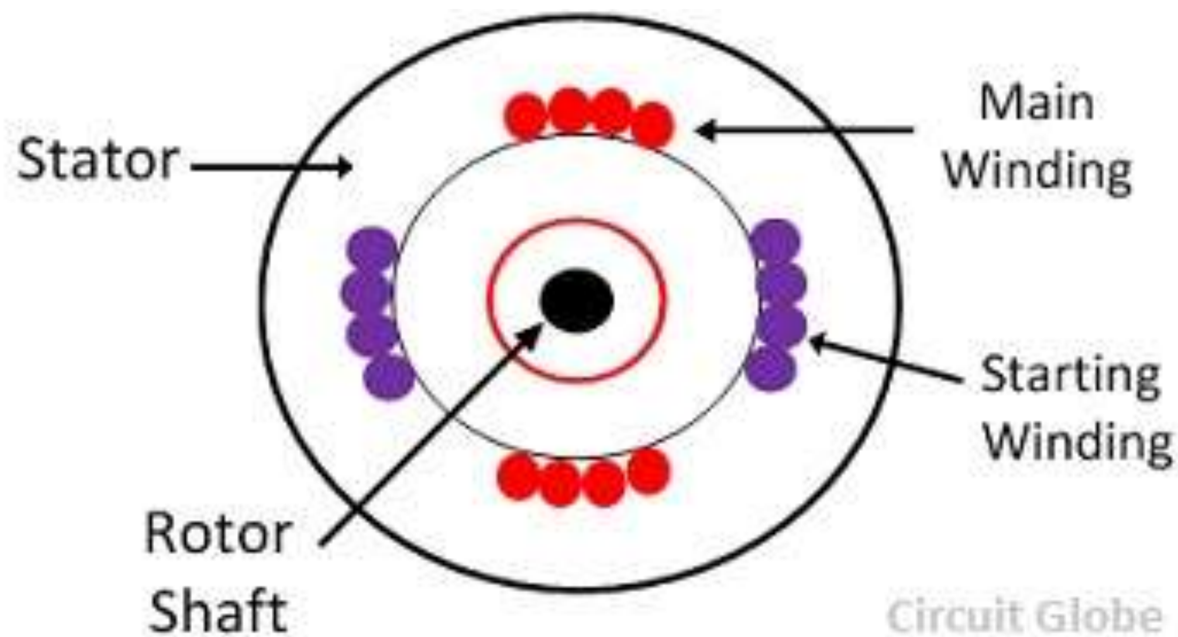
- At the moment illustrated, the current in the stator coil is in the direction shown and increasing. The induced voltage in the coil drives current and results in a clockwise torque. Note that this simplified motor will turn once it is started in motion, but has no starting torque. Various techniques are used to produce some asymmetry in the fields to give the motor a starting torque.

Single Phase Induction motor

- A **Single Phase Induction Motor** consists of a **single phase** winding which is mounted on the stator of the **motor** and a cage winding placed on the rotor. A pulsating magnetic field is produced, when the stator winding of the **single-phase induction motor** is energised by a **single phase** supply.

Single phase Induction motor – Working principle

A **Single Phase Induction Motor** consists of a single phase winding which is mounted on the stator of the motor and a cage winding placed on the rotor. A pulsating magnetic field is produced, when the stator winding of the single-phase induction motor shown below is energised by a single phase supply.



