UNIT - IV

* Impedance:

- The opposition provided by AC circuit to the flow of current is called as Impedance.

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

$Z = \frac{V}{I}$ - opposition by resistor - Resistance . R
$Z = R + j0$

$I = \frac{V}{X_L}$ - opposition by inductor - inductive reactance X_L
$Z = 0 + jX_L$

$Z = \frac{V}{I}$ - opposition by capacitor - Capacitive reactance X_C
$Z = 0 - jX_C$

· combined notation for X_L & X_C is X

Impedance is combination of R & X . Unit - Ω

$$Z = \underbrace{R}_{\text{real}} + j\underbrace{X}_{\text{imaginary part}} \quad \text{- Rectangular}$$

$$Z = \underbrace{|Z|}_{\text{magnitude}} \angle \underbrace{\phi}_{\text{phase}} \quad \text{- polar}$$

$$\text{magnitude} = \sqrt{R^2 + X^2}$$

$$|Z| = \sqrt{R^2 + X^2}$$

$$\text{phase} = \tan^{-1}\left[\frac{\text{imaginary part}}{\text{Real part}}\right]$$

$$\phi = \tan^{-1}\left[\frac{X}{R}\right]$$

* Impedance Triangle:

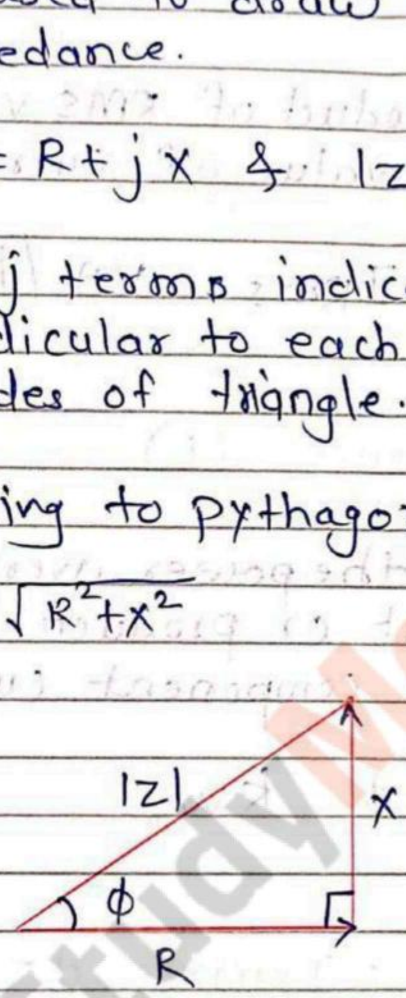
- It is used to draw graphical representation of impedance.

$$Z = R + jX \quad \& \quad |Z| = \sqrt{R^2 + X^2}$$

Here, j terms indicates that R & X are perpendicular to each other. Thus R & X form two sides of triangle.

According to pythagoras, third side (hypotenuse)

$$= \sqrt{R^2 + X^2}$$



Angle betn |Z| & R is ϕ

$R = |Z| \cos\phi$ – Horizontal line

$X = |Z| \sin\phi$ – Vertical line

$$\tan\phi = \frac{X}{R}$$

$$\phi = \tan^{-1}\left[\frac{X}{R}\right]$$

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* Types of power in AC circuit

1. Apparent Power (S)

- It is defined as product of RMS value of voltage and RMS value of current.

$$S = V_{Rms} \times I_{Rms} \quad VA / KVA$$

2. Real or Active Power (P)

- It is defined as the ~~power~~ average power taken by AC circuit or product of supply voltage and active component current ($I\cos\phi$)

$$P = VI\cos\phi \quad KW$$

P - real power
$V = V_{rms}$, $I = I_{rms}$, ϕ = phase betn V & I

3. Imaginary or Reactive power (Q)

- It is defined as product of supply voltage and reactive component current ($\sin\phi$)

$$Q = VI\sin\phi$$

* Power factor ($\cos\phi$)

i] $$P.f = \frac{\text{True Power}}{\text{Apparent power}} = \frac{P}{S}$$

$$P = VI\cos\phi \quad , \quad S = VI$$

$$P.f = \frac{VI\cos\phi}{VI} = \cos\phi$$

ii] $$P.f = \cos\phi = \frac{R}{Z}$$

iii) $$P.f = \cos\phi = \frac{\text{Fundamental comp. of current}}{\text{RMS value of total current}}$$

* Types of power factor.

1) Lagging p.f :
- when current is lagging behind voltage.

purely inductive ckt. current lags by 90°.

$\phi = 90°$

$\cos\phi = \cos 90' = 0$ zero lagging p.f.

2) Leading p f
- current leads voltage.

Purely capacitive ckt.

$p.f = \cos\phi = \cos 90 = 0$. zero leading p.f

III] Unity power factor

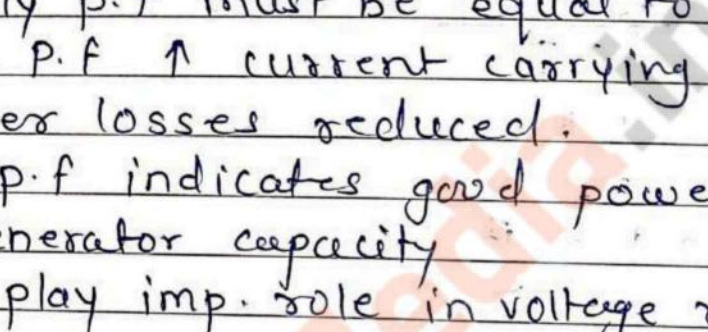
- No phase diff. betn V & I.
- purely resistive

$p.f = \cos\phi = \cos(0) = 1$

* Importance of P.f.

- Ideally p.f must be equal to 1.
- High P.f ↑ current carrying capacity
- power losses reduced.
- high p.f indicates good power utilization of generator capacity
- P.f play imp. role in voltage regulation & η.

* Power Triangle :-

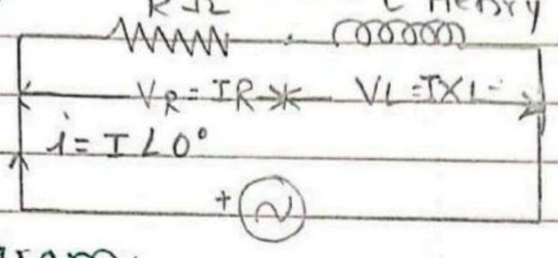


$\tan\phi = \frac{Q}{P}$

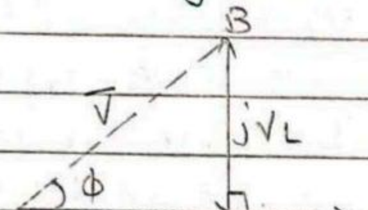
$\phi = \tan^{-1}\left(\frac{Q}{P}\right)$

* R-L Series Circuit

1) Circuit diagram.



2) Phasor diagram.



1) Taking $\bar{I} = I\angle 0°$ as ref. phasor, OA & AB represent V_R & V_L resp.
2) V_R is in phase with I_L while V_L leads I_L by 90°

applied voltage $\bar{V} = \bar{V}_R + \bar{V}_L$ as per KVL & Δ law.

III) Voltage triangle (V-Δ)

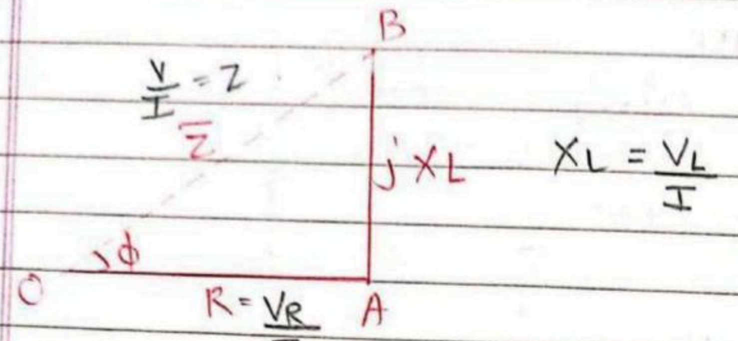
The Δ OAB in phasor diagram is called as V-Δ.

$$\bar{V} = (V_R + jV_L) = V\angle\phi$$

$$V = \sqrt{V_R^2 + V_L^2} = I.Z$$

$$p.f = \cos\phi = \left(\frac{V_R}{V}\right) \text{lagging}$$

iv) Impedance Triangle.

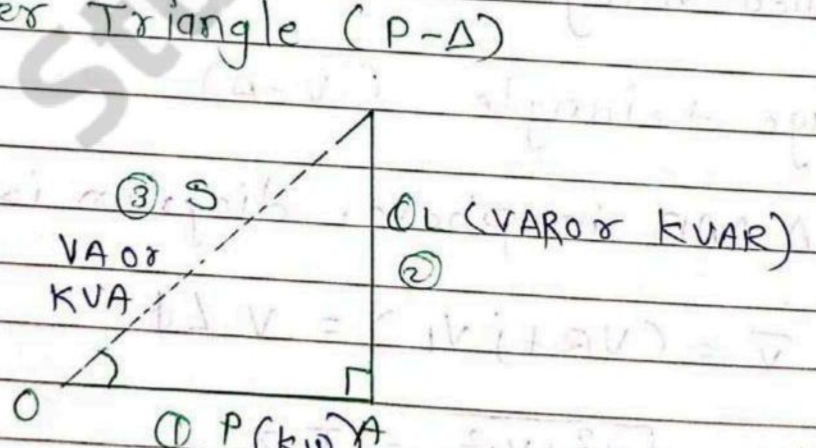


We know, $V_R = I \cdot R$, $V_L = IX_L$, $V = IZ$
if we devide each side of V-Δ by common factor I & assuming $I > 1$, we will get a similar Δ known as Z-Δ, as each sides represents opposition as shown. Z is called total opposition to the current

$$\bar{Z} = (R + jX_L) = Z\angle{+\phi}$$

$$Z = \sqrt{R^2 + X_L^2}, \quad pf = \cos\phi = \left(\frac{R}{Z}\right) \text{ lagging.}$$

v) Power Triangle (P-Δ)



if we multiply each side by $V\Delta$ by a common factor I & assuming $I > 1$, we will get similar but larger Δ shown,

$$\overline{KVA} = KVA \angle +\phi,$$

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

$$p.f = \left(\frac{kW}{KVA}\right) \text{ lagging}$$

$$S = V \times I = I^2 Z.$$
$$Q_L = V_L \cdot I = I^2 \cdot X_L = VI \sin\phi$$
$$P = V_R \cdot I = I^2 R = VI \cos\phi$$

vi) Power factor.

