MODULE - III

AC FUNDAMENTALS

DC ~~is~~ supply has constant magnitude w.r.t ~~to~~ time

AC changes periodically both in magnitude & direction. The change in magnitude & direction is measured in terms of cycle.

Instantaneous value: a value of an alternating quantity at a particular time.

Wave form: graph of instantaneous values of an alternating quantity plotted against time.

Cycle: each repetition or a set of positive and negative instantaneous values of alternating quantity. wave form which exhibit variations that occur after a regular time interval is known as periodical waveforms.

1 cycle corresponds to 2π.

Time period: Time taken by an alternating quantity to complete one cycle. (T). After every T seconds, cycle of an alternating quantity repeats.

Frequency: no. of cycles completed by an alternating quantity per second (f).

$$f = \frac{1}{T}$$ Hertz / cycles per sec.

Amplitude : max value gained by an alternating quantity during positive /negative half cycle.

Angular frequency : frequency expressed in electrical radians per second.

$$\omega = 2\pi f = \frac{2\pi}{T}$$

Peak value : max instantaneous value measured from zero

Peak to peak value : max variation b/w max +ve instantaneous value & max -ve instantaneous value.

For a sinusoidal wave form Vp it is $2V_m$.

peak amplitude : max instantaneous value measured from the mean value of a waveform.

Instantaneous value of ~~a waveform~~ the generated emf

$$e = E_m \sin\theta$$

$$e = E_m \sin\omega t$$

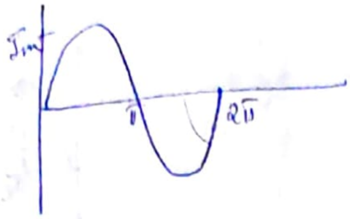
$$e = E_m \sin(2\pi f)t$$

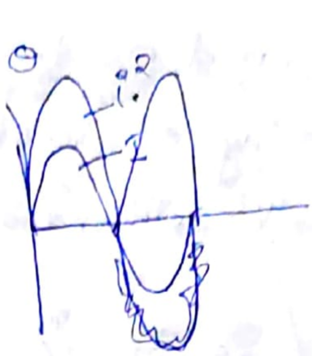
$$e = E_m \sin\left(\frac{2\pi}{T}\right)t$$

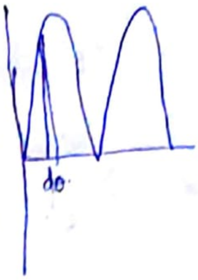
RMS value / Effective value

rms value of an alternating current is given by that steady state current which when flowing through a given ckt for a given time produces the same amount of heat as produced by ac ~~&~~ through the same circuit for the same time.

$i = I_m \sin\theta$







area $= i^2 d\theta$

Total area $= \int_0^\pi i^2 d\theta$

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

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

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

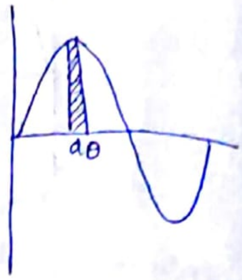
$$= \frac{I_m^2}{\pi}\int_0^\pi \sin^2\theta \, d\theta = \frac{I_m^2}{\pi}\int_0^\pi \frac{1-\cos 2\theta}{2}$$

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

$$\boxed{R_{rms} = \frac{I_m}{\sqrt{2}} = 0.707\, I_m}$$

Average value

Average value of an alternating quantity is defined as that value which is obtained by averaging all instantaneous values over a period of half cycle.



$$1 \quad i_{av} = \frac{1}{\pi}\int_0^{\pi} i \, d\theta$$

$$= \frac{1}{\pi}\int_0^{\pi} I_m \sin\theta \, d\theta$$

$$= \frac{I_m}{\pi}\int_0^{\pi} \sin\theta \, d\theta$$

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

$$\boxed{I_{av} = 0.637 \ I_m}$$

Form factor

$$\frac{I_{rms}}{I_{av}} = \frac{0.707 \ I_m}{0.637 \ I_m} = 1.1 \rightarrow \text{sinusoidal wave form.}$$

Peak factor

$$K_p = \frac{\text{Max value}}{\text{RMS}} = \sqrt{2}$$

An alternating voltage has an equation $v = 141.4 \sin 377t$. What is the value of i) RMS voltage ii) frequency iii) instantaneous value

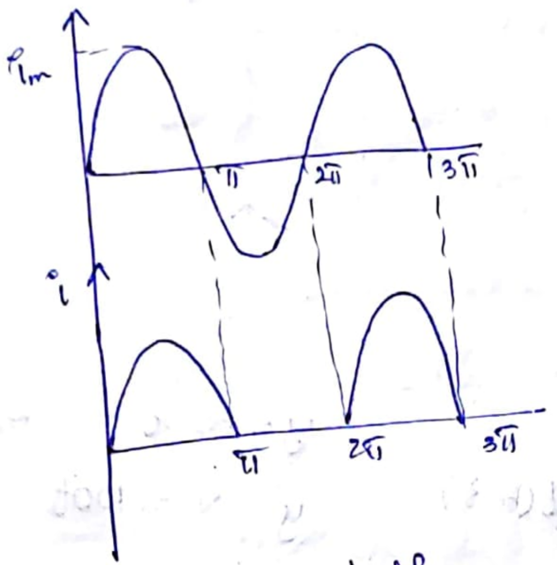
$V = V_m \sin\omega t$ $\qquad \omega = 377$

$= 141.4 \sin 377t$

iii) $V = 127.9$ $= V_m \sin(377 \times 3 \times 10^{-3})$

ii) $f = \frac{\omega}{2\pi} = 60\,Hz$

Find the average and rms value.



RMS – half wave

$= \frac{1}{2\pi} \int_0^{\pi} I_m^2 \sin^2\theta \, d\theta$

$= \frac{I_m^2}{2\pi} \int_0^{\pi} \frac{1-\cos 2\theta}{2}$

$\frac{I_m^2}{4\cancel{\pi}} \times \cancel{\pi} = \frac{I_m^2}{4}$

RMS value $= \frac{I_m}{2}$

Average of ~~full~~ half wave

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

$= \frac{1}{2\pi} \left[\int_0^{\pi} I_m \sin\omega t \, dt + \int_0^{2\pi} 0 \, dt \right]$

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

$I_{avg} = \frac{I_m}{\pi}$

In case of full wave rectifier

$\frac{1}{2\pi} \int_0^{2\pi} I_m \sin\omega t$

$I_{avg} = \frac{2 I_m}{\pi}$

$\frac{1}{2\pi} \int_0^{4\pi} I_m^2 \sin^2\theta \, d\theta$

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

RMS value $= I_m/\sqrt{2}$

RMS

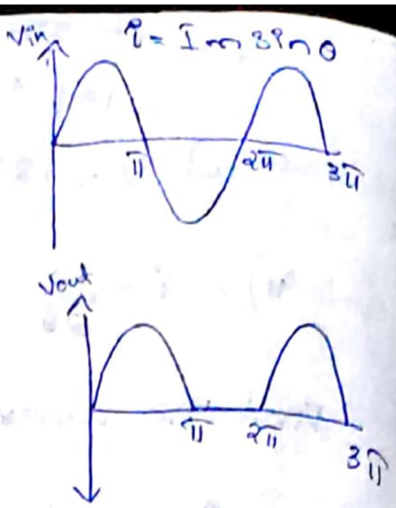
~~Mean~~

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

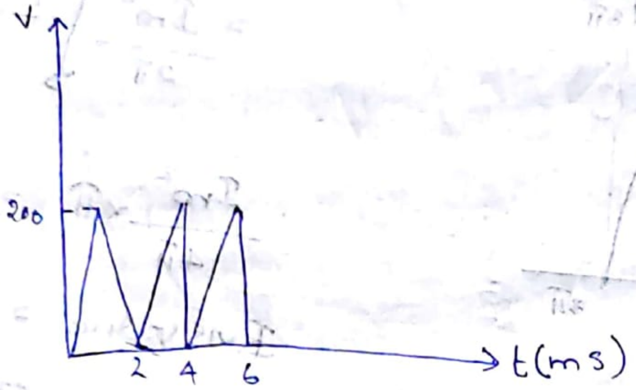
$$= \frac{1}{2\pi}\int_0^{\pi} I_m^2 \sin^2\theta \, d\theta$$

$$= I_m^2 / 4$$

$$\text{rms value} = \frac{I_m}{2}$$



Q)



$y = mx$ $\quad m = \frac{200}{2} = 100$

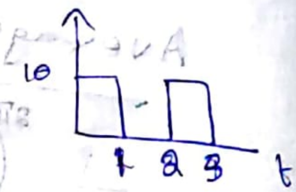
$y = V = 100t$

$$\text{av. g value} = \frac{1}{2}\int_0^2 100t \, dt$$

$$= \frac{1}{2}\left[\frac{100t^2}{2}\right]_0^2$$

$$= \frac{50 \times 4 - 0}{2}$$

$$= \frac{100\,V}{2}$$



$$V = \begin{cases} 10, & 0 < t < 1 \\ 0, & 1 < t < 2 \end{cases}$$

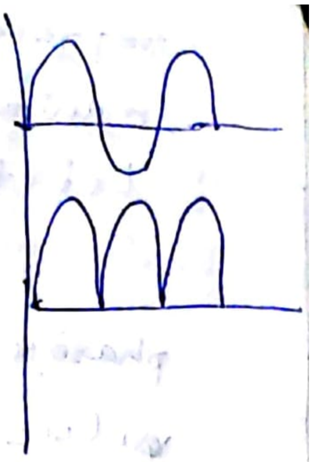
$$\text{R.M.S} = \frac{1}{2}\int_0^2 100^2 t^2$$

$$= \frac{10000}{2}\left[\frac{t^3}{3}\right]_0^2 = \frac{10{,}000 \times \cancel{8}^4}{\cancel{2} \times 3}$$

$$= 13{,}333.3$$

$$\text{rms value} = \underline{115.4\,V}$$

Full wave avg. value =



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

$$= \frac{I_m}{2\pi}\left\{\left[-\cos\omega t\right]_0^{\pi}\right.$$

$$= \frac{I_m}{2\pi}(+1+1) = \frac{2I_m}{\pi}$$

HWR

$$I_{avg} = \frac{I_m}{\pi}$$

$$I_{rms} = \frac{I_m}{2}$$

$$K_f = \pi/2$$

$$K_p = \frac{I_m}{I_m/2} = 2$$

FWR

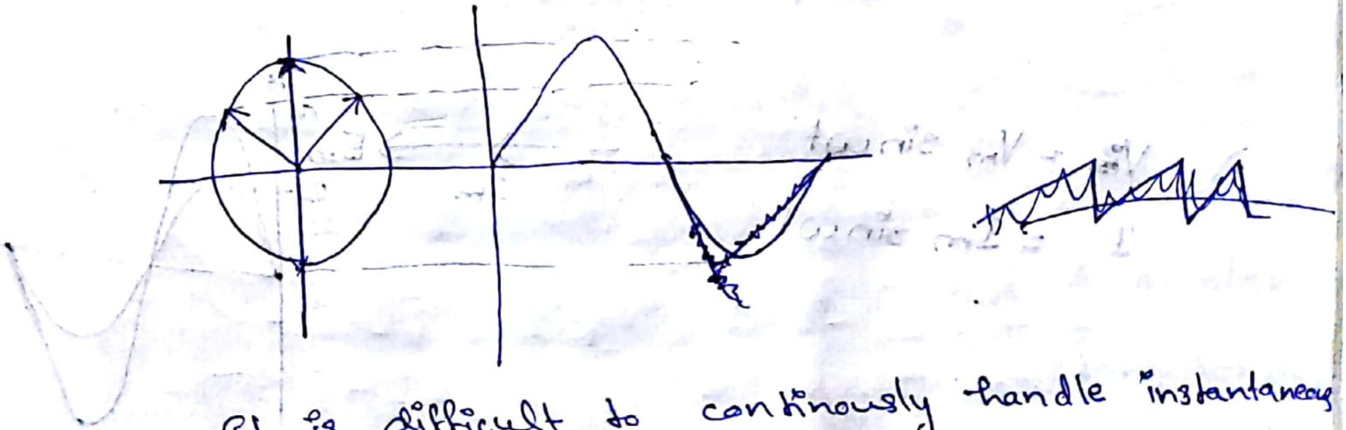
$$I_{avg} = \frac{2I_m}{\pi}$$

$$I_{rms} = \frac{I_m}{\sqrt{2}}$$

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

$$K_p = \frac{I_m}{I_m/\sqrt{2}} = \sqrt{2}$$

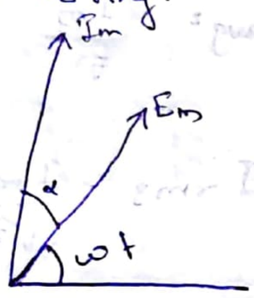
Phasor Representation.

