UNIT-5

APPLICATIONS OF ELECTROMAGNETIC INDUCTION

INTRODUCTION:-

Electromagnetic induction is the production of an electromotive force across an electric conductor in a changing magnetic field.

BASIC LAWS OF ELECTROMAGNETIC INDUCTION:-

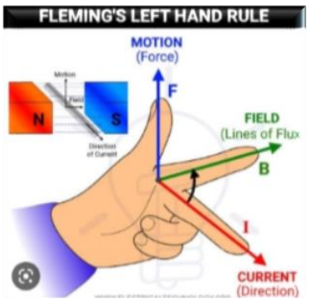
1. **FARADAY'S LAWS OF ELECTROMAGNETIC INDUCTION:-**

- Whenever the magnetic flux linked with the circuit is changed, then an e.m.f is induced in the circuit. This is called Faraday's first law of electromagnetic induction.
- The magnitude of induced e.m.f is directly proportional to the negative rate of change of magnetic flux linked with the circuit.
  $\therefore$ e=-$\frac{d\phi}{dt}$, where ϕ=magnetic flux.
  This is called Faraday's second law of electromagnetic induction.

2. **LENZ'S LAW: -**

Lenz's law states that the direction of an induced current is always such as to oppose the change in the circuit (or) the magnetic field that produces it.

3. **FLEMING'S LEFT HAND RULE: -**



Fleming's Left-hand rule states that if we stretch the thumb, middle finger and the index finger of the left hand in such a way that they make an angle of 90 degrees (perpendicular to each other) and the conductor placed in the magnetic field experiences magnetic force.

Then the direction for each finger is represented as follows:

- **Thumb:** It points towards the direction of force (F).
- **Middle finger:** It represents the direction of current (i).
- **Index finger:** It represents the direction of the magnetic field (B).

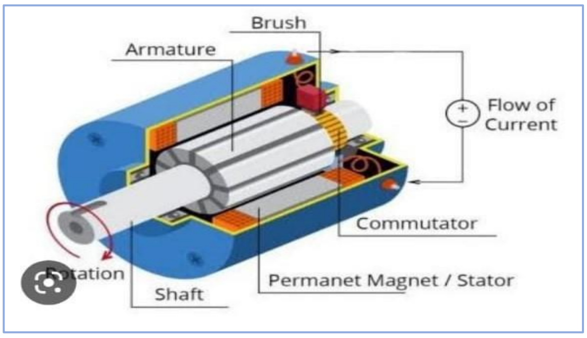
4. **<u>FLEMING'S RIGHT HAND –RULE:</u>**-

Fleming's Right-hand rule states that if we stretch the thumb, middle finger and an index finger in such a way that they are mutually perpendicular to each other.

Then, the direction for each finger is represented as follows:

- **Thumb:** It is along the direction of motion of the conductor
- **Middle finger:** It points in the direction of the induced current.
- **Index finger:** It points in the direction of the magnetic field.

<u>DC MOTOR</u>: -



<u>Fig. DC MOTOR</u>

- A DC motor is a electromechanical energy conversion device that converts direct current (DC) electric energy into mechanical energy.
- Its operation is based on the principle that when a current carrying conductor is placed in a magnetic field, the conductor experiences a mechanical force.
- The direction of the force is given by Fleming's left hand rule and the magnitude of force developed on the conductor is

$$F=Bil\sin\theta$$

<u>CONSTRUCTION</u>: -

- A DC motor consists of six main parts is shown in the figure.

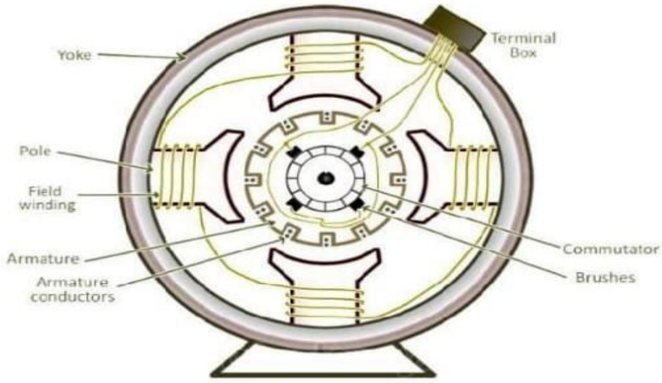


Fig. Construction of DC Motor

1. **YOKE: -**
   - The outer frame of a DC motor is a hollow cylinder made up of cast steel (or) cast iron is known as yoke.
   - The yoke servers the following two purposes.

     (i). It holds the magnetic pole cores of the generator and acts as protecting cover of the generator.

     (ii). It carries the magnetic flux.

2. **FIELD MAGNETS: -**
   - The magnetic field poles of a DC motor is the stationary part of the machine.
   - It produces the magnetic flux in the motor.
   - It consists of an even number of pole cores bolted on the yoke and field winding.
   - The pole core has a pole show having a curved surface and provides support to the field coils.
   - They spread out the flux in the air gap and large cross-sectional area of pole shoe decreases the reluctance of magnetic path.

