DC Machine Construction

→ DC Machine Consists of four parts mainly
(A) Field Magnets
(B) Armature
(C) Commutator
(D) Brushes

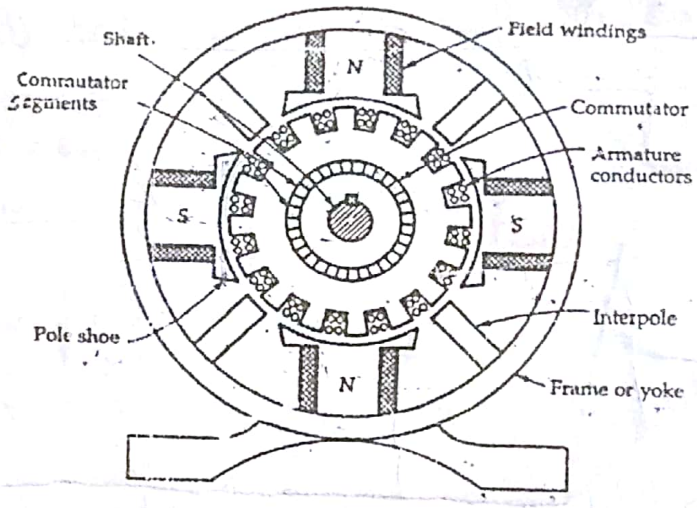


Fig. 6.1(a). Main parts of a 4-pole d.c. machine.

→(A) Field System

(a) The objective of field system is to create a uniform magnetic field, within which the armature rotates.

(b) Field Magnet consists of four parts:
(i) Yoke/Frame (ii) Pole Cores (iii) Pole Shoes
(iv) Magnetising Coils

(i) Yoke/Frame
Outer Frame or Yoke serve two purposes:
→ It provides mechanical support for the poles and acts as protecting cover for the whole machine
→ It carries the magnetic flux produced by the poles.
→ Yoke is made up of cast iron for smaller machines and for larger machines it is made up of cast steel.

(2) Pole Core & Pole Shoes

→ The Pole Core and pole shoe are fixed to magnetic frame.
→ They serve the following purposes:
  → They support the field or exciting coils.
  → They spread out the flux in air gap and also being of larger cross section, reduces the reluctance of magnetic path.
→ Pole Core and Pole shoe are made up of thin Cast steel.

(3) Magnetising Coils

→ Field Coils or Pole Coils, which consists of Copper wire or strip, are former wound for correct dimension.
→ When direct current is passed through the field winding, it magnetises the poles which produces the required flux

(B) Armature Core

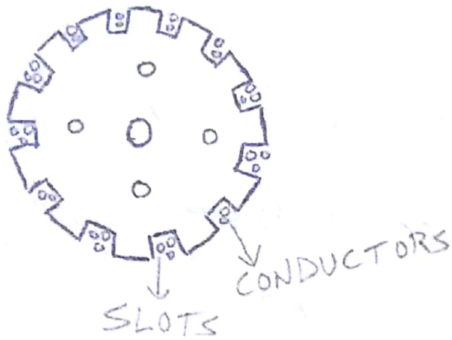
→ It is rotating part of dc machine and is built up in cylindrical shape
→ The purpose of the armature is to rotate the conductors in uniform magnetic field and hence cut the magnetic flux of field magnets.

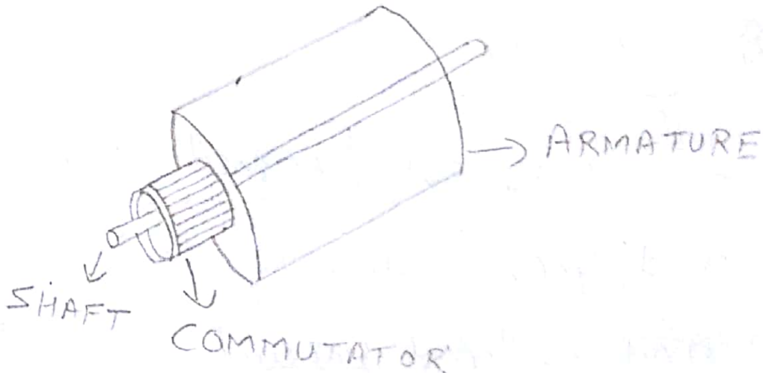
②

→ Armature Core is made from high permeability Silicon steel stampings.

