1

Ch 2 AC Circuits

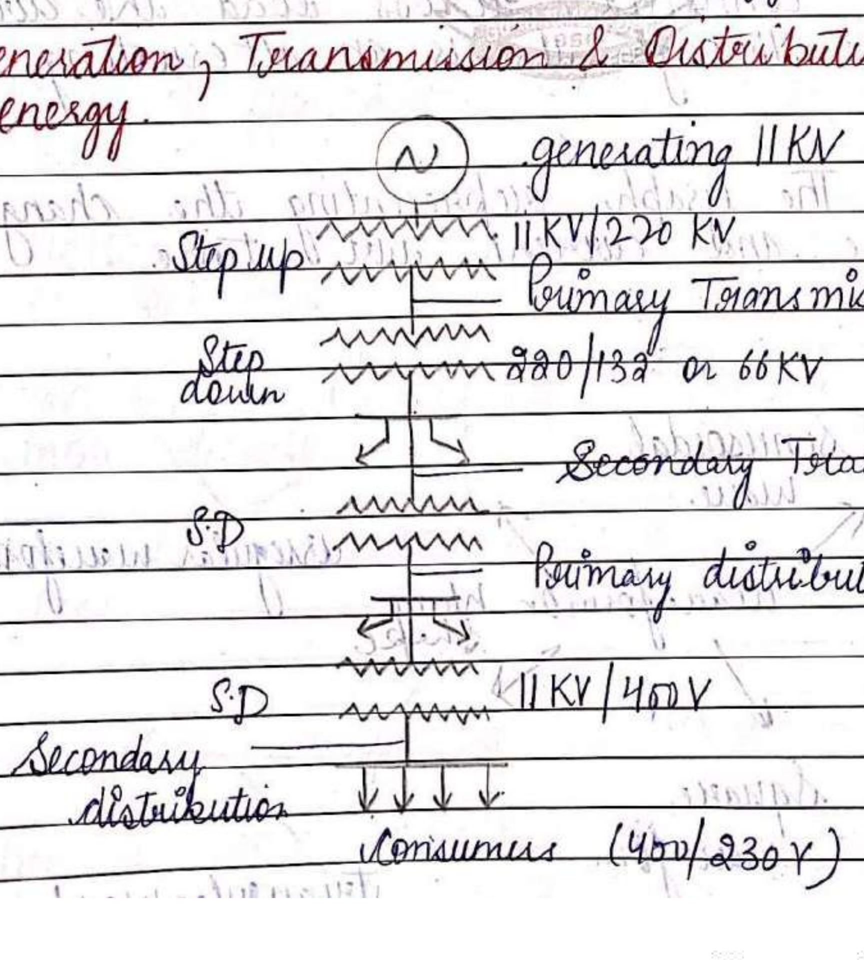
2 Types of system

DC system (steady current flow & in one direction)

Application 1. electroplating
2. electronic circuit

AC system (current that changes the polarity and magnitude at regular Interval of time) app. use in generation, transmission & distribution of electric energy.

Generation, Transmission & Distribution of Electrical energy.



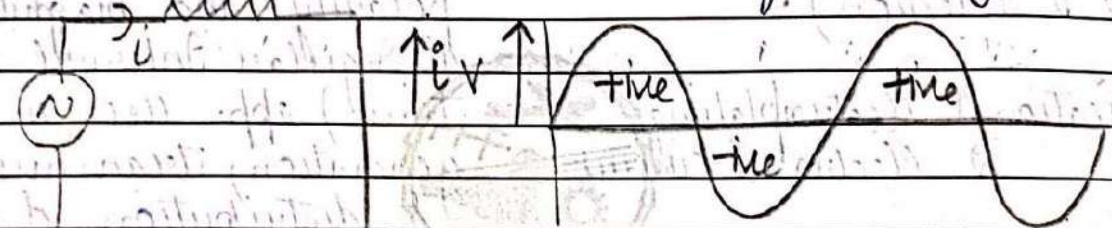
Advantages of AC system over DC system

1. The ac voltage can be stepped up & stepped down using transformer.
2. The ac motor are cheaper in cost, simple in construction and more efficient then dc motors.

Alternating Voltage & Current

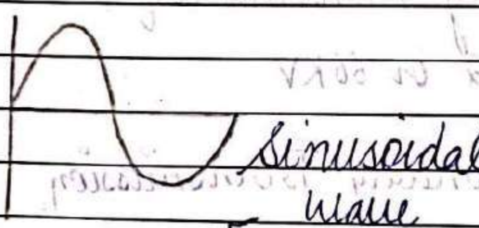
a. Alternating Voltage & current

Alternating Voltage : A voltage that changes its polarity and magnitude at regular interval of time is called an alternating voltage.

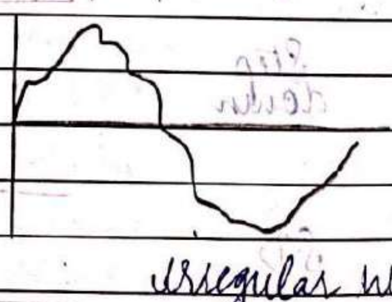


b) Alternating current : When an alternating Voltage source is connected across load the current which flows through it is an alternating current.

c) Waveform The graph representing the change in voltage and current wrt time.

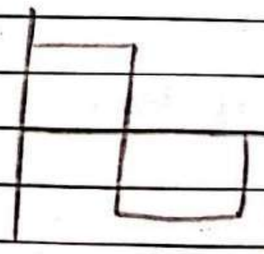


Sinusoidal wave

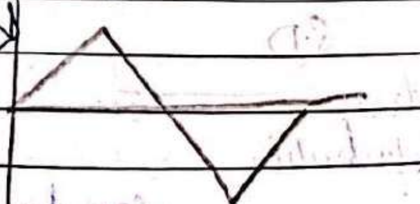


irregular waveform

Waveform or Wave shape



Square waveform



Sinusoidal Alternating quantities

The voltage & current which varies according to sine of angle θ is known as sinusoidal alternating Voltage or current.

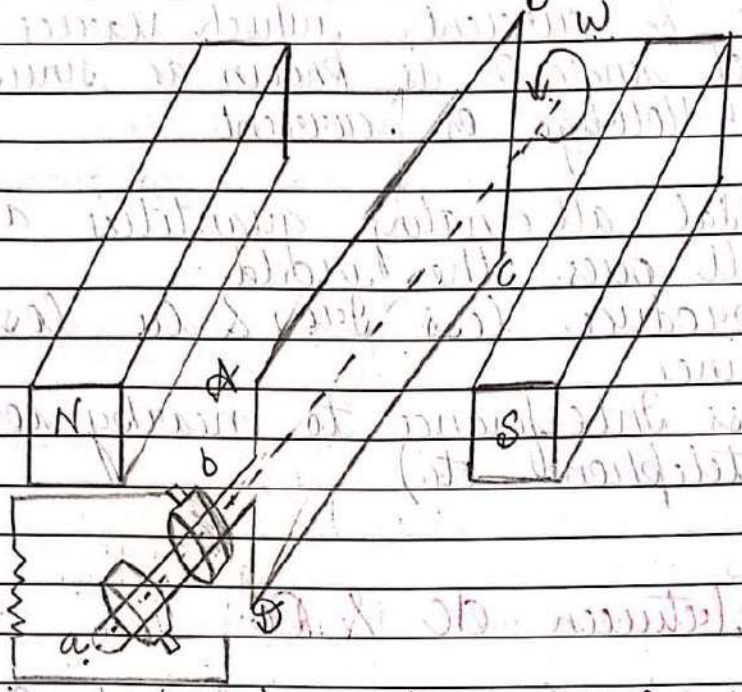
The sinusoidal alternating quantities are used in all over the world.
1. As it produce less Iron & Cu losses in ac machines
2. Offer less Interferance to nearby communication system (telephone etc)

Difference between AC & DC

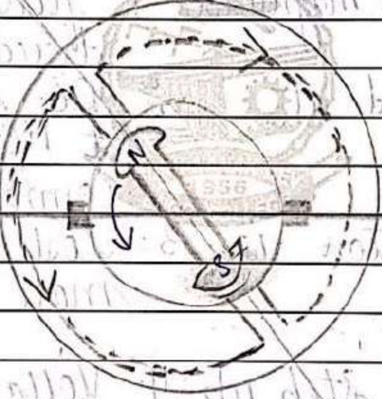
Alternating Current	Direct Current
1. Change polarity & magnitude	1. flow only in one direction
2. Can be generated at higher voltages	2. DC can't be generated at high V because of commutation difficulties
3. cost of generation is less	3. Cost of generation is more
4. Voltage can be step up or step down easily	4. Voltage can't be increased
5. AC motor less costly more durable	5. more costly & less durable
6. maintenance cost is less	6. maintenance cost is high.

Generation of alternating Voltage & Current.

When a coil is placed in a uniform MF and start revolving in anticlock wise direction at const angular velocity (ω) per sec, an emf is induced in the coil side.

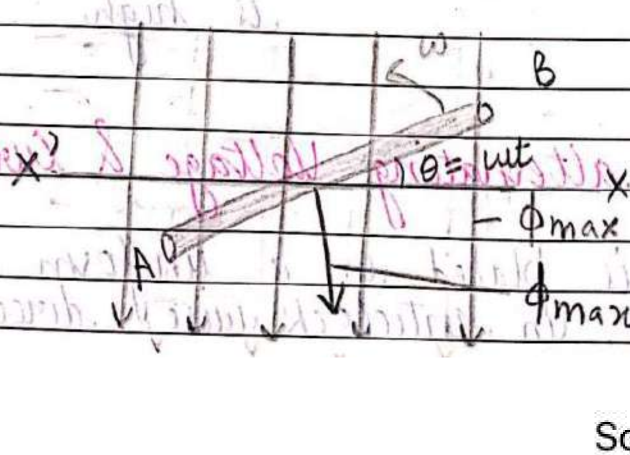


* Rotating coil in uniform M.F at constant speed used in small ac generator.



