RADHAKRISHNA INSTITUTE OF TECHNOLOGY AND ENGINEERING

DEPARTMENT OF ELECTRICAL ENGINEERING

COURSE NAME : ELECTRICAL MACHINES-II
COURSE CODE : REL5C003
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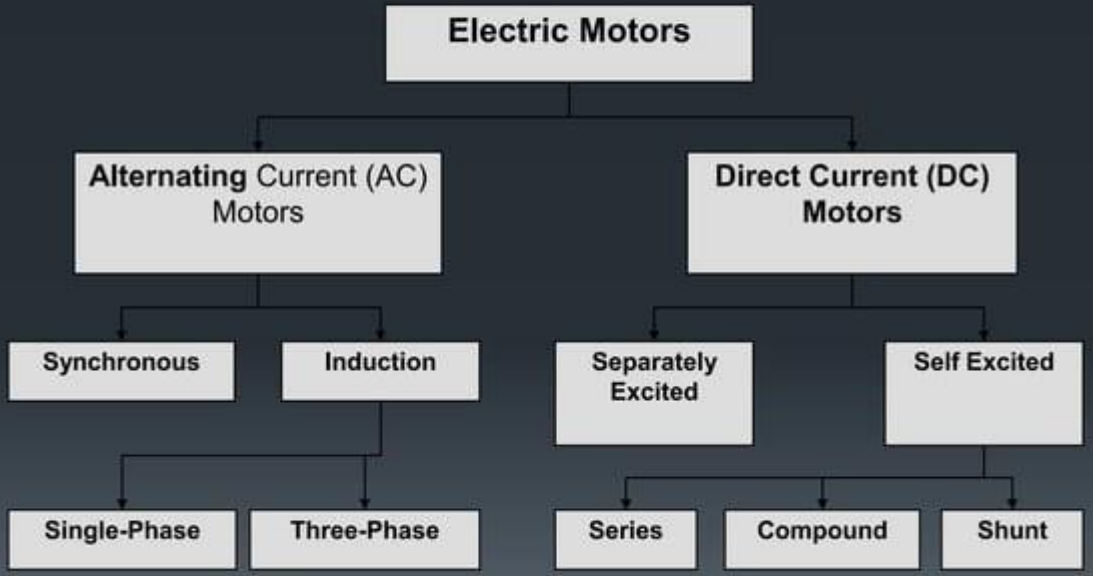
ELECTRIC MOTOR

- An electric motor is an electromechanical device that converts electrical energy to mechanical energy.

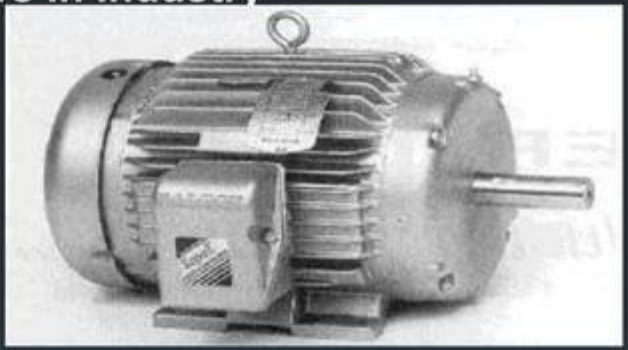
- The mechanical energy can be used to perform work such as rotating a pump impeller, fan, blower, driving a compressor, lifting materials etc.

CLASSIFICATION OF MOTORS



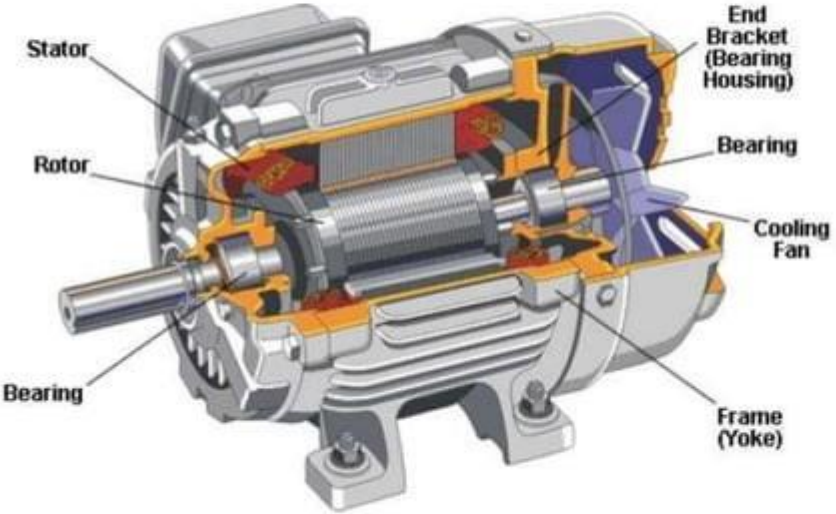
AC MOTOR: INDUCTION MOTOR

- Most common motors in industry



- Advantages:
  - Simple design
  - Inexpensive
  - High power to weight ratio
  - Easy to maintain
  - Direct connection to AC power source