→ Since armature is rotating part of machine, reversal of flux takes place in the core, hence hysterisis losses are produced.

→ To minimize these losses silicon steel material is used for its construction.





Armature Winding

→ The insulated conductors housed in armature slots are suitably connected. This is known as armature winding.

→ It is place where conversion of power takes place

→ On the basis of connection there are two types of armature winding

(a) Lap Winding :- Conductors are connected in such a way that no. of parallel paths is equal to No. of poles.

$$A = P$$

(b) Wave Winding :- Conductors are connected that they are divided into two parallel paths.

$$A = 2$$

(C) Commutator

→ It connects rotating armature conductors to stationary external circuit through brushes

→ It converts alternating current into unidirectional current.

→ It is of cylindrical shape and is made up of Copper segments

(D) Brushes

→ Brushes are pressed upon the commutator and form connecting link between armature winding and external circuit.

→ It is made up of High Grade Carbon

Shaft

→ It is made up of mild steel with maximum breaking strength.

→ It is used to transfer mechanical power from or to the machine.

12.3. D.C. GENERATOR / Need of Commutator

The same d.c. machine can be used as a generator or as a motor. When the machine is used to convert mechanical power into d.c. electrical power it is known as a *d.c. generator.*

Working Principle

The basic principle of a d.c. generator is electromagnetic induction, *i.e.* when a conductor cuts across the magnetic field, an e.m.f. is induced in it.

Simple loop generator

For simlicity, consider only one coil AB placed in the strong magnetic field. The two ends of the coil are joined to slip rings A′ and B′ respectively. Two brushes rest on these slip rings as shown in fig. 12.6.

