Unit 2 - Single Phase AC Circuits

Numerical Problems & Selected Explainations

1) For a sinusoidal function of frequency 50 Hz, find i) Half time period ii) Angular frequency

Solution :- $T = 1/f = \frac{1}{50} = 0.02\,s = 20\ msec$

i) Half time period $T/2 = 20/2 = 10\ msec$

ii) Angular frequency $\omega = 2\pi f = 2\pi(50)$
$= 100\pi\ rad/sec$

2) The maximum value of a sinusoidal alternating current of frequency 50 Hz is 25A. Write the equation for the instantaneous expression of current. Determine its value at 3 ms and 14 ms.

Solution :- $\omega = 2\pi f\ rad/sec = 100\pi\ rad/sec$

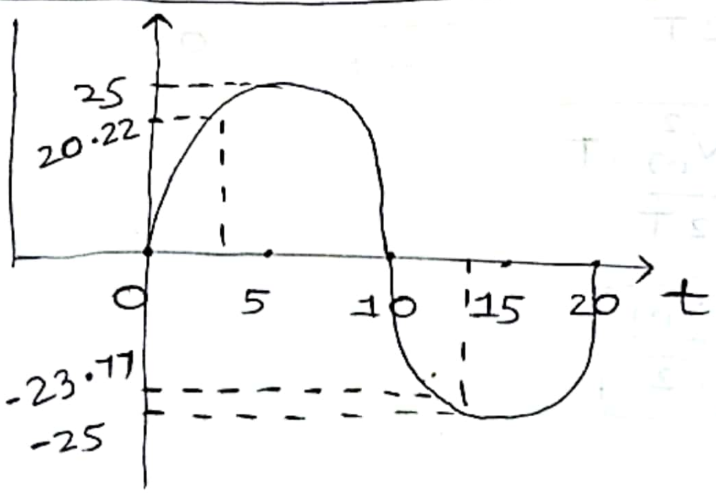
$i(t) = 25 \cdot \sin(100\pi t)\ A$

$i(3ms) = 25 \cdot \sin(100\pi \times 3\ ms)$

$\boxed{i(3ms) = 20.22\ A}$

$i(14ms) = 25 \cdot \sin(100\pi \times 14 ms)$

$\boxed{i(14ms) = -23.77\ A}$



(2) The average value of a sinusoidal function $f(t) = A\cdot\sin(\omega t)$ is :-

$$F_{avg} = \frac{1}{T}\int_0^T A\cdot\sin(\omega t)\cdot dt$$

$$F_{avg} = \frac{1}{T}\cdot A\cdot -\cos(\omega t)\Big|_0^T$$

$$= \frac{1}{T}\cdot A\cdot -\left[\cos\left(\frac{2\pi}{T}\cdot T\right) - \cos 0\right]$$

$$= \frac{-A}{T}\left[\cos(2\pi) - \cos 0\right]$$

$$\boxed{F_{avg} = 0}$$

RMS value of a sine wave :-

$$V = \sqrt{\frac{1}{T}\int_0^T \left[V_m\cdot\sin(\omega t)\right]^2\cdot dt}$$

$$V = \sqrt{\frac{V_m^2}{T}\int_0^T \sin^2(\omega t)\cdot dt}$$

$$V = \sqrt{\frac{V_m^2}{T}\int_0^T \left[\frac{1-\cos(2\omega t)}{2}\right] dt}$$

$$V = \sqrt{\frac{V_m^2}{2T}\left[T - \cancel{\frac{\sin\frac{2\pi}{T}\cdot t}{2\omega}}\right]_0^T}$$

$$V = \sqrt{\frac{V_m^2\cdot T}{2T}}$$

$$\boxed{V = \frac{V_m}{\sqrt{2}}}$$

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3) Write an equation to represent the following sine waves of 50 HZ frequency ?

i) A sinusoidal current with RMS value 10A & starting at 5 msec

ii) A sinusoidal current with peak value 20A & starting at -2.5 msec. Also, comment on the phase relation between them ?

Solution :- $\omega = 2\pi f = 100\pi$ rad/sec

case i) Angle $= \omega t = (100\pi * 5m) = \pi/2$ rad

$$i_1(t) = 10\sqrt{2}\, \sin(100\pi t - \pi/2)\ A$$

case ii) Angle $= \omega t = (100\pi * -2.5m) = -\pi/4$ rad

$$i_2(t) = 20\sqrt{2}\, \sin(100\pi t + \pi/4)\ A$$

4) Consider the following sinusoidal functions

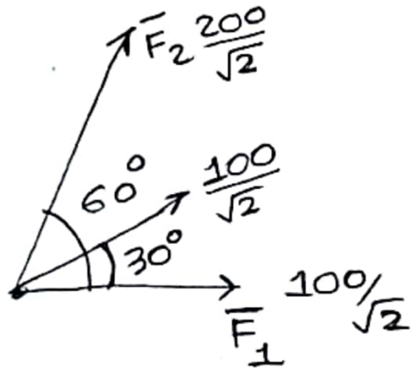
i) $f_1(t) = 100 \sin(100\pi t)$

ii) $f_2(t) = 200 \cdot \sin(100\pi t + 60^\circ)$

iii) $f_3(t) = 100 \cdot \cos(100\pi t - 60^\circ)$

Note : Convert a cosine function to sine form before representing as a phasor

$$f_3(t) = 100 \cdot \sin(100\pi t - 60^\circ + 90^\circ)$$
$$f_3(t) = 100 \sin(100\pi t + 30^\circ)$$



5) There are 3 conducting wires connected to form a junction. The currents flowing into the junction in two wires are $i_1 = 10 \cdot \sin(314t)$ A and $i_2 = 15 \cdot \cos(314t - 45°)$ A. What is the current leaving the junction in the third wire? What is its value at $t=0$?

Solution :- By KCL at the junction :-

$$i_3(t) = i_1(t) + i_2(t)$$

$$\bar{I}_3 = \bar{I}_1 + \bar{I}_2$$

$$i_1(t) = 10\sin(314t) \Rightarrow \bar{I}_1 = \frac{10}{\sqrt{2}}\angle 0° \text{ A}$$

$$i_2(t) = 15 \cdot \cos(314t - 45°)$$

$$i_2(t) = 15 \cdot \sin(314t + 45°) \Rightarrow \bar{I}_2 = \frac{15}{\sqrt{2}}\angle 45°$$

$$\bar{I}_3 = \bar{I}_1 + \bar{I}_2 = \frac{10}{\sqrt{2}}\angle 0° + \frac{15}{\sqrt{2}}\angle 45° = \frac{10}{\sqrt{2}}\angle 0 + 7.5 + j7.5$$

$$= 14.57 + j7.5$$

$$= 16.39\angle 27.24°$$

$$\bar{I}_3 = 16.39\angle 27.24° \text{ A}$$

$$i_3(t) = 23.18\sin(314t + 27.24°) \text{ A}$$

Its value at $t=0$ is

$$i_3(0) = 23.18\sin(27.24°)$$

$$\boxed{i_3(0) = 10.61 \text{ A}}$$

6) A capacitor of capacitance $100\,\mu F$ is connected across an AC voltage source $100 \sin(100\pi t)$ V. Determine i) capacitive Reactance ii) Impedance iii) Instantaneous expression for the current. Also draw the phasor diagram?

Solution :- Given $v(t) = 100 \sin(100\pi t)$

$\omega = 100\pi$ rad/sec

i) capacitive Reactance, $X_c = \dfrac{1}{\omega C} = \dfrac{1}{100\pi \times 100\mu}$

$$\boxed{X_c = 31.83\,\Omega}$$

ii) Impedance, $Z = -j \cdot X_c = -j \cdot 31.83\,\Omega$

iii) $i(t) = I_m \cdot \sin(\omega t + 90^\circ)$

$= V_m \cdot \omega C \cdot \sin(\omega t + 90^\circ)$

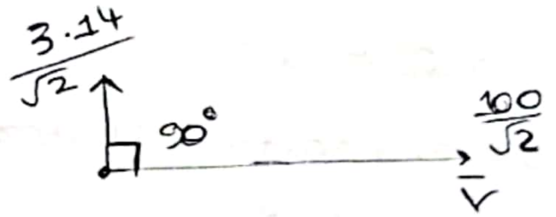
$= 100 \times 100\pi \times 100\mu \times \sin(\omega t + 90^\circ)$

$$\boxed{i(t) = 3.14 \sin(\omega t + 90^\circ)\ A}$$

Phasor Diagram :-

$\bar{V} = \dfrac{100}{\sqrt{2}} \angle 0^\circ$

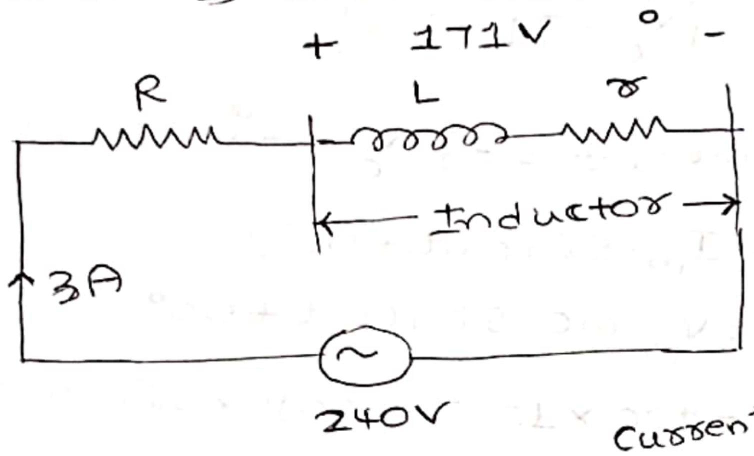
$\bar{I} = \dfrac{3.14}{\sqrt{2}} \angle 90^\circ$



Numerical Examples on Analysis of Series RL & Series RC circuits

1) When a resistor and an inductor in series are connected to a 240 V supply, a current of 3A flows lagging 37° behind the supply voltage, while voltage across the inductor is 171 V. Find the resistance of the resistor, and the resistance and reactance of the inductor. Find the power factor of the circuit ?

