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Unit - 1

Basic Definitions →

1) Circuit : An Electric Circuit is a closed path Component of active and Elements to which Current Can flow.

2) Electric Network ⇒ A Combination of various Electric Elements Connected in any manner whatever is Called Electric network.

3) Excitation ⇒ The input to a network is reffered to as Excitation that is the Excitation represents Energy Supply to the network form an External Source.

4) Response ⇒ The output of the network is Called response that is response represents the Utilization of Energy Supply by the Excitation.

5) Active Element ⇒ Any Energy Source that is a Voltage or a Current Source is Said to be an active Element. Which are Energy producing Element
Eg. Current & Voltage Source. Element

6) Passive Element : An Element Which is not an Energy Source is a passive Element. A Passive Element transform or a Stored Energy Either in the form of magnetic field or Electric field Eg. Capacitor and Inductor

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7) Bilateral and Unilateral Elements ⇒
Bilateral Elements are those which transmite Equally in Either direction. Eg Transmission line.
On the Other hand, Unilateral Element Conduct only in one direction Eg Diode

8) Linear and Non Linear Elements ⇒
These are Elements ~~in~~ in whose Case response is directly proportional to the Excitation that is they follow OHM's Law. this Element are Called as linear Elements While non-linear Elements are those Elements Where the Output is independent of the input & they also do not follow Ohm's law.

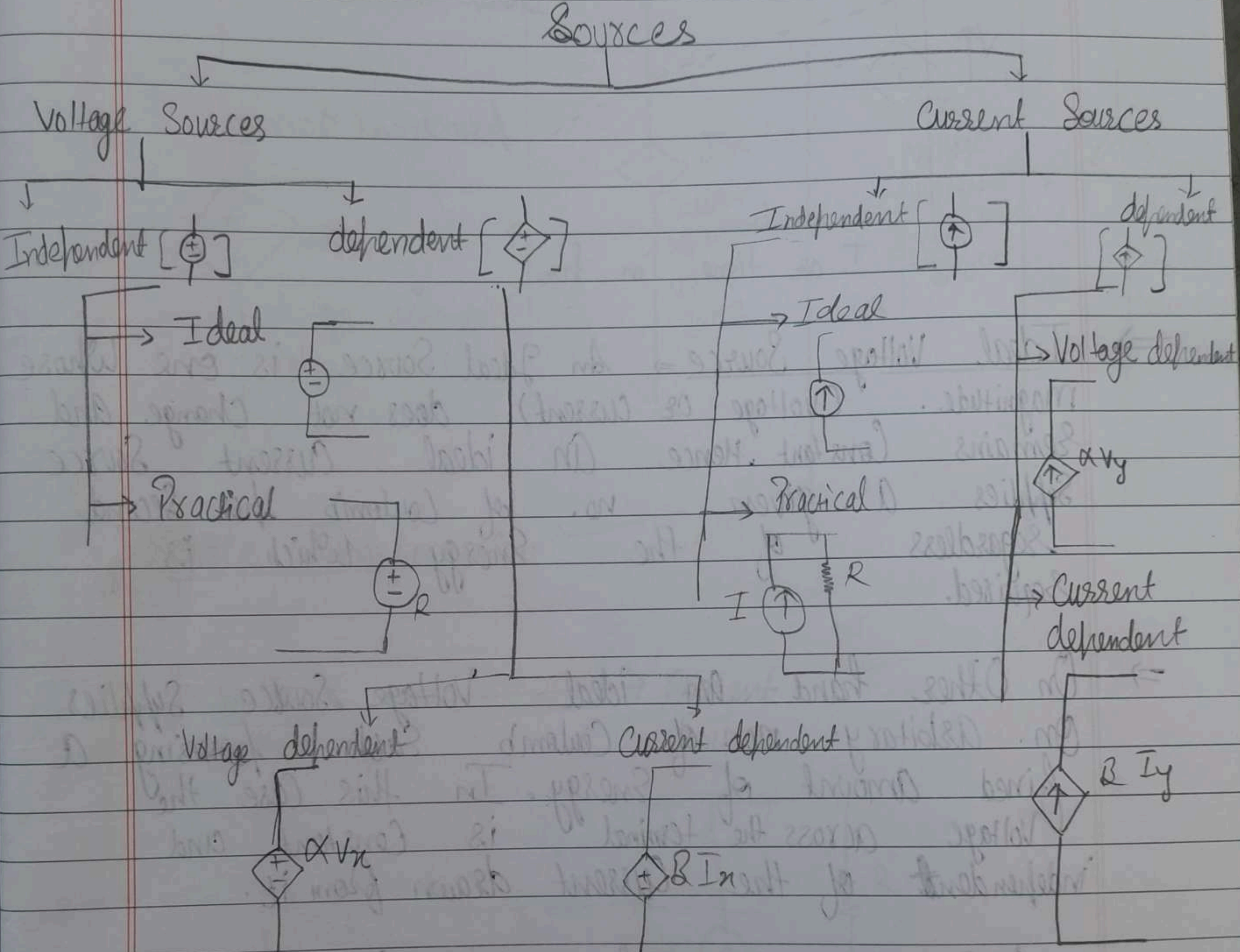
Eg. of Linear Elements : Resistance

Eg. of Non-Linear Elements : Vaccum tubes.

9) Lumped and distributed Parameter ⇒ Physically, Separate Elements Such as resistor inductor and Capacitor are Known as Lumped Elements
While the distributed elements are those Elements which are not Separated for analytics purpose

· An Example of a Circuit with distributed Elements is a transmission line.
Where the Elements in which R, L, G, C are distributed throughout the Whole length of the line.

Classification of Sources :



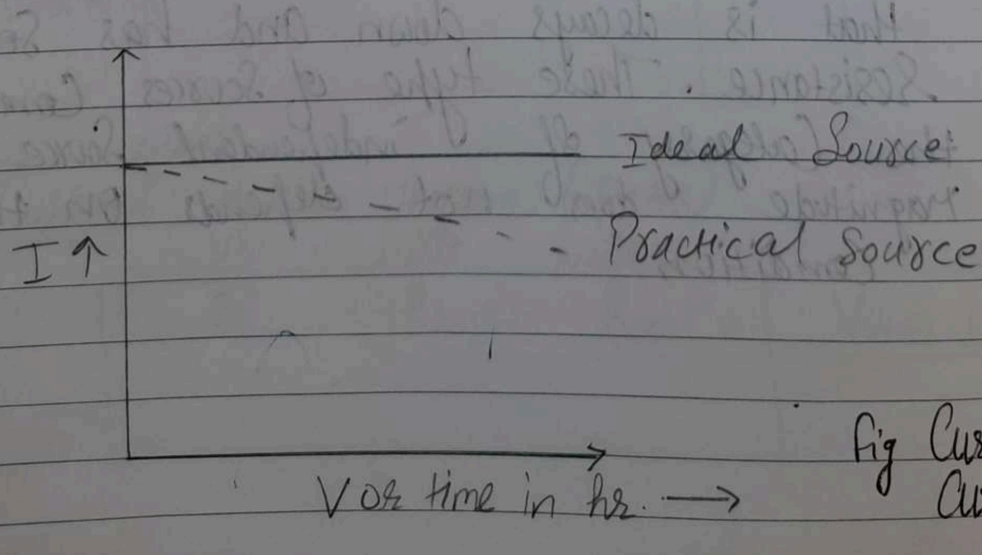


Fig Current Source Curve

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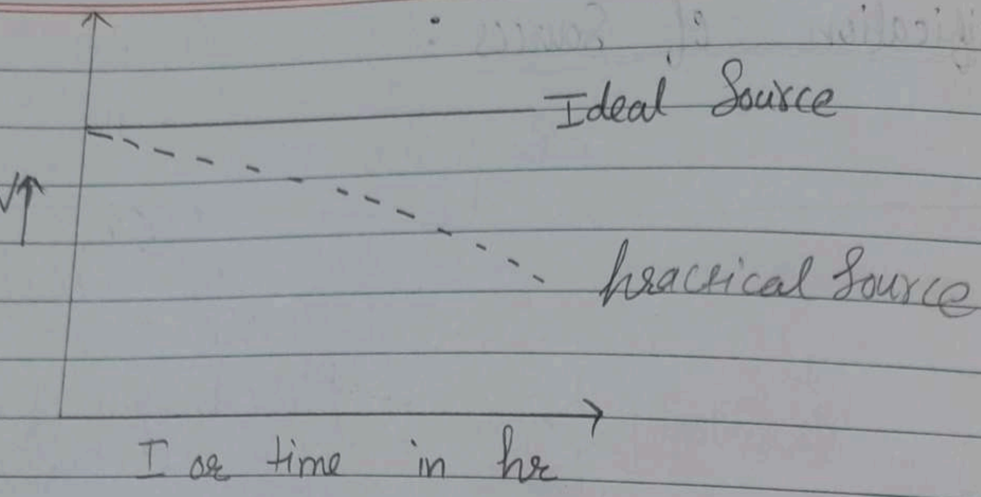
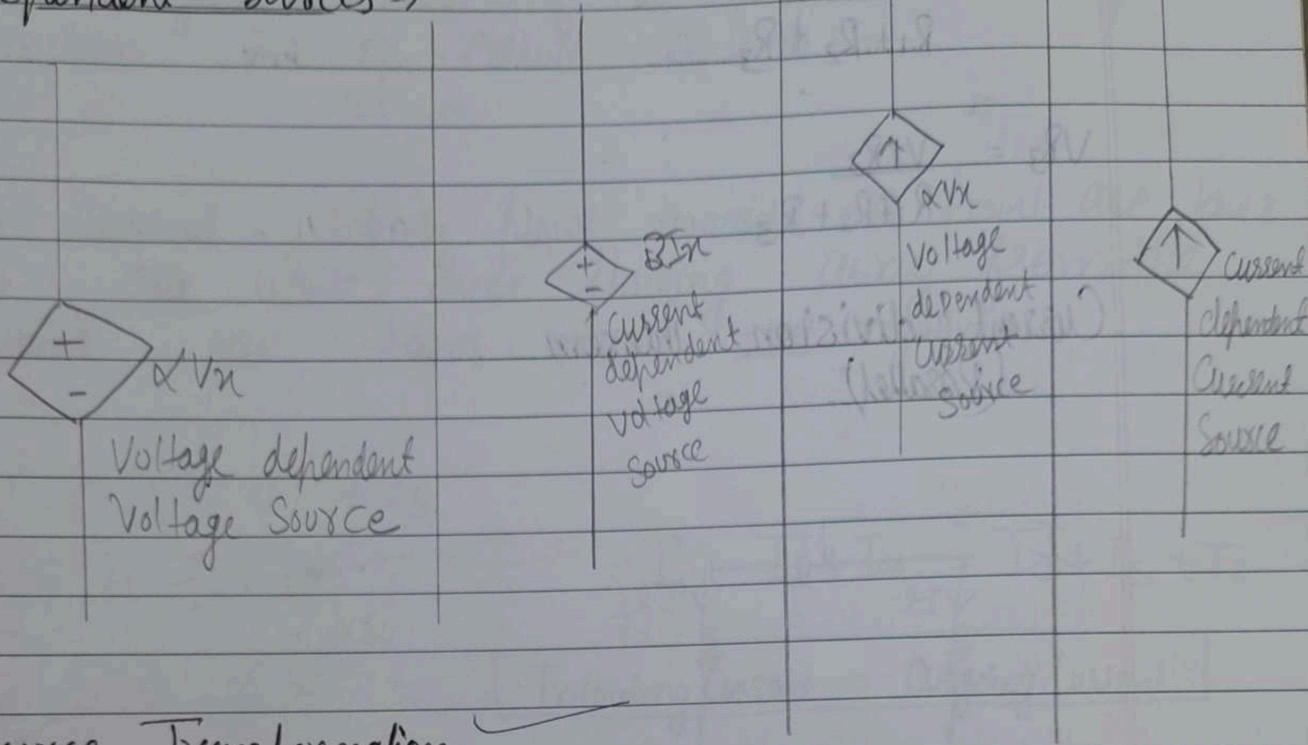


⇒ Ideal Voltage Source ⇒ An Ideal Source is one Whose magnitude. (Voltage or current) does not change and remains constant. Hence an ideal current source supplies a given no. of Coulomb per second regardless of the energy which is required.

⇒ On other hand an ideal Voltage Source supplies an arbitary no. of Coulomb each possesing a fixed amount of energy. In this case the voltage across the terminal is constant and independent of the current drawn from it.

