SATHYABAMA
INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)
Accredited with Grade "A" by NAAC | Approved by AICTE

SCHOOL OF COMPUTING
B.E(CSE,AI,IOT,DS)

ELECTRICAL AND ELECTRONICS ENGINEERING (SEEA1103)
UNIT-II

SEEA1103	ELECTRICAL AND ELECTRONICS ENGINEERING (Common to CSE & IT)	L	T	P	Credits	Total Marks
		3	0	0	3	100

COURSE OBJECTIVES

- To impart knowledge on the analysis of DC and AC Circuits.
- To gain knowledge about the magnetic circuits.
- To impart Knowledge on electronic devices and their applications.

UNIT 1 D.C. CIRCUITS 9 Hrs.

Electrical Quantities - Ohm's law - Kirchoff's laws -Resistance in series and parallel combinations - Current and Voltage division rules - Mesh analysis and Nodal analysis.

UNIT 2 A.C. CIRCUITS 9 Hrs.

Sinusoidal functions - R.M.S and Average values for Sinusoidal waveform - Phasor representation - Sinusoidal excitation applied to purely resistive, inductive and capacitive circuits - RL , RC and RLC series circuits - power and power factor - Introduction to three phase circuits with balanced load.

UNIT 3 MAGNETIC CIRCUITS 9 Hrs.

Definition of MMF, Flux and reluctance -- Electromagnetic induction - Fleming's rule - Lenz's law - Faraday's laws - statically and dynamically induced EMF - Self and mutual inductance - Analogy of electric and magnetic circuits.

UNIT 4 SEMICONDUCTOR DEVICES 9 Hrs.

VI Characteristics of PN-junction diodes and Zener diodes, BJT and its configurations – input/output Characteristics, Junction Field Effect Transistor – Drain and Transfer Characteristics, MOSFET – Depletion type and Enhancement type, Uni Junction Transistors - Silicon Controlled Rectifiers.

UNIT 5 RECTIFIERS, AMPLIFIERS AND OSCILLATORS 9 Hrs.

Half and full wave rectifiers - Capacitive and inductive filters - ripple factor- PIV-rectification efficiency - RC coupled amplifier- positive and negative feedback - Barkhausen criterion for oscillations - RC and LC oscillators.

Max. 45 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 - Analyze electrical circuits using Kirchoff's Laws.
CO2 - Compare the behaviour of R, L and C and their combinations in AC circuits.
CO3 - Understand the concepts of magnetic circuits
CO4 - Demonstrate the characteristics of various semi-conductor devices
CO5 - Recognize the importance of electronic devices.
CO6 - Design Electronic Circuits for various applications.

TEXT / REFERENCE BOOKS

1. B.N.Mittle & Aravind Mittle, Basic Electrical Engineering, 2nd edition, Tata McGraw Hill, 2011.
2. B.L.Theraja, Fundamentals of Electrical Engineering and Electronics, 1st edition, S.Chand & Co., 2009.
3. Smarajit Ghosh, Fundamentals of Electrical and Electronics Engineering, 2nd edition, PHI Learning Private Ltd, 2010.
4. Dr.Sanjay Sharma, Electronic Devices and Circuits, 2nd edition, S.K.Kataria & Sons, 2012.
5. G.K.Mithal, Basic Electronic Devices and circuits, 2nd Edition, G.K.Publishers Pvt, 2008

END SEMESTER EXAMINATION QUESTION PAPER PATTERN

Max. Marks: 100 **Exam Duration: 3 Hrs.**

PART A: 10 Questions of 2 marks each-No choice **20 Marks**

PART B: 2 Questions from each unit with internal choice, each carrying 16 marks **80 Marks**

UNIT 2

UNIT 2 A.C. CIRCUITS **9 Hrs.**

Sinusoidal functions - R.M.S and Average values for Sinusoidal waveform - Phasor representation - Sinusoidal excitation applied to purely resistive, inductive and capacitive circuits - RL , RC and RLC series circuits - power and power factor - Introduction to three phase circuits with balanced load.

AC CIRCUITS

- Alternating current is an electric current which periodically reverses direction and changes its magnitude continuously with time in contrast to direct current which flows only in one direction.
- A DC quantity is one which has a constant magnitude irrespective of time, but an alternating quantity (AC) is one which has a varying magnitude and angle with respect to time.

SOME IMPORTANT TERMS

1. Wave form

A wave form is the graph in which the instantaneous value of any quantity is plotted against time.

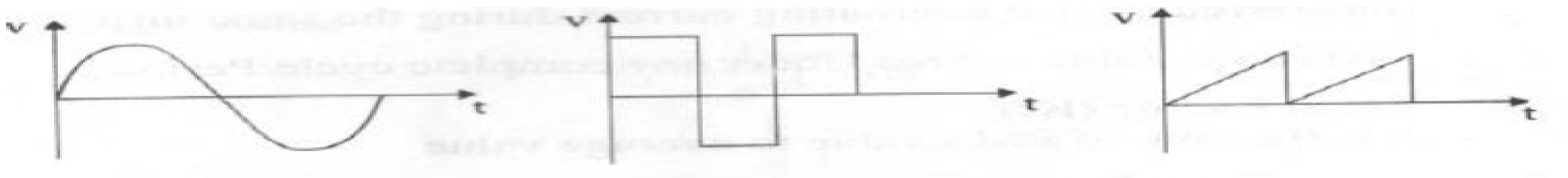


Figure 1(a) Sinusoidal waveform (b) Rectangular waveform (c) sawtooth waveform

2. Alternating Waveform

This is wave which reverses its direction at regularly recurring interval.

3. Cycle

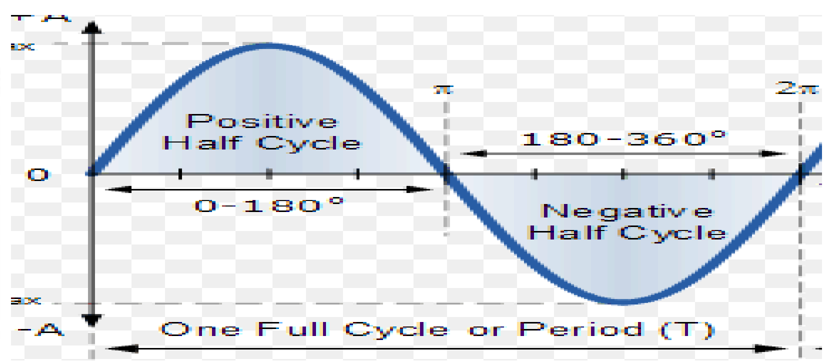


Figure 2

It is a set of positive and negative portion of waveforms.

4. Time Period

The time required for an alternating quantity to complete one cycle is called the time period and it denoted by T.

5. Frequency

The number of cycles per second is called frequency and is denoted by F.It is measured in cycles/second (cps) (or) Hertz

$$f = 1/t$$

6. Amplitude

The maximum value of an alternating quantity in a cycle is called amplitude. It is also known as peak value.

7. R.M.S value [Root Mean Square]

The steady current when flowing through a given resistor for a given time produces the same amount of heat as produced by an alternating current when flowing through the same resistor for the same time is called R.M.S value of the alternating current.

$$\text{RMS Value} = \sqrt{\text{Area Under the square curve for one complete cycle/Period}}$$

8. **Average Value of AC**

The average value of an alternating current is defined as the DC current which transfers across any circuit the same change as is transferred by that alternating current during the same time.

Average Value = Area Under one complete cycle/Period.

9. **Form Factor (K_f)**

It is the ratio of RMS value to average value

Form Factor = RMS value/Average Value

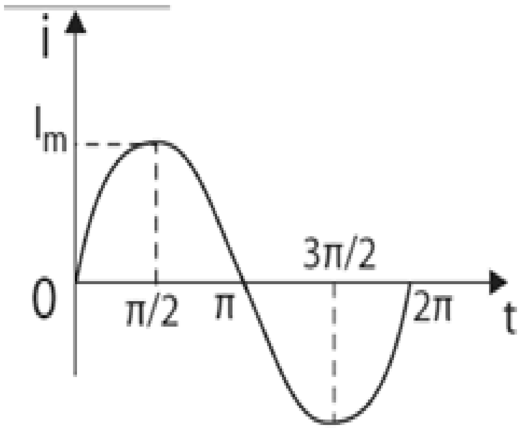
10. **Peak Factor (K_a)**

It is the ratio of Peak (or) maximum value to RMS value.

Peak Factor Ka=Peak Value/RMS value

ANALYTICAL METHOD FOR SINUSOIDAL CURRENT (OR) VOLTAGE

Full Wave Rectifier



Root Mean Square value

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

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

$$= \frac{1}{\pi}\int_0^{\pi} i^2 d\theta \text{ [since it is symmetrical]}$$

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

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

$$= \frac{I_m^2}{2\pi}\left[\theta - \frac{\sin 2\theta}{2}\right]_0^{\pi}$$

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

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

Average Value

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

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

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

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

$$= -\frac{I_m}{\pi}[\cos\pi - \cos 0]$$

$$= -\frac{I_m}{\pi}(-1-1)$$

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

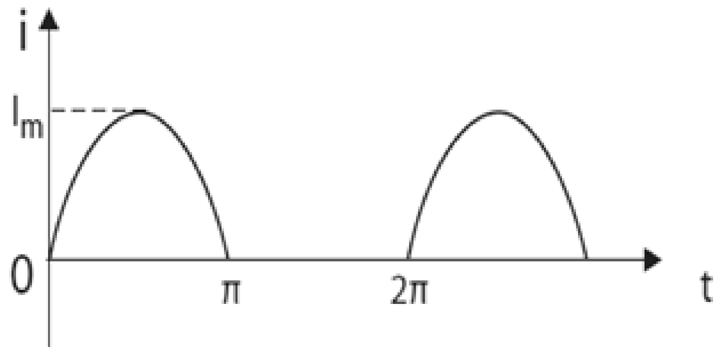
Form Factor

$$\text{Form Factor} = \frac{RMS}{Avg} = \frac{I_m/\sqrt{2}}{2I_m/\pi} = 1.11$$

Peak Factor

$$\text{Peak Factor} = \frac{MAX}{RMS} = \frac{I_m}{RMS} = \frac{I_m}{\left(\frac{I_m}{\sqrt{2}}\right)} = 1.414$$