$p.f = \cos\phi$

$\left(\frac{V_R}{V}\right) \Rightarrow V-\Delta$

$\left(\frac{R}{Z}\right) \Rightarrow Z-\Delta$

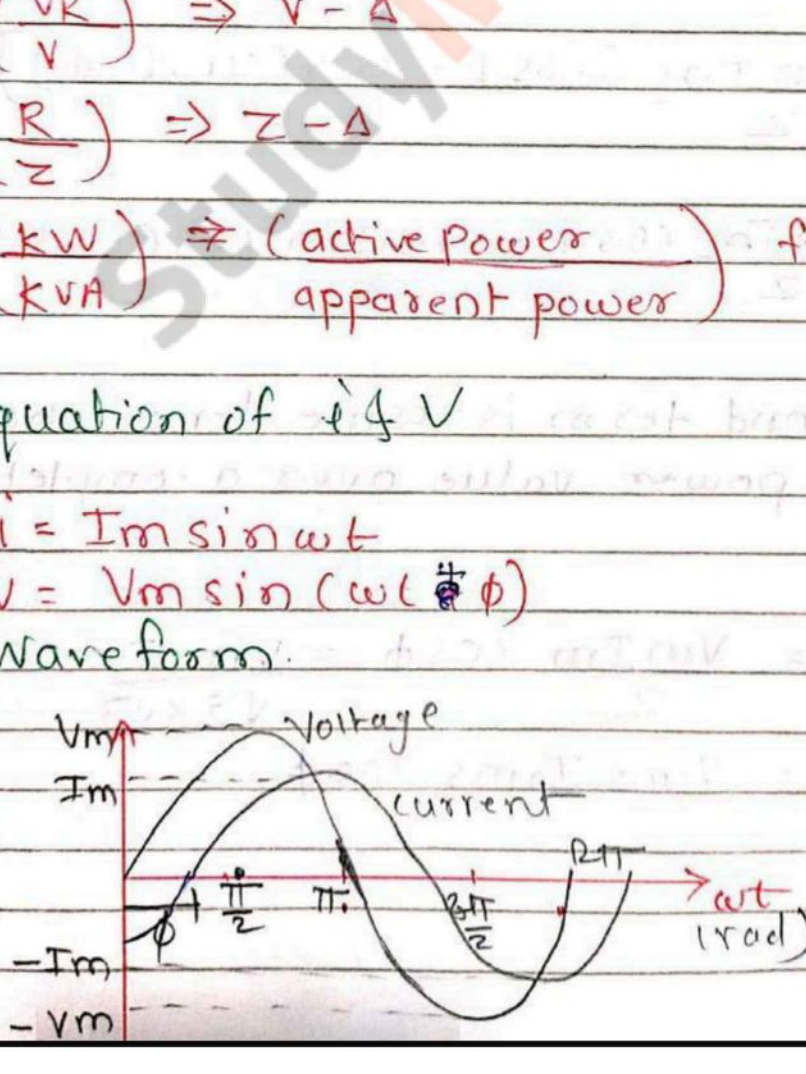
$\left(\frac{kW}{KVA}\right) \Rightarrow \left(\frac{\text{active power}}{\text{apparent power}}\right)$ from $P-\Delta$.

vii) equation of i & V

$i = I_m \sin \omega t$

$v = V_m \sin(\omega t \pm \phi)$

viii) Wave form



* Power

$P = V \times i$

$= V_m \sin(\omega t) \cdot \times I_m \sin(\omega t - \phi)$

$= V_m \cdot I_m \sin(\omega t) \sin(\omega t - \phi)$ —— ①

Use formula

$$\sin A \cdot \sin B = \frac{1}{2}\left[\cos(A-B) - \cos(A+B)\right]$$

$\sin \omega t \cdot \sin(\omega t - \phi)$

$$= \frac{1}{2}\left[\cos(\omega t - (\omega t - \phi)) - \cos(\omega t + \omega t - \phi)\right]$$

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

put this value in eqⁿ ①

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

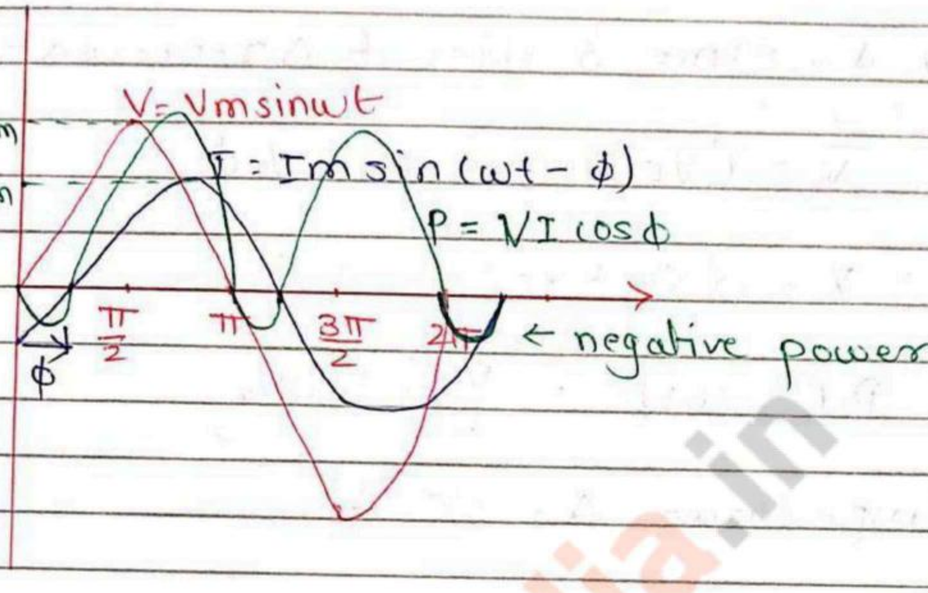
$$P = \frac{V_m I_m}{2}\cos\phi - \frac{V_m I_m}{2}\cos(2\omega t - \phi)$$

The second term is cosine term whose average power value over a complete cycle is zero

$$\therefore P_{av} = \frac{V_m I_m}{2}\cos\phi = \frac{V_m I_m}{\sqrt{2}\times\sqrt{2}}\cos\phi$$

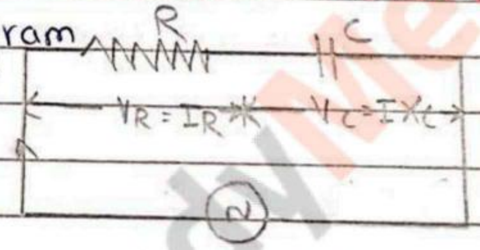
$$P_{av} = V_{rms} I_{rms} \cos\phi$$

Power Waveform.

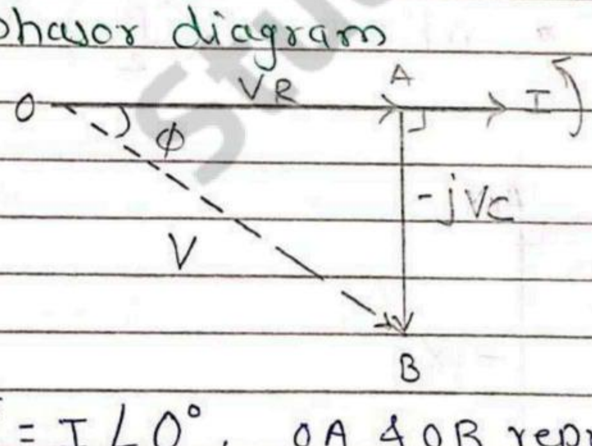


* R-C Series Circuit.

1) ckt Diagram



2) phasor diagram



$\bar{I} = I\angle 0°$, OA & OB represent VR & VL resp.
VR ~~leads~~ in phase with I & Vc lags I by 90°

$\bar{V} = \bar{V}_R + \bar{V}_C$ as per KVL.

III) Voltage triangle ($V-\Delta$)

$V-\Delta$. since 3 sides of Δ represent voltage

$$\overline{V} = (V_R - jV_C) = V \angle -\phi$$

$$V = \sqrt{V_R^2 + V_C^2} = I \cdot Z$$

$$p.f = \cos\phi = \left(\frac{V_R}{V}\right) \text{ leading}$$

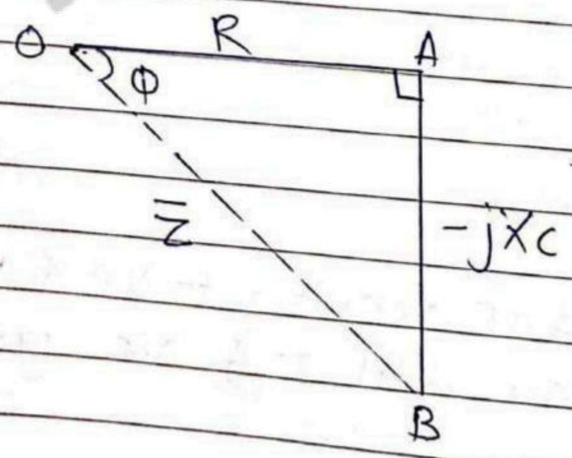
IV) Impedance Δ. ($Z-\Delta$)

$V_R = I \cdot R$, $V_C = I \cdot X_C$

by divide each side $V-\Delta$ by common factor I,

$$\overline{Z} = (R - jX_C) = Z \angle -\phi$$

$$Z = \sqrt{R^2 + X_C^2}, \quad pf = \cos\phi \left(\frac{R}{Z}\right) \text{ leading}$$