* Rotating a uniform M.F with in a stationary coil at constant speed used in large AC generator.

Let the coil is in the position as shown in fig 3.



833.

The angle through which the coil has rotated in t secs = ωt $(\theta = \omega t)$

The flux ⊥ to the plane of coil = $\phi_{max} \cos\omega t$

instantaneous flux linkage (ϕ) = $N \phi_{max} \cos\omega t$

N = No. of turns on coil; ϕ_{max} = linking flux.

∀ $emf = -\frac{d}{dt}(N\phi_{max}\cos\omega t)$

$= N\phi_{max}\frac{d}{dt}(-\cos\omega t) = N\phi_{max}\sin\omega t \times \omega$

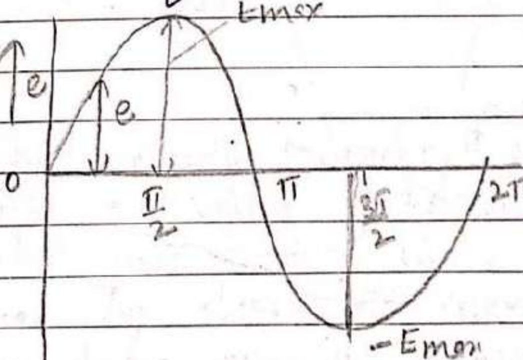
$= \omega N\phi_{max}\sin\omega t$

when $\omega t = 0$ $\quad \sin\omega t = 0$ $\quad emf = 0$

$\omega t = \frac{\pi}{2}$ $\quad \sin\frac{\pi}{2} = 1$ $\quad emf = \cancel{\phi_{max}} = E_{max}$

$= \omega N\phi_{max}$

So emf induced varies as the sine function of the time angle $\omega t = \theta$ such emf is called the sinusoidal emf.



emf induced.

alternating Voltage

$e = E_{max}\sin\omega t$ $\quad e = E_{max}\sin 2\pi f t$ $\quad e = E_m\sin\frac{2\pi t}{T}$

alternating Current

∀ $i = I_{max}\sin\omega t$ $\quad i = I_{max}\sin 2\pi f t$ $\quad i = I_m\sin\frac{2\pi t}{T}$

5/9/2018

6. Instantaneous Value : The value of an alternating quantity at any instant it represented by e or i

Cycle : When an alternating quantity goes through complete set of +ve and -ve value or goes through 360 electrical degrees.

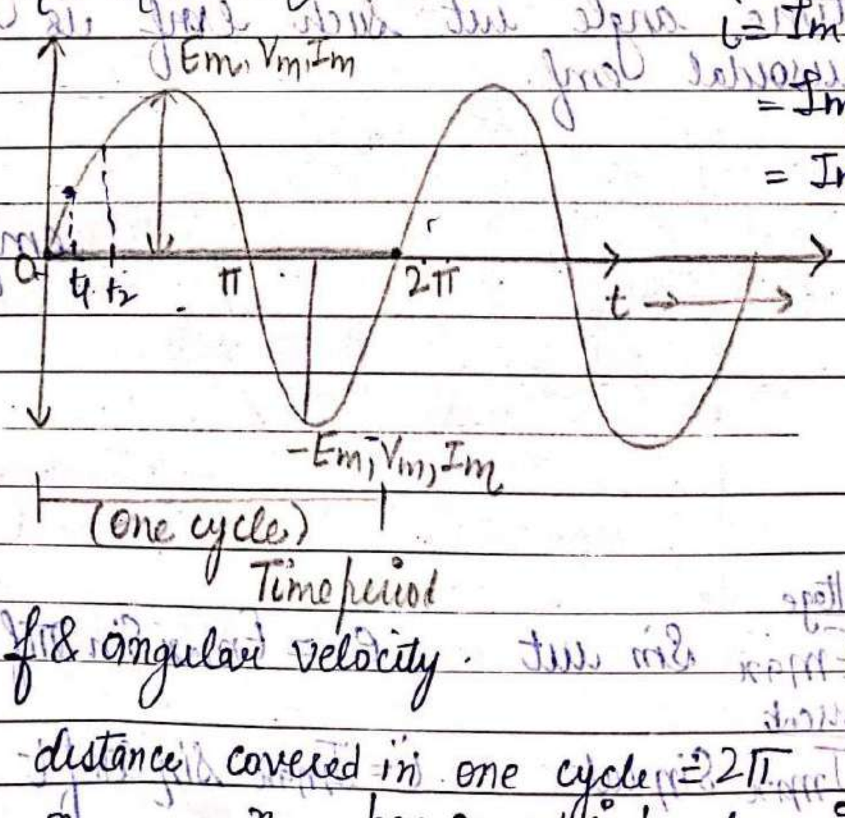
Time period : The time taken to complete one cycle generally it is denoted by T.

frequency : The no. of cycle made per second by an alternating quantity is called f. Unit : Hertz.

Relation b/w f & T $\quad f = \frac{1}{T}$ (cycle/sec) $\quad T = \frac{1}{f}$ (sec)

Amplitude : The maximum value attained by an alternating quantity in one cycle.

E_m, V_m, I_m



$i = I_m \sin \omega t$

$= I_m \sin 2\pi f t$

$= I_m \sin \frac{2\pi}{T} t$

Relation b/w f & angular velocity.

Angular distance covered in one cycle $= 2\pi$

" " " per second in f cycle $= 2\pi f$

$\omega = 2\pi f$ rad/sec.

7 Peak value, Average value and R.M.S value :-

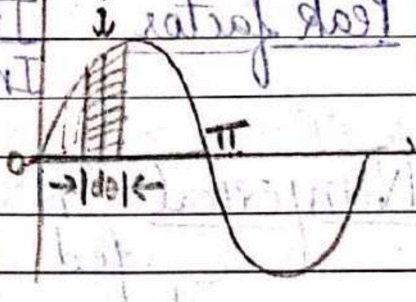
Peak value The max. value attained by alternating quantity during one cycle.

(max value, (creast value or amplitude) =

Average value. The arithmatic average of all the instantaneous value considered of an alternating quantity over one cycle (+ive / -ive)

$$I_{av} = \frac{i_1 + i_2 + \_\_ + i_n}{n} = \frac{\text{Area of alternation}}{\text{base}}$$

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



$$= \frac{1}{\pi}\left[\int_0^{\pi} I_m \sin\theta\, d\theta\right]$$

$$= \frac{I_m}{\pi}\left(-\cos\theta\right)_0^{\pi} = \frac{I_m}{\pi}(-(-1-1))$$

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

RMS Value : That steady current which when flows through a resistor of known resistance for a given time produce same amount of heat as produced by alternating current when flows through same resistor for same time

Effective or value

$$I_{rms} = \sqrt{\frac{i_1^2 + i_2^2 + i_3^2 \_\_ + i_n^2}{n}} \qquad I_{rms} = \sqrt{\frac{1}{\pi}\int_0^{\pi} i^2 d\theta}$$

$$I_{rms} = \sqrt{\frac{1}{\pi}\int_0^{\pi} I_m^2 \sin^2\theta\, d\theta} \qquad i^2 = (I_m \sin\theta)^2$$

$$\frac{I_{rms}^2 \text{ or } (I_{eff})^2 Rt}{J} = \frac{Rt}{J}\frac{(i_1^2 + i_2^2 + i_3^2 + \_\_ i_n^2)}{n}$$

I_{rms}^2

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

$$= \sqrt{\frac{Im^2}{2\pi}} \left[(\theta)_0^{\pi} - \left(\frac{\sin 2\theta}{2}\right)_0^{\pi} \right]$$

$$= \sqrt{\frac{Im^2}{2\pi}} \left[(\pi - 0) - (\sin 2\pi - \sin 2(0)) \right]$$

$$= \sqrt{\frac{Im^2}{2\cancel{\pi}} [\cancel{\pi}]} = \frac{Im}{\sqrt{2}}$$

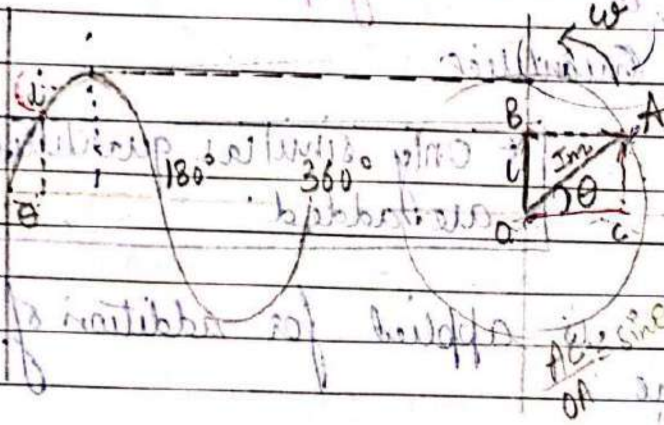
Form factor: $\frac{I_{r.m.s}}{I_{av}} = \frac{Im/\sqrt{2}}{2Im/\pi} = \frac{\pi \cancel{Im}}{2\sqrt{2}\cancel{Im}} = 1.11$

Peak factor: $\frac{Im}{I_{r.m.s}} = \frac{\cancel{Im}}{\cancel{Im}/\sqrt{2}} = \sqrt{2} = 1.4142$

Scanned with CamScanner

Phasor representation of alternating quantities

The alternating quantity can be represented by a line of definite length rotating in counter clockwise direction at const. velocity (ω radian/sec). Such rotating line is called phasor.