Parts of AC Motor



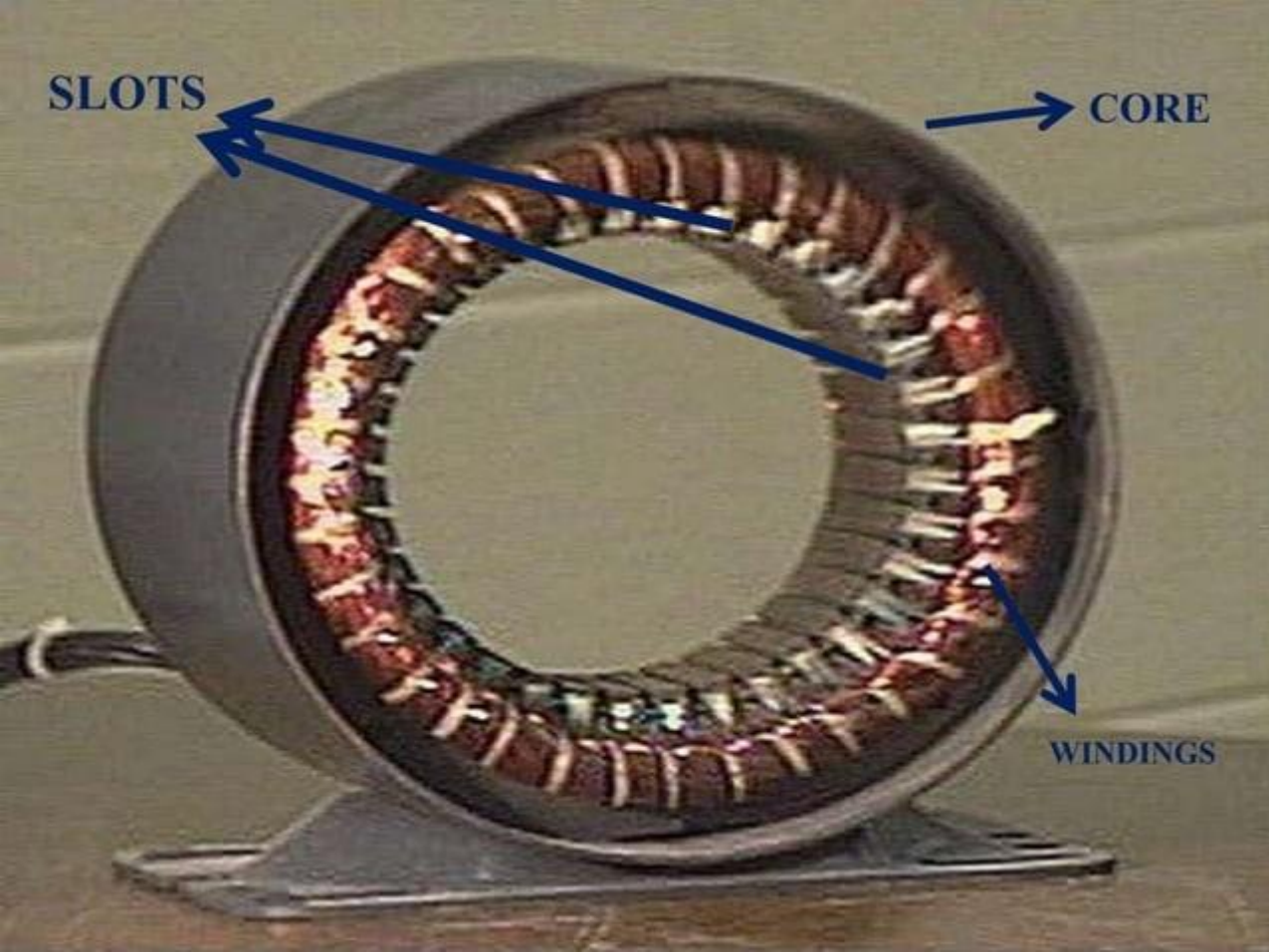
- *An induction motor works on transforming action.*
- *The stator works as the primary while the rotor works as the secondary.*
- *It is also called asynchronous motor.*

- It consists of two parts:

1. ***Stator*** - It is the stationary part of the motor.

2. ***Rotor*** - It is the rotating part of the motor.

STATOR


SLOTS
CORE
WINDINGS

- Stator has three main parts:

- ***Outer Frame*** – It is the outer body of the of the motor.

  It protects the inner part of the machine.
- ***Stator Core*** – Built up of high grade silicon steel.

