Electrical

Assignment-3

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2K19/A13/26

Civil Engineering (IInd sem)

(1) In a particular circuit a voltage of 10 V at 25 Hz produces 100mA, while the same voltage at 75 Hz produces 60mA. Draw the circuit diagram and insert values of the constants. At what frequency will the value of the impedence be twice of that at 25 Hz?

$\nu_1 = 25 Hz$

$V_1 = 10 V$

$I_1 = 100 \times 10^{-3} A$

$Z_1 = 100 \Omega$

$\nu_2 = 75 Hz$

$V_2 = 10 V$

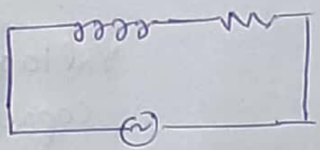
$I_2 = 60 \times 10^{-3} A$

$Z_L = 166.66 \Omega$

$\nu \uparrow, Z \uparrow$

$Z \propto \nu$

The circuit contains an inductor and resistor.



$X_L = \omega L$

$= 2\pi \nu L$

Let resistance be R

when $\nu = 25 Hz$

$X_L = 2 \cdot \pi \cdot 25 \times L = 50\pi L$

$Z = \sqrt{R^2 + X_L^2}$

$100 = \sqrt{R^2 + (50\pi L)^2}$

$R^2 = (100)^2 - (50\pi L)^2 \quad —(1)$

$R^2 = 10000 - 2500 \times 10 \times 0.09$

$R^2 = 7750$

$\boxed{R = \sqrt{7750} \Rightarrow 88.1\Omega}$ Ans

when $\nu = 75 Hz$

$X_L = 2\pi \times 75 \times L = 150\pi L$

$Z = \sqrt{R^2 + X_L^2}$

$\frac{500}{3} = \sqrt{R^2 + 150\pi L}$

Putting $R^2 = 100^2 - 50\pi L^2$

$\frac{(1000)^2}{36} = (100)^2 + (100\pi L)^2 \times 2$

$\Rightarrow 100 (100)^2 = 36 (100)^2 + (100)^2 (\pi L)^2 \times 2 \times 36$

$100 = 36 + (\pi L)^2 \times 2 \times 36$

$36 \times 2 \times \pi^2 L^2 = 64$

$L = \sqrt{\frac{64}{2\pi^2 \times 36}} = \frac{8}{6\pi\sqrt{2}} = \frac{8}{6\sqrt{2}\pi}$

$\boxed{L = 0.3 H}$ Ans

If impedence $Z = 200 \Omega$

$Z^2 = R^2 + \omega^2 L^2$

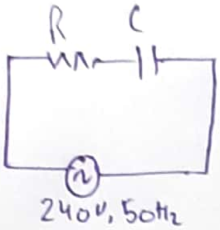
$(200)^2 = (88.1)^2 + 4\pi^2 \times 0.09 \times \nu^2$

$32238.39 = 3.6 \nu^2$

$\nu = \sqrt{\frac{32238}{3.6}} = \boxed{95.22 Hz}$ Ans

(2) A resistor R in series with a capacitance C is connected to a 50 Hz, 240 V supply. Find the value of C so that R absorbs 300 W at 100 V. Also find the maximum charge and maximum energy stored in C.