Solution :-



Solution :- In AC Systems, if voltage and current are given as numerical values, they represent RMS values

Let us consider current as reference

$\bar{I} = 3\angle 0° \, A$;

Therefore, supply voltage phasor, $\bar{V} = 240\angle 37° \, V$

$$Z_T = \frac{\bar{V}}{\bar{I}} = \frac{240\angle 37°}{3\angle 0°} = 80\angle 37° \, \Omega = [63.89 + j\,48.14]\,\Omega \quad -(1)$$

$$Z_T = R + r + jX_L \quad -(2)$$

comparing (1) & (2) $X_L = 48.14\,\Omega$

$R + r = 63.89\,\Omega \quad -(3)$

Across Inductor $\frac{|V_{inductor}|}{|\bar{I}|} = \frac{171}{3} = \sqrt{r^2 + x_L^2}$

$r^2 + x_L^2 = 3249$

$r^2 = 3249 - 2317.45$

$\boxed{r = 30.52\,\Omega}$

$\boxed{R = 33.37\,\Omega}$

$\boxed{\text{Power factor} = \frac{(R+r)}{|Z_T|} = 0.798 \text{ lag}}$

2) A series RC circuit, with $R = 4\Omega$, $C = 120\,\mu F$ is connected across 230V, 50 Hz supply. calculate the current drawn by the circuit. Draw the phasor diagram?

Solution:- Given $V = 230V$; $R = 4\Omega$; $C = 120\,\mu F$; $f = 50\,Hz$;

$I = ?$

$$I = \frac{V}{Z}$$

$$Z = R - jX_C$$

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C} = \frac{1}{2\pi \times 50 \times 120\mu}$$

$$\boxed{X_C = 26.52\,\Omega}$$

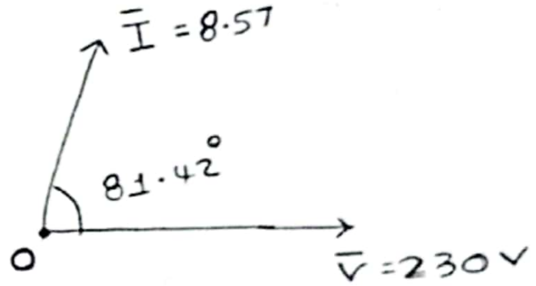
$$Z = R - jX_C$$

$$\boxed{Z = 4 - j26.52}\,\Omega$$

$$I = \frac{230}{4 - j26.52} = \frac{230}{4 - j26.52} = \frac{230}{26.82\angle -81.42^\circ}$$

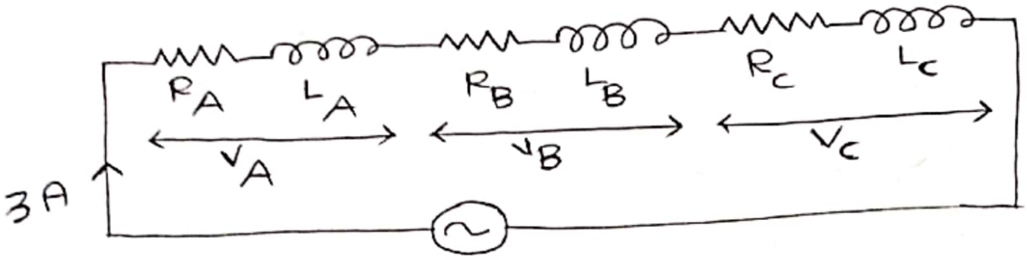
$$\boxed{I = 8.57\angle 81.42^\circ}$$

Phasor diagram:-



3) 3 coils A, B and C are connected in series. When a current of 3 A is passed through the circuit, the voltage drops are respectively 12V, 6V and 9V on direct current and 15V, 9V and 12V on alternating current. Find for each coil i) Internal Parameters ii) Power dissipated when alternating current flows through the circuit iii) Applied voltage across it. Draw the phasor diagram. Find the overall power factor of the circuit?

Solution:



case (i) Direct current ($f=0$)

Under DC condition, inductance will not have any effect $Z_A = R_A$; $Z_B = R_B$; $Z_C = R_C$

$$R_A = \frac{12}{3} = 4\Omega ; \quad R_B = \frac{6}{3} = 2\Omega ; \quad R_C = \frac{9}{3} = 3\Omega$$

Case ii) Under AC conditions

$$Z_A = \frac{15}{3} = 5\Omega ; \quad \sqrt{R_A^2 + X_{L_A}^2} = 5$$

$$X_{L_A}^2 = 25 - 16 \Rightarrow \boxed{X_{L_A} = 3\Omega}$$

$$Z_B = \frac{9}{3} = 3\Omega ; \quad R_B^2 + X_{L_B}^2 = 9$$

$$X_{L_B}^2 = 9 - 4 = 5 \Rightarrow \boxed{X_{L_B} = 2.23\Omega}$$

$$Z_C = \frac{12}{3} = 4\Omega ; \quad R_C^2 + X_{L_C}^2 = 16$$

$$X_{L_C}^2 = 7 \Rightarrow \boxed{X_{L_C} = 2.64\Omega}$$

Power dissipated :-

$P_A = I^2 \cdot R_A = 3^2 \times 4 = 36\,W$

$P_B = I^2 \cdot R_B = 3^2 \times 2 = 18\,W$

$P_C = I^2 \cdot R_C = 3^2 \times 3 = 27\,W$

No power dissipated in inductor & capacitor.

$Z_T = 4 + j3 + 2 + j2.2 + 3 + j2.64$

$\boxed{Z_T = 9 + 7.87j}$

$V = I \cdot Z_T$

$V = 3(9 + 7.87j)$

$\boxed{V = 27 + j23.61}\,\Omega$

$\text{Power} = \frac{R}{|Z_T|} = \frac{9}{\sqrt{9^2 + 9.87^2}} = 0.75$

4) Power dissipated in a series RC circuit is 25 W, while the current and voltage being 0.4 A & 230V respectively. Find the value of capacitance. (Assume supply frequency = 50 Hz) ?

Solution :- $P = VI \cdot \cos\phi$

$\cos\phi = \frac{P}{VI} = \frac{25}{230 \times 0.4}$

$\cos\phi = 0.2717$

$\boxed{\phi = 74.23^\circ}$

$Z = \frac{V}{I} = \frac{230}{0.4\angle 74.23^\circ} = 57.5\angle -74.23^\circ$

$\boxed{Z = 156.27 - j553.35}$

This is of the form :- $Z = R - jX_C$

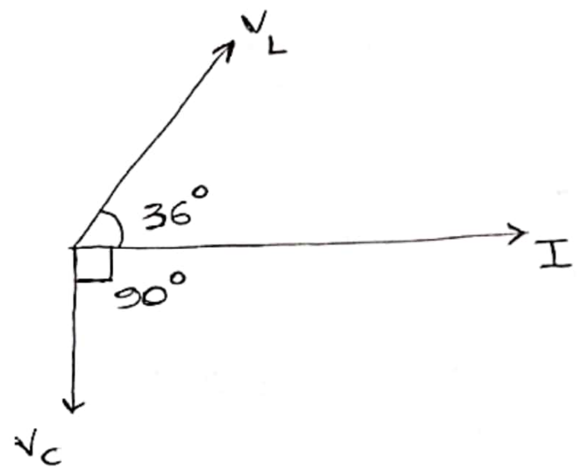
$X_C = 553.35 ; \quad X_C = \frac{1}{\omega C}$

$C = \frac{1}{2\pi \times 50 \times 553.35} = 5.75\,\mu F$

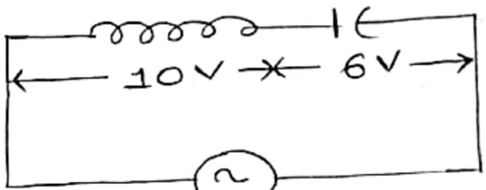
5) The following phasor diagram find the following :-

i) Power factor of the circuit
ii) Reactive power in the circuit
iii) Magnitude of supply voltage

Also, Redraw the phasor diagram by taking supply voltage as reference, mentioning all the voltages & currents. Current phasor is 10 A, V_c is 6 V and V_L is 10V.



solution :-



$\bar{V}_c = 6\angle -90°$; $\bar{V}_L = 10\angle 36°$

$\bar{V} = \bar{V}_L + \bar{V}_c = 8.09 + 5.87i - 6i$

$\bar{V} = 8.09 - 0.122i$

$\boxed{\bar{V} = 8.09 \angle -0.865}$

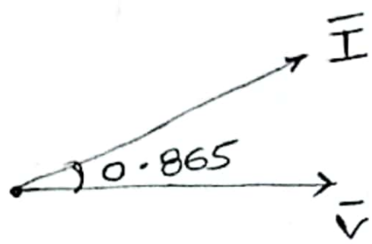
$\bar{I} = 10\angle 0°$; $\phi = -0.86$; Indicates voltage is lagging

$PF = \cos\phi = 0.999$ lead

$Q = VI\sin\phi$

$= 8.09 \times 10 \times \sin(-0.86)$

$\boxed{Q = -1.214 \text{ VAR}}$



Numerical Problems on Series RLC Circuit :-

1) A series RLC circuit draws a current of 20A when connected to 200V, 50 Hz Supply. If the total active power drawn from the source is 500 W and the circuit behaves effectively like an inductive circuit (Series RL type), determine

i) Power factor of the circuit

ii) Inductance in the circuit if capacitance is 100 μF ?

