The d-c Generator

Generator Principle

An electric generator is a machine that converts mechanical energy into electrical energy.
The generation of electricity achieved by moving a conductor in a magnetic field due to the relation (2.1)

$$E=B\ell V \qquad (2.1)$$

The direction of induced e.m.f. (and hence current) is given by Fleming's right hand rule. Therefore, the essential components of a generator are:
(a) a magnetic field
(b) conductor or a group of conductors
(c) motion of conductor w.r.t. magnetic field.

Simple Loop Generator

Consider a single turn loop ABCD rotating clockwise in a uniform magnetic field with a constant speed as shown in Fig.(2.1a). As the loop rotates, the flux linking the coil sides AB and CD changes continuously. Hence the e.m.f. induced in these coil sides also changes but the e.m.f. induced in one coil side adds to that induced in the other.
(i) When the loop is in position no. 1 [See Fig. 2.1a], the generated e.m.f. is zero because the coil sides (AB and CD) are cutting no flux.
(ii) When the loop is in position no. 2, the coil sides are moving at an angle to the flux and, therefore, a low e.m.f. is generated as indicated by point 2 in Fig. (2.1b).
(iii) When the loop is in position no. 3, the coil sides (AB and CD) are at right angle to the flux and are, therefore, cutting the flux at a maximum rate. Hence at this instant, the generated e.m.f. is maximum as indicated by point 3 in Fig. (2.1b).
(iv) At position 4, the generated e.m.f. is less because the coil sides are cutting the flux at an angle.
(v) At position 5, no magnetic lines are cut and hence induced e.m.f. is zero as indicated by point 5 in Fig. (2.1b).

(vi) At position 6, the coil sides move under a pole of opposite polarity and hence the direction of generated e.m.f. is reversed. The maximum e.m.f. in this direction (i.e., reverse direction,See Fig. 2.1b) will be when the loop is at position 7 and zero when at position 1. This cycle repeats with each revolution of the coil. Note that e.m.f. generated in the loop is alternating one. It is because any coil side, say AB has e.m.f. in one direction when under the influence of N-pole and in the other direction when under the influence of S-pole. If a load is connected across the ends of the loop, then alternating current will flow through the load.

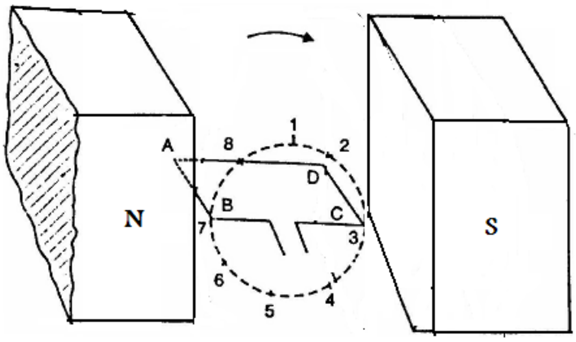

Fig.(2.1a)

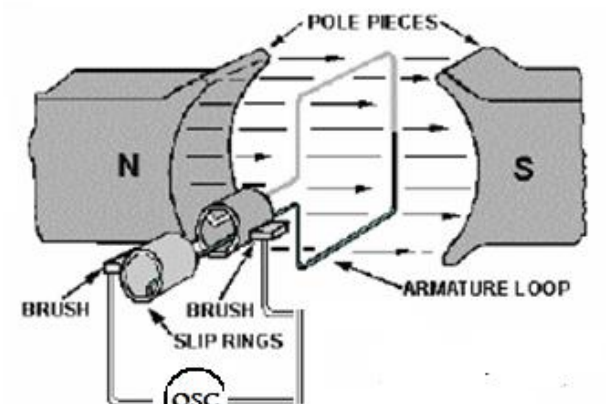

Fig.(2.2a)

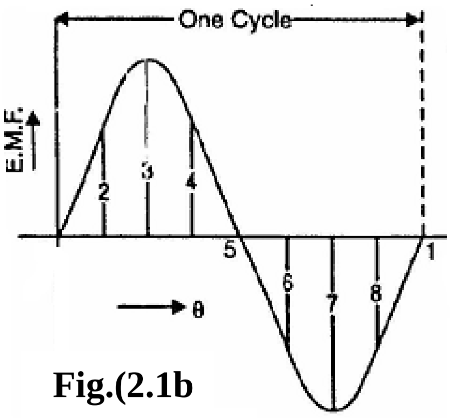

Fig.(2.1b

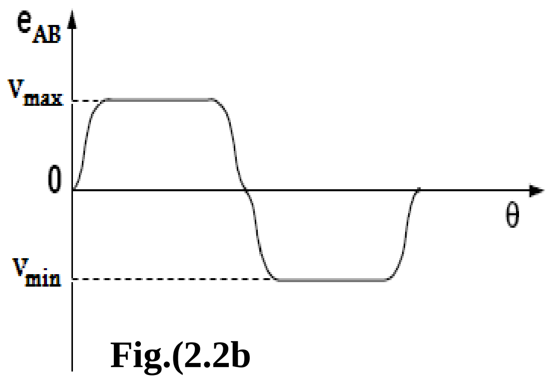

Fig.(2.2b

But if the pole face has a circular shape as shown in Fig. (2.2a) the waveform of the output voltage will be as shown in Fig. (2.2b).