$V = 100\,V, \quad P = 300\,W$



$\frac{V^2}{R} = P \Rightarrow \frac{10000}{R} = 300$

$\boxed{R = 100/3\ \Omega}$

$I^2 R = P$

$I^2 \times \frac{100}{3} = 300$

$\boxed{I = 3\,A}$

Impedence $Z = \frac{V}{I} = \frac{240}{3} = 80\Omega$

$Z = 80\,\Omega$

$Z^2 = R^2 + X_C^2$

$6400 = \frac{10000}{9} + X_C^2$

$X_C = \sqrt{\frac{57600 - 10000}{9}} = \sqrt{\frac{47600}{9}}$

$X_C = \frac{218.17}{3} = 72.72\,\Omega$

Voltage across Capacitor $= I \times X_C$

$\Rightarrow 3 \times 72.72$

$= 218.17\,V$

$\frac{1}{2\pi \nu C} = 72.72$

$\nu = 50\,Hz$

$C \Rightarrow \frac{1}{2\pi\, 50 \times 72.72} = 0.0000437\,F = 43.7\,\mu F$

$Q = CV \Rightarrow 43.7 \times 10^{-6} \times 218.16$

$= 9533.59 \times 10^{-6}$

$= 0.95\,C$ Ans

$Q_{max} = 240 \times 43.7 \times 10^{-6}$

$\Rightarrow 0.0104\,C$ Ans

Max Energy $= \frac{1}{2} C V^2$

$= \frac{1}{2} \times 43.7 \times 240 \times 240 \times 10^{-6}$

$\approx 1.2\,J$ Ans

(3) An alternating voltage $80 + j60\,V$ is applied to a circuit and current flowing is $-4 + j10\,A$. Find

a) the impedence of the circuit.

b) Power consumed

c) the phase angle.

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$V = 80 + j60 = 100\angle 36.86°$
$I = -4 + j100 = 10.97\angle 111.80°$

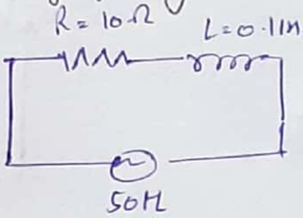
a) Impedence $= Z = \frac{V}{I} = \frac{100\angle 36.86}{10.97\angle 111.8} = 9.285\angle -74.94°$ phase angle

$Z = 9.285$ Ans.

b) Power $= 100 \times 10.97 \times \cos(74.94)$
$= 279.83$ W Ans

c) Phase angle $= 74.94 \simeq 75°$ (I leading) Ans.

④ Calculate a) the admittance Y ; b) the conductance G ; c) the ~~supe~~ susceptance B of a circuit consisting of a resistor of 10 Ω in series with an inductor of 0.1H when the frequency is 50 Hz.



$R = 10\,\Omega$
$Z = 10 + j31.41$
$Z = 32.96\angle 72.34$

$X_L = \omega L$
$= 2\pi \times 50 \times 0.1$
$X_L = 10\pi$

$Y = \frac{1}{Z} = \frac{1}{32.96}\angle -72.34$

$$\boxed{Y = 0.0303\angle -72.34}$$

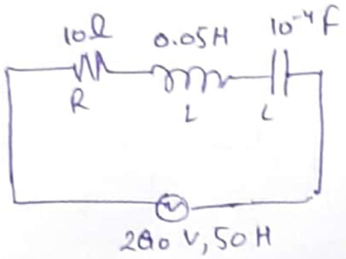
$Y = 0.0303$ Ans mho

$Y = G + jB$
$\Rightarrow Y = 9.19 \times 10^{-3} - j0.028$
$\Rightarrow$ $\boxed{\begin{array}{l} G = 0.00919 \text{ mho} \\ B = 0.028 \end{array}}$ Ans

⑤ Find the impedence, current, power and power factor of the following series circuit and draw the corresponding vector diagrams.

a) R only
b) L only
c) C only
d) R and L
e) R and C
f) R, L and C
g) L and C

In each case $V = 200$V
$\nu = 50$ Hz
$R = 10\,\Omega$
$L = 50$ mH
$C = 100\ \mu$F



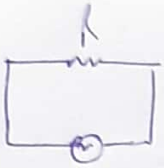
$X_L = \omega L$

$= 2\pi \times 50 \times 0.05$

$X_L = 15.7\ \Omega$

$X_C = \frac{1}{\omega C} = \frac{1}{2\pi \times 50 \times 10^{-4}} = \frac{100}{\pi} = 31.8\ \Omega$

a)