Solution :- Given $V = 200V$; $I = 20A$ & $P = 500W$

i) $P = I^2 \cdot R$

$$R = \frac{P}{I^2} = \frac{500}{(20\phi)^2} = 1.25\Omega$$

$$\therefore \cos\phi = \frac{R}{|Z|} \; ; \; |Z| = \frac{V}{I} = \frac{200}{20} = 10\Omega$$

$$\cos\phi = \frac{1.25}{10} = 0.125 \text{ lag}$$

ii) Net reactance $= X_L - X_C = \sqrt{Z^2 - R^2}$

$$\sqrt{100 - 1.25^2} = X_L - X_C = 9.92\Omega$$

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi \times 50 \times 100 \times 10^{-6}}$$

$$\boxed{X_C = 31.83\Omega}$$

$$X_L = 9.92 + X_C$$

$$X_L = 41.75\Omega$$

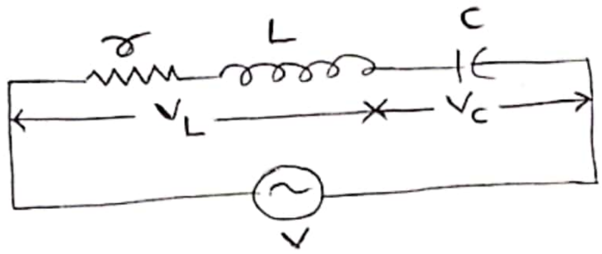
$$X_L = \omega L = 41.75\Omega$$

$$\therefore L = \frac{41.75}{2\pi \times 50}$$

$$\boxed{L = 132.89 \text{ mH}}$$

2) A coil of power factor 0.6 is in series with a 100 μF capacitor. When connected to a 50 HZ supply, the potential difference across the coil is equal to the potential difference across the capacitor. Find the resistance and inductance of the coil?

Solution :-



$$V_L = V_C$$

$$I|Z_L| = I|Z_c|$$

$$|R + jx_L| = |-x_c \cdot j|$$

$$x_c = \frac{1}{\omega C} = 31.83\ \Omega$$

$$\cos\phi = \frac{P}{S} = \frac{R}{|Z|}$$

$$R = |Z| \cdot \cos\phi$$

$$R = 31.83 \times 0.6$$

$$\boxed{R = 19.09\ \Omega}$$

$$R^2 + x_L^2 = 31.83^2$$

$$x_L^2 = 31.83^2 - 19.09^2$$

$$\boxed{X_L = 25.46\ \Omega}$$

$$\omega L = 25.46$$

$$L = \frac{25.46}{100\pi}$$

$$\boxed{L = 81 mH}$$

3) An EMF whose instantaneous value at time t is given by $283 \sin(100\pi t + \pi/4)$ V is applied to an inductive circuit and the current in the circuit is $5.66 \sin(100\pi t - \pi/6)$ A.

Determine

i) the frequency of the EMF

ii) the resistance & the inductance of the circuit

iii) the active power absorbed

If series capacitance is added so as to bring the circuit into resonance at this frequency, and the above emf is applied to the resonant circuit, find the corresponding expression for the instantaneous value of the current and also find the value of the series capacitance. Draw the phasor diagram representing the circuit before and at resonance.

<u>solution:-</u> $\bar{V} = \frac{283}{\sqrt{2}} \angle 45^\circ$; $\bar{I} = \frac{5.66}{\sqrt{2}} \angle -30^\circ$

i)
$$\omega = 100\pi$$
$$2\pi f = 100\pi$$
$$\boxed{f = 50 \text{ HZ}}$$

ii)
$$Z = \frac{\bar{V}}{\bar{I}} = \frac{283/\sqrt{2} \angle 45^\circ}{\frac{5.66}{\sqrt{2}} \angle -30^\circ} = 50 \angle 75^\circ = 12.94 + j48.29$$

$\therefore$ $R = 12.94\,\Omega$; $X_L = 48.29 \Rightarrow \boxed{L = 0.153 \text{ H}}$

iii)
$$P = I^2 . R = \left[\frac{5.66}{\sqrt{2}}\right]^2 \times 12.94 = 207.27 \text{ W}$$

iv) After resonance, $X_L = X_C = 48.29$

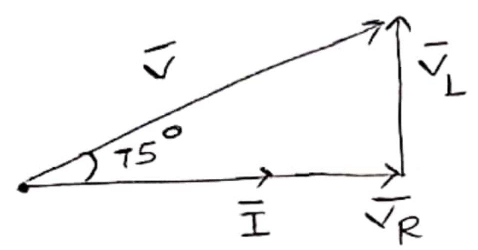
$$\frac{1}{\omega C} = 48.29 \;;\; \boxed{C = 65.91\ \mu F}$$

$$I = \frac{V}{R} = \frac{283/\sqrt{2}\ \angle 45^\circ}{12.94}$$

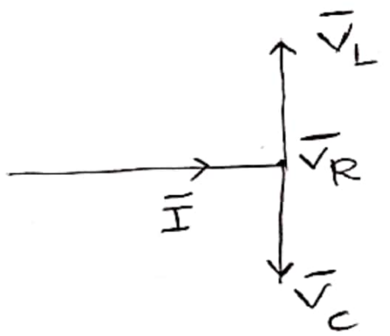
$$I = 15.46 \angle 45^\circ$$

$$\boxed{i(t) = 21.863 \sin(100\pi t + 45^\circ)}$$

Phasor Diagram before resonance :-



At resonance :-



4) A series RLC circuit draws 400 W from a 200V, 50 HZ supply. If the overall resistance is 4Ω & the overall circuit behaves as inductive type, determine

i) Power factor

ii) Inductance in the network if capacitance is 1mF.

iii) what must be the value of capacitance to bring the circuit into resonance ?

Solution :- Given $P = 400\,W$; $V = 200\,V$; $f = 50\,HZ$;
$R = 4\Omega$; $C = 1\,mF$

i) $P = I^2 \cdot R$

$$I = \sqrt{\frac{P}{R}} = \sqrt{\frac{400}{4}} = 10\ A$$

$$P = V \cdot I \cdot \cos\phi$$

$$\cos\phi = \frac{P}{VI} = \frac{400}{200 \times 10} = 0.2 \text{ lag}$$

ii) $\phi = \cos^{-1}[0.2]$

$$\boxed{\phi = 78.46^\circ}$$

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

$$Z = \frac{V}{I} = \frac{200}{10 \angle -78.46^\circ} = 20 \angle 78.46^\circ$$

$$\boxed{Z = 4.00 + 19.59 i}$$

$$X_L - X_C = 19.59$$

$$X_L = 19.59 + \frac{1}{2\pi \times 50 \times 1 \times 10^{-3}}$$

$$X_L = 22.77$$

$$\omega L = 22.77$$

$$L = \frac{22.77}{100\pi}$$

$$\boxed{L = 72.47\ mH}$$

iii) For series resonance, $X_L = X_C$

$$X_C = 22.77\ \Omega$$

$$\frac{1}{2\pi f C} = 22.77$$

$$C = \frac{1}{100\pi \times 22.77}$$

$$\boxed{C = 0.14\ mF}$$

16

5) A series RLC network draws a net reactive power of 3 KVAR from a 500 V, 50 Hz supply and has a overall power factor of 0.8 lag. Determine

i) Total resistance in the network

ii) Inductance if the capacitance is 159.15 μF.

iii) What is the new power factor if an extra resistance of 10 Ω is added in series in the existing network?

Solution :- $Q = 3$ KVAR ; $V = 500$ V ; $f = 50$ Hz ; $\cos\phi = 0.8$

$$\phi = \cos^{-1}[0.8] = 36.86^\circ$$

$$Q = V \cdot I \cdot \sin\phi$$

$$I = \frac{3000}{500 \times \sin(36.86)}$$

$$\boxed{I = 10\,A}$$

$$Z = \frac{V}{I} = \frac{500}{10\angle -36.86^\circ} = 50\angle 36.86^\circ$$

$$Z = 40 + i30$$

$$\Rightarrow \boxed{R = 40\,\Omega}$$

ii) $$X_L - X_C = 30$$

$$X_L = 30 + \frac{1}{2\pi \times 50 \times 159.15 \times 10^{-6}}$$

$$X_L = 50\,\Omega$$

$$L = \frac{50}{2\pi \times 50}$$

$$\boxed{L = 0.159\,H}$$

iii) If extra 10 Ω is added to the network

$$Z = 50 + 30i$$

$$\cos\phi = \frac{50}{\sqrt{50^2 + 30^2}} = \frac{50}{58.30} = 0.857 \text{ lag}$$

6) A series RLC circuit consumes 2 KW of power when connected across 200 V, 50 Hz single phase AC supply. If the overall resistance of the circuit is 5 Ω and the circuit behaves effectively as capacitive type [series RC type], determine

i) Power factor of the network

ii) Total reactive power

iii) capacitance, if the inductance is 10 mH.

iv) what is the value of extra inductance connected in series so that the circuit will be in resonance?

Given :- $P = 2\,KW$; $V = 200\,V$; $f = 50\,Hz$; $R = 5\,\Omega$; $L = 10\,mH$

$$P = I^2 \cdot R$$

$$I^2 = P/R = \frac{2000}{5} = 400 \Rightarrow \boxed{I = 20A}$$

$$P = VI\cos\phi$$

$$\cos\phi = \frac{200\cancel{0}}{20\cancel{0} \times 2\cancel{0}} = 0.5 \text{ lead}$$

$$\boxed{\phi = 60^\circ}$$

ii) Total reactive power :- $Q = VI\sin\phi$

$$Q = 200 \times 20 \times \sin(60^\circ)$$

$$\boxed{Q = -3464\,VAR}$$

iii) $Z = \frac{V}{I} = \frac{200\angle 0^\circ}{20\angle 60^\circ} = 10\angle -60^\circ = 5 - 8.66i$

$$X_L - X_C = -8.66$$

$$\omega L - X_C = -8.66$$

$$X_C = \omega L + 8.66$$

$$X_C = 2\pi \times 50 \times 10m + 8.66$$

$$X_C = \cancel{322.1819371}\ 11.8\,\Omega$$

$$\frac{1}{\omega C} = \cancel{322.1819}\ 11.8\,\Omega$$

$$C = \frac{1}{100\pi \times \cancel{322.819}\ 11.8}$$

$$\boxed{C = 0.27\,mF}$$

iv) for series resonance :-

$$X_L = X_C$$

$$X_L = 11.8$$

$$\omega L = 11.8$$

$$L = 0.03756$$

already present 10 mH

$$37.56\,mH - 10\,mH = 27.56\,mH$$

27.56 mH inductance should be connected in series so that the circuit will be in resonance.