$Z-\Delta$

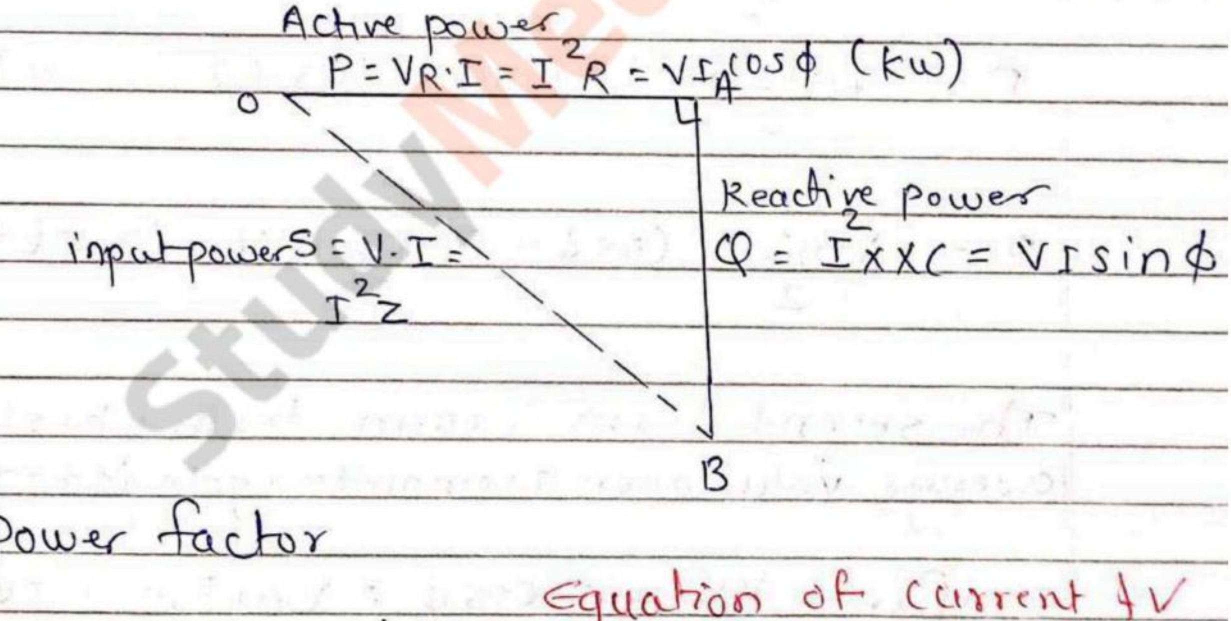
v) Power triangle

If we multiply each side of V-Δ by a common factor I, we will get similar but larger Δ known as PΔ

$$\overline{KVA} = (KW + jKVAR) = KVA \angle +\phi$$

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

$$p.f = \left(\frac{KW}{KVA}\right) \text{ leading}$$



* Power factor

$$V-\Delta = \left(\frac{V_R}{V}\right)$$

$$Z-\Delta = \left(\frac{R}{Z}\right)$$

$$P-\Delta = \left(\frac{KW}{KVA}\right)$$

Equation of current & V

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

$$v = V_m \sin(\omega t)$$

* Power

$$P = V \cdot i$$
$$= V_m \sin\omega t \times I_m \sin(\omega t + \phi)$$
$$= V_m I_m \sin\omega t \cdot \sin(\omega t + \phi)$$

Use formula.

$$\left[\sin A \cdot \sin B = \frac{1}{2}\left[\cos(A-B) - \cos(A+B)\right]\right]$$

$$P = V_m I_m \cdot \frac{1}{2}\left[\cos(\omega t - (\omega t - \phi) - \cos(\omega t + \omega t + \right.$$

$$P = \frac{V_m I_m}{2}\left[\cos(-\phi) - \cos(2\omega t + \phi)\right]$$

$$P = \frac{V_m I_m}{2}\left[\cos\phi - \cos(2\omega t + \phi)\right]$$

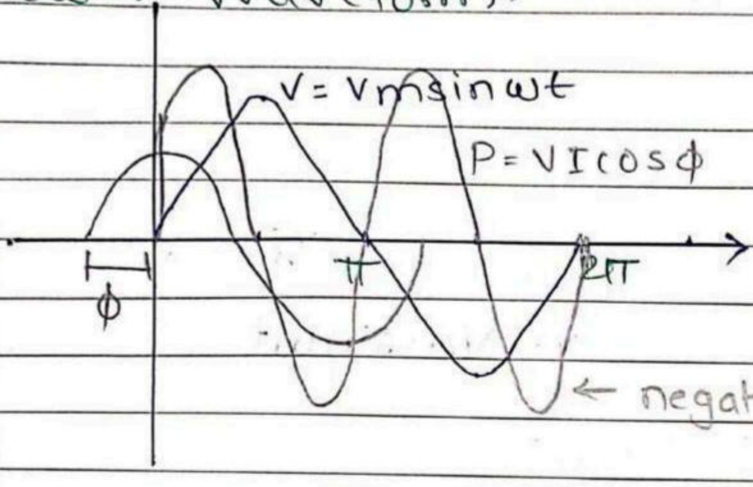
$$P = \frac{V_m I_m}{2}\cos\phi - \frac{V_m I_m}{2}\cos(2\omega t + \phi)$$

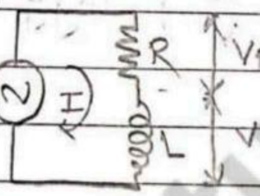
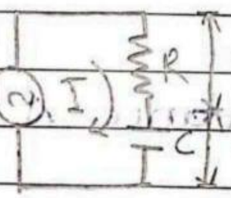
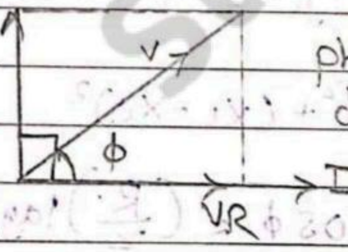
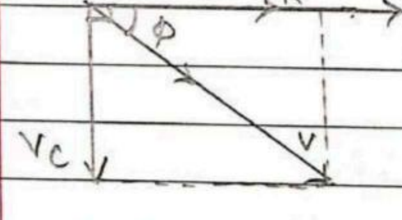
The second term is cosine term whose average value over a complete cycle is zero.

$$P_{av} = \frac{V_m I_m}{2}\cos\phi = \frac{V_m I_m}{\sqrt{2}\sqrt{2}} \cdot \cos\phi$$

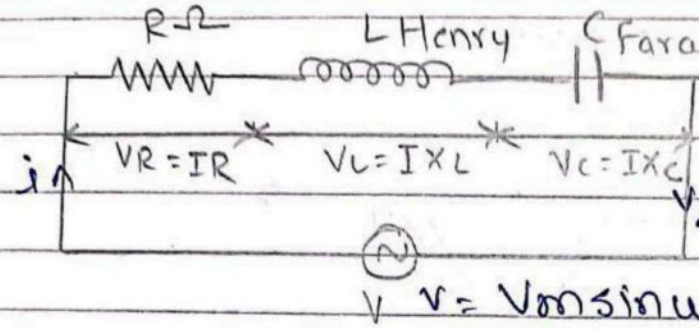
$$P_{av} = V_{rms} \cdot I_{rms} \cos\phi$$

* Power waveform.



Series R-L ckt	Series R-C circuit
1. R & L (inductor) are connected in series with supply voltage.	R & C are connected series with supply voltage.
2.  circuit diagram	 circuit diagram
3.  phasor diagram	 phasor diagram
4. Current lags behind voltage	Current leads behind voltage
5. P.f is lagging	P.f is leading
6. $Z = R + jX_L = \|Z\| \angle \phi$	$Z = R - jX_C = \|Z\| \angle -\phi$
7. It passes high freq. current so act as high pass filter.	It passes low freq. so acts as low pass filter.

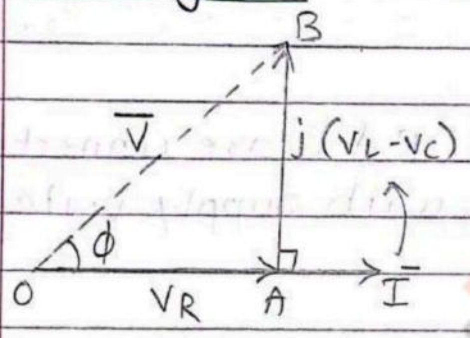
* R-L-C Series Circuit



$v = V_m \sin \omega t$

Case I. $X_L > X_C$

i) Voltage Δ

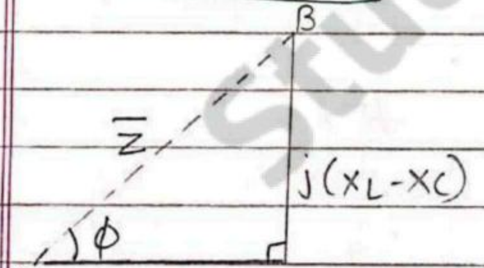


$$\bar{V} = V_R + j(V_L - V_C) = V \angle \phi$$

$$V = \sqrt{V_R^2 + (V_L - V_C)^2}$$

$$p.f = \left(\frac{V_R}{V}\right) \text{ lagging.}$$

ii) Impedance Δ



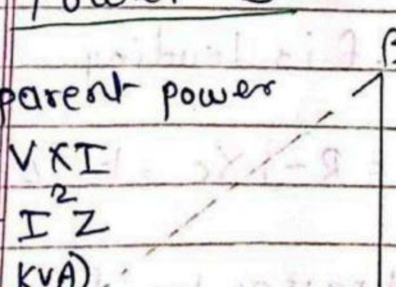
$$\bar{Z} = R + j(X_L - X_C) = Z \angle \phi$$

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

$$P.f = \cos \phi = \left(\frac{R}{Z}\right) \text{lagging.}$$

iii) Power Δ.

Apparent power
$= V \times I$
$= I^2 Z$
(VA or KVA)



Reactive or quadrature power
$= V_L \times I = I^2 \times (X_L - X_C)$
$= VI \sin \phi$
(measured in VAR or KVAR)

Active or usefulpower
$= V_R \times I = VI \cos \phi$ (W or KW)

The ac supply given by,

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

The ckt draws a current I. Due to current I, there are diff. voltage drops across R, L, C.

1) Drop across R is $V_R = I \cdot R$
2) Drop across L is $V_L = I \cdot X_L$
3) Drop across C is $V_C = I \cdot X_C$

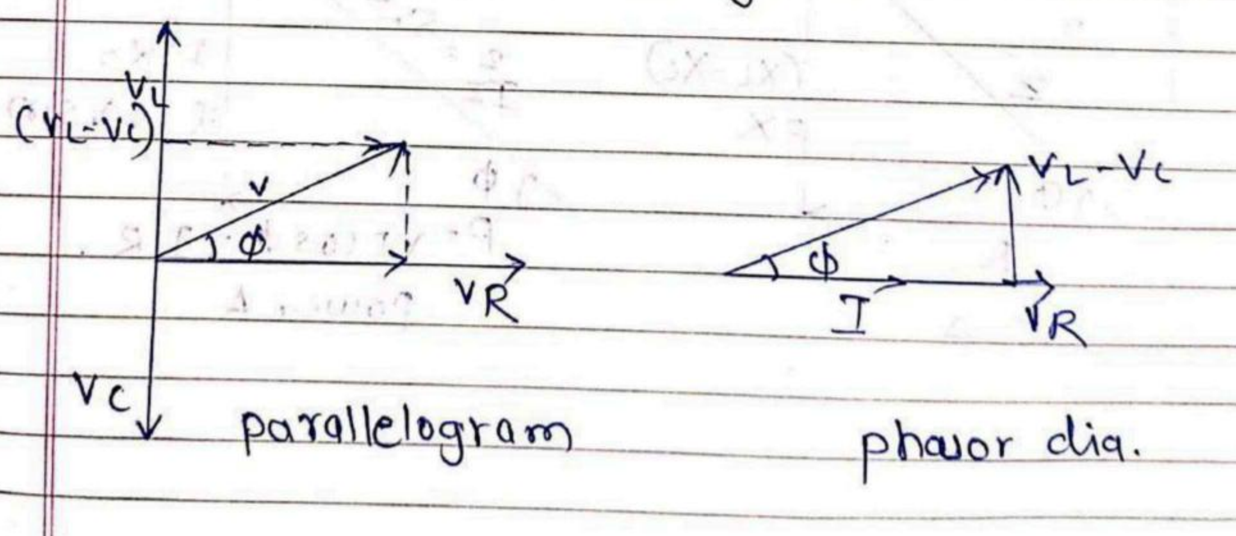
$$\vec{V} = \vec{V_R} + \vec{V_L} + \vec{V_C}$$

1) $X_L > X_C$

When $X_L > X_C$, V_L is greater than V_C. So resultant of V_L & V_C will be directed towards V_L i.e leading current I. Current I will lag the resultant of V_L & V_C i.e $(V_L - V_C)$

The ckt is said to be inductive.

