A.C. CIRCUITS.

→ Alternate current or Voltage :

It is the current in which the magnitude and dirn vary periodically. The nature of AC is that the current first (↑) to max^m & then falls back to the min^m to repeat the process in the opp. dirn in sinosuidal funcn.

→ Cycle : One complete set of ~~change in~~ +ve & −ve values of an alternating quantity constitutes one cycle.

→ Time Period : Time taken to complete one cycle by a AC.

→ Frequency : The no.of cycles completed per second :

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

→ Instantaneous value :

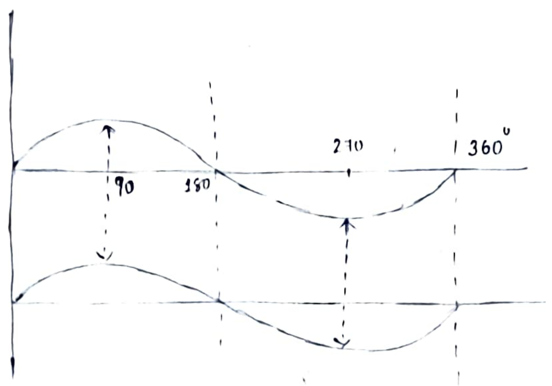
The value of AC at particular instant in a cycle.

→ Peak Value (or) Magnitude (or) Amplitude (or) Max^m value.

The max^m value of AC (current / voltage) during a cycle.

→ Imphase quantities :

When two alternating quantities reach their max^m & min^m values simultaneously.



→ ~~Out phase~~

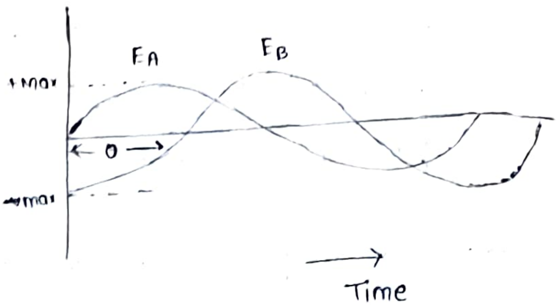
→ Out of phase (Phase diff)

When two alternating quantities donot attain max^m and min^m values simultaneously.

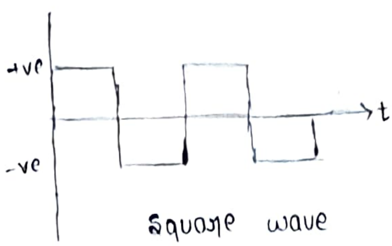
→ Phase Angle :

It is an angular displ^n b/w two alternating quantities.

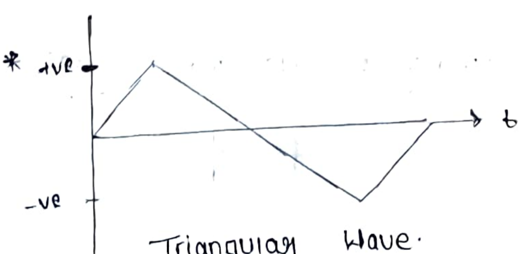
θ → phase angle.



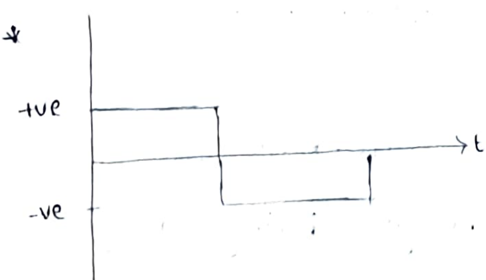
→ Diff types of AC, waves :

* 

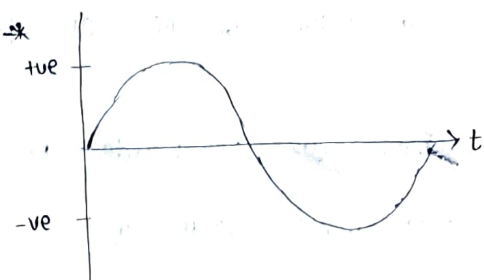
Square wave

* 

Triangular Wave.

* 

Rectangular Wave

* 

Sine wave.

→ Positive temp co-efficient of resistance :

The resistance of metal (↑) with rise in temp.

$\therefore R \propto T$, ex: Cu, Al, etc.

→ Negative temp. co-efficient of resistance :

$\therefore R \propto \frac{1}{T}$, ex: electrolytes, insulators.

~~# Freq~~

Frequency Of A.C. Wave :

The frequency of the alternating voltages generated by an alternator depends upon the no. of poles of the alternator & the speed at which it rotates.

$$f = \frac{PN}{120}$$

where $P \rightarrow$ Total no. of poles of generator

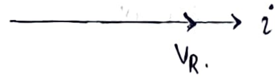
$N \rightarrow$ speed of generator in rpm.

$f \rightarrow$ frequency.

* Alternator : It converts mechanical energy into AC energy.
* Generator : Converts mechanical energy to either DC / AC.

A.C Through Pure Resistor ?

* i & V_R are in same phase.



* $i = \frac{V}{R} = \frac{V_m \sin \omega t}{R} = \frac{V_m}{R} (\sin \omega t)$.

$i = i_m \sin \omega t \longrightarrow$ same phase

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

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

→ Power :

$P = Vi$

$= (V_m \sin \omega t)(i_m \sin \omega t) = V_m i_m \sin^2 \omega t$

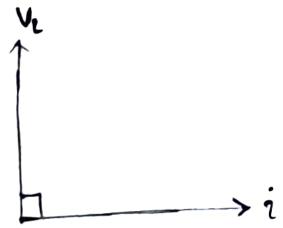
$= \frac{V_m i_m}{2} (1 - \cos 2\omega t)$

$$\therefore P = \underbrace{\frac{V_m i_m}{2}}_{\text{Constant Part}} - \underbrace{\frac{V_m i_m \cos 2\omega t}{2}}_{\text{Fluctuating Part}}$$

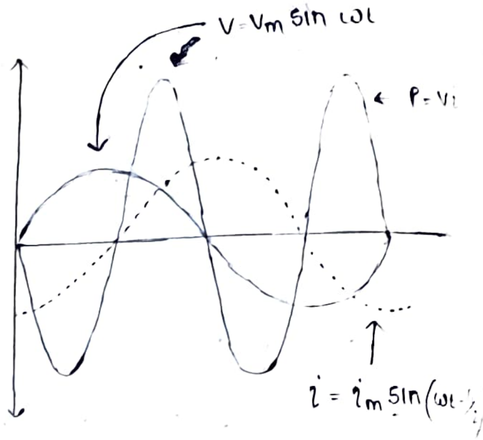
But ~~the has~~ avg power consumed is zero in complete cycle.

: Power consumed $\Rightarrow P = \frac{V_m}{\sqrt{2}} \cdot \frac{i_m}{\sqrt{2}} = V_{rms} i_{rms}$

→ AC Through pure inductor :



* The AC current flowing in the inductor will set up a magnetic field that is alternating in nature but its magnitude will change at every instant.



* This will give rise to an ~~AC~~ alternating induced EMF, often called the EMF of self ~~indu~~ induction, the magnitude of which depends on :
  i) rate of change of current
  ii) inductance of coil.