Numerical Problems on Parallel RL & RC Circuit :-

1) The terminal voltage and current for a parallel cirmit are $141.4\sin(2000t)$ V and $7.07\sin(2000t+36^\circ)$ A. Obtain the simplest two element parallel circuit, which would have the above relationship?

Solution :- To find the elements in a network, use the impedance form if it a series network and use the admittance form if it is parallel network.

$$v(t) = 141.4\sin(2000t)\,V \Rightarrow \bar{V} = \frac{141.4}{\sqrt{2}}\angle 0^\circ\ V$$

$$i(t) = 7.07\sin(2000t + 36^\circ)\,A \Rightarrow \bar{I} = \frac{7.07}{\sqrt{2}}\angle 36^\circ\ A$$

$$\text{Admittance } \bar{Y} = \frac{\bar{I}}{\bar{V}} = \frac{\frac{7.07}{\sqrt{2}}\angle 36^\circ}{\frac{141.4}{\sqrt{2}}\angle 0^\circ} = 0.05\angle 36^\circ\ S$$

$$\boxed{Y = 0.04 + j0.029\ S}$$

comparing this with the standard form :-

$$G + jB_c\ ;\ G = 0.04\,S;\ B_c = 0.029\,S$$

Hence it is a parallel RC circuit

$$R = \frac{1}{G} = 25\,\Omega;\quad B_c = \omega C \Rightarrow C = \frac{B_c}{\omega} = \frac{0.029}{2000}$$

$$\boxed{C = 14.5\,\mu F}$$

2) A resistor of 30 Ω and a capacitor of unknown value are connected in parallel across a 110 V, 50 Hz supply. The combination draws a current of 5A from the supply. Find the value of unknown capacitance ?

Solution :- $|Y_T| = \frac{|I|}{|V|} = \frac{5}{110} = 0.045\ S$ - ①

For a parallel RC network $|Y_T| = \sqrt{G^2 + B_c^2}$ -②

$$G = 1/R = \frac{1}{30} = 0.033\ S$$

Substituting G in ② & equating ① & ②

$$0.045 = \sqrt{0.033^2 + B_c^2}$$

$$0.033^2 + B_c^2 = 2.025 \times 10^{-3}$$

$$B_c^2 = 9.36 \times 10^{-4}$$

$$\boxed{B_c = 0.0306\ S}$$

$$B_c = \omega c \Rightarrow C = \frac{B_c}{\omega} = \frac{0.0306}{100\pi}$$

$$\boxed{B_c = 97.40\ \mu F}$$

3) A parallel RL circuit has $R = 4\Omega, X_L = 3\Omega$. Obtain its series equivalent such that the series circuit draws the same current and power at a given voltage ?

Solution :- $R = 4\Omega\ ;\ X_L = 3\Omega$

$$G = 1/4\ S\ ;\ B_L = 1/3\ S$$

$$G - jB_L = 0.25 - 0.33i$$

$$Y = G - jB_L = 0.25 - 0.33i$$

$$Z = \frac{1}{Y} = \frac{1}{0.25 - 0.33i} = 1.45 + 1.92i$$

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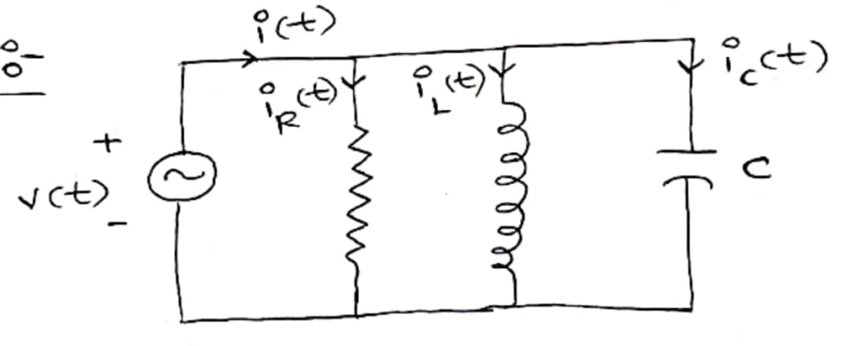
Numerical Problems on Parallel RLC Circuit :-

1) Three circuit elements $R = 2.5\Omega$, $X_L = 4\Omega$ and $X_C = 10\Omega$ are connected in parallel, the reactances being at 50 Hz.

a) Determine the ~~ob~~ admittance of each element and hence obtain the input admittance.

b) If this circuit is connected across a 10V, 50 HZ AC source, determine the current in each branch and the total input current?

Solution :-



i) Admittance of Branch 1 = $Y_1 = \frac{1}{Z_1} = \frac{1}{2.5} = 0.4\,S$

Admittance of Branch 2 = $Y_2 = \frac{1}{jX_L} = -jB_L = -j0.25\,S$

Admittance of Branch 3 = $Y_3 = \frac{1}{-jX_C} = jB_C = j0.1\,S$

Input Admittance = $[0.4 - j0.15]\,S$

ii) Taking supply voltage as reference, $\bar{V} = 10\angle 0^\circ$

current in Branch 1 $= \bar{I}_R = \bar{V}\cdot Y_1 = 10\angle 0^\circ * 0.4$

$\cancel{Y_1 = 0.4\angle 0}\ 4\angle 0^\circ$ $\quad I_1 = 4\angle 0^\circ$ A

current in Branch 2 $= \bar{I}_L = \bar{V}\cdot Y_2 = 10\angle 0^\circ[-j0.25]$

$$\bar{I}_L = 2.5\angle -90^\circ \text{ A}$$

current in Branch 3 $= \bar{I}_C = \bar{V}\cdot Y_3 = 10\angle 0^\circ * j0.1$

$$\bar{I}_C = 1\angle 90^\circ \text{ A}$$

Input current $\bar{I}_S = \bar{I}_R + \bar{I}_L + \bar{I}_C$

$$= 4 - j2.5 + j$$

$$= 4 - j1.5$$

$$\boxed{\bar{I}_S = 4.27\angle -20.55^\circ \text{ A}}$$

2) The admittance of a circuit is $[0.05 - j0.08]$ S. Find the values of the resistance and inductive reactance of the circuit if they are a) in parallel b) in series

Solution :- a) Parallel network

$$Y = 0.05 - j0.08$$

$$Y = G - jB_L$$

$$G = 0.05 ; \quad R = 1/G = 20\,\Omega$$

$$B_L = 0.08 ; \quad X_L = \frac{1}{B_L} = 12.5\,\Omega$$

b) Series network :-

$$Y = 0.05 - j0.08$$

$$\frac{1}{Y} = \frac{1}{0.05 - j0.08} \times \frac{0.05 + j0.08}{0.05 + j0.08} = \frac{0.05 + j0.08}{0.05^2 + 0.08^2}$$

$$\boxed{Z = 5.617 + 8.988i} \qquad R = 5.617\,\Omega$$

$$X_L = 8.988\,\Omega$$

3) Impedance of a two element parallel AC network is $[6+j8]\,\Omega$. Determine the elements and their values if the supply frequency is 50 Hz ?

Solution :- $Z = [6+j8]\,\Omega$

$$Y = \frac{1}{Z} = \frac{1}{6+j8} \times \frac{6-j8}{6-j8}$$

$$Y = \frac{6-j8}{6^2+8^2} = \frac{6-j8}{10}$$

$$\boxed{Y = [0.6 - j0.8]\,\mho}$$

Comparing this with the standard form :-

$$Y = G - jB_L$$

$$G = 0.6;\quad R = \frac{1}{G} = \frac{1}{0.6} = 1.66\,\Omega$$

$$B_L = 0.8;\quad X_L = \frac{1}{B_L} = \frac{1}{0.8} = 1.25\,\Omega$$

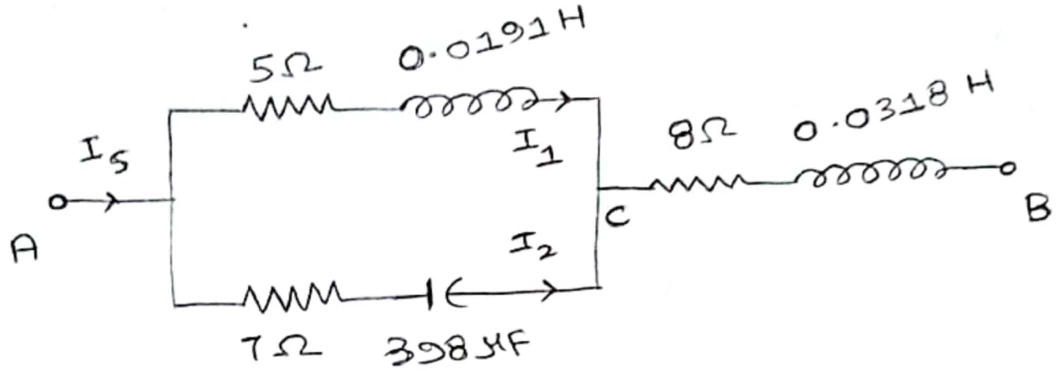
$$X_L = \omega L = 1.25\,\Omega$$

$$L = \frac{1.25}{100\pi}$$

$$\boxed{L = 3.97\text{ mH}}$$

Numerical Problem On Series-Parallel AC Circuits

1)



In the circuit shown, what voltage of 50 Hz frequency is to be applied across A & B that will cause a current of 10 A to flow through the capacitor. Also draw the phasor diagram representing the circuit?

