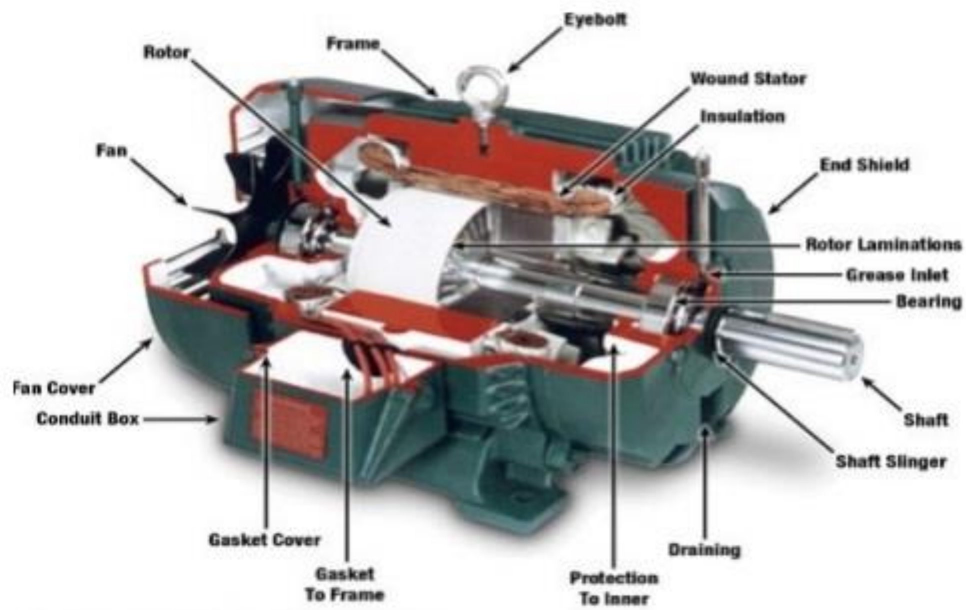
DC Machine: Construction and their Applications

The DC machine can be classified into two types namely DC motors as well as DC generators. Most of the DC machines are equivalent to AC machines because they include AC currents as well as AC voltages in them. The output of the DC machine is DC output because they convert AC voltage to DC voltage. The conversion of this mechanism is known as the commutator, thus these machines are also named as commutating machines. DC machine is most frequently used for a motor. The main benefits of this machine include torque regulation as well as easy speed. The applications of the DC machine is limited to trains, mills, and mines. As examples, underground subway cars, as well as trolleys, may utilize DC motors. In the past, automobiles were designed with DC dynamos for charging their batteries.

What is a DC Machine?

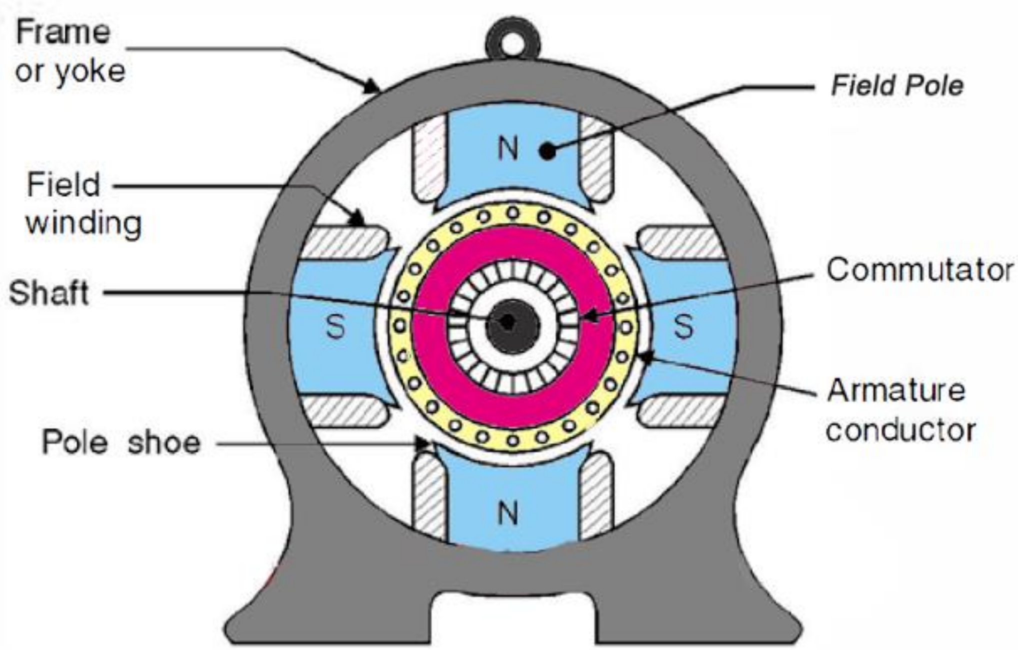
A DC machine is an electromechanical energy alteration device. The working principle of a DC machine is when electric current flows through a coil within a magnetic field, and then the magnetic force generates a torque which rotates the dc motor. The DC machines are classified into two types such as DC generator as well as DC motor. The main function of the DC generator is to convert mechanical power to DC electrical power, whereas a DC motor converts DC power to mechanical power. The AC motor is frequently used in the industrial applications for altering electrical energy to mechanical energy. However, a DC motor is applicable where the good speed regulation & ample range of speeds are necessary like in electric-transaction systems.