* $V = -L\dfrac{di}{dt}$,

* $V = V_m \sin \omega t$

$L\dfrac{di}{dt} = V_m \sin \omega t$

$di = \dfrac{V_m}{L} \sin \omega t \, dt$

$\Rightarrow i = \dfrac{V_m}{\omega L}(-\cos \omega t)$

$\Rightarrow i = \dfrac{V_m}{\omega L}\left(\sin\left(\omega t - \pi/2\right)\right)$

$\Rightarrow i = i_m\left(\sin\left(\omega t - \pi/2\right)\right)$

* Power :

$P = Vi$

$P = V_m \sin \omega t \cdot I_m \sin\left(\omega t - \pi/2\right)$

$P = -V_m I_m \sin \omega t \cos \omega t$

$P = -V_m I_m \dfrac{\sin 2\omega t}{2}$

$P = \dfrac{-V_m I_m}{2}(\sin 2\omega t)$

* Avg Power for one complete cycle:

$P_{avg} = \displaystyle\int_0^{2\pi} \dfrac{-V_m I_m}{2} \sin 2\omega t \, dt = \underline{\underline{0}}$

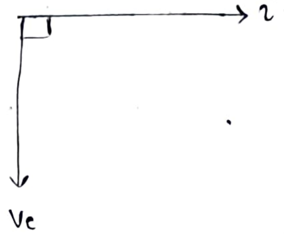
→ Inductive reactance : (X_L)

* $X_L = \omega L = 2\pi f L$

* The opposition offered by an inductor to AC.

→ AC Through pure Capacitive circuit :

* when an alternating voltage is applied to the plates of capacitor, it is charged first in one direction & then in the opp. dirn.



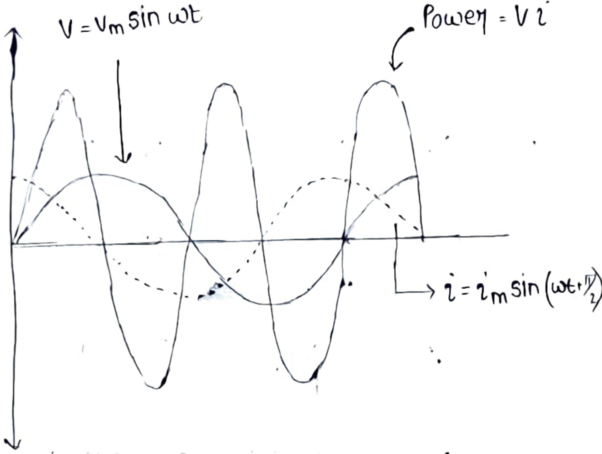
* $q = CV$, $i = \frac{dq}{dt}$, $V = V_m \sin \omega t$

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

$\Rightarrow i = \omega \cdot C \cdot V_m \cos \omega t$

$\Rightarrow i = \frac{V_m}{1/\omega C} \cos \omega t$

$\Rightarrow i = \frac{V_m}{(1/\omega C)} \sin(\omega t + \pi/2)$



* Power :

$P = Vi$

$P = (V_m \sin \omega t)(i_m \sin(\omega t + \pi/2))$

$P = V_m i_m \sin \omega t \cdot \cos \omega t$

$P = \frac{V_m i_m}{2} \sin 2\omega t$

remember.

* Capacitive reactance : (X_c)

* $X_c = 1/\omega C = \frac{1}{2\pi f C}$

* Avg Power for one cycle :

$P_{avg} = \int_0^{2\pi} \frac{V_m i_m}{2} \sin 2\omega t \, dt = \underline{\underline{0}}$

$\phi = \pi/2$

* $\boxed{\langle P_{avg} \rangle = E_{RMS} \, i_{rms} \cos \phi}$

⇒ An AC circuit consists of pure resistor of 10Ω and is connected accross AC supply of 230 V, 50 Hz, Calculate :

i) Current ii) Power iii) Eqⁿ for voltage & current

Solⁿ) i) $i = \frac{V}{R} = \frac{230}{10} = 23\,A$

ii) $P = Vi = (23)(230) = \underline{\underline{5290\,W}}$ (rms value)

iii) $V_m = \sqrt{2}\, V_{rms} = 325.27\ V$

$i_m = \sqrt{2}\, i_{rms} = 32.52\ A$

$\therefore\ \omega = 2\pi f = 2\pi(50) = 314$

$\therefore$
$$\left.\begin{aligned} V &= (325.27)\sin(314)t \\ i &= (32.52)\sin(314)t \end{aligned}\right\}\ \text{same phase}$$

⇒ In pure resistive circuit, the instantaneous voltage & i is :

$V = 250 \sin 314t$, $i = 10 \sin 314t$

i) Peak power ii) Avg Power.

imp

Solⁿ) i) Power (Peak) $= V_m i_m = \underline{\underline{2500\,W}}$

ii) $P_{avg} = \frac{V_m i_m}{2} = \underline{\underline{1250\,W}}$

⇒ Two capacitors of 80 µF & 50 µF resp. connected in series.

i) Current ii) Maxᵐ energy stored in the circuit when 200V at 50 Hz are applied across the series circuit

Solⁿ) $C = \frac{C_1 C_2}{C_1 + C_2} = \frac{400}{13}\ \mu F$

$$X_c = \frac{1}{\omega C} = \frac{1}{2\pi f C} = \underline{\underline{103.4\,\Omega}}$$

i) $i = \frac{V_{rms}}{X_c} = \frac{200}{103.4} = 1.93\text{ A}$

ii) Max energy $= \frac{1}{2} C V_m^2 = \frac{1}{2}\left(\frac{400}{13} \times 10^{-6}\right)(283)^2$

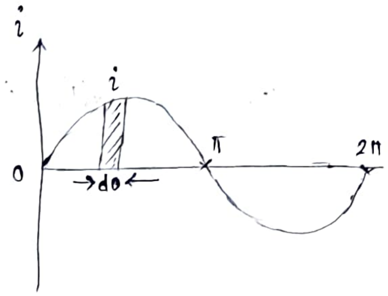
$$\boxed{V_m = \sqrt{2}\,(V_{rms})}$$

Given in capacitor chapter.

$= \underline{\underline{1.23\text{ J}}}$

→ Average value of sinusoidal current :

$i = i_m \sin\theta$



Area of half cycle : $\int_0^{\pi} i\,d\theta = \int_0^{2\pi} i_m \sin\theta\,d\theta$

$= I_m\left[-\cos\theta\right]_0^{\pi}$

$= -I_m\left[\cos\pi - \cos 0\right]$

$= \underline{\underline{2 I_m}}$

$$\boxed{\text{Avg value : } I_{av} = \frac{\text{Area of half cycle}}{\text{Base length of half cycle}} = \frac{2I_m}{\pi}}$$

imp.

∴ $I_{av} = 0.637\, I_m$

∴ $V_{av} = \underline{\underline{0.637\, V_m}}$

↳ this is only for sin

for other trigo learn the whole process

↓

same process for V_{avg} also

⇒ A voltage of $100 \sin \omega t$ is applied to 100Ω. Find the i_{inst}, i_{avg}, i_{rms} & P_{avg}.

Sol^n)

$V = 100 \sin \omega t$

$R = 100\,\Omega$

i) $i_{inst} = i(t) = \frac{v(t)}{R} = \frac{100 \sin \omega t}{100} = \sin \omega t$ A

ii) $i_{avg} = \frac{2I_m}{\pi} = \frac{2\left(\frac{V_m}{R}\right)}{\pi} = \frac{2(1)}{\pi} = 0.697$ A

iii) $i_{rms} = \frac{I_m}{\sqrt{2}} = 0.707$ A.

iv) Power $= v(t) \times i(t) = 100 \sin^2 \omega t$

$= 100 \left(\frac{1 - \cos 2\omega t}{2}\right)$

$= 50\,(1 - \cos 2\omega t)$

⇒ An inductive coil takes 10A & decipates 1000 W when connected to a supply of 125 V, 50 Hz. Calculate the impedence / reactance, inductance & power factor.

