Module 1

1a. State Kirchoff's law for DC circuits. Illustrate with an example

Kirchhoff's laws

This law do not depend on the nature of elements of circuit.
This law is related to the topology of the Circuit.

There are two laws :-

Kirchhoff's Current law [KCL]
Kirchhoff's Voltage law [KVL]

i Kirchhoff's Current law :- In any electric Network, the algebraic sum of currents meeting at a point (junction) is zero.

(or)

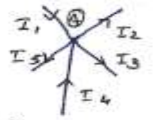
Total current leaving a junction is equal to the total current entering that junction.

There will be no accumulation of charge at the junction of the Network.

Eg:-

@ node-1 $I - I_1 - I_2 - I_3 = 0$

$$\boxed{I = I_1 + I_2 + I_3}$$



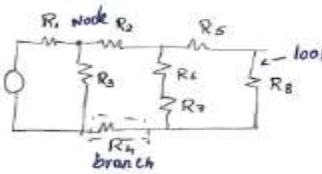
@ A $I_1 - I_2 - I_3 + I_4 - I_5$

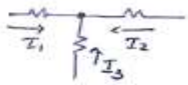
ii. Kirchoff's Mesh law or Voltage law [KVL] :-

The algebraic Sum of the products of currents and resistances in each of the Conductors in any closed path (mesh) in a network plus the algebraic sum of the emfs in that path is zero.

$$\Sigma IR + \Sigma e.m.f = 0$$

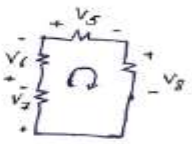
Eg:-





KCL

$I_1 + I_2 + I_3 = 0$



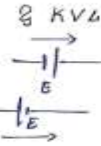
KVL

$V_7 + V_6 + V_5 + V_8 = 0$

* Points to remember for applying KCL & KVL

→ Raise in voltage +ve sign

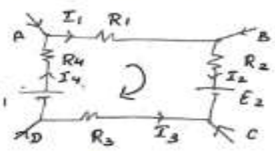
fall in voltage -ve sign



$+E$

$-E$

→ Sign of voltage drop across a resistor depends on the direction of current through that resistor but is independent of the polarity of any other source of emf in the circuit under consideration.



$-I_1R_1 \to$ fall in potential

$I_3R_3 \to$ Raise in potential.

$$E_1 - I_4R_4 - I_1R_1 - I_2R_2 + I_3R_3 - E_2 = 0$$

$$E_1 - E_2 = I_1R_1 + I_2R_2 - I_3R_3 + I_4R_4$$

→ We can either consider clockwise or anticlockwise direction but same direction has to be followed throughout the solution of the question.

1 b

b. What is the voltage across A and B in the circuit shown in Fig.Q.1(b). **(06 Marks)**

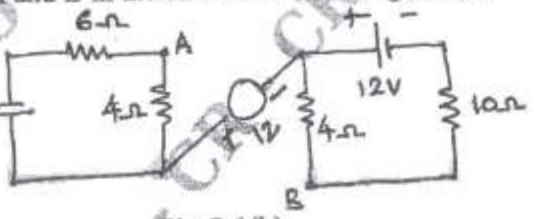


Fig.Q.1(b)

c. Define the following terms:
   i) Average value
   ii) RMS value
   iii) Form factor. **(06 Marks)**

Loop 1

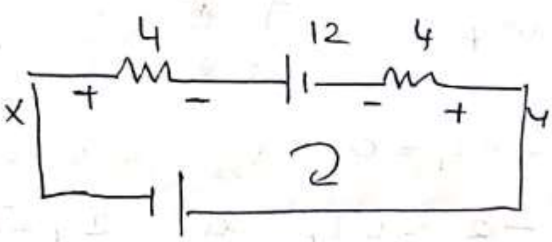
$$-6 - 6I_1 - 4I_1 = 0$$

$$-6 = 10I_1 \quad \text{ie} \quad I_1 = \frac{-6}{10} = 0.6A$$

Loop 2

$$-12 - 10I_2 - 4I_2 = 0$$

$$-12 = 14I_2 \quad \text{ie} \quad I_2 = -\frac{12}{14} = 0.857A$$



V_{xy}

$$-V_{xy} - 4I_1 - 12 + 4I_2 = 0$$

$$V_{xy} = -4 \times \overset{0.6}{\cancel{0.857}} - 12 - 4 \times \overset{0.86}{\cancel{0.6}}$$

$$= -13.04V$$

2/

c. Define the following terms:
   i) Average value
   ii) RMS value
   iii) Form factor. (06 Marks)

Average Value :-

It is the steady current which transfers across any circuit, the same charge as is transferred by that alternating current during the same time.

(or)

It is the algebraic sum of all the values divided by the total number of values.

Root mean square (RMS) Value. or Effective Value.

* It is the steady current which when flowing through a given circuit for a given time produce the same heat as produced by the alternating current when flowing through the same circuit for the same time.

* It is also known as effective or virtual value. of AC.

Form factor :- K_f :- It is defined as ratio of rms value to average value of a Quantity.

$$\boxed{K_f = \frac{\text{rms value}}{\text{average value.}}}$$

OR

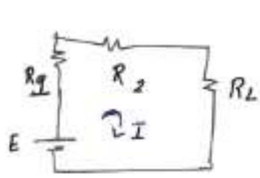
2 a. Prove that the maximum power will be transferred to the load when load resistance is equal to the source resistance. (06 Marks)

Maximum Power transfer theorem

This theorem states as follows,

A resistive load will abstract maximum power from a network when the load resistance is equal to the resistance of the Network as viewed from the output terminals, with all energy sources removed leaving behind their internal resistances.

Eg:- $I = \frac{E}{R_1+R_2+R_L}$



$R = R_1 + R_2$

Power Consumed by load is

$$P_L = I^2 R_L = \frac{E^2}{(R+R_L)^2} \cdot R_L$$

$$P_L = \frac{E^2 R_L}{(R+R_L)^2}$$

For P_L to be maximum $\frac{dP_L}{dR_L} = 0$

$$0 = E^2 \left[\frac{1}{(R+R_L)^2} + R_L \left(\frac{-2}{(R_L+R)^3} \right) \right]$$

$$0 = \frac{E^2}{(R_L+R)^2} \left[\frac{(R_L+R) - 2R_L}{R_L+R} \right]$$

$$0 = E^2 \left[\frac{R - R_L}{R+R_L} \right]$$

$R - R_L = 0$ $\boxed{R = R_L}$

So, $P_L = \frac{E^2}{(R+R)^2} R$

$= \frac{E^2}{(2R)^2} R$

$= \frac{E^2 R}{4R^2}$

$P_L = \frac{E^2}{4R}$

max. power is $P_{Lmax} = \frac{E^2}{4R}$

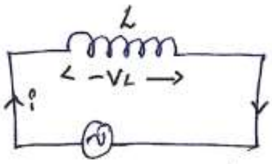
$$\boxed{P_{Lmax} = \frac{E^2}{4R}}$$

→ When load Resistance is made equal to output impedance of the Circuit we say impedance match is done that is when max. Power transfer occurs.

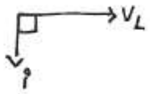
to the source resistance.

b. A pure inductor excited by sinusoidal varying AC voltage, show that the average power consumed by inductor is zero. (08 Marks)

Ac through Pure Inductance Alone.



$V = V_m \sin\omega t$



→ if DC supply is given to inductor it behaves like a magnet

→ When current is passed through a coil magnetic poles are produced

→ By thumb rule we can tell north pole & south pole.

→ If AC supply is given to inductor there is change in flux linked with a coil, an emf is induced in it which will oppose the supply voltage.

∴ Induced emf is given by,

$$e = -L\frac{di}{dt}$$

$$= -L\frac{d}{dt}(I_m \sin\omega t)$$

$$= -L I_m \omega \cos\omega t$$

$$V = -e = \omega L I_m \cos\omega t$$

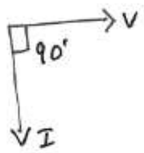
$$V = \omega L I_m \sin(\pi/2 + \omega t)$$

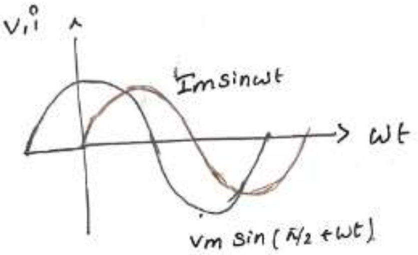
$$i = I_m \sin\omega t$$

So, I lags V by $\pi/2$

or V leads I by $\pi/2$

Phasor





$\boxed{X_L = \omega L}$ - Reactance (inductive)

L - henry ω = rad/s.