The phasor sum of V_R & $(V_L - V_C)$ gives resultant supply voltage.



from voltage Δ

$$V = \sqrt{(V_R)^2 + (V_L - V_C)^2}$$

$$= \sqrt{(IR)^2 + (IX_L - IX_C)^2}$$

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

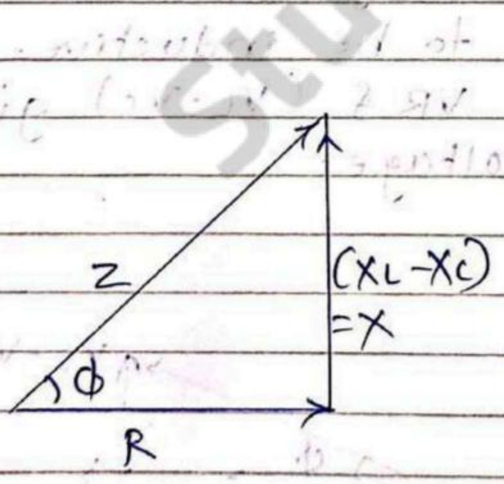
$$V = I \cdot Z$$

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

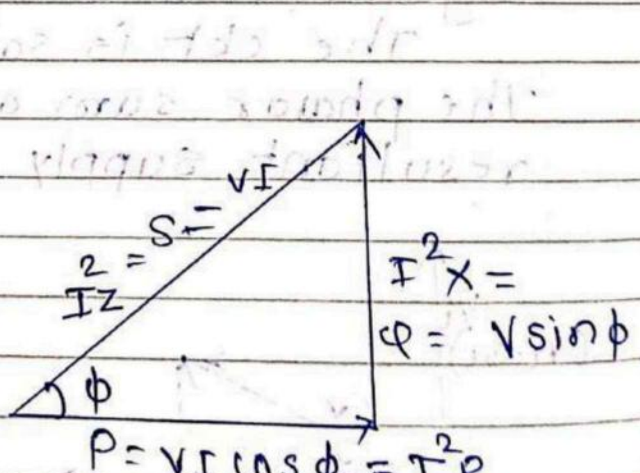
$$|Z| = R + j(X_L - X_C)$$

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

as i lags voltage by ϕ for $X_L > X_C$.



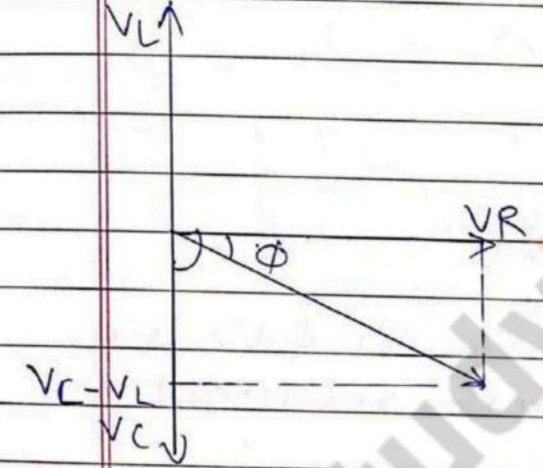
Z Δ

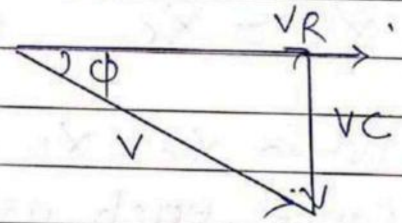


power Δ

2) $X_L < X_C$

When $X_L < X_C$, ie V_L is less than V_C so the resultant of V_L & V_C will be directed toward V_C. Current I will lead $(V_C - V_L)$ This ~~current is said to be capacitive current~~ ~~And~~ circuit said to capacitive ckt. The phasor sum of V_R & $(V_C - V_L)$ gives the resultant supply voltage V.





from voltage - Δ

$$V = \sqrt{V_R^2 + (V_C - V_L)^2}$$

$$= \sqrt{(IR)^2 + (IX_C - IX_L)^2}$$

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

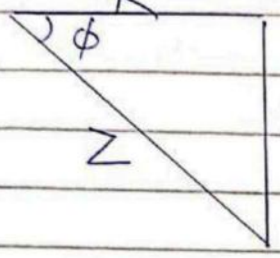
$$\frac{V}{I} = Z$$

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

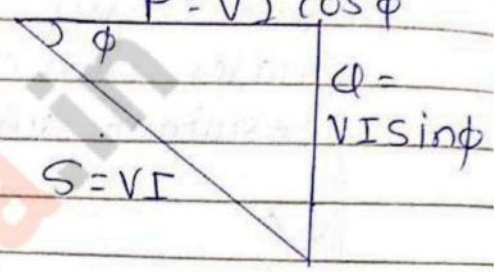
$$\boxed{i = I_m \sin \omega t + \phi}$$

As I lead voltage by angle ϕ for $X_L < X_C$

Impedance Δ



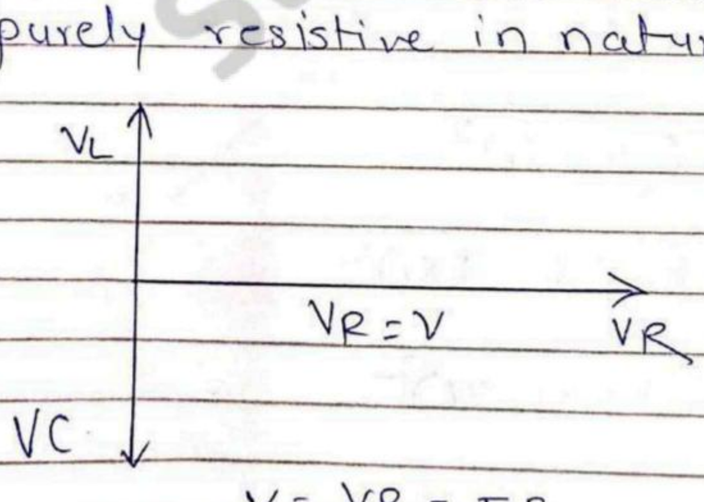
Power Δ.



3) $X_L = X_C$ (Resonant)

When $X_C = X_L$, $V_L = V_C$ so V_L & V_C will cancel each other & their resultant is zero.

So $V_R = V$ in such case & overall circuit is purely resistive in nature.



$$V = V_R = IR$$

$$V = IZ \quad \text{where } R = Z.$$

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Power:

Average power consumed by the circuit is,

P_{avg} = Avg. power consumed by R + Avg power consumed by L + Avg. power consumed by C.

(Pure L & C never consumed power)

$\therefore P_{avg}$ = Avg. power consumed by R.

$$\boxed{P_{avg} = VI\cos\phi}$$

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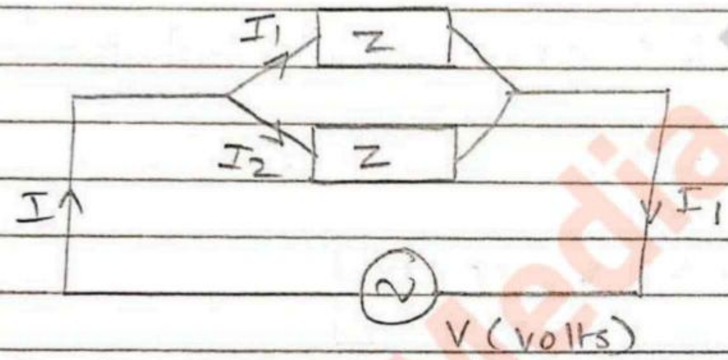
AC parallel circuit.

A parallel ckt is one in which two or more impedances are connected in parallel across the supply voltage. Each impedance is called branch of a parallel ckt.



AC parallel ckt.

voltage across all the impedances is same as supply voltage of V volts.

$$I = \overline{I_1} + \overline{I_2} \quad \text{(phasor)}$$

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

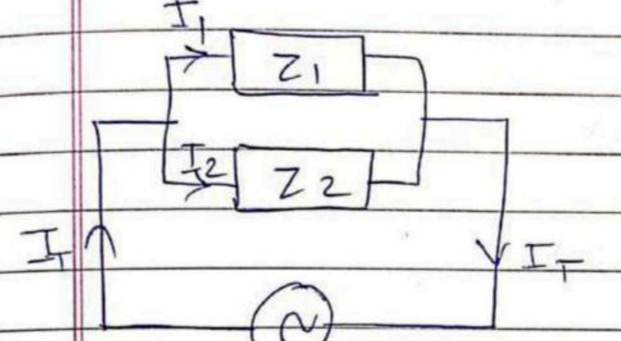
$$\frac{1}{Z} = \frac{1}{Z_1} + \frac{1}{Z_2}$$

Z is called equivalent impedance

$$\boxed{Z_T = \frac{Z_1 Z_2}{Z_1 + Z_2}}$$

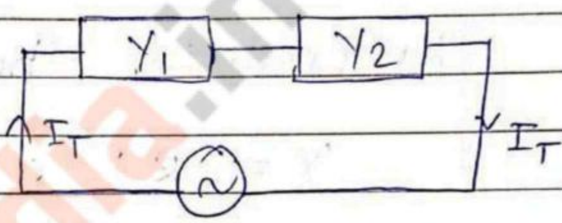
Concept of Admittance

Admittance is defined as reciprocal of the impedance. It is denoted by Y & is measured in simens or mho.