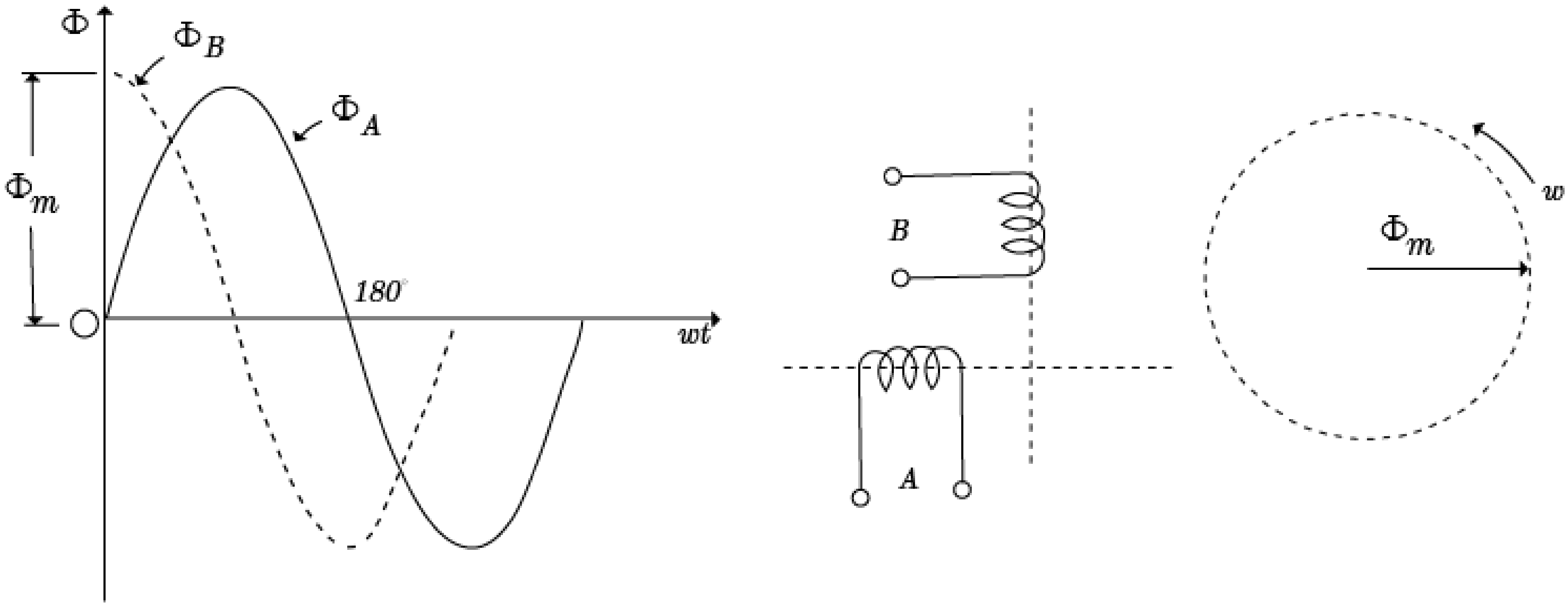
Working principle contd….

- The word Pulsating means that the field builds up in one direction falls to zero and then builds up in the opposite direction. Under these conditions, the rotor of an induction motor does not rotate. Hence, a single phase induction motor is not self-starting. It requires some special starting means.
- If the 1 phase stator winding is excited and the rotor of the motor is rotated by an auxiliary means and the starting device is then removed, the motor continues to rotate in the direction in which it is started.
- The performance of the single phase induction motor is analysed by the two theories. One is known as the **Double Revolving Field Theory**, and the other is **Cross Field Theory**. Both the theories are similar and explain the reason for the production of torque when the rotor is rotating.

Production of Rotating Field

- Consider two winding 'A' and 'B' so displaced that they produce magnetic field 90° apart in space. The resultant of these two fields is a rotating magnetic field of constant magnitude φ_m. Non-Uniform magnetic field produces a non-uniform torque which makes the operation of the motor noisy, affect starting torque.

$$= \frac{d\Phi}{dt} = \frac{\Phi P}{60/N} = \frac{\Phi NP}{60}$$



Production of the uniform magnetic field.

Starting principle

- The single-phase induction motor operation can be described by two methods:
- **1)Double revolving field theory**
- **2)Cross-field theory.**

- Double revolving theory is perhaps the easier of the two explanations to understand

Double revolving field theory

- A single-phase ac current supplies the main winding that produces a pulsating magnetic field.
- Mathematically, the pulsating field could be divided into two fields, which are rotating in opposite directions.
- The interaction between the fields and the current induced in the rotor bars generates opposing torque
- Under these conditions, with only the main field energized the motor will not start.
- However, if an external torque moves the motor in any direction, the motor will begin to rotate.

