BEE QUESTION PAPER SOLUTIONS

(CBCGS DEC 2017)

Q1] a) A voltage v(t) = 282.85sin100πt is applied to a coil, having resistance of 20Ω in series with inductance of 31.83mH. Find:- (4)

(1) RMS value of voltage.
(2) RMS value of current.
(3) Power dissipated in the coil and
(4) Power factor of the coil.

Solution:-

v(t) = 282.85sin100πt R = 20Ω $X_L = 31.83$mH = 0.03183H

(1) RMS value of voltage.

Comparing the given equation with the standard equation we get,
v(t) = 282.85sin100πt
v(t) = $V_m$sin2πft

V_m = 282.85V ω = 2πf => f = 50Hz.

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

$V_{rms} = \sqrt{2} \times V_m = \sqrt{2} \times 282.85$

$\boldsymbol{V_{rms}}$ **= 400.01V**

(2) RMS value of current.

Z(impedance) = $(R^2 + X_L^2)^{1/2}$ = $(20^2 + 0.03183^2)^{1/2}$ = 20.00Ω
V = IZ

$$I_{rms} = \frac{V_{rms}}{Z} = \frac{400.01}{20.00} = 20.00Am$$

$$\boldsymbol{I_{rms} = 20.00Am}$$

(5) Power dissipated in the coil and

P = VIcosφ

$$\varphi = \tan^{-1}\left(\frac{X_L}{R}\right) = \tan^{-1}\left(\frac{0.03183}{20}\right) = 0.09118°$$

φ = 0.09118°

Power = $V_{rms} I_{rms} cos\varphi$

Power = 400.01$\times$ 20.00 $\times$ $cos 0.09118°$

Power = 8000 watts.

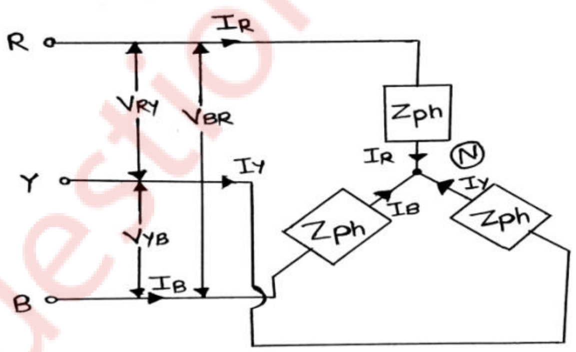
(6) Power factor of the coil.

Pf = cosφ = cos(0.09118)°

Pf = 0.9999

Q1] b) Derive the relation between line voltage and phase voltage in star connected three phase system. (4)

Solution:-



Since the system is balanced , the three-phase voltages V_{RN}, V_{YN}, V_{BN} are equal in magnitude and differ in phase from one another by 120°.

Let $V_{RN} = V_{YN} = V_{BN} = V_{ph}$

Where V_{ph}indicates the rms value of phase voltage .

$\overline{V_{RN}} = V_{ph} \angle 0°$

$\overline{V_{YN}} = V_{ph} \angle -120°$

$\overline{V_{BN}} = V_{ph} \angle -240°$

Let $V_{RY} = V_{YB} = V_{BR} = V_L$

Where V_L indicates the rms value of line voltage.

Applying Kirchhoff's voltage law,

$\overline{V_{RY}} = \overline{V_{RN}} + \overline{V_{NY}} = \overline{V_{RN}} - \overline{V_{-YN}}$

$= V_{ph} \angle 0° - V_{ph} \angle -120°$

$= (V_{ph} + j0) - (-0.5V_{ph} - j0.866V_{ph})$

$= 1.5V_{ph} + j0.866V_{ph}$

$= \sqrt{3}\, V_{ph} \angle 30°$

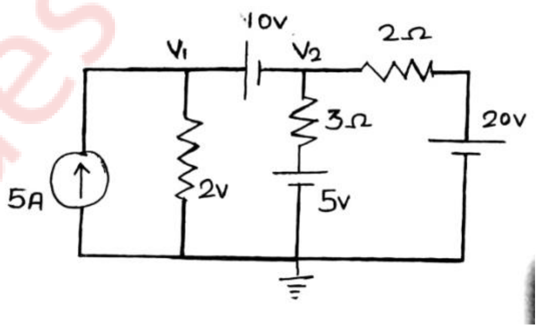
Similarly,

$\overline{V_{YB}} = \overline{V_{YN}} + \overline{V_{NB}} = \sqrt{3}V_{ph}\angle 30°$

$\overline{V_{BR}} = \overline{V_{BN}} + \overline{V_{NR}} = \sqrt{3}V_{ph}\angle 30°$

Thus in a star-connected, three phase system $\boldsymbol{V_L = \sqrt{3}\, V_{ph}}$ and line voltages lead respective phase voltages by 30°.

Q1] c) Find the nodal voltage V_2 by nodal analysis:- **(4)**



Solution:-

Applying KCL rule at node 1

$5 + \frac{V_1}{2} + V_1 - 10 - V_2 = 0$

$10 + V_1 + 2V_1 - 20 - 2V_2 = 0$

$3V_1 - 2V_2 = 10$ ....(1)

Applying KCL at node 2

$(V_2 - (-10) - V_1) + \frac{V_1 - 5}{3} + \frac{V_2 - 20}{2} = 0$

$$V_2 + 10 - V_1 + \frac{V_1 - 5}{3} + \frac{V_2 - 20}{2} = 0$$

Taking LCM we get,

$-4V_1 + 9V_2 = 10$ ....(2)

Solving equation (1) and (2) we get,

V_1 = 5.789V and V_2 = 3.6842V.