$V = V_m \sin \omega t$

$I_T = I_1 + I_2$



As, $I_T = I_1 + I_2$

$$I_T = V \times \frac{1}{Z_1} + V \times \frac{1}{Z_2}$$

$$V \times \frac{1}{Z_T} = V \cdot \frac{1}{Z_1} + V \cdot \frac{1}{Z_2}$$

$$VY = VY_1 + VY_2$$

$$\boxed{Y = Y_1 + Y_2}$$

where, Y is admittance of ckt. The two impedances connected in parallel can be replaced by an eq. ckt where the admittance are connected in series.

Component of admittance

Consider impedance given as,

$$z = R \pm jX$$

$$Y = \frac{1}{Z} = \frac{1}{R \pm jX}$$

Rationalising the above eq^n

$$Y = \frac{R \pm jX}{(R \pm jX)(R \pm jX)} = \frac{R \pm jX}{R^2 \pm jX^2}$$

$$= \frac{R}{R^2 + X^2} \pm j\frac{X}{R^2 + X^2}$$

$$Y = \frac{R}{Z^2} \pm j\frac{X}{Z^2}$$

$$\boxed{Y = G \pm jB}$$

G = conductance ratio of resistance to square of impedance (simens)

B = Susceptance ratio of reactance to square of impedance (simens)

Y = Admittance, Reciprocal of impedance assistance to flow of AC current (simens)

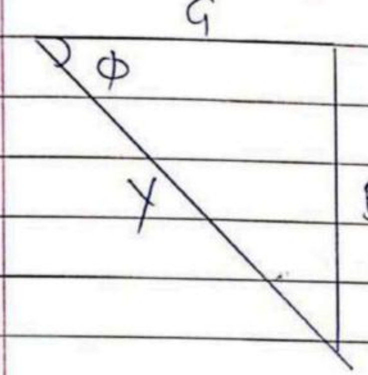
B_L - inductive susceptance

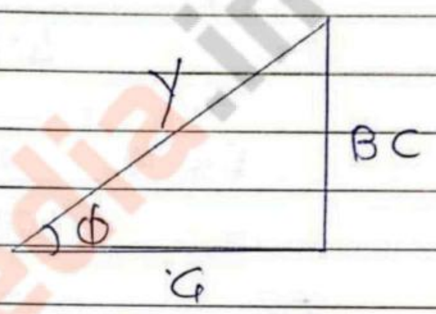
$Y = G - jB_L$ (ϕ is negative)

B_C - Capacitive Susceptance

$Y = G + jB_C$ (ϕ is positive)

* Admittance triangle





RL Admittance Δ   RC admittance Δ

* Resonance in RLC series circuit.

As in case of RLC series ckt X_L & X_C are functions of f, when f will vary X_L & X_C vary.

At a certain frequency X_L becomes equal to X_C, such a condition when $X_L = X_C$ for certain freq. is called series resonance.

At resonance the reactive part in the impedance of RLC series ckt is zero.

The freq. at which resonance occurs is called resonant freq. denoted by ω_r rad/sec or f_r Hz.

Expression for Resonant frequency.

let f_r be the resonant freq. in Hz. at which

$$X_L = X_C$$

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

$$(f_r)^2 = \frac{1}{4\pi^2 LC}$$

$$f_r = \frac{1}{2\pi\sqrt{LC}} \text{ Hz}.$$

$$\boxed{\omega_r = \frac{1}{\sqrt{LC}}}$$

As impedance is minimum the current

$I = \frac{V}{Z}$ is max. at series

Resonance $\Rightarrow (X_L = X_C)$

* Summary of RLC circuit

Complex power

AC ckt has three power. These are real reactive & apparent power, P, Q, S.

$$|S| = \sqrt{P^2 + Q^2}$$

$$\phi = \tan^{-1}\left[\frac{\sin\phi}{\cos\phi}\right]$$

$$= \tan^{-1}\frac{VI\sin\phi}{VI\cos\phi}$$

$$\boxed{\phi = \tan^{-1}\left[\frac{Q}{P}\right]}$$

Apparent power can be expressed in rectangular form.

$$S = P \pm jQ$$

This is called complex power.

The +ve sign indicates lagging nature, of reactive power, while negative sign indicates leading nature of power.

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POLYPHASE AC CIRCUITS.

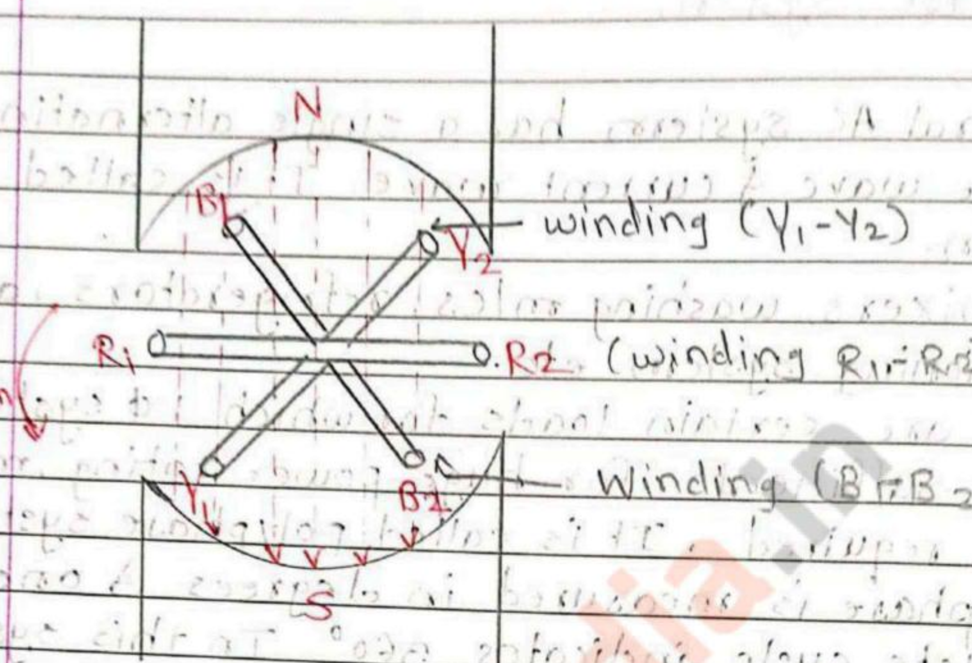
* Polyphase system:

- A general AC system has a single alternating voltage wave & current wave. It is called 1ϕ system.
  e.g mixers, washing m/cs, refrigerators, air conditioning system etc.
- There are certain loads for which 1ϕ system is not sufficient. For huge power rating, many phase required. It is called polyphase system.
- The phase is measured in degrees & one complete cycle indicates 360°. In this system, the diff. windings are arranged in such way that magnitude & frequency of each winding voltage are same. But the voltage of each winding is phase shifted with respect to other voltages.

* Advantages of polyphase system over 1ϕ system

i) Constant power
ii) More output power
iii) Economical transmission
iv) self starting
v) Uniform torque
vi) Constant Instantaneous power
vii) Higher KVA rating
viii) Small cross-sectional area
ix) High power factor & efficiency
x) Smooth AC output
xi) simple parallel operations.

* Generation of 3 ϕ voltages



- 3 ϕ voltage of emf's are generated by using a 3 ϕ AC generator. This generator has 3 identical windings which are displaced by 120° apart from each other.

* Working

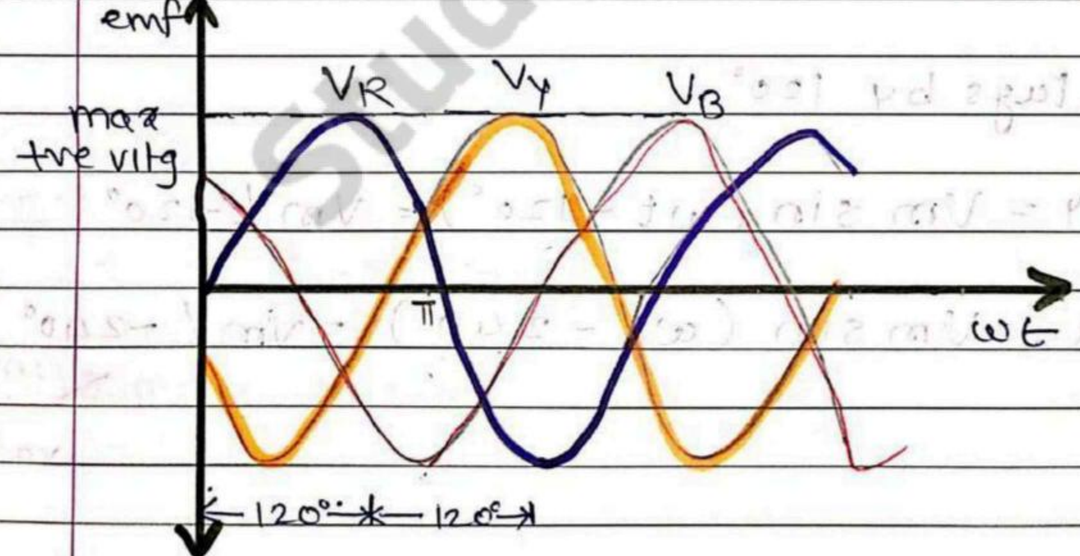
- An emf is induced in each coil either by keeping the mag. field stationary and rotating the winding or by keeping the winding stationa[ry] and rotating the mag. field.
- The 3 winding R_1-R_2, Y_1-Y_2, B_1-B_2 are mounted on same axis.
- The coils of are rotates in anticlockwise direction. It cuts the mag. field lines & an emf is induced in coil.