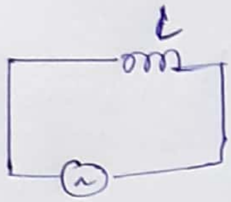
$\Rightarrow$ $Z = 10\ \Omega$ Ans

$I = \frac{V}{R} = \frac{200}{10} = 20A$ Ans

Power $= VI = 4000W$ Ans

Power factor $= R/Z = \frac{10}{10} = 1$ Ans

b)



$X_L = \omega L$

$= 100\pi \times 50 \times 10^{-3}$

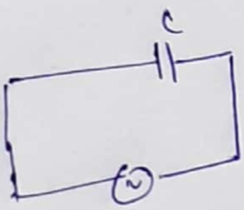
$X_L = 15.7\ \Omega$ Ans

$I \Rightarrow \frac{200}{15.7} = 12.73A$ Ans

$P = VI\cos\phi = 0W$ Ans

power factor $\Rightarrow \cos 90 = 0$ Ans

c)



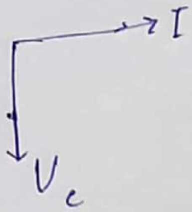
$X_C = \frac{1}{\omega C} = \frac{1}{100\pi \times 100 \times 10^{-6}}$

$X_C = 31.8\ \Omega$ Ans

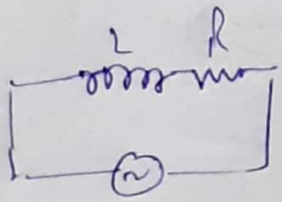
$I = \frac{200}{31.8} = 6.28A$ Ans

$P = VI\cos\phi = 0$

power factor $= \cos 90 = 0$



d)



impedence $Z = 10 + j15.7$

$= 18.61 \angle 57.5$

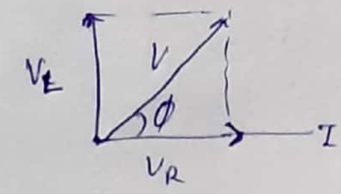
current $= 10.74 \angle -57.5°$

Power $= VI\cos\phi$

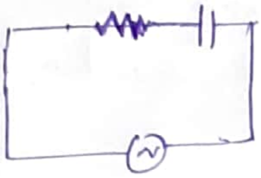
$= 200 \times 10.74 \times \cos(57.5)$

$= 1.154$ KW

$\cos\phi = 0.53$ (lag)



e)



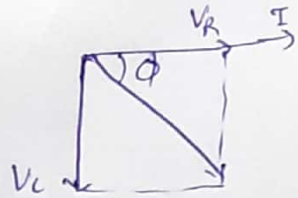
Impedance $= 10 - j31.8 = 33.33\,\Omega \angle -72.54°$

Current $= 6 \angle 72.54°$

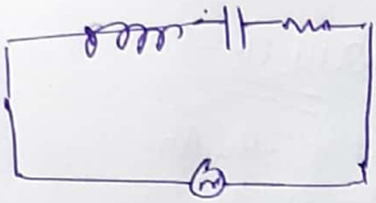
Power $= VI\cos\phi = 200 \times 6 \times \cos(72.54)$

$= 360.04\ W$

Power factor $= 0.3$ (lead)



f)



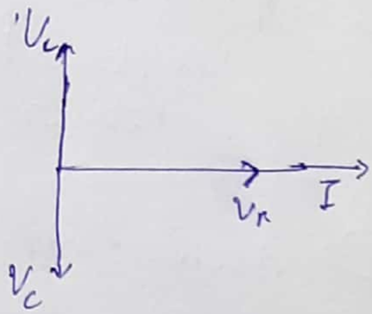
Impedance $= 10 + j15.7 - j31.8$

$= 10 - j16.13$

$Z = 18.97 \angle -58.20°$

$I = \frac{V}{Z} = \frac{200}{18.97} \angle +58.20$

$I = 10.54 \angle 58.20°$



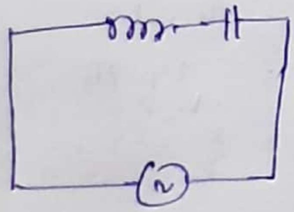
Power $= VI\cos\phi$

$= 200 \times 10.54 \cos(58.2)$

$= 1110.76\ W$

Power factor $= \cos\phi = 0.526$

g)