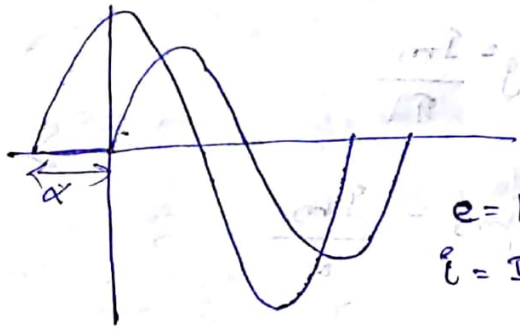


It is difficult to continously handle instantaneous values in form of eqns like $e = E_m \sin\omega t$. A conventional method is to employee vectors for representing these sine waves. These vectors can be manipulated to achieve the desire result.

Let the alternating quantity equal to

$e = E_m \sin \omega t$, this represented by the phasor OP, length of the line gives the max value of the alteranating quantity and inclination of the line with respect to any reference line gives the the direction of the quantity and arrow head gives the direction of the in which its acting.





$e = E_m \sin \omega t$

$i = I_m \sin(\omega t + \alpha)$

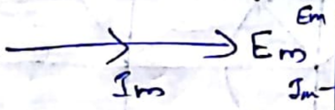
I_m leads E_m

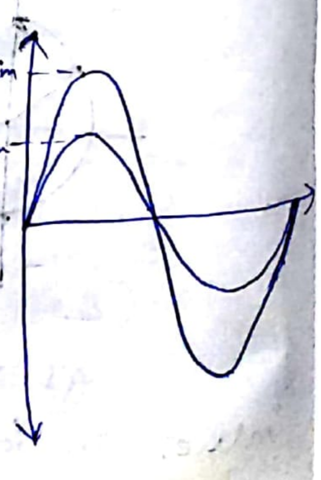
same freq → alternating quantity - same phasor diagram.

difference b/w ~~two~~ phases of two alternating

$V = V_m \sin \omega t$

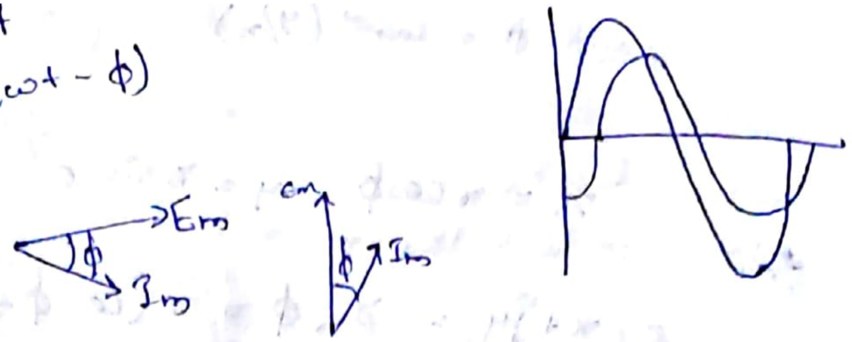
$I = I_m \sin \omega t$





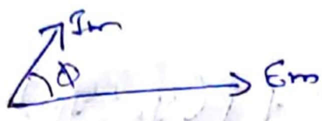
2) $e = E_m \sin \omega t$

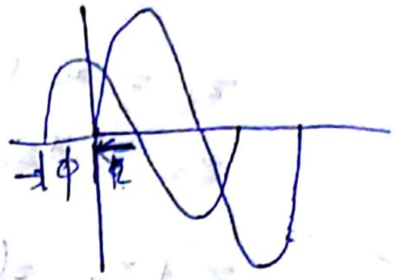
$i = I_m \sin(\omega t - \phi)$



3) $e = E_m \sin \omega t$

$i = I_m \sin(\omega t + \phi)$

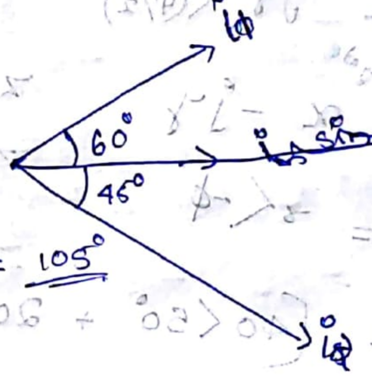




I – alternating quantity have same freq and they reach max +ve and -ve value and zero values @ the same time

Consider two sinusoidal currents $i_1 = 10 \sin(\omega t + \pi/3)$ $i_2 = 15 \sin(\omega t \mp \pi/4)$. Find the phase difference b/w them.

i_2 lags i_1



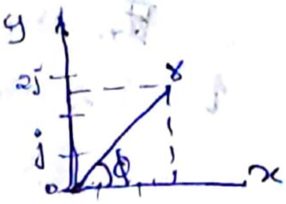
phase difference = $\underline{105^\circ}$

Mathematical representation

A phasor is a complex number that represents the amplitude and phase of a sinusoid. A complex number can be represented in rectangular form as $z = x + jy$, where $j = \sqrt{-1}$.

polar form $z = r\angle\phi$ $\quad r = \sqrt{x^2 + y^2}$

and $\phi = \tan^{-1}(y/x)$



$$x = r\cos\phi \; , \quad y = r\sin\theta$$

$$z = x + jy = r\angle\phi = r(\cos\phi + j\sin\phi)$$

$$z_1 = x_1 + jy_1 = r_1\angle\phi_1$$

$$z_2 = x_2 + jy_2 = r_2\angle\phi_2$$

$$z_1 + z_2 = (x_1 + x_2) + j(y_1 + y_2)$$

$$z_1 - z_2 = (x_1 - x_2) + j(y_1 - y_2)$$

$$z_1 z_2 = r_1 r_2 \angle(\phi_1 + \phi_2)$$

$$z_1/z_2 = r_1/r_2 \angle(\phi_1 - \phi_2)$$

$$\frac{1}{z} = \frac{1}{r}\angle -\phi \quad \text{if } z = r\angle\phi$$

$$\sqrt{z} = \sqrt{r}\angle(\phi/2)$$

$$z^{*\text{-conjugate}} = x - jy \qquad z = x + jy$$

$$= r\angle -\phi \qquad z = r\angle\phi.$$

Evaluate $\left[40\angle 50^\circ + 20\angle -30^\circ\right]^{1/2}$

$\cancel{r = \sqrt{60^2 + (15.6)^2} = 61.9}$

$\cancel{\angle\phi/2 =}$ $\cancel{14.57^\circ}$

$\cancel{\phi = \frac{15.6}{60}}$

Ans: $\cancel{\sqrt{r} = 7.87}$ $\cancel{\angle\phi/2 = 7.285}$ $\boxed{7.87\angle 7.285}$

$\cancel{x^2 + y^2 = 1600}$

$\cancel{\tan^{-1}(y/x) = 50}$

$\cancel{\tan 50 = y/x}$

60x1.3

60x0.36

$x_3 = 60, \; y_3 = 15.6$

$$x_1 = 40\cos 50 \; , \quad y_1 = 40\sin 50$$

$$x_2 = 20\cos -30 \; , \quad y_2 = 20\sin -30$$

$\cancel{x_3 = 60(\cos 50 + \cos -30)} \quad \cancel{y_3 = 60(\sin 50 + \sin(-30))}$

$3+j4 \quad r = \sqrt{x^2+y^2} = 5$

$\tan^{-1}(y/x) = \phi =$

$x_3 = 43.03$

$y_3 = 20.64 \quad \phi =$

$r = \sqrt{\quad 47.7}$

$\sqrt{r} = 6.91 \quad \phi = 12.8$

$8\angle 30 \Rightarrow 8\cos 30 + 8\sin\theta = 6.92 + 4i$

$100\angle -60 \Rightarrow 100\cos +60 + -100\sin +60 = 50 + -86.6i$

$20\angle 240 \Rightarrow -10 + -17.32j$

$5\angle -30 \Rightarrow 4.33 + -2.5j$

$$\frac{(10\angle -30°) + (3 - j4)}{(2+j4)(3-j5)^*}$$

$(3-j5)^* = 3+j5$

$\Rightarrow 5.83\angle 59$

$10\angle -30° = 8.66 + -5j +$

$\quad 3 - 4j$

$(2+j4) \Rightarrow 4.472\angle 63.4$

Numerator $11.66 + -9j \Rightarrow 14.72\angle -37.66$

$5.83\angle 59 \times 4.472\angle 63.4 \Rightarrow 26.1\angle 122.47$ - Denominator