Sol^n). $P = Vi \cos\theta = i^2 R$

$R = \frac{P}{i^2} = \frac{1000}{100} = 10\,\Omega$ → reactance.

$Z = \frac{V}{i} = \frac{125}{10} = 12.5\,\Omega$ → impedence.

$\cos\phi = \frac{R}{Z} = \frac{10}{12.5}$

$X_L = \sqrt{Z^2 - R^2} = 7.5\,\Omega$

$L = \frac{7.5}{2\pi(50)} = 23.8$ mH → inducatance.

⇒ A coil of ~~10 W~~ $R = 10\,\Omega$, and inductance is $0.1H$ is connected in series with capacitor of $150\,\mu F$ across $200V$, $50Hz$ supply. Calculate inductive reactance, capacitive reactance, current, power factor, V across resistor, inductor & capacitor.

Sol^n) $R = 10\,\Omega$, $L = 0.1H$, $C = 150\,\mu F$, $V = 200V$, $f = 50Hz$

$X_L = \omega L = 2\pi f L = 2\pi(50)(0.1) = 31.42\,\Omega \longrightarrow (1)$

$X_C = \frac{1}{\omega C} = \frac{1}{2\pi(50)(150\,\mu F)} = 21.22\,\Omega \longrightarrow (2)$

$\cancel{i = \frac{200}{10} = 20A}$

$Z = \sqrt{R^2 + (X_L - X_C)^2} = 14.28\,\Omega$

$i = \frac{200}{14.28} = 14\,A \longrightarrow (3)$

$\cos\phi = \frac{R}{Z} = \frac{10}{14.28} = 0.7 \longrightarrow (4)$
(lag)
↳ $\because X_L > X_C$

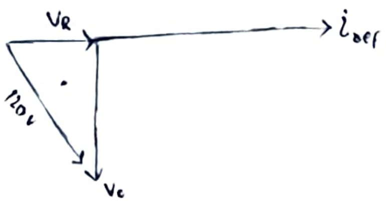
$V_R = iR = (14)(10) = 140\,V \longrightarrow (5)$

$V_L = iX_L = (14)(31.42) = \cancel{461}\ 439.88\,V \longrightarrow (6)$

$V_C = iX_C = (14)(21.22) = 297.08\,V \longrightarrow (7)$

⇒ A capacitance of $20\,\mu F$, $R = 100\,\Omega$ are connected in series across $120V$, $60Hz$ main. Determine the avg power observed by the circuit and also draw the phasor diagram.

Sol^n) $X_C = \frac{1}{\omega C} = \frac{1}{2\pi(60)(20\times10^{-6})} = 132.6\,\Omega$.



~~$P_{avg} =$~~ $Z = \sqrt{R^2 + X_C^2} = 166.1\,\Omega$.

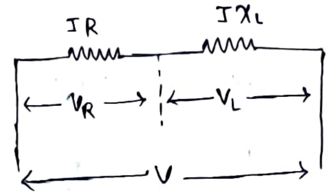
$i = \frac{120}{166.1} = 0.72\,A$.

$\cos\phi = \frac{R}{Z} = 0.601$, $P = \cancel{43.2W}\ 52.01\,W$

~~Pavg~~

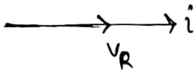
Resistance - Inductance (R-L) series circuit :

* In series, same amount of i flows through all elements so, current should be taken as reference.

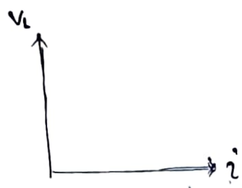


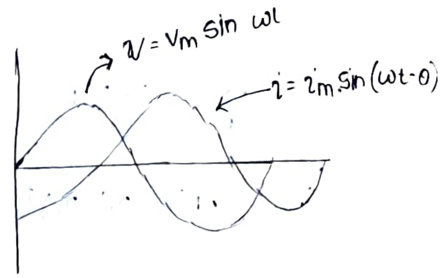
* $V_R = iR$, $V_L = iX_L$

* In resistor :



In Inductor :





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

$\Rightarrow V = \sqrt{V_R^2 + V_L^2} = \sqrt{(iR)^2 + (iX_L)^2} = I\sqrt{R^2 + X_L^2}$

$\Rightarrow i = \dfrac{V}{\sqrt{R^2 + X_L^2}} = \dfrac{V}{Z}$

* $\tan\theta = \dfrac{V_L}{V_R} = \dfrac{X_L}{R}$

* $X_L = \omega L = 2\pi f L$

* Power factor $\Rightarrow \cos\theta = R/Z$

* Instantaneous Power : $P = V \times i$

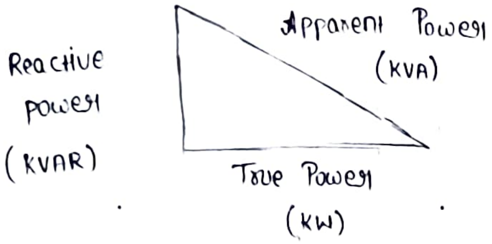
$\Rightarrow P = V_m \sin \omega t \cdot i_m \sin(\omega t - \theta)$

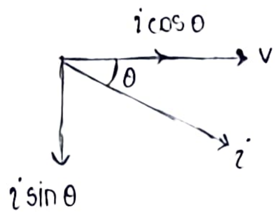
$\Rightarrow P = \dfrac{V_m}{\sqrt{2}} \cdot \dfrac{i_m}{\sqrt{2}} \cos\theta - \cancel{\dfrac{1}{2} V_m I_m \cos(2\omega t - \theta)}$ 0

(fluctuating power is zero for one cycle)

* Avg Power $\Rightarrow P_{avg} = V_{rms}\, i_{rms} \cos\theta$.

→ Apparent Power, True Power, Reactive Power & Power factor :





* Apparent Power : $S = vi = \frac{vi}{1000}$ KVA (kilo ampere ↓ volt)

* True Power (or) Real Power (or) Active Power } ⇒ $P = vi \cos\theta = \frac{vi\cos\theta}{1000}$ (KW) ↙ watts

* Reactive Power ⇒ $Q = vi \sin\theta$ $\quad Q = \frac{vi\sin\theta}{1000}$ KVAR ↳ reactive

* $KVA = \sqrt{(KW)^2 + (KVAR)^2}$

* Real Power : (P) ⟶ The actual power consumed in an A.C circuit

* Reactive Power : The power absorbed by pure reactance

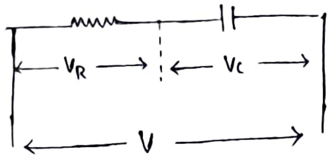
* Apparent Power (or) Total Power (S) : It is given by product of vi

* Power factor : $\cos\theta = \frac{R}{Z} = \frac{vi\cos\theta}{vi}$ ⟶ real power / ⟶ app. power

• The max value of P.F. is 1
  min value of P.F. is 0

R-C Series circuit :

A circuit containing a resistance in series with a capacitance.



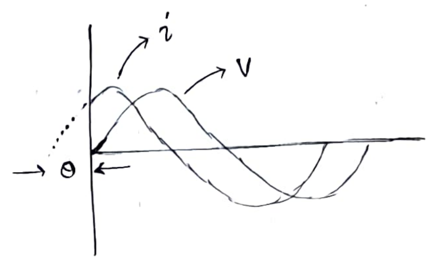
* $V = \sqrt{V_R^2 + V_C^2} = i\sqrt{R^2 + X_C^2}$

* $\tan\theta = \frac{V_C}{V_R} = \frac{X_C}{R}$.