Half wave rectifier



RMS value

$I = I_m \sin\theta \qquad 0 < \theta < \pi$

$I = 0 \qquad \pi < \theta \le 2\pi$

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

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

$$= \frac{1}{2\pi}\left[\int_0^{\pi} i^2 d\theta + 0\right]$$

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

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

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

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

Average Value

$$I_{av} = \frac{1}{2\pi}\int_0^{\pi} i\,d\theta$$
$$= \frac{1}{2\pi}\left[\int_0^{\pi} i\,d\theta + 0\right]$$

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

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

$$= -\frac{I_m}{2\pi}[\cos\theta]_0^{\pi}$$

$$= \frac{I_m}{2\pi}[\cos\pi - \cos 0]$$

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

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

- **Form Factor**

$$Form\ Factor = \frac{RMS}{Avg} = \frac{I_m}{2} / \frac{I_m}{\pi} = 1.57$$

- **Peak Factor**

$$Peak\ Factor = \frac{MAX}{RMS} = \frac{I_m}{RMS} / \frac{I_m}{\frac{I_m}{2}} = 2$$

Problem The equation of an alternating current is given by

$i = 40\sin 314\,t$

Determine

(i) Max value of current

(ii) Average value of current

(iii) RMS value of current

(iv) Frequency and angular frequency

(v) Form Factor

(vi) Peak Factor

Solution:

$$i = 40\sin 314\,t$$

We know that $i = I_m \sin \omega t$

So $I_m = 40$

$\omega = 314\ rad/\sec$

(i) Maximum value of current = 40A

(ii) Average value of current

$$I_{Avg} = \frac{2I_m}{\pi} = \frac{2\times 40}{\pi} = 25.464A$$

(iii) RMS value of current

$$I_{Rms} = \frac{I_m}{\sqrt{2}} = \frac{40}{\sqrt{2}} = 28.28\ Amp$$

(iv) Frequency $f = \frac{\omega}{2\pi} = \frac{314}{2\pi} \approx 50\,Hz$

(v) From Factor $= \frac{RMS}{Avg} = \frac{28.28}{25.46} = 1.11$

(vi) Peak Factor $= \frac{\text{Peak}}{\text{RMS}} = \frac{40}{28.28} = 1.414$

QUANTITY	RMS VALUE	AVERAGE VALUE	FORM FACTOR	PEAK FACTOR
SINUSOIDAL VOLTAGE	$V_{rms}=V_m/\sqrt{2}$	$V_{av}=2V_m/\pi$	1.11	1.41
SINUSOIDAL CURRENT	$I_{rms}=I_m/\sqrt{2}$	$I_{av}=2I_m/\pi$	1.11	1.41
FULL WAVE RECTIFIER VOLTAGE/CURRENT	$V_{rms}=V_m/\sqrt{2}$ $I_{rms}=I_m/\sqrt{2}$	$V_{av}=2V_m/\pi$ $I_{av}=2I_m/\pi$	1.11	1.41
HALF WAVE RECTIFIER VOLTAGE/CURRENT	$V_{rms}=V_m/2$ $I_{rms}=I_m/2$	$V_{av}=V_m/\pi$ $I_{av}=I_m/\pi$	1.57	2

Phasor Representation of Sinusoidal varying alternating quantities

Phase

The phase is nothing but a fraction of time period that has elapsed from reference or zero position.

In Phase

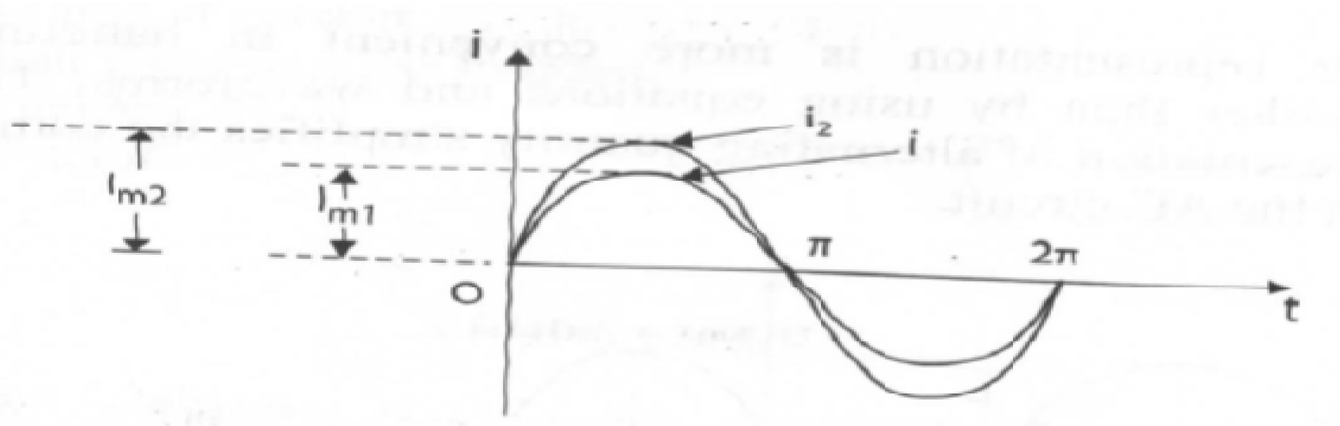
Two alternating quantities are said to be in phase, if they reach their zero value and maximum value at the same time.

Consider two alternating quantities represented by the equation

$i_1 = I_{m1} \sin\theta$

$i_2 = I_{m2} \sin\theta$

can be represented graphically as shown in Figure



Graphical representation of sinusoidal current

From above Figure it is clear that both i_1 and i_2 reaches their zero and their maximum value at the same time even though both have different maximum values. It is referred as both currents are in phase meaning that no phase difference is between the two quantities. It can also be represented as vector as shown in Fig .

Vector diagram

Out of Phase

Two alternating quantities are said to be out of phase if they do not reach their zero and maximum value at the same time. The Phase differences between these two quantities are represented in terms of '**lag**' and '**lead**' and it is measured in radians or in electrical degrees.

Lag

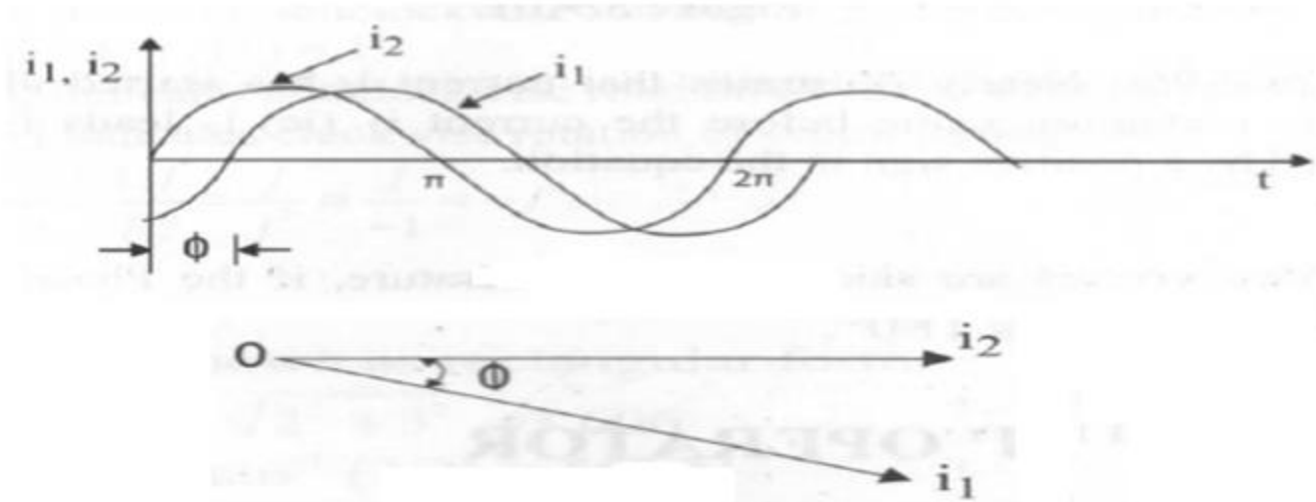
Lagging alternating quantity is one which reaches its maximum value and zero value later than that of the other alternating quantity.

Consider two alternating quantities represented by the equation:

$i_1 = I_{m1} \sin(\omega t - \Phi)$

$i_2 = I_{m2} \sin(\omega t)$

These equations can be represented graphically and in vector form as shown in Figure



Lead

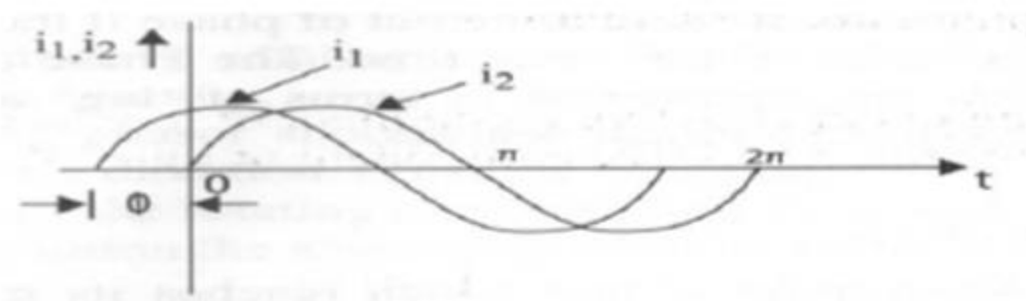
Leading alternating quantity is one which reaches its maximum value and zero value earlier than that of the other alternating quantity.