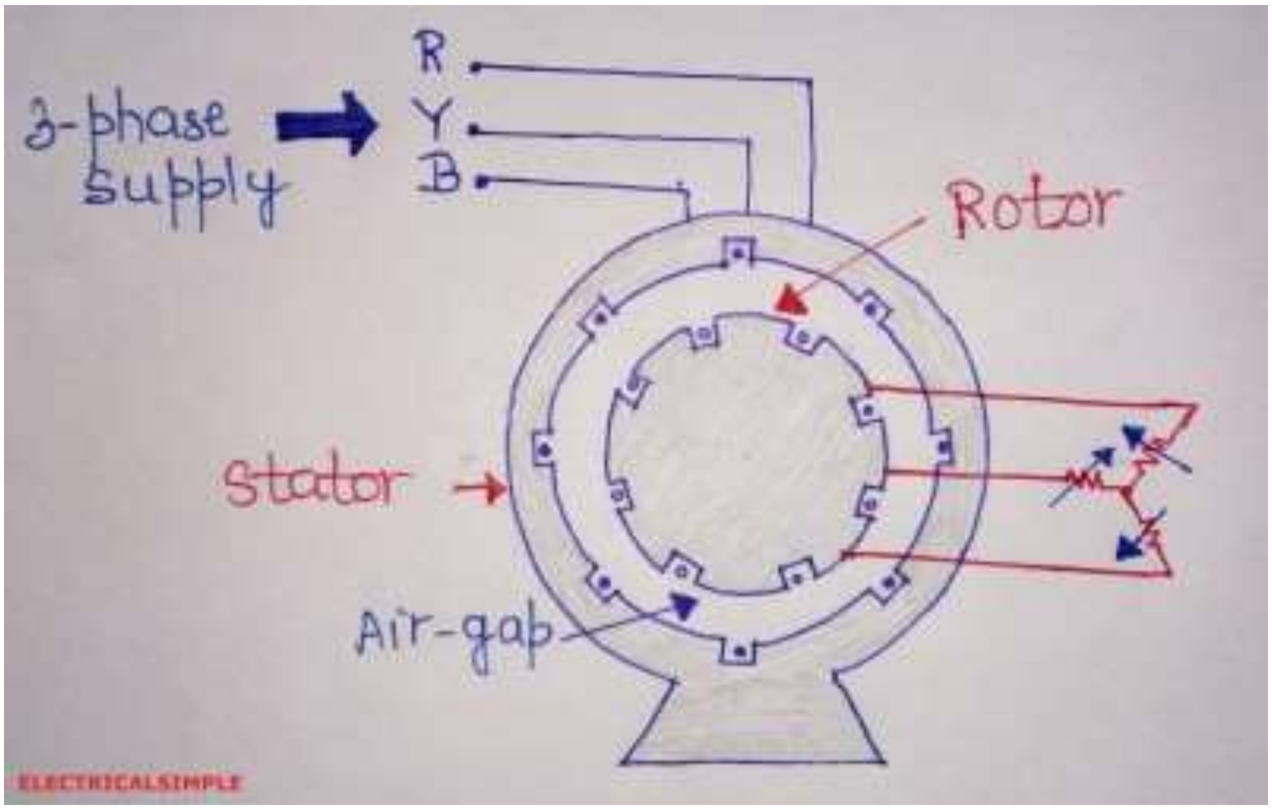
Applications of Single Phase Induction Motor

- These are used in low power applications and widely used in domestic applications as well as industrial such as
- Pumps
- Compressors
- Small fans
- Mixers
- Toys
- High speed vacuum cleaners
- Electric shavers
- Drilling machines

3 phase Induction Motor

- **3 phase induction motor** is an **AC** electric **motor** in which the electric current in the rotor needed to produce torque is obtained by electromagnetic **induction** from the magnetic field of the stator winding. An **induction motor** can therefore be made without electrical connections to the rotor.