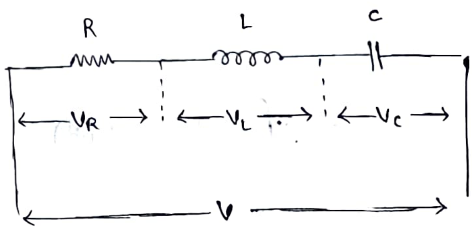
* Instantaneous voltage $\Rightarrow$ $V = V_{max} \sin \omega t$

  " current $\Rightarrow$ $i = i_m \sin(\omega t + \theta)$

$\therefore P = Vi\cos\theta$.



R-L-C Series circuit :



~~Case~~ :

→ Conditions :

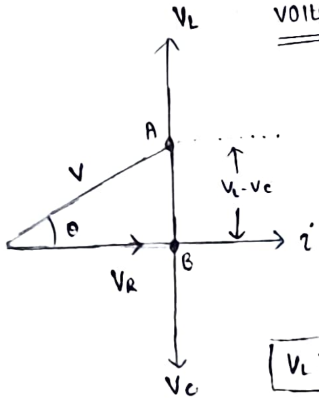
i) $X_L > X_C$ → inductive

ii) $X_C > X_L$ → capacitive

iii) $X_L = X_C$ → Resistive.

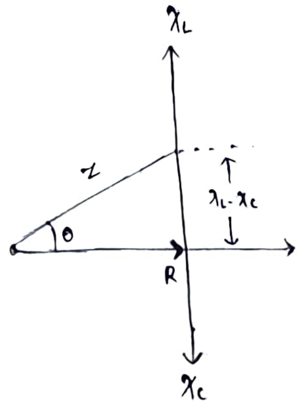
→ Case - 1 :

voltage



$\boxed{V_L > V_C}$

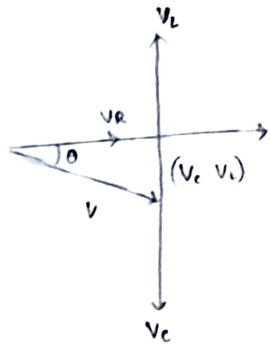
impedence



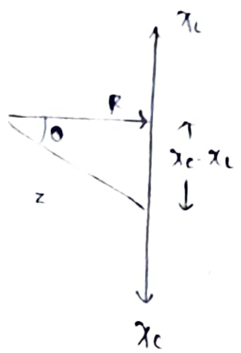
$\boxed{X_L > X_C}$

→ Case - 2 :

$V_c > V_L$

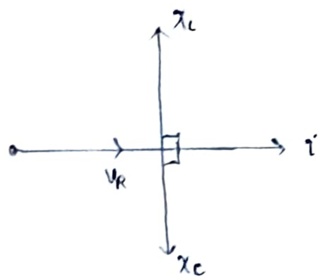


$X_c > X_L$



→ Case - 3 :

$X_L = X_C$



$(X_L - X_C) = 0$

* $X_L > X_C$ → Nature of circuit is inductive, so i lags the voltage

$\theta > 0$ ($\theta \rightarrow$ phase angle).

* $X_C > X_L$ → Nature of circuit is capacitive, so i leads the voltage

$\theta < 0$

* $X_C = X_L$ → Nature of circuit is resistive, i & v are in same phase

$\theta = 0$

CONVERTING POLAR FORM INTO RECTANGULAR FORM & VICE-VERSA :

* Rectangular form : $A + jB$

* Polar form : $A \angle B$

* Note : To perform addition or subtraction, rect form is easy. To perform multiplication or division, polar form is easy.

⇒ Convert $6+j8$ to polar form :

Sol^n Magnitude : $\sqrt{6^2+8^2} = 10$

I quad → θ
II → $\pi-\theta$
III → $\theta-\pi$
IV → $-\theta$

$\tan\theta = \frac{8}{6} \Rightarrow \theta = \tan^{-1}\left(\frac{8}{6}\right) = 53.1^\circ$

Polar form : $10\angle 53.1^\circ$

Exponential form : $10e^{j53.1}$

⇒ Convert $10\angle 53.1^\circ$ to rect form :

Sol^n polar form : $10\angle 53.1^\circ$

$10\left(\cos 53.1^\circ + j\sin 53.1^\circ\right)$

$10\left(0.6 + j\,0.799\right)$

$6 + 7.9j$

$6 + 8j$

→ Addition & Subtraction of vector quantities :

$\vec{V_1} = a_1 + jb_1$ & $\vec{V_2} = a_2 + jb_2$

Addition : $\vec{V} = \vec{V_1} + \vec{V_2} = (a_1+a_2) + j(b_1+b_2)$

$|\vec{V}| = \sqrt{(a_1+a_2)^2 + (b_1+b_2)^2}$, $\theta = \tan^{-1}\left(\frac{b_1+b_2}{a_1+a_2}\right)$

→ Multiplication & division of vector quantities.

$\vec{V_1} = a_1 + jb_1$, $\vec{V_2} = a_2 + jb_2$

⇓ ⇓

$\vec{V_1} = a_1 \angle b_1$ $\vec{V_2} = a_2 \angle b_2$

* Multiplication → $\vec{V_1} \times \vec{V_2} = a_1 \angle b_1 \times a_2 \angle b_2$

$= a_1 a_2 \angle b_1 + b_2$

* Division → $\dfrac{\vec{V_1}}{\vec{V_2}} = \dfrac{a_1 \angle b_1}{a_2 \angle b_2} = \dfrac{a_1}{a_2} \angle b_1 - b_2$

⇒ $10 \angle 30^\circ + 16 \angle -30^\circ$.

Sol^n^ :

$10(\cos 30^\circ + j \sin 30^\circ) = 8.66 + j5$

$16(\cos 30^\circ - j \sin 30^\circ) = 13.86 - j8$

$\Big\}$ ⇒ $22.52 - j3$

⇒ $\dfrac{\vec{A} \cdot \vec{B}}{\vec{C}}$, $\vec{A} = 10 + j10$

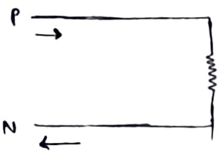
$\vec{B} = 15 \angle -120^\circ$, $\vec{C} = 5 + j0$.

Sol^n^ $\vec{A} = 14.14 \angle 45^\circ$, $\vec{B} = 15 \angle -120^\circ$, $\vec{C} = 5 \angle 0^\circ$

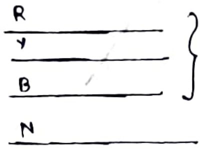
$\dfrac{\vec{A} \cdot \vec{B}}{\vec{C}} = \dfrac{(14.14 \times 15)}{5} \angle 45^\circ - 120^\circ - 0 = 42.42 \angle -75^\circ$

THREE PHASE SYSTEM

→ SINGLE PHASE :



→ THREE PHASE : (Types)
↓
* Balanced System
* Unbalanced System



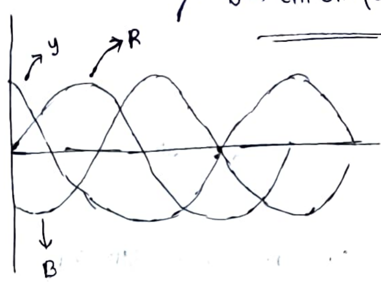
* Balanced System → Same i ~~through~~ (R,Y,B)
* Unbalanced System → Not Same i through (R,Y,B).