In order to generate a "Unidirectional Voltage" the slip-rings replaced by two segments as shown in Fig. (2.3a). these segments generates the waveform shown in Fig. (2.4)

The alternating voltage generated in the loop can be converted into direct voltage by a device called commutator. We then have the d.c. generator. In fact, a commutator is a mechanical rectifier.

Action Of Commutator

If, somehow, connection of the coil side to the external load is reversed at the same instant the current in the coil side reverses, the current through the load will be direct current. This is what a commutator does. Fig. (2.3a) shows a commutator having two segments C1 and C2. It consists of a cylindrical metal ring cut into two halves or segments C1 and C2 respectively separated by a thin sheet of mica. The commutator is mounted on but insulated from the rotor shaft. The ends of coil sides AB and CD are connected to the segments C1 and C2 respectively.

Two stationary carbon brushes rest on the commutator and lead current to the external load. With this arrangement, the commutator at all times connects the coil side under S-pole to the +ve brush and that under N-pole to the –ve brush.

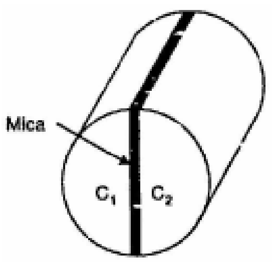

Fig.(2.3a)

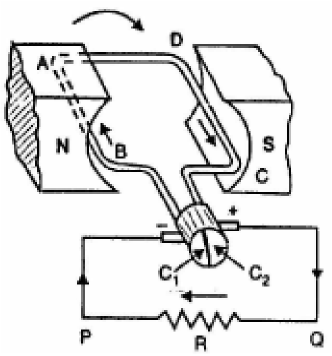

Fig.(2.3b)

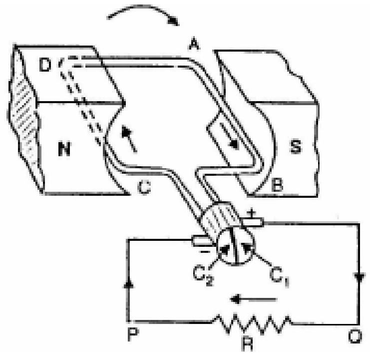

Fig.(2.3c)

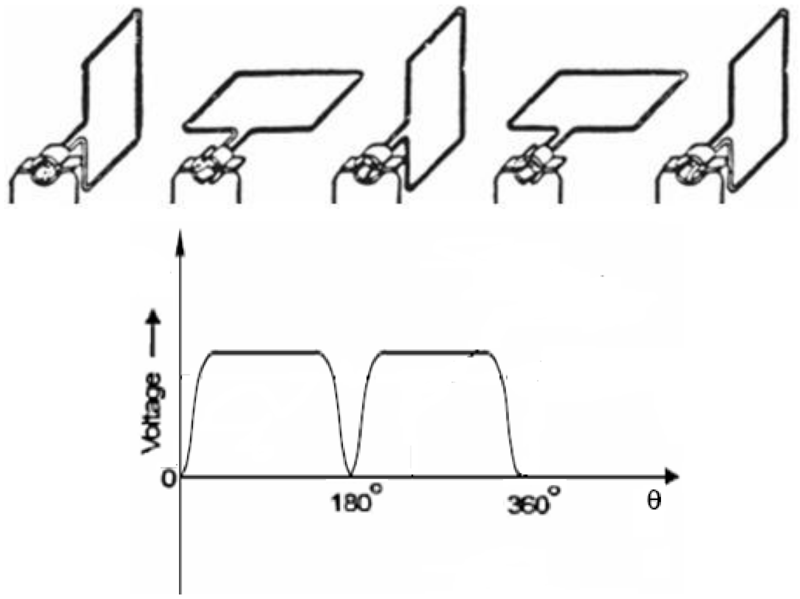

Fig.(2.4)

(i) In Fig. (2.3b), the coil sides AB and CD are under N-pole and S-pole respectively. Note that segment C1 connects the coil side AB to point P of the load resistance R and the segment C2 connects the coil side CD to point Q of the load. Also note the direction of current through load. It is from Q to P.

