Ohm's Law

The ratio of potential difference (V) between any two points on a conductor to the current (I) flowing between them, is constant, provided the temperature of the conductor does not change.

$\frac{V}{I}$ = constant or $\frac{V}{I} = R$.

law.

Assi

1. Derive the vector form of ohm's law
OR
Relation b/w current Density and electric field

$\vec{J} = ne\vec{V_d}$ V_d = drift velocity.

$\vec{J} = ne\left(\frac{e\vec{E}\tau}{m}\right)$ τ = Tao.

$\Rightarrow \vec{J} = \left(\frac{ne^2\tau}{m}\right)\vec{E}$

Also, $\rho = \frac{m}{ne^2\tau}$

$\Rightarrow \vec{J} = \frac{\vec{E}}{\rho}$ $\left[\sigma = \frac{1}{\rho}\right]$

$\Rightarrow \boxed{\vec{J} = \sigma\vec{E}}$

KVL The sum of voltage rises = sum of voltage drop in closed loop.

KCL The sum of current entering through a ~~funct~~ junction is equal to the sum of current leaving through junction.

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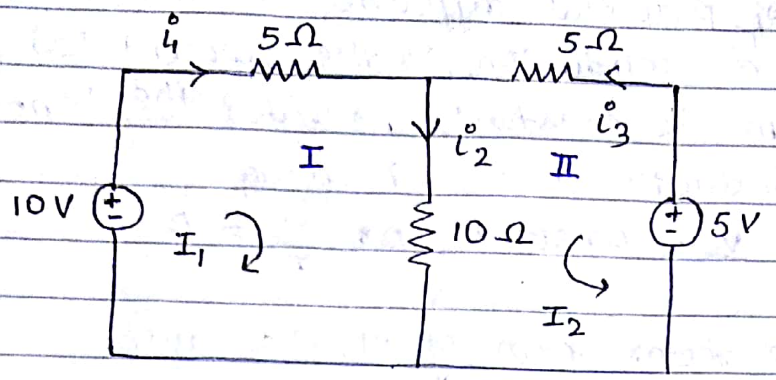
KVL

1. Find the Branch currents and loop currents in the circuit



Branch currents are : i_1, i_2 and i_3

Loop currents are : I_1 and I_2

From loop I,

$$5i_1 + \cancel{5}\,10\,i_2 = 10 \quad \text{—(1)}$$

From loop II,

$$5i_3 + 10\,i_2 = 5 \quad \text{—(11)}$$

$i_1 = I_1$; $i_2 = I_1 + I_2$; $i_3 = I_3$

Replace it in (1) and (11),

$$5I_1 + 10I_1 + 10I_2 = 10$$

$$5I_2 + 10I_1 + 10I_2 = 5$$

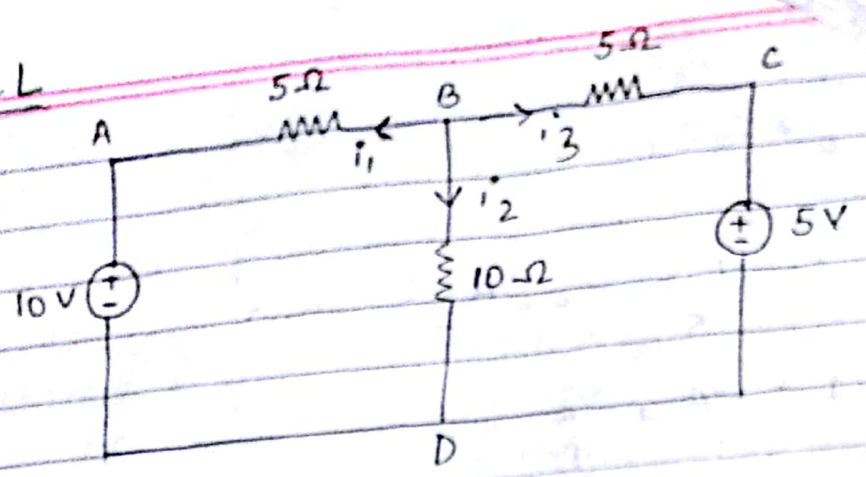
$$3I_1 + 2I_2 = 2$$

$$2I_1 + 3I_2 = 1$$

$$-5I_2 = 1$$

$I_2 = \frac{-1}{5}$ A $\qquad$ $I_1 = \frac{4}{5}$ A

KCL



From KCL,

$$i_1 + i_2 + i_3 = 0$$

$$\frac{V_B - 10}{5} + \frac{V_B - 0}{10} + \frac{V_B - 5}{5} = 0$$

$$\Rightarrow \frac{V_B}{5} - 2 + \frac{V_B}{10} + \frac{V_B}{5} - 1 = 0$$

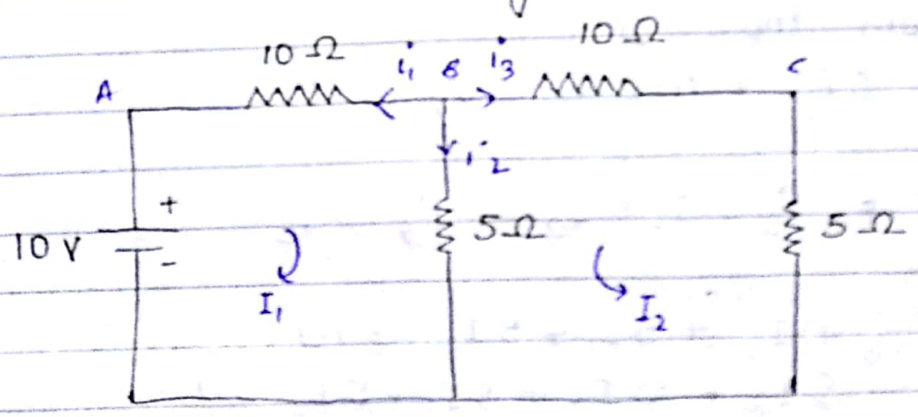
$$\Rightarrow \frac{2V_B}{5} + \frac{V_B}{10} = 3$$

$$\Rightarrow \frac{4V_B + V_B}{10} = 3 \quad \Rightarrow \frac{5V_B}{10} = 3$$

$$\Rightarrow V_B = 6$$

$$i_1 = \frac{V_B - 10}{5} = -\frac{4}{5} \qquad i_2 = \frac{3}{5} \qquad i_3 = \frac{1}{5}$$

2. Find the branch currents using both KCL and KVL in the following circuit :



I) KCL

From KCL,

$$i_1 + i_2 + i_3 = 0$$

$$\frac{V_B - 10}{10} + \frac{V_B - 0}{5} + \frac{V_B - 0}{15} = 0$$

$$\frac{V_B}{10} - 1 + \frac{V_B}{5} + \frac{V_B}{15} = 0$$

$$\cancel{\frac{2V_B}{10} + \frac{V_B}{5} = 1} \Rightarrow \cancel{\frac{2V_B}{5} = 1}$$

$$\cancel{V_B = \frac{5}{2}}$$

$$\cancel{\frac{V_B}{5}\left(\frac{V_B}{2} + V_B\right.}$$

$$\frac{V_B}{5}\left(\frac{1}{2} + 1 + \frac{1}{3}\right) = 1 \Rightarrow \frac{V_B}{5} \times \frac{11}{6} = 1$$

$$\Rightarrow V_B = \frac{30}{11}$$

$$i_1 = \frac{\frac{30}{11} - 10}{10} = 0.7272$$

$$\cancel{= \frac{\frac{30 - 110}{11}}{10} = -\frac{80 \times 10}{11}} = 0.7272$$

$$= \cancel{\frac{-800}{121}} = \cancel{0.72072}$$

II) KVL

From loop I,

$$10 i_1 + 5 i_2 = 10$$

From loop II,

$$5 i_3 + 10 i_3 + 5 i_2 = 0.$$

$$i_1 = I_1 ; \quad i_2 = I_1 + I_2 \quad i_3 = I_2$$

$$10 I_1 + 5 I_1 + 5 I_2 = 10$$

$$5 I_2 + 10 I_2 + 5 I_1 + 5 I_2 = 0$$

$$\Rightarrow 15 I_1 + 5 I_2 = 10$$

$$5 I_1 + 20 I_2 = 0$$

$$3I_1 + I_2 = 2 \quad \times 1$$
$$I_1 + 4I_2 = 0 \quad \times 3$$

$$3I_1 + I_2 = 2$$
$$3I_1 + 12I_2 = 0$$
$$(-) \quad (-) \quad (-)$$

$$-11 I_2 = 2$$

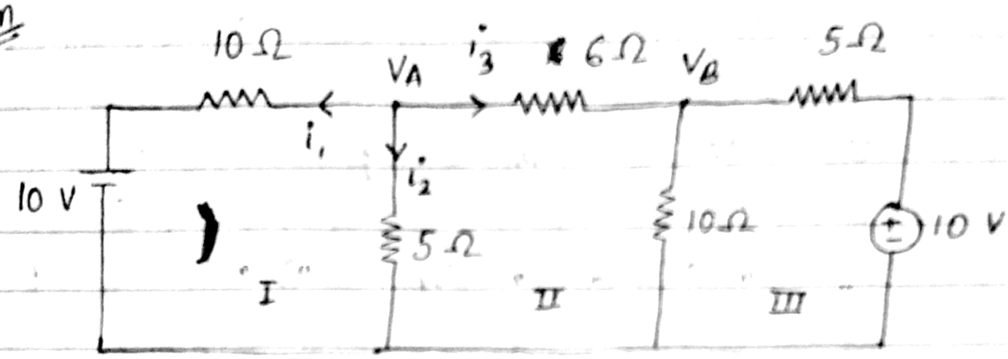
$$I_2 = \frac{-2}{11}$$

$$I_1 = -4I_2 = \frac{4 \times 2}{11} = \frac{8}{11}$$

$$i_1 = \frac{8}{11} = 0.727272$$

Assign

2.



At node A,

$$i_1 + i_2 + i_3 = 0$$

$$\frac{V_A - 10}{10} + \frac{V_A - 0}{5} + \frac{V_A - V_B}{6} = 0 \quad \text{— (i)}$$

At node B,

$$\frac{V_B - V_A}{6} + \frac{V_B - 0}{10} + \frac{V_B - 10}{5} = 0 \quad \text{— (ii)}$$

From (i),

$$\frac{V_A}{10} - 1 + \frac{V_A}{5} + \frac{V_A}{6} - \frac{V_B}{6} = 0$$

$$\Rightarrow \frac{V_A}{5} \times \frac{3}{2} + \frac{V_A}{6} - \frac{V_B}{6} = 1$$

$$\Rightarrow \frac{3V_A}{10} + \frac{V_A}{6} - \frac{V_B}{6} = \frac{7V_A}{15} - \frac{V_B}{6} = 1$$

$$\Rightarrow \frac{7V_A}{15} - \frac{V_B}{6} = 1 \quad \text{— (iii)}$$

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$$\frac{V_B}{6} - \frac{V_A}{6} + \frac{V_B}{10} + \frac{V_B}{5} - 2 = 0$$

$$\frac{7}{15}V_B - \frac{V_A}{6} = 2 \quad \text{— (iv)}$$

$$\frac{7V_A}{15} - \frac{V_B}{6} = 1 \qquad \times 1$$

$$\frac{7}{15}V_B - \frac{V_A}{6} = 2 \qquad \times \frac{42}{15}$$

$\frac{7}{15} \times \frac{6}{6}$

$42 \quad \frac{45}{15}$

$$\frac{7V_A}{15} - \frac{V_B}{6} = 1$$

$$-\frac{7V_A}{15} + \frac{7\times42}{15\times15}V_B = \frac{84}{15}$$

$\frac{7}{15} \times \frac{42}{15}$

$\frac{294}{225}$

1.306

0.166

$$1.14\,V_B = 6.6$$

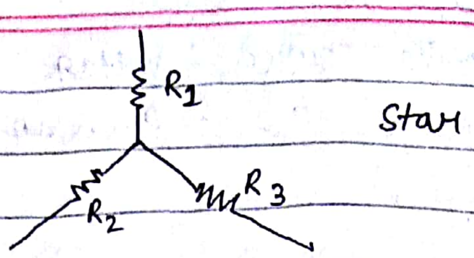
$$V_B = 5.78$$

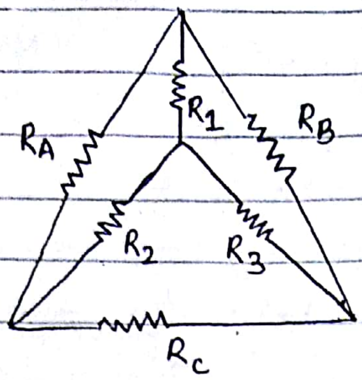
$$\frac{7}{15} \times 5.78 - 2 = \frac{V_A}{6}$$