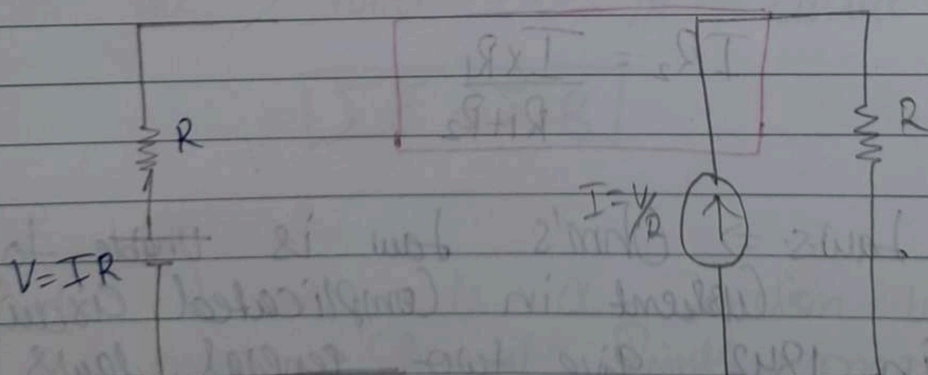
A Practical Source has the characteristics of dropping that is decays down and has some internal resistance. These type of sources come under the category of independent source i.e. their magnitude does not depends on the circuit condition

Dependent Sources =>

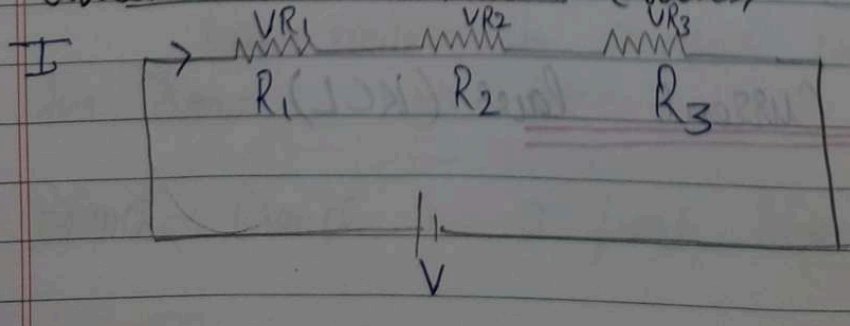


Source Transformation

Voltage Source ⟶ Current Source



~~Current~~ Voltage division theorem: (series)



$$V_{R_1} = \frac{V \times R_1}{R_1 + R_2 + R_3}$$

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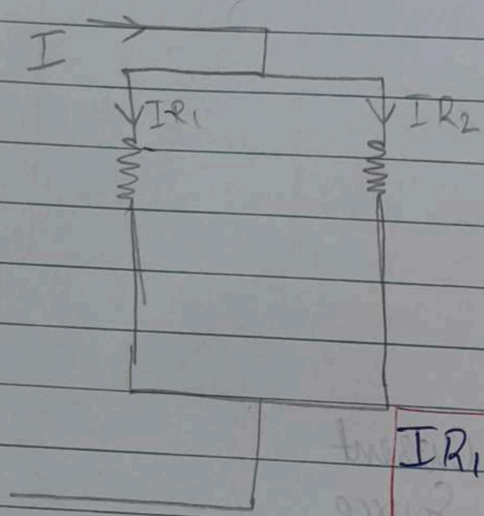
$$V_{R_2} = \frac{V \times R_2}{R_1 + R_2 + R_3}$$

$$V_{R_3} = \frac{V \times R_3}{R_1 + R_2 + R_3}$$

Current division Theorem
(Parallel)



$$\boxed{I_{R_1} = \frac{I \times R_2}{R_1 + R_2}}$$

$$\boxed{I_{R_2} = \frac{I \times R_1}{R_1 + R_2}}$$

Kirchioff's Laws ⇒ Ohm's Law is Unable to give Current in Complicated Circuit. Kirchioff in 1842 give two general laws Which are Extremely Useful in ~~Eletric~~ Electrical Circuits. These are

(1) Kirchioff Current law (KCL)

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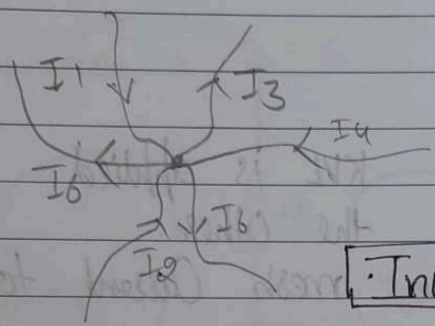
⇒ The algebric Sum of the Current at any Junction in a Circuit is zero
$\Sigma i = 0$

The current which flows towards a point are takes as +ve while those flowing away from the point are takes as -ve (negative)



$$I_1 + I_2 + I_4 = I_3 + I_5 + I_6$$

$\boxed{\text{Incoming Current} = \text{Outgoing Current}}$

Kirchioff Voltage Law ⇒ If any Closed Circuit the algebric Sum of the products of the current and resistance in any closed Circuit of each part of the circuit is the total EMF in circuit

$$\boxed{\Sigma E \Rightarrow \Sigma IR}$$

Node : A node is a Junction where two or more Elemental Points meet.

Path : Path is the root through Elements from one node to another without going through the Same node twice.

Branch : Branch is a part b/w ō two adjoining nodes

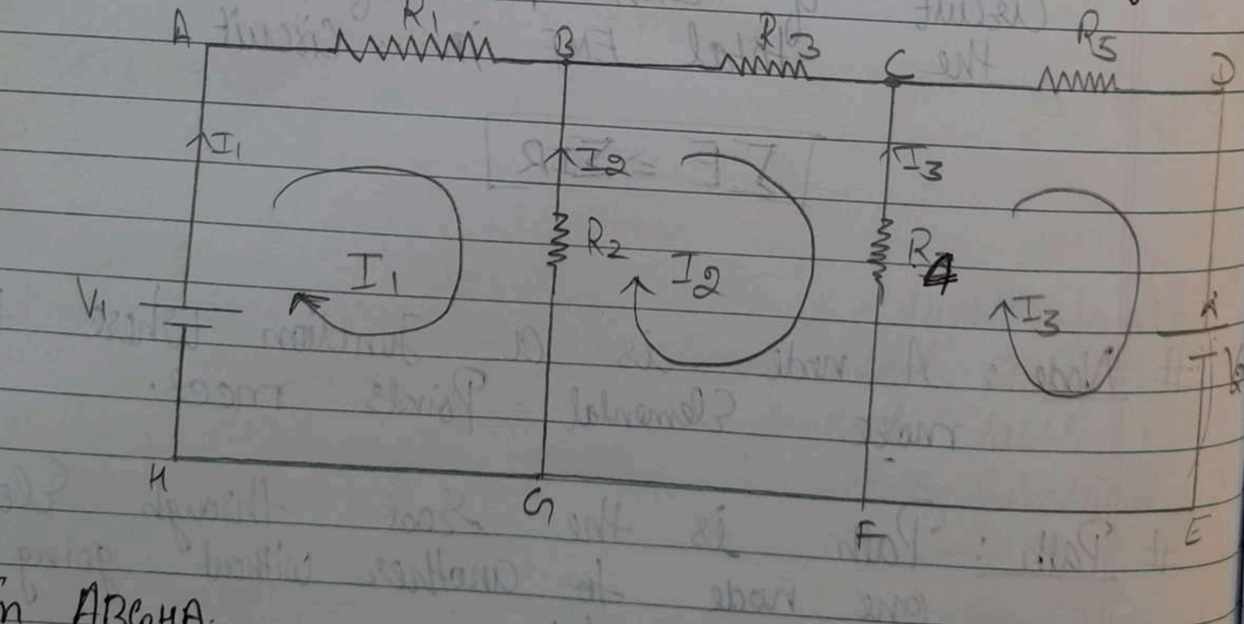
Loop : Loop is a Closed path where the root Ends upon the Starting node.

Mesh: Mesh is a loop that doesnot Contain any Other loop in it.

Mesh Analysis:

Assumptions -

1) The mesh in Which KVL is applied is at a higher potential than the Other.
2) Always assume the mesh Current to be in Clockwise direction.
(3) All the Sources must be a Voltage Source If any practical current Source is there it means to Convert into its Equivalent voltage Source.



In ABGHA.

$$V_1 = I_1R_1 + R_2(I_1 - I_2) \quad -(1)$$

In BCFGB

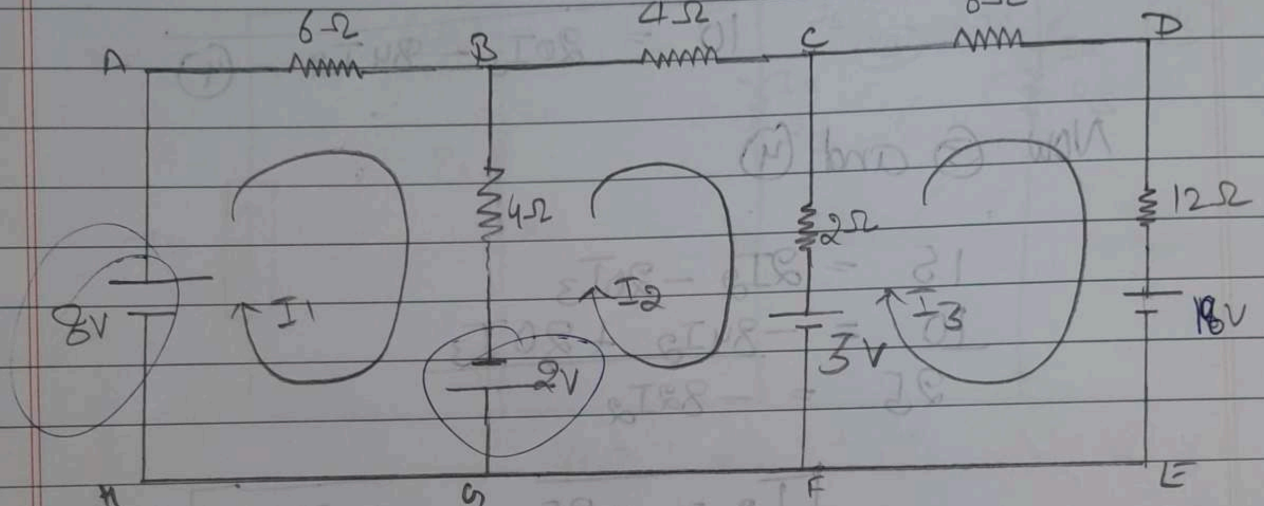
$$0 = R_3 I_3 + R_4 (I_2 - I_3) + R_2 (I_2 - I_1) \quad -(2)$$

In CDEFG

$$-V_2 = R_5 I_3 + R_4 (I_3 - I_2) \quad -(3)$$

$I_1, I_2, I_3 = ?$

Eg



Solⁿ In loop ABGHA

$$8+2 = 6I_1 + 4(I_1 - I_2)$$
$$10 = 6I_1 + 4I_1 - 4I_2$$
$$10 = 10I_1 - 4I_2 \quad —(1)$$

In loop BCFGB

$$-2-3 = 4(I_2 - I_1) + 4I_2 + 2(I_2 - I_3)$$
$$-5 = 10I_2 - 4I_1 - 2I_3 \quad -(2)$$
$$-5 = 4I_1 - 10I_2 + 2I_3$$

In loop CDEFC =

$$3-18 = 6I_3 + 12I_3 + 2(I_3 - I_2)$$
$$-15 = 20I_3 - 2I_2$$
$$15 = 2I_2 - 20I_3 \quad —(3)$$

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2)

By Solving equ^n ① - ②

$$4(10 = 10I_1 - 4I_2)$$
$$10(5 = 4I_1 - 110I_2 + 2I_3)$$

$$40 = 40I_1 - 16I_2$$
$$-\underline{50} = \underline{\cancel{2}40I_1 - 100I_2 + 20I_3}$$
$$\quad\; - \quad\;\; + \quad\;\; -$$

$$10 = 20I_3 - 84I_2 \quad - ④$$

Now ③ and ④

$$15 = 2I_2 - 20I_3$$
$$\underline{10} = \underline{-84I_2 + 20I_3}$$
$$25 = -82I_2$$

$$\boxed{I_2 = \frac{-25}{82} = -0.3049} \text{ Ans.}$$

from equ^n 1^st $\boxed{\begin{array}{l} I_1 = 0.878 \\ I_3 = -0.7805 \end{array}}$ Ans

Nodal Analysis ⇒ A node is a terminal or Collection of more than two Elements. In Nodal analysis, KCL is applicable.

Assumption.

1) All the Sources must be Current Sources
If any practical Voltage Source is there it has to be Controlled into its Equivalent

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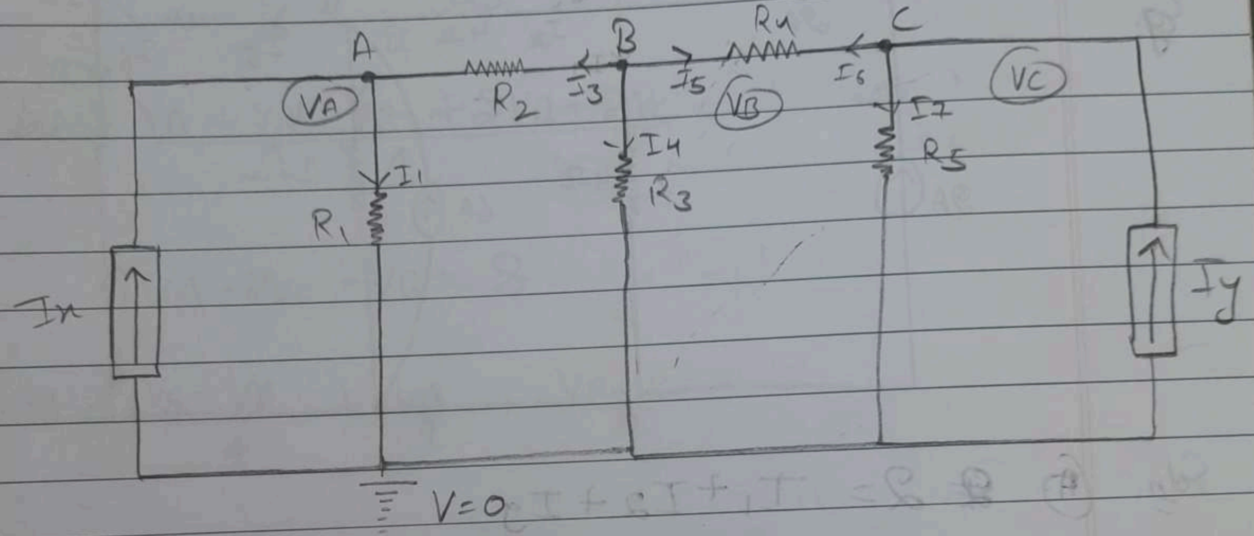
Current Sources..