Q1] d) A single phase transformer has a turn ration (N_1/N_2) of 2:1 and is connected to a resistive load. Find the value of primary current(both magnitude and angle with reference to flux) , if the magnetizing current is 1A and the secondary current is 4A. Neglect core losses and leakage reactance. Draw the corresponding phasor diagram. (4)

Solution:-

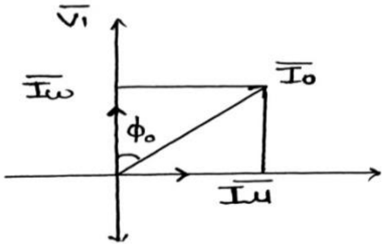
$\frac{N_1}{N_2} = 2:1$ magnetizing current = 1A $I_2 = 4A$

$I_2 = \frac{KVA\ rating \times 1000}{V_2}$

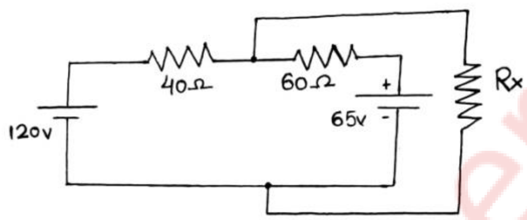
$\frac{N_2}{N_1} = \frac{V_2}{V_1} = \frac{E_2}{E_1} = K$

$$\frac{N_2}{N_1} = K = \frac{1}{2}$$

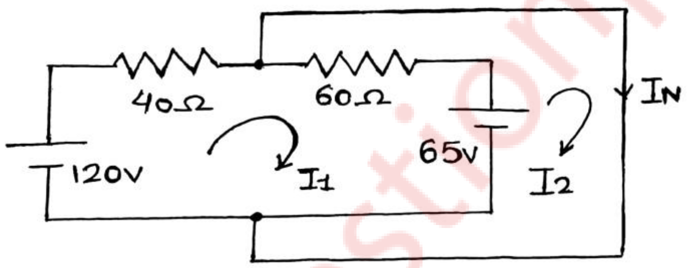
$\frac{I_1}{I_2} = K$ $\frac{I_1}{4} = \frac{1}{2}$ $I_1 = 2A$



Q1] e) Find the Norton's Equivalent of given circuit across R_X (4)



Solution:- Replacing R_X by short circuit



Applying KVL to mesh 1

$120 - 40I_1 - 60(I_1 - I_2) + 65 = 0$

$120 - 40I_1 - 60I_1 + 60I_1 + 65 = 0$

$100I_1 + 60I_2 = 185$ ……………………………………………(1)

Applying KVL to mesh 2

$65 - 60(I_2 - I_1) = 0$

$60I_1 - 60I_2 = -65$ ………………………………………………(2)

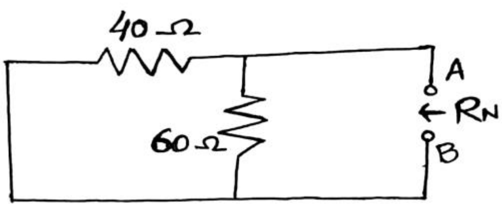
Solving equation (1) and (2) we get

$I_1 = 0.75$Am

$I_2 = 1.833$Am

$\boldsymbol{I_1 = I_N = 1.833}$**Am**

Calculation of R_N

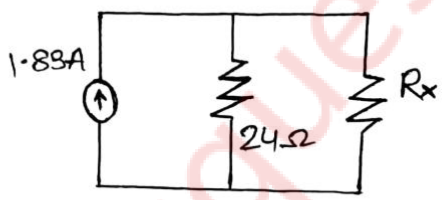


Replacing voltage sources by short circuit

R_N = 60 || 40 = 24Ω

$\boldsymbol{R_N = 24\Omega}$

Norton's Equivalent Network.



Q1] f) A coil having a resistance of 20Ω and an inductance of 0.1H is connected in series with a 50μF capacitor. An alternating voltage of 250V is applied to the circuit. At what frequency will the current in the circuit be maximum? What is the value of this current? Also find the voltage across the inductor and quality factor? (4)

Solution:-

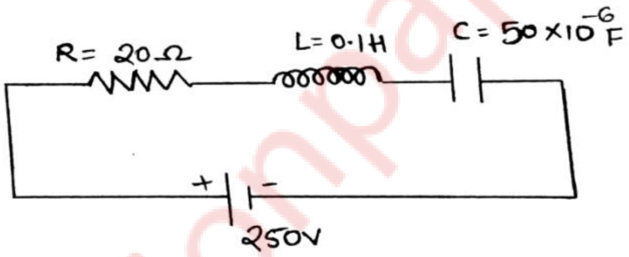
Given:- R = 20Ω $X_L = 0.1H$ $X_C = 50\mu F$ V = 250V.

Find :- 1) At what frequency (f) current is maximum = ?

2) current value = ?

3) voltage across Inductor=?

4) quality factor=?



(1) The frequency at which maximum current flows:-

$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

$$f_o = \frac{1}{2\pi\sqrt{0.1\times50\times10^{-6}}} = 71.17\text{Hz}$$

$$\boldsymbol{f_o = 71.17Hz}$$

(2) Current value

$$X_L = 2\pi f L = 2\pi \times 71.17 \times 0.1 = 44.717\Omega$$

$$X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi \times 71.17 \times 50 \times 10^{-6}} = 45.45\Omega$$

$$\bar{Z} = R + jX_L - jX_C$$

$$\bar{Z} = 20 + j44.717 - j45.45$$

$$\bar{Z} = 20 - j0.77$$

$$\bar{Z} = 20.0148\angle -2.2047$$

Current = $\frac{V}{Z} = \frac{250}{20.0148} = 12.49Am$

Max Current = 12.49Am.