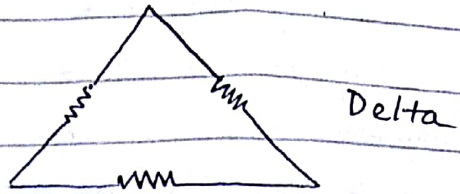
$$V_A = 4.184$$

$$i_2 = \frac{V_A}{5} = 0.83$$

Star and Delta







1. Delta $\rightarrow$ Star

R_A, R_B and R_C are Known

$$R_1 = \frac{R_A \cdot R_B}{R_A + R_B + R_C}$$

$$R_2 = \frac{R_B \cdot R_C}{R_A + R_B + R_C}$$

$$R_3 = \frac{R_A \cdot R_C}{R_A + R_B + R_C}$$

2. Star $\longrightarrow$ Delta

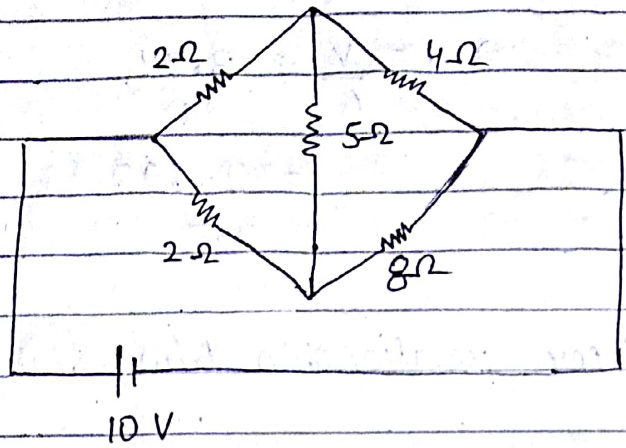
R_1, R_2 and R_3 are Known

$$R_A = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_2}$$

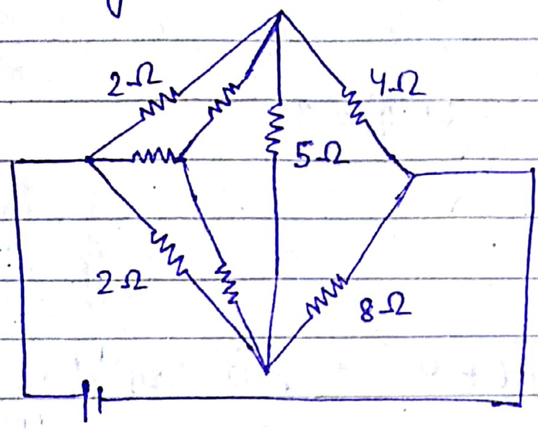
$$R_B = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_3}$$

$$R_C = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_1}$$

3. Find out the total current in the circuit



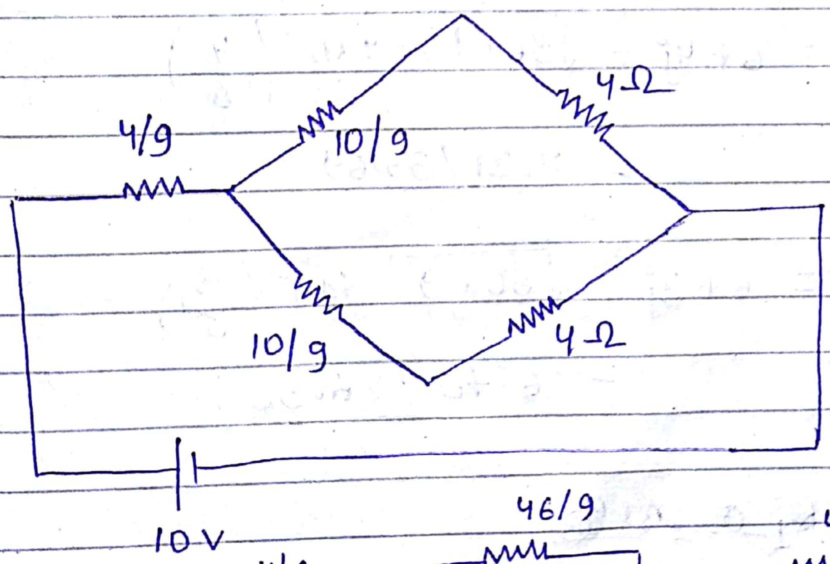
Assuming star,

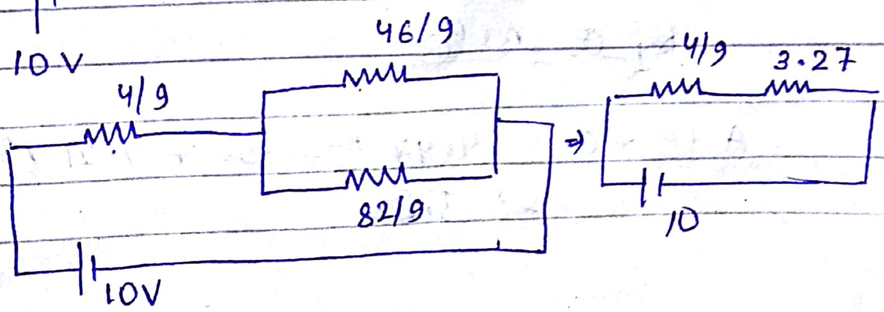


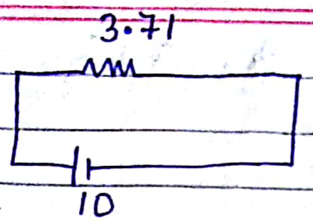
$\frac{10}{9}$

After rearranging it,

$$\frac{\frac{10}{9} \times 4}{\frac{10}{9} + 4} = \frac{40}{9}$$







$V = IR$

$\Rightarrow I = \frac{V}{R} = \frac{3.71}{10}$

$= 2.695$

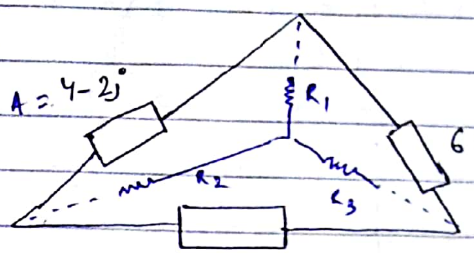
$\simeq 2.7$

Assign

3. Derive the inter relationship b/w star and delta.

Assign

4.



$A = 4-2j = \sqrt{16+4} = \sqrt{20}\ \tan^{-1}\left(\frac{-2}{4}\right)$

$= 4.47 \angle -26.56$

$B = 6+4j = \sqrt{36+16}\ \tan^{-1}\left(\frac{4}{6}\right)$

$= 7.21 \angle 33.69$

$C = 6+3j = \sqrt{36+9}\ \tan^{-1}\left(\frac{3}{6}\right)$

$= 6.70 \angle 26.56$

~~Req = A.B~~

$A + B + C = 4.47 \angle -26.56 + 7.21 \angle 33.69 + 6.70 \angle 26.56$

~~= 18.38~~

$a(\cos\theta + i\sin\theta)$

253.1281

24.9801

$= 4.47(0.89 - j0.44) + 7.21(0.83 + j0.55)$
$+ 6.70(0.89 + j0.447)$

$= 3.97 - 1.96j + 5.98 + 3.96j + 5.96 + 2.99j$

$= 15.91 + 4.99j \simeq 16 + 5j = 16.76\angle 17.35$

$\cancel{= \sqrt{278.0282} \tan^{-1}\left(\frac{4.99}{15.91}\right) = 16.67\angle 17.41}$

$$R_1 = \frac{(4-2j)(6+4j)}{16.67\angle 17.41} = \frac{24 + 16j - 12j + 8}{16.67\angle 17.41}$$

$$= \frac{32 + 4j}{16.76\angle 17.35}$$

$$= \frac{32.24\angle 7.12}{16.76\angle 17.35}$$

$= 1.92\angle -10.23$

$= 1.88 + j(-0.33)$

$$\cancel{= \frac{32 + 4j}{16.67\angle 17.41} = \frac{4(8+j)}{16.67\angle 17.41} = \frac{4 \times 8.06\angle 7.12}{16.67\angle 17.41} = 1.93\angle -10.29 = 1.89 + j(-0.34)}$$

$$R_2 = \frac{A \cdot C}{A + B + C} = \frac{(4-2j)(6+3j)}{16.76}$$

$$= \frac{24 + 12j - 12j + 6}{16.76}$$

$$= \frac{30}{16.76\angle 17.35}$$

$= 1.78\angle -17.35$

$= 1.7 + j(-0.53)$

$$R_3 = \frac{(6+4j)(6+3j)}{16.76 \angle 17.35}$$

$$= \frac{36 + 18j + 24j - 12}{16.76 \angle 17.35}$$

$$= \frac{24 + 42j}{16.76 \angle 17.35} = \frac{48.37 \angle 60.25}{16.76 \angle 17.35}$$

$$= 2.88 \angle 42.9$$

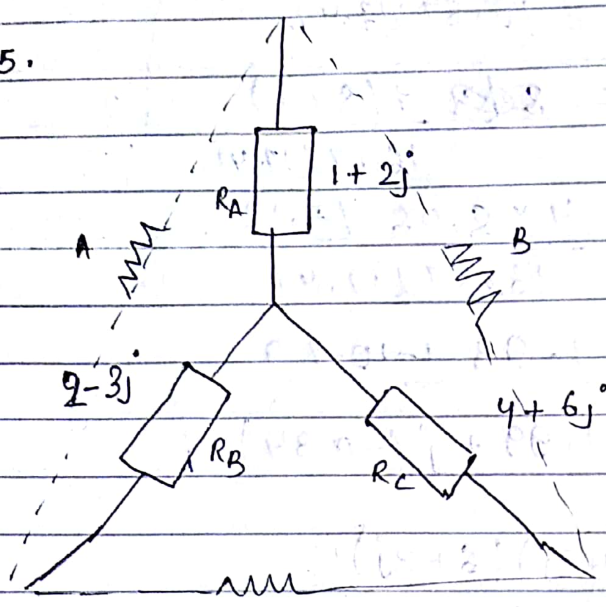
$$= 2.10 + j(1.96)$$

$R_1 = 1.88 + j(-0.33)$

$R_2 = 1.7 + j(-0.53)$

$R_3 = 2.10 + j(1.96)$

5.



$R_A = 1+2j$

$= 2.23 \angle 63.43$

$R_B = 2-3j$

$= 3.6 \angle -56.30$

$R_C = 4+6j$

$= 7.21 \angle 56.30$

$D = R_A R_B + R_B R_C + R_C R_1$

$= (1+2j)(2-3j) + (2-3j)(4+6j) + (4+6j)(1+2j)$

$= 2 - 3j + 4j + 6 + 8 + 12j - 12j + 18 + 4 + 8j + 6j - 12$

$= 26 + 15j$

$= 30.01 \angle 29.98 \approx 30.01 \angle 30$

$$A = \frac{D}{2-3j} = \frac{30.01 \angle 30}{3.6 \angle -56.30} = 8.33 \angle 86.3$$

$= 0.53 + j(8.31)$

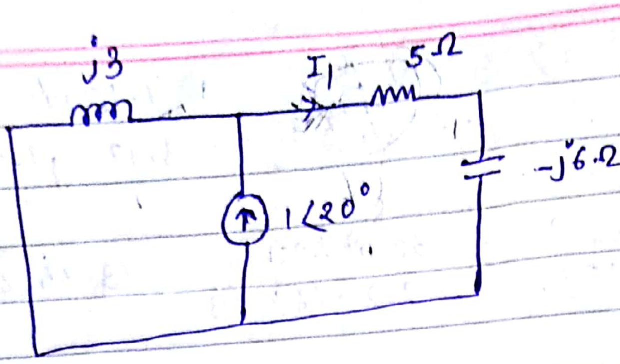
$$B = \frac{D}{4+6j} = \frac{30.01 \angle 30}{7.21 \angle 56.30} = 4.16 \angle -26.3$$

$$= 3.72 + j(-1.84)$$

$$C = \frac{30.01 \angle 30}{1+2j} = \frac{30.01 \angle 30}{2.23 \angle 63.43} = 13.45 \angle -33.43.$$

$$I_1 = \frac{j3}{j3+5-j6} \times 1\angle 20^\circ$$

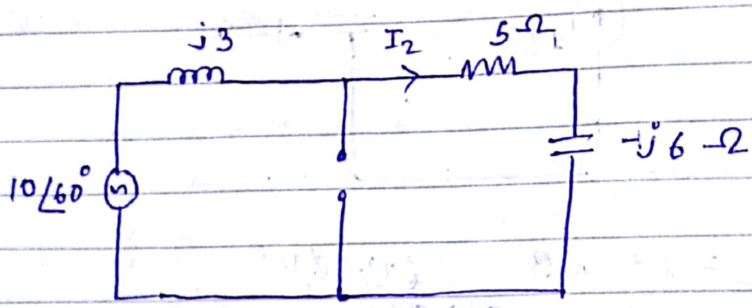
$$I_2 = \frac{5-j6}{j3+5-j6} \times 1\angle 20$$