  Carries the alternating magnetic field.
- ***Stator winding*** – Has a three phase winding.

ROTOR

- There are two types of rotors which are employed in 3 – phase induction motor.
  - ***Squirrel Cage Rotor.***
  - ***Phase Wound/ Slip Ring Rotor.***

SQUIRREL CAGE ROTOR

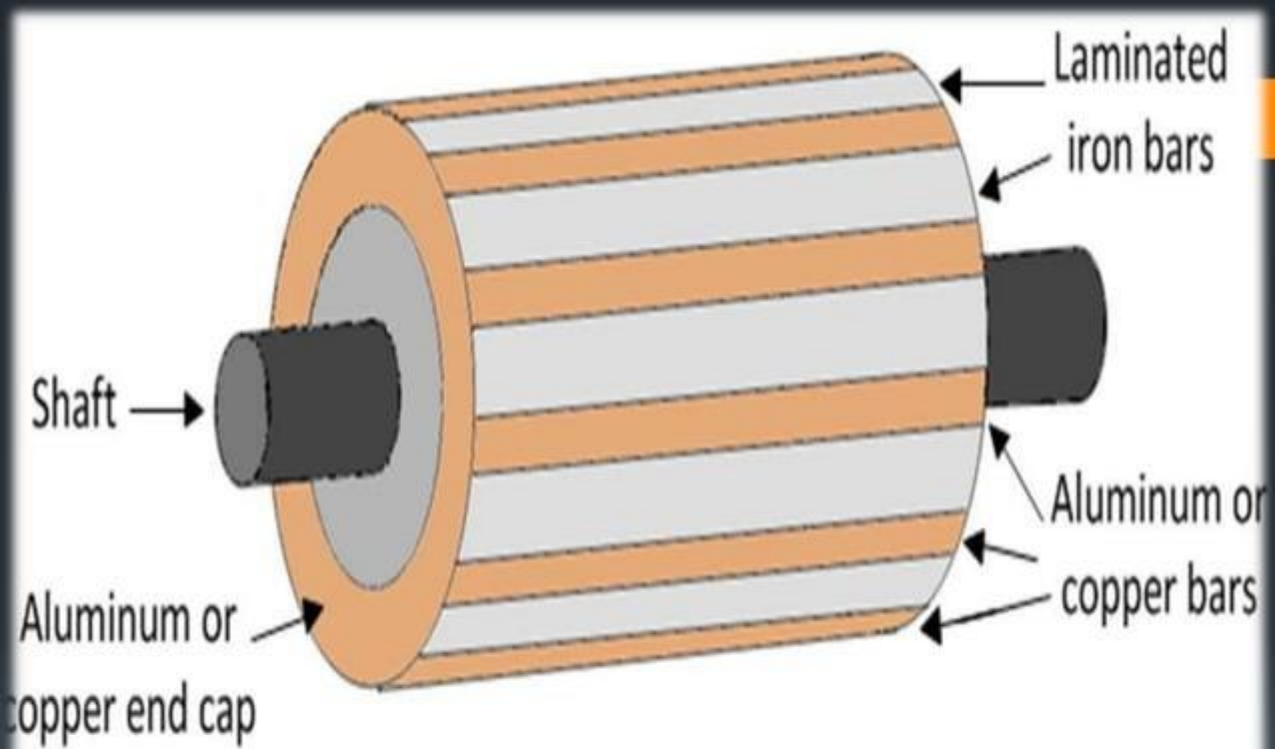
- It consists of a laminated cylindrical core having semi closed circular slots at the outer periphery.
- Copper or aluminum bar conductors are placed in these slots and short circuited at each end by copper or aluminum rings called short circuiting rings.
- The rotor winding is permanently short circuited and it is not possible to add any external resistance.