Solution :-

$$Z_1 = 5 + j\,100\pi \times 0.0191$$

$$\boxed{Z_1 = 5 + j6\ \Omega}$$

$$Z_3 = 8 + j\,100\pi \times 0.0318$$

$$\boxed{Z_3 = (8 + j10)\Omega}$$

$$Z_2 = 7 - j\frac{1}{100\pi \times 398\mu}$$

$$\boxed{Z_2 = 7 - j8\ \Omega}$$

Since current through the capacitor is known, let us take it as reference phasor.

$$\bar{I}_2 = 10\angle 0^\circ\ A$$

$$\bar{V}_{AC} = \bar{I}_2 \cdot Z_2 = 10\angle 0^\circ [7 - j8]$$

$$\bar{V}_{AC} = 10 * 10.63\angle -48.81$$

$$\bar{V}_{AC} = 106.3\angle -48.81^\circ$$

$$\bar{I}_1 = \frac{\bar{V}_{AC}}{\bar{Z}_1} = \frac{106.3\angle -48.81^\circ}{5+j6} = \frac{106.3\angle -48.81^\circ}{7.81\angle 50.19^\circ}$$

$$\bar{I}_1 = 13.61\angle -99^\circ \text{ A}$$

$$\bar{I}_S = \bar{I}_1 + \bar{I}_2 = 13.61\angle -99^\circ + 10\angle 0^\circ \text{ A}$$

$$\bar{I}_S = -2.12 - 13.44j + 10$$

$$\bar{I}_S = 7.88 - 13.44j$$

$$\bar{I}_S = 15.58\angle -59.65^\circ \text{ A}$$

$$\bar{V}_{CB} = \bar{I}_S * Z_3$$

$$\bar{V}_{CB} = 15.58\angle -59.65^\circ * [8 + j10]$$

$$\bar{V}_{CB} = 15.58\angle -59.65^\circ * 12.80\angle 51.34^\circ$$

$$\bar{V}_{CB} = 199.48\angle -8.31^\circ \text{ V}$$

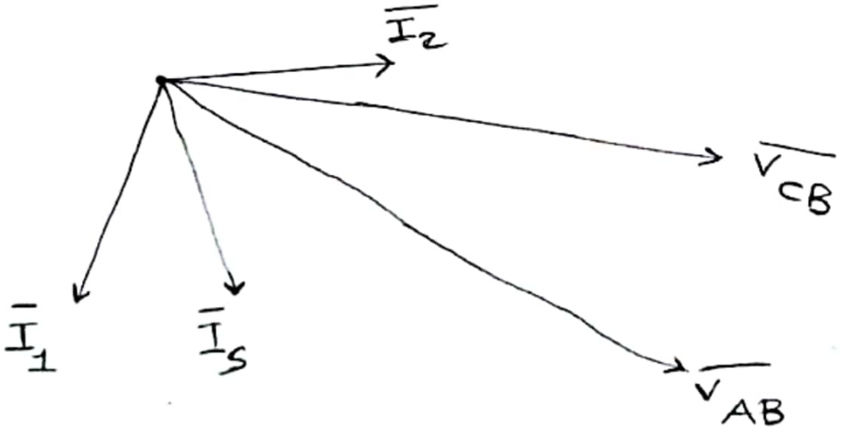
$$\therefore \quad \bar{V}_{AB} = \bar{V}_{AC} + \bar{V}_{CB} = 106.3\angle -48.81^\circ + 199.48\angle -8.31^\circ$$

$$\bar{V}_{AB} = 70 - j79.99 + 197.38 - j28.83$$

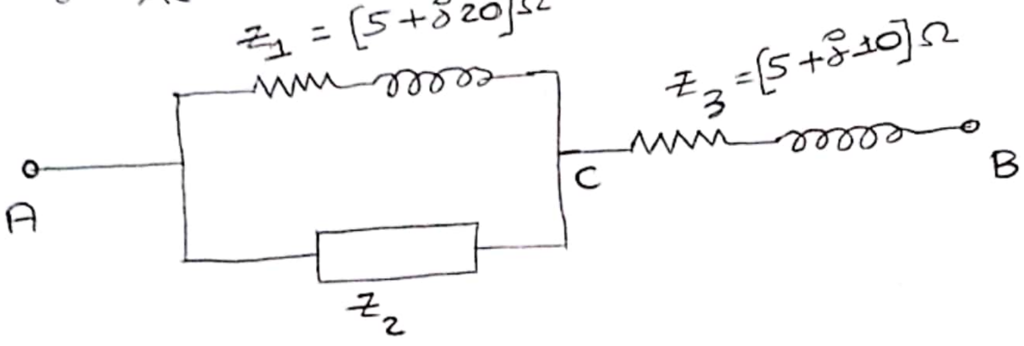
$$\bar{V}_{AB} = 267.38 - j108.82$$

$$\boxed{\bar{V}_{AB} = 288.69\angle -22.14^\circ \text{ V}}$$

Phasor Diagram :-



2) When a 220 V AC supply is applied across terminals A & B of the circuit shown, the total power input is 3.25 KW and the total current is 20 A lag. Find the complex expressions for currents through Z_1 and Z_2, taking V_{AC} as reference phasor?



Solution :- $\bar{V}_{AB} = 220\angle 0^\circ$ V

Total power input = 3.25 KW

$$V_{AB} \cdot I_S * \cos\phi = 3.25 \times 10^3$$

$$\cos\phi = \frac{3.25 \times 10^3}{220 \times 20}$$

$$\boxed{\phi = 42.38^\circ}$$

Since supply current is given as lag, $\bar{I}_S = 20\angle -42.38^\circ$ A

$$\bar{V}_{CB} = \bar{I}_S * Z_3 = 20\angle -42.38^\circ * [5+j10]$$

$$\bar{V}_{CB} = 223.61\angle 21.05^\circ \text{ V}$$

$$\bar{V}_{AC} = \bar{V}_{AB} - \bar{V}_{CB} = 220\angle 0^\circ - 223.61\angle 21.05^\circ$$

$$\bar{V}_{AC} = 81.11\angle -81.98^\circ \text{ V}$$

$$\bar{I}_1 = \frac{\bar{V}_{AC}}{Z_1} = \frac{81.11\angle -81.98^\circ}{5+j20} = 3.93\angle -157.95^\circ \text{ A}$$

$$\bar{I}_2 = \bar{I}_S - \bar{I}_1 = 20\angle{-42.38^\circ} - 3.93\angle{-157.95^\circ}\ A$$

$$\bar{I}_2 = 21.98\angle{-33.1^\circ}\ A$$

We found that $\bar{V}_{AC} = 81.11\angle{-81.98^\circ}$ V.

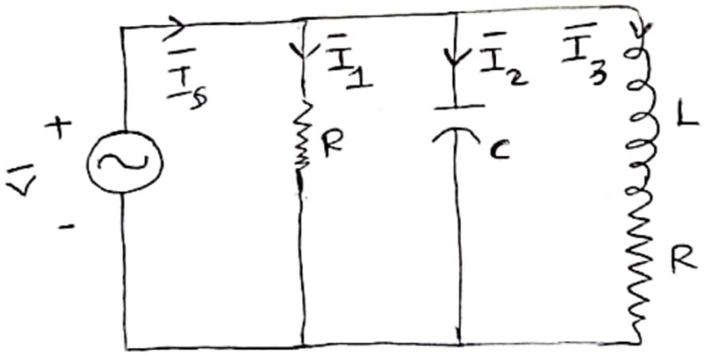
To make $\bar{V}_{AC}$ as reference, add 81.98° to its phase angle.

Also, add the same angle to all the phasors.

Thus, $\bar{I}_1 = 3.93\angle{-75.97^\circ}$ A

$\bar{I}_2 = 21.98\angle{48.88^\circ}$ A

3) A voltage of 200V is applied ~~to~~ to a pure resistor (R), a pure Capacitor (C), and a lossy inductor coil with resistance of 100Ω, all of them connected in parallel. The total current is 2.45 A, while the component currents are 1.5, 2.0 and 1.2 A respectively. Find the total power factor and also the power factor of the coil. Also, find the total active and reactive power?