Working principle – 3 phase induction motor

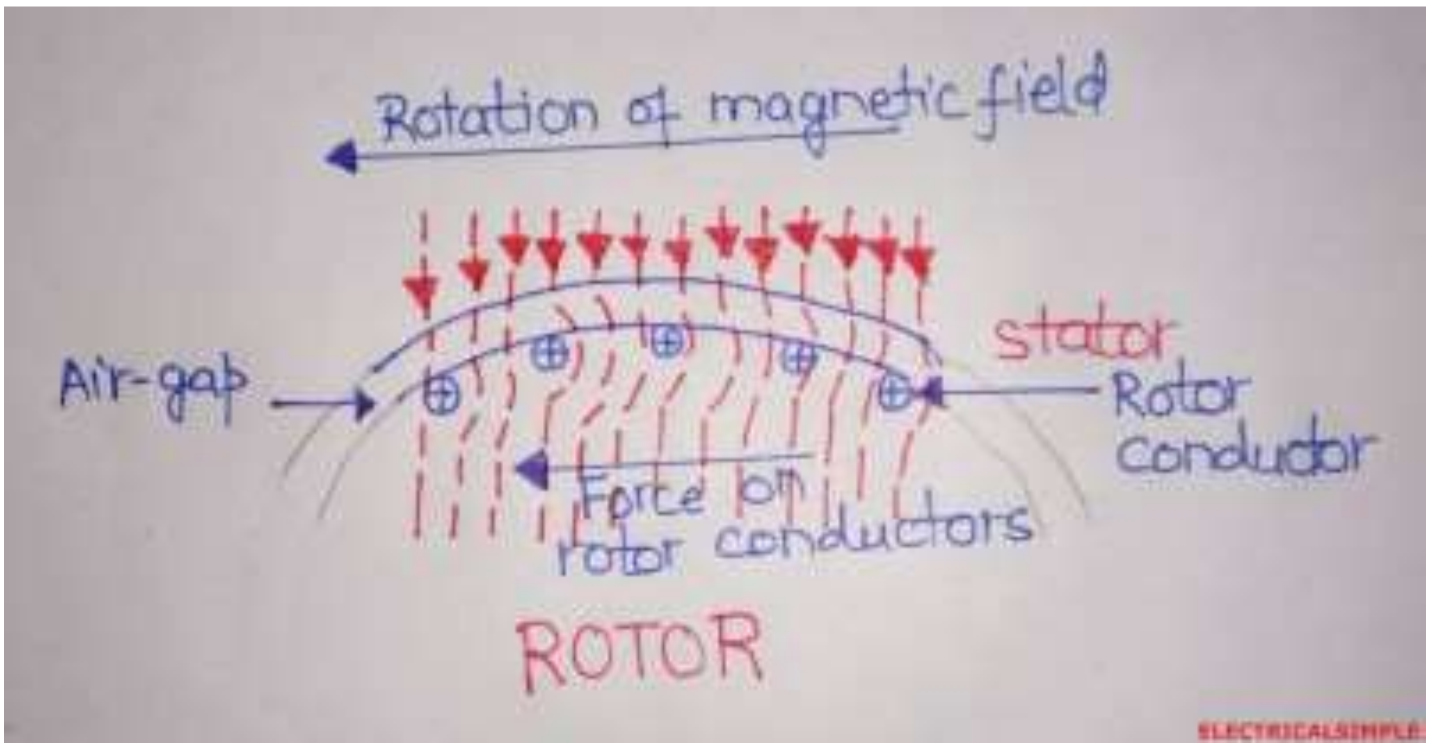


simplified view of a 3 phase induction motor

Working principle

- The stator hosts a three phase winding distributed symmetrically on its inner periphery. This stator winding is energized from a three phase supply.
- The rotor also hosts a 3 phase winding on its periphery. But, the rotor winding is not energised from any source and is short-circuited on itself.

- (1) When the 3 phase stator winding is energised from a 3 phase supply, a rotating magnetic field is produced which rotates around the stator at synchronous speed.



- (2) The rotating magnetic field cuts the rotor conductors, which as yet, are stationary. Due to this flux cutting, emfs are induced in the rotor conductors. As rotor circuit is short circuited, therefore, currents start flowing in it.

- (3) Now, as per Lenz's law , "the direction of induced current will be such that it opposes the very cause that produced it " .

- (4) Here, the cause of emf induction is the relative motion between the rotating field and the stationary rotor conductors. Hence, to reduce this relative motion, the rotor starts rotating in the same direction as that of the stator field and tries to catch it but, can never catch it due to friction and windage and therefore emf induction continues and motor keeps rotating.

- Thus, ***principle of 3 phase induction motor*** also explains why rotor rotates in same direction as the rotating field and why *induction motor is self starting*.

- When rotor winding is short-circuited with no resistance in series, it is called a ***squirrel cage induction motor*** and when rotor winding is shorted through a resistance in series, it is called ***slip ring induction motor***.