$= 0.56\angle -160.13$

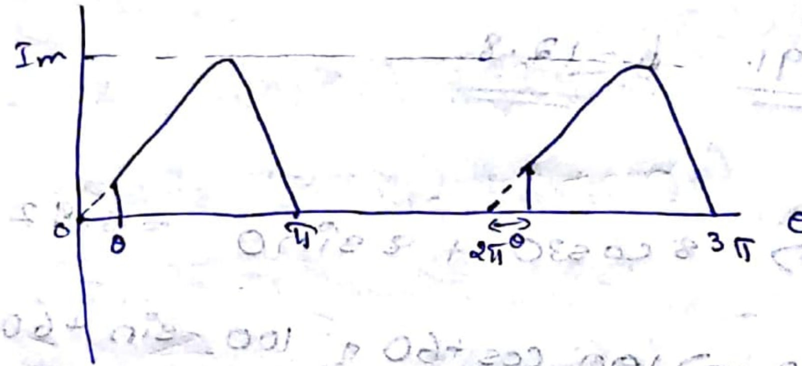
$= 0.5266 - 0.1903i$ //

$$\left[(5+2j)(-1+j4) - 5\angle 60\right]^*$$

~~5+2j~~

$-13+18j - 2.5+4.3j$

$= -15.5 - 13.7j$



$\theta = 30^\circ$

0.43301

~~2.6~~

= 0.137

= 0.208

mean value $= \sqrt{\frac{1}{2\pi}\int_{\pi/6}^{\pi} I_m^2 \sin^2\theta}$

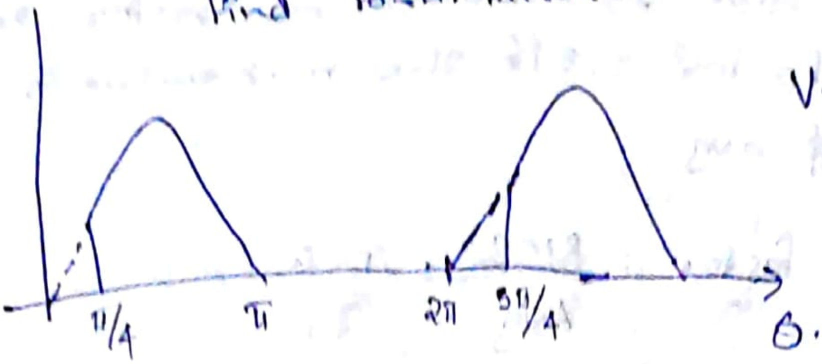
$$= \sqrt{\frac{I_m^2}{2\pi}\int_{\pi/6}^{\pi} \sin^2\theta}$$

$$= \frac{I_m^2}{4\pi}\int_{\pi/6}^{\pi} \frac{1-\cos 2\theta}{2}$$

$$= \frac{I_m^2}{4\pi}\times\left(\frac{5\pi}{6} - \frac{0.4.3}{\pi}\right) \quad \cancel{= \frac{I_m^2}{4\pi}\times \pi - \pi/6} - [0.43$$

rms $= \frac{I_m}{2} = 0.49\, I_m \quad = \frac{I_m^2 \times 5\pi}{4\pi \times 6} - 0.$

Find Form factor.



$V = 100 \sin\theta$

$$I_{mean} = \frac{100}{2\pi}\int_{\pi/4}^{\pi} \sin\theta = \left\{-\cos\pi + \cos\pi/4\right.$$

$+1 +$

$$= \frac{100}{2\pi} + 1.7071$$

$$= + 27.16\,V$$

$$I_{rms} = \sqrt{\frac{100^2}{2\pi}\int_{\pi/4}^{\pi} \sin^2\theta\, d\theta}$$

$$= \sqrt{\frac{100^2}{4\pi}\int_{\pi/4}^{\pi} \frac{1-\cos 2\theta}{\cancel{2}}\, d\theta}$$

$$= \frac{100}{2}\sqrt{\frac{1}{\pi}\times\left(\pi - \pi/4\right) \times + \left(0 + \frac{1}{\sqrt{2}}\right)}$$

$$= \frac{100}{2}\sqrt{\frac{3\cancel{\pi}}{4}\times \frac{1}{\sqrt{2}}}$$

$$= \frac{100}{4}\sqrt{\frac{3}{\sqrt{2}}}$$

$$= \frac{100}{4}\times 1.4 = 47.67$$

$$K_f = \frac{RMS}{Avg.} = \frac{47.67}{27.16} =$$

A certain wave form has a form factor 1.2 and peak ~~volt~~ factor 1.5 if the max value is 100V find rms & avg.

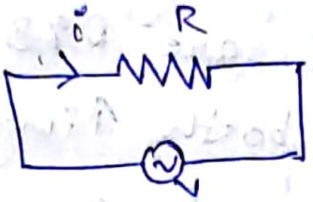
$$\text{form factor} = \frac{RMS}{Avg} = 1.2$$

$$\text{peak factor} = \frac{Max}{rms} = 1.5$$

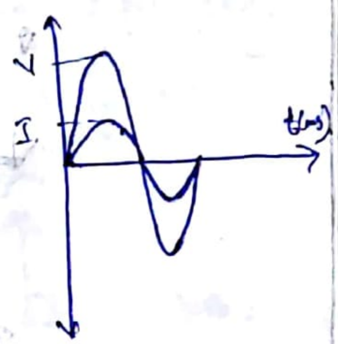
$$rms = \frac{100}{1.5} = 66.67V$$

$$Avg = 79.9V$$

AC through pure resistance.



Applied voltage has to supply ohmic voltage drop only.



$$V = IR$$

$$V_m \sin\omega t = iR$$

$$i = \frac{V_m}{R} \sin\omega t$$

$$i = I_m \sin\omega t.$$

$$P = vi$$

$$= V_m I_m \sin^2\omega t$$

$$= \frac{I_m V_m}{2}(1 - \cos 2\omega t)$$

$$= \frac{V_m I_m}{2} - \frac{V_m I_m}{2}\cos 2\omega t.$$

Average value of fluctuating component of the power in a full cycle is zero. Therefore avg power consumption over 1 cycle is equal to constant component

$$P_{avg} = \frac{V_m I_m}{2} = \frac{V_m}{\sqrt{2}} \cdot \frac{I_m}{\sqrt{2}}$$

$$= V_{rms} \cdot I_{rms}.$$

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The max values of alternating V and I are 400V & 20A respectively. in a ckt connected ~~to~~ a 50Hz supply. And the quantities are sinusoidal. Instantaneous values of V & I are 283V & 10A respectively @ time $t=0$, both ↑ing -ively.

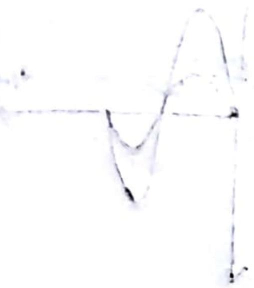
a) Find the expression for V & I @ time t

b) Determine the power consumed.

$V_m = 400V \quad I_m = 20A \quad f = 50Hz.$

$2\pi f = \omega$

$v = 283V \quad i = 10A \quad t=0.$



$\cancel{V_{rms}}\, v = V_m \sin \omega t + \phi$

$= 400 \sin 100\pi t + \pi/4$

$V_m \sin(\omega t + \phi) = 283$

$\phi = 45°$

~~I_{max}~~ = i

$i = 20 \sin(100\pi t + \phi) = 10$

$\sin(\omega t + \phi) = \frac{10}{20} = 1/2$

~~sin~~ $\phi = 30°$

$i = \cancel{2}\ 20 \sin 100\pi t + \pi/6$

$P = \cancel{I_{rms}}\ V_{rms} I_{rms} \cos\phi$

3864W

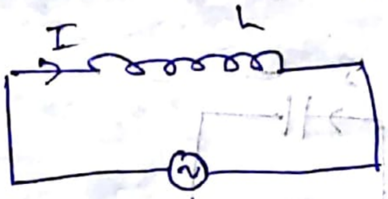
$= \cancel{3038.75W}$

AC through pure inductance.

pure inductance has zero ohmic resistance

when an ac is applied through a purely inductive coil, an back emf is produced due to the self inductance of the coil.

This ~~is~~ back emf at ~~for~~ every instant opposes the rise or fall of current through the current. Since, there is no ohmic ~~drop~~ resistance, ~~the~~ applied voltage opposes the ~~applied voltage~~ self induced emf



$$e_L = -L\frac{di}{dt}$$

$$V = -e_L = L\frac{di}{dt} = L\frac{d}{dt} I_m \sin\omega t$$

$$= L I_m \omega \cos\omega t$$

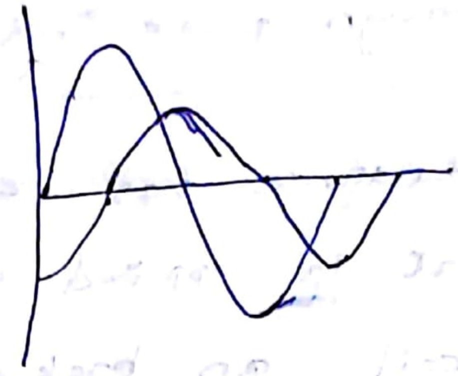
$$V = L I_m \omega (\sin \omega t + 90)$$

$$V = V_m \sin(\omega t + 90)$$

$$V_m = L I_m \omega$$

$$\cancel{\sqrt{2}} V_{rms} = L \cancel{\sqrt{2}} I_{rms} \omega$$

$$WL = \frac{V}{I} \qquad X_L = 2\pi f L$$

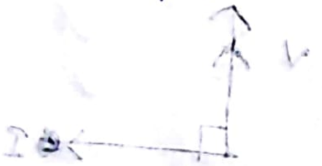


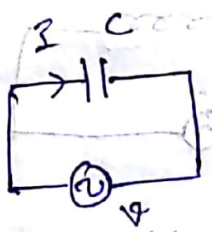
25mH , 50Hz

$$X_L = 2\pi \times 50 \times 25 \times 10^{-3}\ \Omega$$

$$= 7.85\ \Omega$$

AC through pure Capacitance Circuit





$$i = \frac{dq}{dt}$$

$$q = CV$$

$$i = \cancel{\frac{d(cv)}{dt}}\ C\frac{dv}{dt}$$

$$i = C\frac{d}{dt}(V_m \sin\omega t)$$

$$= C\cancel{\frac{d}{dt}} V_m\, \omega \cos\omega t$$

$$\sin(\omega t + 90)$$

$$i = \underbrace{C V_m \omega}\ \sin(\omega t + 90)$$

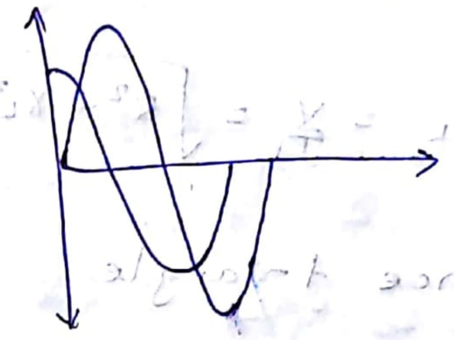
$$i = I_m \sin(\omega t + 90)$$

$$\& \; I_m = C V_m \omega$$

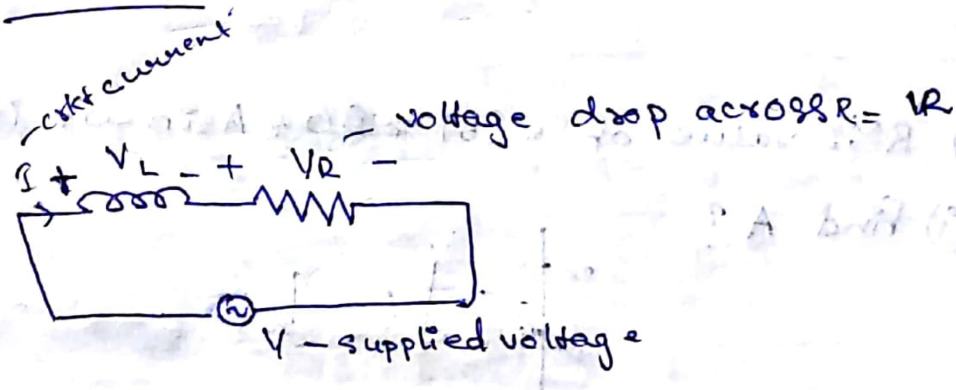
$$\sqrt{2} I = C \sqrt{2} V \omega$$

$$\frac{V}{I} = \frac{1}{C\omega}$$

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

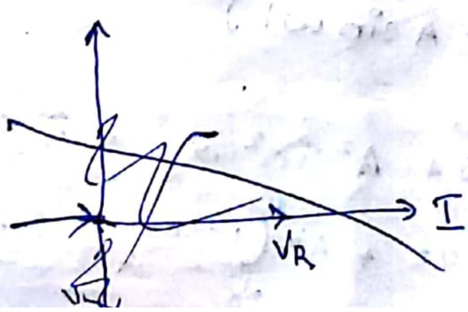


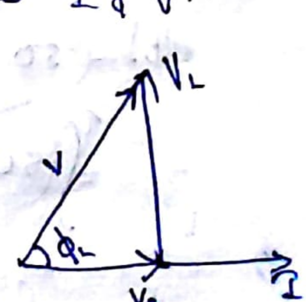
Series R, L circuit



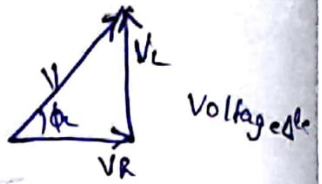
Voltage drop across L = IX_L

ϕ is the phase angle b/w I & V.