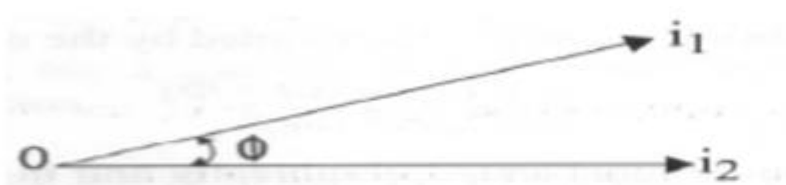
Consider two alternating quantities represented by the equation:

$i_1 = I_{m1} \sin(\omega t + \Phi)$

$i_2 = I_{m2} \sin(\omega t)$

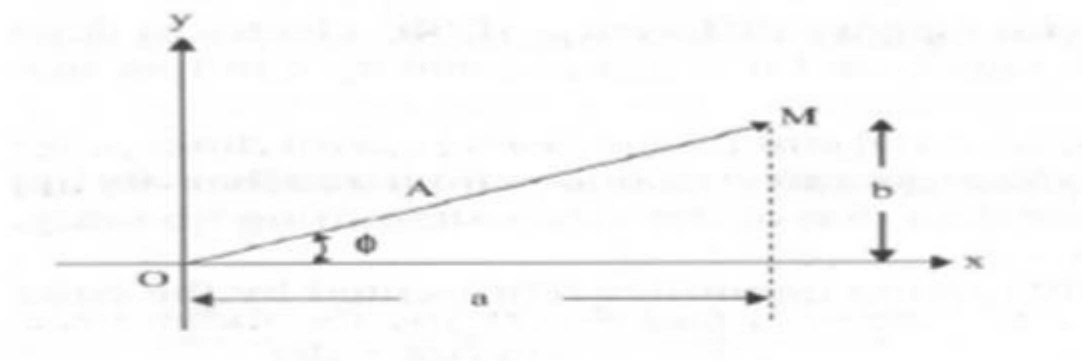
These equations can be represented graphically and in vector form as shown in Figure





Review of 'j' Operator

A vector quantity has both magnitude and direction. A vector' A' is represented in two axis plane as shown in Figure



In Figure OM represents vector A

Φ represents the phase angle of vector A

A = a + jb

a – Horizontal component or active component or in phase component

b – Vertical component or reactive component or quadrature component

The magnitude of vector 'A' = $\sqrt{a^2 + b^2}$

Phase angle of Vector 'A' = $\alpha = \tan^{-1}$ (b/a)

$A = a + jb$

Features of j – Operator

1. $j = \sqrt{-1}$
   It indicates anticlockwise rotation of vector through 90°.
2. $j^2 = j \cdot j = -1$
   It indicates anticlockwise rotation of vector through 180°.
3. $j^3 = j \cdot j \cdot j = -j$
   It indicates anticlockwise rotation of vector through 270°.
4. $j^4 = j \cdot j \cdot j \cdot j = 1$
   It indicates anticlockwise rotation of vector through 360°.
5. $-j$ indicates clockwise rotation of vector through 90°.
6. $\frac{1}{j} = \frac{1.j}{j.j} = \frac{j}{j^2} = \frac{j}{-1} = -j$

:or can be written both in polar form and in rectangular form.

A = 2 + j3

This representation is known as rectangular form.

Magnitude of A = |A| = $\sqrt{2^2+3^2}$ =3.606

Phase angle of A = α = tan-1 (3/2) = 56°.31

A=|A| $\angle\alpha°$

A=3.606$\angle$56°.31

This representation is known as polar form.

Note:

1. Addition and Subtraction can be easily done in rectangular form.
2. Multiplication and division can be easily done in polar form.

Examples:

1. ***A= 2 + j3 ; B = 4 + j5.***

Add Vector A and Vector B and determine the magnitude and Phase angle of resultant vector.

Solution:

$A + B = 2 + j3 + 4 + j5 = 6 + j8$

$\therefore$ Magnitude = $| A + B | = \sqrt{6^2 + 8^2} = 10.0$

Phase angle = $\alpha = \tan^{-1} (B / A) = \tan^{-1} (8/6) = 53°.13$

2. *$A = 2 + j3$; $B = 4 - j5$.*

Perform A x B and determine the magnitude and Phase angle of resultant vector.

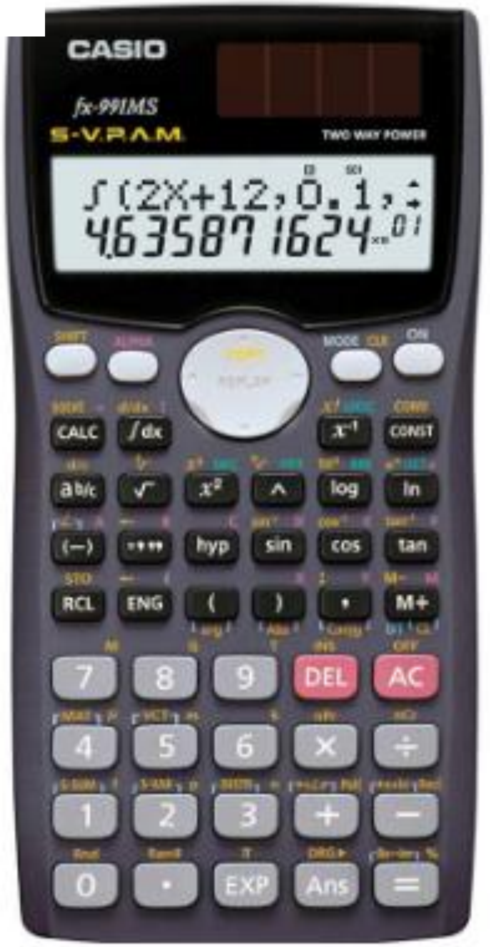
Solution:

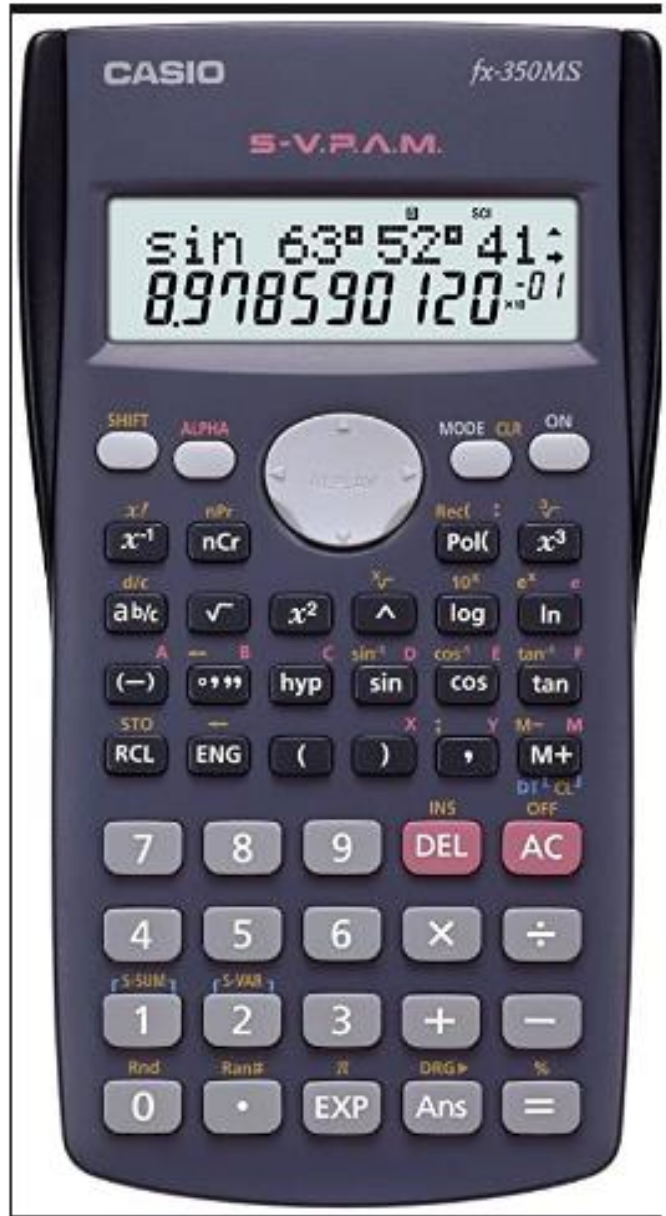
$A = 2 + j3$	$B = 4 - j5$
$\lvert A\rvert = \sqrt{2^2 + 3^2} = 3.606$	$\lvert B\rvert = \sqrt{4^2 + (-5)^2} = 6.403$
$\alpha = \tan^{-1}(3/2) = 56°.310$	$\alpha = \tan^{-1}(-5/4) = -51°.340$
$A = 3.606 \angle 56°.310$	$B = 6.403 \angle -51°.340$

$$A \times B = 3.606 \angle 56°.310 \times 6.403 \angle -51°.340$$

$$= 3.606 \times 6.403 \angle (56°.310 + (-51°.340))$$

$$= 23.089 \angle 4°.970$$


CASIO
fx-991MS
S-V.P.A.M.
TWO WAY POWER


CASIO
fx-350MS
S-V.P.A.M.