2) Always assume that unknown Current through the Element to be flowing away from the node. This means that, the node at which KCL is applied is at upper Potential or higher Potential than the other.



At B: $I_x = I_1 + I_2$ — ①

At B: $0 = I_3 + I_4 + I_5$ — ②

At C: $I_y = I_6 + I_7$ — ③

$I_1 = \frac{V_A - 0}{R_1}$, $I_2 = \frac{V_A - V_B}{R_2}$, $I_3 = \frac{V_B - V_A}{R_2}$, $I_4 = \frac{V_B - 0}{R_3}$

$I_5 = \frac{V_B - V_C}{R_4}$, $I_6 = \frac{V_C - V_B}{R_4}$, $I_7 = \frac{V_C - 0}{R_5}$

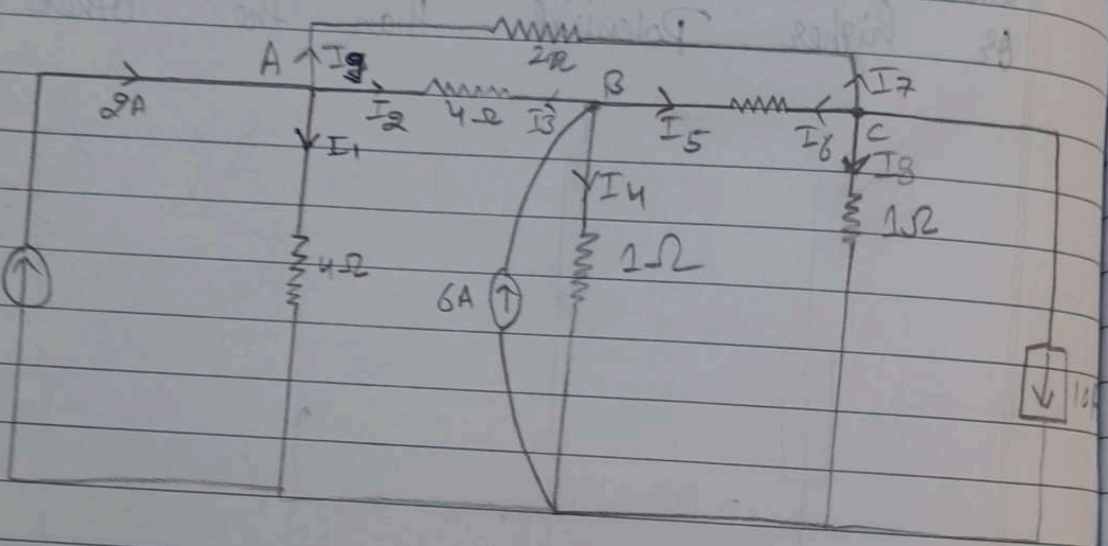
$$I_x = \frac{V_A}{R_1} + \frac{V_A - V_B}{R_2} \quad — ④$$

$$0 = \frac{V_B - V_A}{R_2} + \frac{V_B}{R_B} + \frac{V_B - V_C}{R_4} \quad — ⑤$$

$$I_y = \frac{V_C - V_B}{R_4} + \frac{V_C}{R_5} \quad \text{—} (6)$$

find $V_A, V_B, V_C = ?$

Eg.



Soln

(A) $\cancel{2}\ 2 = I_1 + I_2 + I_9$

(B) $0 = I_3 + I_4 + I_5$

(C) $0 = 10 + I_8 + I_6 + I_7$

$I_1 = \frac{V_A}{4}$, $I_3 = \frac{V_B - V_A}{4}$, $I_5 = \frac{V_B - V_C}{2}$

$I_2 = \frac{V_A - V_B}{4}$, $I_4 = \frac{V_B - 0}{1}$, $I_6 = \frac{V_C - V_B}{2}$

$I_7 = \frac{V_C - 0}{1}$, $I_8 = \frac{V_C - V_A}{2}$, $I_9 = \frac{V_A - V_C}{2}$

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$\Rightarrow \quad 2 = \frac{V_A}{4} + \frac{V_A - V_B}{4} + \frac{V_B - V_A}{2}$

$$V_A = 8$$

$\Rightarrow \quad 2 = \frac{V_A}{4} + \frac{V_A - V_B}{4} + \frac{V_A - V_C}{2}$

$$8 = \frac{V_A + V_A - V_B + 2V_A - 2V_C}{1}$$

$$4V_A - 2V_C - V_B = 8$$

$\Rightarrow \quad 0 = \frac{V_B - V_A}{4} + \frac{V_B}{1} + \frac{V_B - V_C}{2}$

$$V_B - V_A + 4V_B + 2V_B - 2V_B$$

$$\boxed{7V_B - V_A - 2V_C = 0}$$

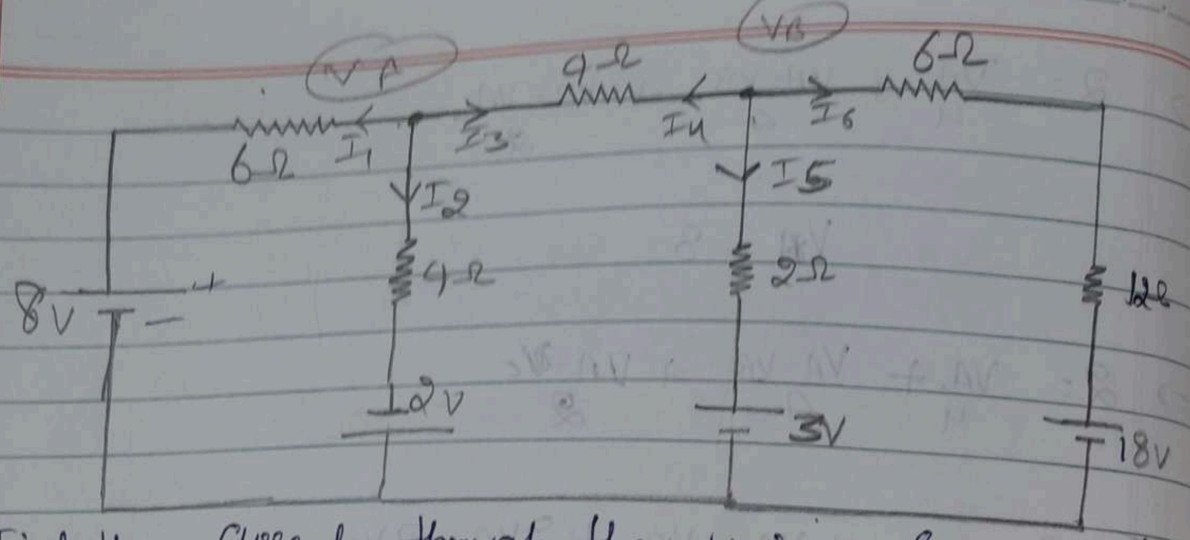
$\Rightarrow 0 = 10 + \frac{V_C - V_A}{2} + \frac{V_C - V_B}{2} + \frac{V_C}{1}$

$$20 + V_C - V_A + V_C - V_B + 2V_C = 0$$

So $V_A \Rightarrow 0.39$ Volt

$V_B \Rightarrow 9.243$ Volt

$V_C = -4.34$ volt.



Find the current through the various resistance by using the nodal Analysis.

Soln

$$I_1 + I_2 + I_3 = 0 \quad (1)$$

$$I_4 + I_5 + I_6 = 0 \quad (2)$$

$$I_1 = \frac{V_A - 8}{6}, \quad I_2 = \frac{V_A + 2}{4}$$

$$I_3 = \frac{V_A - V_B}{4}, \quad I_4 = \frac{V_B - V_A}{4}$$

$$I_5 = \frac{V_B - 3}{2} \quad I_6 = \frac{V_B - 18}{12+6}$$

Put value of I_1, I_2, I_3 in eq (1)

$$\frac{V_A - 8}{6} + \frac{V_A - 2}{4} + \frac{V_A - V_B}{4} = 0$$

$$2V_A - 16 + 3V_A + 6 + 3V_A - 3V_B = 0$$

$$8V_A - 3V_B - 10 = 0 \quad (3)$$

Put value of I_4, I_8, I_6 in eq ②

$$\frac{V_B - V_A}{4} + \frac{V_B - \cancel{3}}{2} + \frac{V_B - 18}{18}$$

$\Rightarrow$ $29V_B - 9V_A - 90 = 0$ ④

On solving $\Rightarrow$ ③ and ④

$$8 \times 29V_B - 9V_A - 90 = 0$$
$$9 \times -3V_B + 8V_A - 10 = 0$$
$$205V_B - 810 = 0$$

$V_B = \frac{810}{205}$ $\boxed{V_B = 3.95}$

Put value of V_B in eq^n ③

$I_1 = \frac{V_A - 8}{6} = \frac{2.74 - 8}{6} = -0.87$

$I_2 = \frac{V_A + 2}{4} = 1.185$, $I_3 = \frac{V_A - V_B}{4} = -0.30$

$I_4 = \frac{V_B - V_A}{4} = 0.30$ $I_5 = \frac{V_B - 3}{2} = \cancel{0.047}$ 0.47

$I_6 = \frac{V_B - 18}{18} = 0.78$

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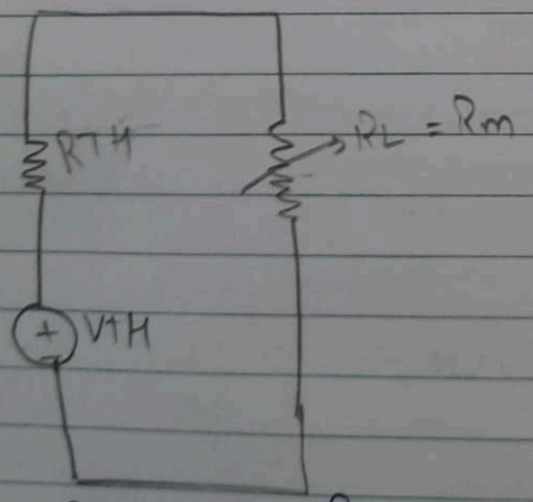
Maximum Power

Transfer Theorem ⇒

Maximum Power transfer theorem determines the value of load resistance which result maximum Power transfer across the terminals of an active network.

__Statment:__ The Theorem State that when the load resistance is Equal to the internal resistance of the System, Maximum Power is transferred to the load. This Internal resistance is the thevenin Equivalent resistance of the network as seen from the load terminal.



Let a generator having Voltage VTH an Internal resistance RTH delievers Power to the load Resistance R_L.