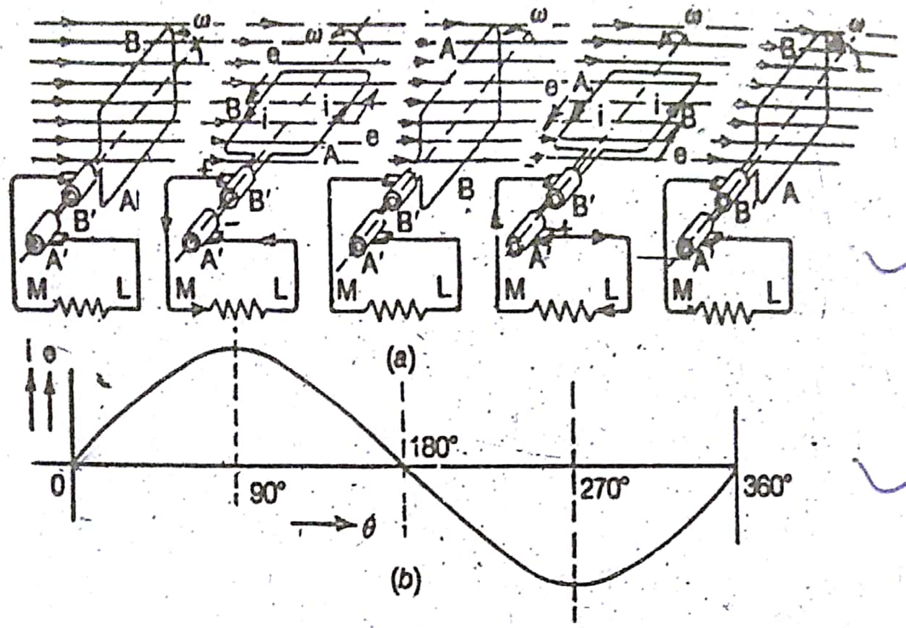


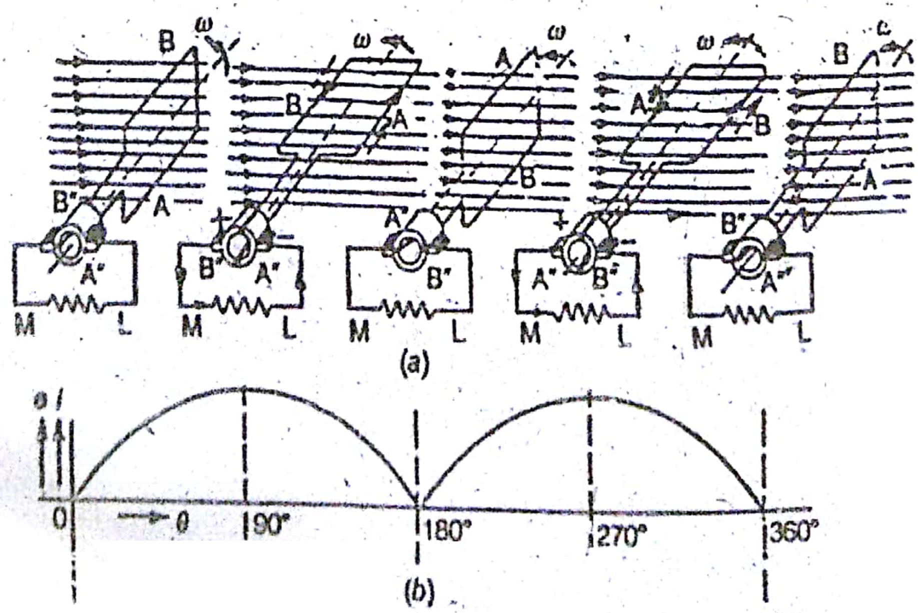
Fig. 12.6

When this coil is rotated in counter clockwise direction at an angular velocity of ω radius per second. The magnetic flux is cut by the coil and an e.m.f. is induced in it. The position of the coil at various instants is shown in fig. 12.6 (*a*) and the corresponding value of the induced e.m.f. and its direction is shown in the fig. 12.6 (*b*). The induced e.m.f. is alternating and the current flowing through the external resistance is also alternating, *i.e.* at second instant current flows in external resistance from M to L, whereas, at fourth instant it flows from L to M as shown in fig. 12.6 (*b*).

Commutator action

Now, consider that the two ends of the coil are connected to only one slip ring splitted into two parts (segment) *i.e.* A′ and B′. Each part is insulated from the other by a mica layer. Two bruses rest on these parts of the ring as shown in fig. 12.7 (*a*).

In this case when the coil is rotated in counter clockwise direction at an angular velocity of ω radians per second, the magnetic flux is cut by the coil and an e.m.f. is induced in it. The magnitude of e.m.f. induced in the coil at various instants will remain the same as shown in fig. 12.6 (*b*).



However, the flow of current in the external resistor or circuit will become unidirection *i.e.* at second instant the flow of current in the external resistor is from M to L as well as the flow of current in the external resistor is from M to L in the fourth instant as shown in fig. 12.7 (*a*). Its wave shape is shown in fig.

Hence, *an alternating current is converted into unidirectional current in the external circuit with the help of* **a split ring** (*i.e.* **commutator**).

In an actual machine, there are number of coils connected to the number of segments of the ring called commutator. The e.m.f. or current delivered by these coils to the external load is shown in fig. 12.8 (*a*). The actual flow of current flowing in the external load is shown by the firm line which fluctuates slightly. The number of coils placed on the armature are even much more than this and a pure direct current is obtained at the output as shown in fig. 12.8 (*b*).

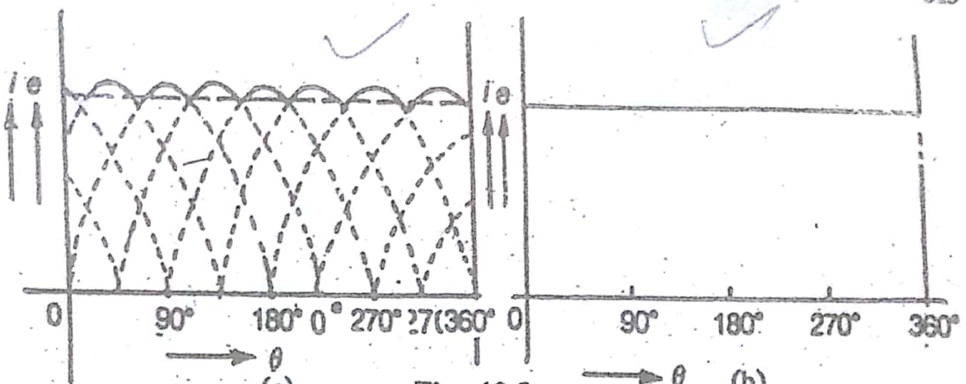


Fig. 12.8

Thus, *in actual machine working as a generator, the function of commutator is to convert the* **alternating current** *produced in the armature into* **direct current** *in the external circuit.*