$A = 2 + j3$

$|A| = \sqrt{2^2 + 3^2} = 3.606$

$\alpha = \tan^{-1}(3/2) = 56°.310$

$A = 3.606 \angle 56°.310$

$B = 4 - j5$

$|B| = \sqrt{4^2 + (-5)^2} = 6.403$

$\alpha = \tan^{-1}(-5/4) = -51°.340$

$B = 6.403 \angle -51°.340$

$A \times B = 3.606 \angle 56°.310 \times 6.403 \angle -51°.340$

$= 3.606 \times 6.403 \angle (56°.310 + (-51°.340))$

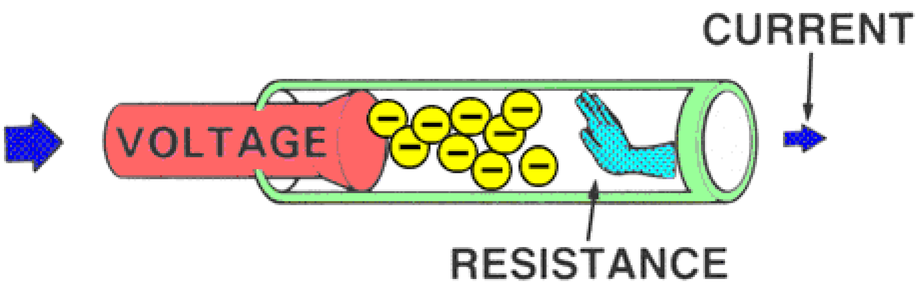
$= 23.089 \angle 4°.970$

TYPES OF AC SERIES CIRCUIT USING RESISTANCE,INDUCTANCE AND CAPACITANCE

- SINUSOIDAL EXCITATION APPLIED TO PURE R
- SINUSOIDAL EXCITATION APPLIED TO PURE L
- SINUSOIDAL EXCITATION APPLIED TO PURE C
- SINUSOIDAL EXCITATION APPLIED TO RL SERIES
- SINUSOIDAL EXCITATION APPLIED TO RC SERIES
- SINUSOIDAL EXCITATION APPLIED TO RLC SERIES

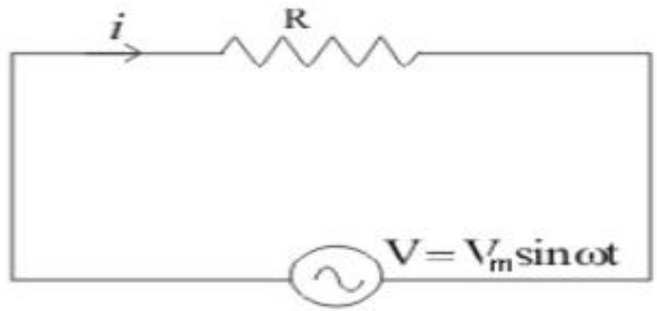
RESISTANCE

OPPOSE THE FLOW OF CURRENT



SINUSOIDAL EXCITATION APPLIED TO PURE RESISTANCE

Consider the circuit, in which a resistor of value R ohms is connected across an alternating voltage source.



Let the applied voltage across the resistance be $V = V_m \sin \omega t$

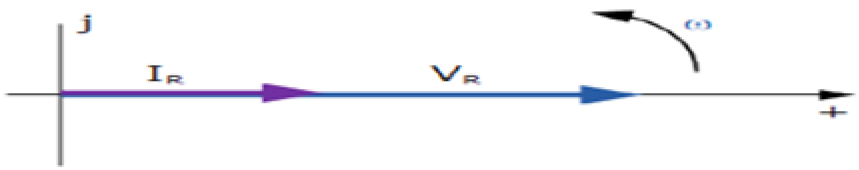
The resulting current has instantaneous value I by ohm's law $V = iR$

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

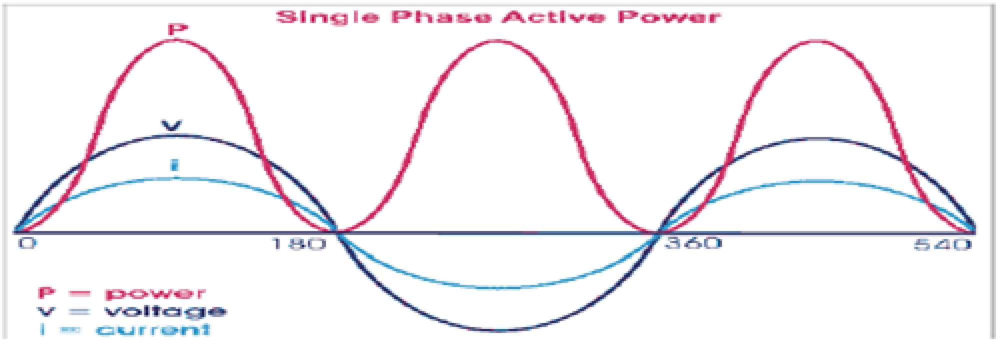
Where, $I_m = \frac{V_m}{R} = Peak\ value\ of\ the\ circuit\ current$

Comparing the voltage and the current we find voltage and the current are in phase with each other.

Phasor representation: In pure resistive circuit, no phase difference between the voltge and current (φ=0).



Waveform representation: Since the current and voltage are in phase, the waveforms reach their maximum and minimum values at the same instant.



Impedance:

$$Z = \frac{V}{I} = \frac{V_m \sin \omega t}{I_m \sin \omega t} = \frac{V_m}{I_m} = \frac{V_m}{V_m/_R} = R$$

Average Power:

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

ωt=θ, $$P = V_m I_m sin^2 \omega t$$

Average power for one cycle $= \frac{V_m I_m}{\Pi} \int_0^{\Pi} sin^2\theta . d\theta = \frac{VmIm}{\pi} \int_0^{\pi} \frac{1-\cos 2\theta}{2} \, d\theta$

$$= \frac{VmIm}{2\pi} \left[0 - \frac{\sin 2\theta}{2}\right]_0^{\pi}$$

$$= \frac{VmIm}{2\pi} \left[\pi - \frac{\sin 2\pi}{2} - 0 + sin \frac{\theta}{2}\right]$$

$$= \frac{VmIm}{2\pi} . \pi = \frac{VmIm}{2} = \frac{Vm}{\sqrt{2}} . \frac{Im}{\sqrt{2}} = V . I$$

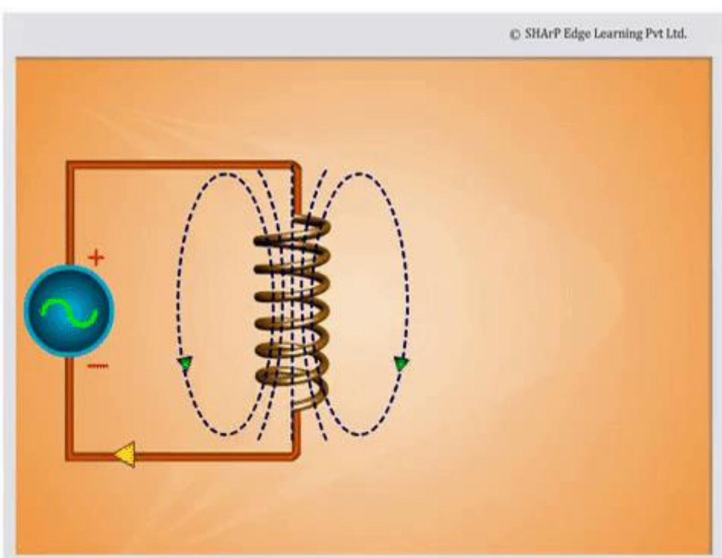
Average Power = VI watts

Power Factor: It is the cosine of the phase angle between voltage and current.

Cos Φ =cos 0= 1 (unity)

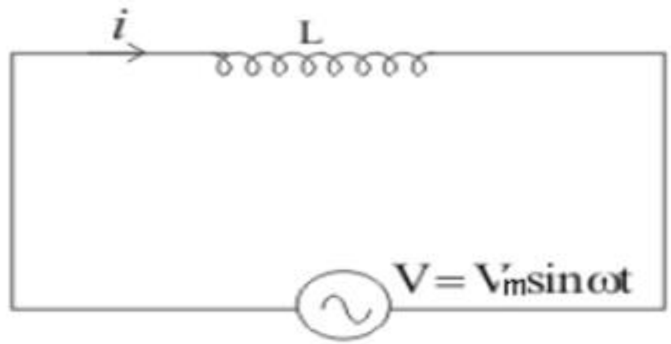
INDUCTANCE

In electromagnetism and electronics, **inductance** is the tendency of an electrical conductor to oppose a change in the electric current flowing through it. The flow of electric current creates a magnetic field around the conductor.
L=INDUCTANCE IN HENRY



SINUSOIDAL EXCITATION APPLIED TO PURE INDUCTANCE

alternating voltage is applied across a pure inductor of self inductance L henry.



Let the applied voltage be $V=V_m \text{ Sin } \omega t$

We know that the self induced emf always opposes the applied voltage. $V = L\frac{di}{dt}$

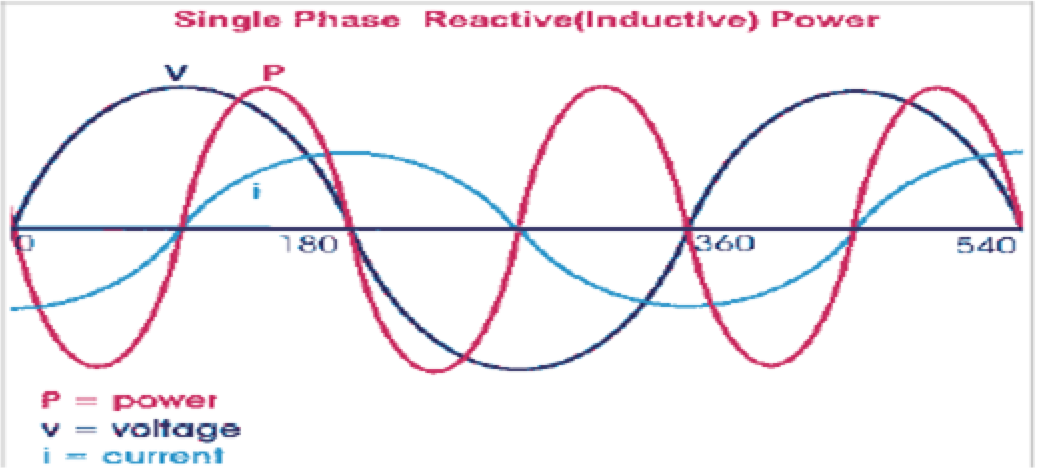
$$i = \frac{1}{L}\int V\,dt = \frac{1}{L}\int V_m \sin\omega t\,dt = \frac{V_m}{L}\left(\frac{-\cos\omega t}{\omega}\right) = \frac{-V_m}{L\omega}\cos\omega t$$

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

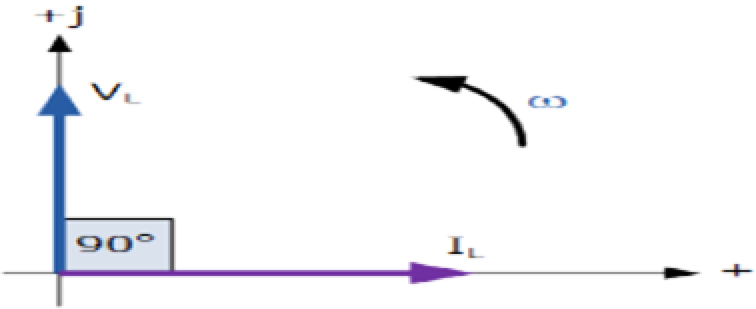
Here the current through the inductor lags the applied voltage by an angle 90°

Waveform representation: The current waveform is lagging behind the voltage waveform by 90°

Waveform representation: The current waveform is lagging behind the voltage waveform by 90°



Phasor representation: voltage is reference and current lags voltage by 90°



Impedence (Z):

$$Z = \frac{\text{Maximum value of v}}{\text{maximum value of I}} = \frac{Vm}{Im} = \frac{Vm}{Vm/L\omega}$$

$$Z = \omega L = inductive\ Reactance = X_l = \omega L = 2\pi f l$$

Power:

$$P = Vi = Vm \sin \omega t\ \ Im \sin\ (\omega t - \pi/2)$$

Average Power:

$$P = -\frac{1}{\pi}\int_0^{\pi} VmIm \sin\theta \cos\theta\ .d\theta = \frac{-1}{\pi}\int_0^{\pi} \frac{VmIm}{2} \sin 2\theta\ .d\theta$$

$$= \frac{VmIm}{2\pi}\left[\frac{\cos 2\theta}{2}\right]_0^{\pi} = \frac{VmIm}{4\pi}(\cos 2\pi - \cos 0) = 0$$

Pure inductor does not consume any real power.

