COMBINED FIRST AND SECOND SEMESTER B.TECH (ENGINEERING) DEGREE EXAMINATION

EN14107 – BASICS OF ELECTRICAL ELECTRONICS AND COMMUNICATION ENGINEERING

Section I (Basics of Electrical Engineering)

Part A

Answer any 4 questions

1. Explain about the basic structure of a.c. power system.

2. Derive the e.m.f. equation of a transformer.

3. Explain the following terms:

    a. frequency

    b. average value

    c. power factor

4. Derive the rms and average values of a sine wave.

5. A sinusoidal flux 0.02Wb (maximum) links with 55 turns of a transformer secondary coil. Calculate the rms value of the induced emf in the secondary. The supply frequency is 50Hz.

(4 x 5) marks

Part B

6. i)Compare between electric and magnetic circuits. **(5 marks)**

ii) Explain about three phase system **(10 marks)**

(OR)

7 i) State and explain Faraday's laws of electromagnetic induction. **(5 marks)**

ii) i) Define the terms
(i)time period
(ii)rms value
(iii)average value
(iv)form factor
(v)peak factor in an ac circuit **(10 marks)**

8 i) Describe the constructional details of a DC machine. **(10 marks)**

ii)Derive an expression for emf equation for dc generator **(5 marks)**

(OR)

9 i) Explain the principle of operation of a 3-phase induction motor . **(10 marks)**

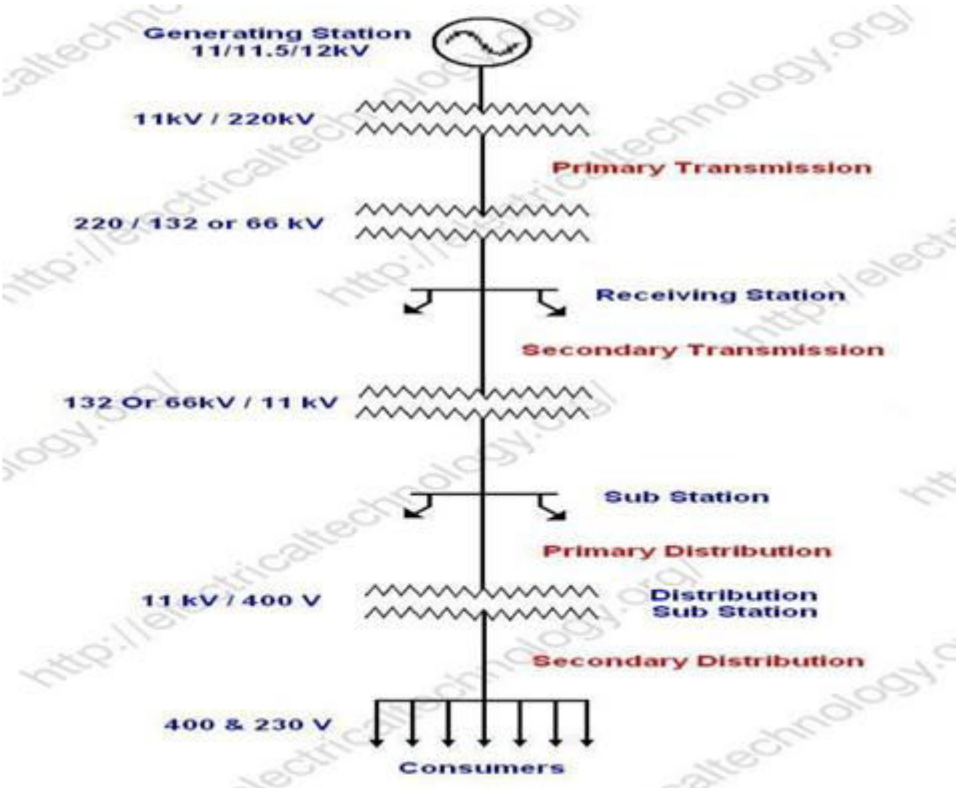
i) Explain the construction and principle of operation single-phase transformer **(10 Marks)**

1. Explain about the basic structure of a.c. power system.

Electric power supply system in a country comprises of generating units that produce electricity; high voltage transmission lines that transport electricity over long distances; distribution lines that deliver the electricity to consumers; substations that connect the pieces to each other; and energy control centers to coordinate the operation of the components.

Power Generation Plant the fossil fuels such as coal, oil and natural gas, nuclear energy, and falling water (hydel) are commonly used energy sources in the power generating plant. Finally turbine rotates the generator to produce electricity.