The current through the load R_L

$$\boxed{I_L = \frac{V_{TH}}{R_{TH}+R_L}} \longrightarrow \text{eq } ①$$

The Power supplied to the load R_L

$$P_L = I_L^2 R_L \quad \text{— (2)}$$

Put value of I_L from eq (1) in eq (2)

$$P_L = \left(\frac{V_{th}}{R_{th}+R_L}\right)^2 \times R_L \quad \text{— (3)}$$

⟹ For the Power transferred to the load to be max.

differentiate eq (3) w.r.t R_L and equate it at 0.

$$\frac{dP_L}{dR_L} = 0.$$

$$P_L = \left(\frac{V_{th}}{R_{th}+R_L}\right)^2 \times R_L$$

$$\Rightarrow \frac{d\left(\frac{V_{th}}{R_{th}+R_L}\right)^2 \times R_L}{dR_L} = 0. \Rightarrow \frac{(V_{th})^2}{(R_{th}+R_L)^2} \times R_L.$$

by using Product Rule

$$\Rightarrow \left[\frac{V_{th}}{R_{th}+R_L}\right]^2 \times 1 + \left[\frac{(R_{th}+R_L)^2 \overset{\to 0}{(V_{th})^2} - 2(R_{th}+R_L)(0+1)\,(V_{th})^2}{\left[(R_{th}+R_L)^2\right]^2}\right] R_L$$

$$\left[\frac{V_{th}}{R_{th}+R_L}\right]^2 + \left[\frac{0 - 2(R_{th}+R_L)\,R_L\,(V_{th})^2}{(R_{th}+R_L)^4}\right] = 0$$

$$\frac{1}{[R_{th}+R_L]^2}\left[\frac{(V_{th})^2(R_{th}+R_L)^2 - 2(R_{th}+R_L)\times R_L}{(R_{th}+R_L)^2}\right] =$$

$$\left[\frac{Vth}{Rth+RL}\right]^2 = \frac{2(Rth+RL)(Vth)^2 \times RL}{(Rth+RL)^4}$$

$$\frac{\cancel{(Vth)^2}}{\cancel{(Rth+RL)^2}} = \frac{2\cancel{(Rth+RL)}\,\cancel{(Vth)^2} \times RL}{\cancel{(Rth+RL)^2}\,(Rth+RL)^2}$$

$$Rth + RL = 2RL \qquad \boxed{Rth = RL}$$

$$\boxed{R_L = Rth}$$

The value of maximum Power

$$P_{max} = \left[\frac{Vth}{Rth+Rth}\right]^2 \times Rth$$

$$P_{max} = \frac{(Vth)^2}{4(Rth)^{\cancel{2}}} \times \cancel{Rth}$$

$$\boxed{P_{max} \Rightarrow \frac{(Vth)^2}{4(Rth)}}$$

Under Condition of max. Power transfer. Power output for the Source is gain

$$\eta = \frac{P_{L\,max}}{P} = \frac{1}{2}$$

~~Or~~ $\cancel{\eta =}$

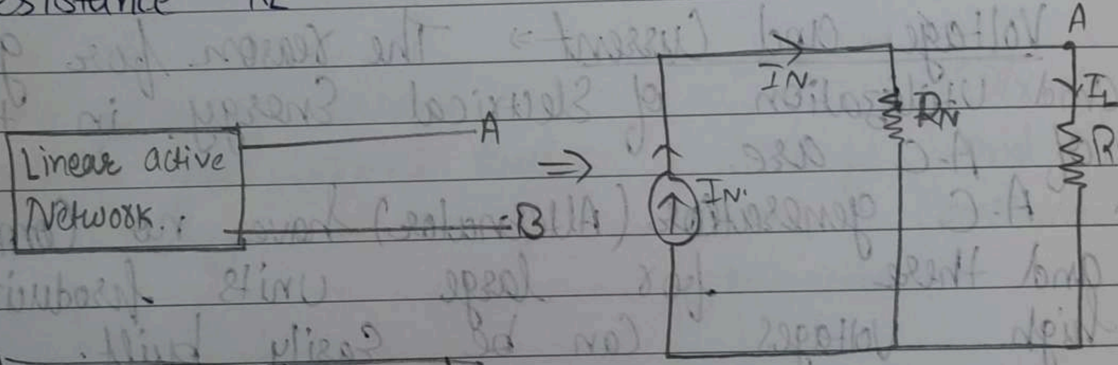
$$P_L = Vth \times \frac{Vth}{2Rth}$$

The Efficiency of power transfer is defined are ratio of average Power Consumed by the load and total Power Supplied to the load.

$$\eta = \frac{P_{L\,max.}}{P} = \frac{1}{2}$$

or $\boxed{\eta = 50\%}$

Norton's Theorm ⇒ This theorem state that any linear active network (having voltage and current sources and Resistances) with output terminal "AB" can be replaced by a single current source I_N is parallel with Resistance with R_N. The current through ~~to~~ the Load resistance R_L



$$\boxed{I_L = \frac{I_N \times R_N}{R_N + R_L}}$$

Procedure :- ① Remove the Load Element.

② Calculate the short circuit current or Norton's current I_N

③ Cal. the Norton's resistance R_N as seen from the load terminal AB

④ ~~Draw~~ Draw Norton's Equivalent Circuit.

⑤ Re Connect the load resistance R_L.

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UNIT = IInd

=> Sinosuidal (A.C)

Voltage and Current => The reason for generation and Utilization of Electrical Energy in the form of A.C are

(1) A.C generator (Alternator) have no Commutator and there for large units producing high Voltages Can be Easily built.

(2) It is Very Easy to Change the Voltage level by use of transformer. Hence high transmission Efficency Can be achieve in transferring Electric Energy from One Place to another.

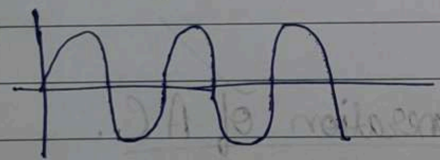
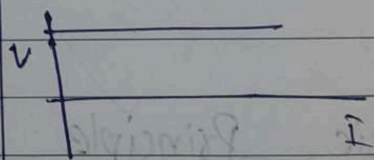
(3) Cost wise the Generation of A.C. is Cheap.

(4) The A.C motors are Cheap Robust and Single as Compare to D.C motors.

5. The Switch gear Equipment used in Sub-Station for Eg. Circuit breaker, Switches, Etc. are also Simple in Case of A.C as Compared to D.C

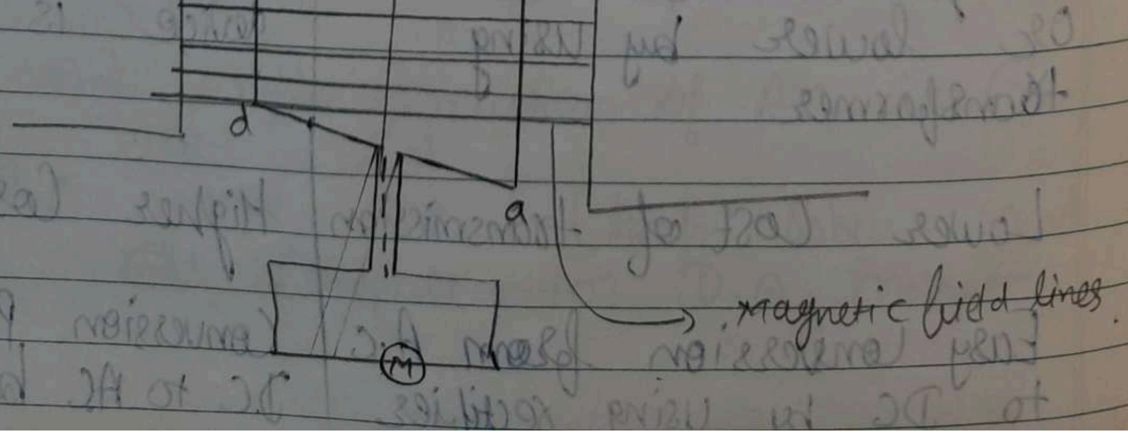
6. The maintaince requirement and the Cost of A.C. machine and equipment is almost negligible as compared to D.C.

7. Even If A.C Unsuitable for Certain applications it can be Easily Converted to D.C by using rectifiers.

Alternating Current	Direct Current.
1 ⇒ Voltage and Current reverses periodically. 	Voltage and Current remains Constant 
2 ⇒ Low cost of Production	Higher Cost of Production
3 ⇒ Voltage level Can be raised ⇒ Or lower by using transformer	No Such Equivalent device is ~~un~~ available
4. Lower Cost of transmission	Higher Cost of transmissi
5. Easy Conversion from A.C to DC by using rectifier	Conversion Possible from D.C to AC by ~~con~~ using Converters

6	A.C Motors are simple, robust. almost maintaincence Free	D.C. Motor s require regular Maintaincence and therefore are less durable
7.	A.C Cannot be used in Certain Applications like Electroplating, Electrotyping. Etc.	D.C is used directly for carrying such operations.
8.	In Case a person Comes in Contact with A.C Supply, It has a tendency to attract Hence the person will get Electric Shock.	In Case a person Comes in Cotact With D.C Supply It gives ~~repaiti~~ repelling Shock Hence it is some what less dangerous
9.	Frequency of AC is 50 Hz	Frequency of D.C is 0

⇒ Basic Principle of Generation of A.C.



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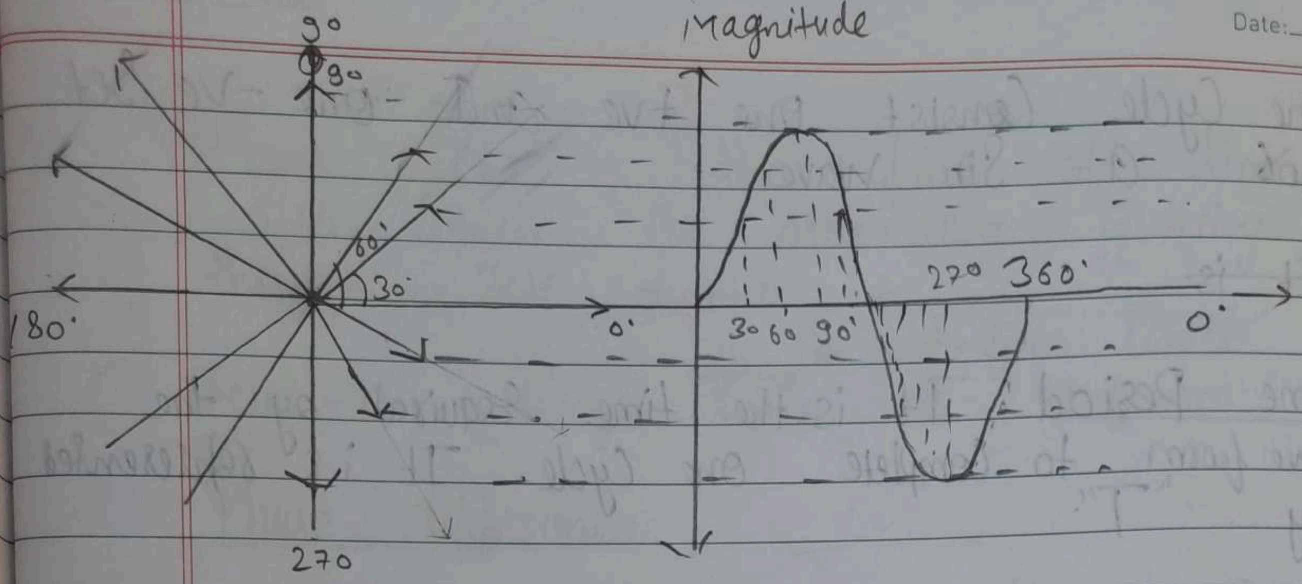

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Terms Related to Sinosuidal:

Instantaneous ~~E~~ Value: It is the quantity (Voltage or ~~Current~~ Current) which changes with time "t". It has different value at ~~on~~ every instant of time. These quantities are represent by small case letters "v or i"

$$v = \underline{V_m} \sin\theta$$

$$i = \underline{I_m} \sin\theta$$

Peak Value: It is the maximum value of voltage or current of the sinosuidal wave form whose value is maximum at $\theta = 90°$. V_m and I_m are the peak values of voltage and current respectively.

Cycle: The shape of sin wave repeat itself after 360°. One repition of the wave form is termed as cycle.

One Cycle Consist one +ve and one -ve set for a Sin wave

~~It is~~

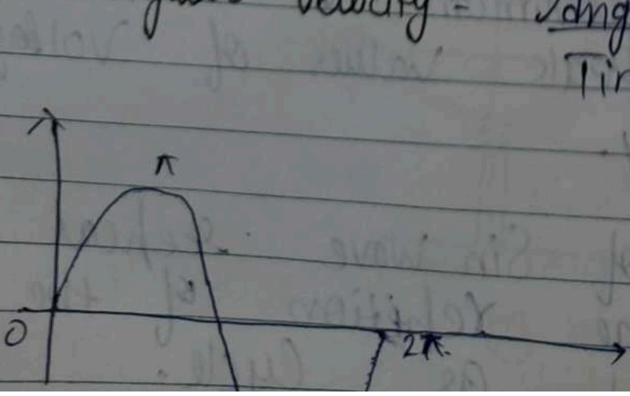
Time Period: It is the time required by the wave form to complete one cycle. It is represented by "T".

Frequency: ⇒ It is defined as no. of repitition of wave form or no. of cycles per second. It is represented by 'f'.

$$f = \frac{1}{T}$$

Angular Velocity: We observed that each cycle span "2π" radius. If it is divided by the time period, Angular velocity of the sin function.
It is represented by "ω"
It's Unit is '$\frac{Radian}{sec}$'

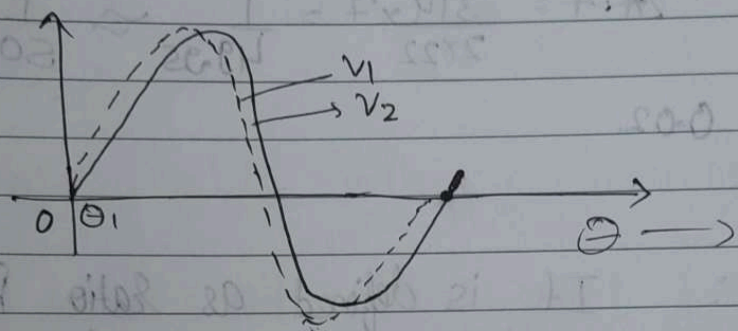
∴ Angular Velocity = $\frac{\text{Angle turned}}{\text{Time period}} = \frac{2\pi}{T} = 2\pi f \frac{rad}{sec}$

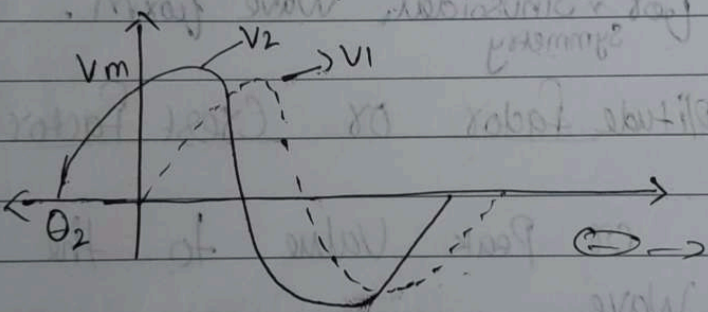


Phase : It is the part of time period after which the alternating quantity passed through zero position.