DC Machine

Construction of DC Machine

The construction of DC machine can be done using some of the essential parts like Yoke, Pole core & pole shoes, Pole coil & field coil, Armature core, Armature winding otherwise conductor, commutator, brushes & bearings. Some of the parts of the DC machine is discussed below.



Construction of DC Machine

Yoke

Another name of a yoke is the frame. The main function of the yoke in the machine is to offer mechanical support intended for poles and protects the entire machine from the moisture, dust, etc. The materials used in the yoke are designed with cast iron, cast steel otherwise rolled steel.

Pole and Pole Core

The pole of the DC machine is an electromagnet and the field winding is winding among pole. Whenever field winding is energized then the pole gives magnetic flux. The materials used for this are cast steel, cast iron otherwise pole core. It can be built with the annealed steel laminations for reducing the power drop because of the eddy currents.

Pole Shoe

Pole shoe in DC machine is an extensive part as well as enlarge the region of the pole. Because of this region, flux can be spread out within the air-gap as well as extra flux can be passed through the air space toward armature. The materials used to build pole shoe is cast iron otherwise cast steed, and also used annealed steel lamination to reduce the loss of power because of eddy currents.

Field Windings

In this, the windings are wounded in the region of pole core & named as field coil. Whenever current is supplied through field winding then it electromagnetics the poles which generate required flux. The material used for field windings is copper.

Armature Core

Armature core includes the huge number of slots within its edge. Armature conductor is located in these slots. It provides the low-reluctance path toward the flux generated with field winding. The materials used in this core are permeability low-reluctance materials like iron otherwise cast. The lamination is used to decrease the loss because of the eddy current.

Armature Winding

The armature winding can be formed by interconnecting the armature conductor. Whenever an armature winding is turned with the help of prime mover then the voltage, as well as magnetic flux, gets induced within it. This winding is allied to an exterior circuit. The materials used for this winding are conducting material like copper.

Commutator

The main function of the commutator in the DC machine is to collect the current from the armature conductor as well as supplies the current to the load using brushes. And also provides uni-directional torque for DC-motor. The commutator can be built with a huge number of segments in the edge form of hard drawn copper. The Segments in the commutator are protected from thin mica layer.

Brushes

Brushes in the DC machine gather the current from commutator and supplies it to exterior load. Brushes wear with time to inspect frequently. The materials used in brushes are graphite otherwise carbon which is in rectangular form.

Types of DC Machines

The excitation of the DC machine is classified into two types namely separate excitation, as well as self-excitation. In separate excitation type of dc machine, the field coils are activated with a separate DC source. In self-excitation type of dc machine, the flow of current throughout the field-winding is supplied with the machine. The principal kinds of DC machine are classified into four types which include the following.

- Separately excited DC machine
- Shunt wound/shunt machine.
- Series wound/series machine.
- Compound wound / compound machine.

Separately Excited DC Machine

In Separately Excited DC Machine, a separate DC source is utilized for activating the field coils.

Shunt Wound DC Machine

In Shunt wound DC Machines, the field coils are allied in parallel through the armature. As the shunt field gets the complete o/p voltage of a generator otherwise a motor supply voltage, it is normally made of a huge number of twists of fine wire with a small field current carrying.

Series Wound DC Machine

In series wound D.C. Machines, the field coils are allied in series through the armature. As series field winding gets the armature current, as well as the armature current is huge, due to this the series field winding includes few twists of wire of big cross-sectional region.

Compound Wound DC Machine

A compound machine includes both the series as well as shunt fields. The two windings are carried-out with every machine pole. The series winding of the machine includes few twists of a huge cross-sectional region, as well as the shunt windings, include several fine wire twists.

The connection of the compound machine can be done in two ways. If the shunt-field is allied in parallel by the armature only, then the machine can be named as the 'short shunt compound machine' & if the shunt-field is allied in parallel by both the armature as well as series field, then the machine is named as the 'long shunt compound machine'.

EMF Equation of DC Machine

The DC machine e.m.f can be defined as when the armature in the dc machine rotates, the voltage can be generated within the coils. In a generator, the e.m.f of rotation can be called the generated emf, and Er=Eg. In the motor, the emf of rotation can be called as counter or back emf, and Er=Eb.