Transmission and Distribution Lines the power plants typically produce 50 cycle/second (Hertz), alternating-current (AC) electricity with voltages between 11kV and 33kV. At the power plant site, the 3-phase voltage is stepped up to a higher voltage for transmission on cables strung on cross-country towers. High voltage (HV) and extra high voltage (EHV) transmission is the next stage from power plant to transport A.C. power over long distances at voltages like; 220 kV & 400 kV. Where transmission is over 1000 Km, high voltage direct current transmission is also favored to minimize the losses. Sub-transmission network at 132 kV, 110 kV, 66 kV or 33 kV constitutes the next link towards the end user. Distribution at 11 kV / 6.6 kV / 3.3 kV constitutes the last link to the consumer, who is connected directly or through transformers depending upon the drawl level of service. The transmission and distribution network include sub-stations, lines and distribution transformers. High voltage transmission is used so that smaller, more economical wire sizes can be employed to carry the lower current and to reduce losses. Sub-stations, containing step-down transformers, reduce the voltage for distribution to industrial users. The voltage is further reduced for commercial facilities. Electricity must be generated, as and when it is needed since electricity cannot be stored virtually in the system. There is no difference between a transmission line and a distribution line except for the voltage level and power handling capability. Transmission lines are usually capable of transmitting large quantities of electric energy over great distances. They operate at high voltages. Distribution lines carry limited quantities of power over shorter distances



2. Derive the e.m.f. equation of a transformer.

The magnetic flux set up in the core of a transformer when an alternating voltage is applied to its

Primary winding is also alternating and is sinusoidal. Let $Øm$ be the maximum value of the flux and f be

the frequency of the supply. The time for 1 cycle of the alternating flux is the periodic time T, where T

$=1/f$ seconds. The flux rises sinusoidally from zero to its maximum value in 1 /4 cycle, and the time for

1cycle is $1/4f$ seconds.

Hence the average rate of change of flux=4 f $Øm$ Wb/s, and since 1 Wb/s=1 volt, the average e.m.f.

induced in each turn=4 $f\,\text{Ø}m$ volts.

As the flux varies sinusoidally, then a sinusoidal e.m.f.

will be induced in each turn of both primary and secondary

windings.

For a sine wave, form factor =1.11

rms value = form factor × average value

= 1.11 × average value

Thus rms e.m.f. induced in each turn

= 1.11 × 4 $f\text{Ø}m$ volts= 4.44 $f\,\text{Ø}m$ volts

Therefore, rms value of e.m.f. induced in primary,

$$\boldsymbol{E1 = 4.44\, f\, \text{Ø}m\, N1} \textbf{ volts}$$

and rms value of e.m.f. induced in secondary,

$$\boldsymbol{E2 = 4.44\, f\, \text{Ø}m\, N2} \textbf{ volts}$$

3. Explain the following terms:

a. frequency

b. average value

c. power factor

a) Frequency is defined as a number of cycles per unit time. the SI unit for frequency is hertz (Hz),

F=1/T

T-time period

b) **Average Value:**

The average value of AC is defined as the D.C current which transfers across any circuit the same charge as is transferred by that AC during the same time..

Average value of AC=$2/\pi * I_m$

For rectangular wave form RMS value = average value

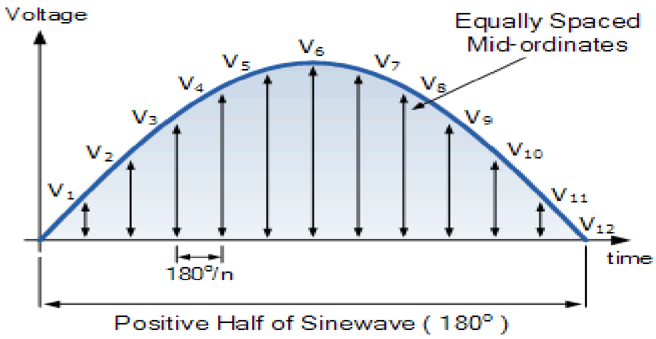
Average value= Area under the curve/base c)Power Factor (P.F.) is the ratio of Working Power to Apparent Power.

P.F. = KW/ KW + KVAR

P.F=KW/KVA

4. Derive the rms and average values of a sine wave.

Average Voltage Graphical Method:- consider only the positive half cycle from the previous RMS voltage. The positive half of the waveform is divided up into any number of "n" equal portions or *mid-ordinates*. The width of each mid-ordinate will therefore be n^o degrees (or t seconds) and the height of each mid-ordinate will be equal to the instantaneous value of the waveform at that point along the x-axis of the waveform.



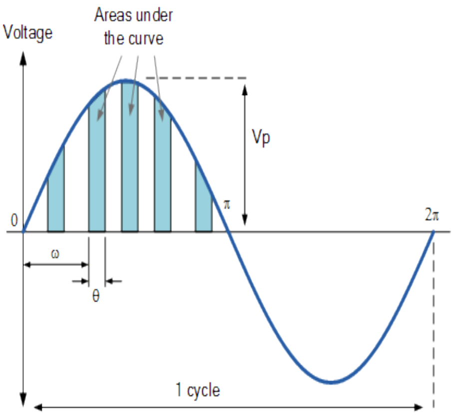
Each mid-ordinate value of the voltage waveform is added to the next and the summed total, V_1 to V_{12} is divided by the number of mid-ordinates used to give us the "Average Voltage". Then the average voltage (V_{AV}) is the mean sum of mid-ordinates of the voltage waveform and is given as:

$$V_{AV} = \frac{\text{sum of all the mid-ordinates}}{\text{number of mid-ordinates}}$$