$$I_1 = \frac{j3}{5-j6+j3} \times 1\angle 20^\circ$$

$$= 0.515 \angle 120^\circ \text{ A}$$

$$= -0.264 + j0.442 \text{ A}$$



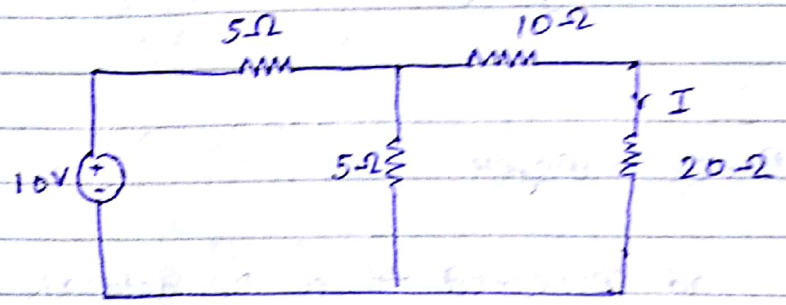
$$I_2 = \frac{10\angle 60^\circ}{5-j3} = 1.71 \angle 90.9^\circ = -0.026 + j1.715 \text{A}$$

$$I = I_1 + I_2$$

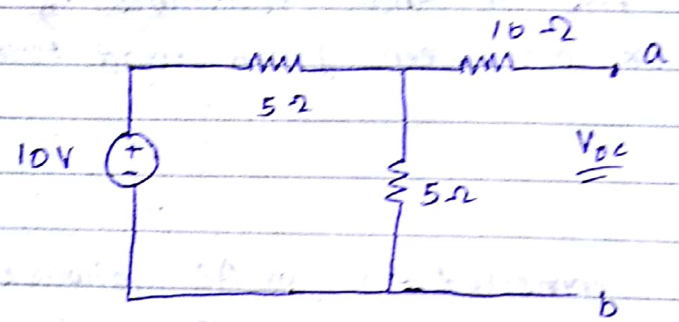
$$= -0.29 + j2.157.$$

Thevenin's th

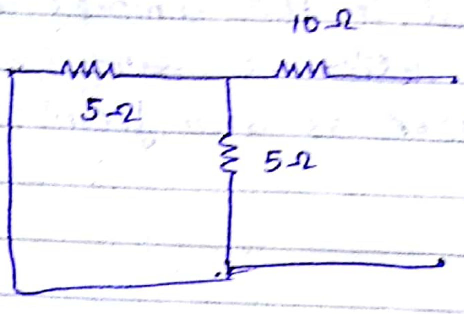
Any linear active network consisting of dependent/independent sources and linear bilateral network elements (resistances, conductance, inductance) can be replaced by an equivalent circuit consisting of a voltage source in a series with a resistance. The voltage source being a open circuited voltage is across the open-circuited load resistance and the resistance being the internal resistance of load ~~[illegible]~~ source network looking ~~[illegible]~~ through open circuited load terminal. with All the active sources either replaced by their internal resistances (if any) or short-circuited (in case of voltage source) or open circuited (in case of current source).



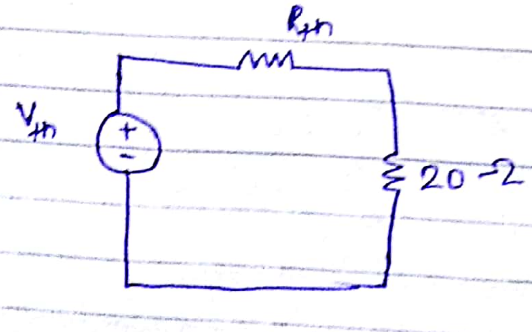
$R_L = 20\Omega$



$V_{oc} = V_{th} = 5V$

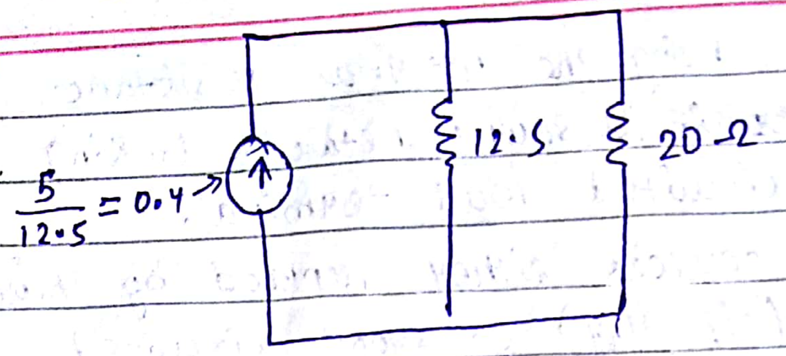


$R^{th} = 5 \| 5 + 10$
$= 12.5$



$I_{th} = \dfrac{5}{12.5 + 20}$
$= 0.153\,A$

Norton.

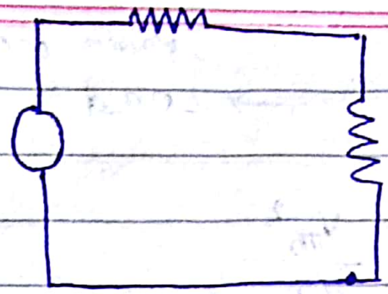


$$I_N = \frac{12.5}{32.5} \times 0.4$$

Maximum Power transfer

A resistive load connected to a DC network recieves maximum power when the load resistance is equal to the internal resistance of source network as seen from load terminal.

An impedence connected to an AC network recieves maximum power when the Load impedence is equal to the complex conjugate of the internal resistance ~~same as above.~~ of source network as seen from load terminal.



$$P_L = I_L^2 R_L$$

$$= \left(\frac{V_{Th}}{R_{Th}+R_L}\right)^2 \cdot R_L$$

$\frac{dP_L}{dR_L} = 0$, then power will be maximum.

$$\cancel{2\left(\frac{V_{Th}}{R_{Th}+R_L}\right)\left(\frac{1}{R_{Th}+R_L}\right)}$$

$$\frac{V_{Th}^2}{(R_{Th}+R_L)^2} \cdot R_L$$

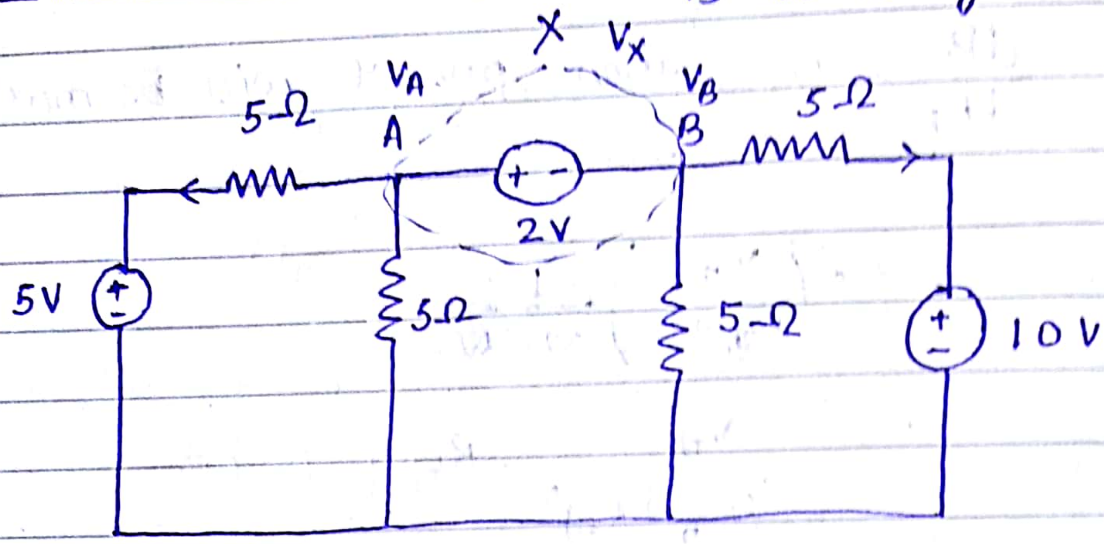
$$\Rightarrow V_{Th}^2 \left[2(R_{Th}+R_L)^2 \cancel{\ldots}\right]$$

$$- (R_{Th}+R_L)^2 \cdot 2V_{Th}$$

$$\Rightarrow R_{Th} = R_L$$

Proof ~~the~~ Maximum power transfer theorem for AC circuit.

Super Node Analysis (In b/w two Node there is a voltage source)



At Node X,

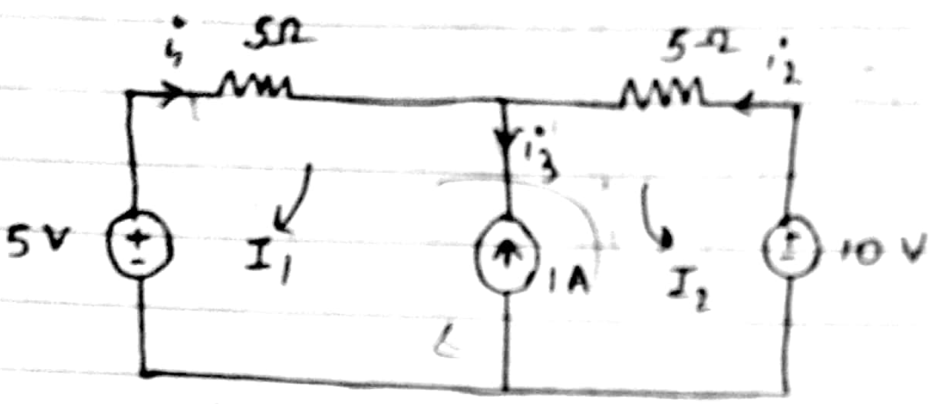
$$\frac{V_A - 5}{5} + \frac{V_A}{5} + \frac{V_B - 10}{5} + \frac{V_B}{5} = 0 \quad \text{— (I)}$$

$$V_A - V_B = 2 \quad \text{— (II)}$$

$V_A =$

$V_B =$

Super Mesh (b/w two mesh a current source)



Considered as 1 mesh

$$5I_2 + 5 = 5I_1 + 10 \quad — ①$$

Voltage rises = Voltage ~~down~~ drops

$$I_1 + I_2 = -1 \quad — ②$$

$$I_1 = -1 - I_2$$

$$5I_2 + 5 = 5(-1 - I_2) + 10$$

$$\Rightarrow 5I_2 + 5 = -5 - 5I_2 + 10$$

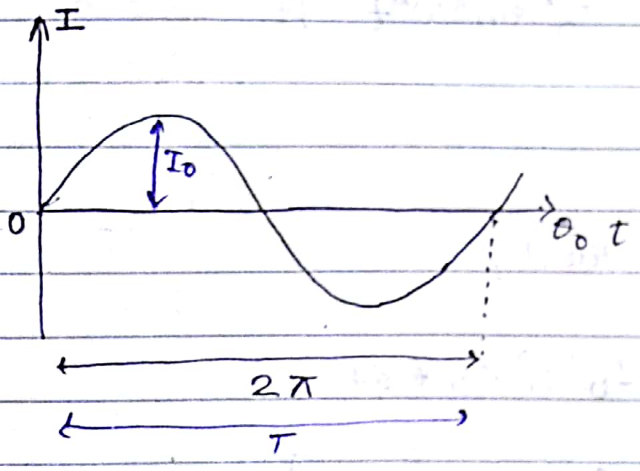
$$\Rightarrow 10I_2 = 0$$

$$\Rightarrow I_2 = 0$$

$$I_1 = -1$$

Rms : value of AC = value of DC ~~***~~ flowing in a circuit producing same amount of ~~***~~ heat as of AC circuit

Avg value.
value of DC charge flowing in a circuit same amount of charge as of AC circuit.



Symmetrical electric signal ;

In a symmetrical electrical signal : average value half ~~of~~ over a half period.
In a unsymmetrical electrical signal : average value over a complete period

$$I_{av} = \frac{1}{T/2}\int_0^{T/2} i\,dt = \frac{1}{\pi}\int_0^{\pi} i\,d\theta.$$

$i = I_0 \sin \omega t$

$$I_{avg} = \frac{1}{\pi}\int_0^{\pi} I_0 \sin \omega t \, dt$$

$$= \frac{I_0}{\pi} \int \left[\frac{-\cos \omega t}{\omega}\right]_0^{\pi}$$

$$= \frac{I_0}{\pi} \cdot [-1-1]$$

$$= -\left(\frac{-2I_0}{\pi}\right) = \frac{2I_0}{\pi}$$

$$I_{rms}^2 = \frac{1}{2\pi}\int_0^{2\pi} i^2 \, d\theta \qquad \text{mean} = 2\pi$$

$$= \frac{1}{2\pi}\int_0^{2\pi} I_0^2 \sin^2 \omega t \, dt$$

$=$

For half period,

$$= \frac{1}{\pi}\int_0^{\pi} I_0^2 \sin^2 \omega t \, dt$$

$$= \frac{I_0^2}{\pi}\left[\sin^2 \omega t \, dt\right]_0^{\pi}$$

$$= \frac{I_0^2}{2\pi}\left[\frac{1-\cos 2\theta}{2}\right]_0^{\pi}$$

$$= \frac{I_0^2}{4\pi}\int_0^{2\pi} \theta - \frac{\sin 2\theta}{2}$$

$$= \frac{I_0}{\sqrt{2}} A$$

Form factor : Ratio of rms value by Vavg

$: \frac{I_{rms}}{I_{avg}}$

$= \frac{I_0}{\sqrt{2}} \times \frac{\pi}{2 I_0}$

$= \frac{\pi}{2\sqrt{2}} = 1.11$

Peak factor : Ratio of peak value by rms value

$= \frac{I_{peak\ value}}{I_{rms}}$

$= I_0 \times \frac{\sqrt{2}}{I_0}$

$= \sqrt{2} = 1.414$

For full ~~value~~ period.