$X_L = 2\pi f L$ so X depends on f directly.

Power

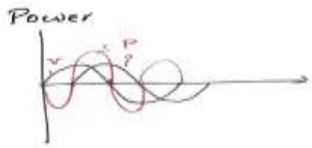
$P = v \cdot i = V_m \sin(\omega t + \pi/2)\, I_m \sin \omega t$

$= -V_m I_m \sin \omega t \cos \omega t$

$= -\frac{V_m I_m}{2} \sin 2\omega t$

$P = -\frac{V_m I_m}{2} \int_0^{2\pi} \sin 2\omega t$ Power for whole cycle

$P = 0$



$\therefore$ Average power consumed is zero. (for a cycle)

Power wave is a sine wave with double the frequency of that of Voltage and Current wave.

max. value of Instantaneous Power $= \frac{V_m I_m}{2}$

Pure Inductor is lossless. $Pf = \cos 90° =$ Zero lagging

consumed by inductor is zero.

c. A 318μF capacitor is connected across a 230V, 50Hz system. Determine: i) Capacitive reactance ii) RMS value of current iii) Extrusions for instantaneous voltage and current v(t) and i(t). **(06 Marks)**

2.6

i) Capacitive reactance

Given

$C = 318\mu F$

$f = 50\,Hz$

$V_{rms} = 230V$

$X_C = \frac{1}{\omega C}$

$\omega = 2\pi f$

$= 2 \times \pi \times 50$

$\omega = 314.15$ rad/s

$V_m = V_{rms} \times \sqrt{2}$

$= 230 \times \sqrt{2}$

$= 325.26V$

$X_C = \frac{1}{314.15 \times 318 \times 10^{-6}}$

$\boxed{X_C = 10\ \Omega}$

ii) Rms value of current

$I_m = \frac{V_m}{X_C}$

$= \frac{325.26}{10} = 32.52\,A$

$I_{rms} = \frac{I_m}{\sqrt{2}} = 23\,A$

iii) Expression for instantaneous Voltage & current $V(t)$ & $I(t)$

$V(t) = V_m \sin \omega t$

$V(t) = 325.26 \sin \omega t$

$i(t) = I_m \cos \omega t$ or $I_m \sin(\omega t + \pi/2)$

($\because$ I lead V in Pure Capacitor)

$i(t) = 32.52 \sin(\omega t + \pi/2)$

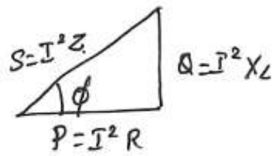
Module-2

3a

a. Define: i) Real power ii) Reactive power iii) Power factor. (06 Marks)

Real Power Reactive Power apparent Power and Power factor

Real [Watt ful component] Power or active power:.(P) It is the actual power that is dissipated in the Circuit. resistance.



$$\boxed{P = I^2 R = VI\cos\phi \; W}$$

Reactive Power(Q) It is the power developed in the inductive reactance of the circuit.
[Wattless]

$$Q = I^2 X_L = I^2 . Z\sin\phi = I(IZ)\sin\phi = IV\sin\phi$$

$$= I^2 X_C \qquad \boxed{Q = VI\sin\phi \; VAr}$$

Apparent Power: Product of r.m.s values of applied voltage & circuit current.

$$S = VI = IZ.I = I^2 Z \; VA$$

$$\boxed{S = VI \; VA} \qquad \boxed{S^2 = P^2 + Q^2}$$

Power factor $\phi = \tan^{-1}\left(\frac{Q}{P}\right) = \tan^{-1}\left(\frac{X_L}{R}\right)$

27 $\cos\phi = \cos\left(\tan^{-1}\left(X_L/R\right)\right) = \frac{R}{Z} = \frac{P}{S} = \frac{\text{Real Power}}{\text{apparent Power}}$

b. A series circuit with R = 10Ω, L = 50mH and C = 100μF is supplied with 200V, 50Hz. Find:
i) The impedance ii) Current iii) Power iv) Power factor. (08 Marks)

2 b.

Given

$R = 10\,\Omega$

$L = 50\,mH$

$C = 100\,\mu F$

$V_{rms} = 200V$

$f = 50Hz$

i) Impedance

$Z = R + j(X_L - X_C)$

$X_L = \omega L \qquad X_C = \frac{1}{\omega C} \qquad \omega = 2\pi f = 314.15\,rad/s$

$X_L = 314.15 \times 50 \times 10^{-3} \qquad X_C = \frac{1}{314.15 \times 100 \times 10^{-6}}$

$X_L = 15.70\,\Omega \qquad X_C = 31.83\,\Omega$

$Z = 10 + j(15.70 - 31.83)$

$Z = 10 - 16.12j\,\Omega \qquad Z = 18.96\angle{-58.18}\,\Omega$

ii) Current

$I = \frac{V}{Z} = \frac{200}{18.96\angle{-58.18}} = 10.54\angle{58.18}\,A$

$I_{rms} = 10.54\angle{58.18}\,A$

iii) Power

$P = VI\cos\phi$

$P = 200 \times 10.54 \times 0.52$

$P = 1096.16\,W$

$\phi = -58.18$

$\cancel{\cos\phi = \frac{R}{Z} = \frac{10}{18}}$

$Pf = \cos(58.18)$

$Pf = 0.52$

iv) Power factor $Pf = \cos\phi$

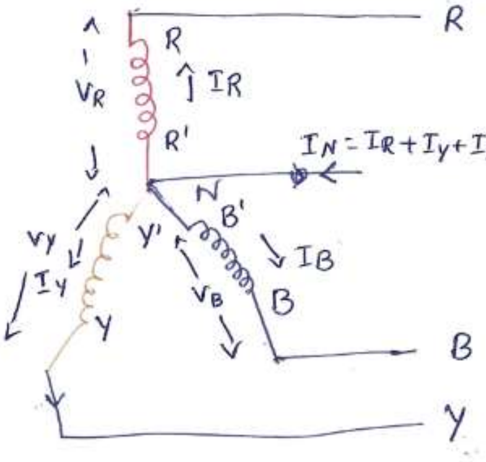
$Pf = \cos(-58.18)$

$Pf = 0.52$

i) The impedance ii) Current ...

c. Deduce the relationship between the phase and the line voltages of a three phase star connected system. (06 Marks)

Star Connection (Y) Wye Connection



Similar ends are connected together. and connected to 'N'.

N - Star point or neutral point. The neutral is is connected to a conductor /wire.

∴ Such a system is 3 phase 4 wire system.

Potential difference between any terminal and neutral wire → Phase Vo

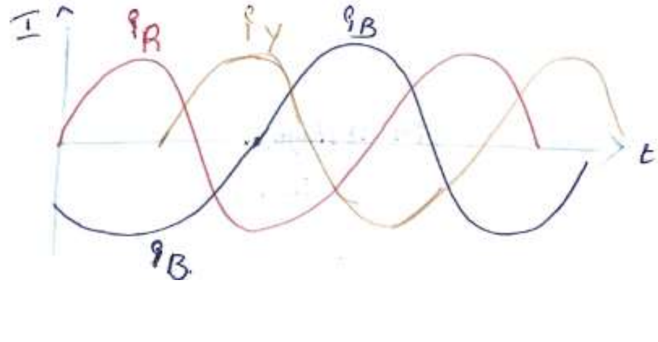
Potential difference between any two lines → line - line voltage. or Line voltage

Note: The arrows shown for currents is not taken at a instant, it is taken assuming to be positive. No instant all three currents flow in the same direction (either inwards /outward.

→ Each conductor in turn provides a return path for the currents of other conductors.