Types of DC Generators:

DC Generators are generally classified according to methods of their field excitation. On the Basis of this criteria they can be classified as:

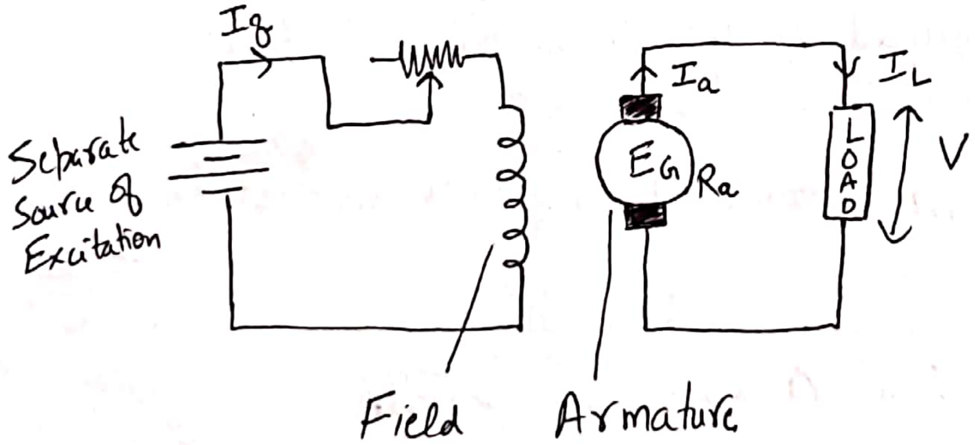
(1) Separately Excited DC Generators

(2) Self Excited DC Generators

- Shunt Wound DC Generator
- Series Wound DC Generator
- Compound Wound DC Generator.

(1) Separately Excited DC Generator:

A DC Generator whose field winding is supplied current from external DC source.



Armature Current I_a = Load Current I_L

$V = E_G - I_a R_a$, Where R_a is Armature Resistance

Power Developed, $P_g = E_G I_a$

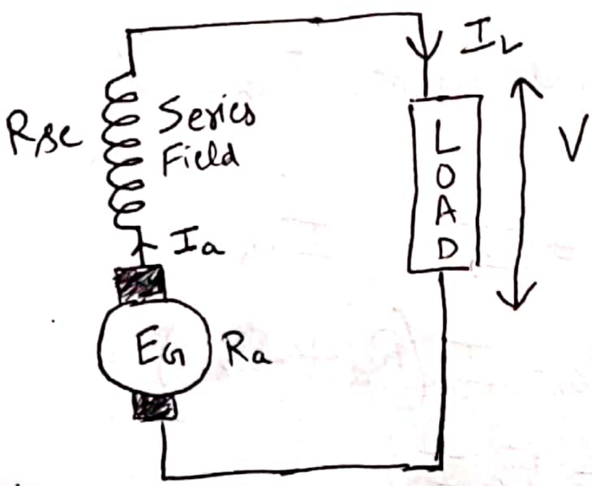
Power Delivered, $P_L = V I_L = V I_a$

(2) Self Excited DC Generator

A DC Generator whose field winding is excited by the current supplied by the generator itself.