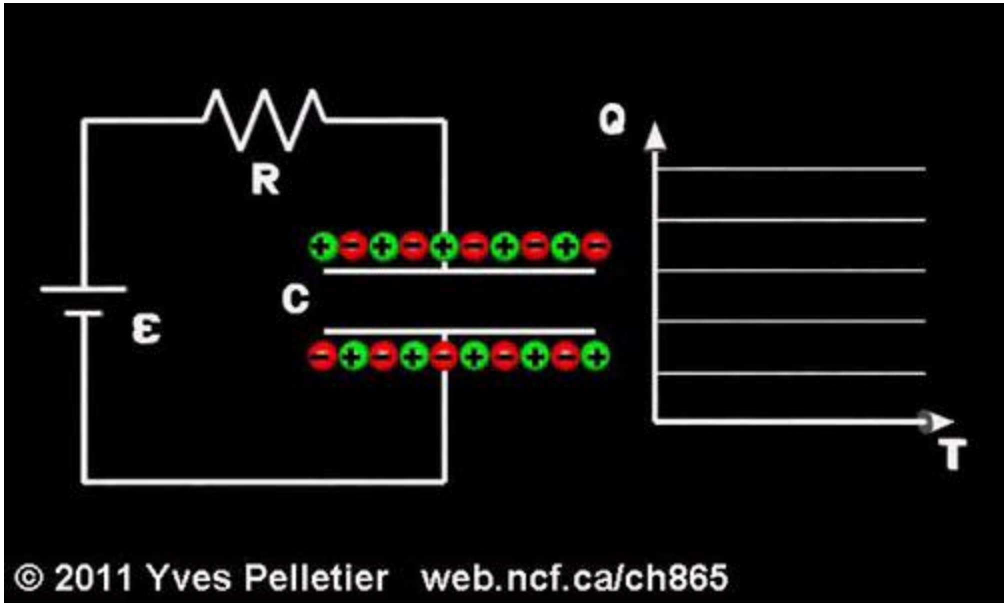
Power Factor: In the pure inductor the phase angle between the current and the voltage phasors is 90˚.

CAPACITANCE

Capacitance is the ratio of the amount of electric charge stored on a conductor to a difference in electric potential.

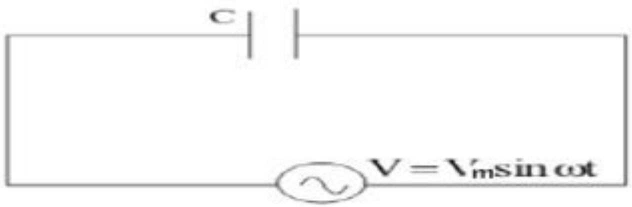
Q= C V

C=CAPACIANCE IN FARAD



SINUSOIDAL EXCITATION APPLIED TO PURE CAPACITANCE

The capacitor of valve C farad is connected across an alternating voltage source. The voltage across the capacitance is $V = V_m \sin \omega t$.



The characteristic equation of the capacitor is $V = \frac{1}{c} \int i \, dt$

Q= C V
di/dt=C V

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

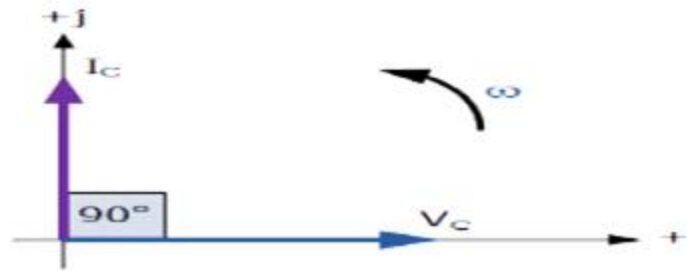
$$= \omega C \; Vm \cos \omega t \; = Im \cos \omega t = Im \cos \omega t$$

$$Im = \omega C \, . Vm$$

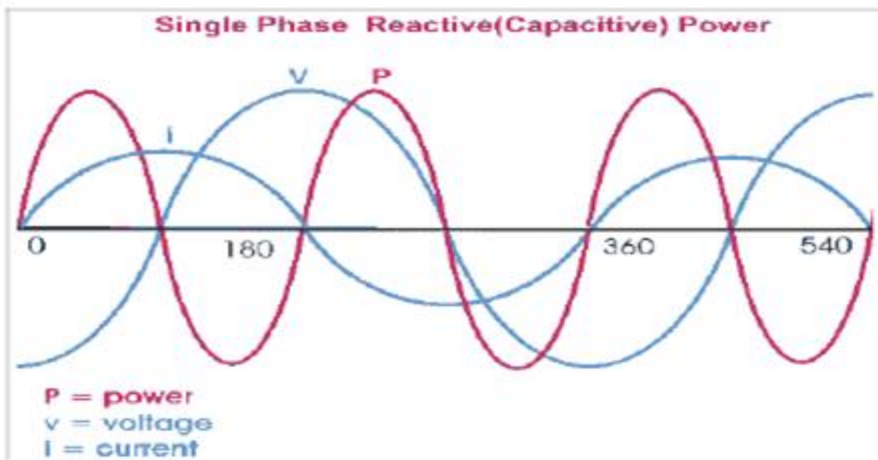
$$i = Im \sin(\omega t + 90^\circ)$$

We find that there is a phase difference of 90˚ between the voltage and the current in a pure capacitor. The current in a pure capacitor leads the applis voltage by an angle 90˚.

Phasor representation: voltage is reference and current leads voltage by 90°.



<u>Waveform Representation</u>: The current waveform is ahead of the voltage waveform by an angle of 90˚.



Impedence(Z):

$$Z = \frac{\text{Maximum value of voltage}}{\text{maximum value of current}} = \frac{Vm}{Im} = \frac{Vm}{\omega C \, . \, Vm} = \frac{1}{\omega C} = XC$$

Capacitive Reactance = $Xc = \frac{1}{\omega C} = \frac{1}{2\pi f C}$

Power:

Instantaneous power P= Vi

$$P = Vm \sin\theta \;\; Im \cos\theta = VmIm \sin\theta \cos\theta$$

Average Power:

$$P = \frac{1}{\pi}\int_0^{\pi} VmIm \sin\theta \cos\theta \, . \, d\theta = \frac{1}{\pi}\int_0^{\pi} \frac{VmIm}{2} \sin 2\theta \, . \, d\theta$$

$$= \frac{VmIm}{2\pi}\left[\frac{\cos 2\theta}{2}\right]_0^{\pi} = \frac{VmIm}{4\pi}(\cos 2\pi - \cos 0) = 0$$

Pure capacitor do not consume any real power.

Power factor: The phase angle between the voltage and current is 90˚ lead.

QUANTITY	SINUSOIDAL EXCITATION TO PURE RESISTANCE	SINUSOIDAL EXCITATION TO PURE INDUCTANCE	SINUSOIDAL EXCITATION TO PURE CAPACITANCE
Voltage & Current	V=VmSinwt I=ImSinwt W=2πf	V=VmSinwt I=ImSin(wt-90) W=2πf	V=VmSinwt I=ImSin(wt+90) W=2πf
Impedance	Z=R	Z=wL	Z=1/wC
Current	Im=Vm/Z Im=Vm/R	Im=Vm/Z Im=Vm/wL	Im= Vm/Z Im=Vm wC
Reactance	Resistance R	Inductive Reacatance XL=wL	Capacitive Reacatance XC=1/wC
Instantantaneous Power	P=V I P=Vm Im Sinwt Sinwt	P=V I P=Vm Im Sinwt Sin(wt-90)	P=V I P=Vm Im Sinwt Coswt
Average Power	P=VmIm/2	0	0
Phase Angle	0(in phase)	90(current lags)	90(current leads)
Power factor Cos ϕ	1	0	0

1: A voltage of 240 sin 377t is applied to a 6Ω resistor. Find the instantaneous current, phase angle, impedance, instantaneous power, average power and power factor.

Solution:

Given: v = 240 sin 377t

$V_m = 240$ V

ω = 377 rad/sec

R = 6Ω

Instantaneous current:

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

$$= \frac{240}{6} \sin 377t$$

$$= 40 \sin 377t A$$

I. Phase angle:

$$\phi = 0$$

II. Impedance:

Z = R = 6Ω

III. Instantaneous power:

IV. $$p = V_m I_m \sin^2\omega t$$

$$= 240.40.\sin^2 377t$$

$$= 9600 \sin^2 377t$$

V. Average power:

$$P = \frac{V_m I_m}{2} = 4800 \text{watts}$$

VI. Power factor:

cosΦ = cos0 = 1

2: A voltage e = 200sinωt when applied to a resistor is found to give a power 100 watts. Find the value of resistance and the equation of current.