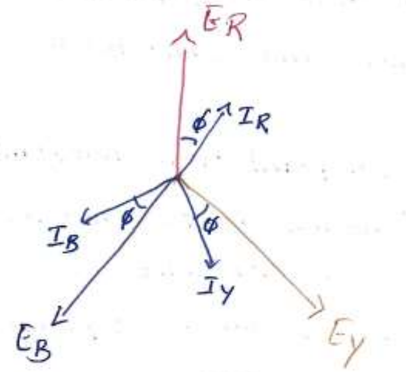
→ even if I in all 3 lines are continuously changing as shown in graph below. at any instant algebraic sum of instantaneous values of all 3 currents. = 0

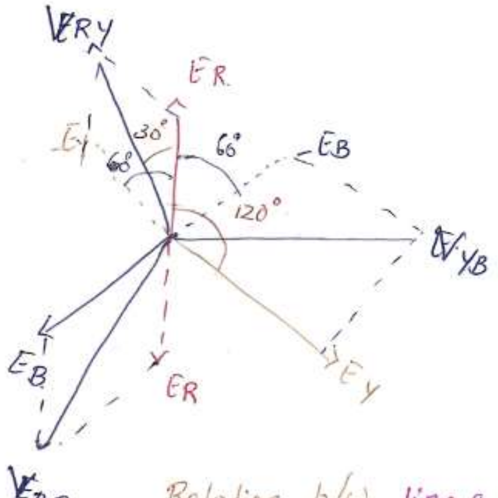
$$i_R + i_Y + i_B = 0$$



Wave form will be similar for voltag

Phasor diagram for Y-connection





E_R, E_Y E_B – Phase values.

Relation b/w line & Phase Voltage

Phase - Voltage / current in each winding. (V_{ph} / I_{ph})

Line - - voltage / current between any pair of terminals. (V_L / I_L)

$\overline{V_{RY}} = \overline{E_R} - \overline{E_Y}$ $\qquad \overline{V_{BY}} = \overline{E_B} - \overline{E_Y}$ $\qquad \overline{V_{BR}} = \overline{E_B} - \overline{E_R}$

Parallelogram rule

$$V_{RY}^2 = E_R^2 + E_Y^2 + 2E_R E_Y \cos 60° \qquad E_R = E_Y = E_B = E_{ph}$$

$$= E_{ph}^2 + E_{ph}^2 + 2E_{ph}^2 \cos 60°$$

$$= 2E_{ph}^2 + 2E_{ph}^2 \left(\tfrac{1}{2}\right)$$

$$= 3E_{ph}^2$$

$$V_{RY} = \sqrt{3}\, E_{ph}.$$

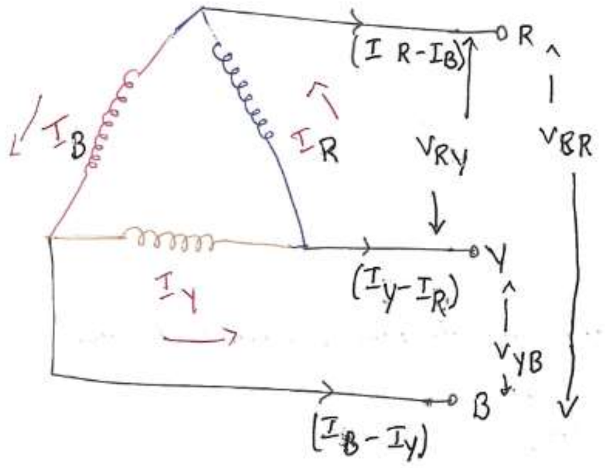
$$V_{RY} = \sqrt{3}\, E_{ph}$$

$$V_{RY} = \sqrt{3}\, E_{ph}$$

$\boxed{\text{line value} = \sqrt{3}\ \text{Phase. value}}$ (for voltage in λ)

4 a. Deduce the relationship between the phase and the line current of a three phase delta connected system. (06 Marks)

Delta (Δ) Connection



It is 3 phase, 3-wire system

- 'Starting' end of one phase is connected to finishing end of other phase.
  i.e interconnection of dissimilar ends

-> All 3 windings are joined in series to form closed mesh.

-> The leads are taken out from junction & they are taken as positive.

-> If system is balanced then sum of the 3 voltages round the closed mesh = 0. hence no current of fundamental frequency can flow around the mesh when terminals are open.

-> The e.m.f in one phase is equal & opposite to resultant of those in the other 2 phases.

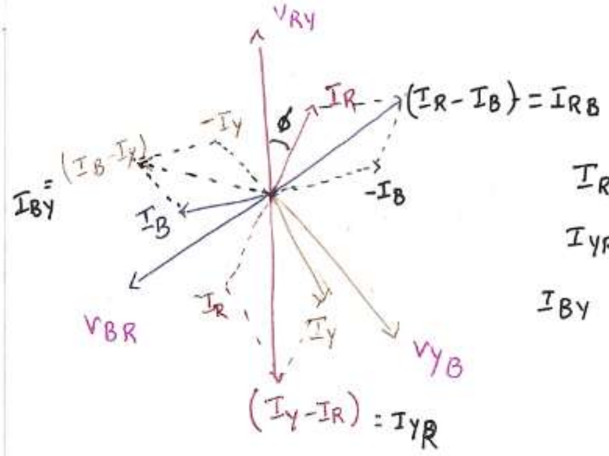
Line Voltages & Phase Voltages

-> The voltage between any pair of lines = phase voltage of the phase winding connected between the two lines considered.

-> Since all the phases are connected in series.

$$\boxed{E_{RY} = E_{YB} = E_{BR} = V_L = V_{ph}}$$

Phasor diagram.



Vector difference of 2 phase currents.

$I_{RB} = I_1 = I_R - I_B$

$I_{YR} = I_2 = I_Y - I_R$

$I_{BY} = I_3 = I_B - I_Y$

From Parallelogram rule

$I_{ph} = I_B = I_Y = I_R$ = Phase current

$I_L = I_{RB} = I_{BY} = I_{YR}$ = line current

$$I_{RB}^2 = I_R^2 + (-I_B)^2 + 2 I_R I_B \cos 60^\circ$$

$$= I_R^2 + I_B^2 + 2 I_R I_B (1/2)$$

$$= I_{ph}^2 + I_{ph}^2 + 2 I_{ph}^2 (1/2)$$

$$= 2 I_{ph}^2 + I_{ph}^2$$

$$I_L^2 = 3 I_{ph}^2$$

$$\boxed{I_L = \sqrt{3}\, I_{ph}}$$

connected system.

b. A balanced star connected load of $(8 + j6)\Omega$ per phase is connected to a three phase 230V supply. Find the current, power factor, power, reactive volt ampere and total voltampere. (05 Marks)

Given, $Z = 8 + j6\ \Omega$ / phase

$V_L = 230V = V_{ph} \times \sqrt{3}$ [Y connected]

$$V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{230}{\sqrt{3}} = 132.79V$$

$$I_L = I_{ph} = \frac{V_{ph}}{Z} = 10.62 - j7.974$$

$$= \underline{13.27} \angle -36.87^\circ A$$

Pf, $\cos\phi = \cos(-36.87) = 0.8$ lagging

$P = \sqrt{3}\, V_L I_L \cos\phi$

$= \sqrt{3} \times 230 \times 13.27 \times 0.8 = \underline{4229.11}\, W$

$Q = \sqrt{3}\, V_L I_L \sin\phi$

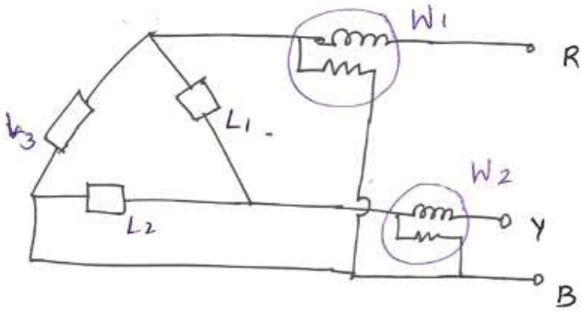
$= \sqrt{3} \times 230 \times 13.27 \sin\phi$

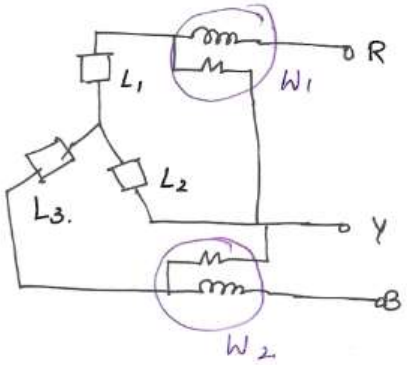
$= \underline{3171.84}$ VAR

$S = \sqrt{3}\, V_L I_L = 52\underline{86.39}\, VA$

c. Three phase power consumed by the balanced load is given by $P = \sqrt{3}\ V_L I_L \cos\phi$ watts, then show that two wattmeter is sufficient to measure three phase power P. **(09 Marks)**

C. Two wattmeter method (Balanced or unbalanced load)





As shown in figure the current coils of two wattmeters are inserted in any two lines and potential coil of each joined to the third line.