Applications of Three Phase Induction Motor

- Lifts
- Cranes
- Hoists
- Large capacity exhaust fans
- Driving lathe machines
- Crushers
- Oil extracting mills
- Textile and etc.

Induction Motor Advantages

- Induction motors are simple and rugged in construction. Advantage of induction motors are that they are robust and can operate in any environmental condition
- Induction motors are cheaper in cost due to the absence of brushes, commutators, and slip rings
- They are maintenance free motors unlike dc motors and synchronous motors due to the absence of brushes, commutators and slip rings.
- Induction motors can be operated in polluted and explosive environments as they do not have brushes which can cause sparks
- 3 phase induction motors will have self starting torque unlike synchronous motors, hence no starting methods are employed unlike synchronous motor. However, single-phase induction motors does not have self starting torque, and are made to rotate using some auxiliaries.

Stepper motor

- **Stepper Motor** is a brushless electromechanical device which converts the train of electric pulses applied at their excitation windings into precisely defined step-by-step mechanical shaft rotation. The shaft of the motor rotates through a fixed angle for each discrete pulse. This rotation can be linear or angular. It gets one step movement for a single pulse input.
- When a train of pulses is applied, it gets turned through a certain angle. The angle through which the stepper motor shaft turns for each pulse is referred as the step angle, which is generally expressed in degrees.

Types of Stepper Motors

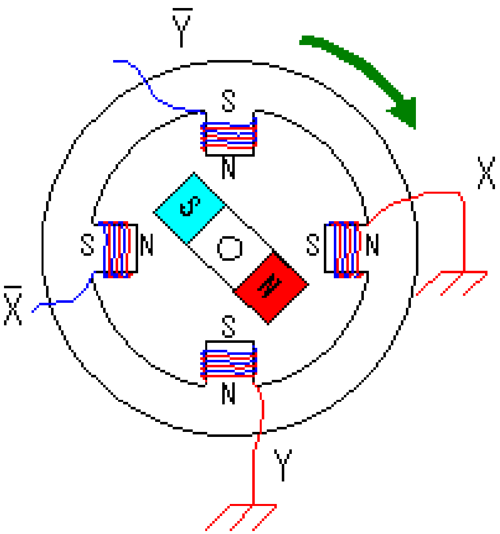
- There are three basic **categories of stepper motors**, namely
- **Permanent Magnet Stepper Motor**
- **Variable Reluctance Stepper Motor**
- **Hybrid Stepper Motor**

working principle of the stepper motor

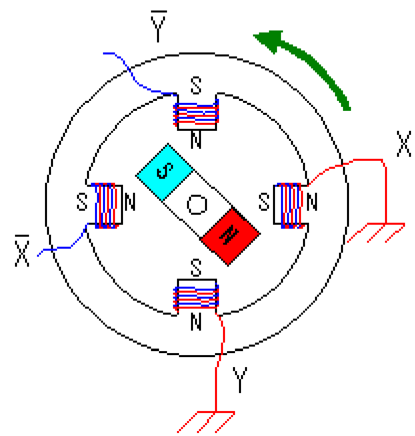
- By energizing one or more of the stator phases, a magnetic field is generated by the current flowing in the coil and the rotor aligns with this field.
- The motor's position can then be commanded to move and hold at one of these steps without any position sensor for feedback (an open-loop controller), as long as the motor is carefully sized to the application in respect to torque and speed.

$X\ \bar{X}\ Y\ \bar{Y}\ X\ \bar{X}\ Y\ \bar{Y}$

The stepper motor rotor is a permanent magnet, when the current flows through the stator winding, the stator winding to produce a vector magnetic field. The magnetic field drives the rotor to rotate by an angle so that the pair of magnetic fields of the rotor and the magnetic field direction of the stator are consistent.



X	$\bar{X}$	Y	$\bar{Y}$
0	1	0	1
1	0	0	1
1	0	1	0
0	1	1	0



X	$\bar{X}$	Y	$\bar{Y}$
0	1	0	1
0	1	1	0
1	0	1	0
1	0	0	1

Clockwise

Counter Clockwise

- .When the stator's vector magnetic field is rotated by an angle, the rotor also rotates with the magnetic field at an angle. Each time an electrical pulse is input, the motor rotates one degree further
- The angular displacement it outputs is proportional to the number of pulses input and the speed is proportional to the pulse frequency. Change the order of winding power, the motor will reverse. Therefore, it can control the rotation of the stepping motor by controlling the number of pulses, the frequency and the electrical sequence of each phase winding of the motor.