Solution:

Given: e = 200sinωt

$V_m = 200$

P = 100w

Average power, $P = \frac{V_m I_m}{2}$

$$100 = \frac{200 I_m}{2}$$

$I_m = 1$ A

Also, $V_m = I_m.R$

R = 200Ω

Instantaneous current, $I = I_m \sin\omega t = 1.\sin\omega t$ A

3: *A coil of wire which may be considered as a pure inductance of 0.225H connected to a 120V, 50Hz source. Calculate (i) Inductive reactance (ii) Current (iii) Maximum power delivered to the inductor (iv) Average power and (v) write the equations of the voltage and current.*

Solution:

Given: L = 0.225 H

$V_{RMS} = V = 120$ V

f = 50Hz

I. Inductive reactance, $X_L = 2\pi fL = 2\pi \times 50 \times 0.225 = 70.68\Omega$

II. Instantaneous current, $i = -I_m \cos\omega t$

$\because I_m = \frac{V_m}{\omega L} and V_{RMS} = \frac{V_m}{\sqrt{2}}$, calculate I_m and V_m

$V_m = V_{RMS}\sqrt{2}$ =169.71V

$$I_m = \frac{V_m}{\omega L} = \frac{169.71}{70.68} = 2.4A$$

maximum Power

$$P = V_m \sin\omega t * I_m \sin(\omega t - 90)$$

$$P = 169.71 \sin 314t * 2.4 \sin(314t - 90)$$

$$P = 407.304 \sin 314t * \sin(314t - 90)$$

$$P = \frac{407.304}{2} = 203.6 \text{ watts}$$

III. Average power, P=0

IV. Instantaneous voltage, v = Vm sinωt = 169.71 sin **314t V**

Instantaneous current, i = -2.4 cos **314t A**

4: *A 135μF capacitor has a 150V, 50Hz supply. Calculate (i) capacitive reactance (ii) equation of the current (iii) Instantaneous power (iv)Average power (v) RMS current (vi) Maximum power delivered to the capacitor.*

Solution:

Given: V_{RMS}= V= 150V

C = 135μF

f = 50Hz

I. $X_C = \frac{1}{\omega C} = 23.58\Omega$

II. $i = I_m \sin\left(\omega t + \frac{\pi}{2}\right) \because I_m - \omega C V_m$ and $V_{RMS} - \frac{V_m}{\sqrt{2}}$

$V_m = 150 X \sqrt{2} = 212.13V$

$I_m = 314 X 135 X 10^{-6} X 212.13 = 8.99A$

$i = 8.99 \sin\left(314t + \frac{\pi}{2}\right) A$

3. $P = V_m \sin wt * I_m \sin(wt+90)$

$= 212.13 \sin 314t * 9 \sin(314t+90)$

$P = 1908 \sin 314t * \sin(314t+90)$

$P_m = \dfrac{1908}{2} = 954$ watts

IV. Average power, P = 0

V. $I_{RMS} = \dfrac{I_m}{\sqrt{2}}$ =6.36A

VI. $P_m = \dfrac{V_m I_m}{2}$ = 953.52 W

5: *A voltage of 100V is applied to a capacitor of 12μF. The current is 0.5 A. What must be the frequency of supply*

Solution:

Given: $V_{RMS} = V = 100V$

$C = 12\mu F$

$I = 0.5A$

I. Find V_m and I_m

$$V_{RMS} = \frac{V_m}{\sqrt{2}}$$

$V_m = 100 X \sqrt{2} = 141.42V$

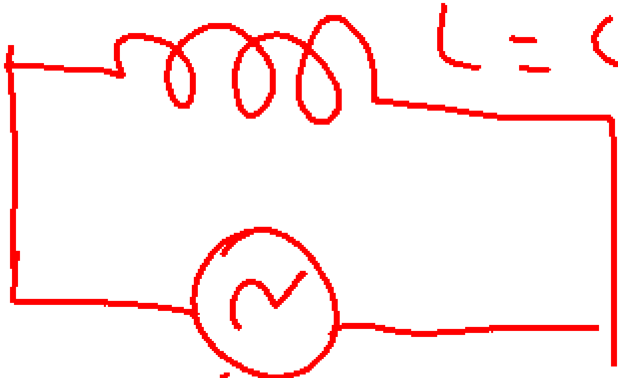
$$I_{RMS} = \frac{I_m}{\sqrt{2}}$$

$I_m = 0.5 X \sqrt{2} = 0.707A$

II. $I_m = \omega C V_m = 2\pi f C V_m$

$f = 66.3Hz$

An alternating voltage of 200V, 50Hz is applied to a coil of negligible resistance and inductance of 0.1H. Find the current draw by the coil. The supply voltage is kept constant.



$L = 0.1\,H$

200V, 50Hz

$I = I_m \sin(\omega t - 90)$

$$I_m = \frac{V_m}{\omega L}$$

$$= \frac{200 * \sqrt{2}}{2 \times \pi \times 50 \times 0.1}$$

$$V_{rms} = \frac{V_m}{\sqrt{2}}$$

$\omega = 2\pi f$

$I_m = 9A$

$I = 9 \sin(314t - 90)$

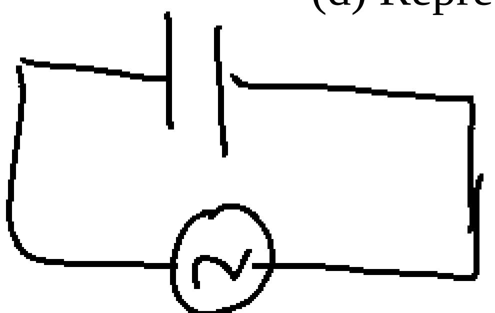
In a circuit having single element i = 4 sin (314t + 90) and the voltage v = 60 Sin 314t.

(a) Find the phase angle and power factor

(b) Identify the circuit element and find its value

(c) Draw the phasor diagrams by taking voltage as reference and then current as reference.

(d) Represent current and voltage in polar form



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

$$I = 4 \sin(314t + 90)$$

$$\boxed{I_m = 4A}$$

$$\omega = 314 \text{ rad/sec}$$

$$\boxed{f = 50Hz}$$

$$V = 60 \sin 314t$$

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

$$\boxed{V_m = 60V}$$

(a) Phase Angle = 90 (Lead)

Power factor = cos(90)

= 0

(b) $Z = \frac{V_m}{I_m} = \frac{60}{4}$

$Z = 15\,\Omega$

$Z = X_C$

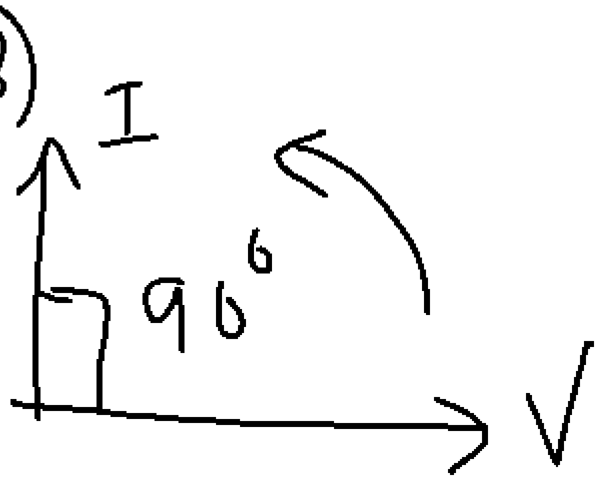
$Z = \frac{1}{\omega C}$

$15 = \frac{1}{2 * \pi * 50 * C}$

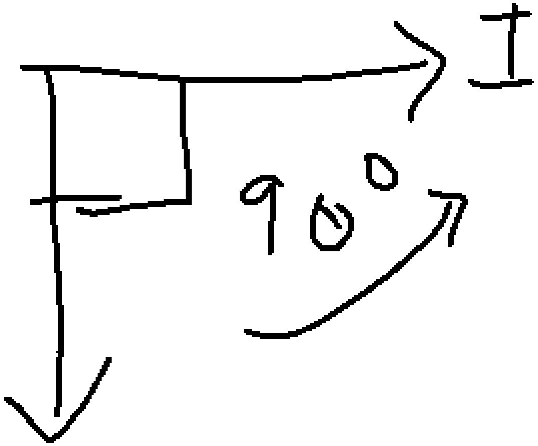
$C = 0.21 \times 10^{-3}\,F$

$C = 0.21\,mF$

3)



(Voltage Ref)



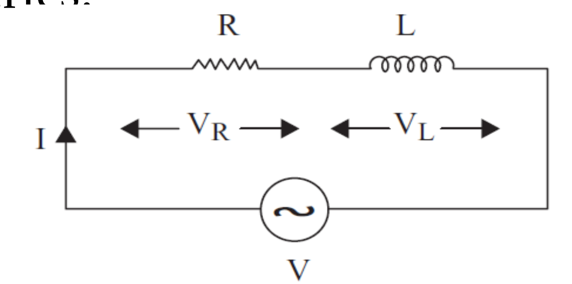
(current ref)

4) $V = 60 \sin 314t = 60 \angle 0^\circ$

$I = 4 \sin(314t + 90) = 4 \angle 90^\circ$

SINUSOIDAL EXCITATION APPLIED TO RL Series Circuit

Let us consider a circuit is which a pure resistance R and a purely inductive coil of inductance L are connected in series.



Let

V=V**m** Sinwt be the applied voltage.

I= Effective Value of Circuit Current.

V_R= Potential difference across inductor.

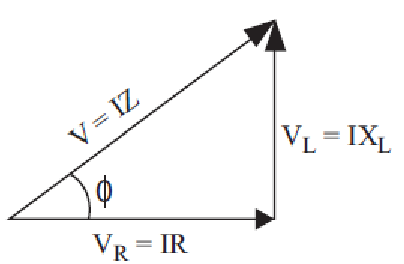
V_L= Potential difference across inductor. F= Frequency of applied voltage.

The same current I flows through R and L hence I is taken as reference vector.