<u>solution</u> :- Let us consider supply as reference

$\bar{V} = 200\angle{0^\circ}$ V

Therefore :- $\bar{I}_1 = 1.5\angle{0^\circ}$ A ; $\bar{I}_2 = 2\angle{90^\circ}$ A

In branch 3, $|Z_3| = \dfrac{200}{1.2} = 166.66\ \Omega$

Therefore, $\phi_3 = \cos^{-1}\frac{r_3}{|Z_3|} = 53.13^\circ$

$\therefore \bar{I}_3 = 1.2\angle -53.13^\circ$ A

$\therefore \bar{I}_S = \bar{I}_1 + \bar{I}_2 + \bar{I}_3$

$= 1.5\angle 0^\circ + 2\angle 90^\circ + 1.2\angle -53.13^\circ$

$$\boxed{\bar{I}_S = 2.45\angle 25.1^\circ \text{ A}}$$

phase angle of the network $= \phi = \angle\bar{V} - \angle\bar{I}_S$

$\phi = -25.1^\circ$

$\therefore$ overall power factor $= \cos\phi = 0.905$ lead

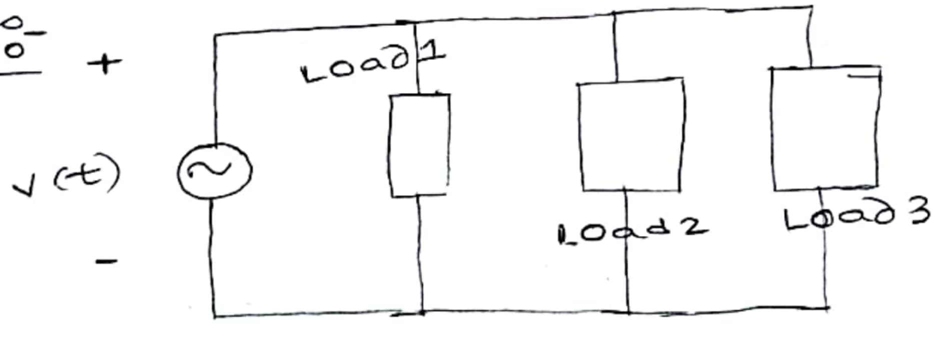
Power factor of the coil $= \cos\phi_3 = 0.6$ lag

Total active power $= P_T = V * I_S * \cos\phi = 443.45$ W

Total reactive power $= Q_T = V * I_S * \sin\phi = -207.85$ VAR

4) The load connected across an AC supply consists of a heating load of 15 KW, a motor load of 40 KVA at 0.6 lag and a load of 20 KW at 0.8 lag. calculate the total power drawn from the supply in (KW & KVA) and its power factor. What would be the KVAR rating of a capacitor to bring the power factor to unity and how must the capacitor be connected?

solution :-



Load 1 :- Heating load $\Rightarrow$ Resistive $\Rightarrow \cos\phi_1 = 1$

$P_1 = 15$ KW ; $Q_1 = 0$; $S_1 = \sqrt{P_1^2 + Q_1^2} = 15$ KVA

Load 2 : Motor load ⇒ Inductive

$S_2 = 40$ KVA & $\cos\phi_2 = 0.6$ lag (given)

$P_2 = S_2 \cdot \cos\phi_2 = 24$ KW

$Q_2 = \sqrt{S_2^2 - P_2^2} = \sqrt{40^2 - 24^2}$

$\boxed{Q_2 = 32 \text{ KVAR}}$

Load 3 : Inductive load :-

$P_3 = 20$ KW & $\cos\phi_3 = 0.8$ (given)

$P_3 = S_3 \cdot \cos\phi_3$

$S_3 = \frac{P_3}{\cos\phi_3} = \frac{20 K}{0.8}$

$\boxed{S_3 = 25 \text{ KVA}}$

$S_3^2 = P_3^2 + Q_3^2$

$Q_3 = S_3^2 - P_3^2$

$Q_3 = \sqrt{(25K)^2 - (20K)^2}$

$\boxed{Q_3 = 15 \text{ KVAR}}$

Net active power $= P_T = P_1 + P_2 + P_3 = 59$ KW

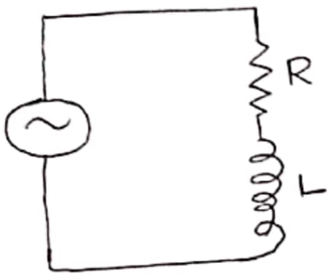
Net reactive power $= Q_T = Q_1 + Q_2 + Q_3 = 47$ KVAR

Net apparent power $= S_T = \sqrt{P_T^2 + Q_T^2} = 75.43$ KVA

To make overall power factor ~~unity~~ unity, real net reactive power must be ~~power~~ zero. Hence, connect a capacitor of rating 47 KVAR in parallel to achieve this.

5) The power consumed in the inductive load is 2.5 KW at 0.71 lagging power factor. The input voltage is 230V, 50 HZ. Find the value of capacitor C which must be placed in parallel, such that the resultant power factor of the input current is 0.866 lagging?

Solution:-



Given:- $P = 2.5\ KW$; $PF = 0.71$ lag ; $V = 230V, 50\ HZ$

$$P = V \cdot I \cdot \cos\phi$$

$$I = \frac{P}{V \cdot \cos\phi}$$

$$I = \frac{2.5 \times 10^3}{230 \times 0.71}$$

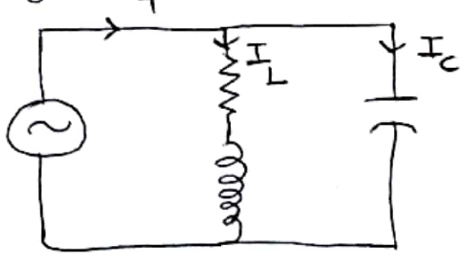
$$\boxed{I = 15.309\ A}$$

$$\cos\phi = 0.71$$

$$\phi = \cos^{-1}[0.71] = 44.76^\circ$$

$$\boxed{\therefore\ I = 15.309\angle{-44.76^\circ}\ A}$$

For power factor improvement, we connect a capacitor in parallel:-



$$I_T\angle{-30^\circ} = 15.309\angle{-44.76^\circ} + I_c\angle{90^\circ}$$

30

By equating real parts :-

$I_T \cdot \cos(30°) = 15.309 \cos(44.76°) + 0$

$\boxed{I_T = 12.55 A}$

$\therefore \quad I_C = I_T - I_L$

$I_C = 12.55 \angle -30° - 15.309 \angle -44.76°$

$I_C = 10.86 - 6.275i - \{10.87 - 10.77i\}$

$\boxed{I_C \simeq 4.504 \angle 90°}$

$X_C = \frac{V_C}{I_C} = \frac{230}{4.504}$

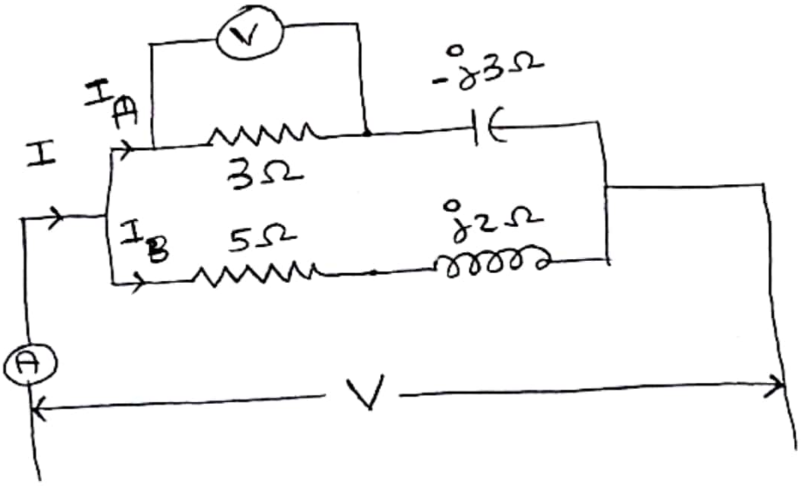
$\boxed{X_C = 51.065 \Omega}$

$\frac{1}{2\pi f C} = 51.065$

$C = \frac{1}{100\pi \times 51.065}$

$\boxed{C = 62.33 \mu F}$

6) Find the reading of the ammeter when the voltmeter across 3Ω resistor in the circuit shown reads 45 V ?



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$Z_A = 3 - j3\ \Omega$; $Z_B = 5 + j2\ \Omega$

$$I_A = \frac{V_{3\Omega}}{3\Omega} = \frac{45}{3} = 15\ A$$

$$V_A = V_B = V$$

$$V_A = I_A \cdot Z_A = 15\{3 - j3\} = 45 - j45$$

$$V_A = V_B = V = 63.63\angle{-45^\circ}\ V$$

$$V_B = I_B \cdot Z_B$$

$$I_B = \frac{V_B}{Z_B} = \frac{63.63\angle{-45^\circ}}{5 + j2}$$

$$\boxed{I_B = 11.81\angle{-66.8^\circ}\ A}$$

$$I = I_A + I_B$$

$$I = 15 + 11.81\angle{-66.8^\circ}\ A$$

$$\boxed{I = 22.45\angle{-28.91^\circ}\ A}$$

7) Two Impedances $Z_1 = 6 + j8\ \Omega$ and $Z_2 = 4 + j3\ \Omega$ are connected in parallel across 200V AC supply.

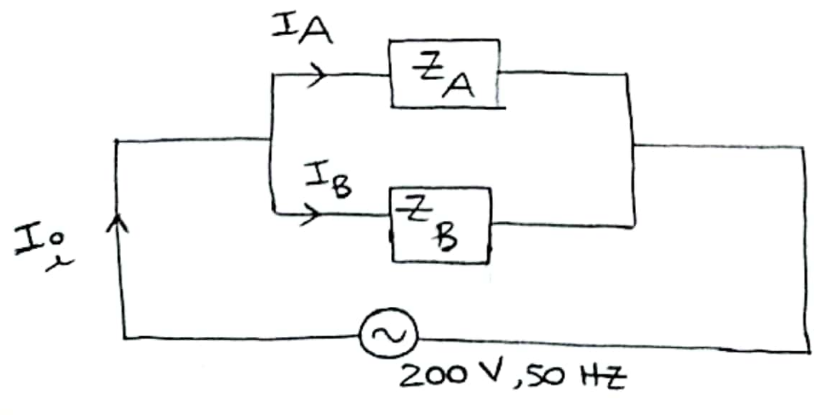
Determine

i) Active power in Branch 1

ii) Reactive Power in Branch 2

iii) Source current

iv) Power factor of the network



(32)

$$I_A = \frac{V}{Z_A} = \frac{200}{6 + j8} = 20\angle{53.1^\circ}\ A$$

$$I_B = \frac{V}{Z_B} = \frac{200}{4 + j3} = 40\angle{-36.8^\circ}\ A$$

$$I_A + I_B = 20\angle{53.1^\circ} + 40\angle{-36.8^\circ}$$

$$\boxed{I_i = 44.7\angle{-10.25^\circ}\ A}$$

Only take magnitude of currents :-

i) Active Power in Branch 1 = $P_1 = I_1^2 * R_1$

$= 20^2 * 6 = 2.4\ KW$

ii) Reactive Power in Branch 2 = $Q_2 = I_2^2 \times X_L$

$= 40^2 \times 3$

$= 4.8\ KVAR$

iii) Source current = $I_i = 44.7\angle{-10.25^\circ}\ A$

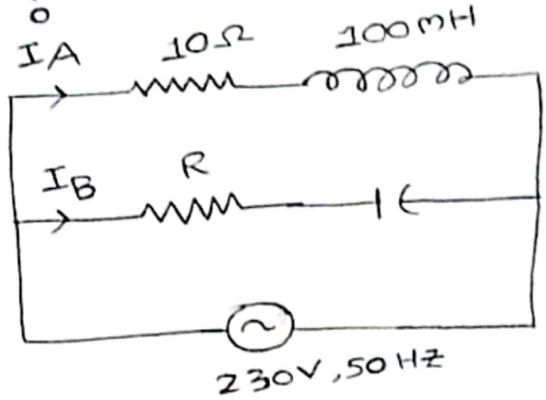
iv) Power factor the network = $\cos\phi$