The wave form which start at zero are always ~~report~~ refffered as refrance quantity.

Phase difference:





Power factor : It is defined as the cosine of the angle b/w voltage and current of the same circuit

It is also defined as ratio of active power to the appearent power.

$$\cos\phi = \frac{\text{Active power}}{\text{Apparent power}}$$

Q For an Instantaneous Value of Current $I = 10\sqrt{2}$ Sin
Cal. Peak Value, Freq. Time Period,
Average value.?

Soln $I_o = 10\sqrt{2}\ \sin(314t)$

Peak value $= 10\sqrt{2}$ | Angular velocity $= 314$ Rad/sec.

Freq. $= 2\pi f = 314$

$2\pi \cdot f = \frac{314 \times 7}{2 \times 22} = \frac{1}{49.95} \approx \frac{1}{50}$ Hz.

$T = 0.02$.

Form factor: It is defined as ratio Rms value to the average value for Symmetry Sinusoidal wave form.

Peak factor or Amplitude factor or Crest factor.

Ratio of Max. or Peak Value to the RMS. Value of the Wave

Average Value Sinosuidal Waveform: The average or the mean value V_{av} of an alternative Voltage is Expressad as that of DC voltage Which when applied to any Circuit transfer the Same Charge as is transferred by the alternative quantity.

It is also defined as the airthmetic sum of all the quantities divided by the total no. of quantities Used to Obtain the Sum

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It can also be defined as area under the Curve divided by the time for which area is calculated.

FOE

UNIT = 3rd.

Three Phase of A.c Circuit.

Advantages of Three phase System:

1) The amount of Conductor material needed to transfer Same amount of power is lesser for three Phase System. Thus it is more Economical.

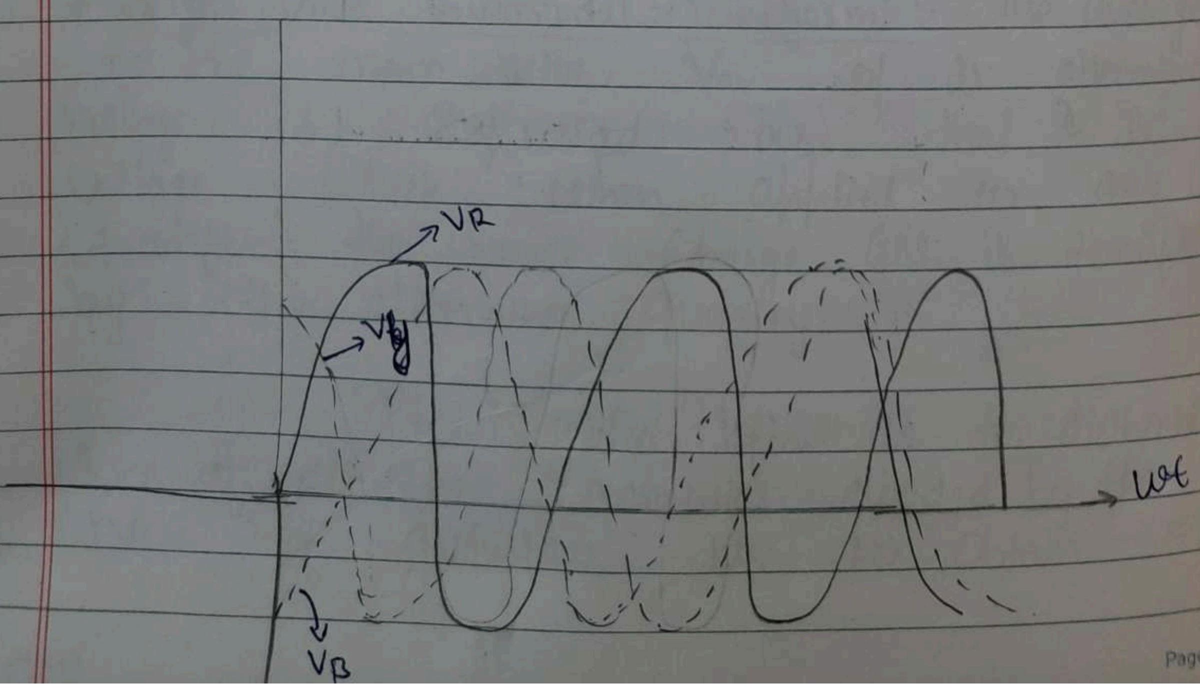
2) Domestic Power and industrial or Commercial power Can be provided from the Some Source.

3) Voltage regulation of Three phase System is better.

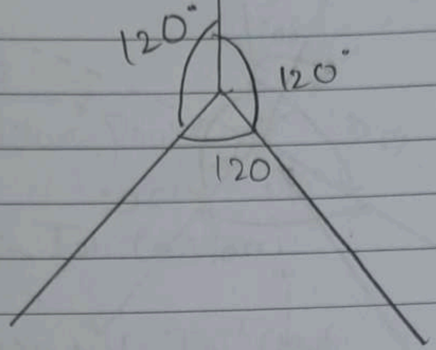
4) As three Phase Induction motor are Self Starting While Single Phase motor's are not.

5) The Torque Produced by three Phase motor is more.

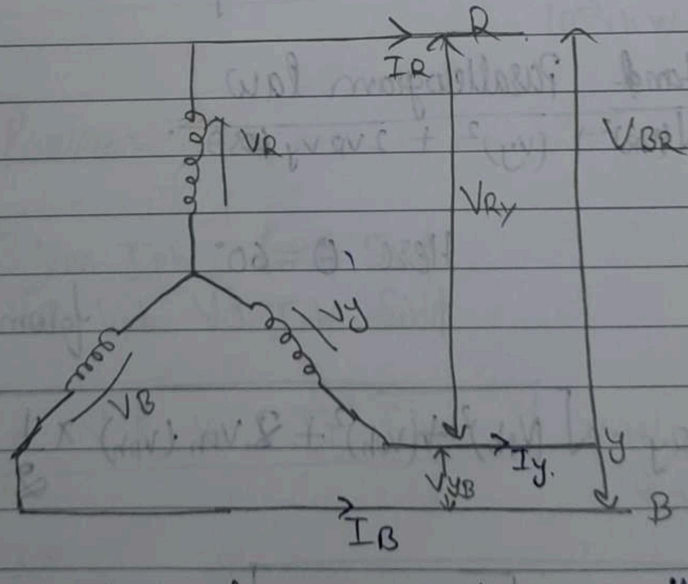
6) For a given Size of the ~~Phrase~~ frame Three Phase generator Provide more Output.



$V_R = V\angle 0°$ Volt.
$V_y = V\angle -120°$ volt.
$V_B = V\angle +120°$ volt
$= V\angle -240$ volt.



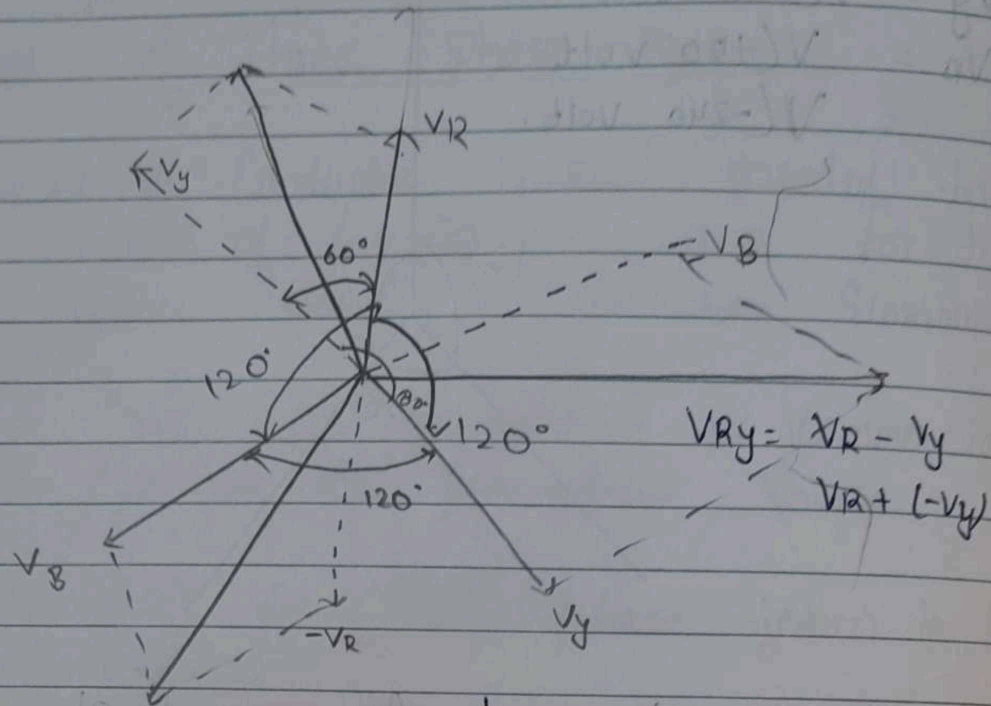
Relationship between line and Phase ~~generally~~ Quantity in Star Connected System.



Let V_R, V_y, & V_B represent the phase Voltag while line voltages are given by V_{Ry}, V_{yB} and V_{BR}.

$V_R = V_y = V_B = V_{ph}$ → eq (a)
$V_{Ry} = V_{yB} = V_{BR} = V_L$. → eq (b)

Phasor diagram:



$V_{Ry} = V_R - V_y$
$V_R + (-V_y)$

V_{BR}
$V_{BR} = V_B - V_R$
$V_B + (-V_R)$

~~V_{By}~~ $V_{yB} =$
$V_y - V_B$
$V_y + (-V_B)$

by using Resultant Parallelogram law

$$V_{Ry} = \sqrt{(V_R)^2 + (V_y)^2 + 2V_R V_y \cos\theta}.$$

Here $\theta = 60°$

from eq (a)

so.

$$V_{Ry} = \sqrt{(V_{ph})^2 + (V_{ph})^2 + 2V_{ph}(V_{ph}) \times \frac{1}{2}}$$

$$\boxed{V_{Ry} = \sqrt{3}\ V_{ph}}.$$

Simillar as V_{yB} and V_{BR}.

Since The line is Connected in Series with it on Phase. Therefore Current remains the Same.

$$\boxed{I_L = I_{Ph}} \rightarrow eq\ (c)$$

Line Current = Phase Current

Power Active

Total Active Power

$P = 3 V_{Ph} I_{Ph} \cos\phi$

$P = \sqrt{3} V_{Ph} \sqrt{3} \underbrace{I_{Ph}}_{I_L} \cos\phi$ from previous equ^ns eq (c)

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

$$\boxed{P = \sqrt{3}\, V_L\, I_L \cos\phi} \quad W.$$

$10^{-3} \times kW.$

Reactive Power:

$Q = 3 V_{Ph} I_{Ph} \cancel{\cos\phi} \sin\phi$

$\sqrt{3} V_{Ph} \sqrt{3} I_{Ph} \sin\phi$

$$\boxed{Q = \sqrt{3}\, V_L\, I_L \sin\theta} \quad \text{Volt Ampere Reactive}$$

$\times 10^{-3}$ kVAR

Appearent Power:

$S = \sqrt{P^2 + Q^2}$

$S = 3 V_{Ph} I_{Ph}$

$= \sqrt{3} V_{Ph} \sqrt{3} I_{Ph}$

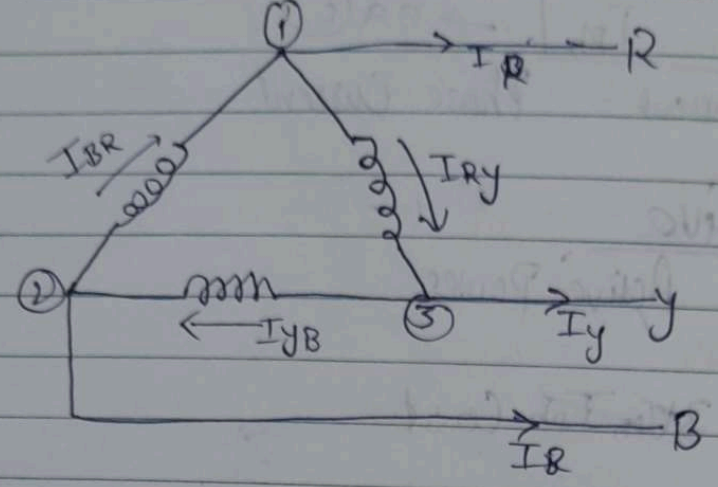
$$\boxed{S = \sqrt{3}\, V_L\, I_L} \quad VA \cdot \text{Volt Ampere}$$