(ii) After half a revolution of the loop (i.e., 180° rotation), the coil side AB is under S-pole and the coil side CD under N-pole as shown in Fig. (2.3c). The currents in the coil sides now flow in the reverse direction but the segments C1 and C2 have also moved through 180° i.e., segment C1 is now in contact with +ve brush and segment C2 in contact with –ve brush. Note that commutator has reversed the coil connections to the load i.e., coil side AB is now connected to point Q of the load and coil side CD to the point P of the load. Also note the direction of current through the load. It is again from Q to P.

Thus the alternating voltage generated in the loop will appear as direct voltage across the brushes. The reader may note that e.m.f. generated in the armature winding of a d.c. generator is alternating one. It is by the use of commutator that we convert the generated alternating e.m.f. into direct .The purpose of brushes is simply to lead current from the rotating loop or winding to the external stationary load.

It is clear that the output voltage is not of constant value always. In order to achieve such a voltage another turn will be added to the generator as shown in Fig. (2.5)

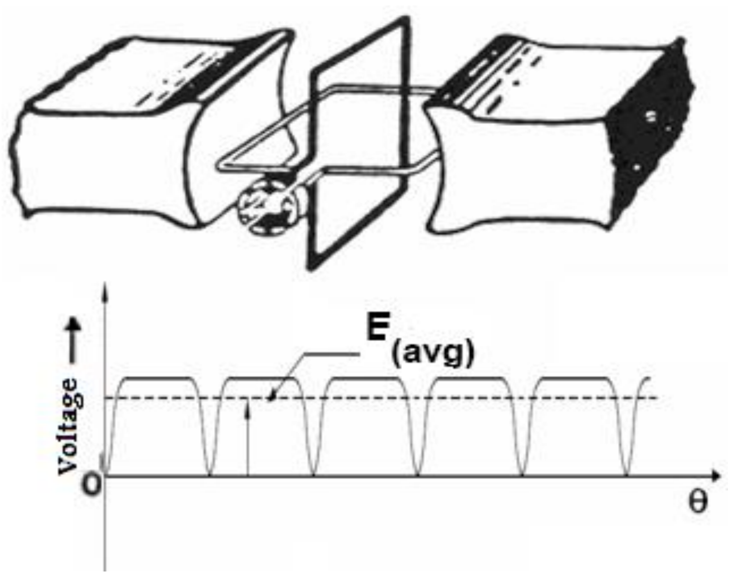

Fig.(2.5)

So Fig.(2.5) presents that we can obtain d-c voltage using this arrangement, but, this quantity of turns is uneconomical, so the actual arrangement use the hall armature surface and to obtained more voltage as will be discussed later

<u>Construction of d.c. Generator</u>

Fig. (2.6) represents a cross-section in a typical d-c

In generally the machine composed of two parts; the stator and the rotor. The stator (is the stationary part) of hollow cylindrical shape (in general) carrying machine poles and inter-poles, also it fixes the brushes arrangement and contains the bearings of the machine rotor. Normally the stator incloses the machine but it permits an air circulation (or water circulation in large machines) for the purpose of heat dissipation and cooling.

The rotor (is the rotating part) composed of armature winding, commutator, rotating shaft, fan arrangement as shown in fig. (2.7)

To imagine the construction is very difficult, but it is better to see the real machine parts as it is in field.