$= \cos(10.25^\circ)$

$$\boxed{\cos\phi = 0.98\ lag}$$

8) An AC circuit has two branches A & B connected in parallel across 230V, 50 Hz supply. Branch A consists of a coil with inductance 100 mH and the resistance of 10 Ω. Branch B takes a leading current from the supply. If the total power drawn from the supply is 1 KW and the overall PF is 0.6 lag, determine capacitance & resistance of B ?

Solution :-



$$P_T = V \cdot I \cdot \cos\phi$$

$$I_T = \frac{P_T}{V \cdot \cos\phi} = \frac{1\times10^3}{230\times0.6}$$

$$I_T = 7.24 \text{ A}$$

$$\bar{I}_T = 7.24\angle 53.13^\circ \text{ A}$$

$$I_A = \frac{230}{10+j\{100\pi * 100m\}} = \frac{230}{10+31.41i}$$

$$I_A = 2.1167-6.6486i = 6.97\angle -72.34^\circ \text{ A}$$

$$I_T = I_A + I_B \Rightarrow I_B = I_T - I_A = 7.24\angle 53.13^\circ - 6.97\angle -72.34^\circ$$

$$I_B = 2.2295 + 0.8495i = 2.38\angle 21.03^\circ \text{ A}$$

$$Z_B = \frac{V_B}{I_B} = \frac{230}{2.38\angle 21.03^\circ} = 96.63\angle -21.03^\circ \ \Omega$$

$$Z_B = 90.19 - 34.67i; \quad R = 90.19\ \Omega$$

$$X_C = \frac{1}{2\pi f C} = 34.67$$

$$C = \frac{1}{100\pi \times 34.67} = 91.81\ \mu F$$

8) The load connected across the AC supply consist of heating load of 20 KW, a motor load of 30 KVA at 0.8 lag and a load of 50 KW at 0.85 lag. calculate the power drawn by the load from supply in KW & KVA and its power factor. What would be the KVAR rating of a capacitor to bring the power factor to unity and how would the capacitor be connected?

Solution:- Load 1

$P_1 = 20\ KW$; $\cos\phi = 1$; $Q_1 = 0$

$\therefore S_1 = \sqrt{Q_1^2 + P_1^2} = 20\ KVA$ - 1M

load 2

$S_2 = 30\ KVA$; $\cos\phi_2 = 0.8$; $\phi_2 = 36.86°$

$P_2 = 24\ KW$

$Q_2 = 17.995\ KVAR$

$Q_2 \simeq 18\ KVAR$ - 1M

load 3

$P_3 = 50\ KW$; $\cos\phi_3 = 0.85$; $\phi_3 = 31.788$

$S_3 = 58.82\ KVA$; $Q_3 = 30.987\ KVAR$

$Q_3 \simeq 31\ KVAR$ - 1M

$P_T = P_1 + P_2 + P_3 = 94\ KW$ - 1M

$Q_T = Q_1 + Q_2 + Q_3 = 49\ KVAR$ - 1M

$S_T = \sqrt{P_T^2 + Q_T^2} = 106.004\ KVA$ - 1M

$\cos\phi_T = \frac{P_T}{S_T} = 0.866$ lag - 2M

To bring the power factor to unity; Q_T must be 0.
Hence we need to connect a capacitor of 49 KVAR in parallel - 1M

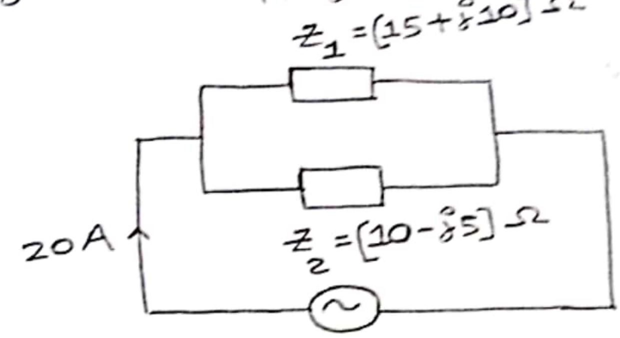
9) A branch with $Z_1 = (15+j10)\,\Omega$ is connected in parallel with another branch $Z_2 = [10-j5]\,\Omega$. If the total current supplied to the combination is 20 A, Find

i) RMS Value of applied Voltage ii) Branch currents in polar form

iii) Power factor of the total circuit iv) Power consumed by each branch

Draw the phasor diagram representing the branch currents, supply voltage and supply current.

Solution:-



$$\bar{Z}_T = \bar{Z}_1 \parallel \bar{Z}_2$$

$$\bar{Z}_T = (15+j10)\parallel(10-j5) = [7.884 - j0.576]\,\Omega$$

$$\bar{Z}_T = 7.9056\angle{-4.184^\circ}\ \Omega \quad - \text{(1M)}$$

$$V = 157.692 - j11.53$$

or

$$V = 158.11\angle{-4.184^\circ}\ V \quad - \text{(1M)}$$

$$I_1 = \frac{V}{Z_1} = 8.77\angle{-33.69^\circ}\ V \quad - \text{(1M)}$$

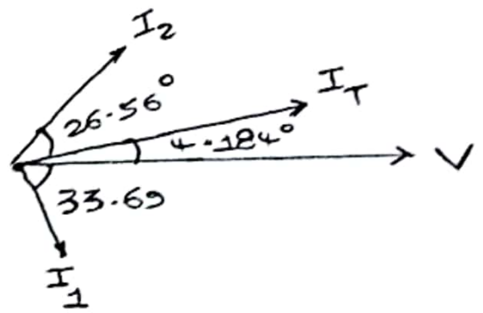
$$I_2 = \frac{V}{Z_2} = 14.14\angle{26.56^\circ}\ V \quad - \text{(1M)}$$

$$\cos(\Phi_T) = \cos(4.184) = 0.9973 \text{ lead} \quad - \text{(2M)}$$

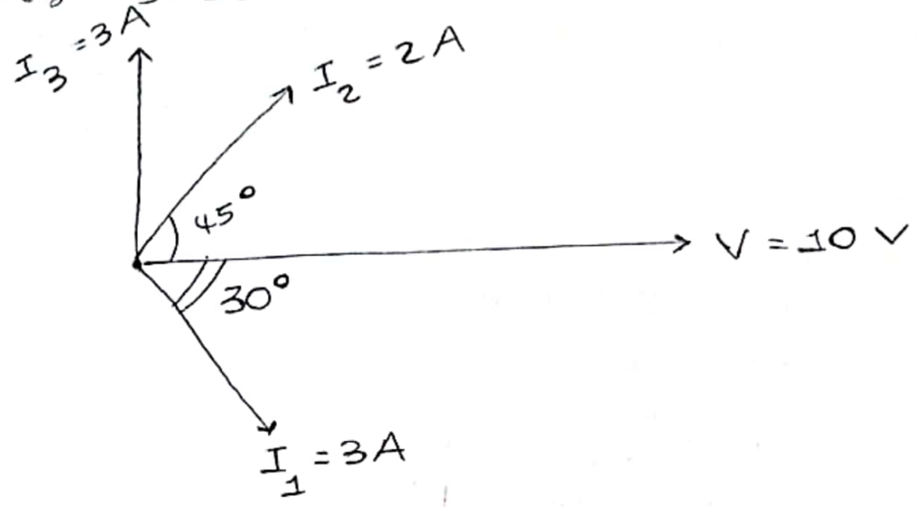
$$P_1 = I_1^2 \cdot R_1 = 1153.69\ W \quad - \text{(1M)}$$

$$P_2 = I_2^2 \cdot R_2 = 1999.39\ W \quad - \text{(1M)}$$

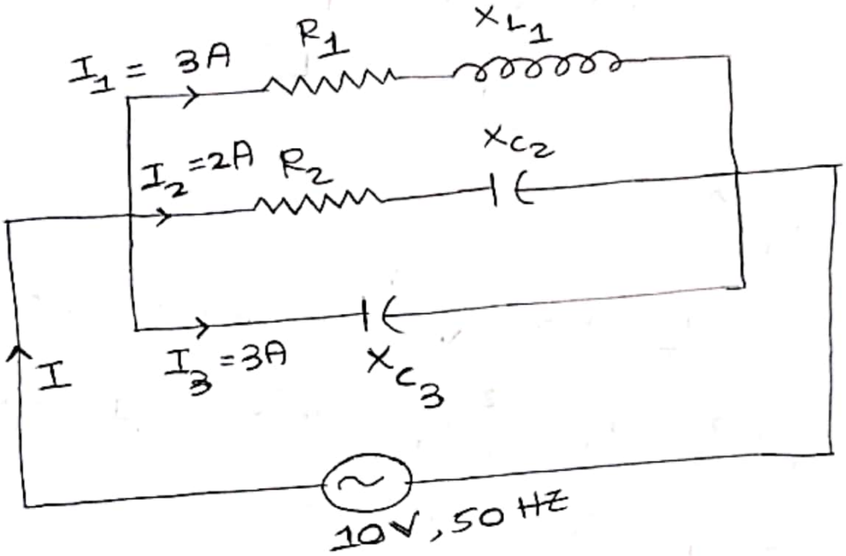
Phasor diagram:-



2 a) From the given phasor diagram, draw the circuit and compute the different circuit elements by taking frequency $f = 50$ Hz.