A star connected load is ~~consisted~~ considered for discussion same applies for Δ- loads also.

Δ- load & Y- load can be replaced with each others equivalent model.

* It is important to take the direction of the voltage through the circuit the same as that taken for the current when establishing the readings of 2 wattmeters.

Instantaneous current through $W_1 = i_R$

Potential difference (P.d) across $W_1 = e_1 = e_R - e_y$

Power by $W_1 = i_R e_1 = i_R(e_R - e_y)$

Instantaneous current through $W_2 = i_B$

Pd. across $W_2 = e_2 = e_B - e_y$

Power through $W_2 = i_B(e_B - e_y)$

Total power $= W_1 + W_2$

$$i_R(e_R - e_y) + i_B(e_B - e_y)$$

$$= i_R e_R - i_R e_y + i_B e_B - i_B e_y$$

$$= i_R e_R + i_B e_B - e_y(i_B + i_R)$$

W.K.T

$i_R + i_B + i_y = 0$

$i_B + i_B = -i_y$

$$= i_R e_R + i_B e_B + e_y i_y$$

$$= P_1 + P_2 + P_3$$

so, $\boxed{W_1 + W_2 = \text{Total power absorbed}}$ by all 3 loads

P_1 - Power absorbed by Load L_1

P_2 - " L_2

P_3 - " L_3

The proof is true for balanced or unbalanced. Y/Δ.

if load is Y-connected No neutral connection should be (3 wire 3 ϕ connected) present. , if neutral is present. it should be exactly balanced so that each case there is no i_n.

Otherwise KCL will be $i_N + i_R + i_y + i_B = 0$.

Module 3

Module-3

5 a. With neat sketch, explain the different parts of a DC generators. (06 Marks)

b. Give the classification of DC generator. Obtain the expression for EMf equation of a DC generator. (08 Marks)

c. Give broad classification of transformers. Explain the construction of transformer. (06 Marks)

a.

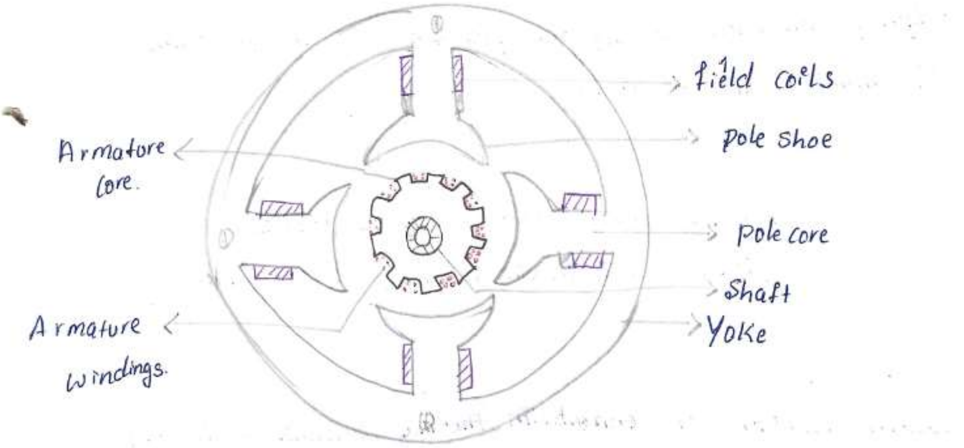
Construction

i) magnetic frame or Yoke   ii) Pole-cores & Pole shoes

iii) Pole coils or Field coils   4.) Armature core   air gap

5) Armature windings or Conductors   6) Commutator   7) Brushes & Bearings.

◯ - Electrical circuit   ▭ magnetic circuit



Yoke Outer frame used for 2 purpose
- Mechanical support for poles & protecting cover for whole m/c
- Carries magnetic flux produced by poles.

Pole Cores → Two types of pole construction
- solid
- lamination.

Pole Shoe → Spread out of flux in air gap
Support exciting coils.

pole coils → Copper wire/strips. When current is passed through strips they electromagnetize the poles, poles further produce flux

Armature Core: Provides the path of very low reluctance to the flux through the armature.
made of laminations.

Armature winding: Armature Conductors, Conductors are wound on core with thick Insulation.

Commutator: Collect current from armature & Convert the ac induced current to unidirectional current. into the load.

Brushes & Bearings: Function of brush is to collect current from commutator
made of Carbon or Graphite, rectangular shape

Induced emf expression.

P - No. of poles in Generator
ϕ - Flux produced by each pole (wb)
N - Speed of armature (RPm) (rotations per minute)
Z - Number of Conductors on armature
A - Number of parallel paths in which conductors are distributed.

Emf Induced in generator by
Faraday's law of electro magnetic induction.

$$e = \frac{d\phi}{dt}$$

45 Total flux = Flux produced by each pole x Number of poles

b.

$d\phi = \phi * P$

Time required for Conductor to Complete

1revelution $dt = \frac{60}{N}$ ($\because$ N Rpm is Speed i.e N rotations per min)

$e = \frac{\phi * P}{\frac{60}{N}}$

so $N \text{ rev} \overset{\text{takes}}{=} 60s$

$1 \text{rev} \overset{\text{time}}{=} \frac{60}{N}$

$e = \frac{P\phi N}{60}$ => Emf generated by one conductor

There are Z conductors

$e = \frac{P\phi NZ}{60}$

These Conductors are arranged in A Parallel paths

$\boxed{e = \frac{P\phi NZ}{60A}}$ => Emf induced across each parallel path.

lap winding	wave winding
$A = P$	$A = 2$
so, $E_g = \frac{P\phi NZ}{60(P)}$	$E_g = \frac{P\phi NZ}{60(2)}$
$\boxed{E_g = \frac{\phi NZ}{60}}$	$\boxed{E_g = \frac{P\phi NZ}{120}}$

Types of Generators.

Broad Classification
- Separately excited generators
- Self excited generators.

Separately excited :- Here the field magnets are energized from an independent external source of dc current.

Self excited :- Here field magnets are energised from current produced by generators themselves.
Due to residual magnetism there is always some flux present in the poles.

They are further divided into
i) Shunt wound
ii) Series wound.
iii) Compound

Shunt wound :- Field windings are connected $\boxed{\text{Parallel}}$ with the armature conductors so, field windings get the full voltage of generator applied across them.

Series wound :- Field windings are in $\boxed{\text{Series}}$ with armature conductors. They will carry full load current they consists of relatively less turns but thick wires.

Compound :- Combination of few $\boxed{\text{Series}}$ and few $\boxed{\text{Shunt}}$.
They can be either short shunt or long shunt.
Here Shunt field is stronger than series field
Series field aids shunt - Commutatively Compound
Series field oppose shunt - Differentially compound.

Types and Construction of 1-phase transformer.

Construction :. In simplest form transformer consist of 2 coils having mutual inductance and a laminated steel core.

* These coils are seperated from each other & wound on steel core.
* Coils are insulated.

Parts of transformer

i. Container for placing assembled core and windings.

ii. A suitable medium for insulating core & container.

iii. Bushings for insulating & bringing out the terminals from tank.

* construction of core in next page * (59.a)

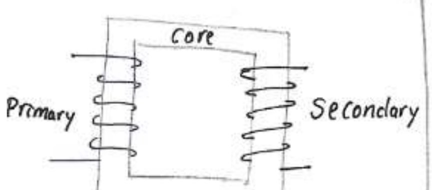
Core is made of sheet steel lamination to provide path for magnetic flux.

Core has more amount of silicon. because.

Core should have high permeability & low hysteresis loss.

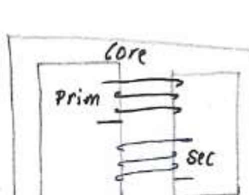
Core is made of laminations insulated from each other., to reduce eddy current loss.

Construction wise there are two types — Core type, shell type.



Core type

* Windings surround a considerable part of core



Shell type

* Core surrounds a considerable part of windings.

c.

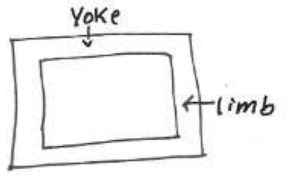
Construction

Core

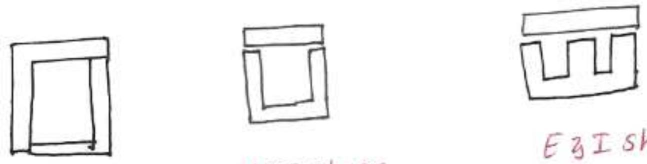
- It is made of silicon or sheet steel with 4% silicon
- It is laminated to reduce eddy current losses

The Core may be either Square or rectangular

The vertical ~~positi~~ Portion on which Coil is wound is Called limb, top & bottom is Called yoke.