- As we know that many industrial electric motors are used with closed-loop feedback control for achieving precise positioning or precise speed control, on the other hand, a stepper motor able to operate on an open-loop controller. This in turn reduces the total system cost and simplifies the machine design compared with servo system control

Advantages and Disadvantages

- **Advantages** of **step motors** are low cost, high reliability, high torque at low speeds and a simple, rugged construction that operates in almost any environment. The main disadvantages in using a **stepper motor** is the resonance effect often exhibited at low speeds and decreasing torque with increasing speed.

Applications of Stepper Motors

- Stepper motors are used in automated production equipments and automotive gauges and industrial machines like packaging, labeling, filling and cutting etc.
- It is widely used in security devices such as security & surveillance cameras.
- In medical industry, stepper motors are widely used in samples, digital dental photography, respirators, fluid pumps, blood analysis machinery and medical scanners etc.
- They are used in consumer electronics in image scanners, photo copier and printing machines and in digital camera for automatic zoom and focus functions and positions.
- Stepper motors also used in elevators, conveyor belts and lane diverters.

Universal Motor

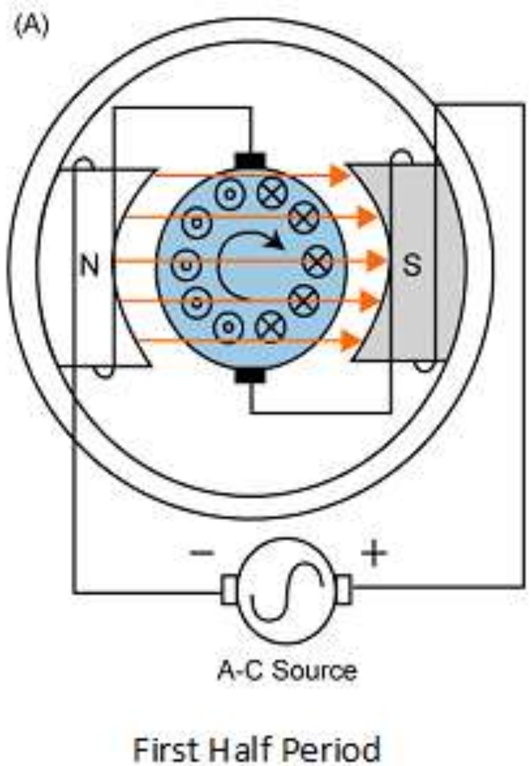
- A universal motor is a single-phase series motor, which is able to run on either alternating current (ac) or direct current (dc) and the characteristics are similar for both ac and dc. The field windings of a series motors are connected in series with the armature windings

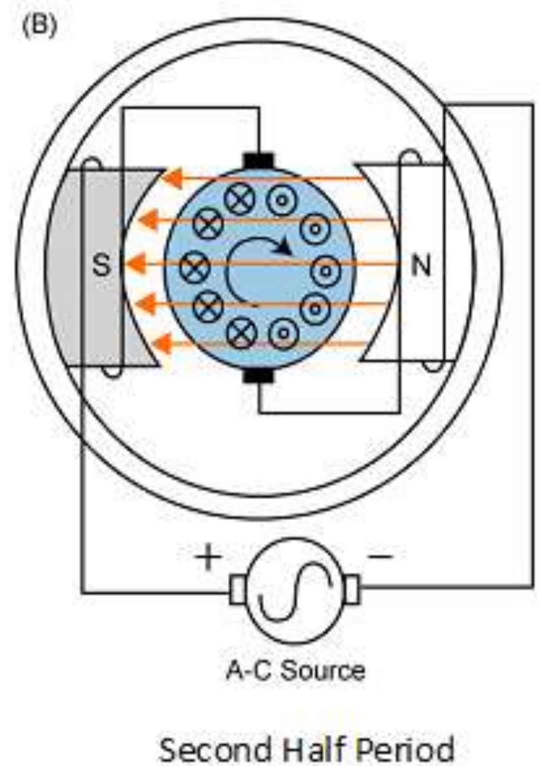
Universal Motor cont…

- **Universal motor** is used in such applications, where you can use AC supply and DC Supply both to run the motor. Generally, the electric motors are operated either in DC Power or AC Power, any one option you can choose. But for some specific applications , it is desirable to introduce a motor that operates in ac and dc supply both. The word "Universal" signifies that something which is compatible with versatile input voltage.