$$V_{AV} = \frac{V_1 + V_2 + V_3 + V_4 \ldots . + V_{11} + V_{12}}{12}$$

Average Voltage Analytical Method

Approximation of the Area



:

$$Area = \int_0^{\pi} V_P \sin(\omega t)\,dt$$

$$V_{AVE} = \frac{1}{\pi}\int_0^{\pi} V_P \sin\theta\,d\theta$$

$$V_{AVE} = \frac{V_P}{\pi}(-\cos\theta)_0^{\pi}$$

$$= \frac{2V_P}{\pi} = \frac{2}{\pi}V_P = 0.637V_P$$

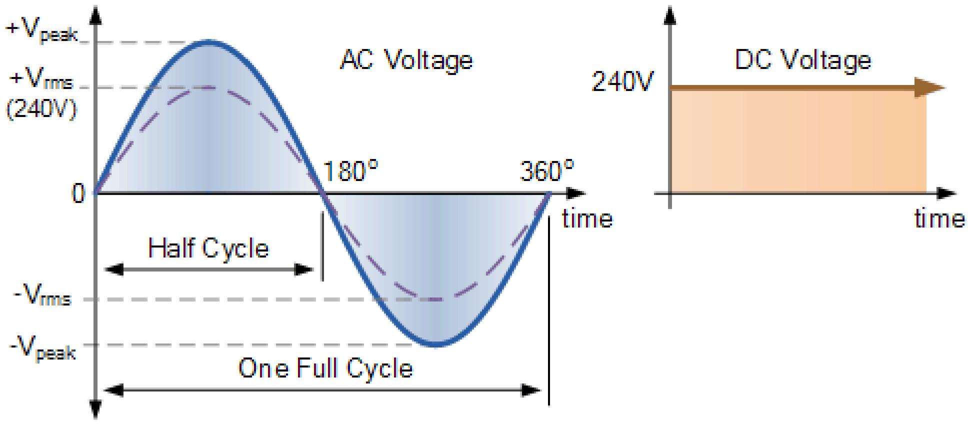
Which is therefore given as the standard equation for the Average Voltage of a sine wave as:

Average Voltage Equation

$$V_{AVE} = \frac{2V_P}{\pi} = 0.637V_p$$

The term “RMS” stands for “Root-Mean-Squared”. Most books define this as the “amount of AC power that produces the same heating effect as an equivalent DC power”

RMS Voltage Equivalent

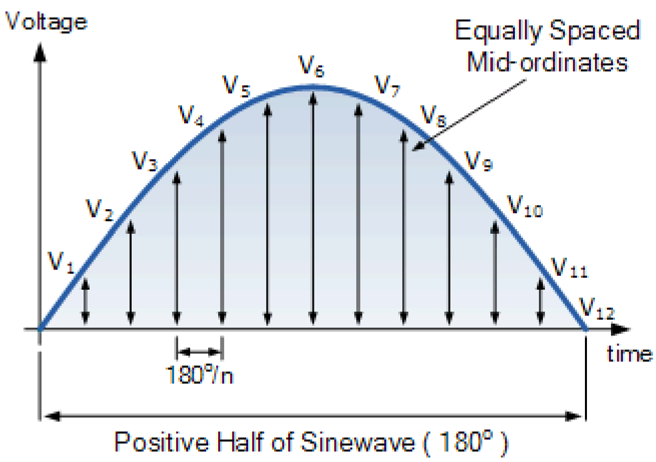


So how do we calculated the **RMS Voltage** of a sinusoidal waveform. The RMS voltage of a sinusoid or complex waveform can be determined by two basic methods.

- Graphical Method – which can be used to find the RMS value of any non-sinusoidal time-varying waveform by drawing a number of mid-ordinates onto the waveform.
- Analytical Method – is a mathematical procedure for finding the effective or RMS value of any periodic voltage or current using calculus.

RMS Voltage Graphical Method

Graphical Method



Each mid-ordinate value of a waveform (the voltage waveform in this case) is multiplied by itself (squared) and added to the next. This method gives us the "square" or **squared** part of the RMS voltage expression. Next this squared value is divided by the number of mid-ordinates used to give us the **Mean** part of the RMS voltage expression, and in our simple example above the number of mid-ordinates used was twelve Finally, the square root of the previous result is found to give us the **Root** part of the RMS voltage.

Then we can define the term used to describe an RMS voltage (V_{RMS}) as being “the square root of the mean of the square of the mid-ordinates of the voltage waveform” and this is given as:

$$V_{RMS} = \sqrt{\frac{\text{sum of mid-ordinate (voltages)}^2}{\text{number of mid-ordinates}}}$$

and for our simple example above, the RMS voltage will be calculated as:

$$V_{RMS} = \sqrt{\frac{V_1^2 + V_2^2 + V_3^2 + V_4^2 \ldots + V_{11}^2 + V_{12}^2}{12}}$$

The **RMS voltage** is therefore calculated as:

Then the RMS Voltage value using the graphical method is given as: 14.14 Volts.