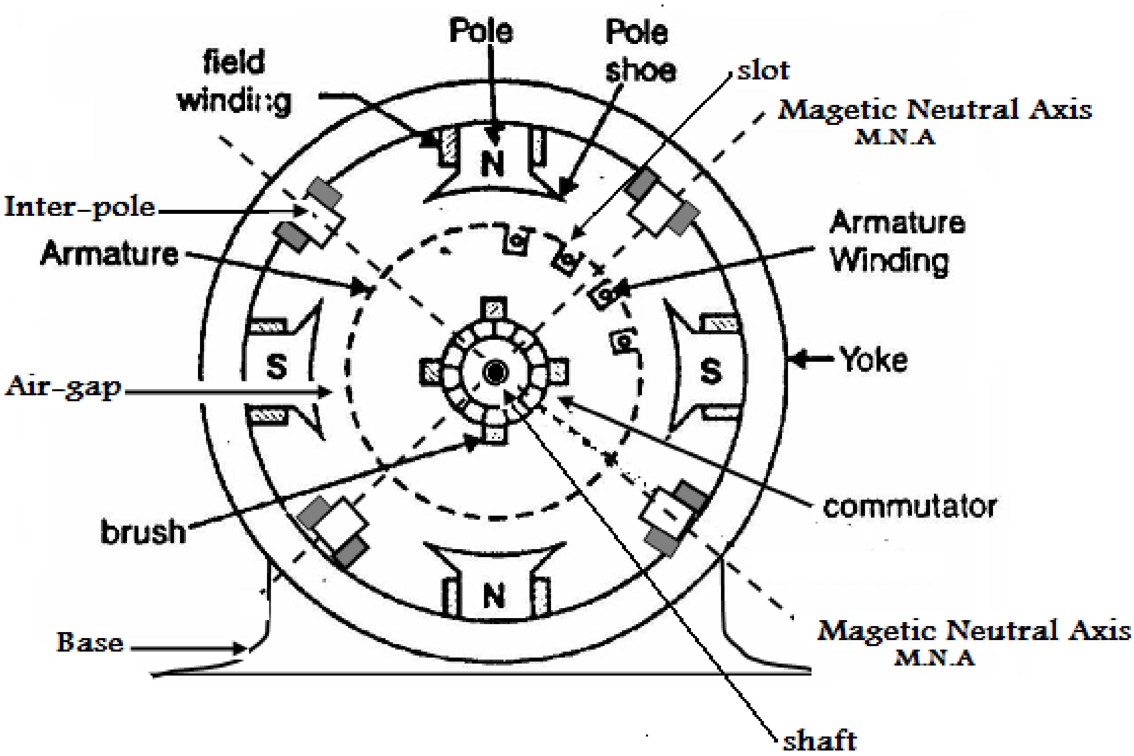

Fig.(2.6)

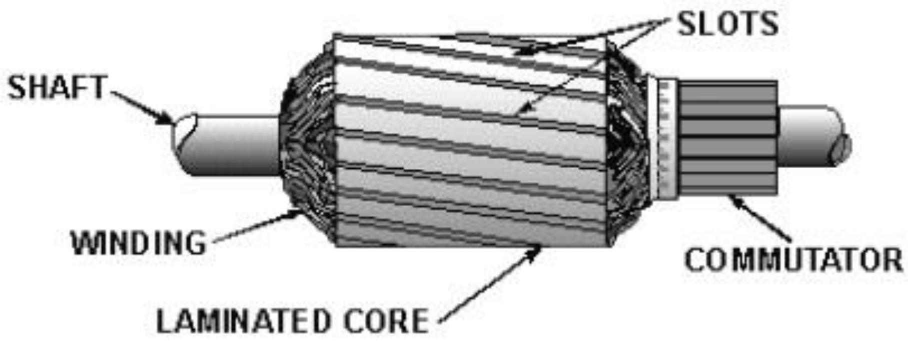

Fig.(2.7)

Description of Machine Parts

1. Pole : each pole composed of three parts as shown in Fig. (2.8.
The pole shoe function is to increase the flux distribution and to support the coils.

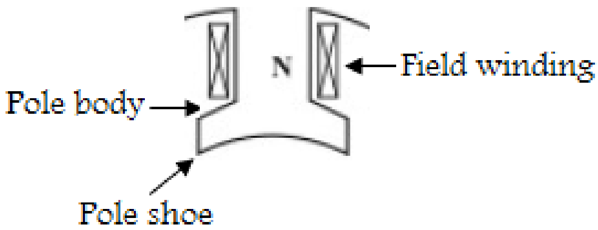

Fig.(2.8)

2. Inter-pole : is a small pole, its position between the poles in order to reduce the commutation problem.
3. Slote : is a long deep hall to occupy the conductors in many layers, and, to protect them from mechanical effect during operation. Fig. (2.9) shows the general design of a slot.

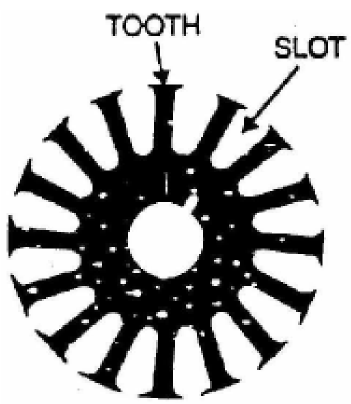

Fig.(2.9)

4. Commutator Segment : The commutator is the most sensitive part in the armature as shown in Fig. (2.10).

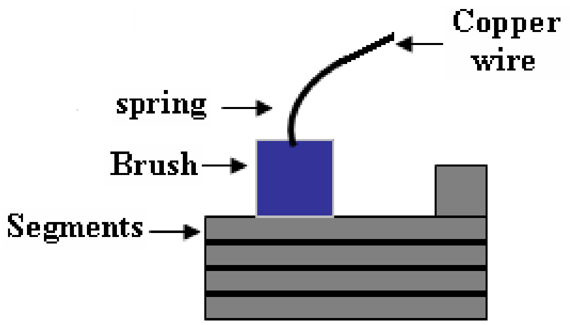

Fig.(2.10)

5. Brush : As shown in Fig. (2.9) it is a part connecting the commutator segments to the electric circuit. It varnishes a smooth continuous contact because it is a carbon alloy