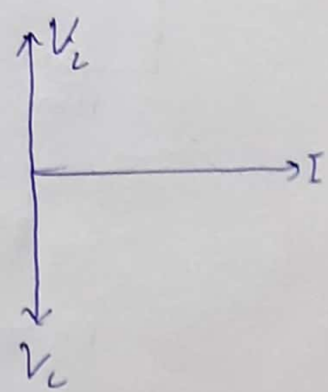


Impedance $= -j1.61\,\Omega = 16.1 \angle -90$

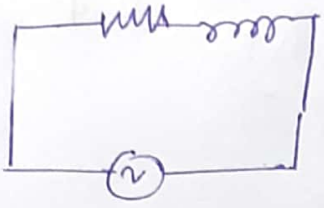
Current $= 12.42\ A$

Power $= 0$

Power factor $= 0$



6) When a resistor and inductor in series are connected to a 240V supply, a current of 3A flowing lagging behind 37° behind the supply voltage, while the voltage across the inductor is 171V. Find the resistance of resistor and the resistance & reactance of the inductor.



$\phi = 37°$

$I = 3\ A \angle -37°$

$V_L = 171V$

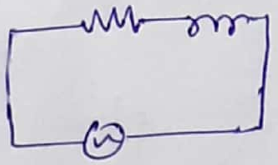
$Z = \frac{V}{I} = \frac{240}{3\angle -37} = 80\angle 37$

$Z = 63.89 + j48.14$ Ans

Reactance / ~~Resistance~~ of inductor $= 48.14\ \Omega$ Ans

Resistance of Resistor $= 63.89\ \Omega$ Ans

(7) A coil having resistance R ohms and inductance L henry is connected across a variable frequency alternating-current supply of 110V. An ammeter in the circuit showed 15.6 A when the frequency was 80 Hz and 19.7 A when the frequency was 40Hz. Find the values of R and L and the time const of the coil.



110v

$\nu_1 = 80Hz$

$I_1 = 15.6\ A$

$V = 110\ V$

$Z_1 = \frac{V}{I} = \frac{110}{15.6} = 7.05$

$\nu_2 = 40\ Hz$

$I_2 = 19.7A$

$V = 110V$

$Z_2 = \frac{V}{I} = \frac{110}{19.7} = 5.58$

$R^2 + \omega^2 L^2 = (7.05)^2$

$R^2 + 4\pi^2 \times 6400 L^2 = (7.05)^2$ — (1)

$R^2 + \omega^2 L^2 = (5.58)^2$

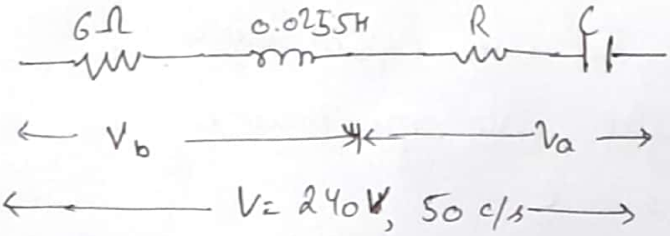
$R^2 + 4\pi \times 1600 L^2 = (5.58)^2$ — (2)

From (1) & (2)

$R = 4.98\ \Omega$, $L = 0.01H$ Ans

Const of coil $= L/R = 2ms$ Ans

(8) Find the values of R and C so that $V_b = 3V_a$ and V_b and V_c are in quadrature. Also find the phase relation b/w ~~V~~ V_b, V_a and I



$V_b = 3V_a \angle 90^\circ$ [$\because$ V_a & V_b are in quadrature]