I is same through the ~~cir~~ V_L, V_r, thus used as reference phasor V_r is in phase with I and V_L leads by 90°.



$$V^2 = V_R^2 + V_L^2$$

$$= (IR)^2 + (I X_L)^2$$

$$\frac{V^2}{I^2} = R^2 + X_L^2$$

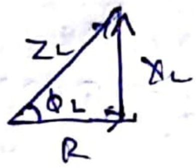
$$Z_L = \frac{V}{I} = \sqrt{R^2 + X_L^2}$$

$\sin\phi_L = \frac{V_L}{V}$

$\cos\phi_L = \frac{V_R}{V}$

$\tan\phi_L = \frac{V_L}{V_R}$

Impedence triangle



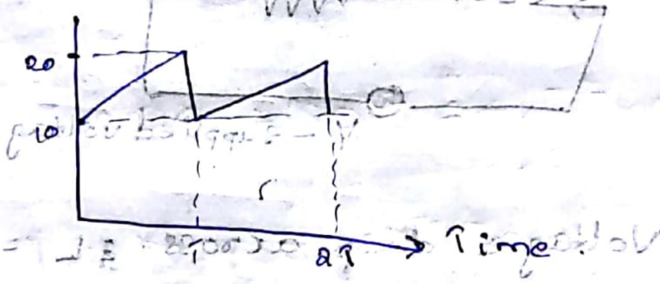
$\sin\phi_L = \frac{X_L}{Z_L}$

$\cos\phi_L = \frac{R}{Z_L}$

$\tan\phi_L = \frac{X_L}{R}$

1) RMS value of $e(t) = 50 + A\sin\omega t$ is 65.6 V

(i) Find A ?



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

$2\pi f = \frac{2\pi}{T}$

$e(t) = 50 + A\sin\omega t$

$$= \int_0^T (50 + A\sin\omega t)^2$$

$$= \int_0^T \left(100 + A^2\sin^2\omega t + 2\times 50\times A\sin\omega t\right)$$

$$= 100t + A^2\int_0^T \frac{1-\cos 2\omega t}{2} + \frac{2\times 50\times A\cos\omega t}{\omega}$$

$$\cancel{100T + \frac{A^2}{2}T - \frac{\sin 2\omega T}{2\omega}\times\frac{A^2}{2} - \frac{100A\cos\omega T}{\omega}}$$

$$I_{rms}^2 = I_{dc}^2 + \left(\frac{I_m}{\sqrt{2}}\right)^2 \quad \text{— dc offset.}$$

$$I_{rms}^2 = \left(\frac{I_{m1}}{\sqrt{2}}\right)^2 + \left(\frac{I_{m2}}{\sqrt{2}}\right)^2 + \left(\frac{A}{\sqrt{2}}\right)^2 \quad \text{— AC component}$$

1) $$\cancel{100}\,(50)^2 + \frac{A^2}{2} = (65.6)^2.$$

$$A = \underline{60.05\,V}.$$

2) $$\cancel{y = mx + c}\ +10$$

$$V = \frac{10t}{T} + 10$$

$$V_{rms} = \sqrt{\frac{\int_0^T \left(\frac{10t}{T} + 10\right)^2 dt}{T}} = \sqrt{\frac{\int_0^T \frac{100t^2}{T^2} + \int_0^T 100 + \int_0^T \frac{200t}{T}}{T}}$$

$$= \sqrt{\frac{\frac{100T^3}{3T^2} + 100T + \frac{200T^2}{2T}}{T}} = \sqrt{\frac{100}{3} + 200}$$

$$= \underline{15.27\,V}$$

$$V_{avg} = \frac{1}{T}\int_0^T$$

A choke coil takes the current of 2 A lagging 60° behind the applied voltage 200 V @ 50Hz. Calculate Resistance, Inductance & Z. Also Determine power consumed when it is connected across 100 V 25Hz supply.

$I = 2A$

$\phi = 60°$

$V = 200V \quad f = 50Hz.$

$Z = \frac{V}{I} = \frac{200}{2} = 100\,\Omega = \sqrt{R^2 + (2\pi 50 \times L)^2}$

$L = X_L \times I \qquad \cos\phi = \frac{1}{2} = \frac{R}{100}$

$\frac{\sqrt{3}}{2} = \frac{X_L}{100} \qquad R = 50\,\Omega$

$1.73 = X_L$

$10000 = (50)^2 + 4 \times \pi^2 \times (50)^2 \times L^2$

$L = \sqrt{\frac{10000 - (50)^2}{4\pi^2 \times 50^2}} = 0.275\ H$

43.1

if $f = 25Hz$

$X_L = 2\pi f \times L$

$= 43.19\,\Omega$

~~R~~,
$$Z = \sqrt{(50)^2 + (43.19)^2}$$
$$= 66.1\Omega$$

$$I = \frac{V}{Z} = \frac{100}{66.1} A$$

$$\cos\phi = \frac{R}{Z} = \frac{50}{66.1} = 0.75$$

$$P = VI\cos\phi$$
$$= 100 \times \frac{100}{66.1} \times \frac{50}{66.1} = 112.7\ W$$

When a certain inductive coil is connected to a dc supply at 240 V. The current in the coil 16A when the same coil is connected to AC 240 V 50Hz current is 12.27 A. Calculate R, Z, X_L of the coil
b) If supply freq is raised to 60 Hz would the current be greater or lesser than the value given above.

$$R = \frac{240}{16} = 15\Omega$$

~~$X_L = 2\times\pi\times$~~

$$Z = \frac{240}{12.27} = 19.6\Omega$$

$$X_L = 12.6\Omega$$

$$L = \frac{X_L}{2\pi f} = \frac{12.6}{2\times\pi\times 50} = 0.04 H$$

~~$X_L = 2\times\pi\times 60\times 0.04$~~
=

$X_L \propto f$

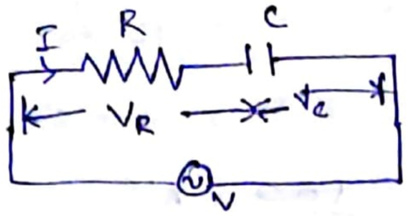
$Z^2 = X_L^2 + R^2$

$Z\uparrow$

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

$I\downarrow$ es.

Series RC circuit

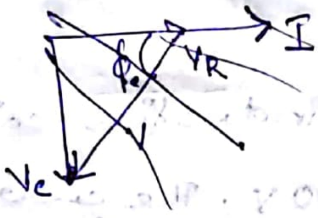


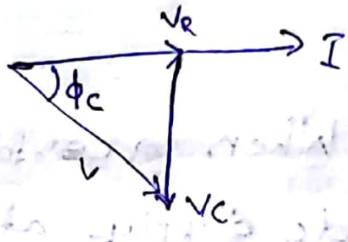
V is the supplied voltage, I is ckt current

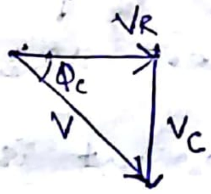
V_R is the voltage across the R = IR

V_C is the voltage across the C $= IX_C$

$= \frac{I}{2\pi fC}$







$$V^2 = V_R^2 + V_C^2$$

$$= (IR)^2 + (IX_C)^2$$

$$\frac{V^2}{I^2} = R^2 + X_C^2$$

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

$$Z = \frac{V}{I} = \sqrt{R^2 + X_C^2}$$

$\cos\phi_c = \frac{V_R}{V}$

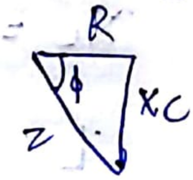
$\sin\phi_c = \frac{V_c}{V}$

$\tan\phi_c = \frac{V_c}{V_R}$

$\cos\phi_c = \frac{R}{Z}$

~~cos φ~~

$\sin\phi_c = \frac{X_c}{Z}$



$\tan\phi_c = \frac{X_c}{R}$

Q) A capacitor of capacitance 79.5μF is connected in series with a non-inductive resistance of 30Ω across 100V, 50 Hz supply. Find Z, I, ϕ, and eqn instantaneous value of current.

$C = 79.5\mu F$

$R = 30\Omega$

$X_C = \frac{1}{2\pi f C} = \frac{1}{2 \times \pi \times 50 \times 79.5 \times 10^{-6}} = 40.03\ \Omega$

$Z = \sqrt{30^2 + (40.03)^2} = \underline{50.02\ \Omega}$

$\cos\phi = \frac{30}{50.02} = 0.599$

$\phi = \cancel{0.92}\ \underline{53.2^\circ}$

$I = \frac{V}{Z} = \frac{100}{50.02} = 1.99\ A \approx 2A$ $\quad I_m = \sqrt{2} \times 2 = 2.82A$

$I = I_m \sin(\omega t + 53.2)$

$\underline{I = 2.82 \sin(\omega t + 53.2)}$.

Q) A 10Ω resistor & 400μF capacitor are connected in series to a 60V sinusoidal supply, ckt I is 5A. Calculate f & ϕ b/w I & V.