Types of lamination



L - Shape

U & I Shape

E & I Shape.

The permeability of material used for Core must have high value $\mu_r > 1000$

The laminations are insulated from each other by a light Coat of Varnish or Paper.

Each lamination is of 0.3mm thickness - for $f = 50$ Hz

0.5mm thickness - for $f = 25$ Hz

OR

6 a. Derive the expression for emf induced in the primary or secondary side of a transformer. (06 Marks)

b. Derive an expression for the torque developed by a DC motor. (06 Marks)

c. A 250KVA, 11000/415V, 50Hz single phase transformer has 80 turns on the secondary, calculate:

i) Rated primary and secondary currents.
ii) Number of primary turns.
iii) Maximum value of core flux.
iv) Voltage induced per turn. (08 Marks)

6a.

Consider a sinusoidally varying voltage V_1 applied to the single phase transformer.

Since the voltage is sinusoidally varying current & flux set up in core is also sinusoidal.

$$\phi = \phi_m \sin \omega t \qquad \omega = 2\pi f$$

ϕ_m - peak value of flux

f - sinusoidal frequency

As per law of electromagnetic induction

$$e = -N \frac{d\phi}{dt} \qquad = -N \phi_m \frac{d \sin\omega t}{dt}$$

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

$$= -N \phi_m \omega \cos\omega t \qquad \cos\theta = \sin(\pi/2 - \theta)$$

$$= N \phi_m \omega \cos(-\omega t) \qquad -\cos\theta = \sin(\theta - \pi/2)$$

$$= N \phi_m \omega \sin(\omega t - \pi/2)$$

$$\therefore e = 2\pi f N \phi_m \sin(\omega t - \pi/2$$

Peak value of induced emf $E \quad = 2\pi f N \phi_m$

Rms value of induced emf

$$E = \frac{E_m}{\sqrt{2}} = \frac{2\pi f N \phi_m}{\sqrt{2}} = 4.44 f \phi_m N.$$

$$\boxed{\therefore E = 4.44 f \phi_m N}$$

$\therefore$ Emf of transformer increases with increase in frequency, & Number of turns & flux.

6b.

Torque equation.

$$E_b = \frac{P \phi N Z}{60 A} \ (V)$$

ङ $V = E_b + I_a R_a$

multiply with I_a

$$V I_a = E_b I_a + I_a^2 R_a \qquad \Rightarrow \text{Input} = \text{output} + \text{losses}.$$

$V I_a$ - Electrical power i/p to motor.

$E_b I_a$ - Electrical equivalent of power developed

$I_a^2 R_a$ - Copper loss in armature

$\therefore$ mechanical power developed by armature

$$P_m = T * W \ (W)$$

Where T is torque developed by armature (Nm)

$$\omega = \frac{2\pi N}{60} \qquad N\text{- speed (rpm)}$$

$$\therefore \ P \ E_b I_a = T * \omega$$

$$\frac{E_b I_a}{\omega} = T$$

$$T = \frac{P \phi N Z}{60 A} * I_a * \frac{60}{2\pi N}$$

$$= \frac{1}{2\pi} P \phi Z \left(\frac{I_a}{A}\right)$$

$$\boxed{T = 0.159 P \phi Z \frac{I_a}{A}} \ N\text{-}m$$

P, A & Z are constants

so $T \propto \phi I_a$

55

6c.

Sol:— Given $V_1 = 11{,}000\,V$

$V_2 = 415\,V$

$f = 50\,Hz$

$N_2 = 80$

$V_1 I_1 = 250\,kVA.$

i) $V_1 I_1 = 250 \times 10^3.$

$I_1 = \dfrac{250 \times 10^3}{11{,}000}$

$\hookrightarrow = 22.72\,A$

$V_2 I_2 = 250 \times 10^3$

$I_2 = \dfrac{250 \times 10^3}{415}$

$\hookrightarrow = 602.41\,A$

ii) $\dfrac{V_2}{V_1} = \dfrac{I_1}{I_2} = \dfrac{N_2}{N_1}$

$\cancel{\dfrac{11{,}000}{415} = \dfrac{80}{N_1}}$

$\cancel{N_1 = \dfrac{80 \times 415}{11{,}000}} = 3.$

$\dfrac{415}{11{,}000} = \dfrac{80}{N_1}$

$N_1 = \dfrac{80 \times 11{,}000}{415}$

$\hookrightarrow = 2121$ Turns

iii) $E_2 = 4.44\,\phi_m f N_2$

$415 = 4.44\,\phi_m \times 50 \times 80$

$\phi_m = \dfrac{415}{4.44 \times 50 \times 80}$

$= 0.023\,wb.$

$\phi_m = 23.36\,mwb.$

iv) $\dfrac{E_2}{N_2} = \dfrac{415}{80} = 5.19\,V$

Module-4

7 a. Explain the concept of rotating magnetic field in case of stator field a 3-phase induction machine with a neat diagram. (08 Marks)

b. Define slip of an induction motor and derive expression for the frequency of rotor currents. (06 Marks)

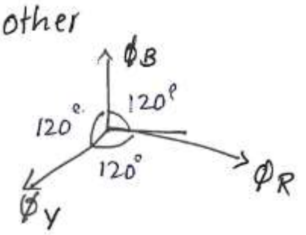
c. Describe the main parts of synchronous generator with neat sketches. (06 Marks)

Rotating magnetic field

→ The winding used are 3-ϕ windings (RYB) they are wound such that they are 120° apart from each other [electrically]

→ Now if we provide supply to these windings which is 3-ϕ it produces a resultant magnetic flux which rotates in space.

→ if the phase sequence is RYB the flux produced are ϕ_R ϕ_Y ϕ_B which are 120° displaced from each other



let the flux be represented with following equations

$\phi_R = \phi_m \sin \omega t$

$\phi_Y = \phi_m \sin(\omega t - 120°)$ $\phi_B = \phi_m \sin(\omega t - 240)$

7I

a.

The total or resultant flux ϕ_T is vector sum of

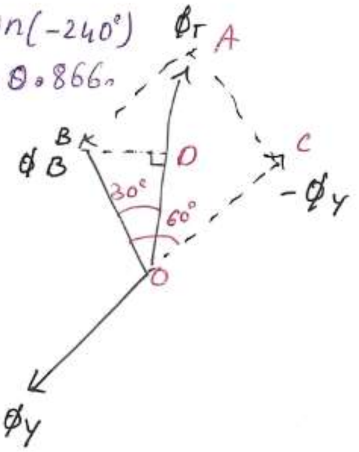
ϕ_R ϕ_Y & ϕ_B

Case i) $\omega t = 0^\circ = \theta$

$\therefore \phi_R = 0$

$\phi_Y = \phi_m \sin(-120^\circ)$ $\quad \phi_B = \phi_m \sin(-240^\circ)$

$\phi_Y = -0.866\phi_m$ $\quad \phi_B = +\phi_m\, 0.866$



So, from vector diagram

$\theta = \omega t = 0^\circ$

BD is $\perp^{lar}$ to ϕ_T

$OD = OA = \frac{\phi_T}{2}$

$\angle BOD = 30^\circ$ $\quad \cos 30^\circ = \frac{BD}{OB} = \frac{\phi_T/2}{\phi_B} = \frac{\phi_T}{2(0.866\phi_m)}$

$$0.866 = \frac{\phi_T}{2(0.866\phi_m)}$$

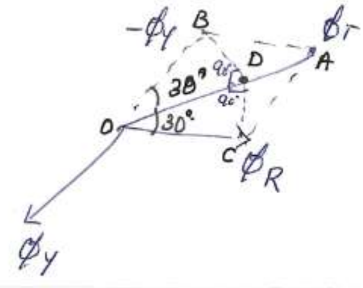
$$\boxed{\phi_T = 1.5\,\phi_m}$$

So, $\phi_T = 1.5\,\phi_m$ is magnitude & it is vertically upwards for $\theta = 0^\circ$

case-2 $\quad \theta = 60^\circ$

$\phi_R = \phi_m \sin(60^\circ)$ $\quad \phi_Y = \phi_m \sin(60-120^\circ)$ $\quad \phi_B = \phi_m \sin(60-240)$

$\phi_R = 0.866\phi_m$ $\quad \phi_Y = -0.866\phi_m$ $\quad \phi_B = 0^\circ$



From the diagram

$OD = DA = \frac{\phi_T}{2}$

$\cos 30^\circ = \frac{BD}{OB} = \frac{\phi_T/2}{-\phi_Y} = \frac{\phi_T}{2(0.866\phi_m)}$

$(0.866)(2)(0.866\phi_m) = \phi_T$ $\quad \boxed{\phi_T = 1.5\phi_m}$

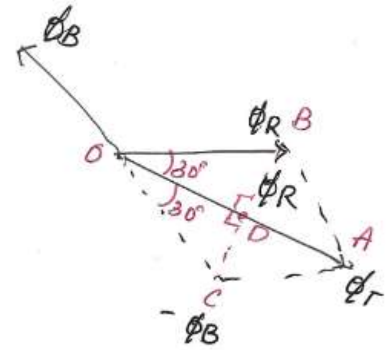
∴ The magnitude of ϕ_T is same i.e $1.5\,\phi_m$ but it is rotated through $60°$ in space in Clock wise direction.