(3) Quality Factor.
Pf = cosφ = cos(2.2047) = 0.9992
Pf = 0.9992

(4) Voltage across Inductor.
$X_L = 2\pi fL$
$X_L = 44.717\Omega$

V = I$X_L = 12.49 \times 44.717 = 558.51V$

V =558.51V

Q2] a) With necessary diagram prove that three phase power can be measured by only two wattmeter. Also prove that reactive power can be measured from the wattmeter readings. **(10)**

Solution:-

Given figure shows a balanced star-connected load, the load may be assumed to be inductive. Let V_{RN}, V_{YN}, V_{BN} be the three phase voltages. I_R, I_Y, I_B be the phase currents. The phase currents will lag behind their respective phase voltages by angle φ. Current through current coil of $W_1 = I_R$

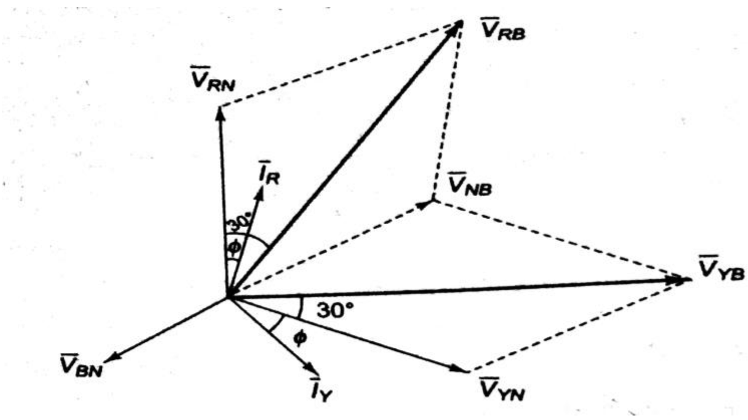
Voltages across voltage coil of $W_1 = V_{RB} = V_{RN} + V_{NB} = V_{RN} - V_{BN}$

From the phasor diagram, it is clear that the phase angle between V_{RB} and I_R is (30° $- \varphi$)

$W_1 = V_{RB} I_R \cos(30° - \varphi)$

Current through current coil of $W_2 = I_Y$

Voltage across voltage coil of $W_2 = V_{YB} = V_{YN} + V_{NB} = V_{YN} - V_{BN}$



From phasor diagram, it is clear that phase angle between V_{YB} and I_Y is $(30° + \varphi)$

$W_2 = V_{YB} I_Y \cos(30° + \varphi)$

But $I_R, = I_Y = I_L$

$V_{RB} = V_{YB} = V_L$

$W_1 = V_L I_L \cos(30° - \varphi)$

$W_2 = V_L I_L \cos(30° + \varphi)$

$W_1 + W_2 = V_L I_L \cos(30° - \varphi) + V_L I_L \cos(30° + \varphi)$

$W_1 + W_2 = V_L I_L (2cos30°cos\varphi)$

P(active power) = $W_1 + W_2 = \sqrt{3}\, V_L I_L (cos\varphi)$

Thus the sum of two wattmeter reading gives three phase power

For calculating reactive power :-

$W_1 - W_2 = V_L I_L \cos(30° - \varphi) - V_L I_L \cos(30° + \varphi)$

$W_1 - W_2 = V_L I_L \left[-2sin\left[\frac{30-\varphi+30+\varphi}{2}\right] sin\left[\frac{30-\varphi-30-\varphi}{2}\right]\right]$

$W_1 - W_2 = V_L I_L [-2\sin(30)\sin(-\varphi)]$

$W_1 - W_2 = V_L I_L (\sin\varphi)$

Q (reactive power) = $W_1 - W_2 = V_L I_L (\sin\varphi)$

Q2] b) A circuit has L = 0.2H and inductive resistance 20Ω is connected in parallel with 20μF capacitor with variable frequency , 230V supply. Find the resonant frequency and impedance at which the total current taken from the supply is in phase with supply voltage. Draw the diagram and derive the formula used(both impedance and frequency). Also the value of the supply current and the capacitor current. (10)

Solution:-

L = 0.2H $X_L = 20\Omega$ C = 200$\times 10^{-6}F$ V = 230V

RESONANT FREQUENCY :-

$$f_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi(0.2 \times 200 \times 10^{-6})^{0.5}} = 25.16Hz$$

IMPEDANCE :-

$Z_1 = jX_L$ $Z_2 = -jX_C$

$$X_C = \frac{1}{2\pi f C} = \frac{10^6}{2\pi \times 50 \times 200} = 15.915\Omega$$

$Z_1 = 20\Omega$ $Z_2 = -15.915\Omega$

$$Z = \frac{Z_1 Z_2}{Z_1 + Z_2} = \frac{(20j)\times(-15.915j)}{(20j)-(15.915j)} = 77.9192\angle -90$$

Z = $\mathbf{77.9192\angle -90°}$

SUPPLY CURRENT:-

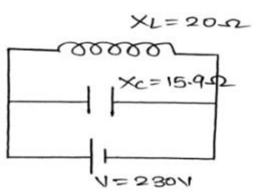
$$I = \frac{V}{Z} = \frac{230}{77.91929} = 2.95Am$$

I = 2.95Am

CAPACITOR CURRENT:-

$$I_C = \frac{V}{X_C} = \frac{230}{15.915} = 14.45Am$$

$I_C = 14.45\text{Am}$



Q3] a) Two impedances 14+j5 and 18+j10 are connected in parallel across 200V, 50Hz single phase supply. Determine, (10)

1) **Admittance of each branch in polar form.**
2) **Current in each branch.**
3) **Power factor in each branch.**
4) **Active power in each branch and,**
5) **Reactive power in each branch.**

Solution:-

Given :- $Z_1 = 14 + 5j\ \Omega$ $\quad$ $Z_2 = 18 + 10j\ \Omega$ connected in parallel across V = 200V

f = 50Hz.