R → $E_m \sin \omega t$
Y → $E_m \sin(\omega t + \theta)$
B → $E_m \sin(\omega t - \theta)$

* Phase order : (~~Phase sequence~~)

RYB → Positive sequence

RBYR → Negative Sequence



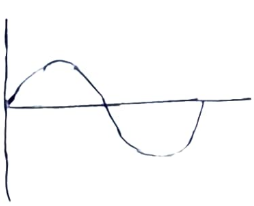
* 

} → one line diagram.

Transformer-1 (Step-up) ↓ Secondary coil has delta config

Transformer-2 (Step-down) ↓ Secondary coil. has star ~~delta~~ config.

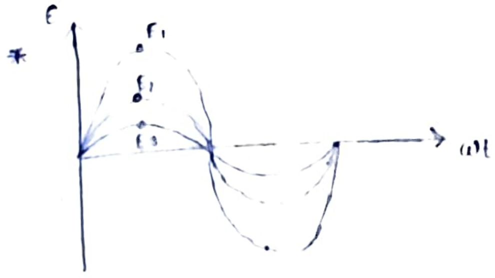
* 3 phase is used for continuous supply of current in a circuit

* 

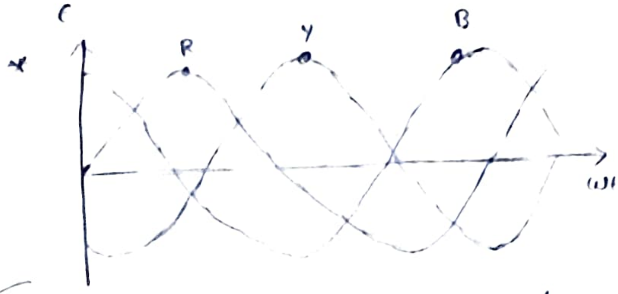
→ In single phase, value goes to zero three times, which may affect the appliance, so we use 3 phase.

* We don't use 4 & 5 phase because the phases may cancel each other

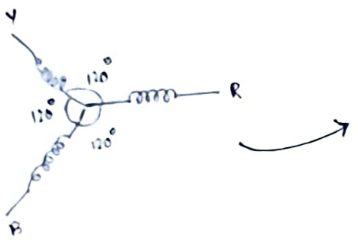
*

* 

diff values of E at one t

* 

diff ~~t for~~ same c at diff time,



$R: \sin(\omega t)$

$Y = \sin(\omega t - 120^\circ)$

$B = \sin(\omega t - 240^\circ)$

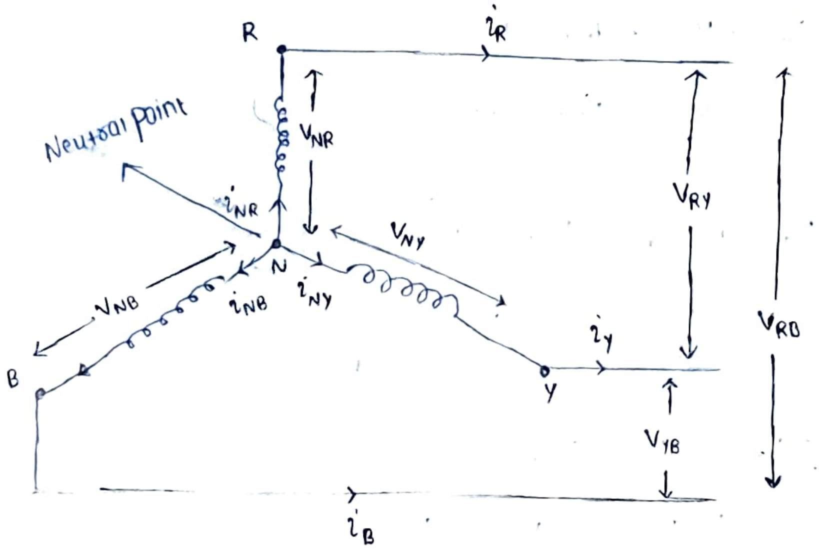
The phase diff. is 120° most times.

+ve phase seq :	RYB
-ve phase seq :	BYR

Connection of 3 phase AC → Star, delta.

→ STAR CONNECTION : (Balanced circuits)

It is a type of connection, where one terminal from each ~~moving~~ winding is connected to a common point and the remaining 3 terminals are connected to circuit.



Line quantities :

It is balanced because phase is 120° each

* Line voltages : $V_{RY} = V_{YB} = V_{BR}$ } $\rightarrow V_L$

* Line currents : $I_R = I_Y = I_B$ } $\rightarrow i_L$

• Phase quantities

* Phase voltages : $V_{NR} = V_{NY} = V_{NB}$ } $\rightarrow V_{Ph}$

* Phase currents : $i_{NR} = i_{NY} = i_{NB}$ } $\rightarrow i_{Ph}$

→ FOR BALANCED CONNECTION :

* Relation b/w line and phase currents :

$$i_{NR} = i_R \; , \quad i_{NY} = i_Y \; , \quad i_{NB} = i_B$$

$$\therefore \; \underline{i_{Ph} = i_L}$$

* Relation b/w line & phase voltages :

Sequence of drawing is R → Y → B

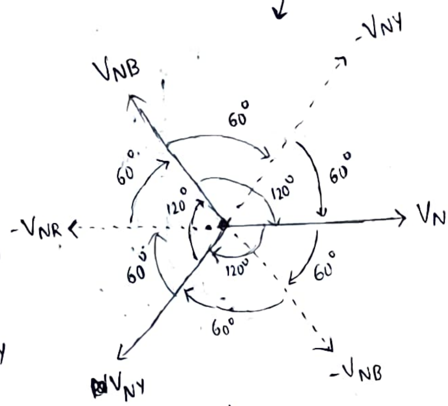
Applying KVL in mesh : (in pre fig.)