$i = I_m \sin\theta_{(\omega t)}$

OA represent I_m and it is rotating in CCW direction with ω

$OB = OA \sin\theta = I_m \sin\omega t$

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

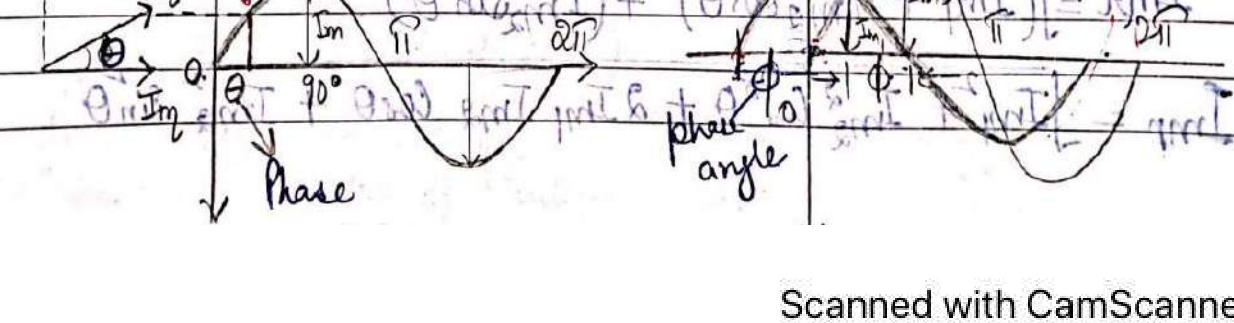
The phasor representation of alternating quantity represent magnitude and position on axis.

Phase and phase difference

Phase:- defined as fractional part of a cycle through which the quantity has advanced from a selected origin. (θ)

Phase difference:- Two alternating quantities having same frequency attain their zero value at different instant.

Phase angle The angle b/w zero point of 2 two alternating quantities

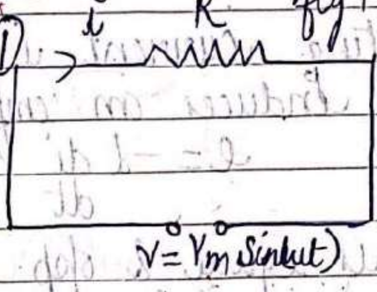


AC Circuit (with single basic network element).

1 Containing Resistance only

Current

Let voltage applied $v = V_m \sin \omega t$ —(1)



So Current $i = \frac{v}{R}$

$i = \frac{V_m}{R}\sin(\omega t)$ —(2)

for max current $\omega t = 90°$

$I_m = \frac{V_m}{R}\sin 90°$ $\quad I_m = \frac{V_m}{R}$

So equation 2 can be written as

$i = I_m \sin(\omega t)$ —(3)

Phase angle

from equation 1 and 3 it is clear that there is no phase difference b/w app voltage & current flowing through R.

phase angle = 0

$O \xrightarrow{\quad I_m \quad} V_m$

Power $p = vi = V_m \sin \omega t \times I_m \sin \omega t$

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

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

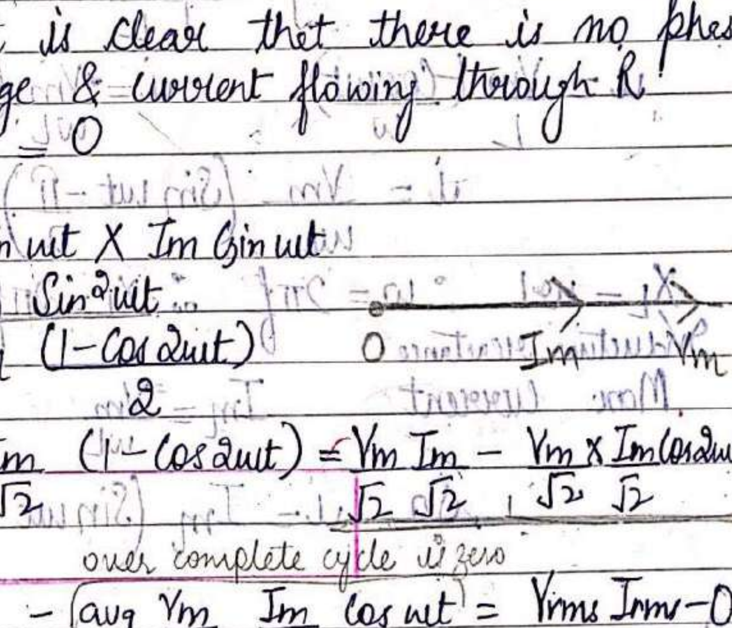
$= \frac{V_m}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}} (1 - \cos 2\omega t) = \frac{V_m I_m}{\sqrt{2}\sqrt{2}} - \frac{V_m}{\sqrt{2}} \times \frac{I_m \cos 2\omega t}{\sqrt{2}}$

over complete cycle is zero

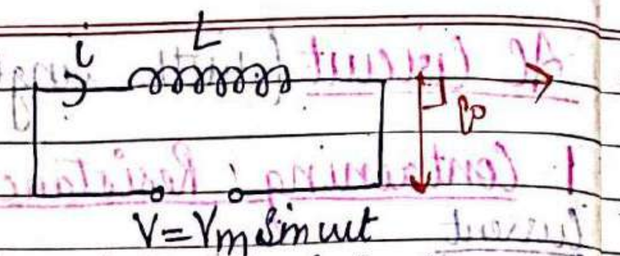
P average power $= \text{avg.} \frac{V_m}{\sqrt{2}} \frac{I_m}{\sqrt{2}} - \text{avg} \frac{V_m}{\sqrt{2}} \frac{I_m}{\sqrt{2}} \cos \omega t = V_{rms} I_{rms} - 0$

$P = V_{rms} I_{rms}$

Power curve fig 2.



2. Pure Inductive only.



Let $V = V_m \sin \omega t$ — (1)

Alternating current i flows through the inductance which induces an emf in it.

$$e = -L\frac{di}{dt}.$$

emf is equal & opp. to applied voltage $V = e = -\left(-L\frac{di}{dt}\right) = L\frac{di}{dt}$

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

$$di = \frac{V_m}{L} \sin \omega t \, dt \qquad * \sin(90 - \omega t) = \cos\theta$$

$$\sin(\omega t - 90) - \cos\theta$$

Integrating both sides

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

$$i = \frac{V_m}{L}\frac{(-\cos \omega t)}{\omega} \qquad i = -\frac{V_m}{\omega L}(\cos \omega t)$$

$$\boxed{i = \frac{V_m}{\omega L}\left(\sin \omega t - \frac{\pi}{2}\right)} = \frac{V_m}{X_L}\left(\sin \omega t - \frac{\pi}{2}\right)$$

$X_L = \omega L \quad \therefore \omega = 2\pi f \quad \therefore X_L = 2\pi f L$ (opposition offered to current by inductor)

Inductive reactance

Max. current $\quad I_m = \frac{V_m}{\omega L} \qquad \left(\sin \omega t - \frac{\pi}{2}\right) = 1$

So $\boxed{i = I_m \left(\sin \omega t - \frac{\pi}{2}\right)}$ — (2)

Phase angle $\quad V = V_m \sin \omega t \qquad i = I_m \sin\left(\omega t - \frac{\pi}{2}\right)$

In a pure inductive load current lags the voltage by 90°

Power

instantaneous power $p = vi$

$= V_m \sin\omega t \times I_m \sin\left(\omega t - \frac{\pi}{2}\right)$

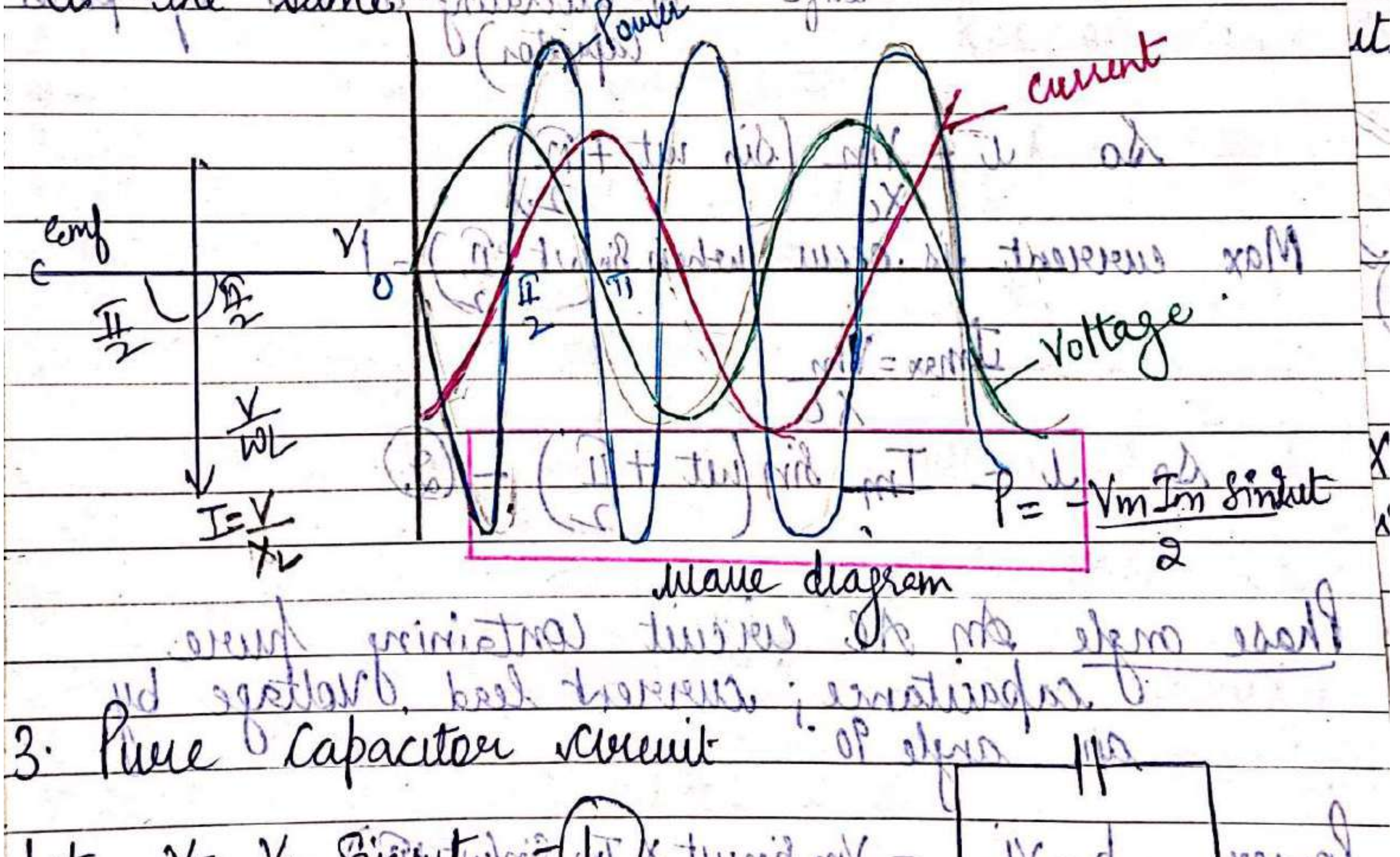
$= -V_m I_m \sin\omega t \cos\omega t \times \frac{2}{2}$