10^{-3} Volt Ampere

Date:

Relationship between Line and Phase quantity in Delta Converted System

⇒



I_{ph} = I_{Ry}, I_{yB}, and I_{BR} are Phase Current

I_L = I_R, I_B & I_y are line Current.

at (1) by using KCL.

$$I_{BR} = I_R + I_{Ry}$$

$$I_R = I_{BR} - I_{Ry} \quad \text{— eq (a)}$$

at (2)

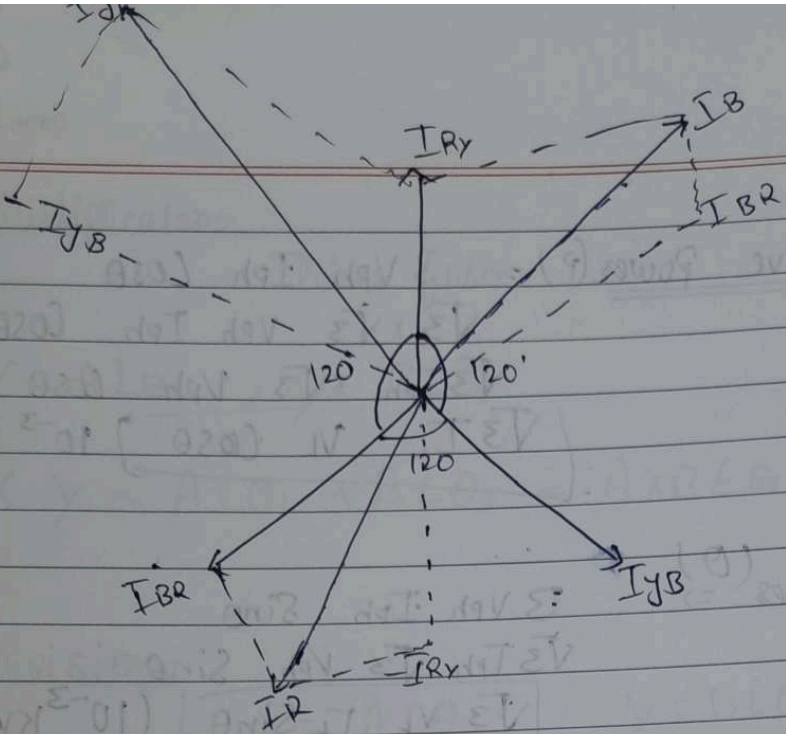
$$I_{yB} = I_{BR} + I_B$$

$$I_B = I_{yB} - I_{BR} \quad \text{— (b)}$$

at (3)

$$I_{Ry} = I_{yB} + I_y$$

$$I_y = I_{Ry} - I_{yB} \quad \text{— (c)}$$



⇒ For eq (a)

$$I_R = I_{BR} + (-I_{RY})$$

For eq (b) $I_B = I_{yB} + (-I_{BR})$

For eq (c) $I_y = I_{Ry} + (-I_{yB})$

So $I_R = \sqrt{(I_{Ry})^2 + (I_{BR})^2 + 2 I_{Ry} \cdot I_{BR} \cos 60}$

$I_R = \sqrt{(I_{Ph})^2 + (I_{Ph})^2 + 2(I_{Ph})^2 \times \frac{1}{2}}$

$I_R = \sqrt{3(I_{Ph})^2}$ $\qquad \because I_R = I_L$

$$\boxed{I_L = \sqrt{3}\ I_{Ph}}$$

Since the neutral does not Exist in Delta Connection Therefore line voltage = Phase voltage i.e

$$\boxed{V_L = V_{Ph}}$$

Date:

Power

Active Power (P) = $3 V_{ph} I_{ph} \cos\theta$

$\sqrt{3} \times \sqrt{3} \, V_{ph} I_{ph} \cos\theta$

$\sqrt{3} I_{ph} \times \sqrt{3} V_{ph} \cos\theta$

$\boxed{\sqrt{3} I_L V_L \cos\theta}$ 10^{-3} KW.

Reactive Power (Q) => $3 V_{ph} I_{ph} \sin\theta$

$\sqrt{3} I_{ph} \sqrt{3} V_{ph} \sin\theta$

$\boxed{\sqrt{3} V_L I_L \sin\theta}$ (10^{-3} KVAR)

Appearent Power (S) = $\cancel{3} V_{ph} I_{ph}$

$\sqrt{3} \, \cancel{V_p I_L}$ $V_L I_L$ (10^{-3}) KVA.

$\boxed{\sqrt{3} V_L I_L}$

30/11/2021

Addition:

Rectangular.

$X = A + iB$, $Y = C + iD$

$X + Y = A + iB + C + iD$

$(A+C) + i(B+D)$

Subtraction:

$X = A + iB$

$Y = C + iD$

$X - Y = (A + iB) - (C + iD) =$

$(A - C) + i(B - D)$

Multiplication

Polar form

$X = A\angle\theta_1$, $y = B\angle\theta_2$

$X \cdot Y = A\angle\theta_1 \times B\angle\theta_2 = A \times B \angle \theta_1 + \theta_2$

Division.

$X = A\angle\theta_1$. $Y = B\angle\theta_2$

$$\frac{X}{Y} = \frac{A\angle\theta_1}{B\angle\theta_2} = \frac{A}{B}\angle\theta_1 - \theta_2$$

Q. $X = 3 + i5$ → Rectangular.
$Y = 8 + i9$

① +. $X + Y = 3 + i5 + 8 + i9$
$3 + 8 + i(5 + 9)$
$11 + 14i$

② (−). $X - Y = 3 + i5 - 8 + i9$
$(3 - 5) + i(5 - 9)$
$-2 - 4i$

③ (×) Multiplication
on Converting into Polar
$A = (3,5) \Rightarrow 5.83 = A$. $\tan^{-1}(b/a) = 59.03$
$B = (8,9) = 12.041 = B$ $\tan^{-1}(b/a) = 48.36$

Now

$X = 5.83 \angle 59.03 \rightarrow A$

$Y = 12.041 \angle 48.36 \rightarrow B$

$X * Y = A \times B \Rightarrow 5.83 \times 12.041 \angle 59.03 + 48.36$

$70.199 \angle 107.39$.

Division

$X = 5.83 \angle 59.03$

$Y = 12.041 \angle 48.36$

$X \div Y = 0.4841 \angle 10.67$.

Q. A Star Connected load has impedance of $(3+i4)$ and is Connected across a balanced three phase Delta connected alternator having a line voltage of 120 Volt. Obtain the Phase Current and the line current.

Soln ~~Ans~~ In Star Connection

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

$Z_{ph} = (3+i4)$

$$I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{V_L/\sqrt{3}}{Z_{ph}}$$

$$I_{RY} = \frac{120 \angle 0^\circ}{\sqrt{3}(3+i4)}$$

$$I_{YB} = \frac{120 \angle -120}{\sqrt{3} \times (3+i4)}$$

$Z \Rightarrow R \angle$

$$I_{BR} = \frac{120 \angle -240}{\sqrt{3}(3+i4)}$$

$$I_{Ry} = \frac{120 \angle 0^\circ}{3\sqrt{3} + i4\sqrt{3}}$$

$$I_{Ry} = \frac{120 \angle 0^\circ}{8.66 \angle 53.13}$$

$$I_{Ry} = 13.85 \angle -53.13$$

$$I_{yB} = \frac{120^\circ \angle -120}{(3\sqrt{3} + i4\sqrt{3})}$$

$$I_{yB} = \frac{120^\circ \angle -120}{8.66 \angle 53.13}$$

$$13.85 \angle -173.13$$

$$I_{BR} = \cancel{13.85\angle}\ \frac{120^\circ \angle -240}{8.66 \angle 53.13}$$

$$I_{BR} = 13.85 \angle -293.13$$

Q. A Three Phase balanced System Supplies 110 volt to a Delta Connected load whose phase impedance's are equal to $(3.54 + i3.54)$ determine the line Current and draw the phasor Diagram.

Soln ~~V_{ph}~~ · $Z_{ph} = 3.54 + i3.54$

$V = 110$ volt

For delta $V_L = V_{ph}$

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

$$I_{Ry} = \frac{V_{ph}}{Z_{ph}} = \frac{110\angle 0^\circ}{3.54 + i3.54} = \frac{110\angle 0^\circ}{5.00\angle 45} = \ldots$$

$$I_{yB} = \frac{110\angle -120^\circ}{3.54 + i3.54} = \frac{110\angle -120}{5.00\angle 45} = 22\angle -165^\circ$$

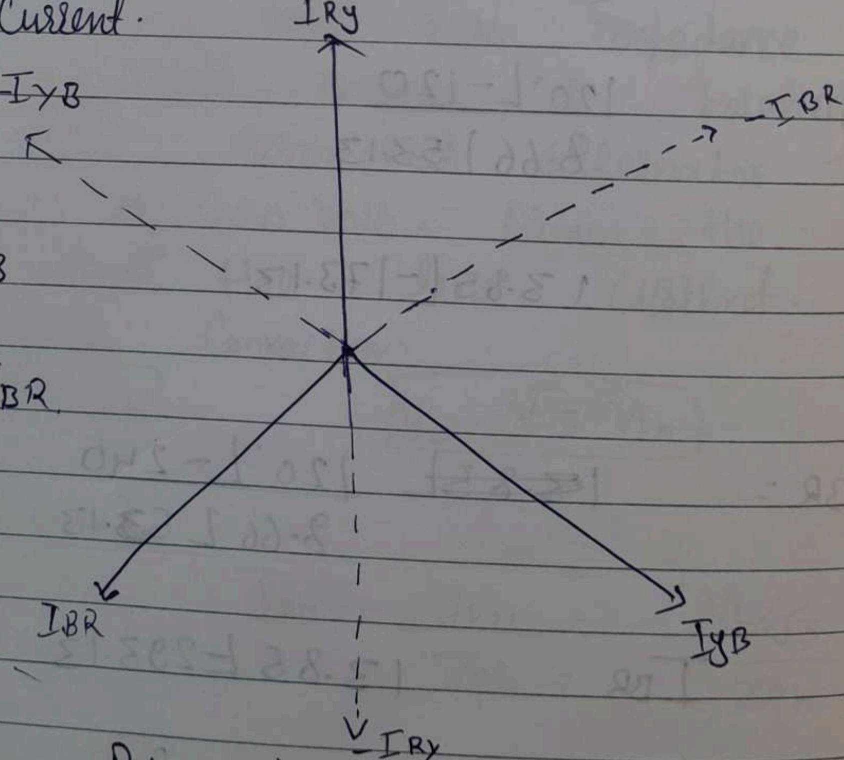
$$I_{BR} = \frac{110^\circ\angle -240}{3.54 + i3.54} = \frac{110\angle -240}{5.00\angle 45} = 22\angle -285$$

by Calculating line Current.

$\Rightarrow I_R = I_{BR} - I_{Ry}$

$I_y = I_{Ry} - I_{yB}$

$I_B = I_{yB} - I_{BR}$



By Converting Polar into rectangular

~~I_{BR}~~ = $I_{Ry} = 15 - 15i$ ~~5.69~~ $15.55 - 15.55i$

~~$I_{yB} = 21 - 5i$~~ = ~~$-21.25 - 5.690i$~~

I_{BR} = ~~$5 + 21i$~~ ~~$5.69 + 21.25i$~~

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$I_R = \cancel{-21 - 5i - 15 + 15i}$
$\cancel{= 17 - 36 + 10i}$

$\cancel{I_R = -15.55 + 15.55i = 21.25 - 5.69i}$

$\cancel{I_R = I_{BR} - I_{YB}}$
$\cancel{= 21}$

Now

$I_{RY} = 22\angle -45^\circ$

on Converting into rec. $\Rightarrow$ $x = 15.55 - 15.55i$

$I_{YB} = 22\angle -165^\circ$
$= x = -21.25$
$y = -5.69$
So $-21.25 - 5.69i$

And $I_{BR} = 22\angle -285$
So
$5.69 + 21.25i$

Therefore $I_R = I_{BR} - I_{RY}$
$5.69 + 21.25i - 15.55 + 15.55i$
I_R. $-9.86 + 36.8i$

$$\boxed{I_R = -9.86 + 36.8i}$$

$I_y = I_{Ry} - I_{YB}$

$I_{Ry} = 15.55 - 15.55i$
$I_{YB} = -21.25 - 5.69i$

$I_y = 15.55 - 15.55i - (-21.25 - 5.6$
$15.55 - 15.55i + 21.25 + 5.69i$

$$\boxed{I_y = 36.74 - 9.83i}$$

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$I_B = I_{YB} - I_{BR}$

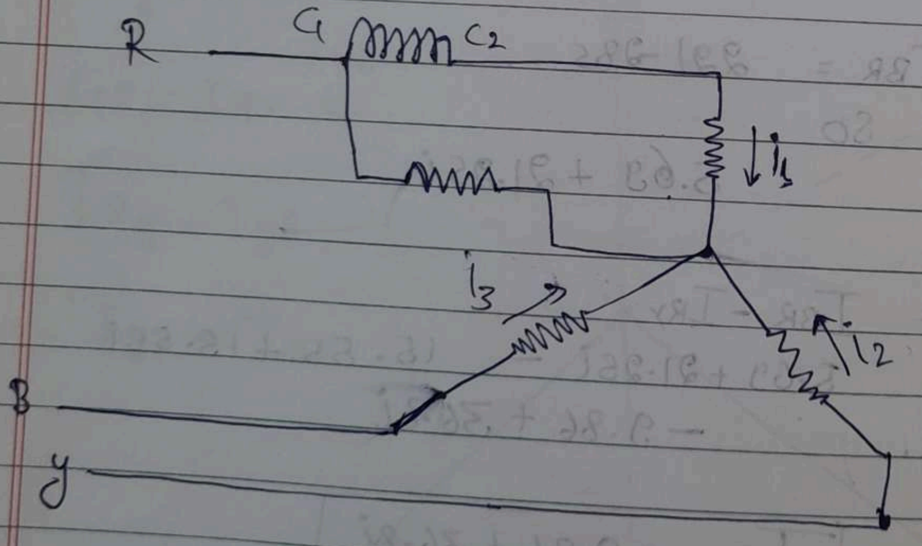
$I_{YB} = 22\angle{-165} - 22\angle{-285}$
$= (-21.25 - 5.69i) - (5.69 + 21.25i)$