1) Admittance of each branch in polar form

$$\overline{Y_1} = \frac{1}{\overline{Z_1}} = \frac{1}{14+5j} = \frac{14}{221} - \frac{5}{221}i = 0.0672\angle -19.65°$$

$\overline{Y_1} = 0.0672\angle -19.65°$ ℧

$$\overline{Y_2} = \frac{1}{\overline{Z_2}} = \frac{1}{18+10j} = \frac{9}{212} - \frac{5}{212}i = 0.048\angle 29.05°$$

$\overline{Y_1} = 0.048\angle 29.05°$ ℧

2) Current in each branch in polar form

$$\overline{I_1} = \frac{\overline{V}}{\overline{Z_1}} = \frac{200}{14+5j} = 13.45\angle -19.65° \text{ Am}$$

$$\overline{I_2} = \frac{\overline{V}}{\overline{Z_2}} = \frac{200}{18+10j} = \frac{50\sqrt{106}}{53}\angle -29.05° \text{ Am}$$

3) Pf of each branch.

$\cos\varphi_1 = \cos(-19.65°) = 0.9417$

$\cos\varphi_2 = \cos(-29.054°) = 0.8741$

4) Active power in each branch

$P_1 = VI_1\cos\varphi_1 = 200 \times 13.45 \times 0.9417 = 2533.173w$

$$P_2 = VI_2\cos\varphi_2 = 200 \times 9.7128 \times 0.8741 = 1697.99w$$

5) Reactive power in each branch

$$Q_1 = VI_1 sin\varphi_1 = 200 \times 13.45 \times \sin(19.65) = 904.575w$$

$$Q_2 = VI_2 sin\varphi_2 = 200 \times 9.7128 \times \sin(29.054) = 943.37w$$

Q3] b) Derive the emf equation of a single phase transformer. Find the value of the maximum flux in a 25KVA, 3000/240V single phase transformer with 500 turns on the primary. The primary winding is connected to 3000V, 50Hz supply. Find primary and secondary currents. Neglect all voltage drops.(6)

Solution:-

As the primary winding is excited by a sinusoidal alternating voltage, an alternating current flows in the winding sinusoidal varying flux φ in the core.

$$\varphi = \varphi_m sin\omega t$$

As per faradays laws of electromagnetic induction, an emf e_1 is induced in the primary winding

$$e_1 = -N_1\frac{d\varphi}{dt} = -N_1\frac{d}{dt}(\varphi_m sin\omega t) = -N_1\varphi_m\omega cos\omega t = N_1\varphi_m\sin(\omega t - 90°)$$

$$e_1 = 2\pi f\varphi_m N_1\sin(\omega t - 90°)$$

Maximum value of induced emf = $2\pi f\varphi_m N_1$

Hence rms value of induced emf in primary winding is given by

$$E_1 = \frac{E_{max}}{\sqrt{2}} = \frac{2\pi f\varphi_m N_1}{\sqrt{2}} = 4.44f\varphi_m N_1$$

$$E_1 = 4.44f\varphi_m N_1$$

Similarly rms value of induced emf in the secondary winding is given by,

$$E_2 = 4.44f\varphi_m N_2$$

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

Thus emf per turn is same in primary and secondary winding and an equal emf I induced in each turn of the primary and secondary winding.

$E_1 = 3000$ $E_2 = 240$ KVA rating = 25KVA $N_1 = 500$

$E_1 = 4.44 f \varphi_m N_1$

3000 = $4.44 \times 50 \times 500 \times \varphi_m$

$$\varphi_m = \frac{3000}{4.44 \times 50 \times 500} = 0.027$$

$\boldsymbol{\varphi_m = 0.027Wb}$

PRIMARY CURRENT AND SECONDARY CURRENT.

$$I_1 = \frac{\text{KVA rating} \times 1000}{V_1} = \frac{25 \times 1000}{3000} = 8.33\text{Am}$$

$\mathbf{I_1 = 8.33Am}$

$$I_2 = \frac{\text{KVA rating} \times 1000}{V_2} = \frac{25 \times 1000}{240} = 104.16\text{Am}$$

$\mathbf{I_2 = 104.16Am}$

Q3] c) Compare core type and shell type transformer (any four point).(4)

Solution:-

CORE-TYPE TRANSFORMER	SHELL-TYPE TRANSFORMER
It consists of a magnetic frame with two limbs	It consists of a magnetic frame with three limbs
It has a single magnetic current.	It has a two magnetic current.
The winding encircles the core.	The core encircles most part of the winding.
It consists of cylindrical winding.	It consists of sandwich type winding.
It is easy to repair.	It is not easy to repair.
It provides better cooling since windings are uniformly distributed on two limbs.	It does not provides better cooling as the windings are surrounded by the core.
It is preferred for low-voltage transform.	It is preferred for high-voltage transform.

Q4] a) An alternating voltage is represented by v(t) = 141.4sin(377t)V. Derive the RMS value of this voltage. Find:- (8)

1) **Instantaneous value at t=3ms and**
2) **The time taken for the voltage to reach 70.7V for the first time.**

Solution:-

To calculate RMS value of this voltage

V(t) = 141.4sin(377t)

V = $V_m sin\theta$ 0< $\theta < 2\pi$

V_m = 141.4 $\theta = 377t$

$V_{rms}^2 = \frac{1}{2\pi}\int_0^{2\pi} V_m^2 sin^2\theta d\theta$ = $\frac{1}{2\pi}\int_0^{2\pi} 141.4^2 sin^2\theta d\theta$ = $\frac{141.4^2}{2\pi}\int_0^{2\pi} sin^2\theta d\theta$

= $\frac{141.4^2}{2\pi}\int_0^{2\pi}\frac{(1-cos\theta)}{2}d\theta$ = $\frac{141.4^2}{2\pi}\int_0^{2\pi}[\frac{\theta}{2} - \frac{sin2\theta}{4}]_0^{2\pi}d\theta$ = $\frac{141.4^2}{2\pi}[\frac{2\pi}{2}]$ = 9996.98