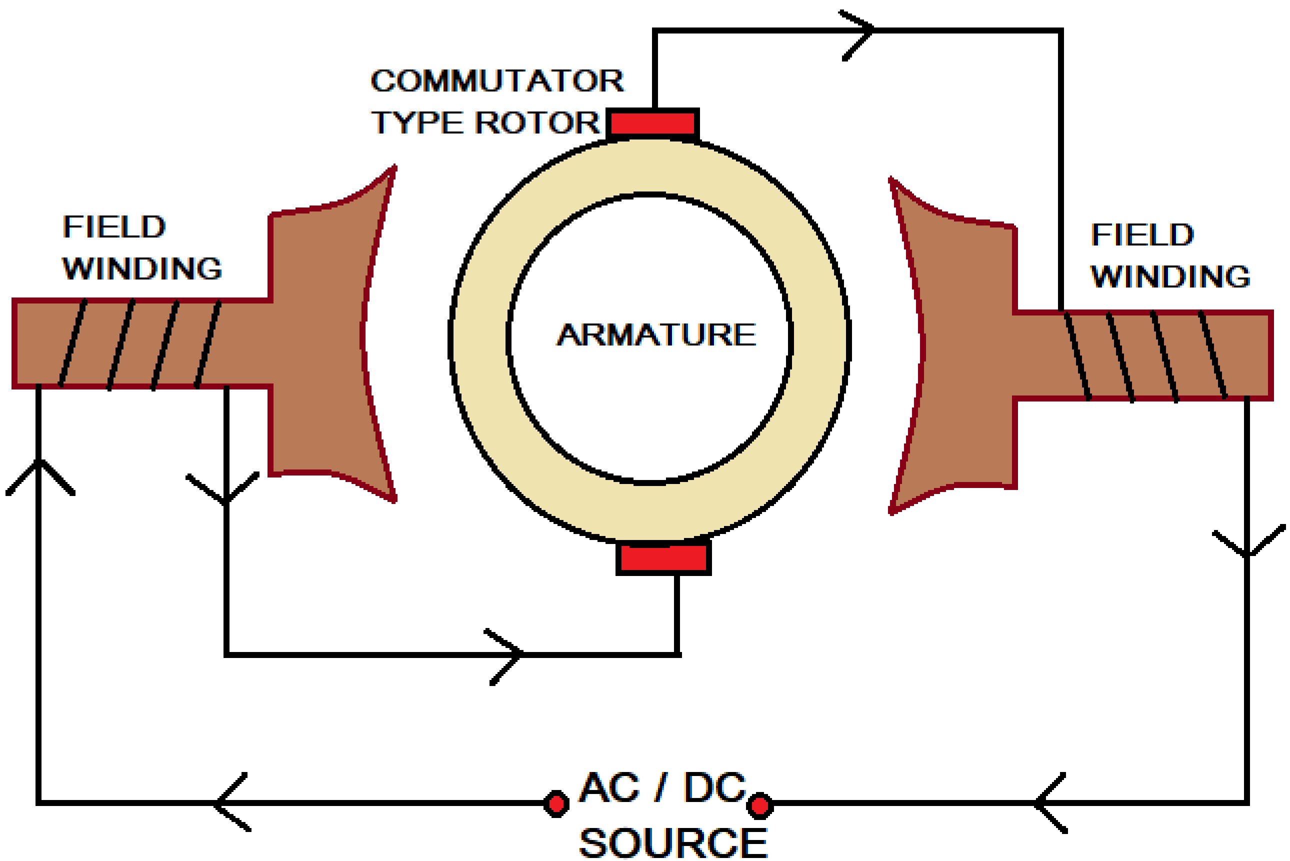
Working principle of universal motor

- . In a series wound motor, the same current flows through the field winding and armature winding. Same way, in an **universal motor**, both winding are connected in series with each other. When the motor is supplied from ac or dc voltage source, magnetic fields are developed in the armature and field winding both. They react on each other to produce an unidirectional torque.