$R = 10$

$C = 400\mu F$

$V = 60$

$I = 5A$

$Z = \frac{V}{I} = \underline{12\Omega}$

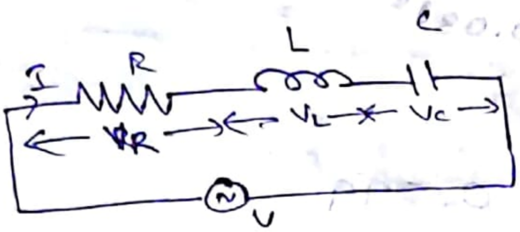
$$X_C = \sqrt{Z^2 - R^2} = \sqrt{144 - 100} = \underline{6.63\Omega}$$

$$6.6 = \frac{1}{2 \times \pi \times f \times 400 \times 10^{-6}} \Rightarrow \underline{f = 60.2Hz}$$

$$\cos\phi = \frac{R}{Z} = \frac{10}{12} = \frac{5}{6} = 0.83$$

$$\phi = \underline{33.5^\circ}$$

RLC circuit

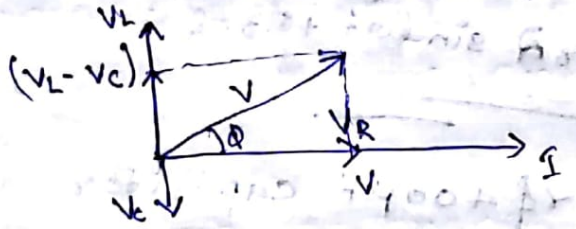


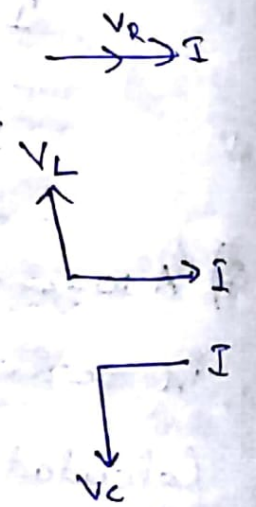
V is the applied voltage I is the ckt current

V_R is the voltage drop across R = IR

V_L is the voltage drop across L $= IX_L = I \times 2\pi f L$

V_C is the voltage drop across C $= I \times X_C = \frac{I}{2\pi f C}$





i) $V_L > V_C$ $(X_L > X_C)$

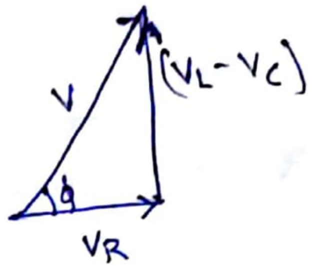
ckt is predominantly inductive.

I lags voltage V by ϕ

Applied voltage is the phasor sum of V_R, V_L & V_C.

To get this, find the phasor sum of V_L & V_C (arithmetic difference $V_L - V_C$). Then phasor sum of $V_L - V_C$ and V_R by parallelogram law.

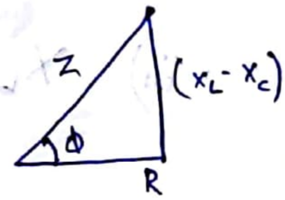
$$V^2 = V_R^2 + (V_L - V_C)^2$$



$$= (IR)^2 + (IX_L - IX_C)^2$$

$$\frac{V^2}{I^2} = R^2 + (X_L - X_C)^2$$

Z is the impedence of the series RLC ckt. It is the ~~total~~ opposition offered to the current flow ~~...~~ by the resistance, inductive reactance & capacitive reactance of the ckt.

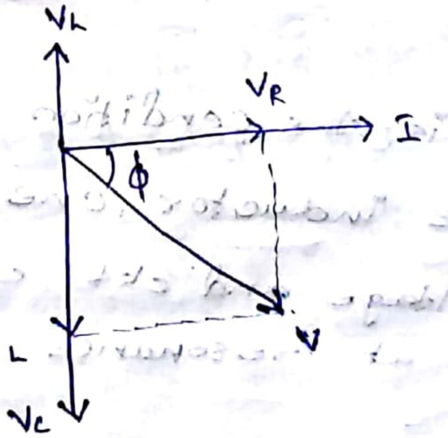


$\sin\phi = \frac{X_L - X_C}{Z}$

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

$\tan\phi = \frac{X_L - X_C}{R}$

ii) $X_L < X_C$ $(V_L < V_C)$

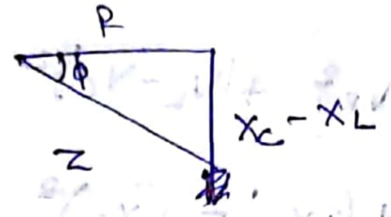


ckt is predominantly capacitive

I leads voltage by ϕ

$$Z = \sqrt{R^2 + (X_C - X_L)^2}$$

$$V^2 = V_R^2 + (V_C - V_L)^2$$

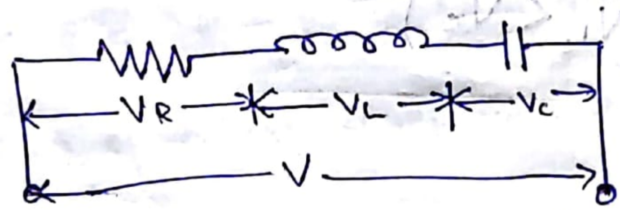


$$\sin\phi = \frac{X_C - X_L}{Z}$$

$$\cos\phi = \cancel{X_C} \frac{R}{Z}$$

$$\tan\phi = \frac{X_C - X_L}{R}$$

iii) $X_L = X_C$ (Resonance)



Resonance is the condition in a ckt containing @least one inductor, one capacitor when supplied voltage and ckt current are in phase.

Power at resonance : $P_0 = V_0 I_0 \cos\phi_0$
$= V^2/R$.

At resonance equivalent impedence of the circuit is purely resistive

Power factor for a resonance ckt is unity.

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$X_L = 2\pi f L$ $\quad X_C = 1/2\pi f C$

$X_{L_0} = X_{C_0}$

Let X_{L_0} be inductive reactance ~~and~~ X_C be capacitive reactance and Z_0 be the impedence ~~to~~ @ resonance.

$$X_0 = X_{L_0} - X_{C_0} = 0$$

$$X_{L_0} = X_{C_0}$$

$$Z_0 = R$$

impedence @ resonance is known as dynamic impedence.

Voltage across $L = V_L = I_0 X_{L_0}$

Voltage across $C = V_C = I_0 X_{C_0}$

$\Rightarrow V_L = V_C$

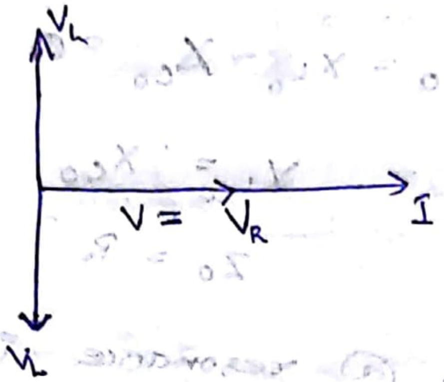
$\Rightarrow V_L - V_C = 0$

at resonance the voltage across Inductor is equal in magnitude and opposite in phase to the voltage across the capacitance.

$$V = \sqrt{V_R^2 + (V_{L_0} - V_{C_0})^2} = \sqrt{V_R^2} = V_R = I_0 R.$$

Thus @ resonance the entire supply voltage is used ~~to~~ develop the voltage drop across R although total reactance voltage is equal to zero V_{L_0} and V_{C_0} may reach values greater than the supplied voltage causing the crkt insulation to be damaged.

@ resonance $\phi_0 = 0$, $\cos\phi_0 = 1$



$$X_L = X_C$$

$$2\pi f_0 L = \frac{1}{2\pi f_0 C}$$

$$\boxed{f_0 = \frac{1}{2\pi\sqrt{LC}}}$$

General results:

$Z = R + jX$

$X = (X_L - X_C)$ is the total reactance

$X_L > X_C$ —— X is positive
crkt is inductive

$X_L < X_C$ —— X is negative
crkt is capacitive

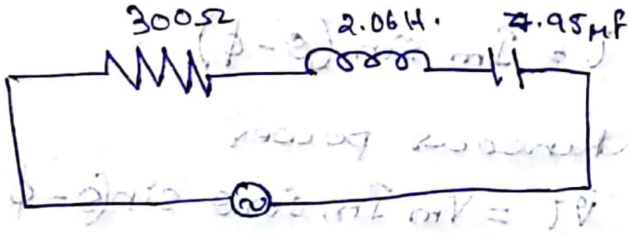
$X_L = X_C$ — $X = 0$
crkt is pure resistive.

$$\cos\phi = \frac{R}{Z}.$$

$$\tan\phi = \frac{X_L - X_C}{R}.$$

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

Q) A series ckt consists of a 300Ω non-inductive resistance, a 7.95μF capacitor and 2.06 H inductor of negligible resistance if the supply voltage is 250V @ 50Hz. Calculate i) ckt current 2) phase angle 3) voltage drop across each element.



$X_L = 2\pi f L$ $\qquad X_C = \frac{1}{2\pi f C}$

$= 647.16\,\Omega$ $\qquad = 400.3\,\Omega$

$Z = \sqrt{R^2 + (X_L - X_C)^2}$ $\qquad X = 246.86$

$= 388.5\,\Omega$

$I = \frac{V}{Z} = \frac{250}{388.5} = 0.64\,A$

$\cos\phi = \frac{R}{Z} = \frac{300}{388.5} = 0.77$

$\phi = 39.43^\circ$ (lag)

$V_R = I \times R = 0.64 \times 300 = 192\,V$

$V_L = I \times X_L = 0.64 \times 647.16 = 414.18$

$V_C = I \times X_C = 0.64 \times 400.3 = 256.19\,V$

V.Vimp Power in an AC circuit

Power in a general series ckt.

Let $v = V_m \sin\theta$

$i = I_m \sin(\theta - \phi)$

Instantaneous power

$$p = vi = V_m I_m \sin\theta \sin(\theta - \phi)$$

$$= \frac{V_m I_m}{2}\left[\cos(\phi) - \cos(2\theta - \phi)\right]$$

$$P_{avg} = \frac{1}{2\pi}\int_0^{\pi}\left[\frac{V_m I_m}{2} \cos\phi - \cos(2\theta - \phi)\right] d\theta$$

cosφ is constant for a given ckt

$$\cancel{= \frac{V_m I_m}{4\pi} \cos\phi \left\{\int_0^{\pi} \frac{\cos(2\theta - \phi)}{2}\right\}}$$

$$\cancel{= \frac{V_m I_m \cos\phi}{2\pi} \int_0^{\pi} \cos 2\theta \cos\phi - \sin 2\theta \sin\phi}$$

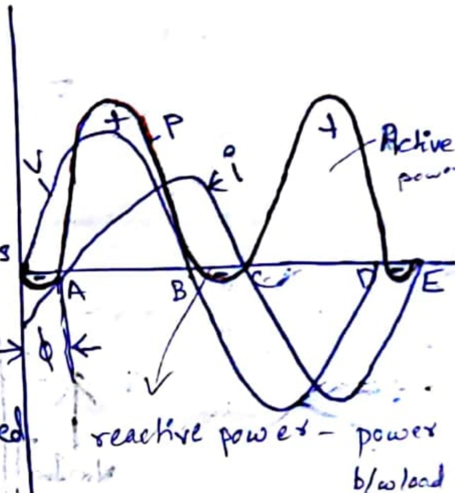
$$\cancel{= \frac{V_m I_m \cos\phi}{2\pi} \left[\cos\phi \left[\frac{\sin 2\theta}{2}\right]_0^{\pi} + \sin\phi \left[\frac{\cos 2\theta}{2}\right]_0^{\pi}\right]}$$

$$\cancel{\frac{V_m I_m \cos\phi}{2\pi}\left[\cos\phi \times \theta + \sin\phi\right.}$$

$$= \frac{V_m I_m}{4\pi} \left\{ \cos\phi \left[\theta\right]_0^{2\pi} - \frac{1}{2}\left[\sin 2\theta - \phi\right]_0^{2\pi} \right\}$$

$$= \frac{V_m I_m}{4\pi} \cos\phi\,(2\pi) - \frac{1}{2}\left[\sin(4\pi - \phi) - \sin(-\phi)\right]$$

$$= \frac{\sqrt{2}V\sqrt{2}I}{2}\cos\phi = VI\cos\phi$$



The voltage, current & power waveforms in general series ckt are as shown. from the power waveform. it is observed that during the interval OA power is -ve. The area represents the ~~pow~~ energy returned to the source from the ckt. During interval AB, power is positive, Area represent the energy supplied from the source to load. Intervals BC and CD are repetition of OA and AB respectively. hence it is observed that during each current (voltage) cycle, a part of energy is called Active energy is consumed while the other part called reactive energy is interchanged b/w source & load.