$V_{rms} = \sqrt{9996.98} = 99.98$

$\mathbf{V_{rms} = 99.98V}$

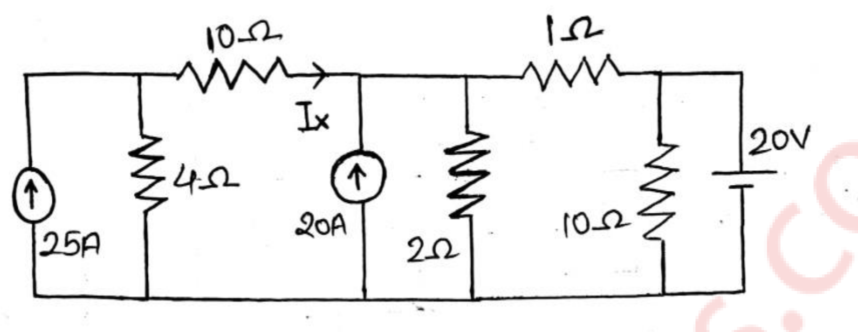
1) Instantaneous value at t = 3ms.
   t = $3 \times 10^{-3} = 0.003sec$
   V = $V_{rms} sin\theta$
   V = 141.4sin(337 x 0.003)
   V = 2.4949V
   Instantaneous voltage at t = 3ms is v = 2.494V.

2) Time taken to reach till 70.7V for first time
   V = $V_{rms} sin\theta$
   V = 70.7V

   70.7 = 141.4sin(377t)
   0.5 = sin(337t)
   $\sin^{-1}(0.5) = 337t$
   30 = 337t
   t = 0.089sec.

   Time required to reach till 70.7V is 0.089sec

Q4] b) State Superposition theorem. Find I_x using Superposition theorem without using source transformation technique. (12)

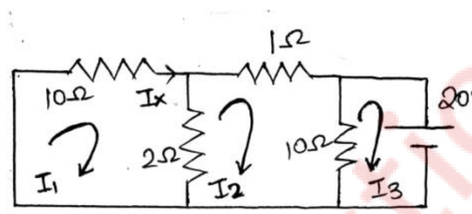


Solution:-

a. When 20V is acting alone other all sources are inactive.

4Ω is redundant, circuit becomes

Applying KVL to mesh 1



$$-10I_1 - 2(I_1 - I_2) = 0$$

$$-12I_1 + 2I_2 = 0$$

$$-6I_1 + I_2 = 0 \quad ………(1)$$

Applying KVL to mesh 2

$$-2(I_2 - I_1) - 1I_2 - 10(I_2 - I_3) = 0$$

$$-2I_2 + 2I_1 - I_2 - 10I_2 + 10I_3 = 0$$

$$2I_1 - 13I_2 + 10I_3 = 0 \quad ………(2)$$

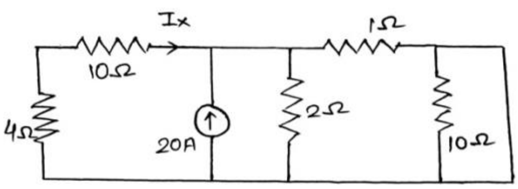
Applying KVL to mesh 3

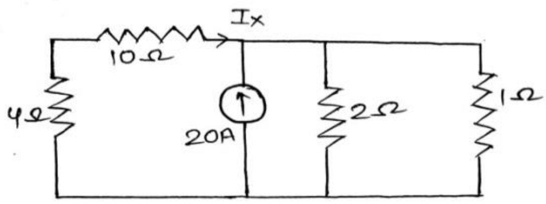
$$-10I_3 = -20$$

$$I_3 = 2A \quad ………(3)$$

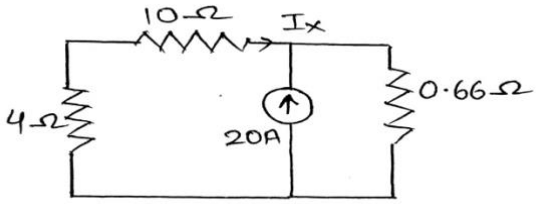
From (1), (2) and (3) we get, $I_X(1) = 0.26Am(\downarrow)$

When 20A is active and other all sources are inactive





10Ω is redundant hence the circuit will get modified. As shown above.



Resistor with 2Ω and 1Ω resistance are in parallel with each other

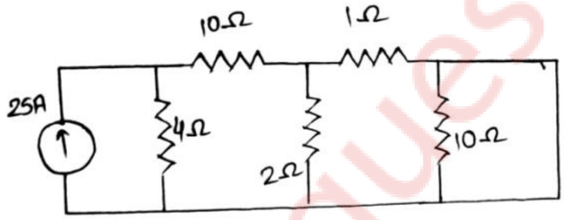
Hence total resistance we get , 0.66Ω

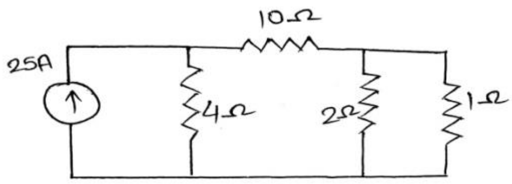
Current division rule,

$$I_X = 20 \times \frac{0.66}{14 + 0.66} = 0.90$$

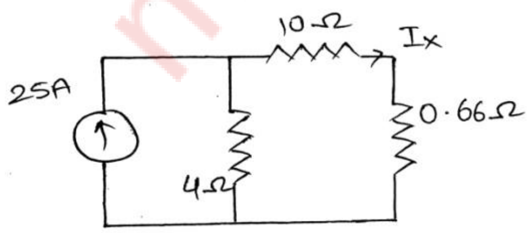
$$I_X(2) = -0.90Am$$

c. 25A active source and other all the inactive.