Case -iii) $\theta = 120°$

$\phi_R = \phi_m \sin(120°)$ $\quad \phi_Y = \phi_m \sin(120-120)$ $\quad \phi_B = \phi_m \sin(120-240)$

$\phi_R = 0.866\,\phi_m$ $\quad \phi_Y = 0$ $\quad \phi_B = -0.866\,\phi_m$

from vector diagram



$OD = OA = \dfrac{\phi_T}{2}$

$\cos 30° = \dfrac{OD}{OB} = \dfrac{\phi_T/2}{0.866\,\phi_m}$

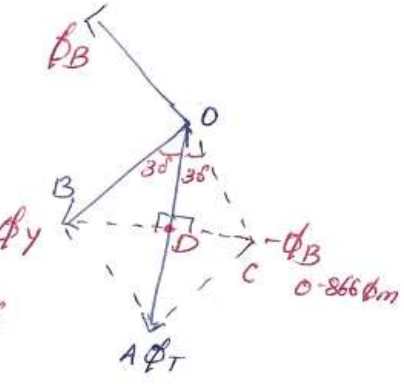
$\boxed{\phi_T = 1.5\,\phi_m}$

∴ The magnitute of ϕ_T is same as $1.5\,\phi_m$ but is further rotated through $60°$ in clockwise direction.

Case -IV. $\theta = 180°$

$\phi_R = 0$ $\quad \phi_Y = \phi_m \sin(+60°) = +0.866\,\phi_m$ $\quad \phi_B = \phi_m \sin(-60) = -0.866\,\phi_m$

So, from vector diagram



from vector diagram

$\phi_T = 1.5\,\phi_m$

But again it has rotated by 60° in Clockwise direction.

So, we can conclude that the resultant flux is constant value $\phi_T = 1.5\,\phi_m$

- And the resultant flux rotates around the stator at a constant synchronous speed given by $N_s = \frac{120f}{P}$.

Slip of I.M.

Slip of I.m. is defined as difference b/w N_s & N and as function of N_s so

$$\boxed{\frac{N_s - N}{N_s} = S}$$

$$\boxed{\%S = \frac{N_s - N}{N_s} \times 100}$$

$$S = \frac{N_s - N}{N_s}$$

$$N_s - N = SN_s$$

$$N = N_s - SN_s$$

$$\boxed{N = N_s(1-s)}$$

Note

So, @ starting as motor is rest $N = 0$

$\therefore$ $\boxed{S=1}$ @ starting.

Effect of slip on Rotor frequency:-

→ Speed of rotating magnetic field is $N_s = \frac{120f}{P}$

→ At start $s=1$ (refer note above) $N=0$ (stationary rotor) so max. relative speed with respect to RMF. So, max. emf will get induced in the rotor at start.

→ The frequency of this emf @ start is same as that of supply frequency

→ As motor actually rotates with speed N
So, relative speed is $N_s - N$.

→ As the Induced emf in rotor depends upon rate of change of flux i.e. relative speed ($N_s - N$) so its frequecy also decreases.

→ So, $N_s - N = \frac{120 f_r}{P}$ P - Rotor & stator slots

÷ by N_s on both sides

$$\frac{N_s - N}{N_s} = \frac{120 f_r}{P N_s}$$

$$s = \frac{120 f_r}{P\left(\frac{120 f}{P}\right)}$$

$$s = \frac{f_r}{f}$$

$$\boxed{f_r = sf}$$

* So, rotor frequency is slip times the supply frequency

c.

BASIC PRINCIPLE & CONSTRUCTION

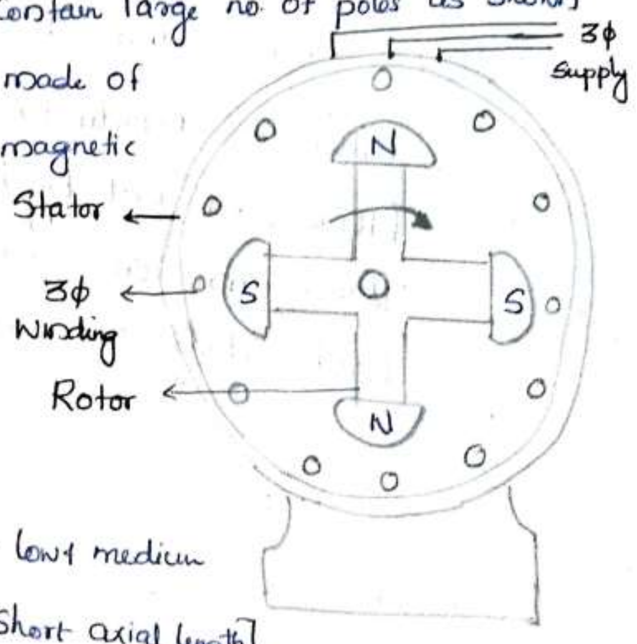
AC generator / Alternators operates on the same fundamental principle of electromagnetic induction as DC generator. There also consist of an armature winding and a magnetic field. Difference between AC & DC generators are that in DC generator, the armature rotates and field system is stationary, but arrangment of alternator is just reverse. In that armature winding wounded on a Stationary element called Stator and field winding on a rotating element called rotor.

Stator :- It Consist of a cast-iron frame which supports the laminated armature core having Slots on its inner periphery of housing the 3 phase winding.

Rotor → Salient [Projecting] pole type
→ Non salient [Smooth cylindrical type]

1) Salient pole type

It is like flywheel Contain large no. of poles as shown That magnetic wheel is made of cast iron/Steel of good magnetic quality. The magnetic pole are excited by small dc generator mounted on the shaft of alternator it self.

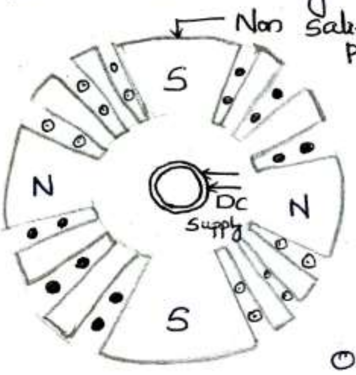


- Such rotor are used for low + medium Speed [Large diameter + Short axial length]

Eg:- Alternator driven by diesel engine + gas turbines

2) Smooth cylindrical type

It Consist of Smooth solid forged-steel cylinder having a number of Slot milled out intervals along the outer periphery for accomodating field coil as shown.



- 2 or 4 regions corresponding to the central polar areas are left unslotted.
- Central polar areas are surrounded by the field winding placed in slot
- Poles are non salient ie they do not project out from the surface of the rotor.

- which run at very high speed [Small diameter & very long axial length]

Eg:- Speed turbine.

