EMF GENERATION

When a magnetic field embracing a conductor moves relative to the conductor, it produces a flow of electrons in the conductor. The flow of electrons connotes the flow of current and this implies that emf has been induced in the conductor. This phenomenon whereby an e.m.f. and hence current (i.e. flow of electrons) is induced in any conductor which is cut across or is cut by a magnetic flux is known as electromagnetic induction.

HOW INDUCED EMF AND CURRENT IS PRODUCED

Tools to perform simple experiment…

Get a wooden stick

Wind an insulated wire around the wooden cylinder to form a solenoid

Connect the two ends of coil to a galvanometer

You will notice that if a stationary magnet is close to an insulated coil that is connected to a galvanometer, there is no deflection. However, when the magnet is moved towards or away from the coil, an emf is induced in it and a jerk in the galvanometer. There is going to be induced emf as long as there is movement. When it is moved towards the coil, the deflection of the galvanometer is in one direction. When it is moved away, it is observed to move in the opposite direction.

The deflection is reduced to zero when the magnet becomes again stationary at its new position CD. It should be noted that due to the approach of the magnet, flux linked with the coil is increased.

The direction of deflection is reversed if the motion direction is reversed. Also, the direction is reversed when the polarity of the magnet is changed.

Induced e.m.f. can be either (i) dynamically induced or (ii) statically induced.

In the first case, usually the field is stationary and conductors cut across it.

But in the second case, usually the conductors or the coil remains stationary and flux linked with it is changed by simply increasing or decreasing the current producing this flux (as in transformers) or rotating a permanent magnet in the neighborhood of the stationary coil.

The value of the emf or voltage generated in either case depends on the number of turns in the coil (N), strength of the field (B) and the speed at which the coil or magnetic field rotates (ω_o).

Alternating voltage may be generated in either of the two ways, but rotating-field method is used in practice.

The deflection of the galvanometer indicates the production of e.m.f. in the coil. The only cause of the production can be the sudden approach or withdrawal of the magnet from the coil. It is found that the actual cause of this e.m.f. is the change of flux linking with the coil. This e.m.f. exists so long as the change in flux exists.

Stationary flux, however strong, will never induce any e.m.f. in a stationary conductor. In fact, the same results can be obtained by keeping the bar magnet stationary and moving the coil suddenly away or towards the magnet.

FACTORS AFFECTING INDUCED EMF IN A COIL

1. Strength of the magnet:

$E_i \propto B$

2. Area of the coil

$E_i \propto A$

3. Number of turns in the coil:

$E_i \propto N$

4. Velocity between the magnet and the coil

$E_i \propto v$

If the velocity is angular velocity

$E_i \propto \omega_o$

On combining,

$E_i \propto BANv$

$E_i = kBANv$

Taking k as 1

$E_i = BANv$

Or

$E_i = BAN\omega_o$

FACTORS AFFECTING THE MOTIONAL EMF (EMF INDUCED IN A WIRE)

When a conductor moves through a magnetic field so as to cut the lines of flux, an induced emf will exist in it. When a conductor is pulled or allowed to move in a uniform field, an emf will be induced in the conductor. This emf is called the motional emf.

1. Magnetic field intensity: Motional Emf is directly proportional to the magnetic flux density

$E_m \propto B$

2. Length of the conductor $E_m \propto l$

3. Relative velocity between the conductor and the field: $E_m \propto v$

4. Angle between the conductor and the field $E_m \propto \sin\theta$

On combining

$E_m \propto Blv\sin\theta$

$E_m = Blv \sin\theta$

The maximum electromotive force in conductors is $E_m = Blv$ where B and v must be perpendicularly

If the conductor has a resistance R, then the current flow is

$$I = \frac{E_m}{R} = \frac{Blv}{R}$$

Recall that the force on a current-carrying conductor is

$F = BIl$

$$F = \frac{v B^2 l^2}{R}$$

$Power = Fv$

$P = I^2 R$

FARADAY'S LAWS OF ELECTROMAGNETIC INDUCTION

First Law:
It states that whenever the magnetic flux linked with a circuit changes, an e.m.f. is always induced in it. or Whenever a conductor cuts magnetic flux, an e.m.f. is induced in that conductor

Second Law: It states that the magnitude of the induced e.m.f. is equal to the rate of change of flux-linkages.

This law states: The induced emf (which appears in a coil of a wire containing N loops) is directly proportional to the rate of change of the magnetic flux

$$Induced\,emf = \frac{Change \in magetic\,flux}{(Change) \in time}$$

$$E_i \propto N \frac{\Delta \Phi}{\Delta t}$$

$$E_i = -kN \frac{\Delta \Phi}{\Delta t}$$

Where k = 1

Here, N is the number of turns in the coil.

Magnetic flux is dependent on the magnetic field intensity (also known as magnetic flux density). Its relation to the flux density is expressed as

$Magnetic\,flux = Magnetic\,flux\,density \times Area$

$\Phi = BA$

Or

$\Phi = BA\cos\theta$

For maximum flex density,

$\phi_m = B_m A$

The unit of magnetic flux is Weber.

$E_i = \frac{-N\Delta\Phi}{\Delta t}$

In the equation above, the negative sign is gotten from Lenz’s law

EQUATIONS OF ALTERNATING VOLTAGES AND CURRENTS

Consider a rectangular coil,having N turns and rotating in a uniform magnetic field, with an angular velocity of ω radian/second. Let time be measured from the X-axis. Maximum flux ϕ_m is linked with the coil, when its plane coincides with the X-axis. In time t seconds, this coil rotates through an angle θ = ωt. In this deflected position, the component of the flux which is perpendicular to the plane of the coil, is Φ = Φ m cos ω t. Hence, flux linkages of the coil at any time are $N\Phi = N\Phi_m \cos\omega t$.

According to Faraday’s Laws of Electromagnetic induction, the emf (E_i) induced in the coil is given by the rate of change of flux-linkages (%phi). Hence the value of the induced emf at this instant ({} or the instantaneous value of the induced emf is)

$E = -\frac{d}{dt}(N\phi)\,volts$

$E = -N\cdot\frac{d}{dt}(\phi_m \cos\omega t)$

$E = -N\phi_m\omega(-\sin\omega t)\,volt$

$E = \omega N\phi_m \sin\omega t\,volt$

$E = \omega N\phi_m \sin\theta\,volt$

For maximum Emf, $\theta = 90$

$E = \omega N\phi_m volts$

$\omega = 2\pi f$

$\phi_m = B_m A$

$E = 2\pi f N B_m A\,Volts$

RMS VOLTAGE AND CURRENT