RMS Voltage Analytical Method

$$V_{RMS} = \sqrt{\frac{1}{T}\int_0^T V_m^2 \cos^2(\omega t)\, dt}$$

Integrating through with limits taken from 0 to 360° or “T”, the period gives:

$$V_{RMS} = \sqrt{\frac{V_m^2}{2T}\left[t + \frac{1}{2\omega}\sin(2\omega t)\right]_0^T}$$

Dividing through further as $\omega = 2\pi/T$, the complex equation above eventually reduces down too:

RMS Voltage Equation

$$V_{RMS} = V_m \frac{1}{\sqrt{2}} = V_m \times 0.7071$$

Then the RMS voltage (V_{RMS}) of a sinusoidal waveform is determined by multiplying the peak voltage value by **0.7071**, which is the same as one divided by the square root of two ($1/\sqrt{2}$). The RMS voltage, which can also be referred to as the effective value, depends on the magnitude of the waveform and is not a function of either the waveforms frequency or its phase angle.

From the graphical example above, the peak voltage (V_{pk}) of the waveform was given as 20 Volts. By using the analytical method just defined we can calculate the RMS voltage as being:

$$V_{RMS} = V_{pk} \text{ x } 0.7071 = 20 \text{ x } 0.7071 = 14.14V$$

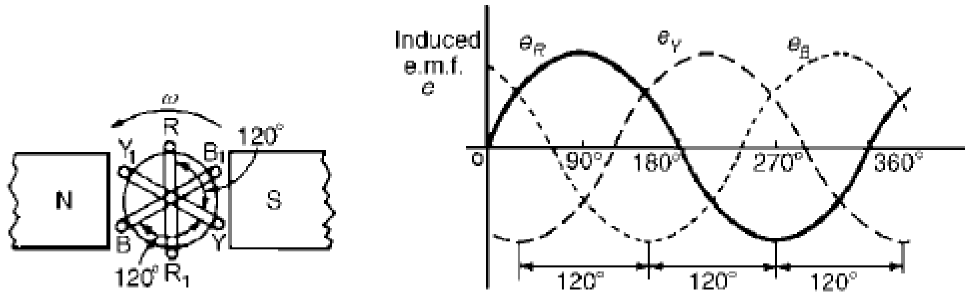
5)A sinusoidal flux 0.02Wb (maximum) links with 55 turns of a transformer secondary coil. Calculate the rms value of the induced emf in the secondary. The supply frequency is 50Hz.

$$E2 = 4.44 f \, \emptyset m \, N2$$

6. i)Compare between electric and magnetic circuits

Electrical circuit		Magnetic circuit	
e.m.f. E	(V)	mmf F_m	(A)
current I	(A)	flux Φ	(Wb)
resistance R	(Ω)	reluctance S	(H^{-1})
$I = \frac{E}{R}$		$\Phi = \frac{\text{mmf}}{S}$	
$R = \frac{\rho l}{A}$		$S = \frac{l}{\mu_0 \mu_r A}$	

ii) A three-phase supply is generated when three coils are placed 120◦ apart and the whole rotated in auniform magnetic field . The result is three independent supplies of equal voltages which are each
displaced by 120◦ from each other.



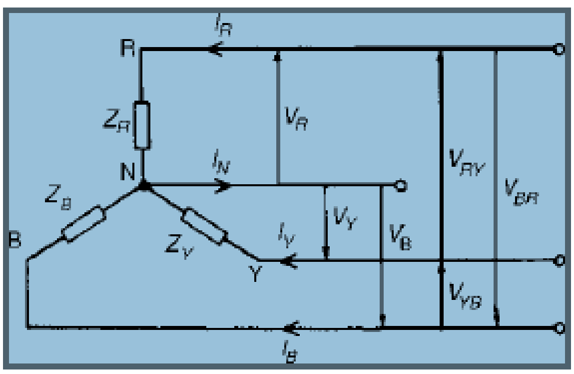
(a) (b)

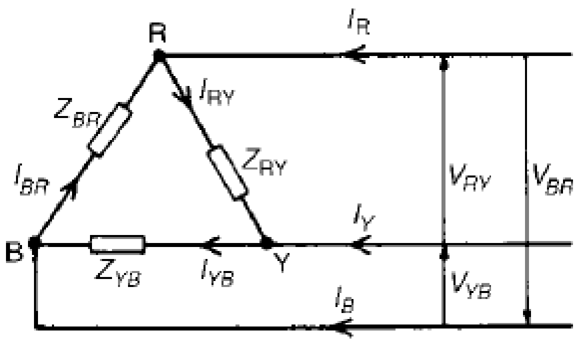
A three-phase a.c. supply is carried by three conductors, called **'lines'**which are coloured red, yellow andblue. The currents in these conductors are known as line currents (*IL*) and the p.d.'s between them areknown as line voltages (*VL*). A fourth conductor, called the **neutral** (coloured black, and connected
through protective devices to earth) is often used with a three-phase supply. To reduce the number of
wires it is usual to interconnectthe three phases. There are two ways in which this can be done, these being:

(a) a **star connection**, and (b) a **delta**, or **mesh, connection**.