Loop (NRYN) $\longrightarrow$ $V_{NR} + V_{RY} - V_{NY} = 0$

$$V_{RY} = V_{NY} - V_{NR}$$

Loop (NYBN) $\longrightarrow$ $V_{NY} + V_{YB} - V_{NB} = 0$

$$\Rightarrow V_{YB} = V_{NB} - V_{NY}$$



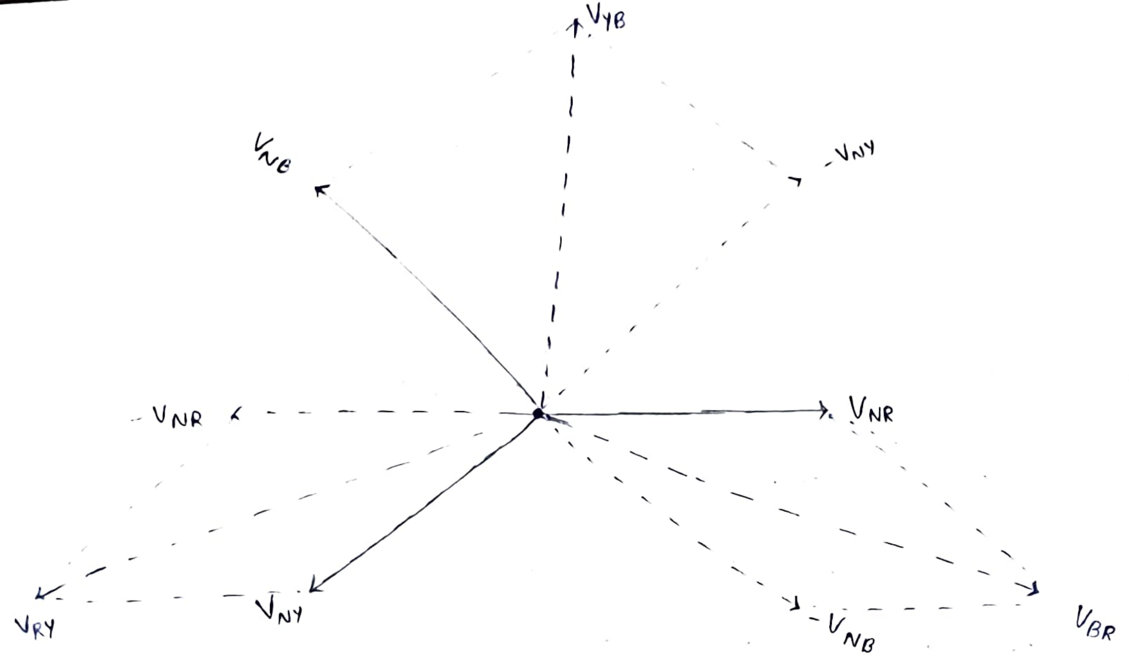
Loop (NRBN) $\longrightarrow$ $V_{NR} - V_{BR} - V_{NB} = 0$

$$\Rightarrow V_{BR} = V_{NR} - V_{NB}$$

$$\therefore \; |V_{RY}| = \sqrt{V_{NY}^2 + V_{NR}^2 + 2 V_{NY} V_{NR} \cos\phi}$$

from phasor above

$$|V_L| = \sqrt{V_{Ph}^2 + V_{Ph}^2 + 2V_{Ph}^2 \cos 60^\circ} \Rightarrow \underline{|V_L| = \sqrt{3}\, V_{Ph}}$$

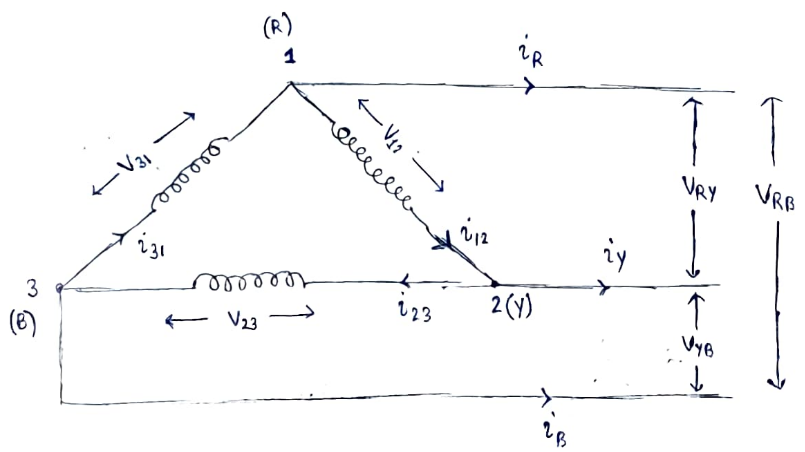


Phasor diagram

Draw phase voltages phases

→ DELTA CONNECTION : (Balanced)

* It is a type of connection of 3 phase windings where all the coils are connected to back to back arrangement.



- Line quantities :

* Line voltage : $V_{RY} = V_{YB} = V_{BR} = V_L$

* Line currents : $i_R = i_y = i_B = i_L$

Phase quantities :

* Phase voltage : $V_{12} = V_{23} = V_{31} = V_{Ph}$

* Phase current : $i_{12} = i_{23} = i_{31} = i_{Ph}$

* Relation b/w line and phase voltages :

$V_{RY} = V_{12}$, $V_{YB} = V_{23}$, $V_{RB} = V_{31}$

$\therefore \boxed{V_{line} = V_{phase}}$

* Relation b/w line and phase currents :

By KCL :

$i_{31} = i_{12} + i_R \Rightarrow i_R = i_{31} - i_{12}$.

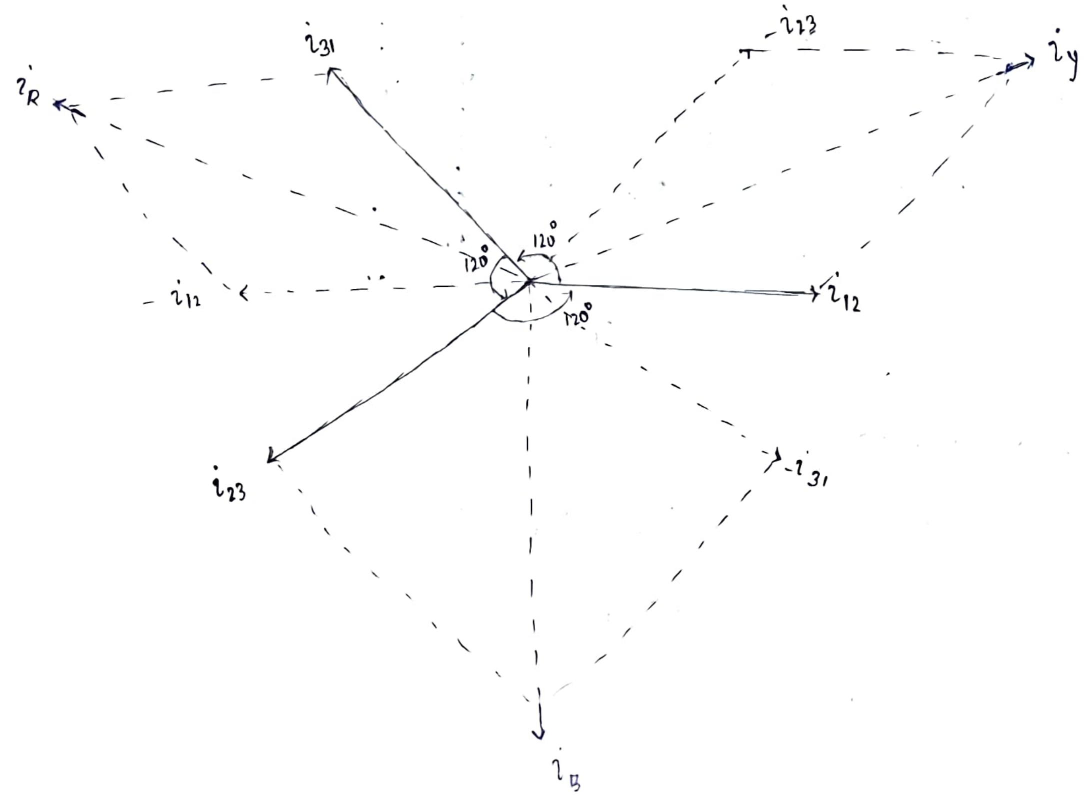
$i_{12} = i_{23} + i_y \Rightarrow i_y = i_{12} - i_{23}$

$i_{23} = i_{31} + i_B \Rightarrow i_B = i_{23} - i_{31}$

$\therefore |i_R| = \sqrt{i_{31}^2 + i_{12}^2 + 2 I_{31} i_{12} \cos\phi}$

$i_L = \sqrt{i_{ph}^2 + i_{ph}^2 + 2 i_{ph}^2 \cos 60^\circ} = \underline{\underline{\sqrt{3}\, i_{ph}}}$

$\therefore \underline{\underline{i_L = \sqrt{3}\, i_{ph}}}$



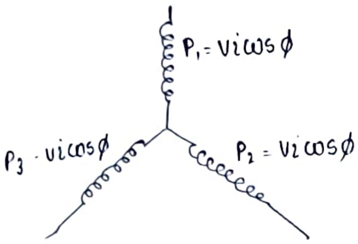
Power in 3ϕ AC : (Balanced)

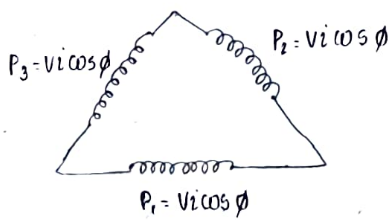
imp.