3. **ARMATURE CORE: -**
   - The armature core of DC motor is mounted on the shaft and rotates between the field poles.
   - It has slots on its outer surface, and it is made up of soft iron laminations that are stacked in the form of cylindrical core.

- It is used to reduce the eddy current loss.

4. **<u>ARMATURE WINDING</u>: -**
   - The slots of armature core hold insulated conductors that are connected in a suitable manner. This is known as armature winding.
   - There are two types of armature windings are used.
     1. Wave Winding 2. Lap Winding
5. **<u>COMMUTATOR</u>: -**
   - A commutator is a mechanical rectifier which converts the alternating voltage generated in the armature winding into direct voltage across the brushes.
   - It consists of a set of copper segments which are insulated from each other.
6. **<u>BRUSHES</u>: -**
   - The brushes are made up of carbon and mounted on the commutator.
   - These are used to collect current form commutator segments.
   - Ball bearing are also used in DC generator.

<u>WORKING</u>: -

Consider a part of DC motor having multiple poles when the terminals of motor are connected to an external source of DC supply.

(i). The field magnets are excited developing alternate N and S poles.

(ii). The armature conductor carries currents. All conductors under N pole carry currents in one direction while all the conductors under S pole carry currents in the opposite direction.

Suppose the conductors under N pole carry current into the plane of the paper and S pole carry currents away from the plane of the paper as shown in fig. Since each armature conductor is carrying current and is placed in the magnetic field, a mechanical force acts on it. By applying Fleming's left hand rule, it is clear that the force on each conductor is tending to rotate the armature in the anticlock-wise direction. All these forces add together to produce a driving torque which sets the armature rotating. When the conductors move from one side of a brush to the other, the current in the conductor is reversed and at the time it comes under the influence of next pole which is of opposite polarity. Consequently, the direction of force on the conductor remains the same.

USES: -

1. DC Motors are used in centrifugal pumps, fans

2. It is used in lifts, elevators, air compressor, etc.

CALCULATION OF POWER, VOLTAGE AND CURRENT IN A DC MOTOR:-

1. **POWER EQUATION OF A DC MOTOR: -**

- The voltage equation for a DC motor is given by the below expression.

  $V=E_b+I_aR_a$

- Multiplying both sides of the above equation by I_a, we get the following expression

  $VI_a=I_aE_b+I_a^2R_a$

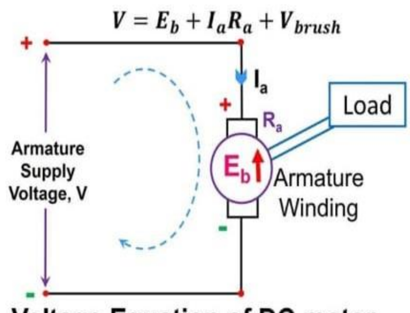
  ∴ The above equation is called as the power equation of a DC motor.

  Here, VI_a=electric power input to the armature.

  I_aR_a= Mechanical power developed in the armature

  $I_a^2R_a$= power loss in armature.

2. **VOLTAGE EQUATION OF DC MOTOR: -**



Voltage Equation of DC motor

- In case of DC motor, supply voltage 'v' has to overcome the back emf E_b which is opposing v and also various drops as armature resistance drop I_aR_a and brush drop etc.

  ∴ From figure, we can write that

  Supply voltage = Back emf + voltage drop across armature + voltage drop across burshes

- Now mathematically expressed as

$$V = E_b + I_aR_a + V_{brush}$$

- But the voltage drop across brushes is negligible. So, we can neglect this voltage drop.

$$V = E_b + I_aR_a$$

∴ This is the final expression for voltage in a DC motor.

3. **CURRENT EQUATION IN DC MOTOR: -**

- In case of a DC motor, the back emf is always less than the supply voltage. But R_a is very small.
- The net voltage across the armature is the difference between the supply voltage and back emf which decides the armature current.
- The voltage equation of DC motor is

$$V = E_b + I_aR_a$$

$$I_aR_a = V - E_b$$

$$I_a = \left(\frac{V - E_b}{R_a}\right)$$

∴The above equation represents current in DC motor.

DC GENERATOR: -

- A DC generator is an electrical generator or machine which converts mechanical energy into direct current (DC) electricity.
- A DC generator construction is similar to DC motor but working principle is different.

PRINCIPLE: -

It works based on the principle of Faraday's law of electromagnetic induction and Fleming's Right hand rule.

CONSTRUCTION: -

The DC generator construction is similar to DC motor. It has following main parts.

1. **STATOR:**

The main function of stator is to provide magnetic fields where the coil spins.

2. **ROTOR:**

A rotor in a DC machine includes slotted iron laminations with slots that are placed in cylindrical armature core.

3. **ARMATURE WINDINGS:**

Armature windings are in a closed circuit are connected in series to parallel to produce the current.