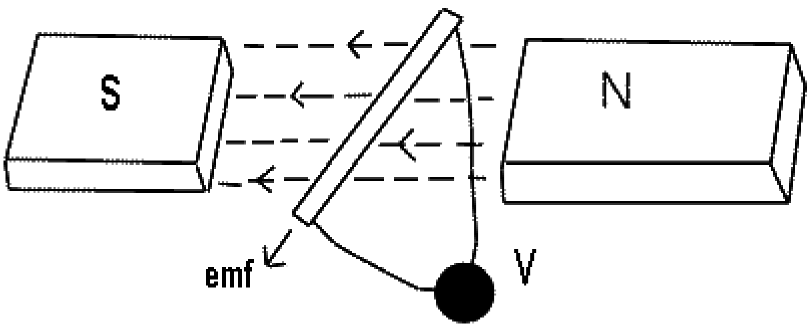
Star connection

A **star-connected load** is shown in Figure 19.3 where the three line conductors are each connected to a
load and the outlets from the loads are joined together at *N* to form what is termed the **neutral point** or
the **star point**.





7 i) State and explain Faraday's laws of electromagnetic induction.



In 1831, Micheal Faraday formulated two laws on the bases of experiments. These laws are called Faraday's laws of electromagnetic induction.

FIRST LAW

First Law of Faraday's Electromagnetic Induction state that whenever a conductor are placed in a varying magnetic field emf are induced which is called induced emf, if the conductor circuit are closed current are also induced which is called induced current.

Or

Whenever a conductor is rotated in magnetic field emf is induced which are induced emf.

SECOND LAW

Second Law of Faraday's Electromagnetic Induction state that the induced emf is equal to the rate of change of flux linkages (flux linkages is the product of turns, n of the coil and the flux associated with it).

Let

Initial flux linkages = $N\varphi 1$

Final flux linkages = $N\varphi 2$

Change in flux linkages= $N\varphi 2 - N\varphi 1$

If $(\varphi 2-\varphi 1)= \varphi$

Then change in flux linkages=$N\varphi$

Rate of change of flux linkages= $N\varphi/t$ wb/sec

Taking derivative of right hand side we get

Rate of change of flux linkages= $Nd\varphi/dt$ wb/sec

Rut according to Faraday's laws of electromagnetic induction, the rate of change of flux linkages equal to the induced emf, hence we can write

$= Nd\varphi/dt$ volt

Generally Faraday's laws is written as

$e = -Nd\varphi/dt$ volt

Where negative sign represents the direction of the induced current in the conductor will be such that the magnetic field produced by it will oppose the verb cause produce it.

Applications of Faraday Law

Faraday law is one of the most basic and important laws of electromagnetism . This law finds its application in most of the electrical machines, industries and medical field etc.

- Electrical Transformers

It is a static ac device which is used to either step up or step down voltage or current. It is used in generating station, transmission and distribution system. The transformer works on Faraday's law.

- Electrical Generators

The basic working principle of electrical generator is Faraday's law of mutual induction. Electric generator is used to convert mechanical energy into electrical energy.

- Induction Cookers

The Induction cooker, is a most fastest way of cooking. It also works on principle of mutual induction. When current flows through the coil of copper wire placed below a cooking container, it produces a changing magnetic field. This alternating or changing magnetic field induces an emf and hence the current in the conductive container, and we know that flow of current always produces heat in it.

- Electromagnetic Flow Meters

It is used to measure velocity of blood and certain fluids. When a magnetic field is applied to electrically insulated pipe in which conducting fluids are flowing, then according to Faraday's law, an electromotive force is induced in it. This induced emf is proportional to velocity of fluid flowing .

- Form the bases of Electromagnetic Theory

Faraday's idea of lines of force is used in well known Maxwell's equations. According to Faraday's law, change in magnetic field gives rise to change in electric field and the converse of this is used in Maxwell's equations.

- Musical Instruments

It is also used in musical instruments like electric guitar, electric violin etc.

ii) Define the terms

(i)time period

(ii)rms value

(iii)average value

(iv)form factor

(v)peak factor in an ac circuit

i) **peak value**-it is the maximum value of the wave either during positive half cycle or during negative

half cycle

ii)**Average value**:- it is the dc value of a wave .In general average value of a wave form x(t) can b

represented as xavg =1/T□

T

x t dt

0

( ) . Where T is the time period of the signal.