$I_{avg} = \frac{1}{T}\int_0^T i\,dt$

$= \frac{1}{T}\int_0^{T/2} i\,dt + \frac{1}{T}\int_{T/2}^{T} i\,dt$

$= \frac{1}{T}\int_0^{T/2} i\,dt$

$= \frac{1}{2\pi}\int_0^{\pi} i\,dt$

$T/2 = \pi$

$T = 2\pi$

$= \frac{I_0}{\pi}$ A

$I_{rms}^2 = \frac{1}{2\pi}\int_0^{2\pi} i^2\,d\theta = \frac{1}{2\pi}\int_0^{\pi} i^2\,d\theta + \frac{1}{2\pi}\int_{\pi}^{2\pi} i^2\,d\theta$

$= \frac{1}{2\pi}\int_0^{\pi} i^2\,d\theta = \frac{I_0}{2}$ A

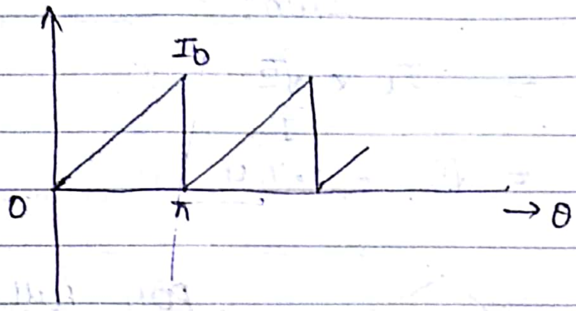
$$\text{Form factor} = \frac{I_0}{2} \times \frac{\pi}{I_0}$$

$$= \frac{\pi}{2} = 1.57$$

$$\text{Peak factor} = I_0 \times \frac{2}{I_0}$$

$$= 2.$$

1. Find form factor and peak factor of :



$\cancel{y = mx + c}$

$$y = \left\{\frac{y_1 - y_2}{x_1 - x_2}\right\} x$$

$$I_{av} = \frac{1}{T/2} \int_0^{T/2} i \, dt$$

$$= \frac{1}{\pi} \int_0^{\pi} i \, d\theta \qquad i = \frac{I_0}{\pi} \cdot \theta$$

$$= \frac{1}{\pi} \int_0^{\pi} \frac{I_0}{\pi} t \, dt$$

$$= \frac{I_0}{\pi^2} \left[\frac{t^2}{2}\right]_0^{\pi}$$

$$= \frac{I_0}{2\pi^2} \left[\pi^2\right]$$

$$= \frac{I_0}{2}$$

$$I_{rms}^2 = \frac{1}{\pi}\int_0^{2\pi} i^2\, d\theta$$

$$= \frac{1}{2\pi}\int_0^{2\pi} \frac{I_0^2}{\pi^2} t^2\, dt$$

$$= \frac{I_0^2}{\pi^3}\left[\frac{t^3}{3}\right]_0^{2\pi}$$

$$= \frac{I_0^2}{3\pi^3}\left[t^3\right]_0^{2\pi}$$

$$= \frac{I_0^2}{3\pi^3}\left[8\pi^3\right] =$$

$$= \frac{I_0^2}{3}, \quad I_{rms} = \frac{I_0}{\sqrt{3}}$$

~~Peak value~~

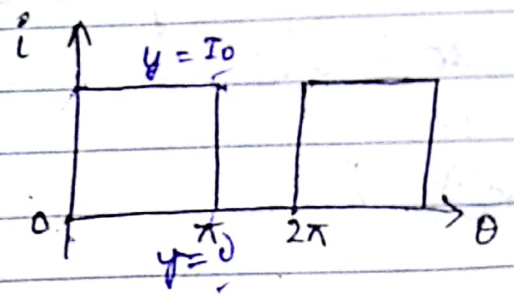
Form factor $= \frac{I_0}{\sqrt{3}} \times \frac{2}{I_0}$

$= 1.15$

Peak factor $= I_0 \times \frac{\sqrt{3}}{I_0}$

$= 1.73$

2.



$$i = \frac{I_0 - I_0}{\pi - 0}\theta$$

$$\cancel{i = \frac{I_0}{2\pi}t + 0}$$

$$I_{av} = \frac{1}{T}\int_0^T i\, dt$$

$$= \frac{1}{T}\int_0^{T/2} i\, dt + \frac{1}{T}\int_{T/2}^{T} 0\, dt$$

$$= \frac{1}{T}\int_0^{T/2} i\, dt + 0$$

$$I_{av} = \frac{1}{2\pi}\int_0^{\pi} I_0\, dt = \frac{I_0}{2\pi}\times \pi = \frac{I_0}{2}$$

$$I_{rms}^2 = \frac{1}{\pi}\int_0^{2\pi} i^2 d\theta$$

$i = I_0 t$

$$= \frac{1}{\pi}\int_0^{2\pi} I_0^2 \, dt$$

$$= \cancel{\frac{I_0^2}{\pi^3}\left[\frac{t^3}{3}\right]_0^{2\pi}}$$

$$= \frac{I_0^2}{\pi} \times \pi$$

$$I_{rms} = I_0$$

$$= \cancel{\frac{I_0^2}{12\pi^3} \times 8\pi^3}$$

$$= \cancel{I_0^2 \, \frac{8}{12}} = \cancel{\frac{2I_0^2}{3}} = \cancel{\sqrt{\frac{2}{3}}\, I_0}$$

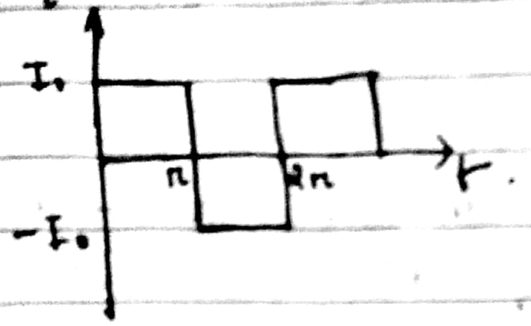
$$= \cancel{0.81\, I_0}$$

Form factor

$$= \frac{I_0}{I_0} \times 2$$

$$= 2$$

Peak factor $= \dfrac{I_0}{I_0} = 1$



$i = I_0 , -I_0$

$$i = \begin{cases} I_0 & 0 < t < \pi \\ -I_0 & \pi < t < 2\pi \end{cases}$$

$$I_{rms}^2 = \frac{1}{T} \int_0^{T/2} i^2 dt$$

$$\cancel{= \frac{1}{T/2} \int_0^{T/2} I_0 \, dt + \frac{1}{T/2} \int_0^{T/2} -I_0 \, dt}$$

$$= \frac{1}{2\pi} \left[\int_0^{\pi} I_0^2 dt + \int_{\pi}^{2\pi} (-I_0)^2 dt \right]$$

$$= \frac{1}{2\pi} \left[I_0^2 (t)_0^{\pi} + I_0^2 (t)_{\pi}^{2\pi} \right]$$

$$= \frac{I_0^2}{2\pi} (\pi + \pi) = \frac{I_0^2}{2\pi} \times 2\pi = I_0^2$$

$I_{rms} = I_0$

$$I_{avg} = \frac{1}{T/2} \int_0^{T/2} i \, dt = \frac{1}{\pi} \int_0^{\pi} I_0 \, dt$$

$$= \frac{I_0}{\pi} \times \pi = I_0$$

Form factor = 1

Peak factor = $\frac{I_0}{I_0} = 1$

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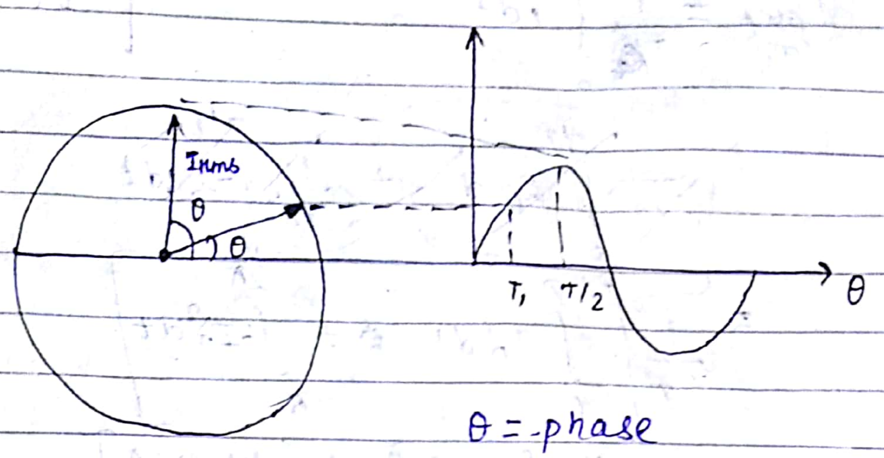
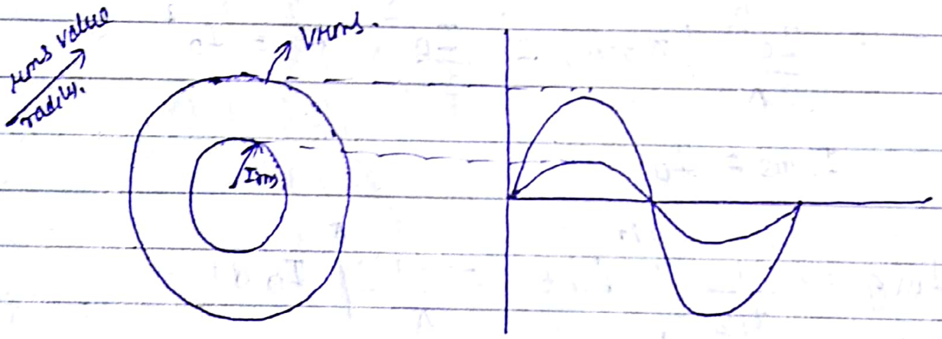
Phasor quantity

Only sunisoidal quantity can be represented as a phasor diagram and the magnitude of that phasor is rms value of that quantity.



θ = phase

V = IR

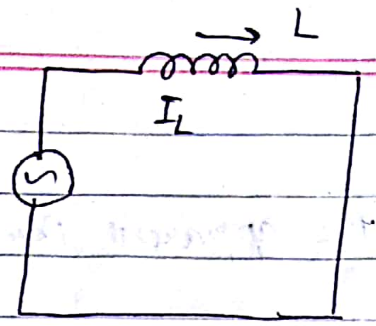


In a resistive ckt, current and voltage are in same phase.

$$E = E_0 \sin \omega t$$

$$I = \frac{E_0}{R} \sin \omega t$$

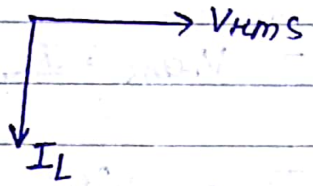
$$= I_0 \sin \omega t$$



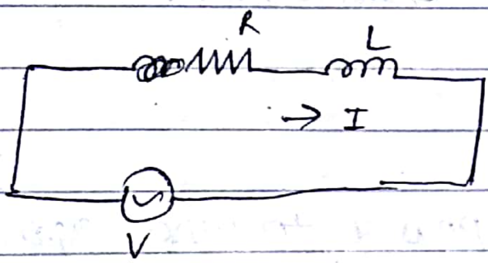
$V = V_0 \sin\omega t$

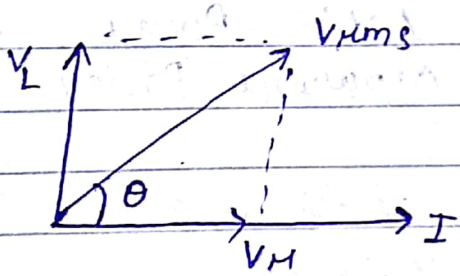
$I_L = \frac{V}{jX_L} \sin\omega t$

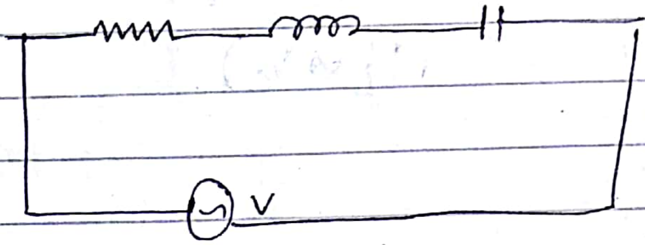
$= \frac{V}{X_L} \sin(\omega t - 90^\circ)$

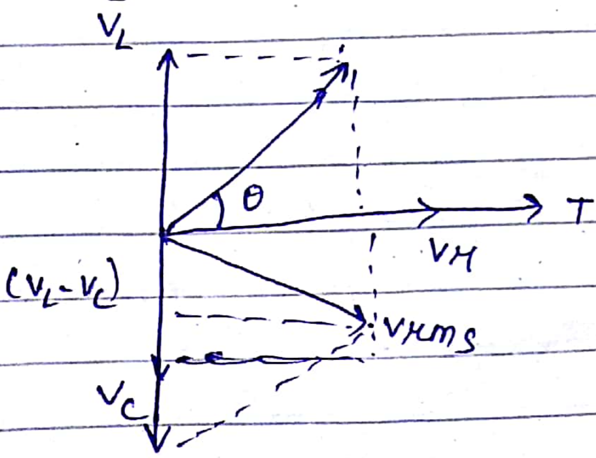


V is reference.