$\dfrac{V_b}{V_a} = 3\angle 90^\circ$

$Z_b = 6 + j(2\pi \times 50 \times 0.0255) = 6 + j\,8.011\ \Omega$

$Z_b = 10.008 \angle 53.16^\circ$ //

$\boxed{I_a = I_b}$

$\Rightarrow \dfrac{V_b}{Z_b} = \dfrac{V_a}{Z_a} \Rightarrow \dfrac{Z_b}{Z_a} = \dfrac{V_b}{V_a} = 3\angle 90^\circ$

$\dfrac{10.08\angle 53.16^\circ}{Z_a} = 3\angle 90^\circ$

$Z_a \Rightarrow 3.336 \angle -36.84^\circ$

$\boxed{Z_a = 2.669 - j\,2}$ $\left[\begin{array}{l} R = 2.669 \\ X_c = 2 \end{array}\right]$

$\Rightarrow R = 2.669\ \Omega$

$C = \dfrac{1}{200\pi} = \dfrac{1}{2\times 50\pi \times 2}$ $\left(C = \dfrac{1}{2\pi f X_c}\right)$

$\boxed{C = 1.591\times 10^{-3}\ F}$ Ans

(9) A circuit comprises of a conductance G in parallel with a susceptance B. Calculate the admittance G + jB ; if the impedence is 10 + j5 Ω

$Z = 10 + j5 \Rightarrow 11.18 \angle 26.56^\circ$

$Y = \dfrac{1}{Z} = \dfrac{1}{11.18} \angle -26.56 \Rightarrow 0.0894 \angle -26.56^\circ$

$= 0.079 - j\,0.039$

$\boxed{G = 0.079 ;\ B = -0.039}$ Ans

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(10) Find the impedances, the current in each branch, the total current and power factor of the following circuits.

a) Resistance R in parallel with inductance L.

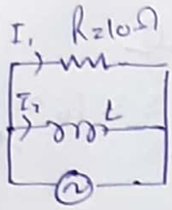
b) Resistance R in parallel with capacitance C

c) Inductance L in parallel with capacitance C.

d) R and L in series with C.

In each case the applied voltage is 200 V at 50 H; R = 10 Ω; L = 70 mH C = 127.2 μF. Draw in each case ~~fallowing~~ the circuit diagram and the vector diagram of the voltages and currents.

a)



$$Z = \frac{Z_1 Z_2}{Z_1 + Z_2} = \frac{jR\omega L}{R + j\omega L}$$

$$Z_1 = R$$

$$Z_2 = jX_L = j\,2\pi\nu L = j\omega L$$

$$\boxed{I_1 = \frac{V}{Z_1}} = \frac{V}{R}, \quad \boxed{I_2 = \frac{V}{Z_2} = \frac{V}{j\omega L}}$$

$$\text{Total current} = \frac{V}{Z} = \frac{V}{jR\omega L}(R + j\omega L) \qquad \boxed{\cos\phi = 0.91}$$

$$Z = \frac{j(10 \times 21.94)}{10 + j(21.99)}$$

$$Z = \frac{219.9\angle 90}{24.15\angle 65.54} = 9.105\angle 24.46\,\Omega$$

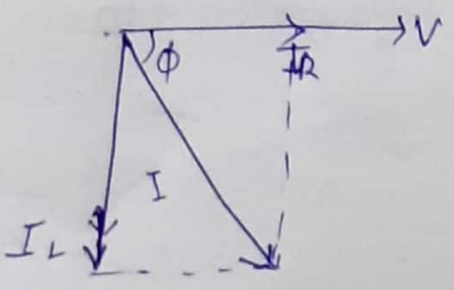
Power factor $= \frac{Z}{R} = \cos\phi$

$$I_R = \frac{200}{10} = 20\text{ A}$$

$$I_L = \frac{200}{21.95} = 9.09\text{ A}$$

$I_{total} = 21.96$ A Ans

$$\cos\phi = \frac{\sqrt{R^2 + \omega^2 L^2}}{R} = 0.91 \text{ Ans}$$



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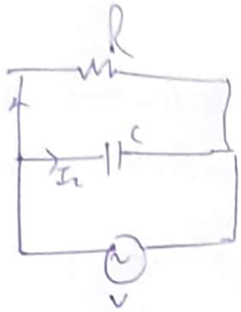
b) I_1