There are two types of armature windings are used:

1. Wave Winding 2. Lap Winding

4. **YOKE:**

The outer frame of DC generator is a hollow cylinder made up of cast steel or cast iron is known as Yoke.

It provides the mechanical power for carrying the magnetic flux given to the poles.

5. **POLES:**

The magnetic poles are used to hold the field windings.

6. **POLE SHOE:**

Pole shoe is mainly utilized for spreading the magnetic flux to prevent the field coil.

7. **COMMUTATOR:**

A commutator is a mechanical rectifier which converts the alternating voltage generated in the armature winding into direct voltage across the brushes.

It consists of a set of copper segments which are insulated from each other.

8. **BRUSHES:**

The brushes are made up of carbon are used to collect current from commutator segments.

WORKING: -

- According to Faraday's law of electromagnetic induction, when a current carrying conductor is placed in a varying magnetic field an emf is induced in the conductor.
- According to Fleming's right hand rule the direction of the induced current changes the direction of motion of the conductor changes.
- Consider an armature rotating in clockwise direction and conductor at the left moving in an upward direction.
- As the armature completes its half rotation the direction of movement of the conductor will get reversed downward. The direction of current will be alternating.
- As the connections of armature conductors get reversed a current direction is reversed. Thus, we get unidirectional DC current at the terminals.

APPLICATIONS: -

- These are used to charge batteries.
- These are used to provide power supply for companies, offices etc.
- These are used in lamps for lighting.

EMF EQUATION OF DC GENERATOR: -

- As the armature coil rotates, a voltage is generated in its coils. In this case of a generator, the emf of rotation is called the generated emf or armature emf and is denoted with E_g.
- In case of generator, the emf of rotation is known as back emf and is denoted with E_b.
- To derive the emf equation of DC generator consider the following parameters.

  Let Z = Total number of armature conductors

  P = Number of poles in a generator.

  A = Number of parallel lines within the armature.

  N = rotation of armature in r.p.m (revolutions per minute)

  E = induced emf in any parallel path within the armature.

  E_g = generated emf in any one of the parallel (path).
- From Faraday's law of electromagnetic the emf induced in the conductor e = rate of change of magnetic flux

  e = $\frac{d\phi}{dt}$ → (1)
- In one revolution armature cut by the flux $d\phi = \phi \times P$

- The time taken for the armature coil to complete one rotation is
  dt = $\frac{60}{N}$seconds
  put the values of dϕ and dt in eq(1)
  $E_g = \frac{d\phi}{dt}$
  $E_g = \frac{p\phi}{\frac{60}{N}}$

  $E_g = \frac{p\phi N}{60} \rightarrow (2)$
- As there are 'A' number of parallel paths with 'Z' number of conductors, then emf per parallel path is given by
  $E_g = \frac{p\phi N}{60} \text{ X } \frac{Z}{A}$
  $E_g = \frac{\phi NZ}{60} \text{ X } \frac{P}{A}$
  ∴ the above equation represents the emf equation of DC generator.

The number of parallel paths in armature winding depends on the type of the armature windings.

I. For wave winding, number of parallel paths A=2
   $E_g = \frac{\phi NZ}{60} \text{ X } \frac{P}{2}$
   $E_g = \frac{\phi NZP}{120} \rightarrow (4)$
II. For lap winding, number of parallel paths A=P
   $E_g = \frac{\phi NZ}{60} \text{ X } \frac{P}{P}$
   $E_g = \frac{\phi NZ}{60} \rightarrow (5)$

or $N = 300$ rpm

DIFFERENCE BETWEEN DC AND AC GENERATORS:

6. Write the differences between D.C and A.C generator? (10&5M)

- An AC & DC generators works on the principle of "Electromagnetic induction".

S. No	PROPERTY	AC GENERATOR	DC GENERATOR
1.	Definition	AC generator is a device that converts mechanical energy into AC electrical power	DC generator is a device that converts mechanical energy into DC electrical power
2.	Direction of current	The electrical current reverses direction periodically.	The electrical current flows only one direction.
3.	Basic Design	The coil through which the current flows is fixed field but the construction is simple and costs are less.	The coil through which the current flows rotate in fixed field but the construction is complex due to commutators and slip rings.
4.	Commutators	AC generators does not have Commutators.	DC generators have Commutators.
5.	Rings	AC generators have slip-rings.	DC generators does not have slip-rings.
6.	Efficiency of brushes	Since slip rings have a smooth and uninterrupted surface, they do not wear quickly and highly efficient.	Both brushes and commutators of DC generator wear out quickly and less efficient.
7.	Output voltage	AC generators produce a high voltage which varies in amplitude and frequency.	DC generators produce a low voltage compared to AC generator which constant in amplitude and frequency is zero.
8.	Transmission	The output from AC generators is easy to distribute using a transformer.	The output from DC generators is difficult to distribute cannot be used transformers.
9.	Efficiency	AC generators are very efficient as the energy losses are less.	DC generators are less efficient and other losses are less.
10.	Applications	It is used to power smaller motors and electrical appliances at homes.	DC generators power very large electric motors those needed for subway systems.