* Active Power : (P) : $V_{rms}\, i_{rms} \cos\phi$
* Reactive Power (Q) : $V_{rms}\, i_{rms} \sin\theta$
* Apparent Power (S) : $V_{rms}\, i_{rms}$

In 1ϕ AC

The power across any load is in line form except impedence which is in phase form





$\therefore P_T = P_1 + P_2 + P_3$

$\boxed{P_T = 3Vi\cos\phi}$

$\because V_1 = V_2 = V_3 = V_{ph}$

$i_1 = i_2 = i_3 = i_{ph}$

$\therefore \boxed{P_{Ph} = 3V_{ph}\, i_{ph} \cos\phi}$

$\therefore P_T = P_1 + P_2 + P_3$

$\because V_1 = V_2 = V_3 = V_{ph}$

$i_1 = i_2 = i_3 = i_{ph}$

$\boxed{P_{Ph} = 3V_{ph}\, i_{ph} \cos\phi}$

$\therefore$ Power won't change in phase values irrespective of type of connection.

$I_L = I_{ph}$ & $V_L = \sqrt{3}\, V_{ph}$.

$\therefore \boxed{P_L = \sqrt{3}\, V_L\, i_L \cos\phi}$

$V_L = V_{ph}$, $I_L = \sqrt{3}\, I_{ph}$.

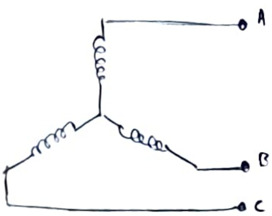
$\boxed{P_L = \sqrt{3}\, V_L\, i_L \cos\phi}$

Power won't change in line values irrespective of type of connection.

imp.

* we take power mostly in terms of line because, the load is connected to line currents or voltages

ex :



we connect load through A, B, C & i flowing through A, B, C are line currents and line voltages

* Power in 3ϕ AC : In terms of phase | In terms of line

Active Power (P) : $P = 3 V_{Ph} i_{Ph} \cos\phi$ (watts) | $\sqrt{3} V_L i_L \cos\phi$ (watts)

Reactive Power (Q) : $Q = 3 V_{Ph} i_{Ph} \sin\phi$ (VAR) | $\sqrt{3} V_L i_L \sin\phi$ (VAR)

Apparent Power (S) : $S = 3 V_{Ph} i_{Ph}$ (VA) | $\sqrt{3} V_L i_L$ (VA)

* in 3ϕ AC, we express anything by default in line form except given in que.

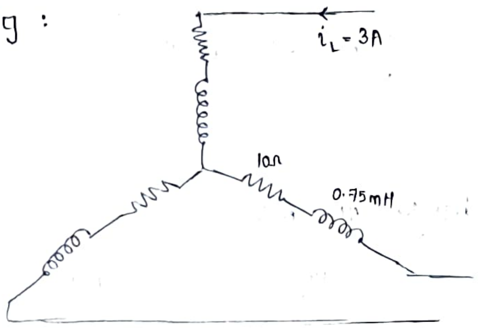
NUMERICALS :

⇒ In 3ϕ balanced star system is having a coil of resistance 10Ω & inductance 0.75 mH at supply of 3A. Calculate :

a) Total impedence b) Total supply voltage

c) Net power d) Phasor

Soln fig :



imp.

$Z \rightarrow$ always in phase,
so, if in que given V_L & Z and asked i_L.
then, $i_{Ph} = \frac{V_{Ph}}{Z}$
then $i_{Ph} \rightarrow i_L$
we cannot do, $i_L = \frac{V_L}{Z}$
cause Z in phase

If nothing mention then assume V & i as line

$\therefore X_L = 2\pi f L = 2\pi(50)(0.75 \times 10^{-3})$

$X_L = 0.235\,\Omega$

a) $Z_{Ph} = \sqrt{R^2 + X_L^2} = \sqrt{10^2 + (0.235)^2} = 10.002\,\Omega$

b) V_L is asked.

$\therefore V_{Ph} = i_{Ph} \times Z_{Ph} = i_L \times Z_{Ph}$ ($\because$ in star $i_{Ph} = i_L$)

$= (3)(10.002)$

$V_{Ph} = 30.006\,V$

$\therefore V_L = \sqrt{3} V_{Ph} = 51.971\,V$

c) $P = \sqrt{3} V_L i_L \cos\phi$, $\cos\phi = \frac{R}{Z} = \frac{10}{10.002} = 0.999$.

$P = (\sqrt{3})(51.971)(3)(0.999) = 269.779 \, W$

d) we need V_m, i_m, ϕ for phasor :

$V_m = \sqrt{2} V_{rms} = \sqrt{2} V_L = 73.498 \, V$

$i_m = \sqrt{2} i_{rms} = \sqrt{2} i_L = 4.242 \, V$

$\phi = \cos^{-1}(R/Z) = 2.562^\circ$.

i_L & i_{ph} are by default rms values

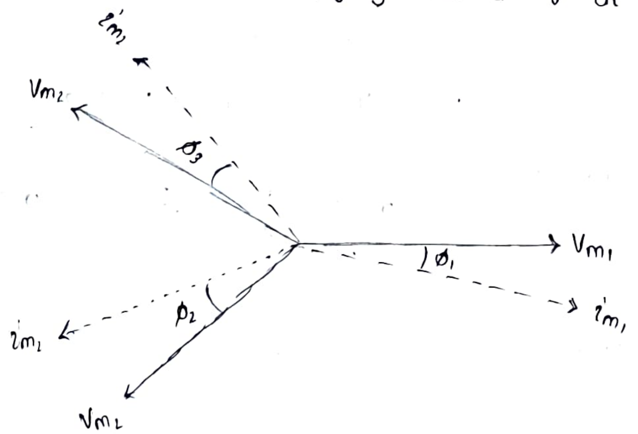
for balanced, $V_{m_1} = V_{m_2} = V_{m_3} = V_m$

$i_{m_1} = i_{m_2} = i_{m_3} = i_m$

$\phi_1 = \phi_2 = \phi_3 = \phi$

first draw, V, 120° apart ($\because$ it is balanced).

then draw, i, lagging behind V at ϕ° ($\because$ inductor present)



(Ans)

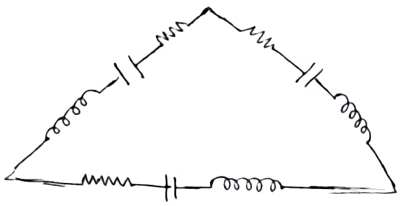
$\Rightarrow$ If a load of $Z = 3 - 7j \, \Omega$ in series with an inductor of 5Ω is connected in balanced 3ϕ delta across 440V, 50Hz supply. Calculate

a) Total impedence b) Net supply current.

c) If same load at same current in a 3ϕ balanced star formation then find KVAR rating. , d) phasor