- The rotor slots are not parallel to the shaft but skewed to –

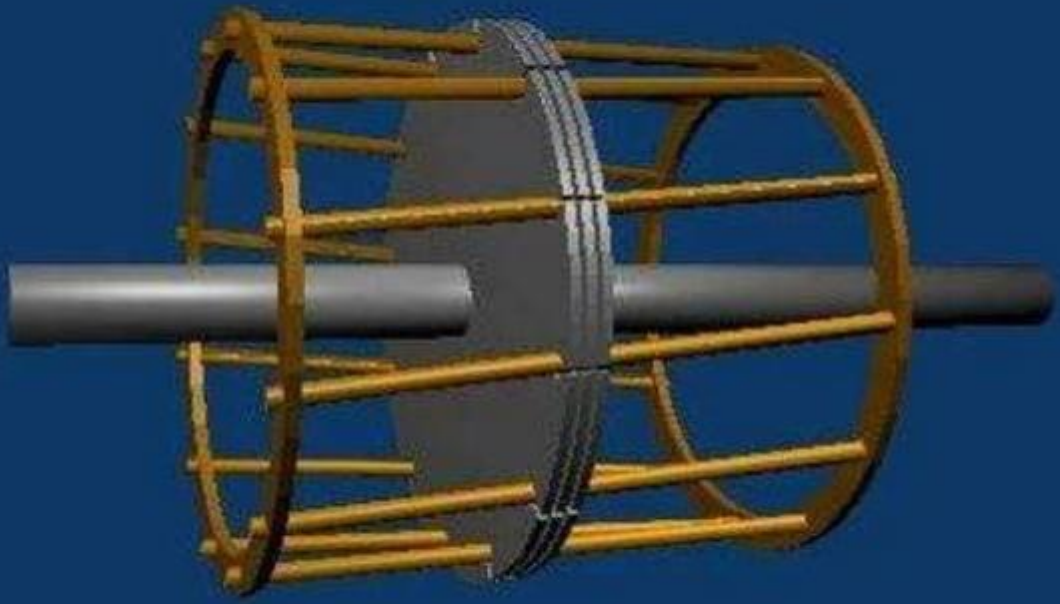
✓ Reduce humming .

✓Provide smoother torque for different positions of rotor.

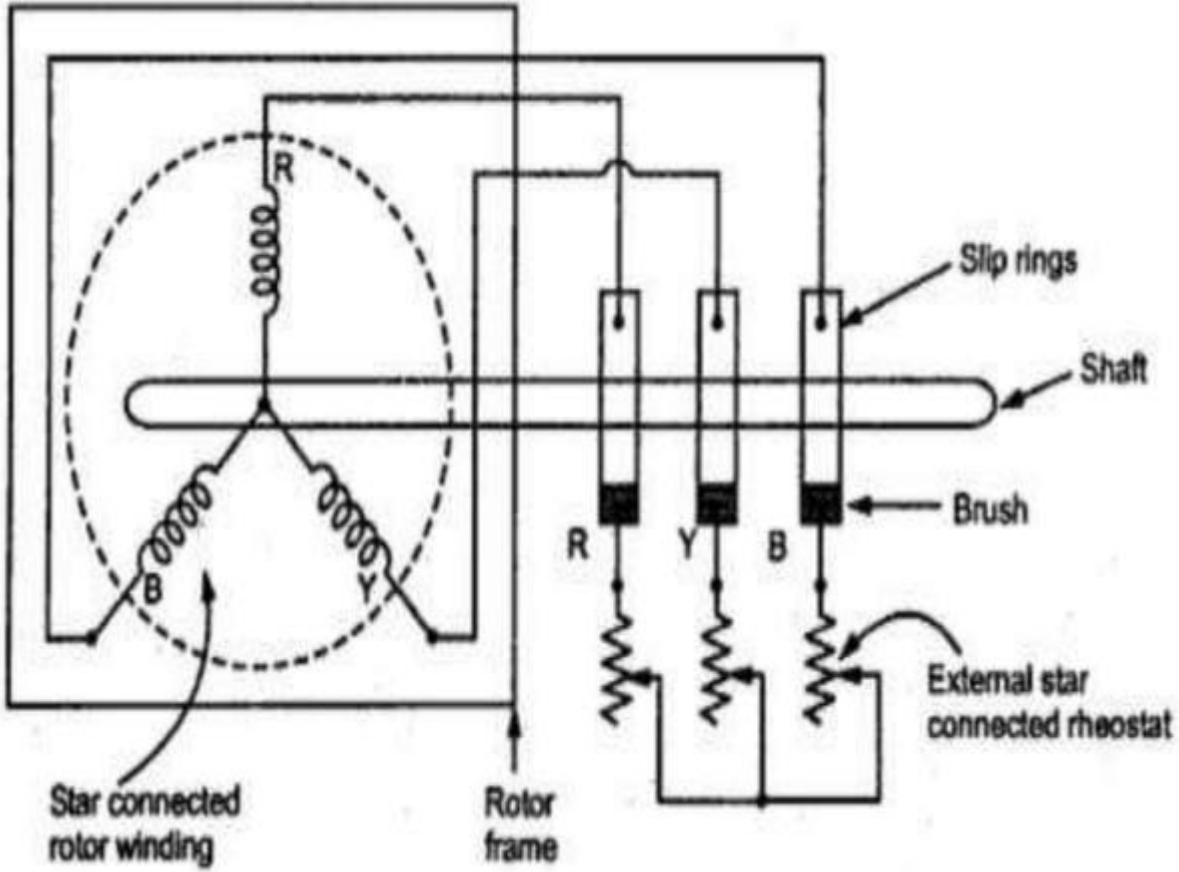
✓Reduce magnetic locking of stator and rotor.