Power factor angle

$P = V_{rms} I_{rms}$ P = apparent Power

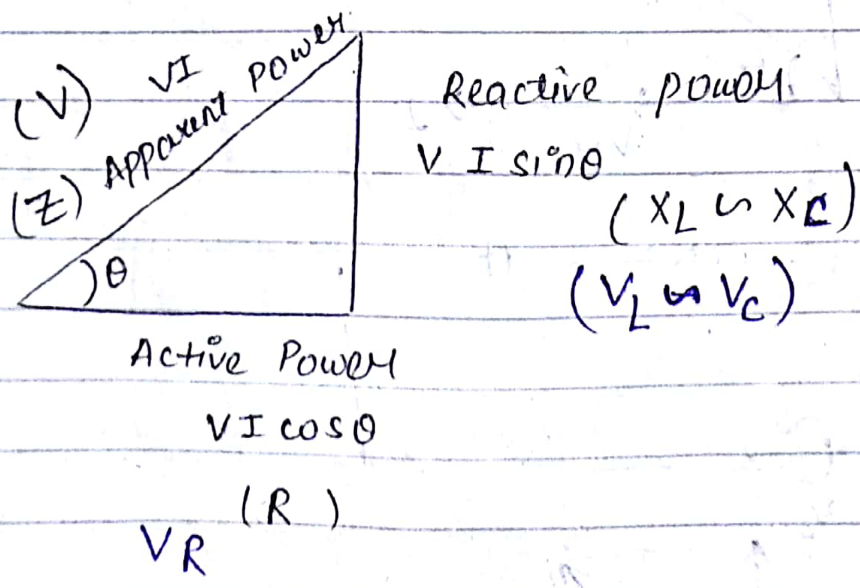
Unit of P = VA = Volt-Ampere.

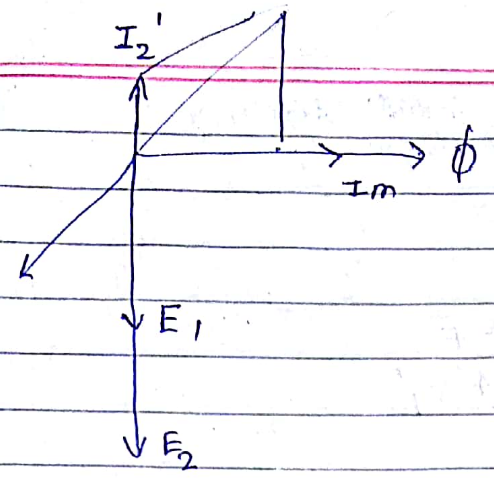
Active / Available Power = $V_{rms} \cdot I_{rms} \cos\theta$

Reactive Power = $V_{rms} \cdot I_{rms} \sin\theta$.

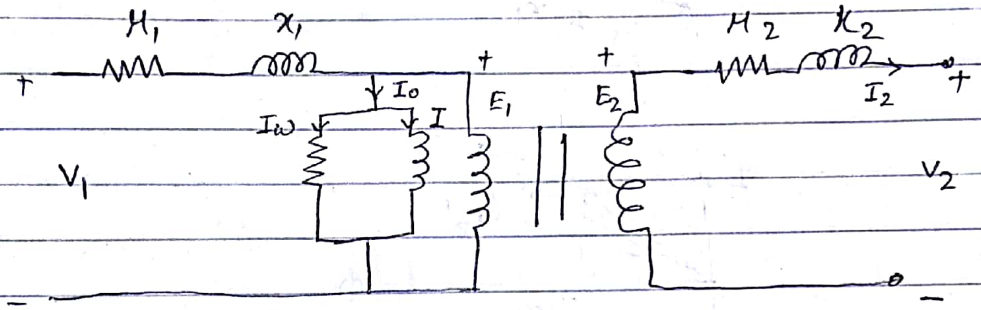
Power factor

The ratio of active power to the apparent Power. $= \frac{\text{Active Power}}{\text{apparent Power}}$



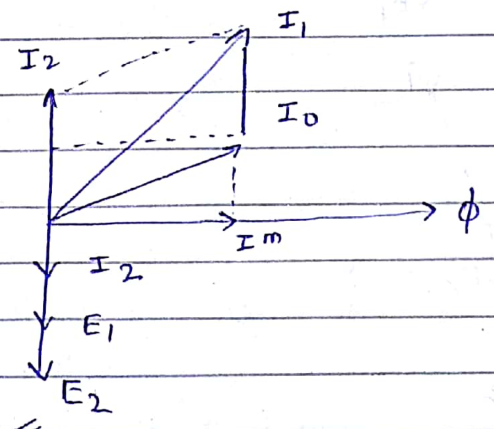


— X —

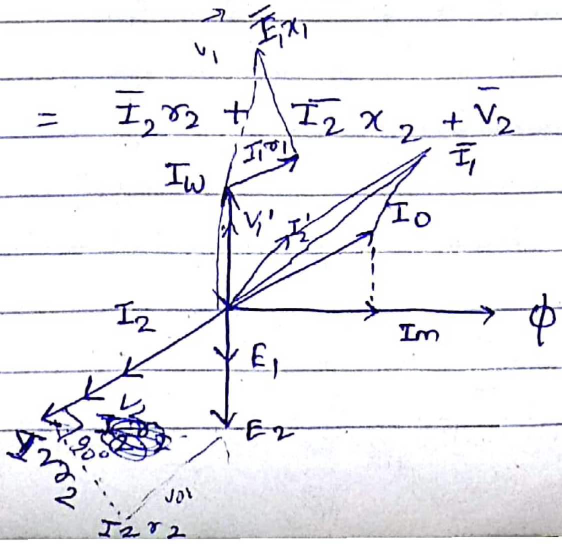


Applying KVL at Primary, phasor eqn

$$V_1 = \bar{I}_1 r_1 + \bar{I}_1 x_1 + \bar{E}_1 \quad \text{—} \; (1)$$



$$E_2 = \bar{I}_2 r_2 + \bar{I}_2 x_2 + \bar{V}_2$$



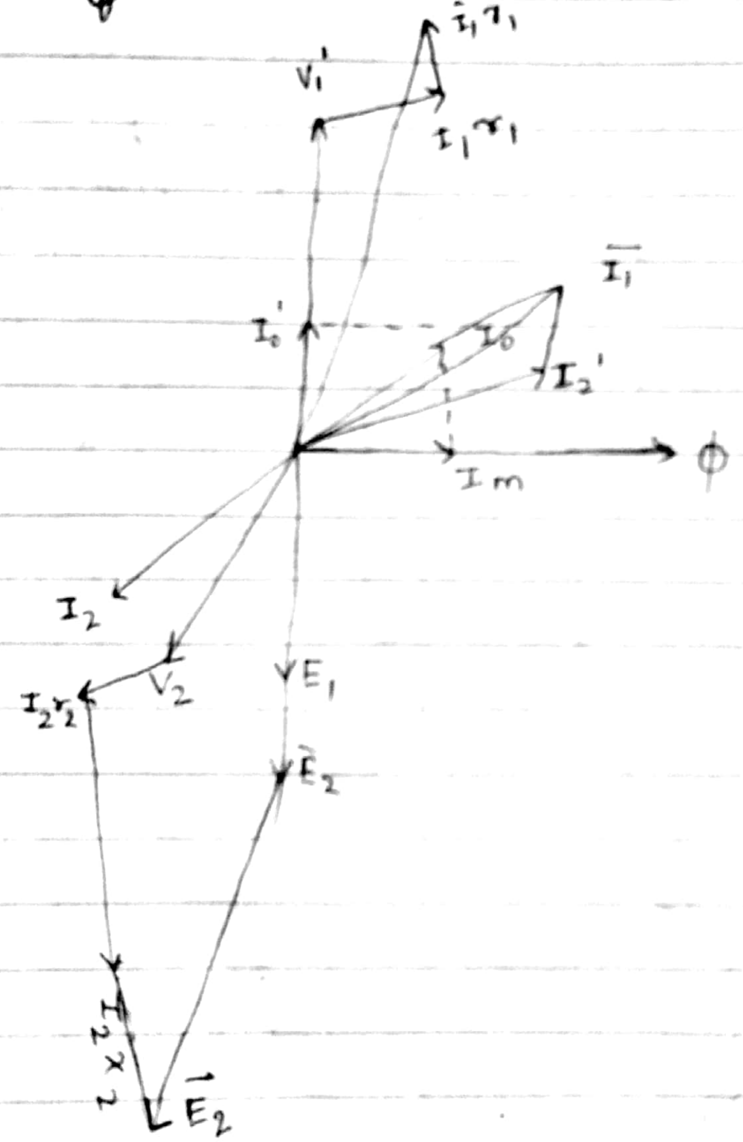
unity power factor load.

$E_1 = -\overline{V_1}'$ [(-) to indicate direction not magnitude.]

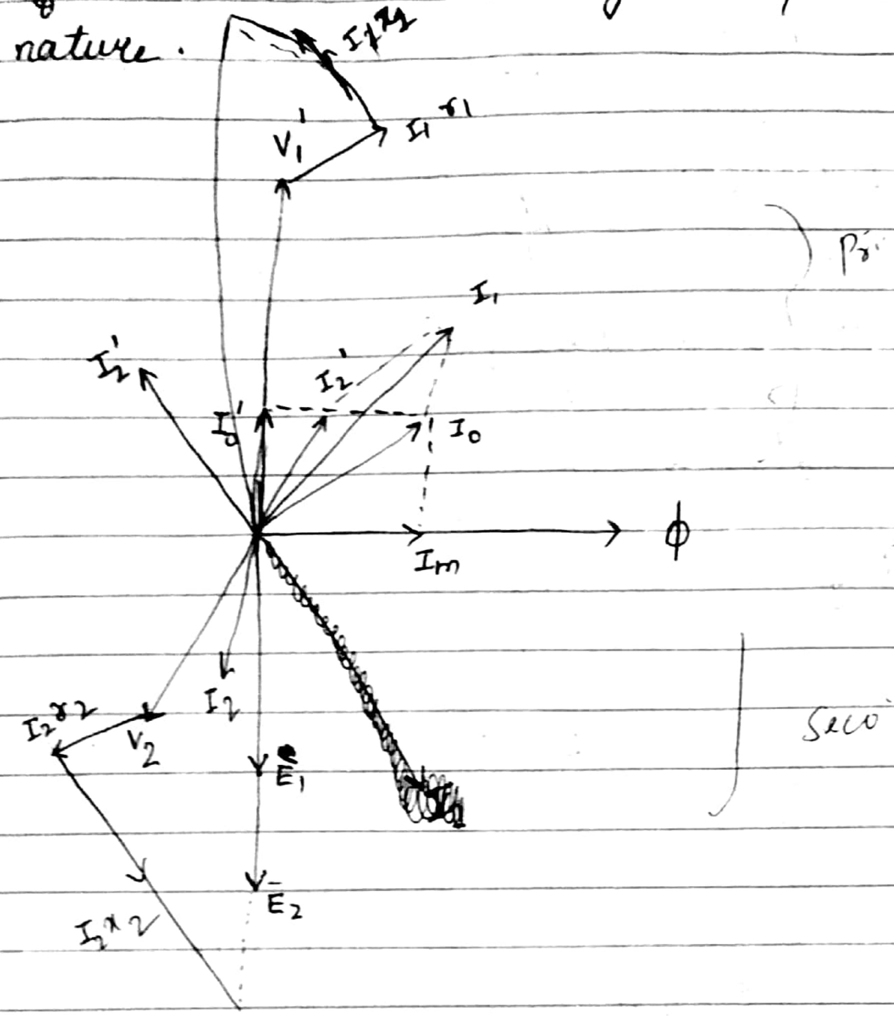
From ①,

$$\overline{V_1} = \overline{I_1} r_1 + \overline{I_1} x_1 + \overline{E_1}$$
$$= \overline{I_1} r_1 + \overline{I_1} x_1 + V_1'$$

ii) If the Load connected is lagging

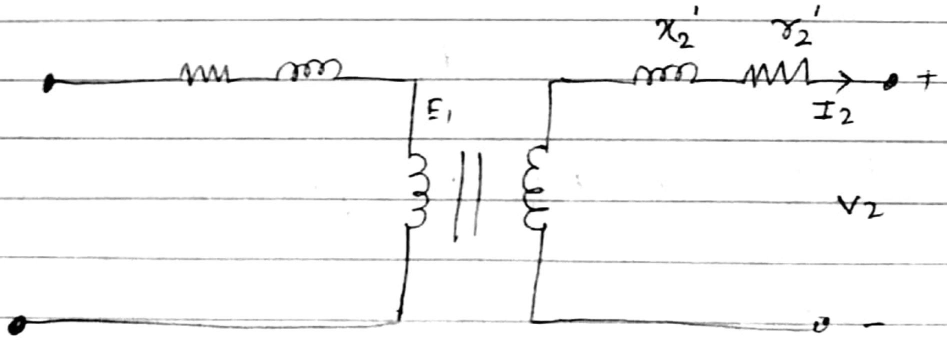


iii) If the Load is leading or capacitive in nature.