Universal Motor



UNIVERSAL MOTOR

- Suppose you have provided supply voltage across the Field coil and Armature coil, from the same voltage source. Thus the field and armature coil forms a series circuit in together, where the same current flows in both coils. Now, a primary torque is required to start the motor. Here the current induced in the series field coils and armature coil interacts with each other and corresponding magnetic fields act on each other, which leads to generate the primary torque to move the rotor shaft.
- If an universal motor is designed to be operated under steady DC voltage, and you apply AC voltage on it, the motor will run for sure. But there will be some effect on the motor performance:

- In case of universal motor, the speed of rotation is slightly lesser when operating in AC voltage. Because, the reluctance voltage drop is present on ac but not in DC. So, the motor speed is little bit lower for the same load capacity in ac operation, compared to DC.
  - The motor efficiency becomes low due to hysteresis and eddy current effects.
  - The power factor becomes low due to large reactance of the field and armature winding.
  - The sparking at the brushes is excessive.

Types of universal motors

- Universal motors are of two types. They are :
- **1. Compensated type (distributed field) :** It is of again two types namely:
- (i) Single field compensated motor:
  (ii) Two-field compensated motor
- **2. Uncompensated type (concentrated field**

Applications Of Universal Motor

- **Universal motors** finds its applications in various devices . These are:
- Very small power output rating universal motors, which usually does not exceed 5 to 10 watts are employed in equipment such as sewing machines , fans , portable hand tools, hair dryers , motion picture projectors and electric shavers.
- The higher rating (5-500 W) universal motor are used in vacuum cleaners, food mixers, blenders, cameras and calculating machines.
- This type of machine is used in table fans , polishers , portable drills and other kitchen appliances .

Servo motor

- The servo motor is most commonly used for high technology devices in the industrial applications like automation technology. It is a self contained electrical device, that rotates parts of machine with high efficiency and great precision. Moreover the output shaft of this motor can be moved to a particular angle. Servo motors are mainly used in home electronics, toys, cars, airplanes and many more devices.

Servo motor cont …

- A servo motor is a rotary actuator or a motor that allows for a precise control in terms of the angular position, acceleration, and velocity. Basically it has certain capabilities that a regular motor does not have. Consequently it makes use of a regular motor and pairs it with a sensor for position feedback .

Types of servo motors

- Servo motors can be of different types on the basis of their applications. The most important amongst them are : AC servo motor, DC servo motor, brushless DC servo motor, positional rotation servo motor, continuous rotation servo motor, and linear servo motor.
- A typical servo motor comprises of three wires namely- power, control, and ground. The shape and size of these motors depends on their applications.

Principle of working of Servo motor

- Servo motor works on the PWM (Pulse Width Modulation) principle, which means its angle of rotation is controlled by the duration of pulse applied to its control PIN. Basically servo motor is made up of DC motor which is controlled by a variable resistor (potentiometer) and some gears.

Working of a Servo Motor

- The Servo Motor basically consists of a DC Motor, a Gear system, a position sensor and a control circuit. The DC motors get powered from a battery and run at high speed and low torque. The Gear and shaft assembly connected to the DC motors lower this speed into sufficient speed and higher torque. The position sensor senses the position of the shaft from its definite position and feeds the information to the control circuit. The control circuit accordingly decodes the signals from the position sensor and compares the actual position of the motors with the desired position and accordingly controls the direction of rotation of the DC motor to get the required position. The Servo Motor generally requires DC supply of 4.8V to 6 V.

Applications

- 1**. Robotics :** At every joint of the robot, we connect a servomotor. Thus giving the robot arm its precise angle.
- 2. **Conveyor belts** : servo motors move , stop , and start conveyor belts carrying product along to various stages , for example , in product packaging/ bottling, and labelling .
- **3. Camera auto focus** : A highly precise servo motor build into the camera corrects a camera lens to sharpen out of focus images.
- 4. **Solar tracking system** : Servo motors adjust the angle of solar panels throughout the day and hence each panel continues to face the sun which results in harnessing maximum energy from sunup to sundown .

Thank You