Induction Motor Squirrel Cage Rotor



PHASE WOUND ROTOR


R
Slip rings
Shaft
Brush
R
Y
B
B
Y
External star
connected rheostat
Star connected
rotor winding
Rotor
frame

- It is also called ***SLIP RING ROTOR***

- Consists of a laminated core having semi closed slots at the outer periphery and carries a 3-phase insulated winding.

- The rotor is wound for the same number of poles as that of stator.

- The three finish terminals are connected together forming a star point and the three star terminals are connected to three slip rings fixed on the shaft.

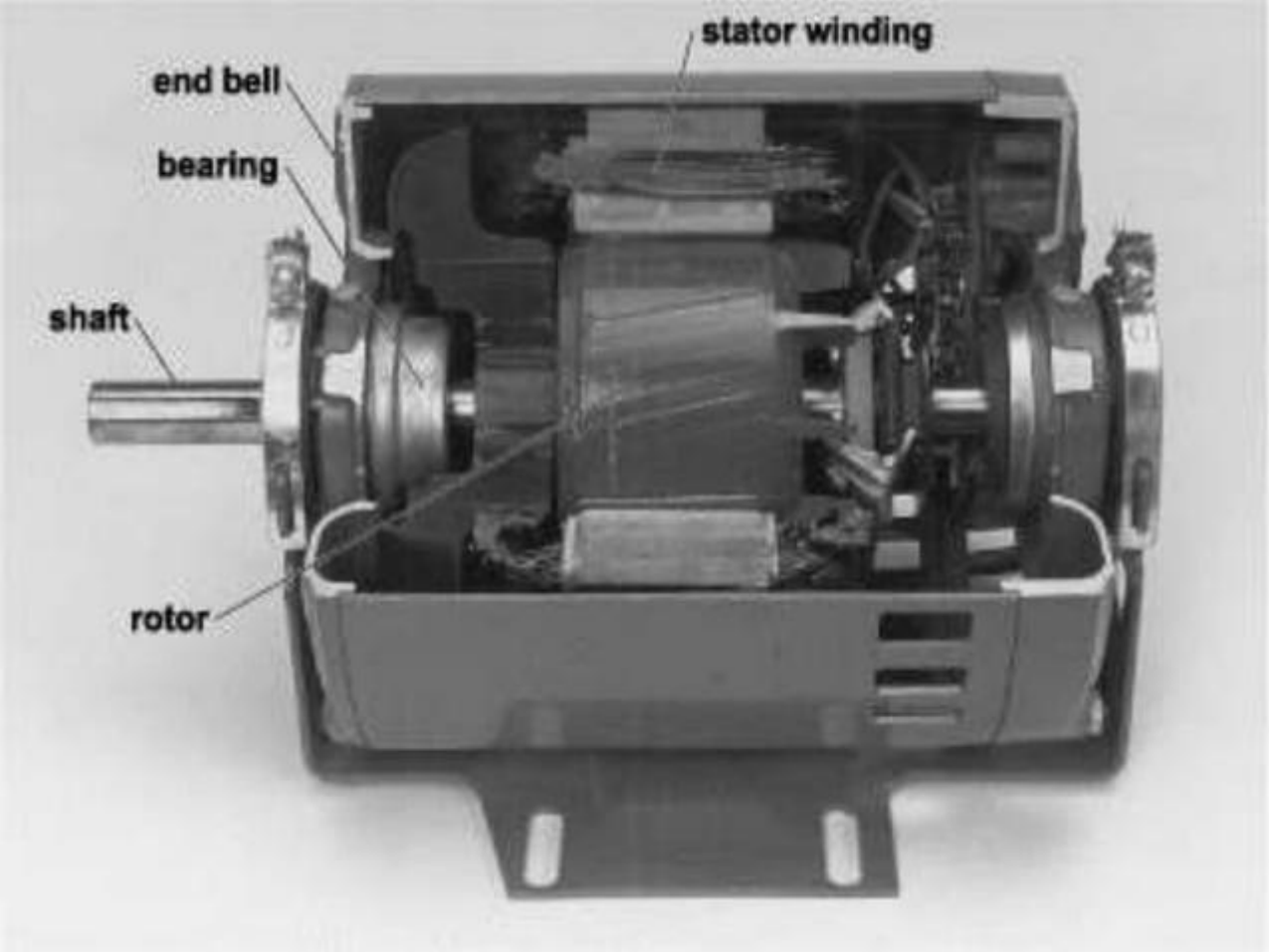
- ***Principle of Operation***
  - A rotating field is set up in the stator when a 3- Phase supply is given.
  - The stationary rotor cut the revolving field and due to electromagnetic induction an *e.m.f.* is induced in the rotor conductor.
  - As the rotor conductor is short circuited current flows through them.
  - It becomes a current carrying conductor in magnetic field and start rotating.