(a) Series Wound Generator:

Field Winding is connected in series with armature winding.



$$I_L = I_a$$

Series Field Winding Resistance $= R_{se}$

$$V = E_G - I_a (R_a + R_{se})$$

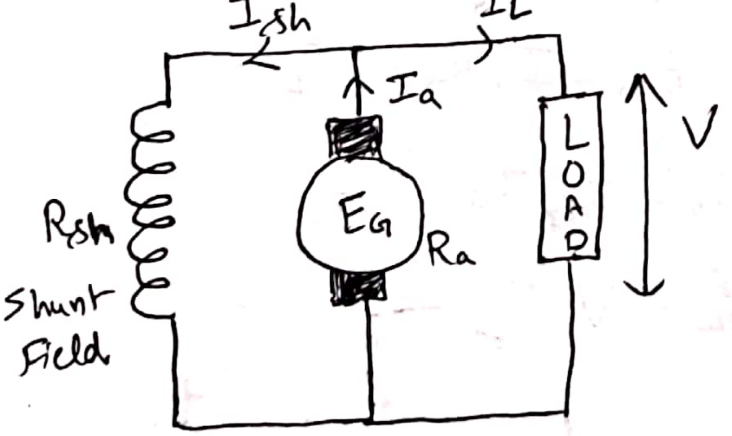
$$P_G = E_G I_a$$

$$P_L = V I_L = V I_a$$

(b) Shunt Wound Generator

Field Winding is connected across the armature winding forming a parallel circuit.

Shunt Field Current, $I_{sh} = \dfrac{V}{R_{sh}}$



$$I_a = I_L + I_{sh}$$

$$V = E_G - I_a R_a$$

$$P_G = E_G I_a$$

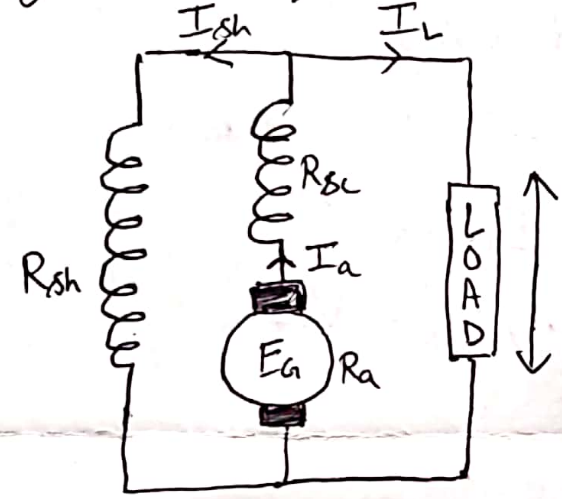
$$P_L = V I_L$$

(3) Compound Wound Generator

There are two sets of field winding. One of those is connected in series and other is connected in parallel with armature

(a) Long Shunt Compound Wound Generator:

Shunt Field Winding is parallel with Both armature and series field winding



Shunt Field Current, $I_{sh} = \frac{V}{R_{sh}}$

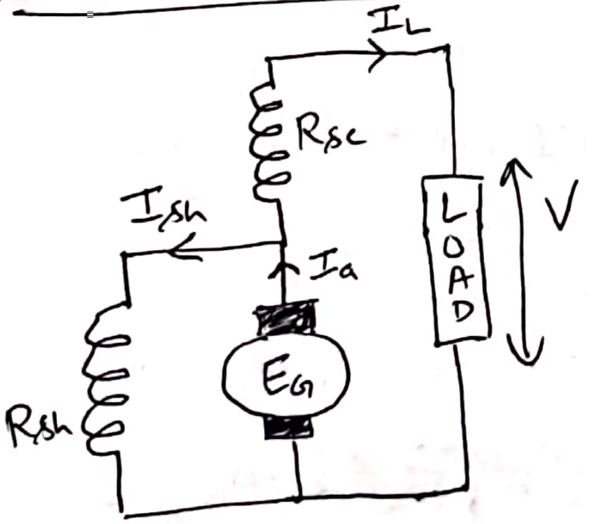
$$I_a = I_L + I_{sh}$$

$$V = E_G - I_a(R_a + R_{se})$$

$$P_G = E_G I_a$$

$$P_L = V I_L$$

(b) Short Shunt Compound Wound Generator



$$I_a = I_{sh} + I_L$$

$$V = E_G - I_a R_a - I_L R_{se}$$

$$P_G = E_G I_a$$

$$P_L = V I_L$$

12.25. D.C. MOTOR

A machine which converts mechanical power into d.c. electrical power is called a *d.c. generator. The same machine when used to convert d.c. electrical power into mechanical power is known as* **d.c. motor.** From construction point of view there is no difference between a d.c. generator and motor.