- Voltage waveform

V_R = Voltage (emf) induced in winding $R_1 - R_2$
V_Y = — " — $Y_1 - Y_2$
V_B = — " — $B_1 - B_2$

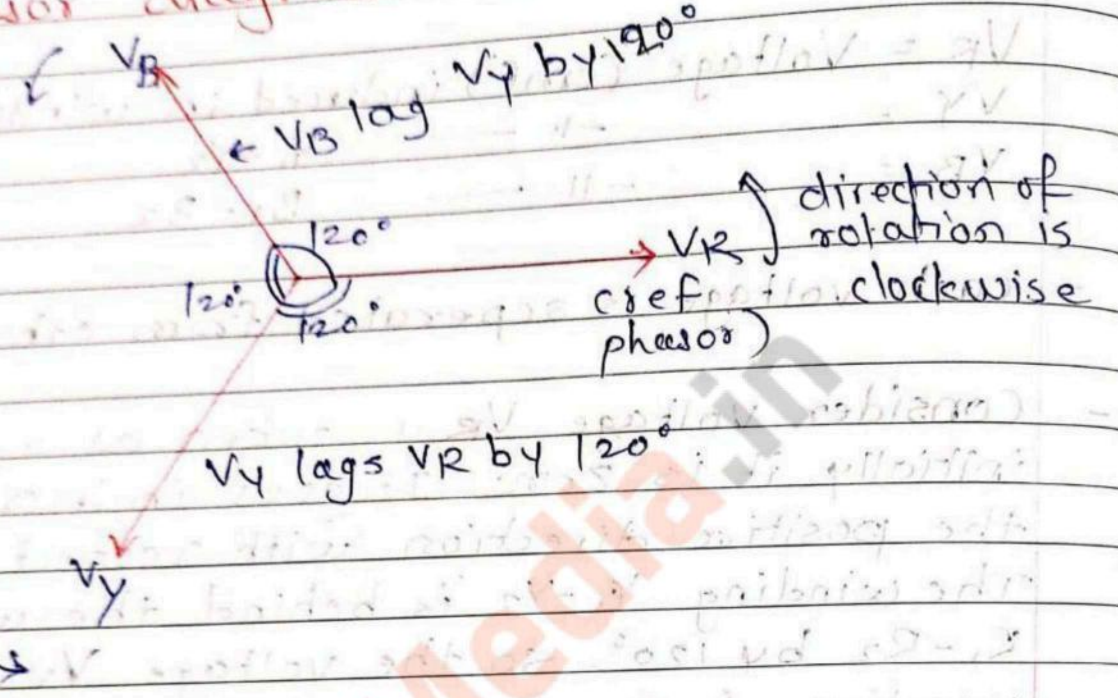
- each voltage is seperated from other by 120°

- Consider voltage V_R is taken as a ref & initially it is zero. It goes in increasing in the positive direction with respect to ωt. The winding $Y_1 - Y_2$ is behind the winding $R_1 - R_2$ by 120°. so the voltage V_Y is initially negative & $B_1 - B_2$ are behind by 240° so, initially positive.



Voltage waveform for 3 ϕ

phasor diagram



Mathematical equations

1) $V_R = V_m \sin \omega t = V_m \angle 0°$

2) V_Y lags by 120°

$V_Y = V_m \sin(\omega t - 120°) = V_m \angle -120°$ $\left(\frac{2\pi}{3}\right)$ rad

3) $V_B = V_m \sin(\omega t - 240°) = V_m \angle -240°$ $\left(\frac{4\pi}{3}\right)$ rad.

Symmetrical system:

If the magnitude & freq. of all 3 voltages are same and voltage displaced by 120° from eachother, then it is called symmetrical

Unsymmetrical system:

A system said to be unsymmetrical when any one of voltages are unequal in magnitude and ~~time~~ angle is not equally displaced.

Balanced load

A load is said to be balanced when the load connected in each phase are same in magnitude as well as in phase & same parameter.

Unbalanced load

A load is said to be unbalanced when the load connected in each phase are not same in magnitude or phase.

* phase Sequence :

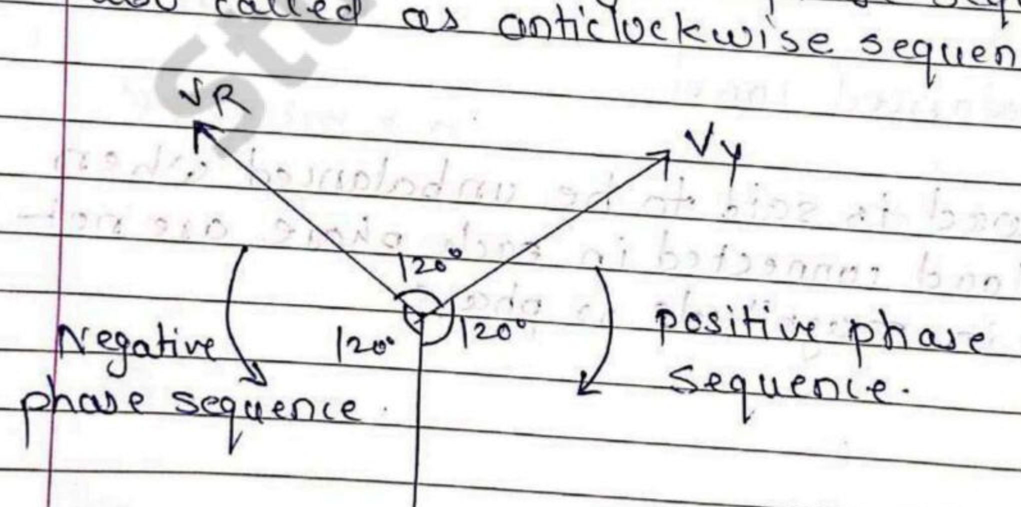
- The sequence by which voltage in three phase attain maximum positive value, is called as phase sequence.

1. Positive phase sequence

If max value attended by phase voltage is in the sequence V_R, V_Y, V_B then it is called positive phase sequence

2. Negative phase sequence

If the max. value attended by phase voltage is in the sequence V_R, V_B, V_Y then it is called negative phase sequence. also called as anticlockwise sequence.



Application:

- In parallel operation of alternator.
- change the direction of AC motor.

* Line current: (I_L)
the current passing th^r any line R, Y, B is called line current. As the current flowing th^r each line is equal to current flowing th^r corresponding branch. line current denoted as I_L.

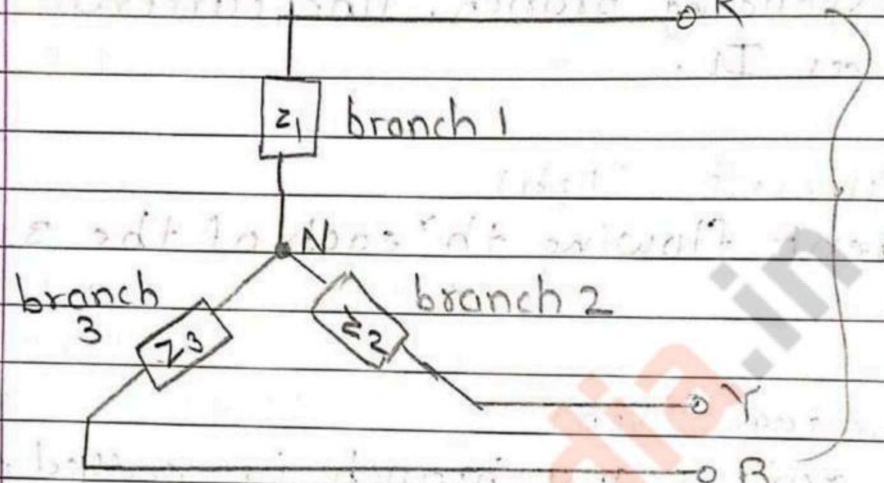
* phase current (I_{ph})
The current flowing th^r each of the 3ϕ winding.

* phase voltage (V_{ph})
voltage across any branch is called phase voltage

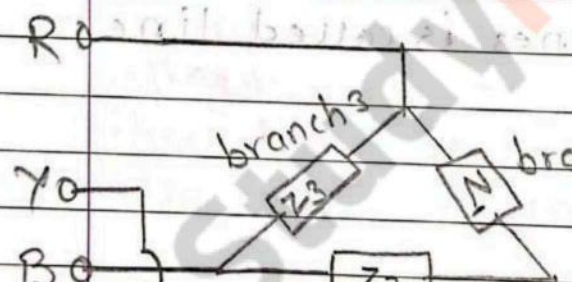
* line voltage (V_L)
voltage across 2 lines is called line voltage

* Types of load connections.

* Star connection



* Delta connected load.



* Balanced load -

- The load is said to balanced load if the following conditions are satisfied:

i) The magnitudes of all impedance (Z_1, Z_2 & Z_3) are equal & p.f is same in all phase.

ii) phase angles betn impedances are equal.

iii) The nature of all impedance is same. That means all impedances are inductive, all are capacitive or all are resistive.

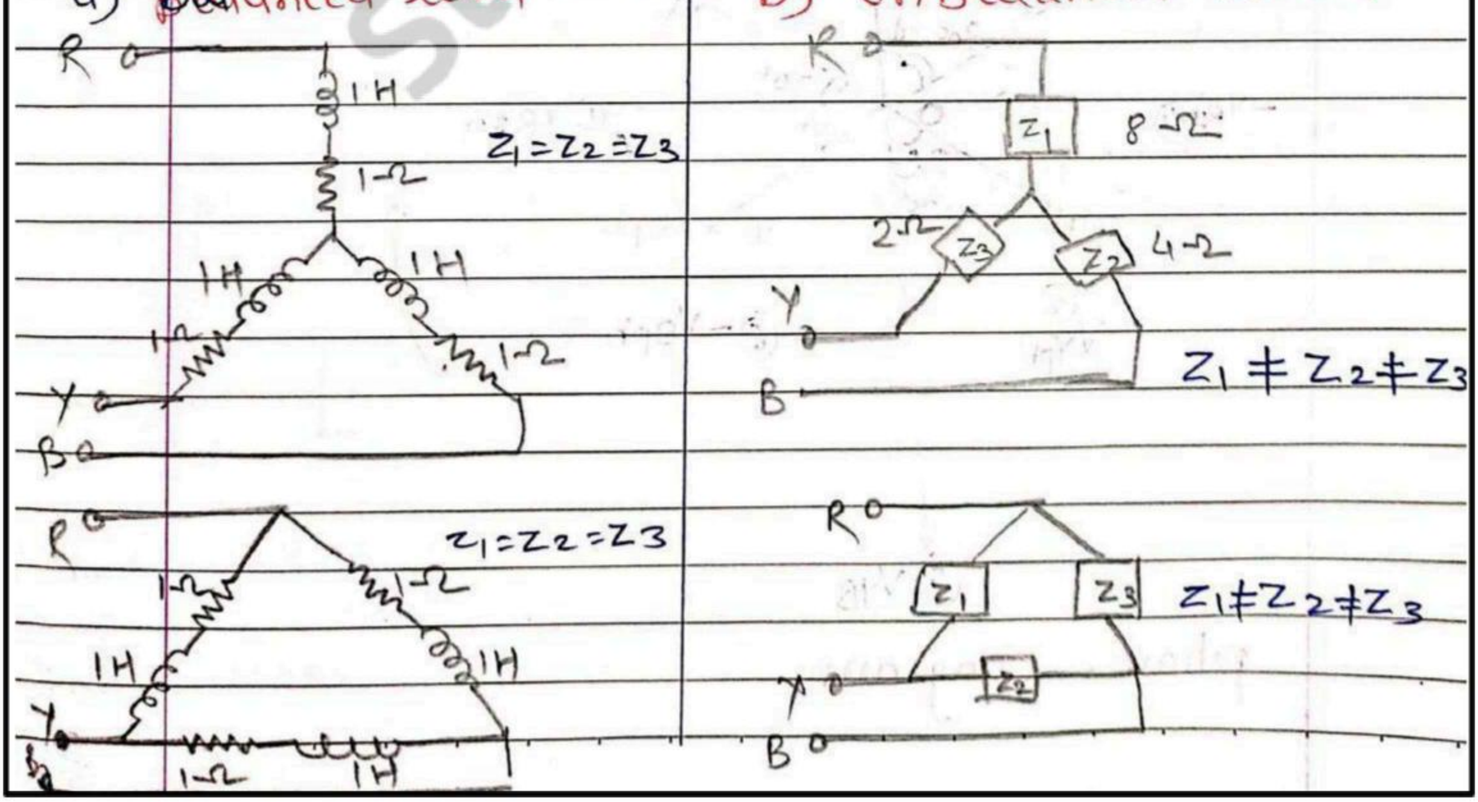
2. In case of balanced load, all parameters like phase voltages, phase current, line voltage & line current having same magnitude, Similarly the phase shift between each other is 120°.