Soln) $Z = 3 - 7j \, \Omega \longrightarrow R = 3\Omega$, $X_C = 7\Omega$

$X_L = 5\Omega$, $V_L = 440V$, $f = 50 Hz$

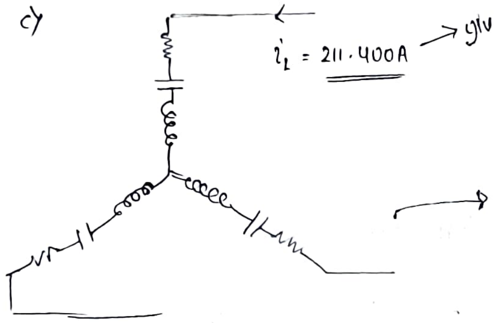


a) $Z = \sqrt{R^2 + (X_L - X_C)^2} = Z_{ph}$

$Z_{ph} = 3.605\,\Omega$

b) $i_{ph} = \frac{V_{ph}}{Z} = \frac{V_L}{Z} = \frac{440}{3.605} = 122.052\text{ A}$ $(\because V_L = V_{ph}$ in delta$)$

$\therefore i_L = \sqrt{3}\, i_{ph} = 211.400\text{ A}$

c) 

$\therefore$ KVAR $\Rightarrow Q = \sqrt{3}\, V_L i_L \sin\phi$ VAR

$i_L = i_{ph}$

$V_{ph} = i_{ph} \times Z = (211.4) \times (3.605)$

$V_{ph} = 762.09$

$V_L = \sqrt{3}\, V_{ph} = 1319.99\text{V}$

$\cos\phi = \frac{R}{Z} = \frac{3}{3.605} = 0.822$

$\phi = 33.695^\circ$

$Q = (\sqrt{3})(1319.99)(211.4)(\sin\phi)$

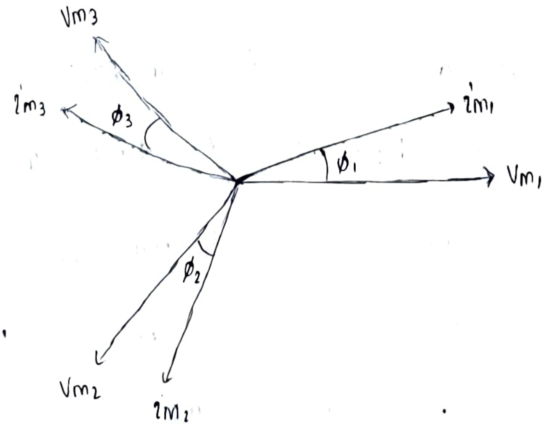
$Q = 268133.234$ VAR

$Q = 268.133$ KVAR (Ans)

d) $V_m = 622.253\text{ V}$

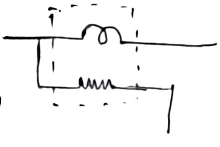
$i_m = 298.964\text{ V}$

$\phi = 33.695^\circ$



* Wattmeter consists of 2 coils namely current & pressure coil. It is used to find power in 3ϕ

* We use two wattmeter method to find power in 3ϕ, i.e, wattmeter present on 2 wires.



$P_{Total} = W_1 + W_2$

⇒ Two wattmeters P_{out} = 150 KW, 440V, 3 phase slip ring induction motor running at full load, the wattmeter reading are 115 KW, 50 KW.

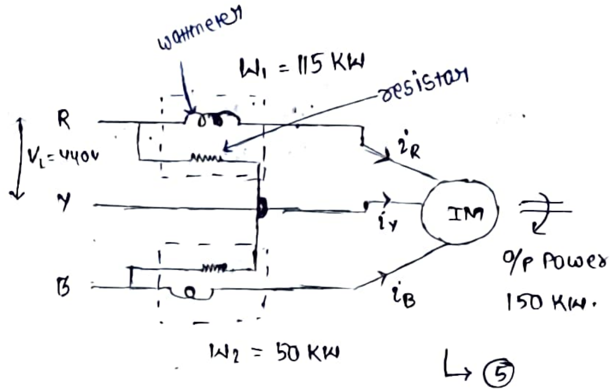
i) The input to the motor

ii) Power factor of the motor

iii) Line current drawn by the motor.

iv) η.

v) Diagram.



Sol^n) Given : 150 KW → O/P Power.

440 V → voltage

3 phase I.M

W_1 = 115 KW, W_2 = 50 KW

Power i/p to the motor = $W_1 + W_2$ = 165 KW → 1

$$\boxed{\tan\theta = \sqrt{3}\left[\frac{W_1 - W_2}{W_1 + W_2}\right]} = \sqrt{3}\left[\frac{65}{165}\right] = 0.682$$

$\tan\theta = 0.682$

$\theta = 34.3^\circ$

⇒ $\cos 34.3^\circ = 0.826$ → 2.

Power i/p to the motor : $\sqrt{3}\, V_L i_L \cos\theta$

⇒ 165 KW = $(\sqrt{3})(440)(i_L)(0.826)$

⇒ i_L = 1262.1 A → 3

O/P = 150 W

i/p = 165 W

$$\eta = \frac{O/P}{i/P} \times 100 = 90.9\% \rightarrow 4$$

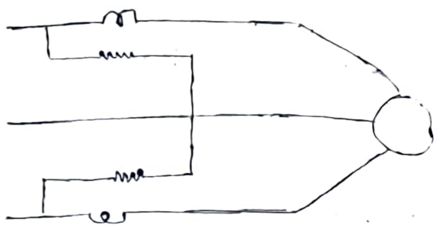
⇒ Two wattmeters connected to measure the power input to 3 phase circuit which indicates 15 KW, 1.5 KW resp. The latter reading being reversing the current coil connection. Calculate Power and Power factor.

↳ The cosine angle b/w i & V of an ac circuit

Soln)

$W_1 = 15$ KW

$W_2 = -1.5$ KW ← reversed

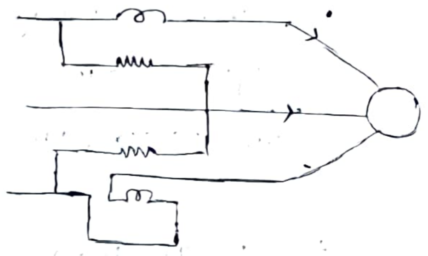


Total i/p power : ~~16.5 KW~~ 13.5 KW

$$\tan\theta = \sqrt{3}\left[\frac{W_1 - W_2}{W_1 + W_2}\right], \ \theta = 64.7^\circ$$

⇓ reverse

$\therefore \cos\theta = 0.43$



⇒ P input to a 3 phase, 400V, 37.3 KW inductor motor $\eta = 88\%$ $\cos\theta = 0.82$ is to be by 2 wattmeter method. Find reading of W_1, W_2 & I_L.

Soln)

$\eta = 88\%$

$$\eta = \frac{o/p}{i/p} \times 100$$

$\cos\theta = 0.82$

$V_L = 400$ V

$$\Rightarrow i/p = \frac{o/p}{\eta} \times 100 = \frac{37.3 \text{ KW}}{88} \times 100 = 42.386 \text{ KW}$$

Rating $= 37.3$ KW.

$P_T = W_1 + W_2 = 42.386$ KW.

$\cos\theta = 0.82$

$\theta = 34.91^\circ$

$$\tan\theta = \sqrt{3}\left[\frac{W_1 - W_2}{W_1 + W_2}\right]$$

$W_1 - W_2 = 17.081$ KW

$\therefore W_1 = 29.734$ KW

$W_2 = 12.65$ KW

$P = \sqrt{3}\, V_L \cdot i_L \cos\theta$

So $i_L = 74.8$ A