10Ω is redundant hence to get,



10+0.66 = 10.66Ω

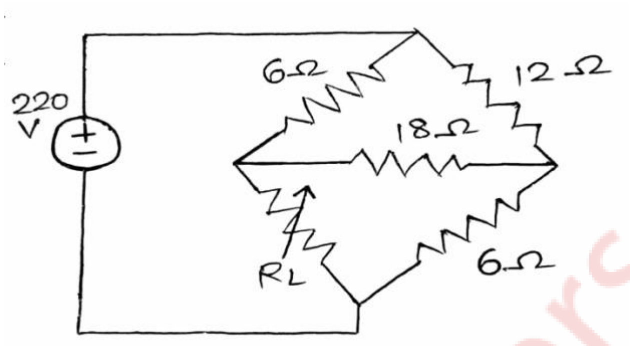
Current division rule,

$$I_X(3) = 25 \times \frac{4}{10.66 + 4} = 6.821A$$

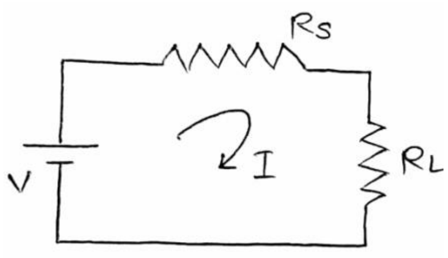
Total current $I_X = 6.821 + 0.26 - 0.90 = 6.181Am$

$I_X = 6.181Am$

Q5] a) State and prove maximum power transform theorem and find the value of R_L. **(10)**



Solution:-



$$I = \frac{V}{R_S + R_L}$$

Power delivered to load

$$R_L = P = I^2 R_L = \frac{V^2 R_L}{(R_S + R_L)^2}$$

To determine the value of $R_L$of maximum power to be transferred to the load,

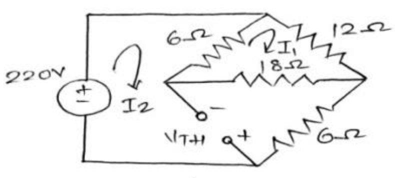
$\frac{dp}{dR_L} = 0$ => $\frac{dp}{dR_L} = \frac{d}{dR_L}\frac{V^2}{(R_S+R_L)^2}R_L$ => $\frac{V^2\left[(R_S+R_L)^2-(R_S+R_L)^1(2R_L)\right]}{(R_S+R_L)^4}$

$\frac{dp}{dR_L}$ = $(R_S + R_L)^2 - 2R_L(R_S + R_L)^1 = 0$

$R_S^2 + R_L^2 + 2R_SR_L - 2R_SR_L - 2R_L^2 = 0$

$R_L = R_S$

Hence the maximum power will be transferred to the load when load resistance is equal to the source resistance.



Applying KVL to mesh 1

$-18I_1 - 6(I_1 - I_2) - 12I_1 = 0$

$-18I_1 - 6I_1 + 6I_2 - 12I_1 = 0$

$-36I_1 + 6I_2 = 0$ ....(1)

Applying KVL to mesh 2

$220 - 6(I_2 - I_2) - 18(I_2 - I_1) - 6I_2 = 0$

$24I_1 - 30I_2 = -220$ ....(2)

From (1) and (2) we get, $I_1 = 1.410Am$ and $I_2 = 8.461Am$

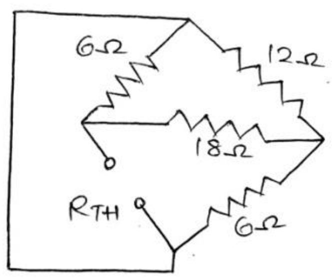
For calculation of V_{TH}

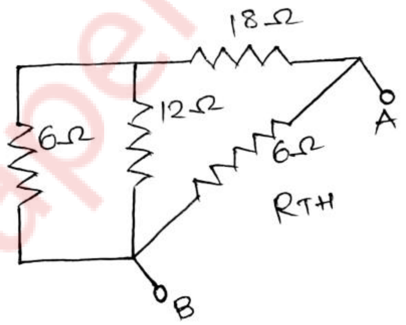
$V_{TH} - 18I_1 - 6I_2 = 0$

$V_{TH} = 6I_2 + 18I_1$

$\boldsymbol{V_{TH} = 76.146V}$

For calculation of R_{TH}



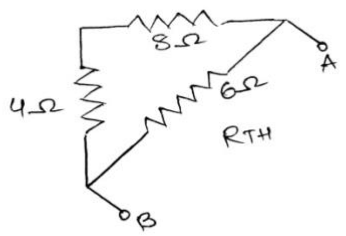


6Ω resistor is parallel with 12Ω gives resultant resistance 4Ω

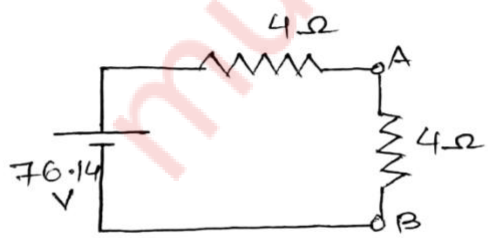
4Ω resistor is in series with 8Ω and is in parallel with 6 Ω gives resultant resistance 4Ω

[(4+8) || 6] = 4 Ω

$\boldsymbol{R_{TH}} = \mathbf{4}\Omega$



Calculation of P_{max}



$$P_{max} = \frac{V_{TH}^2}{4R_{TH}} = \frac{(76.146)^2}{16} = 362.38\, w$$

$\boldsymbol{P_{max} = 362.38}$

Q5] b) A balanced load of phase impedance 100Ω and power factor 0.8(lag) is connected in delta to a 400V, 3- phase supply . calculate :- (10)

(1) Phase current and line current.

(2) Active power and reactive power. If the load is reconnected in star across the same supply, find

(3) Phase voltage and line voltage .

(4) Phase current and line current. What will be the wattmeter readings if the power is measured by two wattmeter method(either star or delta).