Voltage across resistor V_R= IR in phase with I

Voltage with inductor V_L= IX_L leading I by 90°

At any constant, applied voltage



Phasor Diagram

At any instant, applied voltage

$$V = V_R + V_L$$
$$V = IR + jIX_L$$
$$V = I\,(R + jX_L)$$
$$\frac{V}{I} = R + jX_L$$
$$= z \text{ impedance of circuit}$$
$$Z = R + j\,X_L$$
$$|z| = \sqrt{R^2 + X_L^2}$$

From phasor disgram,

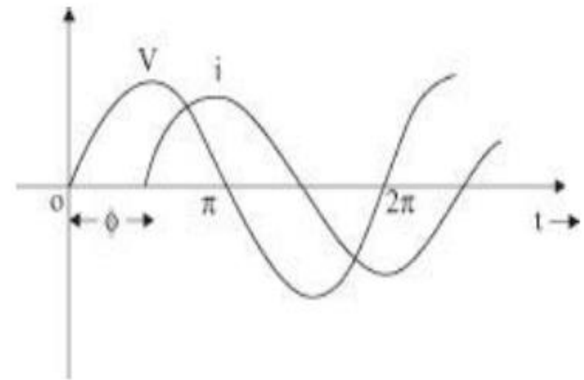
$$\tan\phi = \frac{X_L}{R}$$

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

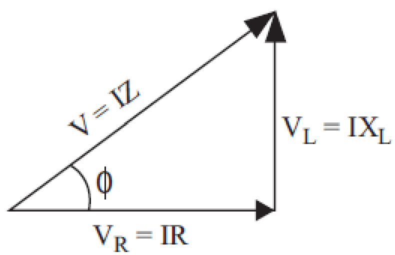
ϕ is called the phasor angle and it is the angle between V and I, its v between 0 to 90^0.

So impedence $Z = R + jX_L$

$= |Z| \angle \phi$



Waveform Representation



Phasor Diagram

$V = V\mathbf{m} \sin\omega t$

$I = I\mathbf{m} \sin(\omega t - \phi)$

The current I lags behind the applied voltage V by an angle ϕ.

From phasor diagram,

Power factor cos ø=R/Z

Actual Power P = VI cos ø = Current component is phase with voltage (W)

Reactive or Quadrature Power

Q = VI sinϕ = Current component is quadrature with voltage (VAR)

Complex or Apparent Power

S = VI = Product of voltage and current (VA)

S = P + jQ

A coil having a resistance of 6Ω and an inductance of 0.03 H is connected across a 100V, 50Hz supply, Calculate.

(i) The current

(ii) The phase angle between the current and the voltage

(iii) Power factor

(iv) Real Power

Solution:

$R = 6\Omega$

$L = 0.03\ H$

$X_L = 2\pi fL$

$X_L = 2\pi \times 50 \times 0.03$

$X_L = 9.42\Omega$

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

$$= \sqrt{(6)^2 + (9.42)^2}$$

$$|Z| = 11.17\Omega$$

$$\text{(i) } I = \frac{V}{Z} = \frac{100}{11.17} = 8.95 \text{ amps}$$

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

$$= tan^{-1}\left(\frac{9.42}{6}\right)$$

$\Phi = 57.5$ (lagging)

(iii) Power factor $= \cos \phi$

$= \cos 57.5$

$= 0.537$ (lagging)

(iv) Power = Average power

$= VI \cos \Phi$

$= 100 \times 8.95 \times 0.537$

Power = 480.6 Watts

7: ***10Ω resistor and a 20 mH inductor are connected is series across a 250V, 60 Hz supply. Find the impedence of the circuit, Voltage across the resistor, voltage across the inductor, apparent power, active power and reactive power.***

Solution:

R = 10Ω

L = 20 mH = 20×10-3H

XL = 2πfL

= 2π×60×20×10-3

XL = 7.54Ω

(i) $Z = \sqrt{R^2 + X_L^2} = \sqrt{10^2 + 7.54^2} = 12.5\Omega$

(ii) $I = \frac{V}{Z} = \frac{250}{12.5} = 20A$

V_R = IR = 20×10=200 volts

Active power = VI cos ϕ

=250×20×0.8

P = 4000 Watts

(iii) V_L = I X_L = 20×7.54=150.8 volts

(iv) Apparent power S = VI

= 250×20

S= 5000VA

$\cos \emptyset = \frac{R}{Z} = \frac{10}{12.5}$ = 0.8(Lagging)

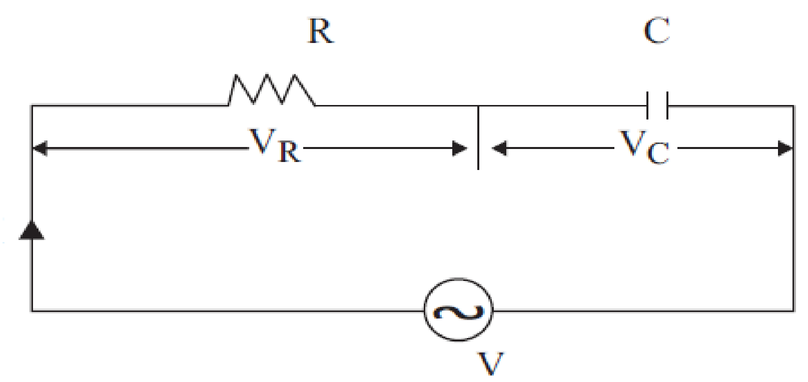
$\sin\phi = \sqrt{1-\cos^2\Phi} = \sqrt{1-(0.8)^2} = 0.6$

Reactive Power Q = VI sin ϕ

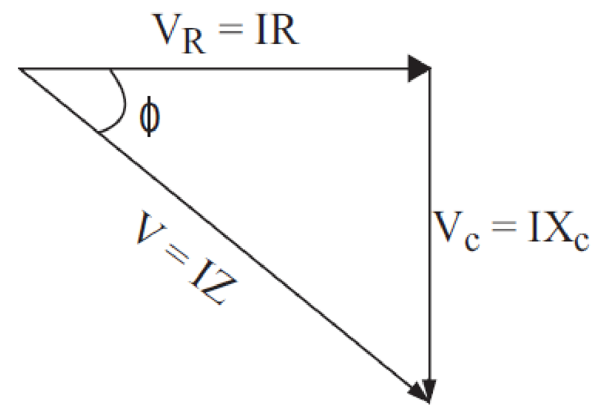
= 250×20×0.6

Q= 3000 KVAR

SINUSOIDAL EXCITATION APPLIED TO RC Series Circuit



Phasor Diagram of RC series circuit is,



Voltage across R = V_R = IR in phase with I

Voltage across C = $V_c = IX_c$ lagging I by 90^0

Applied voltage $V = IR - jIX_c$

$= I(R - jx_c)$

$$\frac{V}{I} = R - jX_c = Z$$

Z – Impedence of circuit

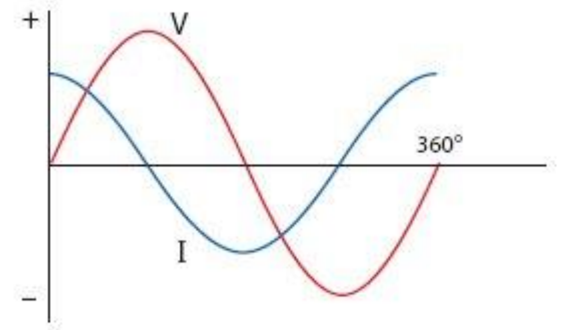
$$|Z| = \sqrt{R^2 + X_c^2}$$

$$\tan\phi = \frac{X_c}{R} = \frac{1/\omega c}{R} = \frac{1}{\omega c R}$$

$$\phi = \tan^{-1}\left(\frac{1}{\omega c R}\right)$$

SINUSOIDAL EXCITATION APPLIED TO RC Series Circuit

ϕ is called Phase angle and it is angle between V and I. Its value lies between 0 and – 90°.



Waveform Representation

$V = V_m \sin \omega t$

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

The current I leads the applied voltage V by an angle ϕ.

From Phasor Diagram,

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

Actual or real power P = VI cosϕ

Reactive or Quardrature power Q = VI sinϕ

Complex or Apparent Power S = P + jQ

= VI

A capacitor having a capacitance of 10 μF is connected in series with a non-inductive resistor of 120Ω across 100V, 50HZ calculate the current, Real power and the Phase Difference between current and supply voltage.

C = 10 μF

R = 120Ω

V = 100V

F = 50Hz

$$X_c = \frac{1}{2\pi fc} = \frac{1}{2\pi \times 50 \times 10 \times 10^{-6}}$$

$$= 318\,\Omega$$

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

$$= 340\,\Omega$$

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

$$= \frac{100}{340}$$

$$= 0.294\, amps$$

$$Phase Difference\, \phi = \tan^{-1}\left(\frac{X_c}{R}\right)$$

$$= \tan^{-1}\left(\frac{318}{120}\right)$$

$$\phi = 69.3^\circ \ \ (Leading)$$

$$\cos\phi = \cos(69.3)^\circ$$

$$= 0.353 \ \ (Leading)$$

$$Power = |V||I|\cos\phi$$

$$= 100 \times 0.294 \times 0.353$$

$$= 10.38\ Watts$$

A Capacitor and Resistor are connected in series to an A . C . Supply of 60volts,50 Hz. The current is 2A and the power dissipated in the Resistor is 80Watts. Calculate the Impedance, Resistance, Capacitance and Power factor

$|V|=60V \quad f=50Hz \quad |I|= 2A$

Power Dissipated =P=80W

$|Z| = \frac{|V}{|I|} = \frac{60}{2} = 30\ \Omega$

$P=I^2R \quad R = \frac{P}{I^2} = \frac{80}{4} = 20\Omega$

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

$$X_C = \sqrt{Z^2 - R^2} = \sqrt{30^2 - 20^2} = 22.36\Omega$$

$X_C = \frac{1}{2\pi f_c} = 22.36\Omega \qquad C=\frac{1}{2\pi\times50\times22.36} \qquad C=142\times 10^{-6}\ F$

Power Factor $=\cos\Phi = \frac{R}{|Z|} = \frac{20}{30} = 0.67$(Leading)

4.A metal filament lamp, Rated at 750 watts, 100V is to be connected in series with a capacitor across a 230V, 60Hz supply. Calculate (i) The capacitance required (ii) The power factor

Rating of the metal filament W =750watts

V_R = 100 volts

W = I^2R = $V_R I$

I =W/V_R

=750/100=7.5A

It is like RC Series Circuit. So

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

$$V_C = \sqrt{V^2 - V_R^2}$$

$$= \sqrt{(230)^2 - (100)^2}$$

$$= 207 volts$$

$$|X_C| = \frac{|V_C|}{|I|} = \frac{207}{7.5}$$

$$= 27.6\Omega$$

$$\frac{1}{2\pi fc} = 27.6$$

$$c = \frac{1}{2\pi \times f \times 27.6} = \frac{1}{2\pi \times 60 \times 27.6}$$

$$= 96.19\ \mu F$$

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

$$|Z| = \frac{|V|}{|I|} = \frac{230}{7.5} = 30.7\Omega$$

$$R = \frac{W}{I^2} = \frac{750}{(7.5)^2}$$

$$= 13.33\Omega$$

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

$$\cos\phi = \frac{13.33}{30.7}$$

$$= 0.434(\text{Leading})$$

Resistor R in series with capacitance C is connected to a 50HZ, 240V supply. Find the value of C so that R absorbs 300 watts at 100 volts. Find also the maximum charge and the maximum stored energy in capacitor.