* Unbalanced load :

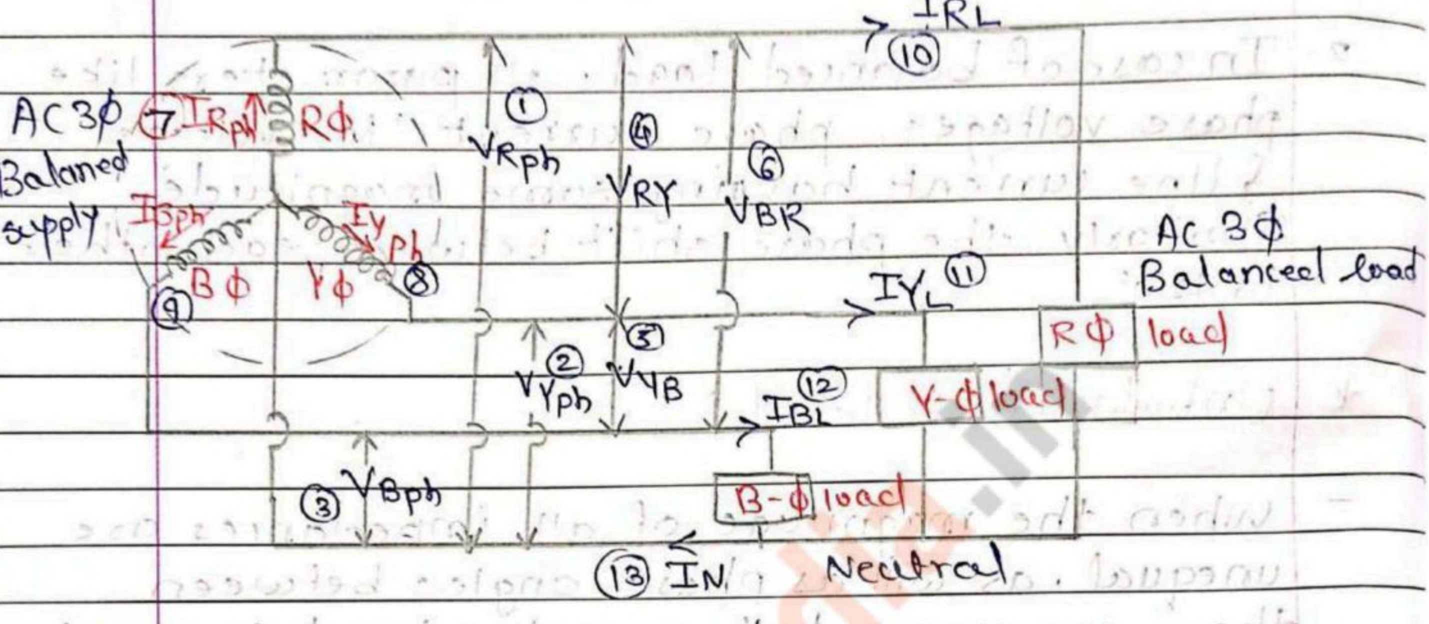
- When the magnitude of all impedances are unequal, as will as phase angles between them are unequal then such a load is called as unbalanced load.

- The phase voltage & phase current are not equal, as well as they are not phase shifted from each other by 120°.

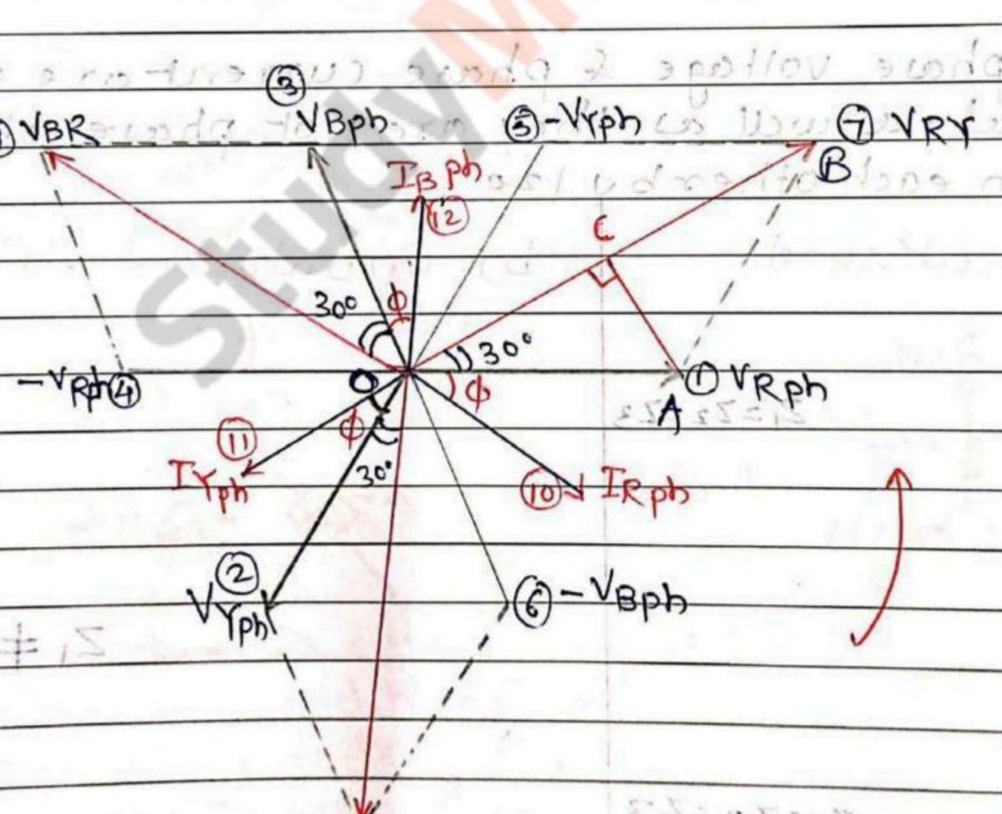
a) balanced load   b) Unbalanced load



* Star connection :- (Wye connection)



* Relationship between line & phase voltage



phasor diagram.

Applying KVL betn R & Y lines

$$\overline{V_{RY}} = \overline{V_{Rph}} - \overline{V_{Yph}}$$

similarly,

$$\overline{V_{YB}} = \overline{V_{Yph}} - \overline{V_{Bph}}$$

$$\overline{V_{BR}} = \overline{V_{Bph}} - \overline{V_{Rph}}$$

a. In phasor diagram OA & OB represent V_{Rph} & V_{RY} resp.

$$\therefore OB = V_{RY} = 2(OC) = 2\,(OA \cdot \cos 30^\circ)$$

$$= 2\left(V_{Rph} \cdot \frac{\sqrt{3}}{2}\right) = \sqrt{3}\, V_{Rph}$$

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

V_L leads respectivey V_{ph} by 30°.

2) Relationship betn line & phase current

from connection dia. it is seen that each phase of supply is connected in series with respective load

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

3) Power consumed

The total power in 3ϕ system is sum of power in each of 3ϕ

a) Total active power

$$P_T = 3\, V_{ph} I_{ph} \cos\phi_{ph}$$

$$= 3\left(\frac{V_L}{\sqrt{3}}\right) I_L \cos\phi_{ph}$$

$$\therefore P_T = \sqrt{3}\, V_L I_L \cos\phi_{ph} \quad \because I_L = I_{ph}$$