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

Average power $P = \text{avg.}\left(-\frac{V_m}{\sqrt{2}}\right) \times \frac{I_m}{\sqrt{2}} \sin 2\omega t = 0$.

Hence no power and energy is consumed in circuit

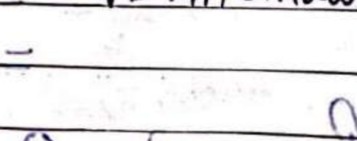
Power curve Avg power in half cycle is zero as the negative & positive loop area under power curve is the same.



wave diagram

3. Pure Capacitor circuit

Let $V = V_m \sin\omega t$ — (1)



Charge stored on capacitor $q = CV$

As $\frac{dq}{dt} = i$ $\qquad q = CV$

So $\boxed{i = \frac{d(CV)}{dt}}$

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

$i = V_m C \cos\omega t \times \omega$ $\qquad \boxed{X_C = \frac{1}{\omega C} \quad \cos(\omega t) = \sin\left(\omega t + \frac{\pi}{2}\right)}$

$i = \omega C \times V_m \cos\omega t$

$i = \frac{V_m}{X_C} \cos\omega t$ or $\frac{V_m}{X_C}\left(\sin \omega t + \frac{\pi}{2}\right)$

$X_C = \frac{1}{\omega C}$ or $X_C = \frac{1}{2\pi f C}$ (opposition offered to the flow of alterating current by pure capacitor)

(Capacitive reactance)

current

So $i = \frac{V_m}{X_C}\left(\sin \omega t + \frac{\pi}{2}\right)$

Max current is occur when $\sin\left(\omega t + \frac{\pi}{2}\right) = 1$

$I_{max} = \frac{V_m}{X_C}$

So $\boxed{i = I_m \sin\left(\omega t + \frac{\pi}{2}\right)}$ — (2)

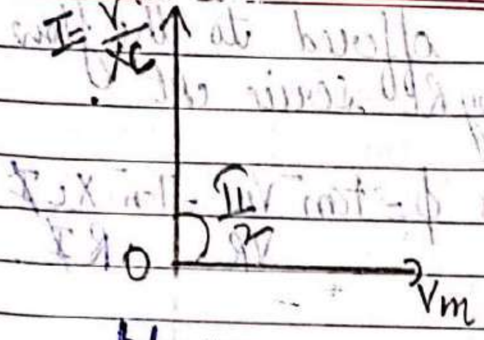
Phase angle In AC circuit containing pure capacitance; current lead voltage by an angle 90°

Power $\quad p = Vi$ $= V_m \sin\omega t \times I_m \sin\left(\omega t + \frac{\pi}{2}\right)$

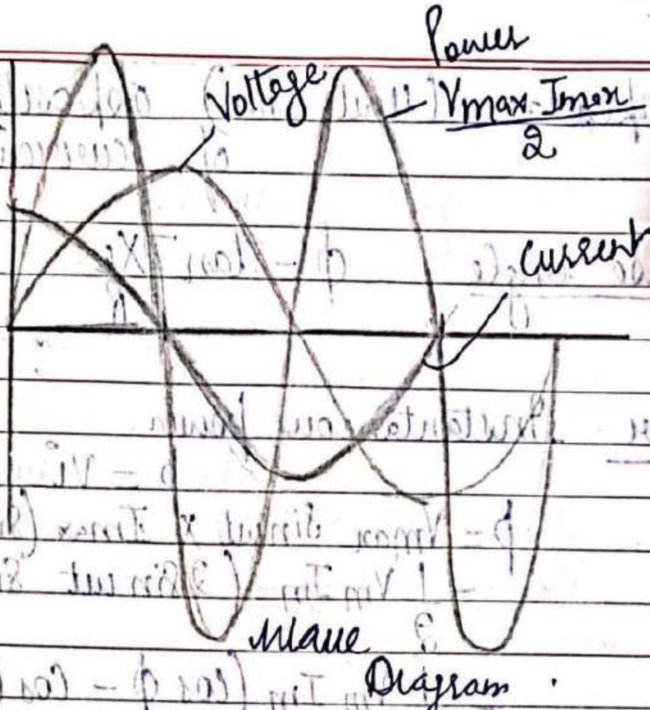
instantaneous $= V_m I_m \sin\omega t \cos\omega t$

$= V_m I_m \frac{\sin 2\omega t}{2}$

$P_{(average)} = 0$ power consumed by pure C is zero



Phasor diagram

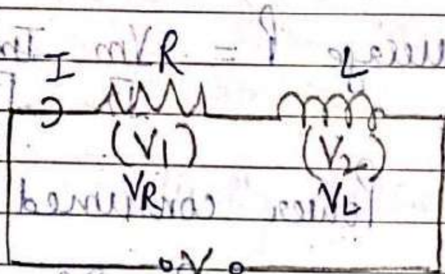


Wave Diagram.

Single phase series circuit

RL series circuit — RC series circuit — RLC series circuits

1. RL series ckt: AC circuit in which R and L are connected in series.



frequency = f   Current = I

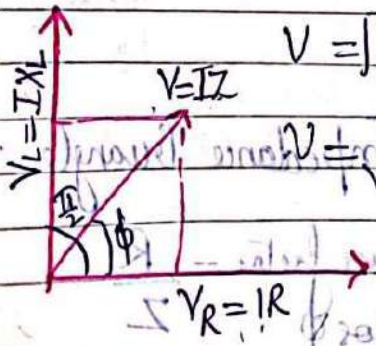
Voltage drop across R = IR (V_R) (in phase with current)

Voltage drop across L = IX_L (V_L) $= I(\omega L)$ (I lags behind V by 90°)

Applied $V = \sqrt{V_R^2 + V_L^2}$ (||gm method)

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

$V = \sqrt{I^2(R^2 + X_L^2)}$ $V = I\underbrace{\sqrt{R^2 + X_L^2}}_{\text{Impendance}}$ $V = IZ$ (ohm)



waveform from book.

Z Impedance (Unit ohm) opposition offered to the flow of current by RL series ckt.

Phase angle $\phi = \tan^{-1}\frac{X_L}{R}$ | As $\phi = \tan^{-1}\frac{V_L}{V_R} = \tan^{-1}\frac{X_L I}{R I}$

Power Instantaneous power

$$p = vi$$

$$p = V_{max}\sin\omega t \times I_{max}(\sin\omega t - \phi)$$

$$= \frac{1}{2}V_m I_m\left(2\sin\omega t\,\sin(\omega t-\phi)\right) \qquad 2\sin A\sin B = \cos(A-B) - \cos(A+B)$$

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

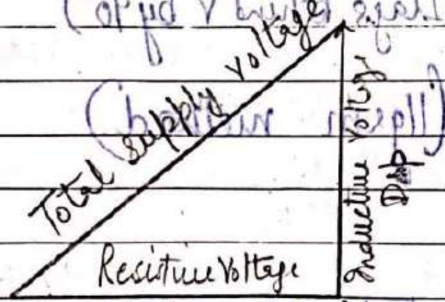
$$= \frac{V_m I_m}{2}\cos\phi - \underbrace{\frac{V_m I_m}{2}\cos(2\omega t-\phi)}_{\text{for pulsating component average power} = 0}$$

average $P = \frac{V_m}{\sqrt{2}}\frac{I_m}{\sqrt{2}}\cos\phi = V_{rms} I_{rms}\cos\phi$

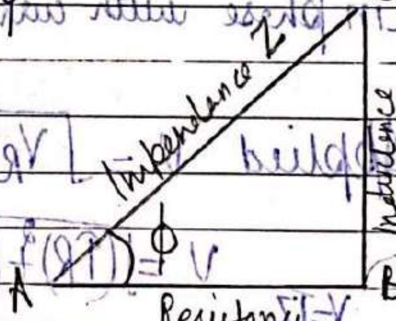
Power consumed by ckt $= I^2R$ (only due to resistance)

$$P = I^2R = I(IR) = V\left(\frac{IR}{}\right)$$

$$= VI\left(\frac{R}{Z}\right) = VI\cos\phi$$



Voltage Triangle



Impedance Triangle

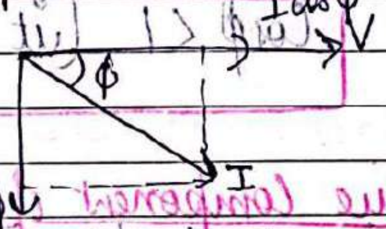
Power factor $= \frac{R}{Z} = \cos\phi$

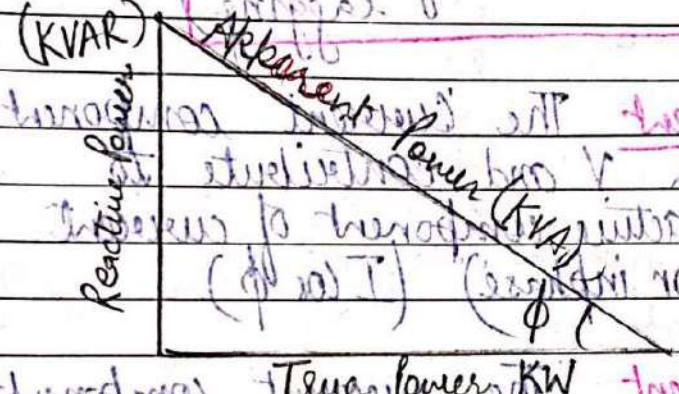
Power (Power in AC circuit)

$$\text{Power} = VI\cos\phi$$

Product of rms value of current and voltage and cosine of phase angle b/w V & I.

power
- True power / real power / active power (imp)
- Reactive power
- apparent power.





power Triangle.