- ***Slip***

  - Induction motor rotor always rotate at a speed less than synchronous speed.
  - The difference between the flux (N_s) and the rotor speed (N) is called slip.

$$\% \text{ Slip} = \frac{(N_s - N)}{N} \quad 100$$

$$\text{Slip speed} = N_s - N$$


stator winding
end bell
bearing
shaft
rotor

CONTENT

- Definition and Types of Alternator
- Working Principle of Alternator
- Construction of Alternator
- Armature Reaction in Alternator or Synchronous Generator
- Armature Winding of Alternator
- Rating of Alternator
- Application of Induction Generator

DEFINITION AND TYPES OF 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.

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

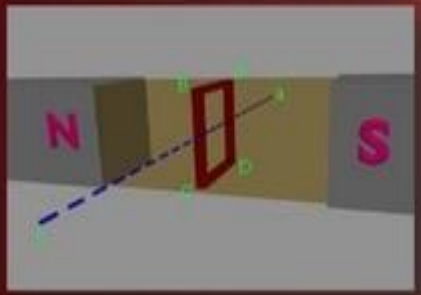
- Salient pole type.
- Cylindrical rotor type.

WORKING PRINCIPLE OF ALTERNATOR

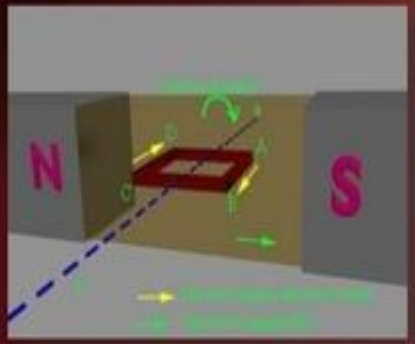
- The **working principle of alternator** depends upon Faraday's law of electromagnetic induction which says the current is induced in the conductor inside a magnetic field when there is a relative motion between that conductor and the magnetic field.

#Working

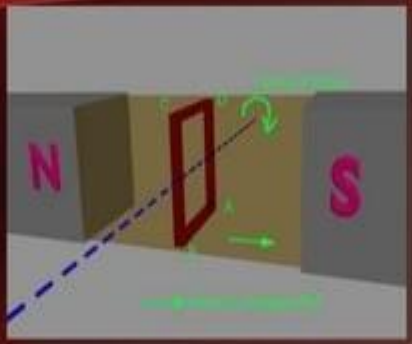
1. For understanding **working of alternator** let's assume a single rectangular turn placed in between two opposite magnetic pole as shown.



- The single turn loop ABCD starts rotating clockwise against axis a-b

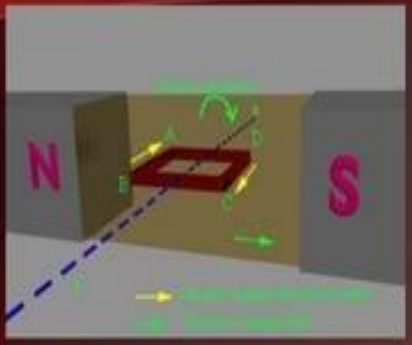


- After 90° rotation the side AB or conductor AB of the loop comes in front of S-pole and conductor CD comes in front of N-pole.
- As per Fleming right hand rule the direction of this current will be from A to B. At the same time conductor CD comes under N pole and here also if we apply Fleming right hand rule we will get the direction of induced current and it will be from C to D.



- Now after clockwise rotation of another 90° the turn ABCD comes at vertical position as shown below. At this position tangential motion of conductor AB and CD is just parallel to the magnetic flux lines, hence there will be no flux cutting that is no current in the conductor.

- While the turn ABCD comes from horizontal position to vertical position, angle between flux lines and direction of motion of conductor, reduces from 90° to 0° and consequently the induced current in the turn is reduced to zero from its maximum value.



- As at this position the turn comes at horizontal position from its vertical position, the current in the conductors comes to its maximum value from zero. That means current is circulating in the close turn from point B to A, from A to D, from D to C and from C to B

- During every full revolution of the turn, the current in the turn gradually reaches to its maximum value then reduces to zero and then again it comes to its maximum value but in opposite direction and again it comes to zero.

- In this way the current completes one full sine wave form during each 360° revolution of the turn. Thus an alternating current is produced in a turn is rotated inside a magnetic field. From this, we come to the actual **working principle of alternator**.

CONSTRUCTION OF ALTERNATOR

I. Stator :

- Stator is the stationary part of the alternator and contains 3-phase armature windings. Stator core is built up of silicon steel laminations to reduce eddy current losses.
- The laminations are provided with slots on its inner periphery and are packed tightly together by cast iron frame.
- The three phase windings are placed in these slots and serves as the armature windings of the alternator.
- The armature windings are always connected in star and the neutral is connected to ground.