The d.c. motors are very useful where wide range of speeds and good speed regulation is required such as electric traction.

12.26. WORKING PRINCIPLE OF D.C. MOTORS

The operation of d.c. motor is based on the principle that when a current carrying conductor is placed in a magnetic field, a mechanical force is experienced by it. The direction of this force is determined by Fleming's Left Hand rule and its magnitude is given by the relation:

$$F = BIl \text{ newton}$$

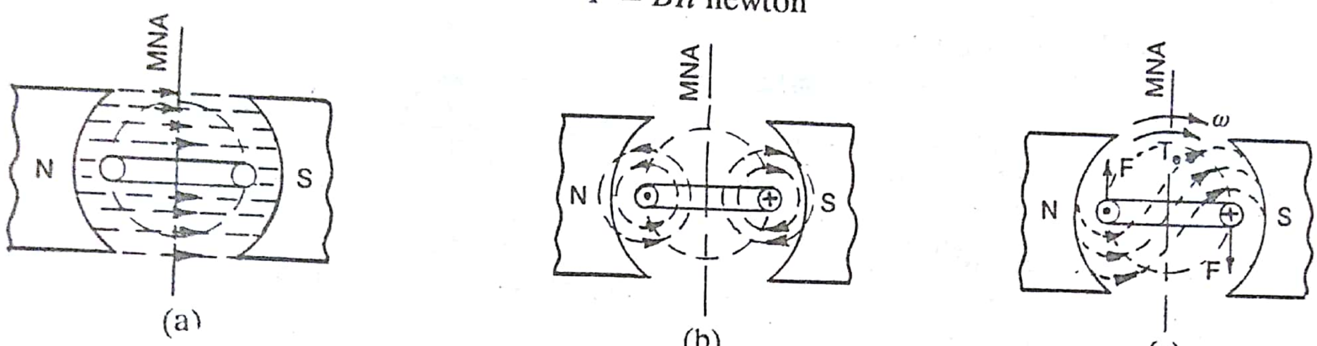
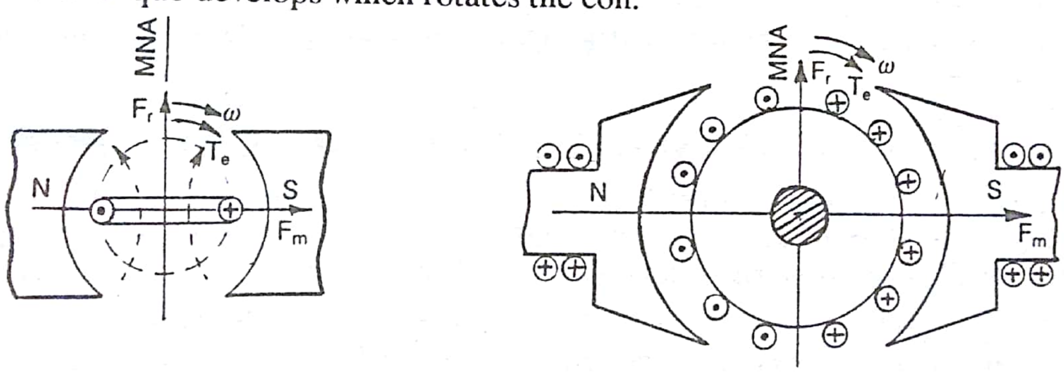


Fig. 12.39

For simplicity, consider only one coil of the armature placed in the magnetic field produced by a bipolar machine [see fig. 12.39 (*a*)]. When d.c. supply is connected to the coil, current flows through it which sets up its own field as shown in fig. 12.39 (*b*). By the interaction of the two fields (*i.e.* field produced by the main poles and the coil), a resultant field is set up as shown in fig. 12.39 (*c*). The tendency of this field is to come to its original position *i.e.* in straight line due to which force is exerted on the two coil sides and torque develops which rotates the coil.