Solution:-

1) Phase current and line current.

$I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{400}{100} = 4Am$

$\boldsymbol{I_{ph}} = \mathbf{4}$**Am …………………..(Phase current in delta connection)**

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

$I_L = \sqrt{3} \times 4$

$\boldsymbol{I_L} = \mathbf{6.928}$**Am …………………..(Line current in delta connection)**

2) Active power and reactive power

Active power(P) = $\sqrt{3} \times V_L \times I_L cos\varphi$

Pf = 0.8

$0.8 = cos\varphi$

$\varphi = \cos^{-1} 0.8$

$\varphi = 36.86°$

$P = \sqrt{3} \times 400 \times 6.928 \times cos36.86°$

P = 3840.38 watts. ……………………..(Active power in delta connection)

Reactive power(Q) = $\sqrt{3} \times V_L \times I_L sin\varphi$

Q = $\sqrt{3} \times 400 \times 6.928 sin36.86°$

Q = 2879.2521 watts …………………….(Reactive power in delta connection)

FOR STAR CONNECTION

1) $V_{ph} =?$ And $V_L =?$

$V_L = \sqrt{3} \times V_{ph}$

$V_{ph} = 400V$
$V_L = \sqrt{3} \times 400 = 692.820V$

$\boldsymbol{V_{ph} = 400V}$ **And** $\boldsymbol{V_L = 692.820V}$

2) I_L =? And I_{ph} =?

$I_L = I_{ph}$
$I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{400}{100} = 4\text{Am}$

$\boldsymbol{I_L = 4Am}$ **And** $\boldsymbol{I_{ph} = 4Am}$

WATTMETER READING

$w_1 = V_L I_L \cos(30 - \varphi)$

$w_1 = 692.820 \times 4 \times \cos(30 - 36.86)$

$w_1 = 2751.44\text{w}$

$w_2 = V_L I_L \cos(30 + \varphi)$

$w_2 = 692.820 \times 4 \times \cos(30 + 36.86)$

$w_2 = 1089.055\text{w}$

Wattmeter readings for star connection are as follows:-

$\boldsymbol{w_1 = 2751.44}$**w**

$\boldsymbol{w_2 = 1089.055}$**w**

Q6] a) The reading when open circuit and short circuit tests are connected on a 4KVA, 200/400V, 50Hz, single phase transformer are given below:-

1) **Find the equivalent circuit parameters and draw the equivalent circuit referred to primary.**
2) **Also find the transform efficiency and regulation at full load and half load for 0.8pf lagging.** **(12)**

OC test on LV side	**200V**	**0.7A**	**70w**
SC test on HV	**15V**	**10A**	**85w**

Solution:- 1) Equivalent circuit of the transform and parameters

From OC test(meters are connected on LV side i.e. primary)

$W_i = 70w$ $\quad$ $V_1 = 200V$ $\quad$ $I_0 = 0.7$Am

$\cos\varphi_0 = \frac{W_i}{V_1 I_0} = \frac{70}{200\times0.7} = 0.5$

$\sin\varphi_0 = (1 - 0.5^2)^{0.5} = 0.866$

$I_w = I_O cos\varphi_o = 0.7 \times 0.5 = 0.35$

$R_O = \frac{V_1}{I_w} = \frac{200}{0.35} = 571.428\Omega$

$I_\mu = I_o sin\varphi_o = 0.7 \times 0.866 = 0.6062$Am

$X_o = \frac{V_1}{I_\mu} = \frac{200}{0.6062} = 329.924\Omega$

From SC test (meters are connected on HV side i.e. secondary)

$W_{sc} = 85w$ $\quad$ $V_{sc} = 15V$ $\quad$ $I_{sc} = 10A$

$Z_{02} = \frac{V_{sc}}{I_{sc}} = \frac{15}{10} = 1.5\Omega$

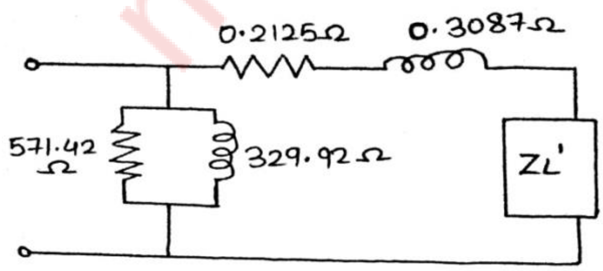
$R_{02} = \frac{W_{sc}}{I_{SC}^2} = \frac{85}{10^2} = 0.85\Omega$

$X_{02} = ({Z_{02}}^2 - {R_{02}}^2)^{0.5} = (1.5^2 - 0.85^2)^{0.5} = 1.235\Omega$

$K = \frac{400}{200} = 2$

$R_{01} = \frac{R_{02}}{K^2} = \frac{0.85}{4} = 0.2125\Omega$

$X_{01} = \frac{X_{02}}{K^2} = \frac{1.235}{4} = 0.3087\Omega$



2)Efficiency and regulation at full and half load for 0.8pf lagging

x = 0.5 pf = 0.8 $W_i = 70w = 0.70kw$ $W_{cu} = 85w = 0.85kw$

$$\%\eta = \frac{\text{x } \times \text{full load KVA} \times \text{pf}}{(\text{x} \times \text{full load KVA} \times \text{pf}) + \text{W}_\text{i} + \text{x}^2\text{W}_\text{cu}} \times 100$$

$$\%\eta = \frac{0.5 \ \times 4 \times 0.8}{(0.5 \times 4 \times 0.8) + (0.7) + (0.5)^2(0.85)} \times 100$$

$$\%\boldsymbol{\eta} = \mathbf{63.681}\%$$

On primary side ,

$$\% \text{ regulation} = \frac{I_2(R_{02}cos\varphi + X_{02}sin\varphi)}{V_2} \times 100$$

$$I_1 = \frac{4 \times 1000}{400} = 10A$$

$cos\varphi = 0.8$ $sin\varphi = 0.6$

$$\% \text{ regulation} = \frac{10(0.85 \times 0.8 + 1.235 \times 0.6)}{400} \times 100$$

$$\% \textbf{ regulation} = \mathbf{3.55}\%$$

Efficiency at full load;

x = 1

$$\%\eta = \frac{\text{x } \times \text{full load KVA} \times \text{pf}}{(\text{x} \times \text{full load KVA} \times \text{pf}) + \text{W}_\text{i} + \text{x}^2\text{W}_\text{cu}} \times 100$$

$$\%\eta = \frac{1 \ \times 4 \times 0.8}{(1 \times 4 \times 0.8) + (0.7) + (0.5)^2(0.85)} \times 100$$