$I_B = -21.25 - 5.69 - 5.69i - 21.25i$

load

⟹ Measurment of Power

① One Wattmeter Method

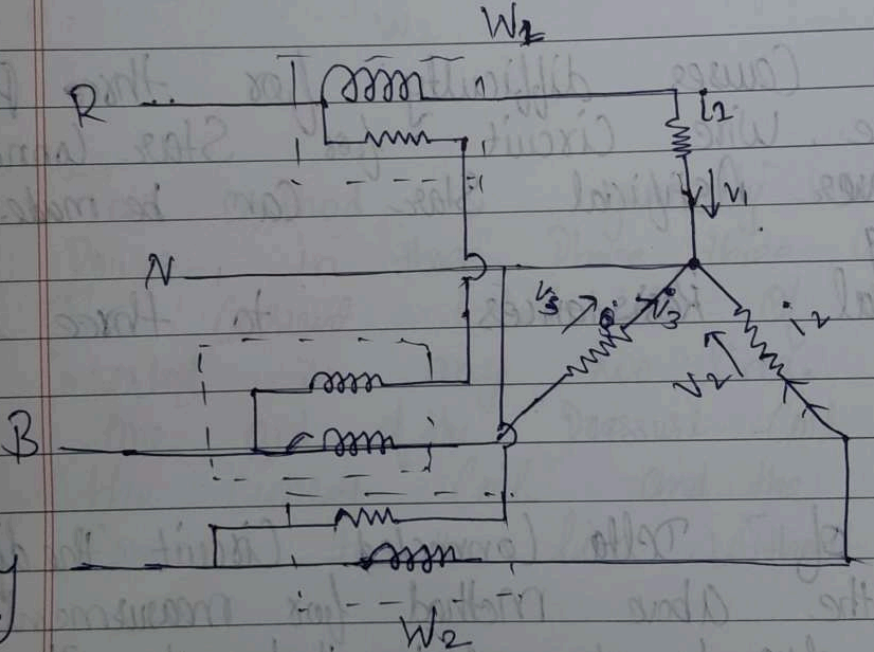


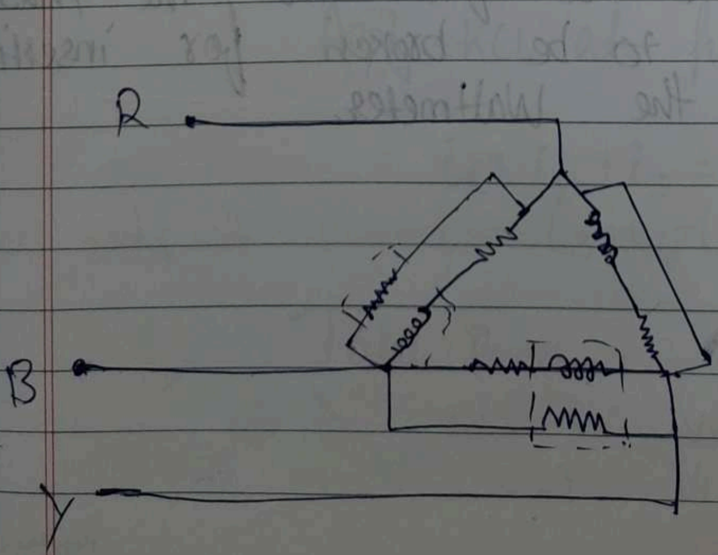
In balanced Three Wire Three Phase load Circuit the Power in each Phase is Equal. Therefore The total Power of the Circuit Can be determine by multiplying the Power measured in any one phase by three.

Total Power of 3 Phase = 3 × Power Measured by one Wattmeter.

Demerit: One wattmeter method has a demerit that Even a Slight difference of unbalanced in the load Produces a ~~ta~~ large Error in the measurement.

Three Wattmeter Method:





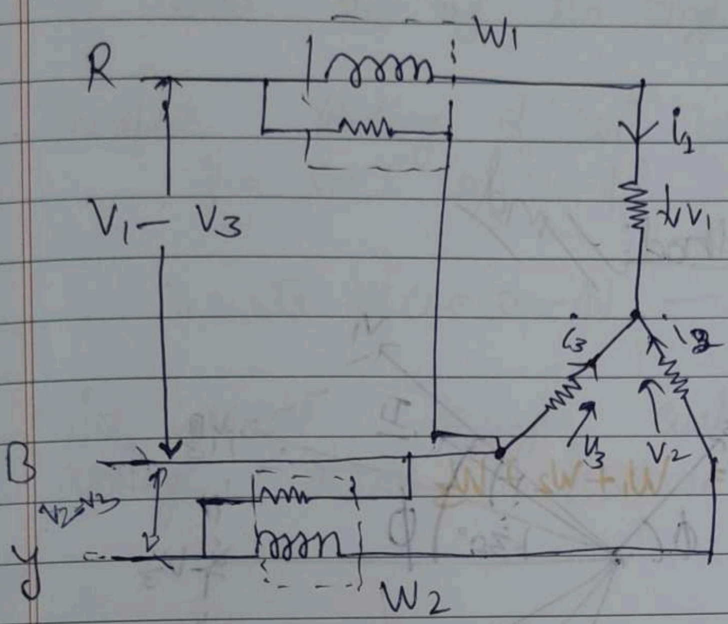
The Three Wattmeter Method is used for the measurement of power ~~ß~~ is three phase four wire circuit. In this method the neutral wire is ~~Goo~~ common to three phases, Each wattmeter ~~sense~~ reads power in its own phase and the total power of the load circuit is given by the sum of the readings of three wattmeter. W_1, W_2 and W_3

Total Power $P = W_1 + W_2 + W_3$

Demerit. It causes difficulty for three phase three wire circuit for star connected load. However Artificial Star can be made by connecting three equal resistances to three line conductors

In case of Delta connected circuit the difficulty in adopting the above method for measurement of power is due to the fact that, the phase coils are required to be broken for inserting current coil of the wattmeter.

Two Wattmeter Method :



This method is generally use for measurement of Power in three Phase three wire load Circuit. The current ~~Coint~~ coil of two wattmeter are inserted in any two lines.
One end of the Pressure Coil is Connected to the current Coil and the Other End is Connected to the line without a current Coil

"Apply KCL at point P"

$$i_1 + i_2 + i_3 = 0$$
$$i_3 = -(i_1 + i_2)$$

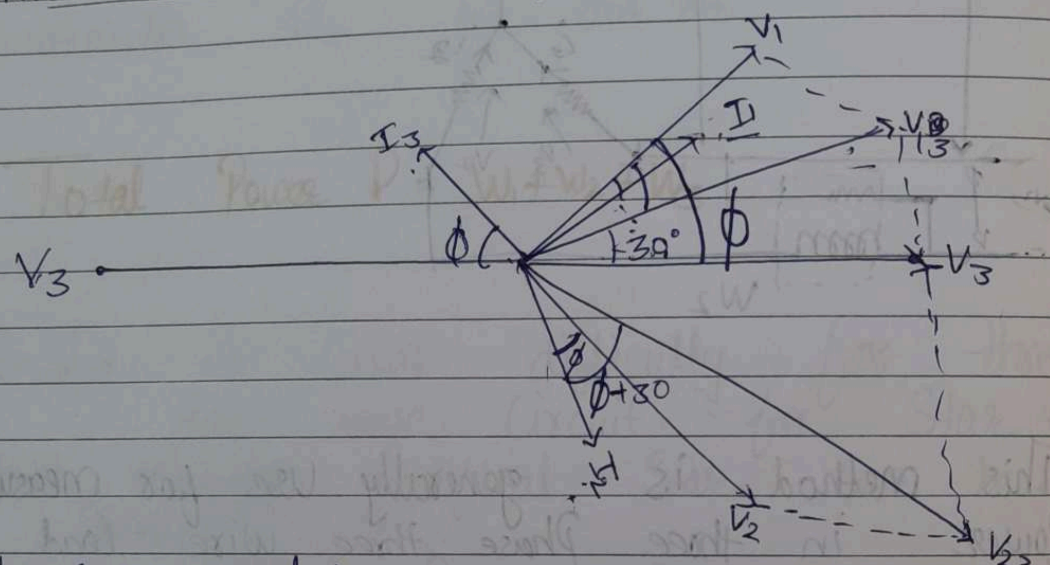
$$\text{Total Power} = V_1 i_1 + V_2 i_2 + V_3 i_3$$
$$= V_1 i_1 + V_2 i_2 + V_3(-i_1 - i_2)$$
$$= V_1 i_1 + V_2 i_2 - V_3 i_1 - V_3 i_2$$

$= (V_1 - V_3) i_1 + (V_2 - V_3) i_2$

$\boxed{P = W_1 + W_2}$

$\boxed{P = P_1 + P_2}$

Two Wattmeter Method: 2nd



As load is balanced therefore phase voltages $V_1 = V_2 = V_3 = V$ and Line voltages $V_{12} = V_{23} = V_{31} = \sqrt{3}\, V$

Phase Current $= I_1 = I_2 = I$
and
Line Current

$I_1 = I_2 = I_3 = I$

Power factor $= \cos\phi$

Thee phase Current lag Corresponding the phase voltage ϕ

⟹ The Current through Voltmeter
$P_1 = I_1$ & Voltage across its pressure

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Coil is V_{13}

→ It leads V_{13} by an angle

Therefore reading of "W_1" wattmeter

$$P_1 = V_{13} I \cos(30-\phi)$$

$$V_1 = \sqrt{3}\ VI\cos(30-\phi) \quad — (1)$$

The current through wattmeter W_2 is I_2 and Voltage across pressure coil is V_{23}

I_2 leads V_{23} by an angle $(30+\phi)$ Therefore Reading of wattmeter W_2 is

$$P_2 = V_{23}\ I_2 \cos(30+\phi)$$

$$P_2 = V_{23}\ I_2 \cos(30+\phi)$$

$V_1 = V_2 =$

$$P_2 = \sqrt{3}\ VI \cos(30+\phi) \quad --- (2)$$

$$P_1 + P_2 = \sqrt{3}\ VI\cos(30-\phi) + \sqrt{3}\ VI \cos(30+\phi)$$

$$\sqrt{3}\ VI[\cos(30-\phi) + \cos(30+\phi)]$$

$$\sqrt{3}\ VI \cdot 2\cos\left[\frac{30-\phi+30+\phi}{2}\right]\cos\left[\frac{30-\phi-30-\phi}{2}\right]$$

$$2\sqrt{3}\ VI \cos 30 \cos\phi$$

$$2\sqrt{3}\ VI \frac{\sqrt{3}}{2} \times \cos\phi$$

Voltages

$$\boxed{P_1 + P_2 = 3VI\cos\phi} \quad eq(1)$$

sure

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$$P_1 - P_2 = \sqrt{3}\, VI\, [\cos(30-\phi)] - \cos(30+\phi)$$

$$2\sqrt{3}\, VI \left[\sin\left(\frac{30-\phi+30+\phi}{2}\right) \sin\left(\frac{30-\phi-30-\phi}{2}\right) \right]$$

$$2\sqrt{3}\, VI \sin 30 \sin\phi$$

$$P_1 - P_2 \quad \boxed{\sqrt{3}\, VI \sin\phi} \quad - \text{eq } 2$$

⇒ Divide eq 2 & eq 1

$$\frac{\sqrt{3}\, VI \sin\phi}{3\, VI \cos\phi} = \frac{P_1 - P_2}{P_1 + P_2}$$

$$\tan\phi = \sqrt{3}\left[\frac{P_1 - P_2}{P_1 + P_2}\right]$$

$$\phi = \tan^{-1}\left[\frac{\sqrt{3}\,[P_1 - P_2]}{[P_1 + P_2]}\right]$$

Power factor $\cos\phi$

$$\cos\left[\tan^{-1}\left[\sqrt{3}\,\frac{(P_1 - P_2)}{(P_1 + P_2)}\right]\right]$$

Effect of Power factor on reading of watt meters

1. When power factor is unity

$$\cos\phi = 1 \quad \& \quad \phi = 0$$

$$P_1 = \frac{3}{2} \cancel{\cos}\, VI$$

$$P_2 = \frac{3}{2}\, VI$$

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Total Power $= P_1 + P_2 = 3VI$

When power factor is 0.5

$\phi = 60.$

then $P_1 = \frac{3}{2} VI$

$P_2 = 0$

Total power $P_1 + P_2$ is

$\frac{3}{2} VI$

(3) When P.f. is 0

then $\phi = 90.$

$P_1 = \sqrt{3}\ VI \cos(30-90)$

$\sqrt{3}\ VI \frac{1}{2}$

$\frac{\sqrt{3}}{2} VI$

$P_1 + P_2 = 0$

A Three phase balanced load power was measured by two wattmeter method.