1. Apparent power: It is the product of rms value of I and V.

$S = VI$ (KVA, MVA, VA) (Volt ampere)

2. True power: power which is actually consumed by circuit.

(P) True power $= VI\cos\phi$ (Watts (W), Kilo Watts (KW), MW)

Apparent power × power factor

3. Reactive power: the power which flow in both the direction and does not do any useful work.

$Q = VI\sin\phi$ (VAR, KVAR, MVAR)

Volt ampere reactive.

So $KVA = \sqrt{KW^2 + KVAR^2}$

Power factor

$\cos\phi = \frac{B}{H}$

$\cos\phi$ = Cosine angle b/w V and I

or

$\cos\phi$ = Ratio of $\frac{R}{Z}$ (Impedance triangle)

$\cos\phi$ = Ratio of $\frac{\text{True Power}}{\text{Apparent Power}} = \frac{VI\cos\phi}{VI}$ (from Power Triangle).

$\boxed{\cos\phi < 1 \text{ (it may be leading or lagging)}}$.

Active component of current The current component which is in phase with V and contribute to real power is called active component of current or (wattful or inphase) ($I\cos\phi$)

Reactive component of current The current component which is 90 out of phase to circuit V and contribute to reactive power. (wattless) ($I\sin\phi$).

Q factor Reciprocal of power factor is known as Q factor of the coil.

Imark

$$Q = \frac{1}{\cos\phi} = \frac{1}{R/Z} = \frac{Z}{R} \qquad Q = \frac{\sqrt{R^2+X_L^2}}{R}$$

R is small as compared to X_L

$$Q = \frac{X_L}{R} \qquad Q = \frac{\omega X_L}{R}$$

Power factor and its important

In an ac circuit

Range (0 to 1)

$$p.f = \cos\phi = \frac{R}{Z} = \frac{\text{true power}}{\text{apparent power}}$$

Pure resistive circuit $\phi = 0$ So $\cos\phi = 1$
Pure inductive circuit $\phi = 90°$ So $\cos\phi = 0$ lagging pf
Pure capacitive circuit $\phi = 90°$ $\cos\phi = 0$ leading pf

lagging pf because current lags behind Voltage by 90°

Importance of power factor

Power of ac circuit $= VI\cos\phi$

$$I = \frac{P}{V\cos\phi} \qquad I \propto \frac{1}{p.f}$$

At low p.f. current ↑es and result following dis-advantages

1. increase conductor size.
2. poor efficiency - ↑current losses ↑ed.
3. larger V.D ↑es V.D ↑es Voltage regulation poor.
4. larger KVA rating of equipment.

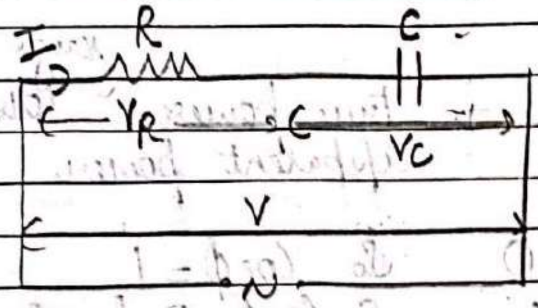
$KVA = \frac{KW}{\cos\phi}$ (Alternator, transformer)

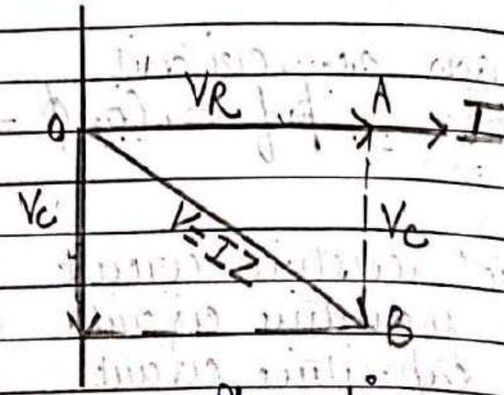
So in order to improve the power factor the capacitor are connected in shunt to the circuit.

(Improving p.f means reducing phase difference b/w Voltage & current)

* Shunt Capacitor
* Synchronous condenser (overexcited syn motor)
* Phase advancer

R-C series circuit





Phasor diagram

$V_R = IR \quad V_C = IX_C$

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

$V = \sqrt{(IR)^2 + (IX_C)^2}$
$= I\sqrt{R^2 + X_C^2}$

$V = IZ$ where $Z = \sqrt{R^2 + X_C^2}$

The total opposition offered to flow ac by R-C series circuit

Phase angle $\tan\phi = \frac{V_C}{V_R} = \frac{IX_C}{IR} = \frac{X_C}{R}$

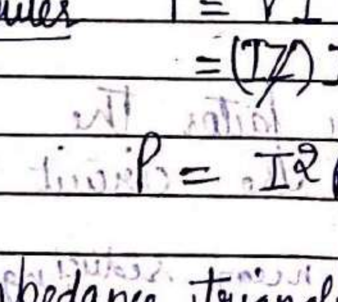
$\phi = \tan^{-1}\frac{X_C}{R}$

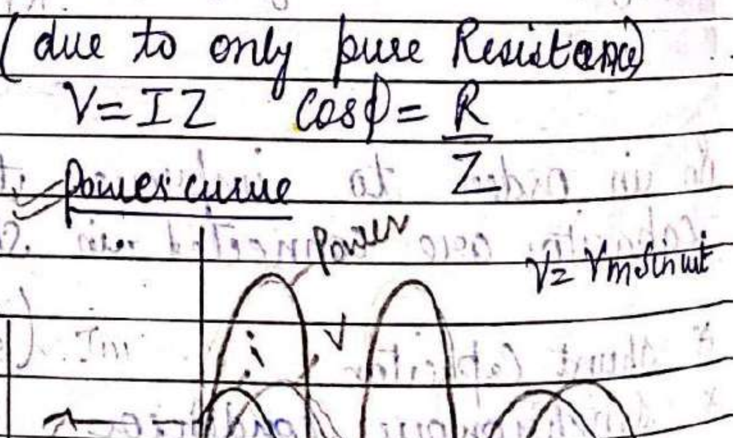
Power $P = VI\cos\phi$ (due to only pure Resistance)
$= (IZ) I \left(\frac{R}{Z}\right)$ $\quad V = IZ \quad \cos\phi = \frac{R}{Z}$

$P = I^2 R$

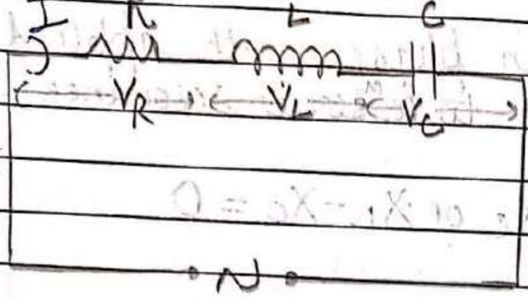
Power curve

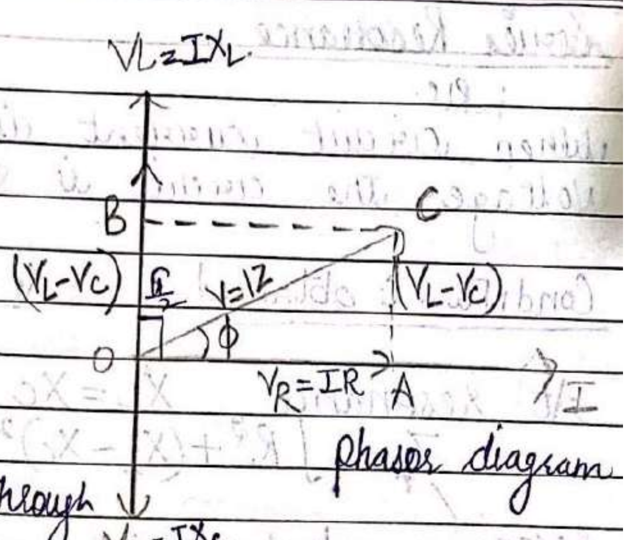
Impedance triangle





RLC Series circuit





When current I flows through a circuit, the voltage across each component will be

$V_R = IR$ (in phase) $\quad V_L = IX_L$ V lead I by 90 $\quad V_C = IX_C$ V lags I by 90

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

or

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

where $Z = \cancel{X_L} \sqrt{R^2 + (X_L - X_C)^2}$ opposition offered to I by RLC series circuit.

Phase angle $\tan\phi = \frac{V_L - V_C}{V_R} = \frac{IX_L - IX_C}{IR} = \frac{I(X_L - X_C)}{IR}$

$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$.