Let Φ is the useful flux for every pole within webers
P is the total number of poles
z is the total number of conductors within the armature
n is the rotation speed for an armature in the revolution for each second
A is the no. of parallel lane throughout the armature among the opposite polarity brushes.
Z/A is the no. of armature conductor within series for each parallel lane
As the flux for each pole is 'Φ', every conductor slashes a flux 'PΦ' within a single revolution.

The voltage produced for each conductor = flux slash for each revolution in WB / Time taken for a single revolution within seconds

As 'n' revolutions are completed within a single second and 1 revolution will be completed within a 1/n second. Thus the time for a single armature revolution is a 1/n sec.

The standard value of produced voltage for each conductor

$p\,\Phi/1/n = np\,\Phi$ volts

The voltage produced (E) can be decided with the no.of armature conductors within series I any single lane among the brushes thus, the whole voltage produced

E = standard voltage for each conductor x no. of conductors within series for each lane

$E = n.P.\Phi \times Z/A$

The above equation is the e.m.f. the equation of the DC machine.

Losses in DC Machine

We know that the main function of a DC machine is to convert mechanical energy to electrical energy. Throughout this conversion method, the whole input power cannot be changed into output power because of the power loss in different forms. The type of loss may change from one apparatus to another. These losses will decrease the apparatus efficiency as well as the temperature will be increased. The DC machine energy losses can be classified into Electrical otherwise Copper losses, Core losses otherwise Iron losses, Mechanical losses, Brush losses, and Stray load losses.

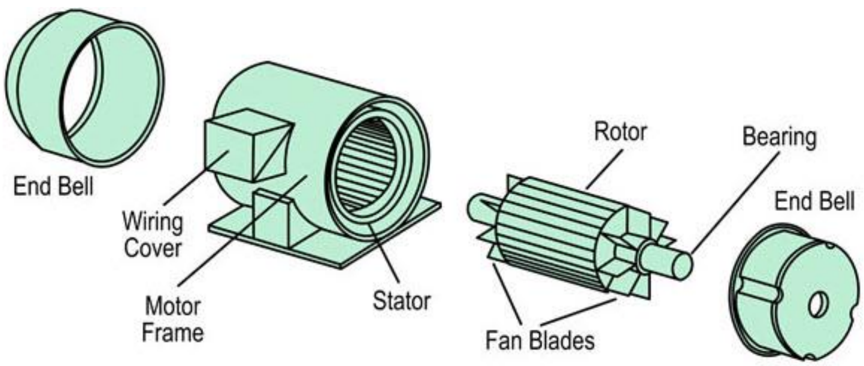
INDUCTION MOTOR:

Three Phase AC Induction Motor

The three-phase AC induction motor is a rotating electric machine that is designed to operate on three phase supply. This 3 phase motor is also called as an asynchronous motor. This AC motors are of two types: squirrel and slip-ring type induction motors. The principle of operation of this motor is based on the production of rotating magnetic field.

3 Phase Induction Motor Construction

These three phase motors consist of a stator and a rotor and between which no electrical connection exists. These stator and rotors are constructed with the use of high-magnetic core materials in order to reduce hysteresis and eddy current losses.



3 Phase Induction Motor Construction

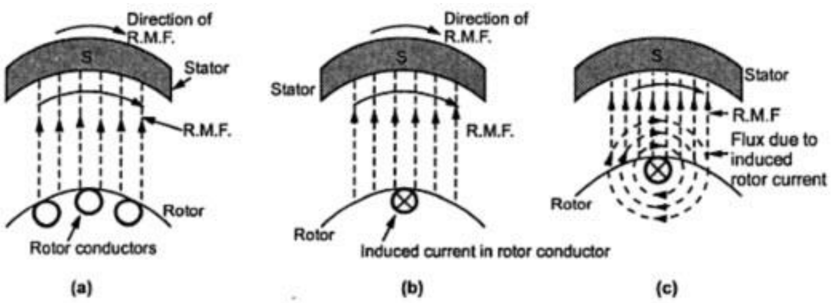
Stator frame can be constructed using cast iron, aluminum or rolled steel. Stator frame provides necessary mechanical protection and support for stator laminated core, windings and other arrangements for ventilation. Stator is wounded with three-phase windings which are overlapped with one another at 120 degree phase shift fitted into slotted laminations. The six ends of the three windings are brought out and connected to the terminal box so that these windings are excited by three-phase main supply.

These windings are of copper wire insulated with varnish fitted into insulated slotted laminations. At all working temperatures, this impregnated varnish remains rigid. These windings have highinsulation resistance and high resistance to saline atmosphere, moisture, alkaline fumes, oil and grease, etc. Whichever suits the voltage level, these windings are connected in either star or delta connections.