Q The reading of two wattmeter is so connected are 5kW and 0.5kW. The ~~batter~~ later reading being obtained after reversal of current coil connection. Calculate the power factor of the ~~tool~~ load.

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$P_1 = 5kW$

$P_2 = -0.5kW$

$$\phi_1 = \tan^{-1}\sqrt{3}\left[\frac{5+0.5}{5-0.5}\right]$$

$$\phi_1 = \tan^{-1}\left[\sqrt{3} \times \frac{5.05}{4.5}\right]$$

$$\tan^{-1}\left[\sqrt{3} \times 1.12\right]$$

$$\tan^{-1}\left[1.943\right]$$

$$= 62.76$$

Power factor will be

$$\cos\phi = 0.4577\ldots$$

Date:

Transformer:- A transformer is an AC Static device. Which transfer Electric Power from one Circuit to another from one circuit to another without changing its frequency. Hence the main function of transformer is to raised or lower voltage in a circuit with a corresponding decrease or increase in current at the same frequency.

Any transformer has two coils Electrically insulated from each other and wound on a common core that is magnetically coupled. The Energy from the coil is transformed

The coil which receives Energy from an A.C Source k/a Primary(P) and the coil which deliver the Energy to the node is called Secondary(S)

If the primary coils has smaller number of turns of a thick wire. While the secondary coil has large no. of turns of thin wire then that is called Step-up transformer.

Similarly in Step-down transformer the primary (P) Consist of large no. of turns of thin wire while the secondary has smaller no. of turns of thick wire

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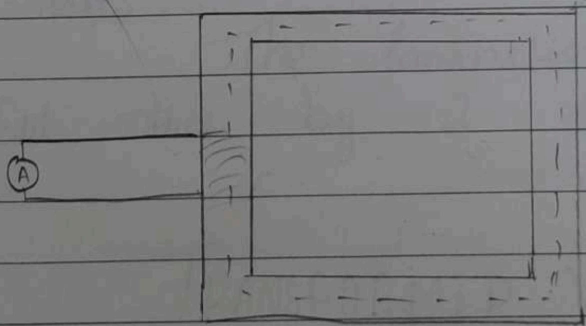
Transformer operate on the principal of mutual Induction.

Energy Can be Efficiently transferred by induction from one Set of a Coil to another by meanes of a varying magnetic flun provided that both Set of Coils are on a Common magnetic Circuit.

A/c to "Faraday law" of Electromagentic Induction, The rate of Change of flun is directly proportional to Induced Emf.

"Lenz" law give the direction of Induced Emf to be the oppose of the Cause producing it.

$$\boxed{e = -N\frac{d\phi}{dt}}$$



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OPERATION

When an alternative Current is applied t primary, An alternative Current Set up i As the Winding is linked with a magnetic Core, It produces a alternat flux in the Core.

This alternative flux is linked with t turns of the Secondary Coil, Since the flux is alternative in the nature, It induces the mutually Induced "Emf" in Secondary of the Same frequency.

Then according to faraday law of Electro magnetic Induction an Emf is Induced in Secondary coil. Due to this Induced Emf the Secondary coil is capable of Supplying Current and Enhance the load.

The main Elements of Construction's are
(1) Magnetic Circuit. Comprising. limbs, Yoke. Clamping Structure.
(2) Electric & Circuit. Comprising Primary & Secondary Winding, Former's, Insulation devices
(3) Terminals Comprising tapping and tapping Switches, terminal bushings and leads.

(4) Tank Comprising of Oil and Cooling apparatus, Conservator, Breather, and auxilary apparatus Such as Oil gauge, temperature gauge and bulb

TRANSFORMER CORE

In all type of transformer, Core is Constructed of the Sheets, Steel, lamination, assembled to provide a Continous magnetic path with a min. of air gap. The thickness of Lamination varies from 0.35 mm for a freq. of 50 Hz to 0.55 mm for a frequency of 25 Hertz. The lamination's are insulated from Each Other by a thin Coating of Varnish.

TRANSFORMER WINDING

A transformer assembly Consist of two Windings, The Windings are made up of high Conductivity Copper Wire of Suitable Cross Sectional area. Each Winding is split up into two equal Number of Coils and are & wrapped on both limbs of the Core.

By dividing the winding in two half there is reduction in leakage flux, By wrapping high voltage winding on low Voltage winding the amount of high voltage insulation is minimized

TERMINALS AND LEADS

The Connection to the winding are of insulated Coppers bars. They are brought through the tank by means of bushing.

TANK

A Suitable Container for the assembled Core and winding if the transformer tank. Insulating medium is oil which is generally kla transformer Oil. The Tank has ~~to~~ a No. of radiators tubes or fins which increases the area for heat dissipitation

TEMPERATURE GAUGE

This Gives the temperature of the hot oil Where as level of oil is indicated by oil gauge Situated in the conservator.

1) The function of valve one is for taking out transformer oil during Maintainence

to Check the ~~determination~~ diteriortion of oil

⇒ Valve ~~One~~(1) & Valve (2) are Connected together to the Centrifugal ~~maching~~ machine for removing the moisture content from the oil Even while the transformer is On.

BUCHHOLZ Relate is a protective device which is gas actuated Relay

When Some minor volt is developed this relays ~~th~~ Senses the fault and a alarm is given To the operator. In Case of major fault this relays will trip the transformer

Conservative & Breather

The oil of the transformes should not Come in Contact with atomspheric air as it may take a moisture which may Spoil its insulating property. Also air may Cause acidity and Sludging of oil. To Prevent this the transformer are provided with Conservator which take a Contraction and Expansion of oil without allowing it to work Come in Contact with air.

EMF Equation

15/12/2021

Induced EMF $\cdot$ $e = -N\frac{d\phi}{dt}$

$e \rightarrow$ instantaneous value of Emf ~~indue~~ induced in

$\phi \rightarrow$ instantaneous flux of mutual flux

$N \rightarrow$ Number of turns in coil.

Let N_1 & N_2 be the Number of turns of primary or Secondary.

$$e_1 = -N\frac{d\phi}{dt} = -N_1\frac{d}{dt}(\phi_m \sin\omega t)$$

$$= -N_1\frac{d}{dt}(\phi_m \sin 2\pi ft)$$

$$= -N\phi_m 2\pi f \cos 2\pi ft$$

$$= -N\phi_m 2\pi f \sin(2\pi f - \frac{\pi}{2}) \text{ Radian}$$

Now $E_{max} = N_1\phi_m 2\pi f$ volt

$$E_{rms} = \frac{E_{max}}{\sqrt{2}} = E_1 = \frac{2\pi f N_1 \phi_m}{\sqrt{2}}$$

$$\boxed{E_1 = 4.44\phi_m N_1 f \text{ Volts}}$$

$$\boxed{E_2 = 4.44\phi_m N_2 f \text{ Volts}}$$

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Transformer Ratio :

$$\frac{E_1}{E_2} = \frac{4.44\,\phi_m f N_1}{4.44\,\phi_m f N_2}$$

$$\boxed{\frac{E_1}{E_2} = \frac{N_1}{N_2} = a}$$

Ideal transformer

Initial VA = output VA

$$V_1 I_1 = V_2 I_2$$

or $\boxed{\frac{V_1}{V_2} = \frac{I_2}{I_1} = \frac{1}{a}}$

Efficiency: The Efficiency of a transformer at a particular load and power factor is defined as the ratio of output to the input (The two being measured in the same unit Either watt or KiloWatt)

Efficiency $\eta = \frac{\text{Output}}{\text{Input}}$

$$= \frac{\text{Output}}{\text{Output} + \text{loss}} = \frac{\text{Output}}{\text{Output} + \text{Ironloss} + \text{Copper loss}}$$

$$= \frac{V_2 I_2 \cos\phi}{(V_2 + I_2 \cos\phi) + W_i + W_w}$$

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Here, $V_2 I_2$ is the volt ampere of transformer when it is given KVA.

$$\eta = \frac{(\text{KVA rating} \times 1000) \cos\phi}{(\text{KVA rating} \times 1000 \times \cos\phi) + W_i + W_w}$$

$$\eta = \frac{\text{KVA} \times 1000 \times \cos\phi \times x}{(\text{KVA} \times 1000 \times \cos\phi \times x) + W_i + (x^2 W_w)}$$

Where $x = \dfrac{\text{given load}}{\text{full load}}$.

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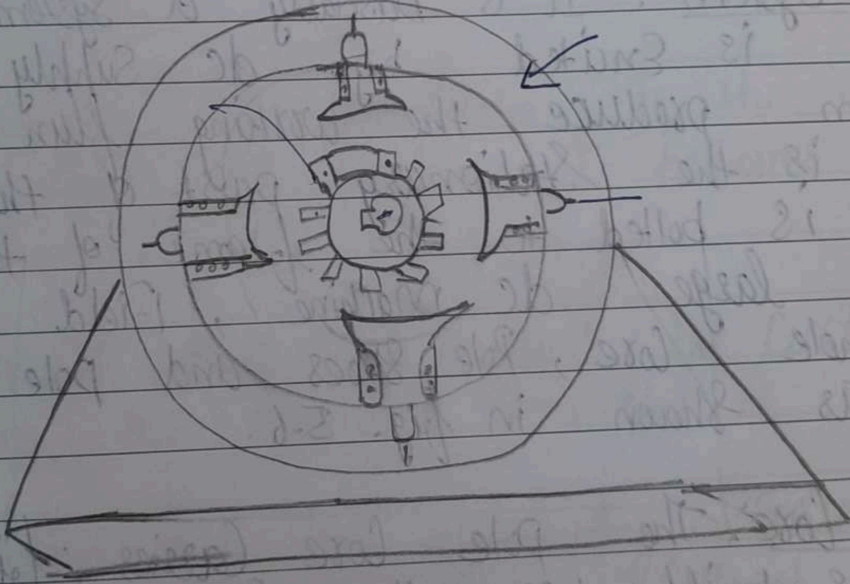
~~flux~~ The direction of Induced Emf in a Conductor Flemming left hand Rule. This

and if Fore finger point in the dirc^n of flux, Middle finer finger in the dirc^n of current an then thumb will be point the direction of force

Construction of DC. Machine



View of DC Machine.

A dc machine Consist of the following Parts

1) Yoke or Frame
2) Field System
3) Armature
4) Commutator
5) Brushes
6) Bearings

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Yoke : It is the outer frame of the machine. Frame Serves the following Purposes
a) It acts as Protective Cover for the machines
b) It houses field system and Supports the armature through bearings.
c) It carries the working flux

The material of yoke Should have high permeability and high mechanical strength. Generally yoke is made of Cost Steel

Field System : It is bascially a System of Electromagnets Which is Excited by dc Supply. the field System produce the working flux of the machine. It is the Stationary part of the machine and is bolted to the frame of the machine. For large dc machine, Field System Consists of pole core, Pole Shoes and pole (Field) Winding as Shown in fig. 5.6.

(a) Pole Core: The pole core carries field winding. It is built using thin Steel laminations one End of the pole core, is bolted to the frame and other and has pole Shoe.

(b) Pole Shoes: The pole Shoe is projected part of the pole core has large Crossectional area. It Serves following Purposes

(i) It Spread the flux the flux Uniformly in the air gap and offers low reluctance path to the flux.

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Field coils: Field Coils are made of Copper Wire or copper strip. They are former wound and inserted around the pole core. When field windings are excited by dc supply, they become Electromagnets and produce the working flux.

Armature: Armature is a System of Conductor or Coil Which is free to rotat on the Supported bearings. Emf's and torques are developed in the armature Coils. The armature Consist of the following Parts.

Commutator: The commutator is the important part of the dc machine. It performs the following functions.

(a) To ~~Collect~~ collect (or to allow) the Current from (or to) the armature Conductor.

(b) To Convert the alternating Current of the armature into Unidirectional Current in the External circuits with the help of brushes and Vice-versa.

Brushes: The function of brushes is to Collect Current from moving Commutator. They are usually made of Carbon or graphite. They are housed in brush holds and are in Contact with Commutator Surface with the help of Spring pressure.

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<u>Bearings</u>: The function of bearings is to support the ~~maching~~ machine -shaft with minimum friction. For dc machines, generally ball bearing or roller bearing are used.