Power. Average Power $= I^2 R$ $\quad$ P.f. $\cos\phi = \frac{R}{Z} = \frac{V_R}{V}$

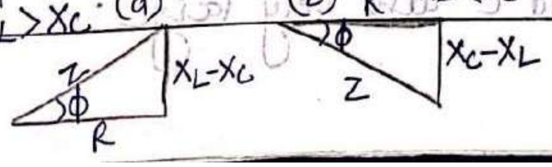
Voltage $\cancel{V_m} = V_m \sin\omega t$ $\quad$ Current $i = I_m \sin(\omega t - \phi)$ $X_L > X_C$

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

$i = I_m \sin\omega t$ $X_L = X_C$

Impedance Δ

when $X_L > X_C$ (a) $\quad$ (b) $X_L < X_C$



Series Resonance

in RLC

When circuit current is in phase with applied Voltage the circuit is said to be in series resonance.

Condition is obtained $X_L = X_C$ or $X_L - X_C = 0$

At resonance $X_L = X_C$

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

resonance impedance $V = I Z_r$ $V = I Z_r$

$$I_r \text{ (resonance current)} = \frac{V}{Z_r} = \frac{V}{R}$$ $\boxed{V = IZ}$

* At resonance the opposition to flow of current is only due to R, hence circuit draws max. current.

Resonant frequency. $X_L = X_C$

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

$$f_r^2 = \frac{1}{2\pi C \times 2\pi L} = \frac{1}{4\pi^2 LC}$$

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

Effect of series resonance

1. $Z_r = R$ min. impedance.
2. $I_r = \frac{V}{Z_r}$ max. current.
3. $P = I_r^2 R$ max power
4. $I_r \uparrow$ V.D across L and C also very large.

* In power system.

At resonance, the excessive voltage build up across the inductive and capacitive component (CB, reactors etc). This may cause damage these components, ∴ series resonance should be avoided in power system.

In electronic devices such as antenna circuit of radio and TV, Tunning circuits etc, the principle of series resonance is used to

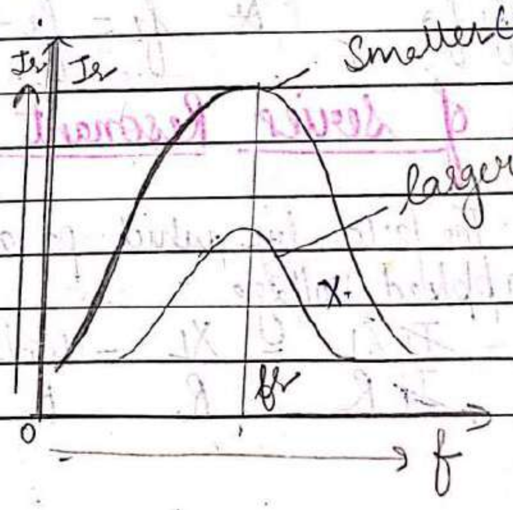
As ↑es the signal voltage & current at desired frequency (f_r)

A series resonant circuit has capability to draw heavy current & power from the mains, so it is also known as acceptor circuit.

Resonance curve

When The graph b/w current & frequency is plotted the curve which obtained is known as resonance curve.

Resonance curve of RLC series circuit



$f < f_r$ $X_C > X_L$

$f > f_r$ $X_L > X_C$

* $Z > Z_r$

* I_r is max current at f_r.

* $f < f_r$ $\quad X_C > X_L$ $\quad$ * In both the cases $Z > Z_r$

  $f > f_r$ $\quad X_C < X_L$ $\quad$ so the value of current decreases

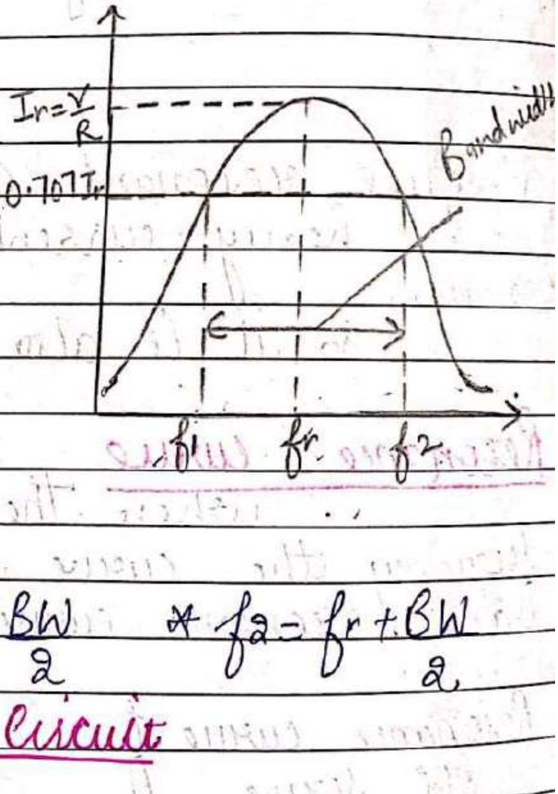
$$V = IZ$$

(less) $I = \frac{V}{Z}$ (more) $\quad$ This is the reason why current falling off rapidly on the both side.

* Smaller the R greater the current at resonance.

Bandwidth

The range of f over which current is equal to more than 70.7% of I_r is known as bandwidth



$$BW = f_2 - f_1$$

f_2 – higher or upper cut off f; $\quad$ f_1 – lower cut off

* $f_r = \sqrt{f_1 f_2}$ $\quad$ * $f_1 = f_r - \frac{BW}{2}$ $\quad$ * $f_2 = f_r + \frac{BW}{2}$

Q factor of series Resonant circuit

Q factor: The factor by which pd across L or C rises to that of applied voltage

$$Q\ factor = \frac{I_r X_L}{I_r R} = \frac{X_L}{R} = \frac{\omega_r L}{R} = \frac{2\pi f_r L}{R} = \frac{2\pi X L}{2\pi\sqrt{LC} \times R} = \frac{1}{R}\sqrt{\frac{L}{C}}$$

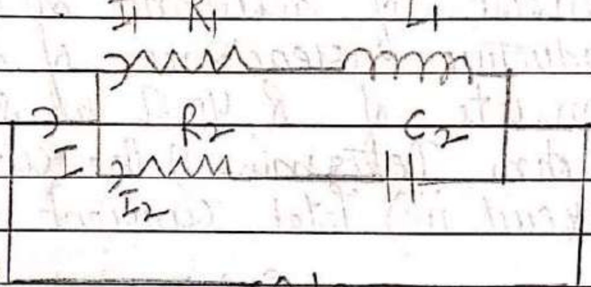
AC Parallel circuit (extra)

The ac circuit in which no. of branches are connected in such a way that V across each branch is same but current flowing through them is different.

Methods for solving parallel ckt

- Phasor or Vector method
- Admittance method
- method of phasor algebra or J method

1. Phasor or vector method



Step 1st find impedance of each branch

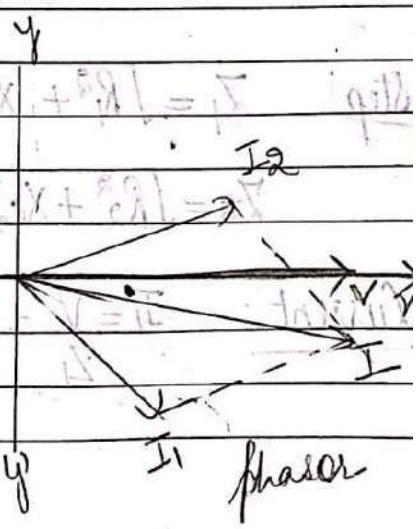
$Z_1 = \sqrt{R_1^2 + X_{L_1}^2}$ $Z_2 = \sqrt{R_2^2 + X_{C_2}^2}$

Step 2nd Determine the magnitude of current & phase angle with Voltage in each branch.

$I_1 = \frac{V}{Z_1}$ $\phi_1 = \tan^{-1} \frac{X_{L_1}}{R_1}$ (lagging)

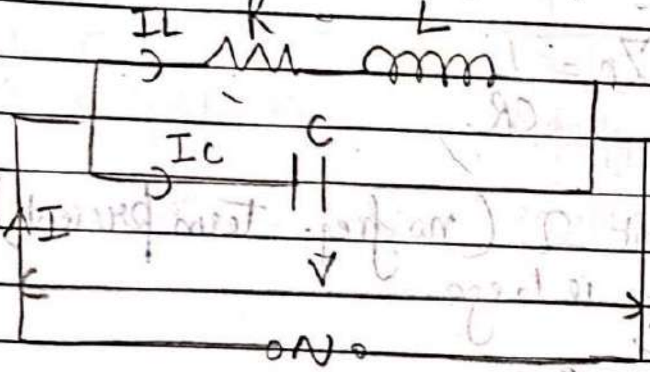
$I_2 = \frac{V}{Z_2}$ $\phi_2 = \tan^{-1} \frac{X_{C_2}}{R_2}$ (leading)

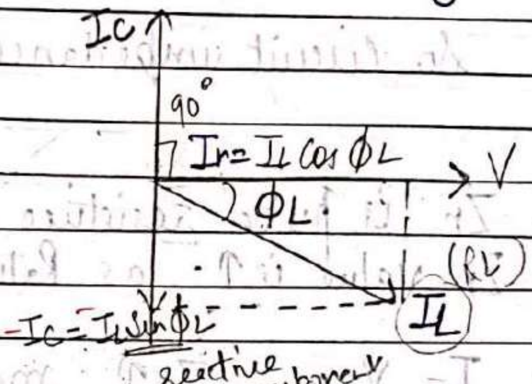
Step 3rd Draw the phasor diagram taking Voltage as reference phasor.



Parallel resonance

An AC circuit containing an inductor & C in parallel is said to be in parallel resonance when the current is in phase with applied Voltage.