iii)**RMS value**:-Root Mean Square value.It is the capability of a sine wav in terms of heating power

iv) **Form factor**:-

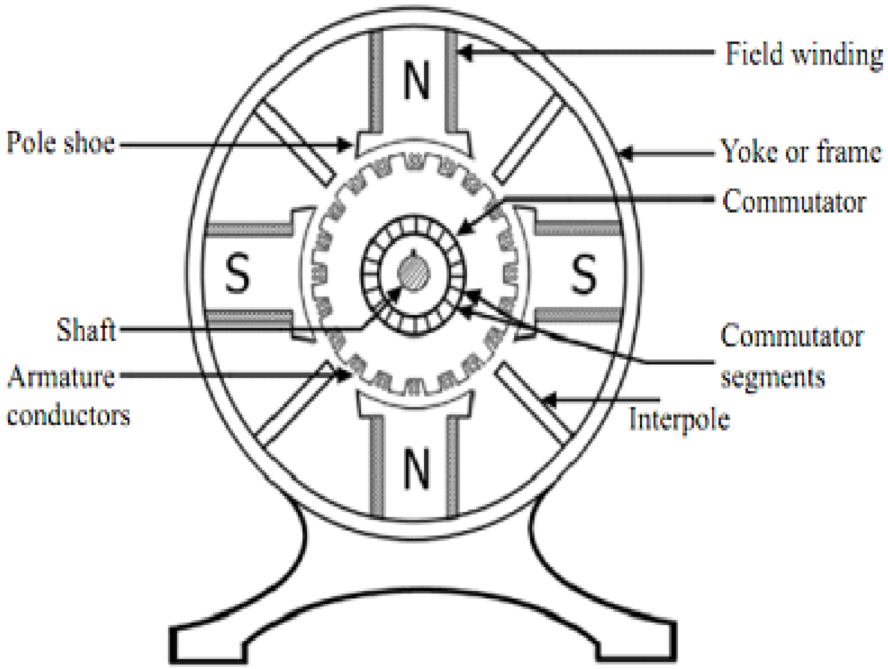
FF=RMS value/ Average value

For a sin wave form factor is 1.11

v)**Time period**:-It is the time taken to complete one cycle

8 i) Describe the constructional details of a DC machine.

ii)Derive an expression for emf equation for dc generator



The major parts can be identified as,

1. Body

2. Poles

3. Armature

4. Commutator and brush gear
5. Commutating poles
6. Compensating winding
7. Other mechanical parts

Body The body constitutes the outer shell within which all the other parts are housed. This will be closed
at both the ends by two end covers which also support the bearings required to facilitate the rotation of the
rotor and the shaft.

Main poles Solid poles of fabricated steel with seperate/integral pole shoes are fastened to the frame by
means of bolts. Pole shoes are generally laminated. Sometimes pole body and pole shoe are formed from
the same laminations.

Inter-poles These are small additional poles located in between the main poles. These can be solid, or
laminated just as the main poles. These are also fastened to the yoke by bolts. Sometimes the yoke may be
slotted to receive these poles.

Armature The armature is where the moving conductors are located. The armature is constructed by
stacking laminated sheets of silicon steel. Thickness of these lamination is kept low to reduce eddy
current losses.

Field windings In the case of wound field machines (as against permanent magnet excited machines) the
field winding takes the form of a concentric coil wound around the main poles. These carry the excitation
current and produce the main field in the machine. Thus the poles are created electromagnetically.

Brush and brush holders Brushes rest on the surface of the commutator. Normally electro-graphite is
used as brush material. The actual composition of the brush depends on the peripheral speed of the

commutator and the working voltage. The hardness of the graphite brush is selected to be lower than that
of the commutator.

Bearings Small machines employ ball bearings at both ends. For larger machines roller bearings are used
especially at the driving end.

ii) Let *Z* =number of armature conductors,

Ø=useful flux per pole, in webers

p=number of **pairs** of poles

and *n*=armature speed in rev/s

The e.m.f. generated by the armature is equal to the e.m.f. generated by one of the parallel paths. Each
conductor passes 2p poles per revolution and thus cuts 2p Øn webers of magnetic flux per revolution.

Hence flux cut by one conductor per second=2*p* Ø *n* Wb and so the average e.m.f. *E* generated per
conductor is given by: $E = 2pn$ Ø

Let *c* = number of parallel paths through the winding
between positive and negative brushes