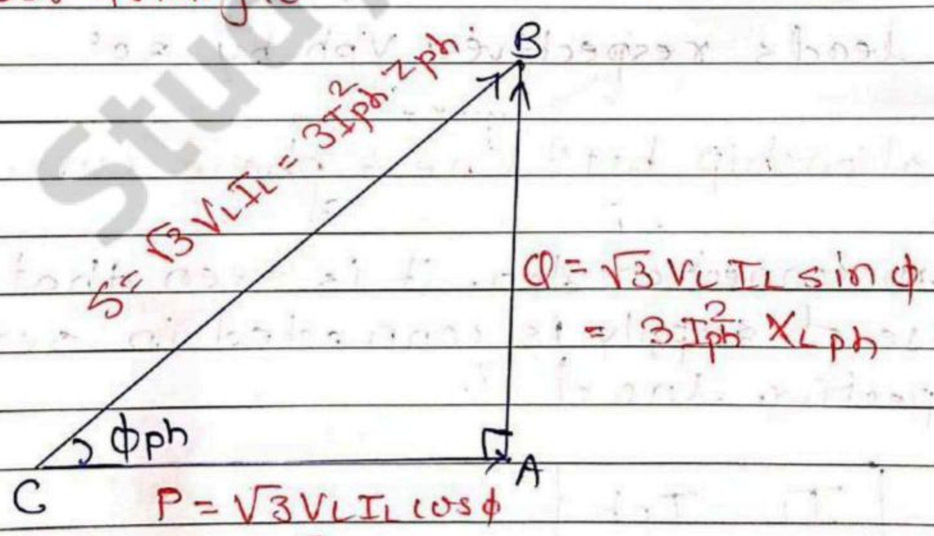
b) Total reactive power

$$Q_{TL} = \sqrt{3}\, V_L I_L \sin\phi_{ph}$$

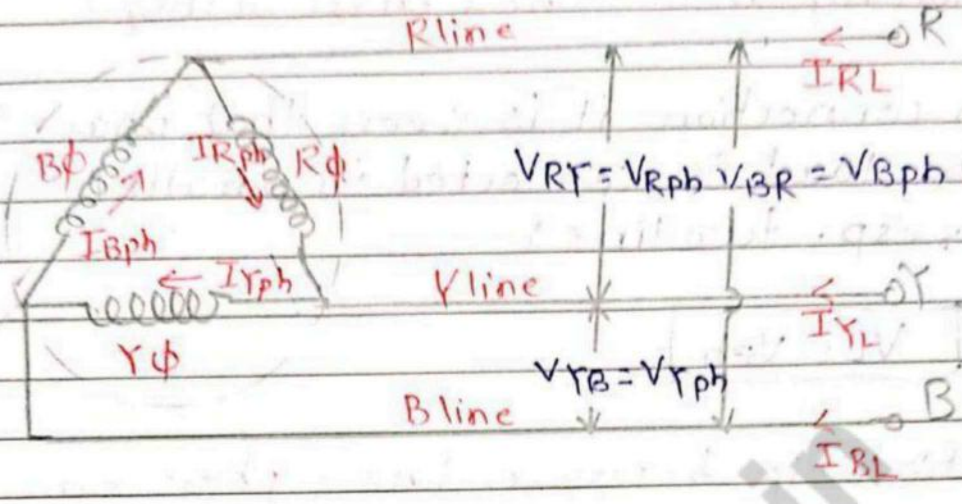
c) Apparent power

$$S_T = \sqrt{3}\, V_L I_L$$

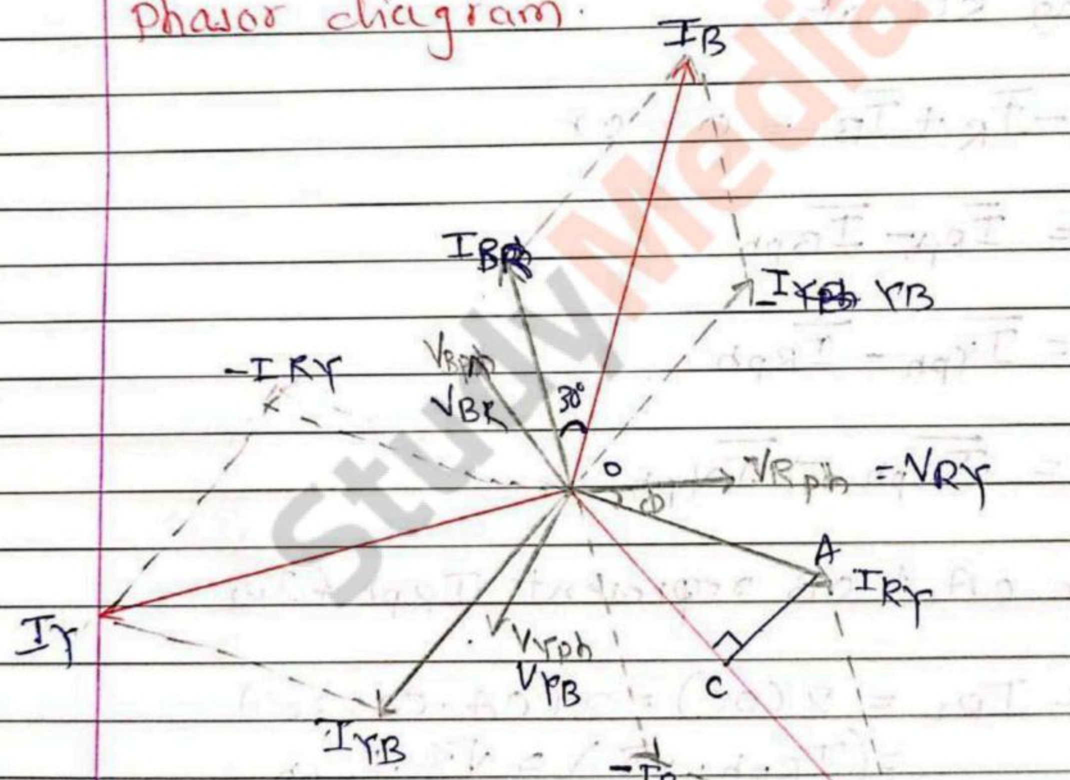
* Power triangle



★ Delta (mesh) connection.



Phasor diagram.



* Relationship betn line & phase voltage

from connection it is seen that phase of the load is connected in parallel with resp. two lines

$$\boxed{V_L = V_{ph}}$$

* relationship between line & phase current

Applying KCL at

$$+\bar{I}_{R_L} - \bar{I}_R + \bar{I}_B = 0 \text{ or}$$

$$\bar{I}_{R_L} = \bar{I}_{Rph} - \bar{I}_{Bph}$$

$$\bar{I}_{Y_L} = \bar{I}_{Yph} - \bar{I}_{Rph}$$

$$\bar{I}_{BL} = \bar{I}_{Bph} - \bar{I}_{Yph}$$

phasor OA & OB represent I_{Rph} & I_{RL}

$$OB = I_{RL} = 2(OC) = 2(OA \cdot \cos 30^\circ)$$
$$= \left(I_{Rph} \cdot \frac{\sqrt{3}}{2}\right) = \sqrt{3} \cdot I_{Rph}$$

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

power consumed

$$P = 3 V_{ph} I_{ph} \cos\phi$$
$$= \sqrt{3} V_L I_L \cos\phi$$

$$Q = \sqrt{3} V_L I_L \sin\phi$$

$$S = \sqrt{3} V_L I_L.$$

Star connection	Delta connection
1. starting or Finishing end connected together to form neutral point.	end of each coil is connected to start of another coil.
2. There is neutral or star point	No neutral point
3) 3 phase 4 wire system	3 phase 3 wire system.
4. Line current = phase current $I_L = I_{ph}$	Line voltage = phase voltage $V_{ph} = V_L$
5. $V_L = \sqrt{3} V_{ph}$	$I_L = \sqrt{3} I_{ph}$
6. $P = \sqrt{3} V_L I_L \cos\phi$	$P = \sqrt{3} V_L I_L \cos\phi$
7. speed of motor are slow $1/\sqrt{3}$ voltage received	High speed, each phase get total line voltage.
8. less insulation require as low voltage	High insulation required.
9. need low no. of turns, save copper	need more no. of turns.
10. Power x'mission, is general & typical to be used.	In power distribution & industries connection used.

problem based on star connected load.

1. 3 identical impedances each of $6+j8$ are connected in star across 3ϕ 400V, 50 Hz. ac supply calculate
1) line current, 2) Active power 3) Q.

→ $V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{400}{\sqrt{3}} = 230.94\,V$

$Z_{ph} = 6+j8 = 10\angle 53.13^\circ$

$I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{230.94\angle 0^\circ}{10\angle 53.13^\circ} = 23.09\angle -53.13^\circ$

In star connection
$I_{ph} = I_L = 23.09\angle -53.13$

Active power
$P = \sqrt{3}\, V_L I_L \cos\phi$
$= \sqrt{3}\times 400\times 23.09\times \cos(-53.13)$
$P = 9598\,W$

$Q = \sqrt{3}\, V_L I_L \sin\phi$
$= \sqrt{3}\times 400\times 23.09\times \sin(-53.13)$
$Q = 12800\,VAR$

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YOUVA

2) Three coils each having a series resistance of 20 Ω & reactance 15 Ω are connected in star to a 400 V, 3φ 50 Hz supply. Cal line current, p.f & power supplied

→ $R_{ph} = 20\,\Omega$, $X_L = 15\,\Omega$
$V_L = 400\,V$, $f = 50\,Hz$.

$$V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{400}{\sqrt{3}} = 230.94\,V$$

$$I_L = I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{230.94}{(20+j15)} = \frac{230.94}{25\angle 36.87}$$

$$I_L = 9.2\angle -36.87^\circ$$

power factor $= \cos\phi$
$= \cos(-36.87)$
$= 0.8$ lag.

$$P = \sqrt{3}\, V_L I_L \cos\phi$$
$$= \sqrt{3} \times 400 \times 9.2 \times 0.8$$
$$P = 5099.15\,W.$$

$$Q = \sqrt{3}\, V_L I_L \sin\phi$$
$$= \sqrt{3} \times 400 \times 9.2 \times 0.6$$

$$Q = 3824.48\ VAR$$

problem based on Δ connection

1) Three indentical coils each having a resistance 15 Ω & an inductance of 0.03 H are in delta across 400V, 50Hz supply. Det.
1) Iph , 2) IL 3) power consumed (P.D)

→ $R_{ph} = 15\ \Omega$, $L = 0.03H$

$X_L = 2\pi f L = 2 \times \pi \times 50 \times 0.03$
$= 9.42\ \Omega$

$Z = R + jX$
$= 15 + j9.42$

$Z_{ph} = 17.71 \angle 32.12°$

$V_L = V_{ph} = 400V$

$V = I_{ph} \times Z_{ph}$

$I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{400}{17.71 \angle 32.12}$

$I = 22.58 \angle -32.12$

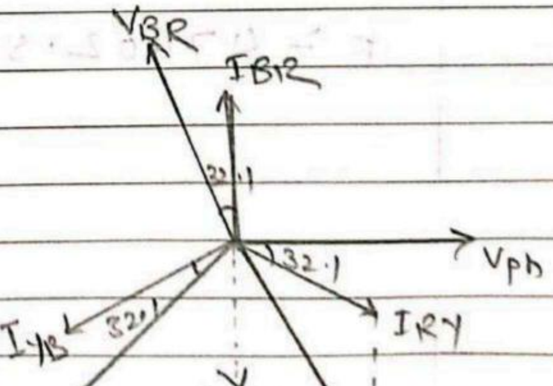
$I_L = \sqrt{3}\ I_{ph}$
$= \sqrt{3} \times 22.58$

$I_L = 39.12 A$

$P = \sqrt{3} V_L I_L \cos\phi$
$= \sqrt{3} \times 400 \times 39.10 \times 0.84$

~~$P = 22942.9 W$~~

$P = 22766.79\ W$



2) 3 coils each of 5 Ω R & 6 Ω X_L are connected in delta across 3 φ 440V, 50Hz. cal. current drawn, p.f & power consumed.

→ $R_{ph} = 5\Omega$, $X_L = 6\Omega$, $V_L = 440$,

$Z = R + jX$
$= 5 + j6$
$Z = 7.81 \angle 50.19°$

$V_{ph} = I_{ph} \cdot Z_{ph}$

$I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{440}{7.81 \angle 50.19} = 56.33 \angle -50.19°$

$I_L = \sqrt{3}\, I_{ph} = \sqrt{3} \times 56.33$
$I_L = 97.56\ A.$

$P = \sqrt{3}\, V_L I_L \cos\phi$
$= \sqrt{3} \times 440 \times 97.56 \times 0.64$

$P = 47602.5\ W.$