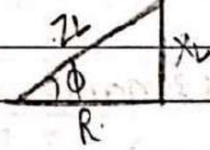




The circuit current I_r is in phase with V

$$I_C = I_L \sin\phi_L$$

At resonance reactive of component of current is suppressed, the circuit draws min. current under this condition



Resonant freq. At parallel resonance

$$I_C = I_L \sin\phi_L$$

$I_L = \frac{V}{Z_L}$ $\boxed{I_C = \frac{V}{X_C}}$ $\sin\phi_L = \frac{X_L}{Z_L}$ circuit

$$\frac{V}{X_C} = \frac{V}{Z_L} \times \frac{X_L}{Z_L} \qquad Z_L^2 = X_L X_C \qquad f_r = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$$

$$\boxed{Z_L^2 = \frac{\omega L}{\omega C}}$$

$$Z_L^2 = R^2 + X_L^2 = \frac{\omega L}{\omega C}$$

$$Z_L^2 = R^2 + (2\pi f_r L)^2 = \frac{L}{C}$$

$$R^2 + 4\pi^2 f_r^2 L^2 = \frac{L}{C}$$

$$4\pi^2 f_r^2 L^2 = \frac{L}{C} - R^2$$

$$f_r^2 = \frac{1}{4\pi^2 L^2}\left[\frac{L}{C} - R^2\right] = \frac{1}{2\pi\sqrt{LC}}$$

small

$$f_r = \frac{1}{2\pi L}\sqrt{\frac{L}{C} - R^2} = \frac{1}{2\pi}\sqrt{\frac{L}{CXL^2}}$$

Effect of parallel resonance
line current

$\boxed{Z_L^2 = \frac{L}{C}}$ proved above

$I_r = I_L \cos\phi$

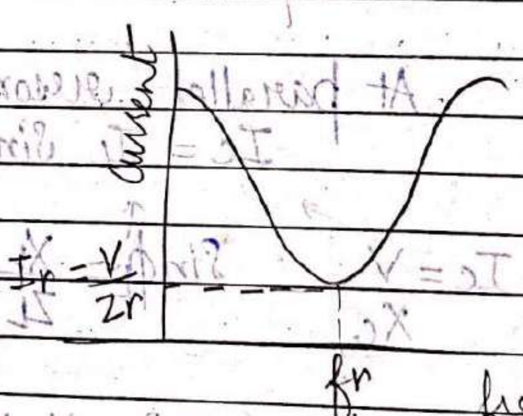
$\frac{V}{Z_r} = \frac{V}{Z_L} \times \frac{R}{Z_L}$; $\frac{1}{Z_r} = \frac{R}{Z_L^2}$; $\frac{1}{Z_r} = \frac{R}{\frac{L}{C}} = \frac{CR}{L}$

So circuit impedance $Z_r = \frac{L}{CR}$

1. Z_r is pure resistive unit Ω (no freq. term present)
2. Z_r value is ↑ as Ratio $\frac{L}{C}$ is large
3. $I_r = \frac{V}{Z_r}$ Z_r↑ means I_r↓es

Since in parallel resonant ckt it draw a very small current and power so it is often regarded as rejector ckt.

Resonance curve



So $I_r = \frac{V_r}{Z_r}$ min at f_r

Q factor

Q factor $= \frac{I_C}{I_r} = \frac{V/X_C}{V/Z_r} = \frac{Z_r}{X_C} = \frac{L}{CR} \times \frac{2\pi f_r C}{1} = \frac{2\pi f_r L}{R}$

$Q = \frac{2\pi L}{R} \cdot \frac{1}{2\pi\sqrt{LC}} = \frac{1}{R}\sqrt{\frac{L}{C}}$

* Comparision Series & Parallel resonance.

	Series	Parallel
1. Impedance	min. $Z_r = R$	max $Z_r = L/CR$
2. Current	max	min
3. f_r	$1/2\pi\sqrt{LC}$	$\frac{1}{2\pi}\sqrt{\frac{1}{LC}-\frac{R^2}{L^2}}$
4. $\cos\phi$ (pf)	1	1
5. Q factor	X_L/R	X_L/R
6 Amplification	amplify V	amplify current
	acceptor ckt.	rejector ckt

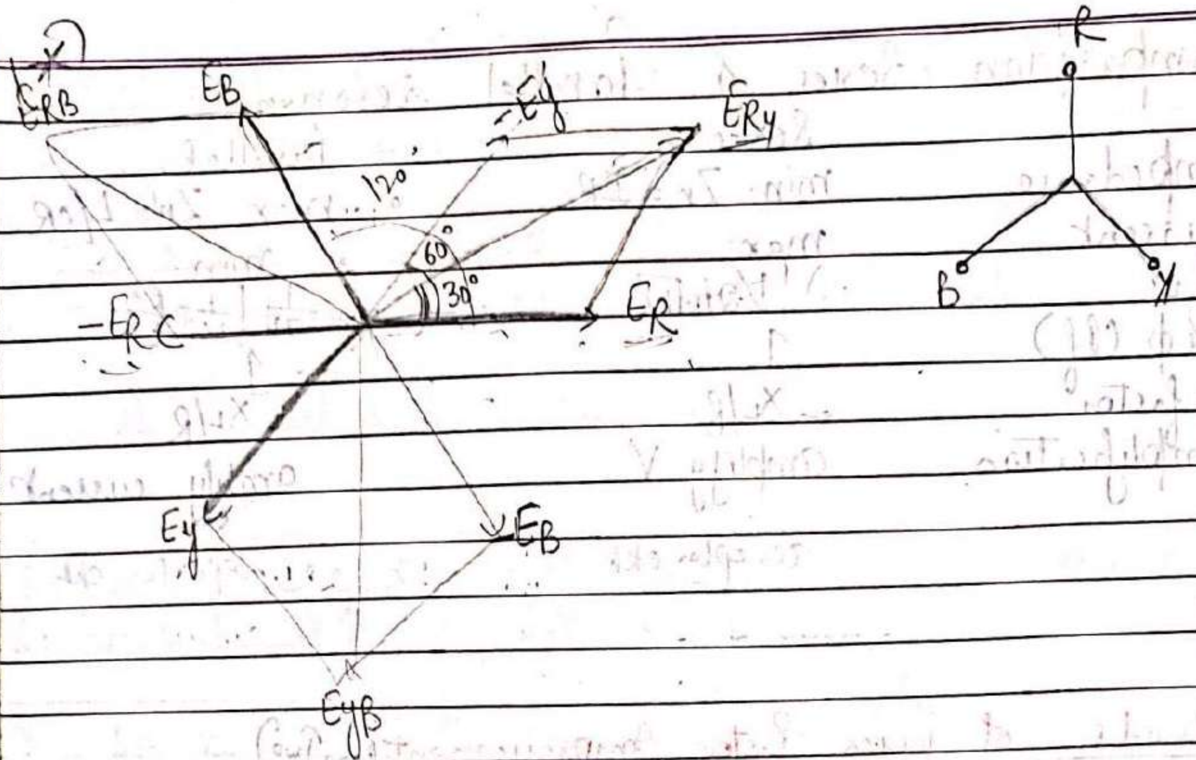
V. Imp

Methods of Power factor Improvement (any Two)

1. Capacitor: Improving power factor means reducing the phase difference between Voltage & current. Since the majority of loads are of Inductive nature, they require some amount of reactive power for them to function. The Capacitor are installed in parallel to the load provides this reactive power. They act as source of local reactive power, and thus less reactive power flows through the line. The reduce the ph difference b/w the V & I.

2. Synchronous Condenser 3 ϕ synchronous motor with no load attached to its shaft. The Sync. motor has Characteristics of operating under any p.f leading, lagging or unity depending upon the excitation. For inductive loads, a synchronous condenser is connected towards load side and is overexcited. Synchronous condenser makes it behave like a Capacitor. It draws the lagging current from the supply or supplies the reactive power.

Scanned with CamScanner



3. <u>Phase advancer</u>: This is an ac exciter mainly used to improve pf of Induction motor. They are mounted on the shaft of motor and connected to the rotor circuit of motor. It improves the pf by providing the exciting ampere turns to produce required flux at slip frequency. Further, if ampere turns res, it can be made to operate at leading power factor.

Polyphase s/s. (poly = many)

AC system having a group of 2 or more, equal voltages of same freq. arranged to have equal phase difference b/w them.

$$\text{phase difference} = \frac{360^\circ}{\text{No. of phases}}$$

Unbalance source
3φ supply will be unbalance when either of 3φ voltages are unequal ~~mgn~~ magnitude as well as in phase.