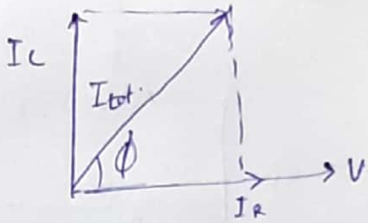
$$Z = \frac{Z_1 Z_2}{Z_1+Z_2} = \frac{\frac{-jR}{\omega R}}{R - j\frac{1}{\omega C}} = \frac{-j10\times 25.02}{10-j25.02} = 9.28\angle -21.8$$

$$\boxed{Z = 9.28\angle -21.8^\circ}$$

$I_R = \frac{V}{R}$, $I_C = \frac{V\omega C}{j} = j V\omega C$

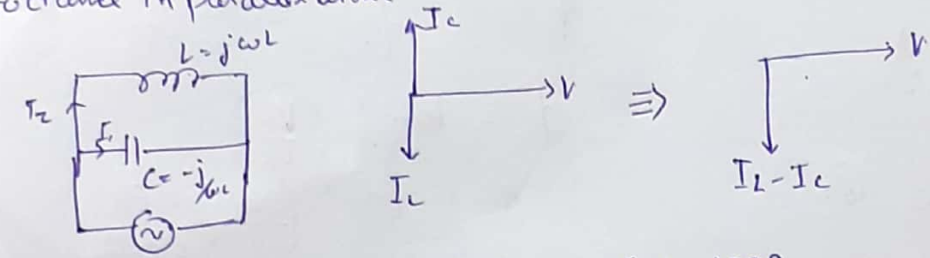
$I_R = 10A$, $I_C = \frac{200}{25.02} = 7.95 =$

$$\boxed{I_{total} = 21.55A}$$



Power factor $= \cos\phi = \frac{I_R}{I} = \frac{\sqrt{R^2 \frac{1}{\omega^2 C^2}}}{R} = \boxed{0.92 \text{ lagging behind } I}$

c) Inductance in parallel with C



$Z_1 = (j\omega L) = j21.95\,\Omega$

$Z_2 = -j\frac{1}{\omega C} = -j(25.02)$

$$Z_{eq} = \frac{Z_1 Z_2}{Z_1+Z_2} = \frac{550.1898}{-j3.03} = \frac{550.1898 \angle 0}{3.03 \angle -90}$$

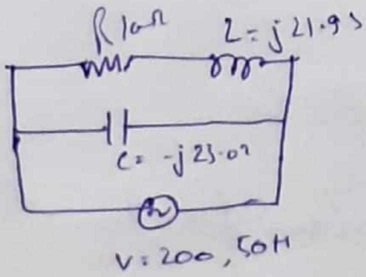
$\boxed{Z_{eq} = 181.58\angle 90^\circ}$ $\boxed{\cos\phi = 0}$ (lag)

$I_L = \frac{V}{X_L} = \frac{200}{21.95} = 9.09A$

$\boxed{I_{total} = 1.10A}$ A

$I_C = \frac{V}{X_C} = \frac{200}{25.02} = 7.99A$

d)



$Z = 57.83\angle 7.61^\circ$

$I_{total} = 3.45A$

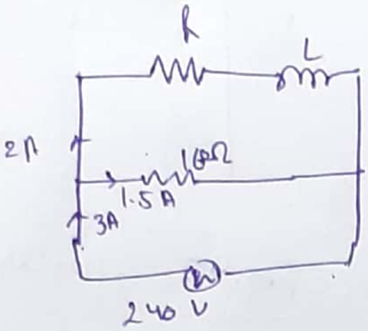
$\cos\phi = \cos 7.61 = 0.99$ (lead)

$Z_1 = 10 + j21.99$

$Z_2 = -j25.02$

$$Z = \frac{Z_1 Z_2}{Z_1+Z_2} = \frac{604.23\angle(24.48)}{10-j3.03}$$

(11) A small single phase 240 V induction motor tested in parallel with a 160 Ω resistor, the motor takes 2 A and total current is 3 A. Find the power and power factor a) the whole circuit, b) the motor.