Power through pure resistance.

$v = V_m \sin\theta$

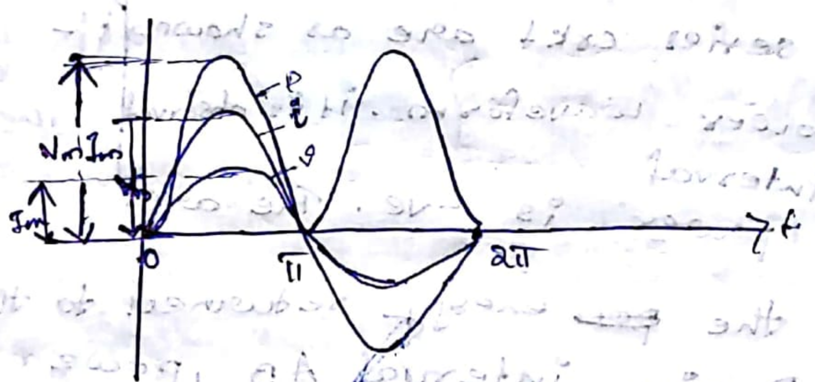
$i = I_m \sin\theta$

p = instantaneous power = $vi = V_m I_m \sin^2\theta$

$= \frac{V_m I_m}{2}(1 - \cos 2\theta)$

$$P_{avg} = \frac{V_m I_m}{2\pi \times 2}\int_0^{2\pi}(1 - \cos 2\theta)\,d\theta$$

$$= \frac{V_m I_m}{2\pi \times 2} \times 2\pi - 0 = \frac{V_m I_m}{2} = V_R I$$



Instantaneous power p remains ~~consta~~ positive, irrespective direction of current. This is because voltage & current are in phase.

Even when V_R and i are $-ve$, p is positive it shows that the power flow is only in the direction of source to load. The energy received by the resistor is called active energy. It is consumed in R and appears in the form of heat. The rate of this energy consumption is called active power.

Power through pure inductance

$v = V_m \sin(\theta + 90)$

$i = I_m \sin\theta$

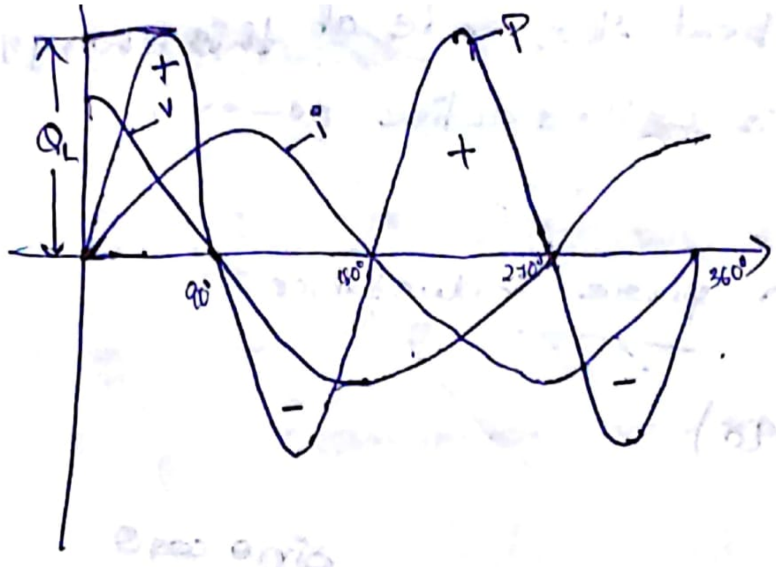
Inst power $p = vi = V_m I_m$ $\cancel{\sin(\theta+90)\cos\theta + \cos(\theta+90)\sin\theta}$ $\sin\theta\cos\theta$

$= \frac{V_m I_m}{2} \sin 2\theta$

$P_{avg} = \frac{V_m I_m}{2} \times \frac{1}{2\pi}\int_0^{2\pi} \frac{\cos 2\theta}{2} d\theta$

$= \frac{V_m I_m}{4\pi} \times [\sin 2\theta]_0^{2\pi}$

$= \frac{V_m I_m}{4\pi} \times 0 = 0$



power curve is a sine wave of twice the freq. of current or voltage wave (power curve completes two cycles when the current or voltage wave completes one cycle.

for ~~when~~ $\theta = 0$ to $\theta = 90°$ power curve is above the horizontal axis, power is positive ~~that~~ ckt draws energy from the source.

This energy is stored in the magnetic field and represented by +ve shaded area b/w power curve and axis

for $\theta = 90°$ to $\theta = 180°$, power is negative previously stored energy is returned to source. This is represented by the -ve shaded area b/w power curve and horizontal axis. Thus it is seen that energy stored in the ckt during the first quarter cycle is equal to the energy returned to the source during the second quarter cycle. III^{rd} & IV^{th} quarter cycle is the repetition of I^{st} & II^{nd} quarter cycle. Thus total energy dissipated is zero. The avg power over a complete cycle of current in a purely inductive ckt is therefore zero.

Power through pure capacitance

$$v = V_m \sin\theta$$

$$i = I_m \sin(\theta + 90)$$

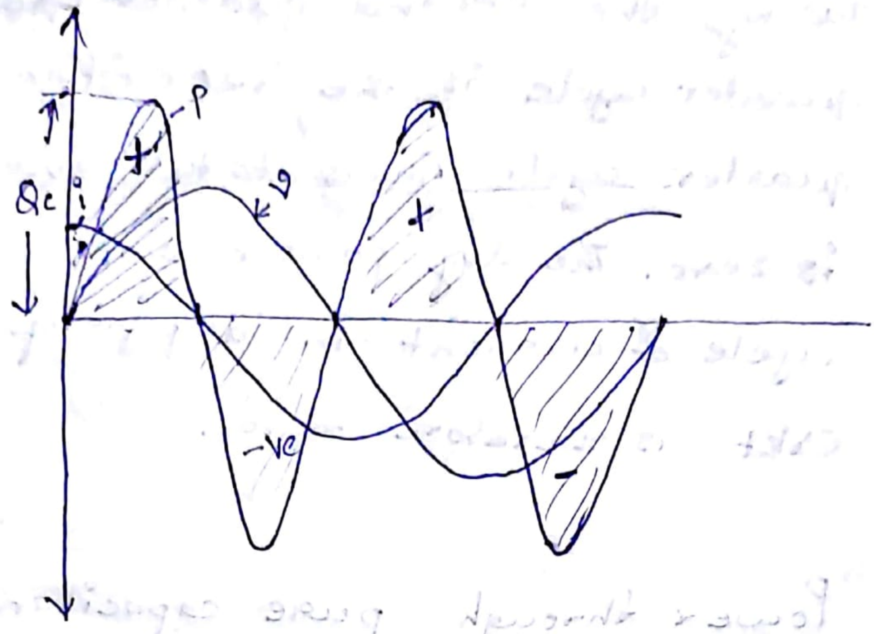
Inst. power, $p = vi = V_m I_m \sin\theta \sin(\theta + 90)$

$$p = \frac{V_m I_m}{2} \sin 2\theta$$

$$P_{avg} = \frac{1}{2\pi} \int_0^{2\pi} \frac{V_m I_m}{2} \sin 2\theta$$

$$= \frac{V_m I_m}{2\pi \times 2} \left[\frac{\cos 2\theta}{2} \right]_0^{2\pi}$$

$$= \frac{V_m I_m}{2\pi \times 2} \times 0 = 0$$



Power curve is a sine wave with freq twice that of voltage or current wave. for θ = 0 to 90°, power curve is above the horizontal axis and is +ve. The applied voltage gradually increases from 0 to its maximum value, ckt draws energy from the source and capacitor is charged. Energy is stored in the electric field of the capacitor.

During the 4th quarter cycle, power curve is below horizontal axis and is -ve ~~and~~ voltage gradually decreases max to zero. Capacitor discharges and energy is returned to the source.

~~Reac~~ →(Var)

Reactive voltamperes (Q_L)

peak value of P, $Q_L = \frac{V_m I_m}{2} = VI$

In a purely inductive crkt, $V = V_L = I X_L$

and $Q_L = V_L I = \frac{V_L^2}{X_L} = I^2 X_L$

Q_L is the reactive voltamperes for an inductive crkt, energy which is continuously exchanged b/w the source and reactive load is called reactive enery. By convention Q_L is +ve.

Reactive voltampere (Q_C)

peak value of P, $Q_C = \frac{V_m I_m}{2} = VI$

In a purely capacitive crkt, $V = V_C = I X_C$

& $Q_L = V_C I = \frac{V_C^2}{X_C} = I^2 X_C$

Q_C is the reactive voltampere for a capacitive crkt. It is measured in 'VAr'. It is the rate of interchange of energy b/w capacitor & load & source

By convention Q_C is taken -ve.

Voltamperes : product of RMS values of voltage and current in a ckt is called circuit voltamperes. It is also called apparent power denoted by S.

$$S = VI$$

$$V = IZ$$

Power Triangle

1) Resistance circuit

$$P_R = I^2R = V_R^2/R = I^2Z \qquad \cos\phi = \frac{R}{Z}$$

$$Q_R = 0$$

2) Inductive ckt (purely)

$$P_L = 0$$

$$Q_L = V_L \cdot I \quad -\ +ve$$

$$= I^2 X_L = \frac{V_L^2}{X_L}$$

3) Purely capacitive ckt

$$P_C = 0$$

$$Q_C = V_C I = I^2 X_C = \frac{V_C^2}{X_C} \quad (-ve)$$

Net reactive voltampere

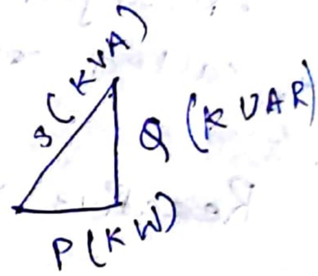
$$Q = Q_L - Q_C$$

$$= I^2 X_L - I^2 X_C$$

$$= I^2 (X_L - X_C)$$

$$Q = I^2 X$$

Apparent power (S) (VA)



$$\cos\phi = P/S$$

$$\sin\phi = Q/S$$

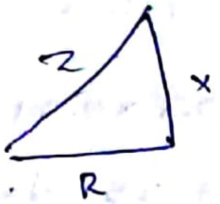
$$S = VI$$

$$P = VI\cos\phi$$

$$Q = VI\sin\phi$$

$$P^2 + Q^2 = S^2$$

$$S = P \pm jQ$$



$\cos\phi = R/Z$

$\sin\phi = \dfrac{X}{Z}$

$V = IZ$ $\quad X = Z\sin\phi$

$$Q = VI\sin\phi = I^2X = \frac{V^2}{X} = I^2Z\sin\phi \ (\text{VAr})$$

A voltage of $250\angle 0^\circ$ is applied to an inductive circuit of impedence $(5+11j)\,\Omega$. Calculate ⓐ circuit current ⓑ P.F ⓒ Power consumption ⓓ Apparent power ⓔ Reactive power.

a) $Z = (5+11j)$ $\quad V = 250\angle 0^\circ = 250 + 0j$

$$I = \frac{V}{Z} = \frac{250\angle 0^\circ}{12.08\angle 65.56^\circ} = 20.70\angle -65.56^\circ$$

$= 8.5 - 18.84\,j$

b) P.F $= \cos(-65.56^\circ)$

$= 0.4137$

$\sin\phi = \dfrac{X_L}{Z}$

$X = -0.91 \times (5+11j)$

$= \cancel{-4.55 - 10.014}$

$= -0.91 \times 12.08\angle 65.56$

$= -4.54 - 10.0j\,\Omega$

$R = Z\times\cos\phi = \cancel{0.91}$ $0.4137 \times 12.08\angle 65.56$

$= 2.667\,\Omega$

Power consumption $= VI\cos\phi$

$= 250 \times 20.70 \times 0.4137 = 2142.45$ W

Apparent power (S) $= vi = (250+0j)(6-18.84j)$ $+18.84j$

$= 250 \times 20.70 = 5175$ W

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Reactive power $= Q = VI\sin\theta$

(Lagging) $= 250 \times 20.7 \times 0.91$

$= -4709.25$ Watts (volts).