Unbalance load.
Any 3φ load in which the impedance in one or more phases differ from the impedance of other phases is called an unbalance 3φ ~~load~~ load

Advantages of 3φ system over 1φ system Imp

1. Constant power (ie The total power delivered is constant if load are balanced.)

(As in 1φ I and V are in same phase, so power is zero twice in each cycle. When I lead or lags behind V power is -ive twice and zero four time which cause vibrabration in large motor)

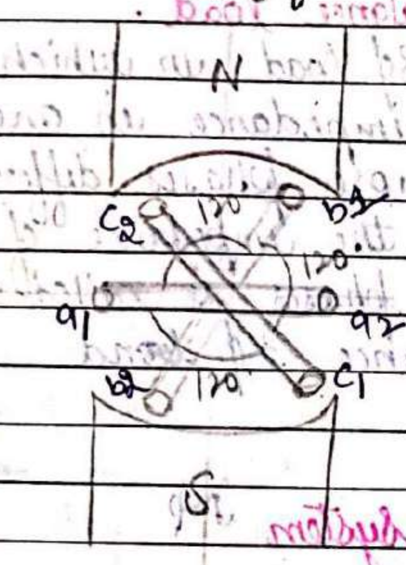
2. Rating of machince ↑es with Increase in no. of phase
So higher o/p in 3φ ie is 1.5 times the o/p of 1φ

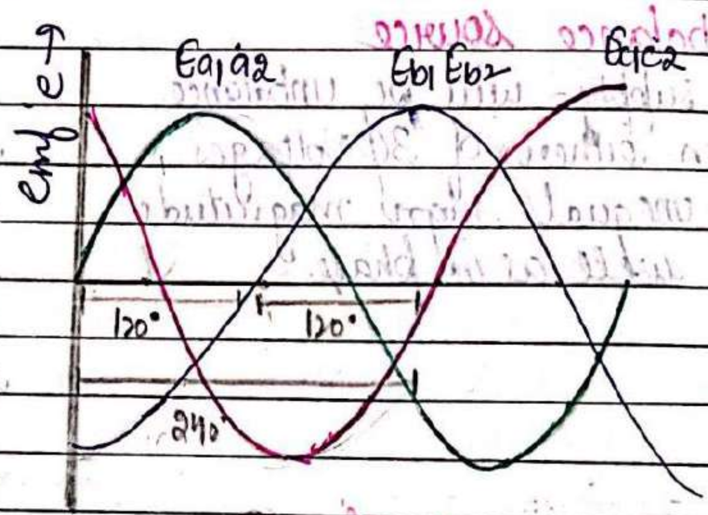
3. 3φ motor are self starting while 1φ induction motor have no starting torque so need of provinding an auxiliary mean for starting

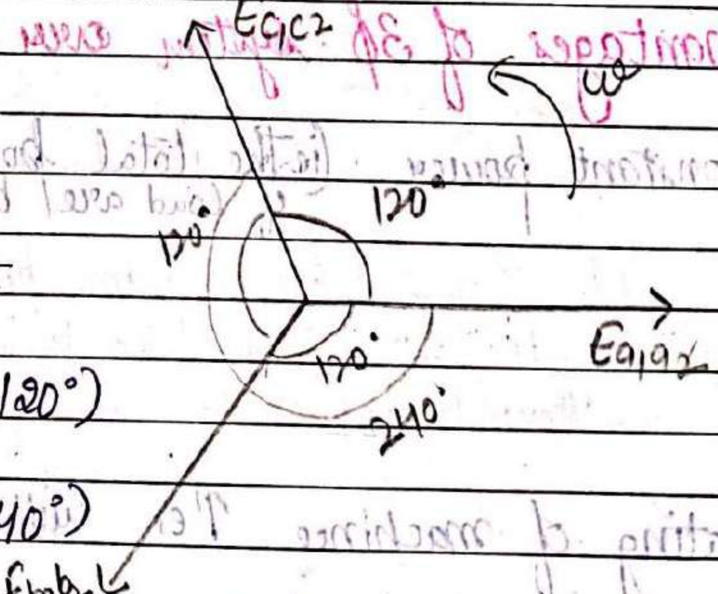
4. 3ϕ motor have high pf & η

5. less cost : (3ϕ s/s require $\frac{3}{4}^{th}$ wt of Copper of that required by 1ϕ to transmit same power at given V & over a give distance).

Generation of EMF's.







$e_{a_1a_2} = E_{max} \sin \omega t$

$e_{b_1b_2} = E_{max} \sin(\omega t - 120°)$

$e_{c_1c_2} = E_{max} \sin(\omega t - 240°)$

or

$= E_{max} \sin(\omega t + 120)$

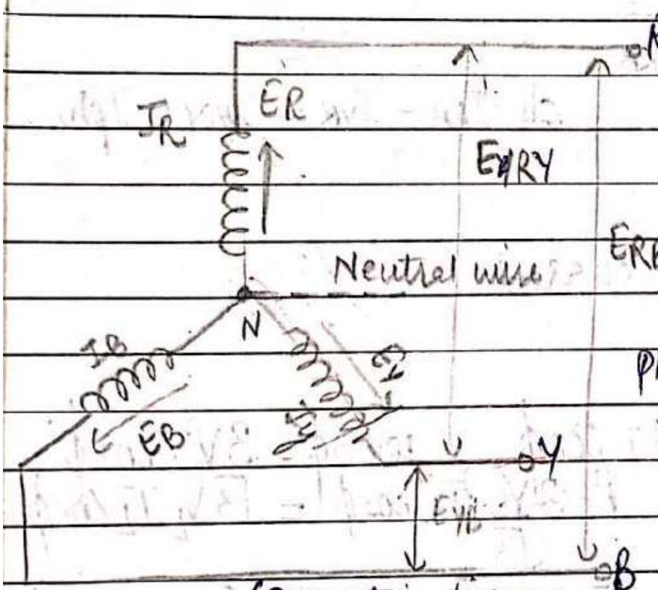
Phase sequence

The order in which the ~~tha~~ current & voltage in 3ϕ attain their maximum value one after other. (abc)

Importance 1. The direction of rotation of 3ϕ IM depend upon the phase sequence of 3ϕ supply. To reverse the direction of rotation, the phase sequence of supply given to the motor has to be changed.

2. The parallel operation of 3ϕ alternator & T/F is only possible if phase sequence is known.

Star connection



Connection diagram

E_{ph} V_{ph} = phase voltage (b/w R-N)

$E_L = V_L$ = line voltage (b/w 2 outers R-Y)

In loop NRYN

$E_{RY} = E_R - E_Y$ · Phasor diff.

$= E_R + (-E_Y)$ Phasor sum.

Phase angle b/w E_R & E_Y is 60°

$E_{RY} = \sqrt{E_R^2 + E_Y^2 + 2E_R E_Y \cos 60°}$

$= \sqrt{E_R^2 + E_Y^2 + 2E_R E_Y \times 0.5}$

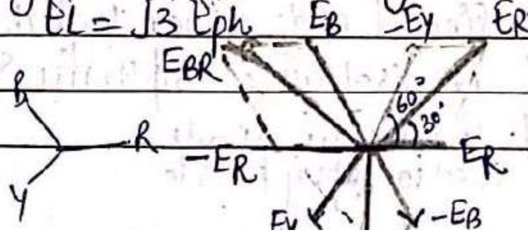
Assume balanced s/s So

$E_R = E_Y = E_B = E_{ph}$

$E_{RY} = \sqrt{3E_{ph}^2} = \sqrt{3}\,E_{ph}$

line voltage = $\sqrt{3}$ phase voltage.

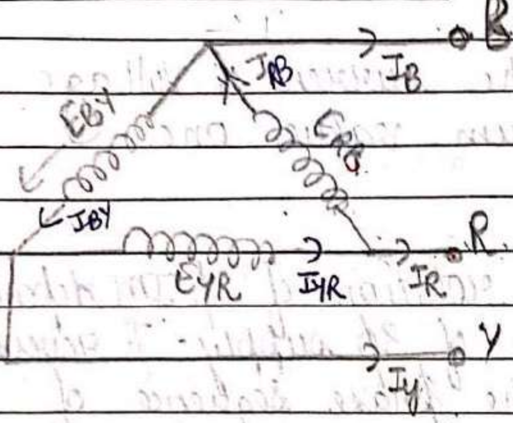
$\therefore E_L = \sqrt{3}\,E_{ph}$

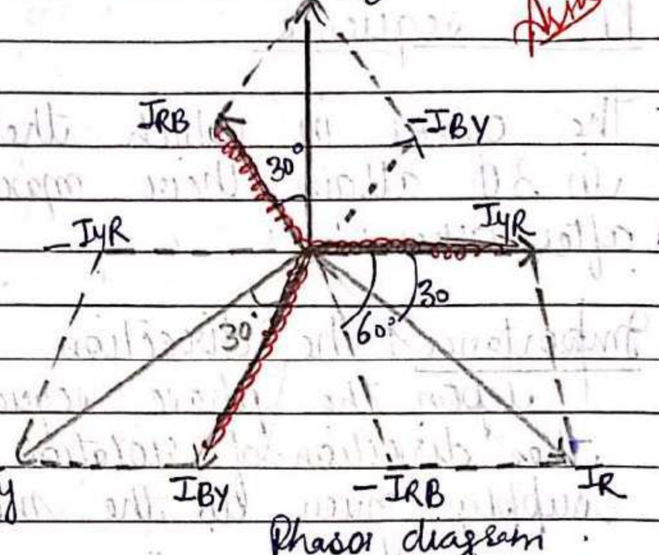


* Same amount of current flow through the phase winding as well as line conductor

So ~~$I_R = I$~~ $I_L = I_{ph}$

Delta connected s/s.





Phasor diagram.

Line current

$I_R = I_{YR} - I_{RB}$

$= I_{YR} + (-I_{RB})$. phase angle b/w three current is 60°

$I_R = \sqrt{I_{YR}^2 + I^2_{RB} + 2 I_{YR} I_{RB} \cos 60^\circ}$

$I_R = \sqrt{I_{YR}^2 + I^2_{RB} + I_{YR} I_{RB}}$

As $I_{RB} = I_{YR} = I_{BY} = I_{ph}$.

$I_R = \sqrt{3 I_{ph}^2} = \sqrt{3}\, I_{ph}$

∴ Line current = $\sqrt{3}$ phase current.

Here $V_L = V_{ph}$

Power in 3φ ckt $1\phi = VI\cos\phi$ for $3\phi = 3 V_{ph} I_{ph} \cos\phi$

Δ Connection $P = 3 V_L \frac{I_L}{\sqrt{3}} \cos\phi = \sqrt{3} V_L I_L \cos\phi$

Y Connection $P = 3 \frac{V_L}{\sqrt{3}} I_L \cos\phi = \sqrt{3} V_L I_L \cos\phi$

Comparison Star s/s	Delta s/s
1. $V_L = \sqrt{3} V_{ph}$ $I_L = I_{ph}$	1. $V_L = V_{ph}$ $I_L = \sqrt{3} I_{ph}$
2. Similar ends joined togtether	2. dissimilar ends joint together
3. Neutral wire 3φ 4 wire s/s	3. No neutral wire
4. Domestic loads used to supply power to	4. used in transformer for power transmission.