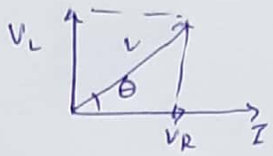


$Z_1 = \frac{V}{I_1} = \frac{240}{2} = 120$

$Z_1 = 120\angle\theta$

$Z_2 = 160$

for Z_1



$Z \Rightarrow \frac{240}{3} = 80\angle\phi$

$Z_1 = \frac{240}{2} = 120\angle\theta$

$\phi = \tan^{-1}\left[\frac{I_2 \cdot \sin\theta}{I_R + I_2\cos\theta}\right]$

$\frac{1}{Z} = \frac{1}{Z_1} + \frac{1}{Z_2}$

$\phi = \tan^{-1}\left(\frac{V_L}{V_R}\right)$

$\frac{1}{80\angle\phi} = \frac{1}{120\angle\theta} + \frac{1}{160}$

$\phi = \tan^{-1}\left(\frac{4\sin\theta}{3+4\cos\theta}\right)$ — (2)

$0.0125\angle-\phi = 0.0083\angle-\theta + 0.00625$ — (1)

$\Rightarrow$ from (1) & (2)

$\cos\phi = \frac{3+4\cos\theta}{\sqrt{25+24\cos\theta}}$; $\sin\phi = \frac{4\sin\phi}{\sqrt{25+24\cos\theta}}$

Putting it in eq (1)

$0.0125\left(\frac{3+4\cos\theta}{\sqrt{25+24\cos\theta}}\right) - j0.0125\left(\frac{4\sin\theta}{\sqrt{25+24\cos\theta}}\right) = 0.0083\cos\theta - j0.0083\sin\theta + 0.00625$

Comparing imaginary parts.

$\frac{0.0125 \times 4\sin\theta}{\sqrt{25+24\cos\theta}} = 0.0083\sin\theta$

solving $\boxed{\cos\theta = 0.4704}$ → Power factor

Pow = $VI\cos\theta$ = 225.792 W Ans

$\boxed{\cos\phi = \frac{3+4\cos\theta}{\sqrt{25+24\cos\theta}} = 0.8103}$ Ans

Power of circuit = 583.49 W Ans

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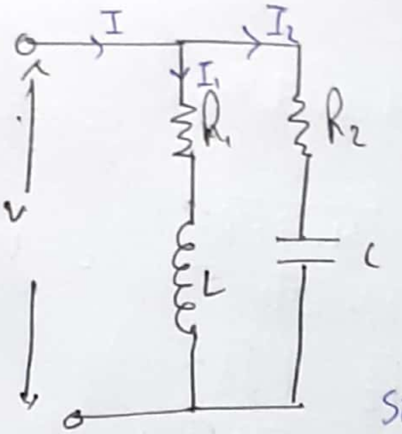
(12) Find the condition that the currents in the two branches of the alternating current circuit shown shall remain in quadrature when R_1 & R_2 are varied simultanously. Determine a) the frequency at which the total current remains const in magnitude under this condit^n
b) the magnitude of this current



$$I_1 = \frac{V}{Z_1}, \quad I_2 = \frac{V}{Z_2}$$

Let take the angular freq

$$I_1 = \frac{V}{R_1 + j\omega L} \; ; \; I_2 = \frac{V}{R_2 - \frac{1}{\omega C}}$$

$$\phi_1 = \tan^{-1}\left(\frac{X_L}{R}\right) \; ; \; \phi_2 = \tan^{-1}\left(-\frac{X_C}{R}\right)$$