An alternative voltage $(80 + j60)$ is applied & current $(-4 + 10j)$ A, find Z, P, ϕ,

$V = 100 \angle 36.87^\circ$

$i = 10.77 \angle 111.8^\circ$

$$Z = \frac{V}{I} = \frac{100 \angle 36.87^\circ}{10.77 \angle 111.8^\circ} = 9.28 \angle -74.93$$

$$= 2.413 - 8.96j$$

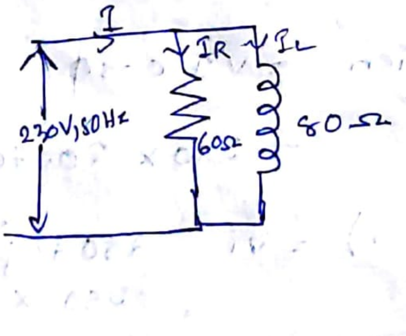
$R = 2.413\ \Omega$

$P = i^2 R = (10.77)^2 \times (2.413)' = 280.89\ W$

$P = VI\cos\phi$

$$\cos\phi = \frac{280.89}{100 \times 10.77} = 0.26 \implies \phi = 74.9^\circ$$

A $60\ \Omega$ Resistance is connected in parallel with an inductive resistance of $80\ \Omega$ to a 240V, 50Hz, Calculate (1) current through R & X_L. (2) Supply current (3) phase current



$I_R = 4A$

$I_L = 3A$

$\therefore I = \sqrt{I_R^2 + (I_C)^2}$

$= \sqrt{16+9} = 5A$

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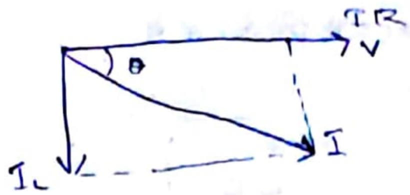


$\tan\phi = 5/4$

$\phi = \tan^{-1}(5/4)$

$\phi = 51.34$

$$Z = \frac{60 \times j80}{60 + 80j} = 38.4\,\Omega$$

Admittance

It is the reciprocal of impedence. It is denoted by (Y). Its SI units is siemens (s)

$$\boxed{Y = 1/Z = \frac{I}{V}}$$

$Z = R + jX$

For pure resistor

$Y_R = \frac{1}{Z_R}$	$1/Z_R$.
$1/R = G$	

For pure inductance circuit.

$$\boxed{Y_L = \frac{1}{Z_L} = \frac{1}{jX_L} = \frac{j}{X_L} = -jB_L}$$

$$B_L = \frac{1}{X_L} = \frac{1}{2\omega L}$$

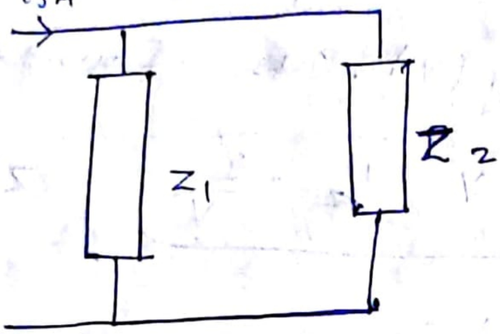
For purely capacitor

$$\boxed{Y_C = 1/Z_C = \frac{1}{-jX_C} = \frac{j}{X_C} + jB_C}$$

Capacitive succesptance

$$\boxed{B_C = \frac{1}{X_C} = \omega C}$$

Two circuit impedance given by $Z_1 = (10+j15)\,\Omega$ & $Z_2 = (6-j8)\,\Omega$ are connected in parallel. If total current is 15A. What is the power ~~each other~~ consumed by each branch.



$Z_1 = 18.03 \angle 56.31°$ $\quad Z_2 = 10 \angle -53.13°$

$$Z_{eq} = \frac{Z_1 \times Z_2}{Z_1 + Z_2} = \frac{18.03 \angle 56.31 \times 10 \angle -53.13}{10 + j15 + 6 - j8}$$

$$= \left(\frac{180.3 \times 3.18}{16 - 7j}\right) = \frac{180.3 \times 3.18}{17.46 \times 23.63}$$

$$10.33 \angle 26.81° = 9.23$$

$$V = IZ = 15 \times 10.33 = 154.95\text{ V}$$

$$I \text{ through } Z_1 (I_1) = \frac{154.95}{18.03} = 8.60$$

$$I \text{ through } Z_2 (I_2) = \frac{154.95}{10} = 15.50$$

$$P_1 = I^2 R = 10 \times (8.59)^2 = 737.8\text{ W}$$

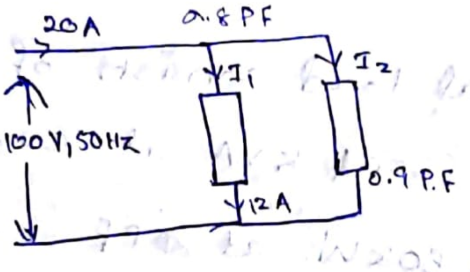
$$P_2 = (15.48)^2 \times 6 = 1437.78\text{ W}$$

Two inductive coils A & B are in parallel across a 100 V 50Hz supply coil A takes 12 A at 0.9 power factor and the total current for both coils is 20 A at 0.8 power factor determine.

① Equivalent resistance & reactance

② Individual resistance & reactance

③ Powerfactor of coil B.



$V = 100 \angle 0°$

$0.8 = \cos\phi$ lagging.

$I = 20 \angle -\cos^{-1}(0.8)$

$= 20 \angle -36.86° A = 16 - 12.00j$

$I = I_1 + I_2$

$I_1 = 12 \angle -\cos^{-1}(0.9)$

$= 12 \angle -25.8419 = 10.8 - 5.2j$

$I_2 = 5.2 - 6.8i \quad (I - I_2)$

Equivalent Impedence

$$Z = \frac{V}{I} = \frac{100 \angle 0°}{20 \angle -36.86} = 5 \angle 36.86°$$

$Z_{eq} = R_{eq} + jX_{eq} = 4 + 2.99i$

$$Z_1 = \frac{V}{I} = \frac{100 \angle 0°}{12 \angle -25.84} = 8.33 \angle 25.84 \Omega$$

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$I_2 = I - I_1 = 5.2 - 6.79j = 8.552 \angle -52.55$

$$Z_2 = \frac{100\angle 0°}{8.55\angle -52.55} = 11.695\angle 52.55$$

$= 7.11 + 9.2j$

Power factor of coil B $= \cos -52.55$

$= 0.6080 W$

An industrial load consists of the following

① load of 200 kVA at 0.8 pf lagging

② load of 50 kW at 0 pf

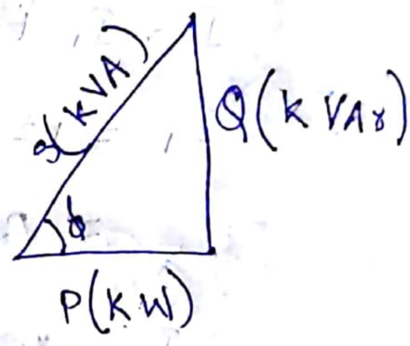
③ 48 kW at 0.6 pf leading.

Calculate kW, kVar, kVA, overall pf.

~~pf~~ $\cancel{\cos^{-1}(0.8) = \phi = 36.86}$

$\phi = 36.86°$

$$\cos\phi = \frac{kW}{kVA}$$



$P_1(kW) = 160\ kW$ $\cancel{\pm 120}$

$$\cos\phi = \frac{kW}{kVA}$$

$Q_1 = \sin\phi * 200 = 120$

$$\sin\phi = \frac{kVAr}{kVA}$$

$S_1 = 160 + j120$

+ — lag

— — leading

$S_2 = 50 \pm j0$

$S = P \pm jQ$

S_3

48 KW

$\cos\phi = 0.6$

$\phi = 53.13$

KVAr

$Q = 63.99 \approx 64$

$S_3 = 48 - j64$

$S_{Total} = 258 + j56$

$P_{Total} = 258\ W$

$Q_{Total} = 56\ KVAr$

P.F overall $\phi = \tan^{-1}\left(\frac{56}{258}\right) = 12.24$

$\cos\phi = 0.97$ lagging.

3 phase Systems

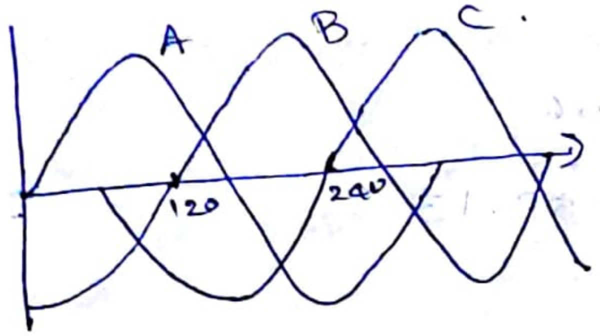
HW. Advantages of 3 phase sys.

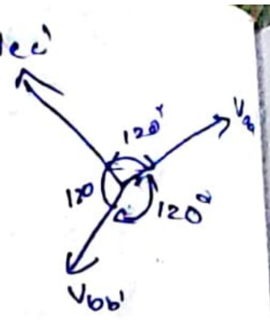
$V_{aa'} = V_m \sin \omega t$ $V\angle 0$

$V_{bb'} = V_m \sin(\omega t - 120)$ $V\angle -120$

$V_{cc'} = V_m \sin(\omega t + 120)$ $V\angle +120$

When 3 identical coils are placed with axis 120° apart from each other & rotated in a uniform manner, a sinusoidal wave is form.





Order in which the phase voltage reach the max voltage ~~..~~ is called phase sequence.