8 a. A 3 phase induction motor with 4 poles is supplied from an alternator having 6 poles and running at 1000rpm. Calculate synchronous speed of the induction motor, its speed when slip is 0.04 and frequency of the rotor emf when speed is 600rpm. (08 Marks)

b. Derive the emf equation of a synchronous generator. (06 Marks)

c. A 24 pole turbo alternator has a star connected armature winding with 144 slots and 10 conductors per slot. It is driven by a low speed Kaplan turbine at a speed of 250rpm. The winding has full pitched coils with a distribution factor of 0.966. The flux per pole is 67.3mWb. Determine: i) Frequency and magnitude of the line voltage ii) Output KVA of the machine if the total current in each phase is 50A. (06 Marks)

3a. Given

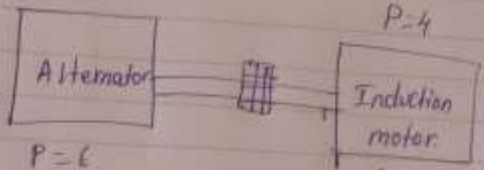
Im

$P = 4$

Alternator

$P = 6$

$N_s = 1000$ rpm



$P = 6$

$N_s = 1000$ rpm

$$N_s = \frac{120f}{P}$$

$$1000 = \frac{120(f)}{6}$$

$$f = 50 \text{ HZ}$$

$$N = \frac{120f}{P}$$

$$= \frac{120(50)}{4}$$

$$\boxed{N = 1500 \text{ rpm}}$$

$$S = 0.04$$

$$0.04 = \frac{N_s - N}{N_s}$$

$$0.04 = \frac{1500 - N}{1500}$$

$$\boxed{N = 1440 \text{ rpm}}$$

$$f_r = sf$$

$$f_r = 0.6(50)$$

$$\boxed{f_r = 30 \text{ Hz}}$$

$$S = \frac{N_s - N}{N_s} \qquad \frac{1500 - 600}{1500}$$

$$\boxed{S = 0.6}$$

b.

Induced EMF equation

Let Z = No. of Conductors or coil side in series/phase

$= 2T$ [Where T is no. of Coil turns + one turn has 2 sides]

P = No. of rotor poles

f = frequency of induced emf

ϕ = flux/pole [Wb]

N - Speed of rotor in rpm

In one revolution of the rotor [ie in $\frac{60}{N}$ Second] each stator Conductor is cut by a flux of ϕP webbers.

$$\text{So} \quad d\phi = \phi P \quad \& \quad dt = \frac{60}{N}$$

ie average emf induced per Conductor $= \frac{d\phi}{dt}$

$$= \frac{\phi P}{60/N} = \frac{\phi P N}{60} \text{ volt}$$

We know that $f = \frac{PN}{120}$ or $N = \frac{120f}{P}$

$\therefore$ average emf per Conductor $= \frac{\phi P}{60} \times \frac{120f}{P} = \underline{\underline{2f\phi}}$ volt

If there are z Conductor in series/phase, then

average emf / phase $= 2f\phi z = 4\phi f T$ volt

RMS Value of emf / phase $= 1.11 \times 4\phi f T = 4.44\phi f T$ Volt

In practice coils are short pitched and the winding is distributed. Hence the rms value of induced emf by pitch factor k_p & distribution factor k_d to give

$$E = 4.44 \ \phi f T \times k_d \times k_p$$

$$\boxed{E = 4.44 \ \phi f T k_d k_p}$$

Module-5

9. (a) What is electric power supply system? Draw a single line diagram of typical a.c. supply scheme.

Ans:

→ Electrical Energy fed at the Consumer end is generated in Generating sites which usually are away from Consumer (b/c of availability of natural resources like water Coal etc)

→ So This power Gets generated at a particular place Called - Generation sector

→ To reach the Consumer it has to travel a certain distance which is called as - Transmission sector.

→ Finaly the electricity is distributed among the Consumers (generally low voltage 415V/230V) such network is called - Distribution Network.

→ so basically three sector division.

→ As the Generation happen few thousands of km away from Consumer, and the range of Voltage generated is in 11KV.

→ The major loss that is going to occur is Copper loss Which is I^2R loss, So from this we got to Know I should be less, So to keep power constant

to reduce I means ↑ Voltage

→ As we Cannot increase generated Voltage b/c it leads to problems in machine. We will increase transmission Voltage. Using a transformer (may be to 33KV, 66KV or 110KV)

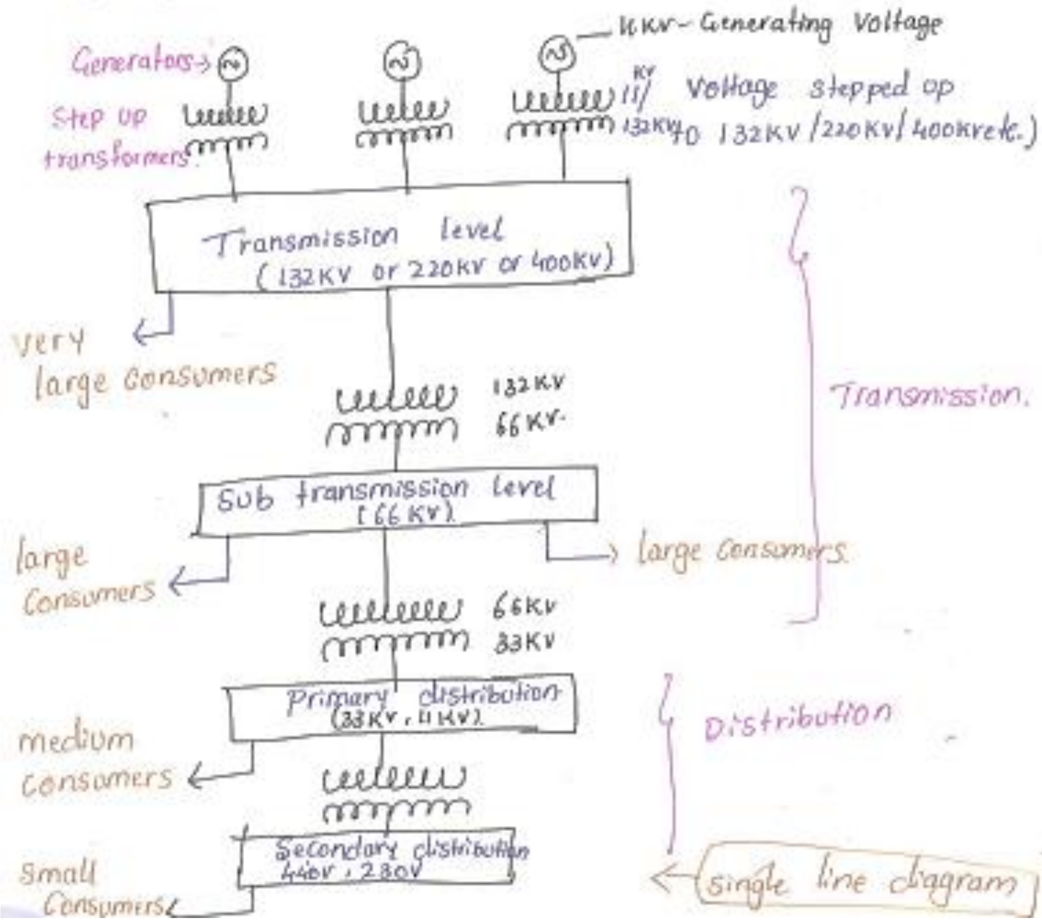
→ So This high voltage is transmitted from Generating site through transmission Network to Consumer.

→ There are different set of consumers i) large scale
ii) small scale

→ large scale can directly take supply from transmission Network. This is known as primary Distribution

→ For small scale ~~supply~~ consumers, supply has to be reduced to low voltage (In range of 415V- for 3-phase supply, 230V- for single phase), done by a transformer called distribution transformer.

So, this whole electric power supply system has a single line diagram as shown below.



single line diagram

2

(b) What is the necessity of earthing? Explain plate earthing.

Ans:

Earthing

It is also termed as Grounding.

It is a system which connects specific parts of an electric system to ground

Definition:- The process in which the instantaneous discharge of electrical energy takes place by transferring charges directly to the earth through low resistance wire.

Need for Earthing.

-> Done to ensure safety of persona and devices

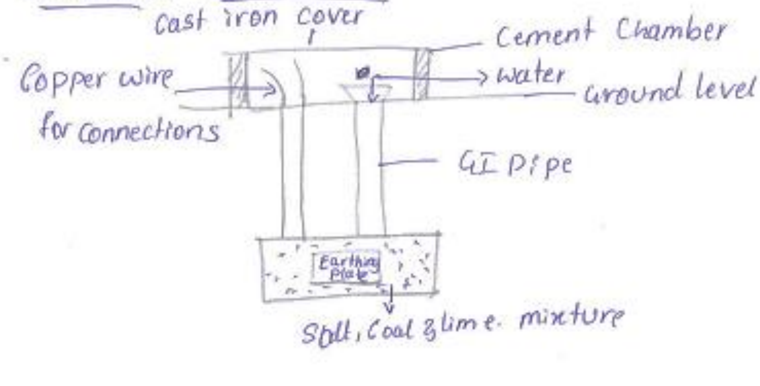
-> protect equipments from damage due to high current flow.