The rotor of three phase AC induction motor is different for the slip-ring and squirrel-cage induction motors. Rotor in slip-ring type consists of heavy aluminum or copper bars shorted on both ends of the cylindrical rotor. The shaft of the induction motor is supported on two bearings at each ends to ensure free rotating within the stator and to reduce the friction. It consists of stack of steel laminations evenly spaced slots that are punched around of its circumference into which un-insulated heavy aluminum or copper bars are placed.

A slip-ring-type rotor consists of three-phase windings are internally starred at one end, and the other ends are brought outside and connected to the slip rings mounted on the rotor shaft. And for developing a high-starting torque these windings are connected to rheostat with the help of carbon brushes. This external resistors or rheostat is used at the starting period only. Once the motor attains the normal speed, the brushes are short circuited, and the wound rotor works as squirrel cage rotor.

Principle of Operation of 3-Phase Induction Motor



Principle of Operation of 3-Phase Induction Motor

- When the motor is excited with three-phase supply,three-phase stator winding produce a rotating magnetic field with 120 displacements at constant magnitude which rotates at synchronous speed. This changing magnetic field cuts the rotor conductors and induces a current in them according to the principle of Faraday’s laws of electromagnetic induction. As these rotor conductors are shorted, the current starts to flow through these conductors.
- In the presence of magnetic field of stator, rotor conductors are placed, and therefore, according to the Lorenz force principle, a mechanical force acts on the rotor conductor. Thus, all the rotor conductors force, i.e., the sum of the mechanical forces produces torque in the rotor which tends to move it in the same direction of rotating magnetic field.
- This rotor conductor’s rotation can also be explained by Lenz’s law which tells that the induced currents in the rotor oppose the cause for its production, here this opposition is rotating magnetic field. This result the rotor starts rotating in the same direction of the stator rotating magnetic field. If the rotor speed more than stator speed,then no current will induce in the rotor because the reason for rotor

rotation is the relative speed of the rotor and stator magnetic fields. This stator and the rotor fields difference is called as slip. This how 3-phase motor is called as asynchronous machine due to this relative speed difference between the stator and the rotors.

- As we discussed above, the relative speed between the stator field and the rotor conductors causes to rotate the rotor in a particular direction. Hence, for producing the rotation, the rotor speed Nr must always be less than the stator field speed Ns, and the difference between these two parameters depends on the load on the motor.

The difference of speed or the slip of the AC induction motor is given as

Formula , $s = \frac{n_s - n_r}{n_s}$

The slip may also be expressed as percent slip as follows :

Percent slip = $\frac{n_s - n_r}{n_s} \times 100$

- At other speeds, the rotor frequency is proportional to the slip (s): that is,

$f_r = sf$

where f_r - frequency of rotor currents

- When the stator is stationary, Nr=0; so the slip becomes 1 or 100%.
- When Nr is at synchronous speed, the slip becomes zero; so the motor never runs at synchronous speed.
- The slip in the 3 phase induction motor from no load to full load is about 0.1% to 3%; that's why the induction motors are called as constant-speed motors.

<u>Synchronous Motors</u>

What is Synchronous Motor?

The definition of synchronous motor states that " An AC Motor in which at steady state, rotation of the shaft is in sync with the frequency of applied current". The synchronous motor works as AC motor but here the total number of rotations made by the shaft is equal to the integer multiple of the frequency of the applied current.

Synchronous Motor Design

Stator and rotor are the main components of the synchronous motor. Here stator frame has wrapper plate to which keybars and circumferential ribs are attached. Footings, Frame mounts are used to support the machine. To excite field windings with DC, slip rings and brushes are used.

Cylindrical and round rotors are used for 6 pole application. Salient pole rotors are used when a larger quantity of poles is required. Construction of the synchronous motor and synchronous alternator are similar.

Synchronous Motor Working Principle

Working of synchronous motors depends on the interaction of the magnetic field of the stator with the magnetic field of the rotor. The stator contains 3 phase windings and is supplied with 3 phase power. Thus, stator winding produces a 3 phased rotating Magnetic- Field. DC supply is given to the rotor.

The rotor enters into the rotating Magnetic-Field produced by the stator winding and rotates in synchronization. Now, the speed of the motor depends on the frequency of the supplied current.
Speed of the synchronous motor is controlled by the frequency of the applied current. The speed of a synchronous motor can be calculated as

$$N_s = 120f/p$$

where, f = frequency of the AC current (Hz)
p = total number of poles per phase
P = total pair number of poles per phase.

If the load greater than breakdown load is applied, the motor gets desynchronized. The 3 phase stator winding gives the advantage of determining the direction of rotation. In case of single-phase winding, it is not possible to derive the direction of rotation and the motor can start in either of the direction. To control the direction of rotation in these synchronous motors, starting arrangements are needed.