i) Reffered to primary

$$\frac{E_1}{N_1} = \frac{E_2}{N_2} \Rightarrow E_2 = \frac{N_2}{N_1} E_1$$



Value of E_2 is reffered to primary $= E_2'$

$N_2 \longrightarrow r_2$

$N_1 \longrightarrow r_2 \left(\frac{N_1}{N_2}\right)^2$

$$\frac{E_2'}{E_2} = \frac{N_1}{N_2}$$

$$E_2' = \frac{N_1}{N_2} E_2$$

$N_2 \longrightarrow r_2$

For 1 turn $\longrightarrow \dfrac{r_2}{N_2^2}$

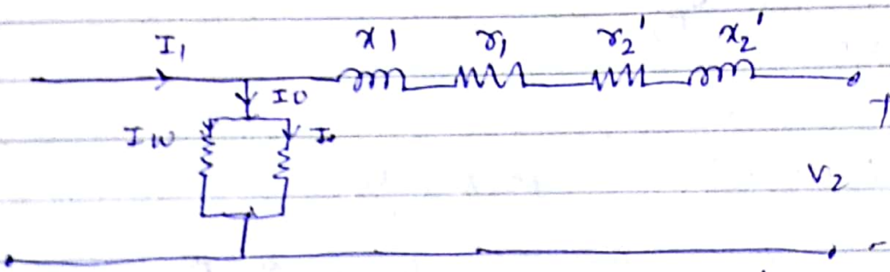
$$N_1' \longrightarrow r_2 \times \left(\frac{N_1}{N_2}\right)^2$$

$$r_2' = r_2 \left(\frac{N_1}{N_2}\right)^2$$

$$x_2' = x_2 \left(\frac{N_1}{N_2}\right)^2$$

$$I_2' = I_2 \left(\frac{N_2}{N_1}\right)$$

After refferring, it is known as approximate equivalent circuit



I_0 is very small

$$r_1 + r_2' = R_{01}$$

$$x_1 + x_2' = X_{01}$$

R and X refferred to primary.

ii) Referred to secondary

value of E_1' is reffered to secondary $= E_1'$

$$\frac{E_1'}{E_1} = \frac{N_2}{N_1}$$

$$E_1' = \left(\frac{N_2}{N_1}\right) E_1 \qquad x_1' = \left(\frac{N_2}{N_1}\right)^2 x_1$$

$$r_1' = \left(\frac{N_2}{N_1}\right)^2 r_1 \qquad I_1' = \frac{N_1}{N_2} I_1$$

$$I_W' = \frac{N_1}{N_2} I_W \qquad I_m' = \frac{N_1}{N_2} I_m$$

$$R_W' = \left(\frac{N_2}{N_1}\right)^2 R_W \qquad X_m' = \left(\frac{N_2}{N_1}\right)^2 X_m$$

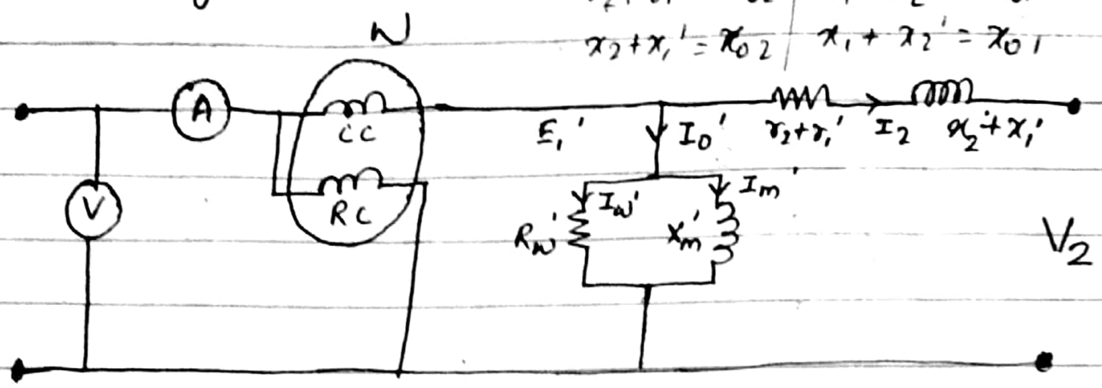
$$r_1' + r_2 = R_{02}$$
$$x_1' + x_2 = x_{02}$$

R_{02} and x_{02} are reffered to secondary

As the name suggest, we will open the circuit Apply rated voltage. Open-ckt test perform on low voltage side

$r_2 + r_1' = R_{02}$ | $r_1 + r_2' = R_{01}$

$x_2 + x_1' = X_{02}$ | $x_1 + x_2' = X_{01}$



1 KVA, 100 V / 400 V $\quad I_0 \uparrow \quad V \uparrow$

OC test : 100 V, 1A, 50 W (Readings)

$I_m = I_0 \sin\phi$

$I_w = I_0 \cos\phi$

$V I_0 \cos\phi = 50$

$\cos\phi = \frac{50}{1 \times 100}$

$= \frac{1}{2}$

$\cos\phi = 0.5$

$\sin\phi = 0.867$

$I_m = 0.867$ A

$I_w = 0.5$

$X_m = \frac{100}{0.867}$ $\qquad R_w = \frac{100}{0.5} = 200\,\Omega$

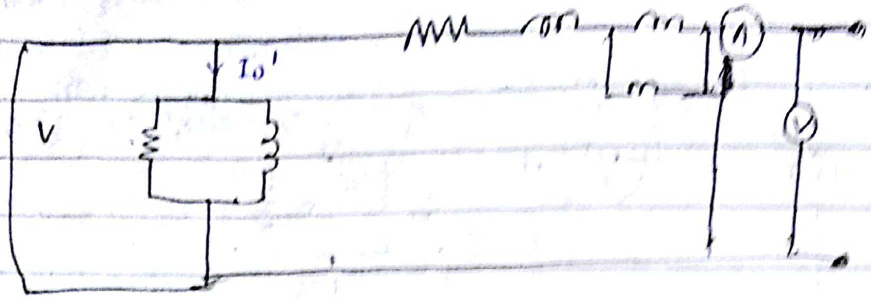
$= 115.34\,\Omega$

why low voltage Not high voltag.

1) very high voltag needed i.e 400 V.

2) Dangerous.

SC perform on high voltage side. LV side is sort circuited.



1 KVA, 1000 V/400 V

OC test : 100V, 1A, 50 W

SC test : 40V, 2.5A, 80 W → Ohmic loss or Variable loss or I^2R loss

$$I^2 R_{02} = 80$$

$$R_{02} = \frac{80}{(2.5)^2} \quad \therefore R_{02} = 12.8\ \Omega$$

$$Z_{02} = \frac{40}{2.5} = 16\ \Omega$$

$$X_{02} = \sqrt{Z_{02}^2 - R_{02}^2}$$

$$= \sqrt{16^2 - (12.8)^2} = \sqrt{256 - 163.84}$$

$$= 9.6\ \Omega$$

$$R_{01} = 12.8 \times \left(\frac{100}{400}\right)^2$$

$$= \frac{12.8}{16}$$

$$X_{01} = 9.6 \times \left(\frac{100}{400}\right)^2 \Omega$$

$$X_m' = X_m \times \left(\frac{400}{100}\right)^2$$

$$R_w' = R_w \times \left(\frac{400}{100}\right)^2$$

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Primary

OC test $\rightarrow$ Low voltage side
Convert high voltage side parameter to low voltage side.

Secon

SC test $\rightarrow$ high voltage side
convert low voltage side parameter to high voltage side.

Find parameters for primary and secondary res

5 KVA, 500 V / 200 V

OC test : 200 V (Rated voltage V), 1.5 A (I_0), 80 W ($VI_0\cos\phi$, No load losses).

SC test : 50 V, 10 A, 200 W.

Primary :

$$I_m = I_0 \sin\phi$$
$$I_w = I_0 \cos\phi$$

$V = 200$

$$V I_0 \cos\phi = 80$$
$$\cancel{\cos\phi = \frac{80}{200 \times 25}}$$
$$\cancel{= \frac{8}{25 \times 20} = \frac{8}{500} = 0.016}$$

~~cos φ = 0.016~~

$$\cos\phi = \frac{80}{200 \times 1.5} = 0.26$$

$$\sin\phi = 0.965$$

$$I_m = 1.5 \times 0.965 = 1.44$$
$$I_w = 1.5 \times 0.26 = 0.4$$

$$X_m = \frac{200}{1.44} = 138.88 \qquad R_w = \frac{200}{0.40} = 500$$

Secondary :

$$I^2 R_{01} = 200$$

$$R_{01} = \frac{200}{10 \times 10} = 2$$

$$Z_{01} = \frac{50}{10} = 5$$

$$X_{01} = \sqrt{25 - 4} = \sqrt{21} = 4.58$$

$$R_{02} = R_{01} \times \left(\frac{200}{500}\right)^2$$

$$= \frac{2 \times 2 \times 2}{5 \times 5} = \frac{8}{25} = 0.32$$

$$X_{02} = X_{01} \times \left(\frac{200}{500}\right)^2$$

$$X_m' = X_m \times \left(\frac{500}{200}\right)^2$$

$$R_w' = R_w \times \left(\frac{500}{200}\right)^2$$

2. 10 KVA, 1000 V/500 V

OC test → 500V, 2A, 100 W
SC test → 50 V, 10 A, 300 W

Find the eq. ckt parameters i) OC
ii) SC.

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Low voltage :

$$I_0 = 2A$$

$$V I_0 \cos\phi = 100$$

$$\cos\phi = \frac{100}{500 \times 2}$$

$$= \frac{1}{10} = 0.1$$

$$\sin\phi = \sqrt{1-(0.1)^2} = 0.99$$

$$I_m = I_0 \sin\phi$$

$$= 2 \times 0.99 = 1.98$$

$$I_w = I_0 \cos\phi$$

$$= 2 \times 0.1 = 0.2.$$

$$X_m = \frac{500}{1.98} = 252.52$$

$$R_w = \frac{500}{0.2} = 2500$$

High Voltage :

$$I^2 R_{01} = 300$$

$$R_{01} = \frac{300}{10 \times 10} = 3\,\Omega$$

$$Z_{01} = \frac{50}{10} = 5\,\Omega$$

$$X_{01} = \sqrt{25-9} = \sqrt{16} = 4\,\Omega$$

$$X_{02} = X_{01} \times \left(\frac{500}{1000}\right)^2$$

$$= 4 \times \frac{1}{4} = 1$$

$$R_{02} = R_{01} \times \left(\frac{500}{1000}\right)^2 = 3 \times \frac{1}{4} = 0.75$$

$$X_m' = 252.52 \times \left(\frac{25}{4}\right) = 9864.0 \quad R_w' = 2500 \times \left(\frac{25}{4}\right)$$

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Voltage regulation.

Fractional change of txr from No load to Full load.