I. Rotor :

- The rotor is rotating part of the alternator. It carries a field winding which is supplied with dc current through two slip rings by a separate dc source.
- This dc source (exciter) is generally a small dc generator mounted on the shaft of the alternator.

- There are two types of rotors :
  i. Salient pole type
  ii. Cylindrical rotor type

Salient pole type

- Salient means sticking out or projected out. A salient pole is a magnetic pole that is projected out of the rotor surface.
- The salient pole alternators are slow-speed machines, speed varying from **150 to 600 rpm**. These alternators are driven by hydraulic turbines. They are also called water-wheel generators or hydro-generators
- Salient type rotor has non-uniform air-gap and two or four poles
- Salient-pole construction can not be made strong enough to withstand the mechanical stress at higher speeds

ARMATURE REACTION IN ALTERNATOR OR SYNCHRONOUS GENERATOR

- Every rotating electrical machine works based on Faraday's law.
- Every electrical machine requires a magnetic field and a coil (Known as armature) with a relative motion between them.
- In case of an alternator, we supply electricity to pole to produce magnetic field and output power is taken from the armature. Due to relative motion between field and armature, the conductor of armatures cut the flux of magnetic field and hence there would be changing flux linkage with these armature conductor.
- According to Faraday's law of electromagnetic induction there would be an emf induced in the armature. Thus, as soon as the load is connected with armature terminals, there is an current flowing in the armature coil.
- As soon as current starts flowing through the armature conductor there is one reverse effect of this current on the main field flux of the alternator (or synchronous generator). This reverse effect is referred as **armature reaction in alternator or synchronous generator**.
-

- The armature reaction of alternator or synchronous generator, depends upon the phase angle between, stator armature current and induced voltage across the armature winding of alternator.
- The phase difference between these two quantities, i.e. Armature current and voltage may vary from - 90° to + 90° .
- If this angle is θ, then,

- When θ = 0 (Unity Power Factor)
- When θ = 90° (Lagging Zero Power Factor)
- When θ = - 90° (Leading Power Factor)

A. **When θ = 0** (Unity Power Factor)

- At unity power factor, the angle between armature current I and induced emf E, is zero. That means, armature current and induced emf are in same phase

B. **When θ = 90°** (Lagging Zero Power Factor)

- At lagging zero electrical power factor, the armature current lags by 90° to induced emf in the armature. As the emf induced in the armature coil due to main field flux. The emf leads the main field flux by 90°.

C. **When θ = - 90°** (Leading Power Factor)

- At leading power factor condition, armature current I leads induced emf E by an angle 90°. Again, we have shown just, field flux leads, induced emf E by 90°.

ARMATURE WINDING OF ALTERNATOR

- Armature winding in an alternator may be either closed type open type. Closed winding forms star connection in **armature winding of alternator**.
- Common properties of armature winding.
  - First and most important property of an armature winding is, two sides of any coil should be under two adjacent poles. That means, coil span = pole pitch.
  - The winding can either be single layer or double layer.
  - Winding is so arranged in different armature slots, that it must produce sinusoidal emf.

- There are different **types of armature winding** used in alternator. The windings can be classified as
  - Single phase winding.
  - Lap winding
  - wave winding
  - Concentric winding
  - Full pitched coil winding
  - fractional pitched coil winding.

- Single phase and poly phase armature winding

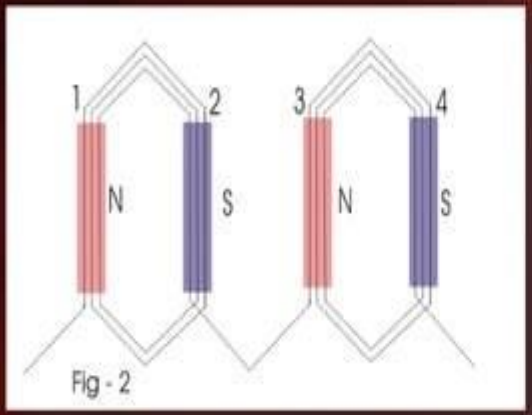


Fig - 2

- Lap winding

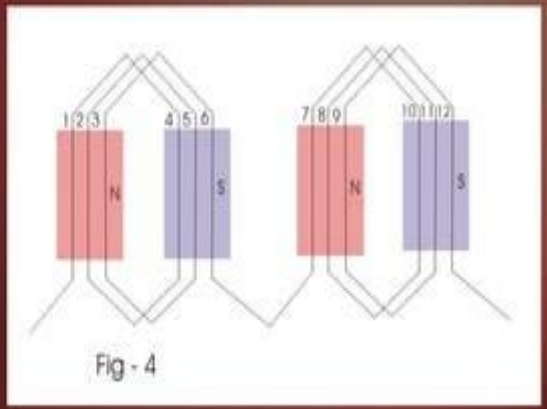


Fig - 4

- wave winding.