End of the coil where the current leaves ~~or simply~~ is starting end / start

end of the coil where the current enters is ~~ending~~ finishing end / finish.

No. of wires can be reduced by interconnecting phases.

Advantages of 3 phase system

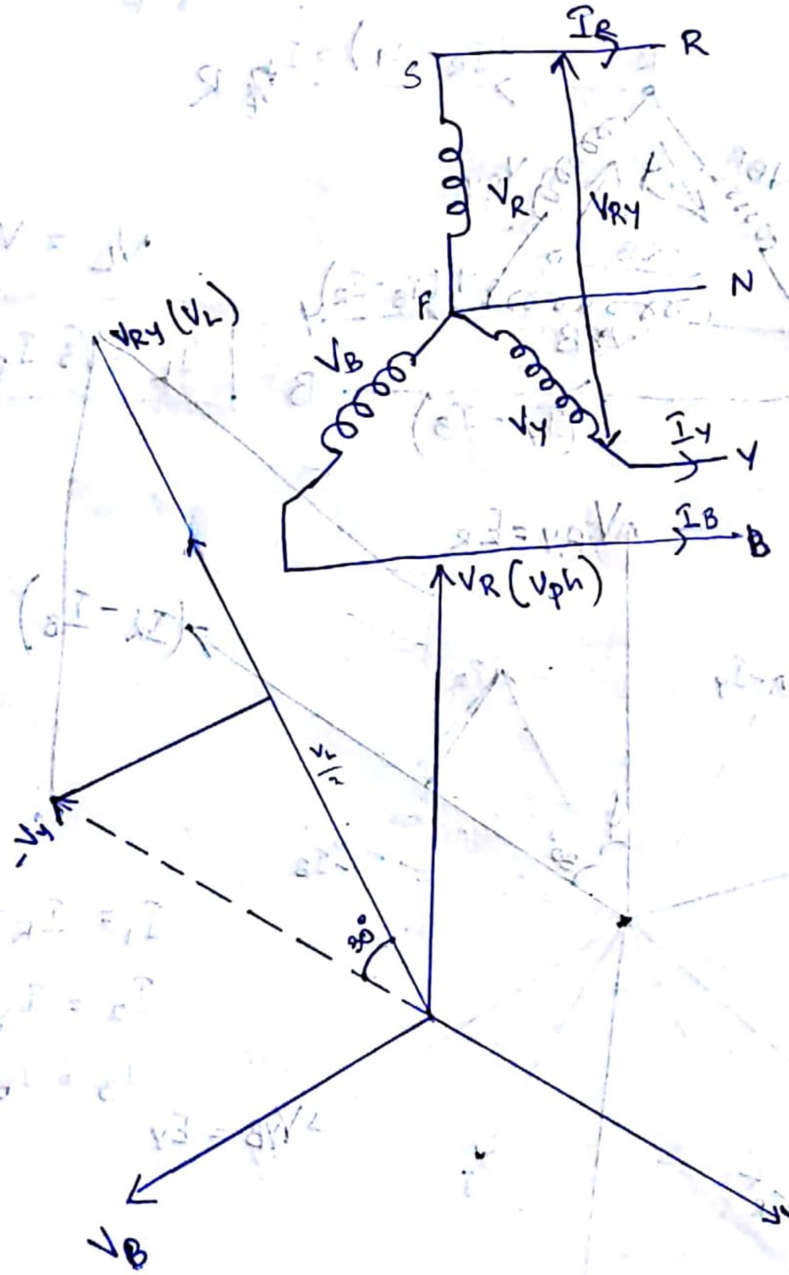
* No. of wires will be less
* Power delivered is constant. In single phase crkt, the power is pulsating & objectionable for many applications.
* For a given frame size a 3 phase machine gives a higher o/p than single phase machine.
* For transmitting the same amount of power at the same voltage, a 3 phase transmission line requires less conductor material than a single phase

line. 3 phase transmission system is so cheaper.

* Three phase motors have uniform torque whereas most of the single motors have pulsating torque

* Comparing with single phase motor, three phase induction motor has high power factor & efficiency Also they are self starting.

3 ϕ 4 Wire System (Star Connection)



$I_L = I_{ph}$

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

$\cos 30 = \frac{V_L}{2 V_{ph}}$

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

~~$= V_L \, I_L \cos\phi$~~

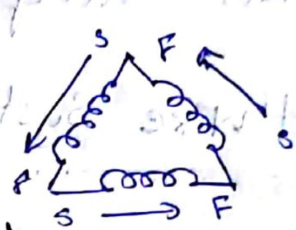
~~$P = 3 V_{ph} I_{ph} \cos\phi$~~

Total power : 3x Power

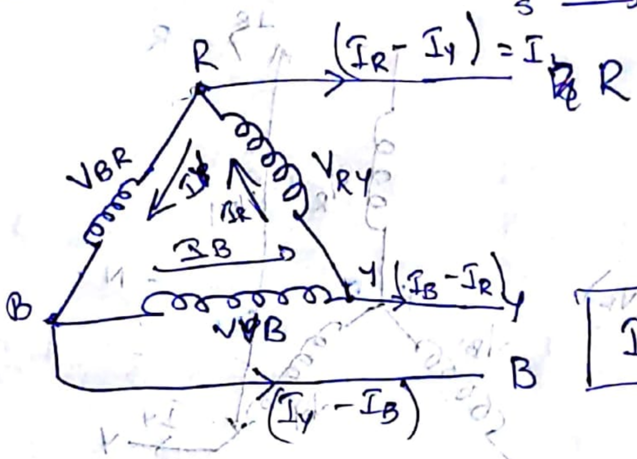
$$= 3 \times V_{ph} I_{ph} \cos\phi$$

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

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

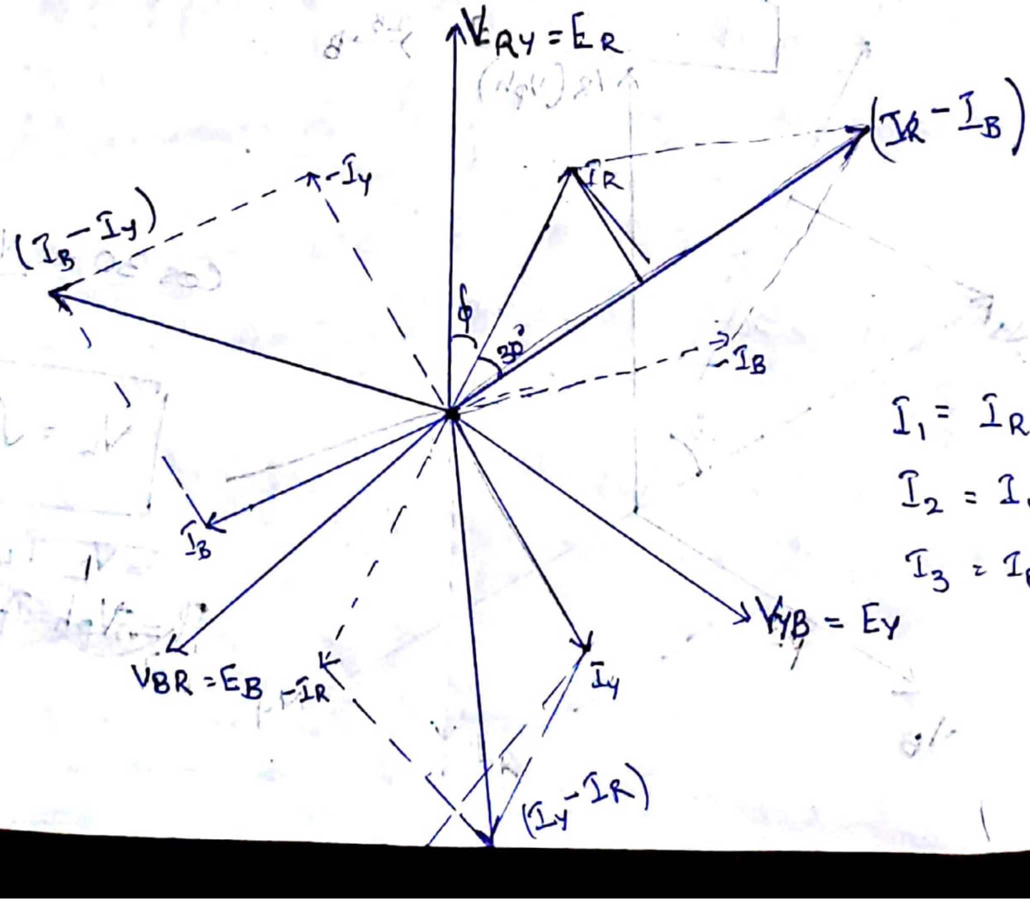


Delta connection



$V_L = V_{ph}$.

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



$I_1 = I_R - I_B$

$I_2 = I_Y - I_R$

$I_3 = I_B - I_Y$

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$$\cos 30^\circ = \frac{I_R - I_B}{2 \times I_R} = \frac{I_2}{2 I_R} = \frac{I_L}{2 I_{ph}}$$

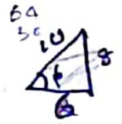
$$\cancel{I_{ph}}\ I_L = \frac{\sqrt{3}}{\cancel{2}} \times \cancel{2} \times I_{ph} \quad \boxed{I_L = \sqrt{3} I_{ph}}$$

Power/(phase) $= V_{ph} I_{ph} \cos\phi$

Total power $= 3 \times V_{ph} I_{ph} \cos\phi = \sqrt{3} V_L I_L \cos\phi$

A 3 phase star connected alternator supplies a delta connected load impedence of each branch is $(8 + j6)\ \Omega/ph$. Line voltage is 230V. Determine ① I in Load branch ② P consumed ③. Power factor ④ Reactive power of the load.

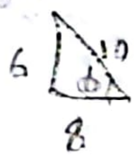
a) $I_{ph} = \dfrac{230}{10} = \underline{\underline{23A}}$ $\quad Z = 10\Omega$



b) $P_{active} = \sqrt{3} V_L I_L \cos\phi = 3 V_{ph} I_{ph} \cos\phi$ $\quad I_{ph} = \dfrac{I_L}{\sqrt{3}}$ $\quad \tan^{-1}\dfrac{8}{6}$

$P_{reactive} = \sqrt{3} V_L I_L \sin\phi$

$I_{ph} =$



3) $\cos\phi = \dfrac{8}{10} = \underline{\underline{0.8}}$

Comparison b/w
Star & Delta
↳ Applications.

* Comparison b/w Star and Delta connection.

Star connection	Delta connection
(i) A star connection is a 4 wire connection	(i) A Delta connection is a 3 wire connection.
(ii) Two types of star connection systems are possible: 4-wire, 3-phase system and 3-wire 3 phase system	(ii) In Delta connection, only 3-wire 3 phase system is possible.
(iii) Out of the 4 wires, 3 wires are the phases and 1 wire is the neutral.	(iii) All the 3 wires are phases in a Delta connection.
(iv) The common pt. of the star connection is called Neutral or star point.	(iv) There is no neutral in Delta connection.
(v) line voltage & phase voltage is different $\boxed{V_L = \sqrt{3} V_p}$	(v) line voltage and phase voltage are same.
(vi) line current & phase current is same.	(vi) line current & phase current is different. $\boxed{I_L = \sqrt{3} I_p}$