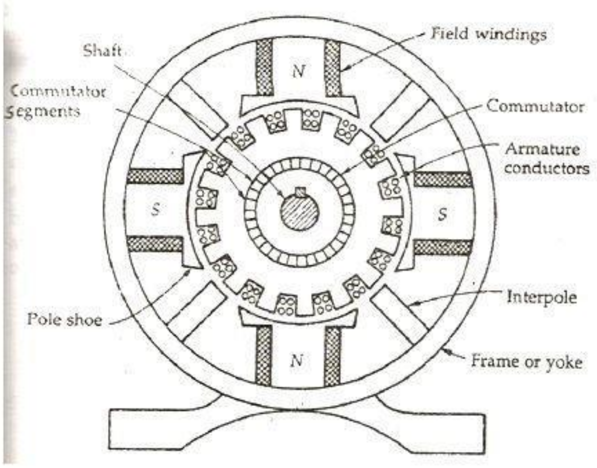
$$\%\boldsymbol{\eta} = \mathbf{67.36}\%$$

Q6] b) With neat diagram explain the main parts of a DC machine? Mention the functions of each part. (8)

Solution:-

A DC Generator is an electrical device which converts mechanical energy into electrical energy. It mainly consists of three main parts, i.e. Magnetic field system, Armature and Commutator and Brush gear. The other parts of a DC Generator are Magnetic frame and Yoke, Pole Core and Pole Shoes, Field or Exciting coils, Armature Core and Windings, Brushes, End housings, Bearings and Shafts.

The diagram of the main parts of a 4 pole DC Generator or DC Machine is shown below.



Magnetic Field System of DC Generator

The Magnetic Field System is the stationary or fixed part of the machine. It produces the main magnetic flux. The magnetic field system consists of Mainframe or Yoke, Pole core and Pole shoes and Field or Exciting coils. These various parts of DC Generator are described below in detail.

Magnetic Frame and Yoke

The outer hollow cylindrical frame to which main poles and inter-poles are fixed and by means of which the machine is fixed to the foundation is known as Yoke. It is made of cast steel or rolled steel for the large machines and for the smaller size machine the yoke is generally made of cast iron.

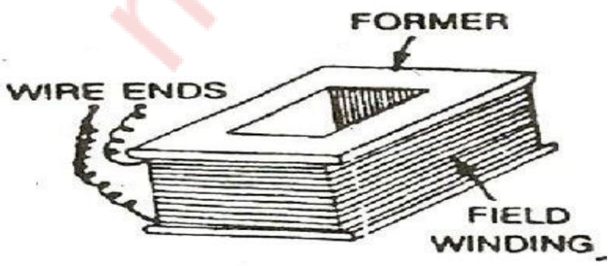
The two main purposes of the yoke are as follows:-

- It supports the pole cores and provides mechanical protection to the inner parts of the machines.
- It provides a low reluctance path for the magnetic flux.

Field or Exciting Coils

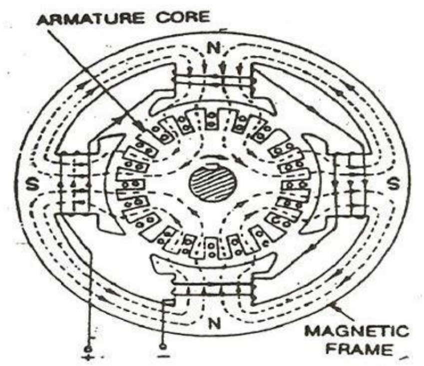
Each pole core has one or more field coils (windings) placed over it to produce a magnetic field. The enamelled copper wire is used for the construction of field or exciting coils. The coils are wound on the former and then placed around the pole core.

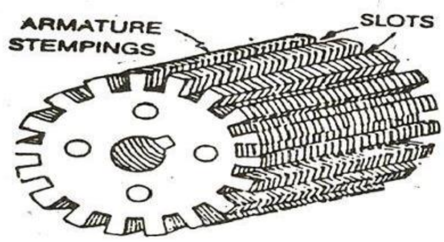
When direct current passes through the field winding, it magnetizes the poles, which in turns produces the flux. The field coils of all the poles are connected in series in such a way that when current flows through them, the adjacent poles attain opposite polarity.



Armature Core

The armature core of DC Generator is cylindrical in shape and keyed to the rotating shaft. At the outer periphery of the armature has grooves or slots which accommodate the armature winding as shown in the figure below.





The armature core of a DC generator or machine serves the following purposes.

- It houses the conductors in the slots.
- It provides an easy path for the magnetic flux.

As the armature is a rotating part of the DC Generator or machine, the reversal of flux takes place in the core, hence hysteresis losses are produced. The silicon steel material is used for the construction of the core to reduce the hysteresis losses.

The rotating armature cuts the magnetic field, due to which an emf is induced in it. This emf circulates the eddy current which results in Eddy Current loss. Thus to reduce the loss the armature core is laminated with a stamping of about 0.3 to 0.5 mm thickness. Each lamination is insulated from the other by a coating of varnish.