***c* = 2 for a wave winding**

***c* = 2*p* for a lap winding**

The number of conductors in series in each path=Z/c

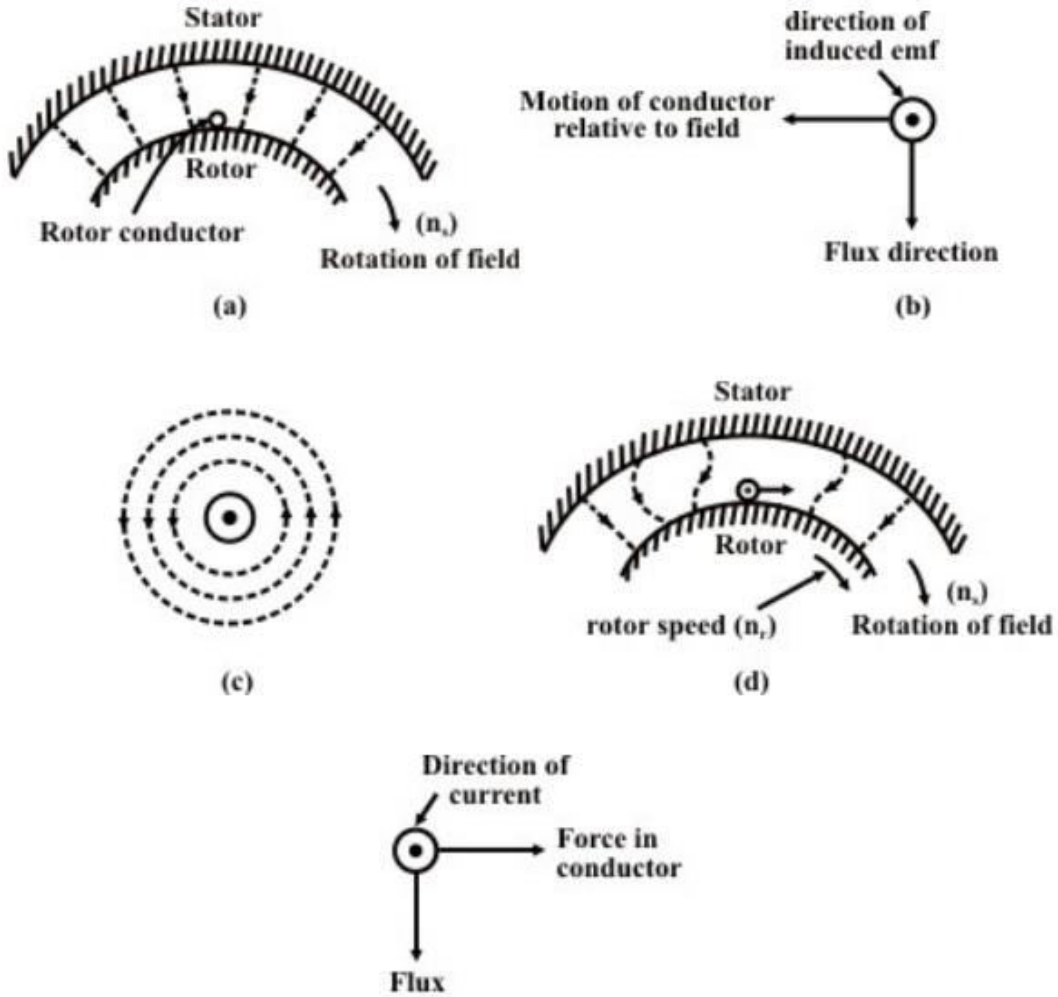
The total e.m.f. between brushes
=(average e.m.f./conductor)(number of conductors in series per path)= 2*pn* Ø Z/c

generated e.m.f., *E* =2*p* Ø *n* *Z/c* volts

9 i) Explain the principle of operation of a 3-phase induction motor.

Principle of Operation The balanced three-phase winding of the stator is supplied with a balanced threephase voltage. the current in the stator winding produces a rotating magnetic field, the magnitude of which remains constant. The axis of the magnetic field rotates at a synchronous speed a function of the supply frequency (f), and number of poles (p) in the stator winding. The magnetic flux lines in the air gap cut both stator and rotor (being stationary, as the motor speed is zero) conductors at the same speed. The emfs in both stator and rotor conductors are induced at the same frequency, i.e. line or supply frequency, with

No. of poles for both stator and rotor windings (assuming wound one) being same. The stator conductors are always stationary, with the frequency in the stator winding being same as line frequency. As the rotor winding is short-circuited at the slip-rings, current flows in the rotor windings. The electromagnetic torque in the motor is in the same direction as that of the rotating magnetic field, due to the interaction between the rotating flux produced in the air gap by the current in the stator winding, and the current in the rotor winding. This is as per Lenz's law, as the developed torque is in such direction that it will oppose the cause, which results in the current flowing in the rotor winding. This is irrespective of the rotor type used − cage or wound one, with the cage rotor, with the bars short-circuited by two end-rings, is considered equivalent to a wound one The current in the rotor bars interacts with the air-gap flux to develop the torque, irrespective of the no. of poles for which the winding in the stator is designed. Thus, the cage rotor may be termed as universal one. The induced emf and the current in the rotor are due to the relative velocity between the rotor conductors and the rotating flux in the air-gap, which is maximum, when the rotor is stationary . As the rotor starts rotating in the same direction, as that of the rotating magnetic field due to production of the torque as stated earlier, the relative velocity decreases, along with lower values of induced emf and current in the rotor. If the rotor speed is equal that of the rotating magnetic field, which is termed as synchronous speed, and also in the same direction, the relative velocity is = 0.0 r n zero, which causes both the induced emf and current in the rotor to be reduced to zero. Under this condition, torque will not be produced. So, for production of positive (motoring) torque, the rotor speed must always be lower than the synchronous speed. The rotor speed is never equal to the synchronous speed in an IM. The rotor speed is determined by the mechanical load on the shaft and the total rotor losses, mainly comprising of copper loss. The difference between the synchronous speed and rotor speed, expressed as a ratio of the synchronous speed, is termed as 'slip' in an IM. So, slip (s) in pu is s r s rs n n n nn s −= − = 1 or, r nsn s = (−)1 ⋅ where, and are synchronous and rotor speeds in rev/s. ns r n In terms of and s 60×= nN s r r = 60× nN , both in rev/min (rpm), slip is ( )/ s r s sNNN = − If the slip is expressed in %, then = − NNNs srs]/)[(×100 Normally, for torques varying from no-load (≈ zero) to full load value, the slip is proportional to torque. The slip at full load is 4-5% (0.04-0.05).