12.27. BACK E.M.F.

It has been seen that when current is supplied to the armature conductors placed in the main magnetic field, torque develops and armature rotates, the armature conductors cut the magnetic field and an e.m.f. is induced in these conductors. The direction of the induced e.m.f. in the armature conductors is determined by Fleming's Right Hand Rule. It is marked in fig. 12.42.

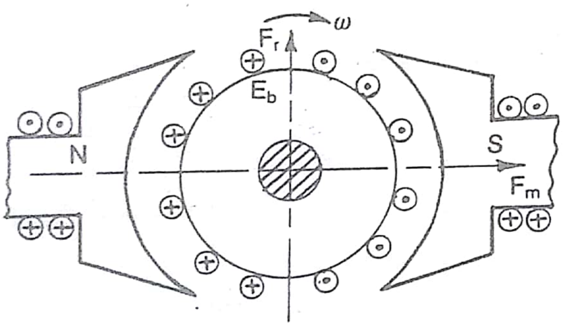


Fig. 12.42

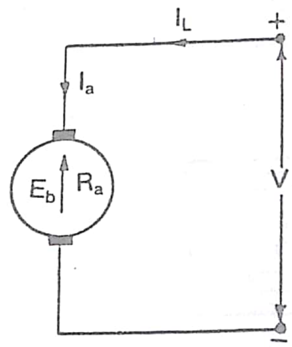


Fig. 12.43

It can be seen that the directioon of this induced e.m.f. is opposite to the applied voltage. That is why this induced e.m.f. in the armature, when the machine works as a motor, is called back e.m.f. (E_b).

The magnitude of this induced e.m.f. is given by the relation ; $E_b = \dfrac{PZ\phi N}{60\ A}$

12.37. SPEED CONTROL OF SHUNT MOTORS

1. **Field Control Method :** The flux produced by the shunt winding depends upon the current flowing through it (*i.e.* $\phi \propto I_{sh}$ and $I_{sh} = \frac{V}{R_{sh}}$). When a variable resistance R is connected in series with the shunt field winding as shown in fig. 12.59, the shunt field current $\left(I_{sh} = \frac{V}{R_{sh} + R}\right)$ is reduced and hence the flux ϕ. Consequently, the motor runs at a speed higher than the normal speed (since $N \propto 1/\phi$). The amount of increase in speed depends upon the value of variable resistance R.

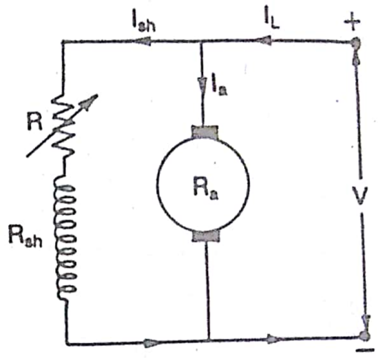


Fig. 12.59

This method is most commercial as very little power (I_{sh}^2 R) is wasted in the shunt field variable resistance due to relatively small I_{sh}. But the main disadvantage is that the speeds above normal only can be obtained.

There is a limit to the maximum speed obtainable with this method. It is because of poor communication at weak fluxes. A ratio of maximum to minimum speeds of 6 : 1 is fairly common.

2. **Armature Control Method :** In a shunt motor flux is constant when applied terminal voltage and shunt field resistance are constant. Therefore, speed of the motor is directly proportional to induced e.m.f. (*i.e.* $N \propto E_b$ and $E_b = V - I_a R_a$). The value of E_b depends upon the drop in the armature circuit. When a variable resistance is connected in series with the armature as shown in fig. 12.60, the induced e.m.f. [$E_b = V - I_a (R_a + R)$] is reduced and hence the speed. Thus, the motor runs at a speed lesser than the normal speed.

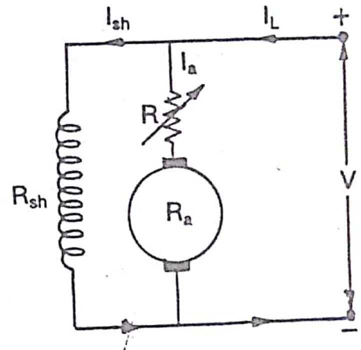


Fig. 12.60