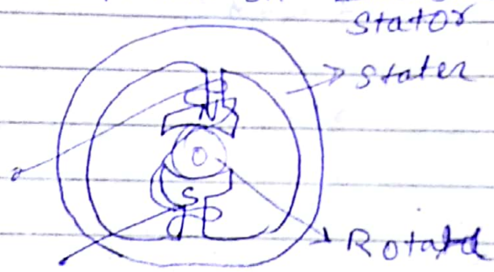
V_{NL} = No load Voltage $= E_2$

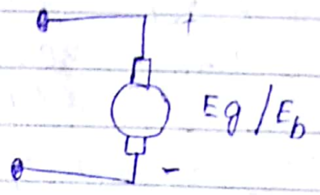
Full load Voltage $= V_2$

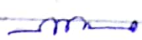
Voltage Regulation $= \dfrac{E_2 - V_2}{E_2}$

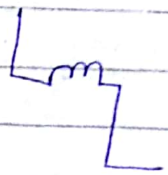
DC Machine

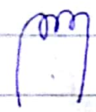
Mech. part
- → Rotating Machine
- → Stator : Stationary part
- → Rotator : Rotating part
- → Electrical part : Field and Ammerature.
- → Field placed on ~~Ammerture~~ Stator and Rotator in ~~B~~ Ammerin

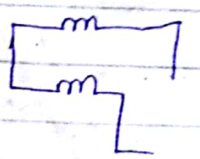





Series


Parallel

Separetly exited



compound

DC Motor

- Work both as generator and motor,
- Brush and commutator assembly : Rectifier :
  convert AC to DC.
- Field windings are place in the stater and armmeture windings are place in the rotator
- Flux due to each pole is ϕ
  Amount of flux cut / revolution i.e. $P\phi$ where P no. of poles.

  speed of machine N rpm

  No. of conductors / parallel path $\frac{Z}{A}$

$$\text{emf induced} = \frac{d\phi}{dt}$$

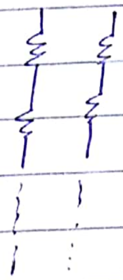
- In one rotation flux change

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

$N \rightarrow 60\,s$

$1 \rightarrow \frac{60}{N}$

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



emf induced in one conductor $= \frac{P\phi N}{60}$

No. of conductors per parallel path

$$= \frac{P\phi N}{60} \times \frac{Z}{A}$$

In case of generator → $\boxed{\text{Emf induced (Generator emf)} = \frac{P\phi N}{60} \times \frac{Z}{A}}$

(Back emf) → In case of motor.

(A)

Wave Connection = No. of parallel path = 2
Lap Connection = No. of parallel path = P = No. of poles.

1. A wave connected 200 V DC machine has 400 conductors it has 4 poles and the useful flux/pole is 0.03 wb. It runs at the speed of 1000 rpm. Find the emf induced.

$$e = \frac{P\phi N}{60} \times \frac{Z}{A}$$

$N = 1000$ rpm
$P = 4$ $\qquad Z = 400$
$A = 2$
$\phi = 0.03$

$$e = \frac{4 \times 0.03 \times 1000}{60 \times 100} \times \frac{400}{2}$$

$= 400$ V $\qquad$ ∴ It is a Generator.

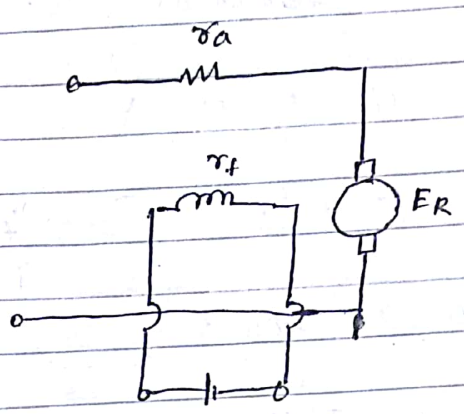
emf induced > Terminal voltage = Generator

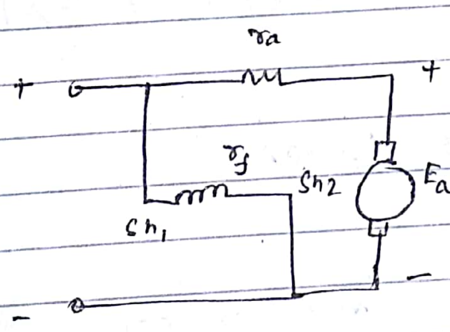
emf induced < Terminal voltage = Motor

Based on exitation DC machine is classified into 4 types :

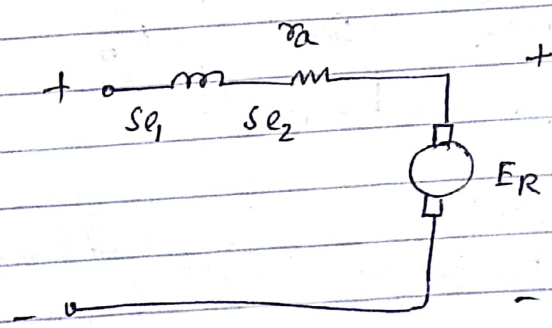
1) Separately excited

Field and ~~armature~~ armature power supplies are diffrent ~~externally~~, excited from two different supplies.

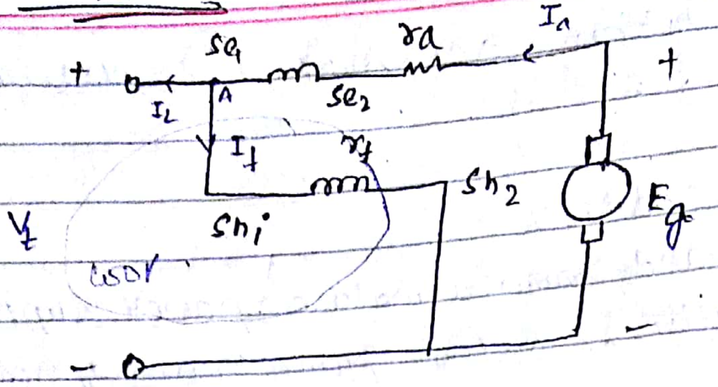




Series excited : If armature field same supply and series



Compound : Both series and ... same ...



Work both generator and motor

1) When worked as Generator.

Applying KCL at pt. A.

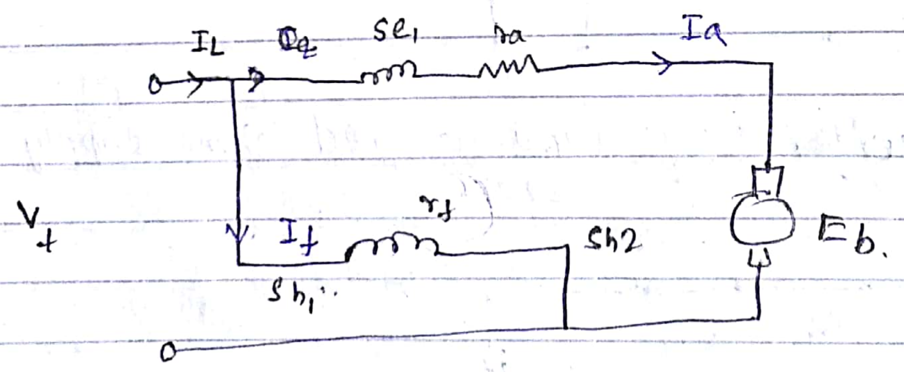
$$I_a = I_L + I_f \qquad I_f = \frac{V_t}{r_f}$$

Applying KVL at loop 1

$$E_g = V_t + I_a r_a$$

As it is generator $E_g > V_t$ (Terminal Voltage)

11) When works as Motor.



$$I_L = I_a + I_f$$

$$V_t = E_b + I_a r_a$$

Only given for any DC machine

$$E_g = \frac{P \phi_g N_g Z}{60 A}$$

$$E_b = \frac{P \phi_m N_m Z}{60 A}$$

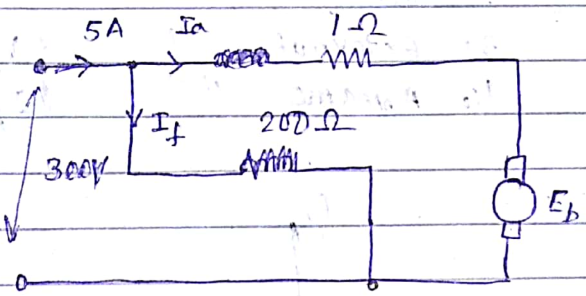
$$\boxed{\frac{E_g}{E_b} = \frac{\phi_g N_g}{\phi_m N_m}}$$

** For DC shunt machine ϕ is constant.

2. A 300V DC shunt machine takes a load current of 5A the field resistance is 200 Ω and armeture resistance is 1 Ω. Find out the ratio of the speeds of the machine as the generator and a motor.

$I_L = 5A$

$V_t = 300V$



$V_t = E_b + I_a r_a$

$300 = E_b + I_a$

$E_b = 300 - I_a$

$300 = I_f \times 200$

$I_f = \frac{300}{200}$

$= \frac{3}{2}$

$I_L = I_a + I_f$

$I_a = I_L - I_f$

$= 5 - 1.5 = 3.5$ V

$E_b = 300 - 3.5$

$= 296.5$.

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Armature Reaction: Reaction to the armature current

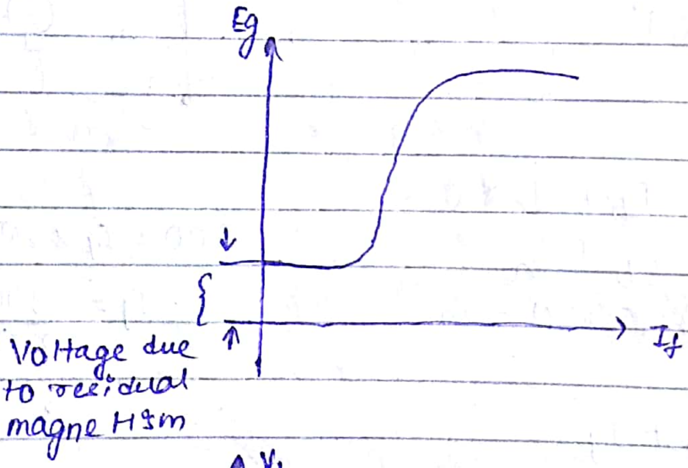
$$E_g = 300 + 3.5 \times 1$$
$$= 300 + 3.5$$
$$= 303.5$$

$$V_f = I_f r_f$$
$$= \frac{3}{2} \times 200$$
$$V_f = 300$$

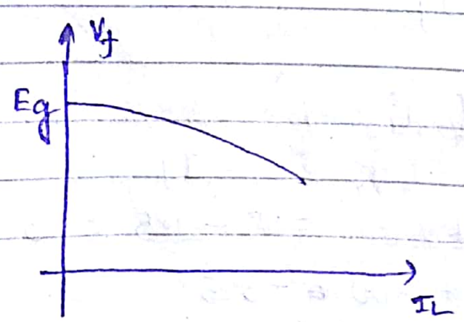
$$\frac{E_g}{E_b} = \frac{N_g}{N_m} \Rightarrow \frac{N_g}{N_m} = \frac{303.5}{296.5}$$
$$= 1.024.$$

Characteristics of DC generators.

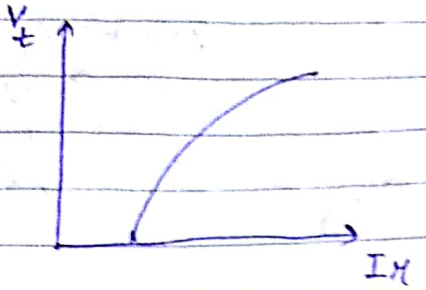
1. No Load characteristics (E_g Vs I_f)
2. Load " (V_f Vs I_f)
3. External " (V_L Vs I_L)
4. Armature " (I_f Vs I_a)



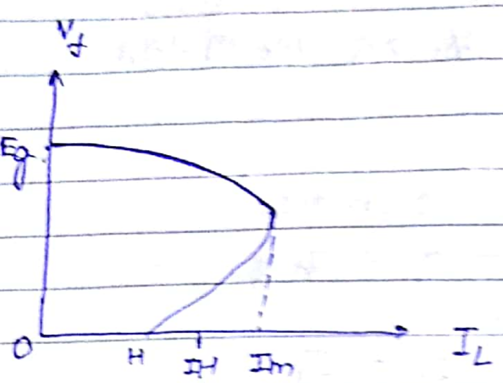
FOR ALL



external characteristics for separately excited DC machine.



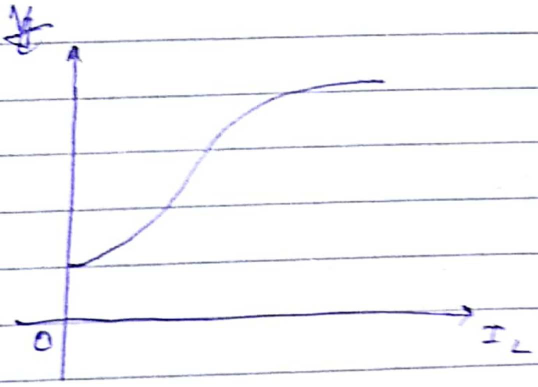
series + Shunt



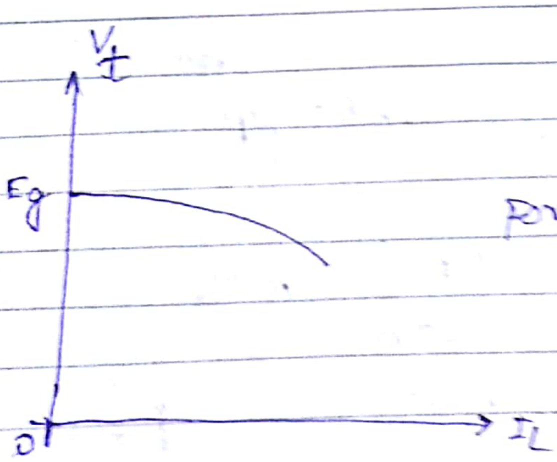
For shunt

I_m = Max. current can flow through the DC machine.