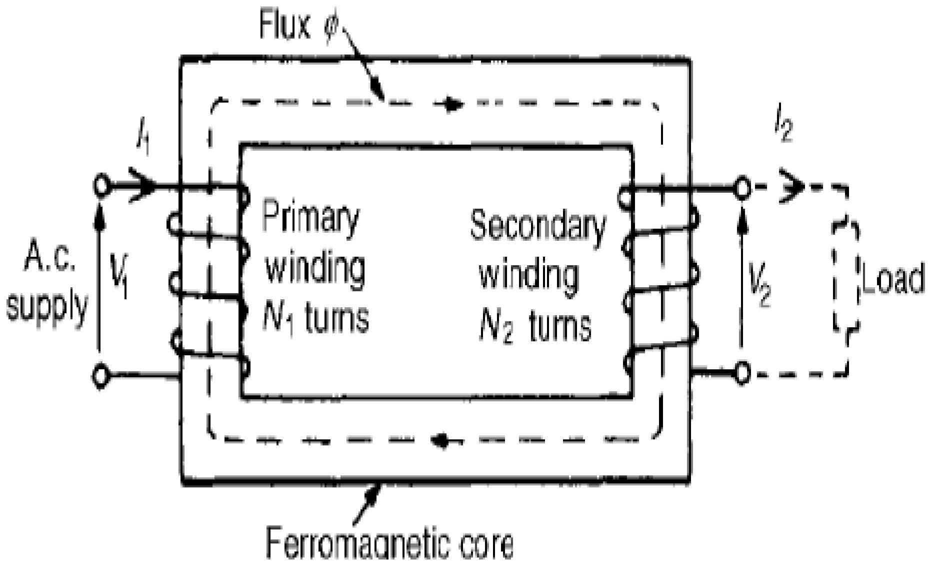


An alternative explanation for the production of torque in a three-phase induction motor is given here, using two rules (right hand and left hand) of Fleming.. Also shown is the path of the flux in the air gap. This is for a section, which is under North pole, as the flux lines move from stator to rotor. The rotor conductor shown in the figure is at rest, i.e., zero speed (standstill). The rotating magnetic field moves past the conductor at synchronous speed in the clockwise direction. Thus, there is relative movement between the flux and the rotor conductor. Now, if the magnetic field, which is rotating, is assumed to be at standstill as, the conductor will move in the direction shown. So, an emf is induced in the rotor conductor as per Faraday's law, due to change in flux linkage. The direction of the induced emf as shown in the figure can be determined using Fleming's right hand rule.

As described earlier, the rotor bars in the cage rotor are short circuited via end rings. Similarly, in the wound rotor, the rotor windings are normally short-circuited externally via the slip rings. In both cases, as emf is induced in the rotor conductor (bar), current flows there, as it is short circuited. It is known that force is produced on the conductor carrying current, when it is placed in a magnetic field. The direction of the force on the rotor conductor is obtained by using Fleming's left hand rule, being same as that of the rotating magnetic field. Thus, the rotor experiences a motoring torque in the same direction as that of the rotating magnetic field. This briefly describes how torque is produced in a three-phase induction motor.

ii) Explain the principle of operation single-phase transformer (5 Marks)

Transformer principle of operation



When the secondary is an open-circuit and an alternating voltage $V1$ is applied to the primary winding, a

small current called the no-load current $I0$ — flows, which sets up a magnetic flux in the core. This

alternating flux links with both primary and secondary coils and induces in them e.m.f.'s of $E1$ and $E2$

respectively by mutual induction. The induced e.m.f. E in a coil of N turns is given by

$E = -Nd\text{Ø}/dt$ volts where $d\text{Ø}/dt$ is the rate of change of flux. In an ideal transformer, the rate of change of

flux is the same for both primary and secondary and thus $E1/N1 = E2/N2$, i.e. **the induced e.m.f. per turn**

is constant.

Assuming no losses, $E1 = V1$ and $E2 = V2$. Hence $V1/N1 = V2/N2$ or $V1/V2 = N1/N2$ $V1/V2$ is called the

voltage ratio and $N1/N2$ the **turns ratio**, or the **'transformation ratio'** of the transformer. If $N2$ is less
than $N1$ then $V2$ is less than $V1$ and the device is termed a **step-down transformer**. If $N2$ is greater then
$N1$ then $V2$ is greater than $V1$ and the device is termed a **step-up transformer**. When a load is connected
across the secondary winding, a current $I2$ flows. In an ideal transformer losses are neglected and a
transformer is considered to be 100% efficient. Hence input power=output power, or $V1I1 = V2I2$, i.e. in
an ideal transformer, the **primary and secondary volt-amperes are equal**.