Solution :-



(2M)

$X_{C_3} = \frac{V}{I_3} = \frac{10}{3} = 3.33\,\Omega$; $\frac{1}{2\pi f C_3} = X_{C_3}$

$\Rightarrow \boxed{C_3 = \frac{1}{2\pi \times 50 \times 3.33} = 955.8\,\mu F}$

(1M)

$X_{C_2} = \frac{1}{2\pi f C_2}$

$C_2 = \frac{1}{2\pi f \times X_{C_2}}$

$C_2 = \frac{1}{2\pi \times 50 \times 3.541}$

$\boxed{C_2 = 900.4\,\mu F}$

(1M)

$Z_1 = \frac{V}{I_1} = \frac{10}{3\angle -30^\circ} = 3.33\angle 30^\circ$

$= [\underbrace{2.88}_{R_1} + j\underbrace{1.611}_{X_{L_1}}]\,\Omega$

$X_{L_1} = 2\pi f L_1$

$\boxed{L_1 = \frac{1.611}{2\pi \times 50} = 5.23\,mH}$; $\boxed{R_1 = 2.88\,\Omega}$

(1M)

$Z_2 = \frac{V}{I_2} = \frac{10}{2\angle 45^\circ} = 5\angle -45^\circ = [\underbrace{3.53}_{\boxed{R_2}} - j\underbrace{3.541}_{X_{C_2}}]\,\Omega$

(2)

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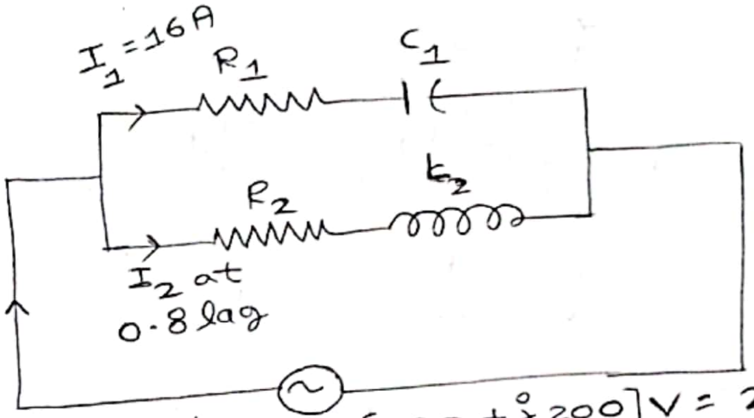
54 ②

2b) 2 impedances Z_1 and Z_2 are connected in parallel. The first branch takes a leading current of 16 A and the resistance of 5 Ω. While the second branch takes a lagging current at a power factor of 0.8. The total power supplied is 5 KW and the applied voltage being $(100+j200)$ V. Determine the complex expressions of branch currents & total current. Also, draw the complete phasor diagram representing the circuit taking voltages as the reference.

Solution :-



1M

$P_T = 5\,KW$ $\quad V = [100 + j200]\,V = 223.60\angle 63.43^\circ\,V$

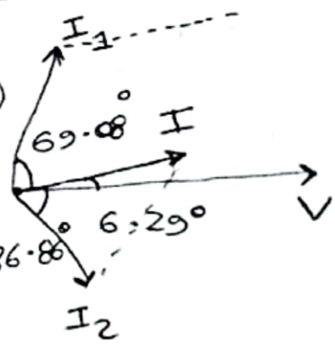
$P_T = P_1 + P_2$; $P_1 = I_1^2 \cdot R_1 = 16^2 \times 5 = 1.28\,KW$

$P_2 = P_T - P_1 = 3.72\,KW$

$P_2 = V \cdot I_2 \cdot \cos\phi_2$ 1M

$I_2 = \dfrac{3.72 \times 10^3}{223.60\angle 0^\circ \times 0.8}$ $\Rightarrow$ $\boxed{I_2 = 20.79\angle -36.86^\circ\,A}$

$Z_1 = \dfrac{V}{I_1} = \dfrac{223}{\cancel{16.179}\ 16} = 13.975\,\Omega$ 1M



$\cos\phi = \dfrac{R_1}{Z_1} = \dfrac{5}{13.975} = 0.357$ lead

1M $\boxed{I_1 = 16\angle 69.08^\circ\,A}$

$\bar{I}_T = \bar{I}_1 + \bar{I}_2 = 16\angle 69.08^\circ + 20.79\angle -36.86^\circ$

$\boxed{\bar{I}_T = 22.5\angle 6.29^\circ\,A}$ 1M

2c) When 100 V, 50 Hz 1ϕ AC supply is supplied to a coil A, the current drawn is 8 A and the power is 120 W. When the same voltage is applied to a coil B, the current drawn is 10 A and power is 500 W. What current will be taken when 100 V is applied to the two coils connected in series? ③

Solution :- $I_A = 8$ A ; $I_B = 10$ A

Coil A

$$P_A = V \cdot I \cdot \cos\phi_A$$

$$\cos\phi_A = \frac{\cancel{100} \times \cancel{8}\ 120}{100 \times 8} = 0.15$$

$$\phi_A = 81.37^\circ$$

1M $\boxed{\bar{Z}_A = 12.5 \angle 81.37^\circ \ \Omega}$

Coil B

$$P_B = V \cdot I \cdot \cos\phi_B$$

$$\cos\phi_B = \frac{500}{100 \times 10}$$

$$\cos\phi_B = 0.5$$

$$\phi_B = 60^\circ$$

1M $\boxed{\bar{Z}_B = 10 \angle 60^\circ \ \Omega}$

$$\bar{Z}_T = \bar{Z}_A + \bar{Z}_B = 12.5 \angle 81.37^\circ \ \Omega + 10 \angle 60^\circ$$

1M $\boxed{\bar{Z}_T = 22.10 \angle 71.88^\circ \ \Omega}$

$$I_T = \frac{V}{Z_T} = \frac{100}{22.10 \angle 71.88^\circ} = 4.52 \angle -71.88^\circ \text{ A}$$ 1M

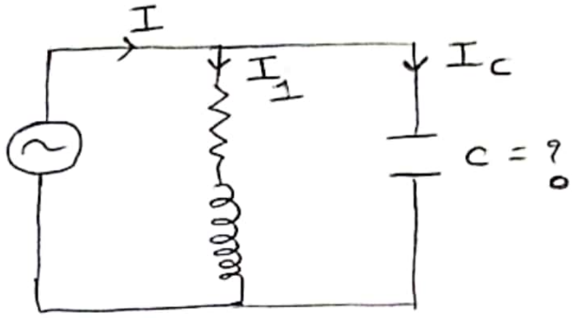
$$P_T = V \cdot I \cdot \cos\phi_T$$

$$P_T = 100 \times 4.52 \angle -71.88^\circ$$

$\boxed{P_T = 140.72 \text{ W}}$ 1M

2 d) The power consumed in the inductive load is 2.5 kW at 0.71 lagging power factor. The input voltage is 230 V, 50 Hz. Find the value of capacitor C which must be placed in parallel, such that the resultant power factor of the input current is 0.866 lagging

Solution :- $P_1 = 2.5\ KW$; $V = 230V$; $f = 50\ Hz$ (4)



2M

$\cos\phi_1 = 0.71$; $P_1 = V \cdot I_1 \cdot \cos\phi_1$

$$V \cdot I_1 = \frac{P_1}{\cos\phi_1} = 3.52\ KVA = S_1$$

2M

$$Q_1 = \sqrt{S_1^2 - P_1^2} = 2.48\ KVAR$$

$P_1 = P_2 = 2.5\ KW$; $\cos\phi_2 = 0.866$ lag

$$P_2 = V \cdot I \cdot \cos\phi_2 = 2.5\ KW$$

$$V \cdot I = S_2 = 2.88\ KVA$$

$$Q_2 = \sqrt{S_2^2 - P_2^2} = 1.44\ KVAR$$

2M

$$Q_c = Q_1 - Q_2$$

$$Q_c = 2.48 - 1.44$$

$$\boxed{Q_c = 1.04\ KVAR}$$

$$Q_c = \frac{V^2}{X_c} \Rightarrow X_c = \frac{V^2}{Q_c}$$

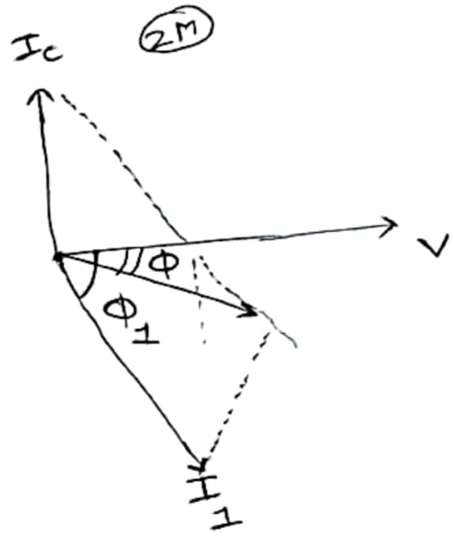
$$X_c = 50.865\ \Omega$$

$$\Rightarrow \frac{1}{2\pi f C} = 50.865$$

2M

$$\boxed{C = 62.57\ \mu F}$$

2M



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