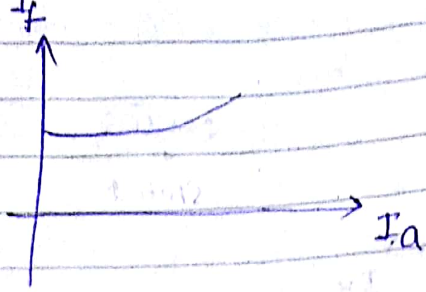
OH - current flow through the residual flux



For series.



For compound



Armature char. for separately excited DC generators.

Torque equation of DC motor

Voltage for DC motor.

$$V_t = E_b + I_a r_a$$

$$I_a V_t = E_b I_a + I_a^2 r_a$$

$E_b I_a$ = Output mechanical Power. (P_m)

$$P_m = \omega T$$

$$E_b I_a = \omega T$$
$$= 2\pi \underset{\text{rps}}{n} T$$

Also, $E_b = \dfrac{P\phi N Z}{60A}$

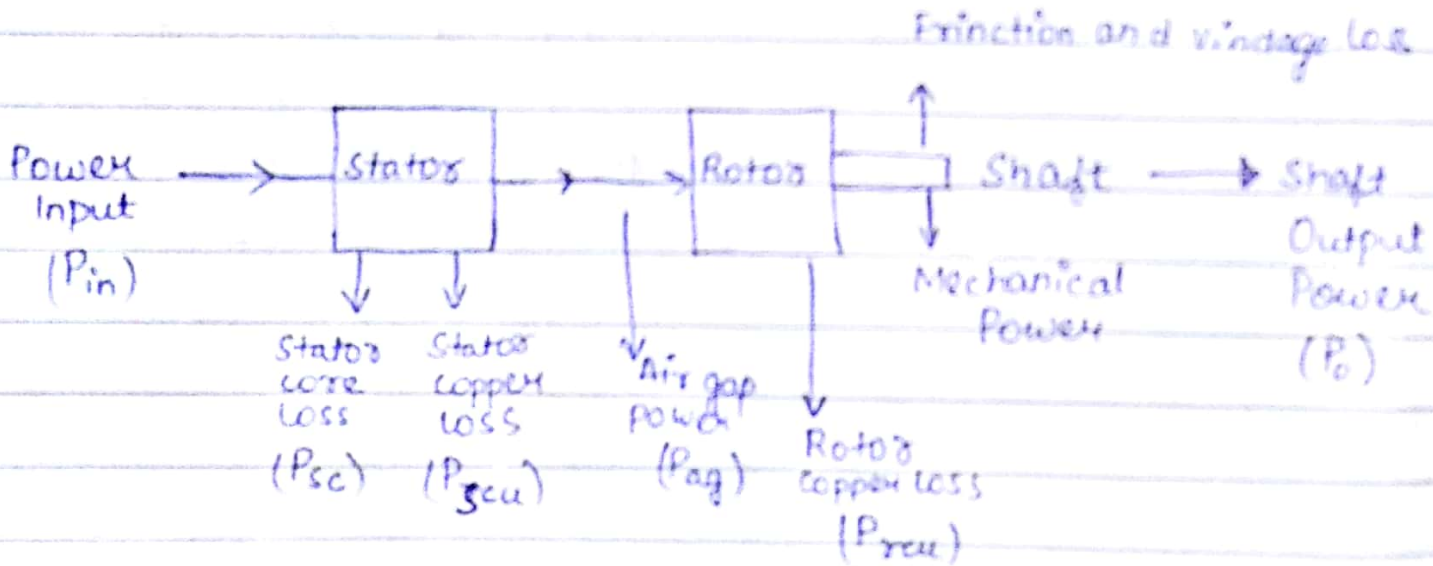
$$\frac{P\phi NZ}{60A} I_a = \frac{2\pi \overset{\text{rpm}}{N}}{60} \times T$$

$$T = \left(\frac{PZ}{2\pi A}\right) \phi I_a$$

$$\boxed{T = R\phi I_a}$$ R = constant.

$$T \propto \phi I_a$$

Power and losses



Rotor Copper loss (P_{rcu}) = Slip × P_{ag}

Mechanical Power (P_m) = (1 - slip) × P_{ag}

$= P_{ag} - P_{rcu}$ S = slip

$= P_{ag} - S.P_{ag}$

$= (1 - S)\, P_{ag}$

2. A 3 phase 4

2. ~~A four~~ pole ~~3-phase~~ inductor motor is running at 1440 rpm. Rotor Input power is 2 KW. Find the rotor copper loss and Rotor output power.

$$N_S = \frac{120 \times F}{P}$$

$$= \frac{120 \times 50}{4}$$

$$= 1500 \text{ rpm}$$

$$N_D = 1440 \text{ rpm.}$$

$$\frac{1500 - 1440}{1500} = S.$$

$$S = \frac{6\cancel{0}}{150\cancel{0}} = 4\%.$$

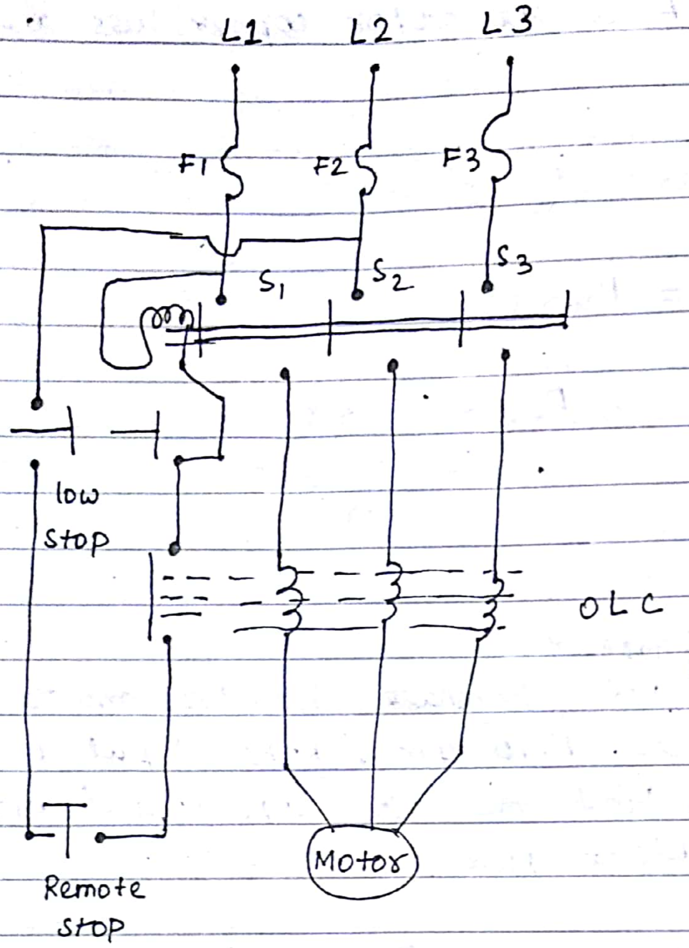
$$P_{ag} = 2 \text{ KW}$$

$$P_{rcu} = 0.04 \times 2 \times 10^3 = 0.08 \times 10^3$$

$$= 80$$

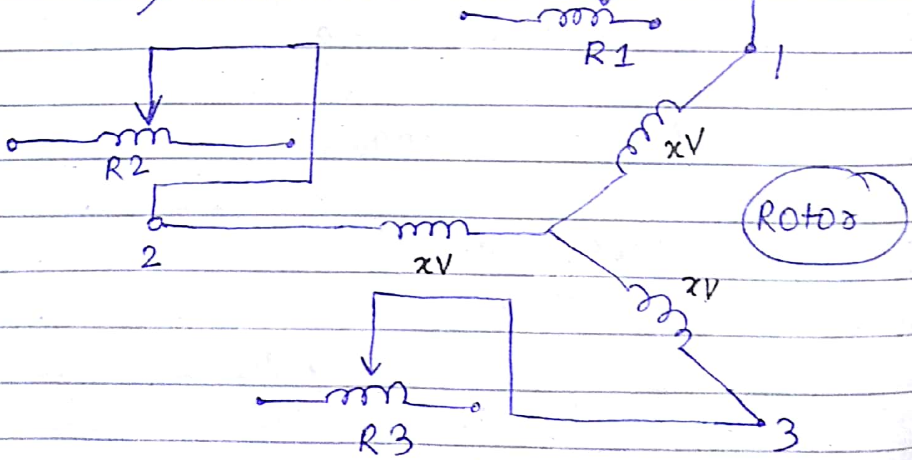
Mechanical Power $= (1 - 0.04) \times 2 \times 10^3 = 1920.$

Direct ON Line



The starting current is very high of DOL starter

i) Rectance starting



$I_{st} = x I_{sc}$

I_{sc} = Intial current

I_{st} = Intial current.

$\tau \propto V^2$

$\tau \propto (xV)^2$

Torque is decreased x^2 times

$$T_{st} = I_{2st}^2 \frac{r_2}{S} \qquad \text{Slip} = 1$$

$$T_{st} = I_{2st}^2 \, r_2$$

$$T_{fl} = I_{2fl}^2 \cdot \frac{r_2}{S_{fl}}$$

$$\frac{T_{st}}{T_{fl}} = \left(\frac{I_{st}}{I_{fl}}\right)^2 S_{fl}$$

$\boxed{\text{Proof of } T = I_2^2 \frac{r_2}{s}}$

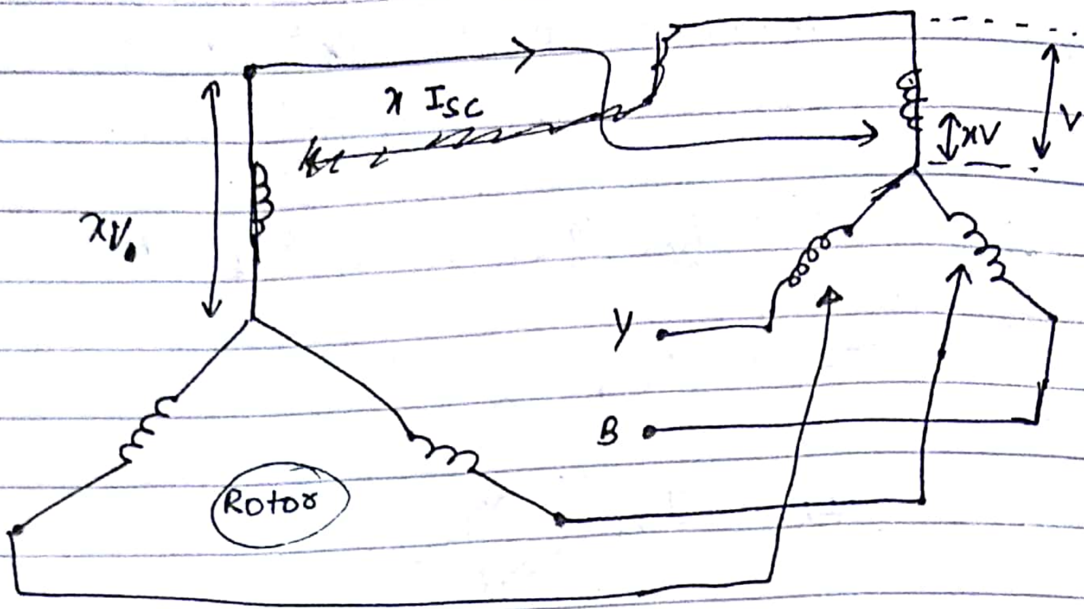
$$T = \frac{K \cdot E_1^2 \cdot r_2 \cdot S}{r_2^2 + (S x_2)^2}$$

$$= K \frac{E_1^2 \cdot S \cdot r_2}{S^2 \left\{ \left(\frac{r_2^2}{S^2}\right) + x_2^2 \right\}}$$

$$= K \frac{E_1^2 \cdot S \cdot r_2}{S^2 \left\{ \sqrt{\left(\frac{r_2}{S}\right)^2 + (x_2)^2} \right\}^2} = K \cdot \frac{I_2^2 \, r_2}{S}$$

$\left\{ \sqrt{\left(\frac{r_2}{S}\right)^2 + (x^2)} \right\}^2 = \text{Impedence } (Z)$

ii) Auto - transformer starting



3-ϕ auto transformer.

current decreases x^2 times.

$$I_{st} = x^2 \cdot I_{sc}$$

$$xV \times x\,I_{sc} = V \cdot I_{st}$$

$$I_{st} = x^2 I_{sc}$$

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