It is done by connecting the non-current carrying part of equipment or neutral of supply to the Ground.

Plate Earthing:- Here A plate made of either Copper or Galvanized iron is buried vertically into the earth around 10ft from Ground level.

-> To maintain moister Condition, put Coal, lime mixture around the earth plate.

Schematic representation



(c) Explain the working principle of Fuse and MCB.

Ans:

Fuse :-

The working principle of fuse is heating effect of electric current.

Heat is produced. When current flows in the wire. When heat production is more due to excessive flow of current, it melts the fuse which normally has a low melting point, therby preventing any damage to electrical appliances.

The thickness of fuse wire is determined based on the amount of current it has to withstand. i,e the amount of current the components can handle without self damage.

Material used for fuse → Alloy of tin & lead. it has high resistivity and low melting point.

Once the fuse melts it has to be replaced.

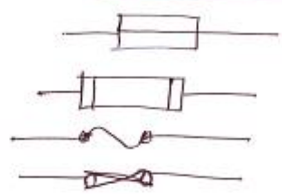
Other elements used to make fuse - Zinc, copper, Aluminium Silver.

A fuse acts as a circuit breaker and breaks the circuit in case of any fault occurs in the circuit

Functions of Electric fuse

1. Restricting the flow of current.
2. Preventing the wires from catching fires or breakdown
3. Terminating the Current from the circuit if a short.
4. prevention from blackouts.

Symbols of Fuse



ii) miniature Circuit breaker. (MCB)

→ It is automatically operated electrical switch used to protect ~~circuit from high voltages~~. low voltage electrical circuit components getting damage due to flow of excess current due to overload or short circuit.

→ General rating of MCB is around 125A
While fuse - 5, 10, 15A.

→ MCB has many advantages compared to fuse.

1. MCB is much reliable in detection of abnormal conditions, more sensitive to change in current.
2. MCB has ON & Off positions. so if it is tripped that can be easily identified. While fuse has to be Opened ~~fuse~~ with fuse grip and check for blow of fuse wire.

3. Restoration of circuit supply is possible quickly in MCB but fuse has to be replaced once its trips. MCB can be reused.

4. MCB can be Controlled remotely while fuse cannot.

Disadvantage is MCB is costly compared to fuse

Working Principle.

MCB works on ~~ob~~ two different Concepts

1) thermal effect of over current
2) Electromagnetic effect of over current.

→ MCB has a bimetallic strip whenever continuous over current flows through MCB, the strip gets heated and deflects by bending.

→ The bimetallic strip will operate the mechanical latch when it bends at that causes the MCB contacts to open.

→ While during short circuit conditions sudden raise in current causes the plunger associated with tripping coil or solenoid of MCB, to displace electro-mechanically.

→ The plunger causes immediate release of trip lever causing the immediate release of latch mechanism thus opening the circuit breaker.

10. (a) Explain components of low voltage distribution system with neat sketches.

Ans:

Components of Distribution system.

i) Distribution ~~subs~~ substation - It is a sub-station (transformer) which transfers power from transmission system to distribution system.

ii) Feeder - Conductor which connects distribution substation to ~~power where~~ area where power is distributed.

iii) Distribution transfomer :- It is a step down transformer in which it can be Y or Δ on primary and secondary.
Output voltage is 440v 3phase
230V - 1 phase

iv) Distributor :- Conductor from which tappings are taken to supply consumers.

v) Service mains - Small cable which connects distributor to consumer's meter.

8 m.

Low voltage distribution system (440V & 230V) for domestic commercial and small scale.

Classification of Distribution system.

-> Based on nature of current - DC distribution system
AC distribution system

-> Based on Type of construction - over head system
underground system

-> Based on scheme of Connection. - Radial System.
Ring main system
Inter-connected system

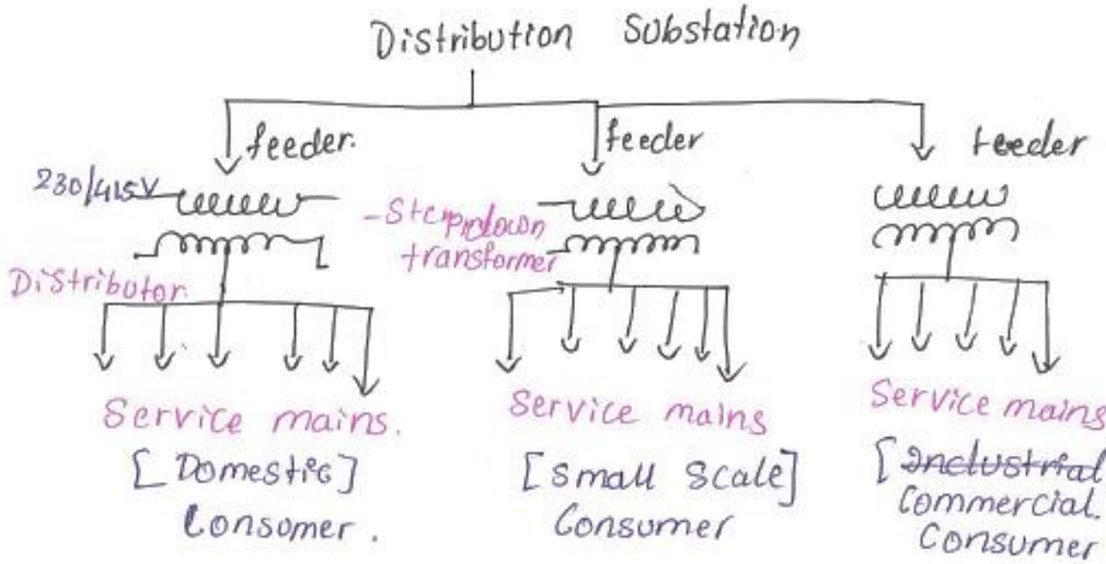
low voltage(LV) distribution system operates at voltage levels those which are directly utilised without any further reduction.

-> The voltage level of LV Distribution system is typically equal to mains voltage of electrical appliances.

The LV system is typically a 4wire-3-phase system.

-> loads connected to such N/w. are either star or Delta.

Block diagram



(b) A consumer uses a 10kW geyser, a 6kW electric furnace and five 100W bulbs for 8 hours. How many units of electrical energy have been used? Define an electrical energy unit.

Ans:

Appliances :-

i) Geyser = 10 KW × 1 (hour) × 30 (days)
= 300 KWh.

ii) Electric furnace = 6 KW × 2 (hours) × 30 (days)
= 360 KWh.

(iii) 5 Bulbs = 5× 0·1 KW × 8 (hours) × 30 (days)
= 120 KWh

∴ Total Units in a month = 300 + 360 + 120
= 780 KWh

So, 780 Units.

[Here, it is assumed that geyser and Electric furnace is on for 1 hour and 2 hours in a day respectively].

Electricity bill

Power rating of house hold appliances.

→ Power rating of appliances will usually be mentioned in watts.

→ The electricity bill is calculated in terms of unit:

Unit :- One KWh is considered as unit

i,e one Kilo watt hour = ~~1hour~~ 1 unit.

Daily KWh = (Wattage X hours in a day (24))/1000.

monthly Kwh = (wattage × hours in a month (30×24)) /1000

Yearly Kwh = wattage X hours in year (365×24)

(c) What do you mean by electric shock? Write a short note on precautions against an electric shock.

Ans:

Electric shock

→ It is Injury to body due to direct Contact with a high-voltage source.

→ It is also sudden discharge of electricity through a part of the body.

Effects of electrical shock.

- Affects breathing, heart, brain, nerves and muscles.
- Rearly death depending on type & severity of supply.

type → AC or DC

severity → amount of current, Voltage, frequency

There are four types of injuries due to electrical

Shock - flash
flame
lightning
burns.

So, to avoid electric shock and for person and equipment safety we do Earthing.

Precautions against electric shock

1. Never use a damaged extension cord.
2. Donot used defective electrical device
3. Pull on plug not on the cable to unplug an electrical wire

4. Before Changing the light bulb switch the light off.

5. Avoid water at all the times when working with electricity, Kepps hands dry not wet when ~~to~~ using a electric device.

6. Used insulated tools [like skrew drivers,]

7. use gloves & shoes while doing any maintanence work.

8. Always Check GFCI's (Ground fault circuit interrupter)

9. Turn off the supply to the device while any maintanence work is ~~happ~~ done.