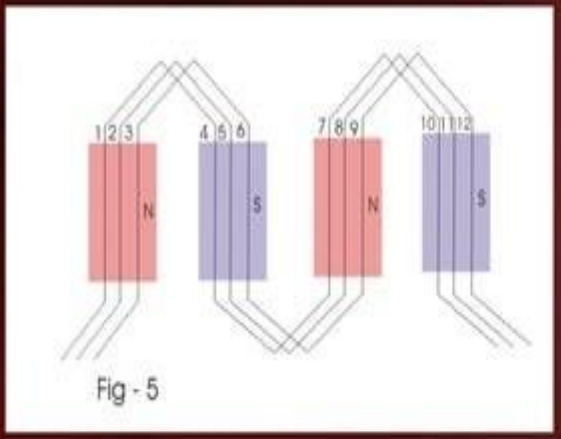


Fig - 5

- Concentric winding

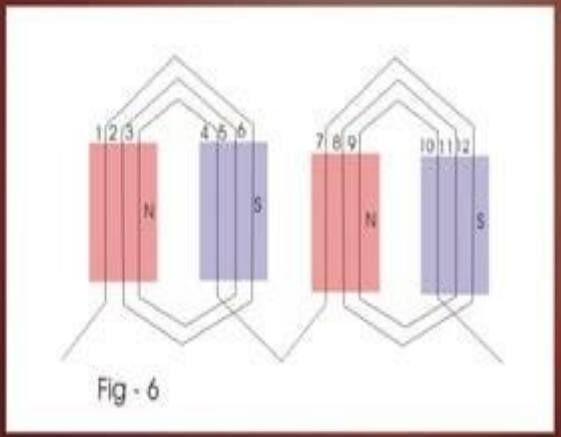


Fig - 6

RATING OF ALTERNATOR

- Power **rating of alternator** is defined as the power which can be delivered by an alternator safely and efficiently under some specific conditions.
- The power rating of an alternator is so specified, that at that maximum load, the temperature rise of different parts of the machine does not cross their specified safe limit.
- The copper losses i.e. I^2R loss varies with armature current and core losses vary with voltage.
- The temperature rise or heating of alternator depends upon cumulative effect of copper losses and core losses. As there is no role of power factor upon these losses, the rating of alternator generally given in VA or KVA or MVA.
- The electrical output of an alternator is product of power factor and VA and output is expressed in KW. Some times alternators are also rated by its power instead of VA rating.

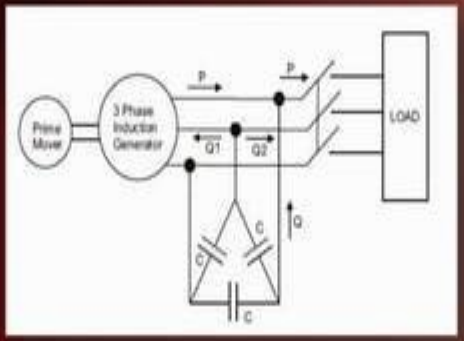
Standered rating Of Alternators

Kilo Watt Rating	5000
Power Factor	0.85 lag
KVA Rating	5,88,000
Stator Volt	21,000
Stator Ampere	16,200
Rotor Volt	340
Rotor Ampere	4040
R.P.M	3000
Hz	50
Phase	3
Armature Connection	Double Star
Coolant	Water & Hydrogen (Forced)
Gas Pressure	3.5 bar
Insulation Type	+ F
Specification	IS5422 & IEC34

APPLICATION OF INDUCTION GENERATOR

- The conditions when the induction machine will behave as an **induction generator** are written below:
  I. Slip becomes negative due to this the rotor current and rotor emf attains negative value.
  II. The prime mover torque becomes opposite to electric torque.
- These conditions can be achieve when an induction machine is coupled with the prime mover whose speed can be controlled. If the speed of the prime mover is increased such that the slip becomes negative .
- Due to this, all the conditions that we have mentioned above will become fulfilled and machine will behave like an induction generator.
- Induction generator is not a self excited machine therefore in order to develop the rotating magnetic field, it requires magnetizing current and reactive power.

- we can have a self excited or isolated induction generation in one case if we will use capacitor bank for reactive power supply instead of ac supply system



- The function of the capacitor bank is to provide the lagging reactive power to the induction generator as well as load

- Externally excited generators are widely used for regenerative breaking of hoists driven by the three phase induction motors.
  - The efficiency of the externally excited generator is not so good.
  - We cannot use externally excited generator at lagging power factor which major drawback of this type of generator.
  - The amount of reactive power used to run these types of generator required is quite large.
- Self excited generators are used in the wind mills. Thus this type of generator helps in converting the unconventional sources of energy into electrical energy


The End


Thank you