Since I_1 & I_2 are in quadrature

$$\phi_1 - \phi_2 = 90°$$

$$\tan^{-1}\left(\frac{X_L}{R_1}\right) + \tan^{-1}\left(\frac{X_C}{R_2}\right) = 90°$$

Taking tan on both sides.

$$\frac{\frac{X_L}{R_1} + \frac{X_C}{R_2}}{1 - \frac{X_L X_C}{R.R}} = \tan 90$$

a) $$1 - \frac{X_L \cdot X_C}{R_1 R_2} = 0 \Rightarrow \boxed{R_1 R_2 = X_L X_C = \frac{L}{C}}$$

b) $$|I| = \sqrt{I_1^2 + I_2^2 + 2I_1 I_2 \underbrace{\cos\phi}_{0}}$$

$$\phi = 90$$

$$I = \sqrt{\frac{V^2}{R_1^2 + \omega^2 L^2} + \frac{V^2 \omega^2 C^2 R_1^2}{R_1^2 + \omega^2 L^2}}$$

$$I = \frac{V}{\sqrt{R_1^2 + \omega^2 L^2}} \sqrt{1 + \omega^2 C^2 R_1^2}$$

$$|I| = \text{con} = \frac{dI}{dR_1} = 0$$

$$\frac{dI}{dR_1} = \frac{V\left[\frac{\sqrt{R_1^2 + \omega^2 L^2}\,(2R_1\omega^2 C^2)}{2\sqrt{1+\omega^2 C^2 R_1^2}} - \frac{\sqrt{1+\omega^2 C^2 R_1^2}}{2\sqrt{R_1^2 + \omega^2 C^2}} \cdot 2R_1\right]}{(R_1^2 + \omega^2 L^2)}$$

Putting $\frac{dI}{dR_1} = 0$ & solving

$$R_1^2 \omega^2 C^2 + R_1 \omega^4 L^2 C^2 - R_1 \omega^2 C^2 R_1^3 = 0$$

b) $$\boxed{\omega = \frac{1}{\sqrt{LC}}}$$ Ans //

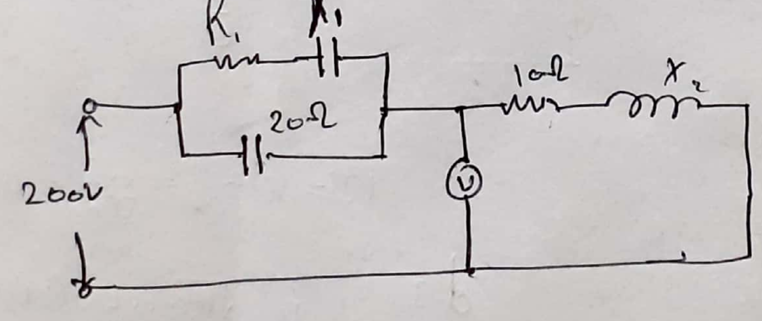
Hence, frequency at this condition = $\frac{1}{2\pi\sqrt{LC}}$ //

Magnitude of current = $\frac{V\sqrt{1+\omega^2 C^2 R_1^2}}{\sqrt{R_1^2 + \omega^2 L^2}} = \frac{V\sqrt{1+\frac{C}{LC}R_1^2}}{\sqrt{1+\frac{L^2}{C}}}$

$= V\sqrt{\frac{C}{L}}\frac{\left(\sqrt{\frac{L}{C}+R_1^2}\right)}{\left(\sqrt{R_1^2 + L/C}\right)}$

Magnitude of current = $V\sqrt{\frac{C}{L}}$ Ans //

(13) The circuit shown takes 12 A at a lagging pf and dissipates 1.8 kW when the voltmeter reading is 200V. Calculate the value of R_1, X_1 & X_2



when reading of voltmeter = 200V

$VI\cos\phi = 1.8 \times 10^3$

$\cos\phi = \frac{R_1}{X_2}$

$\frac{200 \times 12 \times 10}{X_2} = 1.8 \times 10^3$

$$\boxed{X_2 = 13.32\Omega}$$