V = 240 volt

F = 50Hz

Power absorbed by R = 300 watts

Voltage across R = 100 volts

$$|V|^2 = |V_R|^2 + |V_C|^2$$
$$|V_C| = \sqrt{|V|^2 - |V_R|^2}$$
$$= \sqrt{(240)^2 - (100)^2}$$
$$|V_C| = 218.2\,volts$$

For Resistor, Power absorbed = 300 volts

$$|I|^2 R = |V_R||I| = 300$$
$$|I| = \frac{300}{|V_R|} = \frac{300}{100} = 3amps$$
$$|X_C| = \frac{V_C}{|I|} \quad (Apply\ ohm's\ law\ for\ C)$$
$$= \frac{218.2}{3} = 72.73\,\Omega$$
$$\frac{1}{2\pi fc} = 72.73$$
$$C = \frac{1}{2\pi \times 50 \times 72.73} = 43.77 \times 10^{-6} F$$
$$C = 43.77\,\mu F$$

Maximum charge = Q_m = C × maximum V_c

Maximum stared energy = 1/2 (C × maximum V_c^2)

Maximum $V_c = \sqrt{2}$ × Rms value of V_c

= $\sqrt{2}$ × 218.2 = 308.6 volts

Maximum charge = Q_m = $43.77 \times 10^{-6} \times 308.6$

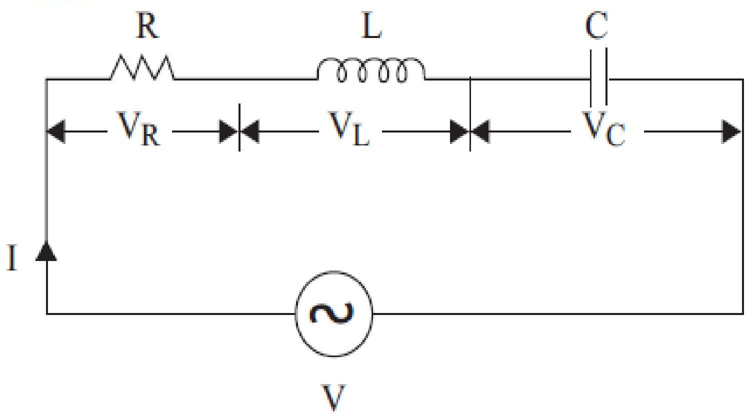
= 0.0135 Coulomb

Maximum energy stored

= $\frac{1}{2} (43.77 \times 10^{-6}) (308.6)^2$

= 2.08 joules.

SINUSOIDAL EXCITATION APPLIED TO RLC Series Circuit



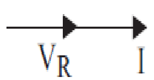
- **Phasor diagram**

  Take I as reference

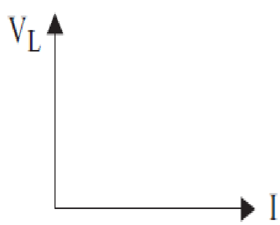
  $V_R = I \times R$

  $V_L = I \times X_L$

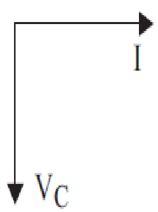
  $V_C = I \times X_C$



For pure Resistance



For pure Inductance

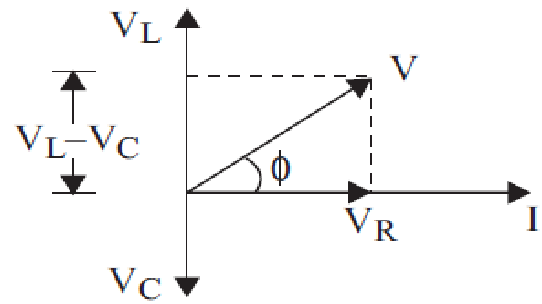


For pure Capacitance

Assume Inductive reactance > Capacitive reactan

$X_L > X_C$

Then $V_L > V_C$



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

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

$$= |I|^2 \, [R^2 + (X_L - X_C)^2]$$

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

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

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

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

RLC Series Circuit

- **Three cases of Z**

Case 1 If $X_L > X_C$

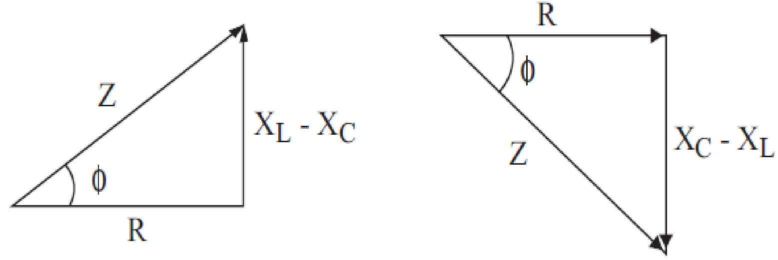
The circuit behaves like RL circuit. Current lags behind voltage. So powe factor is lagging.

Case 2 If $X_L < X_C$

The circuit behaves like RC circuit Current leads applied voltage. So powe factor is leading.

Case 3 When $X_L = X_C$, the circuit behaves like pure resistive circuit. Current is in phase with the applied voltage. So power factor is unity.

Impedance triangle



1. If applied voltage $v = V_m \sin \omega t$ and ϕ is phase angle then 'i' is g
   1) $i = I_m \sin(\omega t - \phi)$, for $X_L > X_C$
   2) $i = I_m \sin(\omega t + \phi)$, for $X_L < X_C$
   3) $i = I_m \sin \omega t$ for $X_L = X_C$
2. Impedance for RLC series circuit in complex form (or) rectangular form is given by

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

In a RLC series circuit, the applied voltage is 5V. Drops across the resistance and inductance are 3V and 1V respectively. Calculate the voltage across the capacitor. Draw the phasor diagram.

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

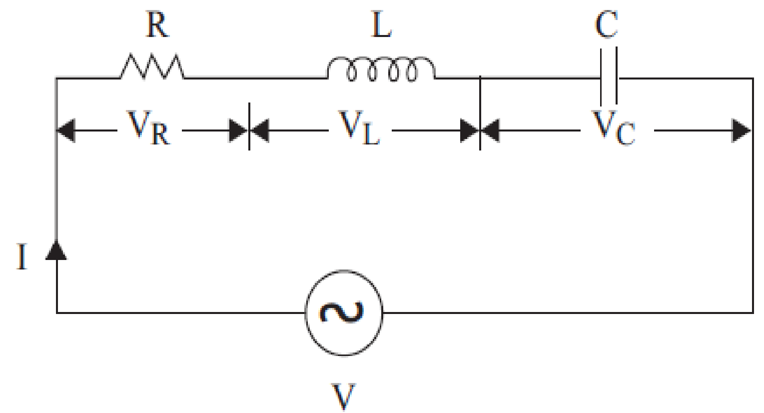
$$(V_L - V_C)^2 = V^2 - V_R^2$$

$$= 25 - 9 = 16$$

$$V_L - V_C = \pm 4$$

$$V_C = V_L \pm 4 = 1 + 4$$

$$V_C = 5V$$



A coil of resistance 10Ω and in inductance of 0.1H is connected in series with a capacitance of 150µF across a 200v, 50HZ supply. Calculate

a) the inductive reactance of the coil.

b) the capacitive reactance

c) the reactance

d) current

e) power factor

$R = 10\Omega$

$L = 0.1\ H$

$C = 150\ \mu F \quad = 150 \times 10^{-6}\ F$

$V = 200V \qquad f = 50\ Hz$

Solution

a) $X_L = 2\pi f L = 2\pi\,(50)\,0.1$

$= 31.4\ \Omega$

b) $$X_C = \frac{1}{2\pi fc} = \frac{1}{2\pi\,(50)\,(150\times10^{-6})}$$

$=21.2\Omega$

c) the reactance $X = X_L - X_C$

$= 31.4 - 21.2$

$= 10.2\ \Omega$ (Inductive)

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

$$= \sqrt{10^2 + (10.2)^2}$$

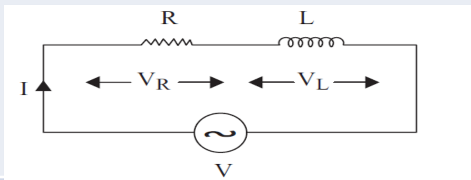
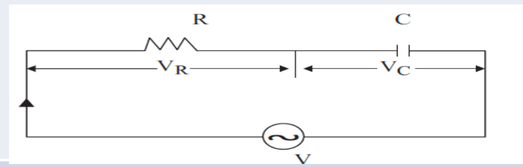
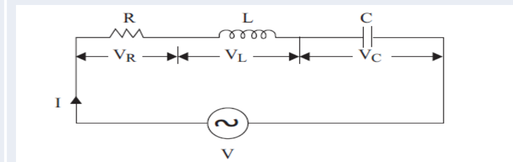
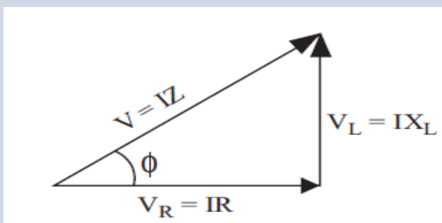
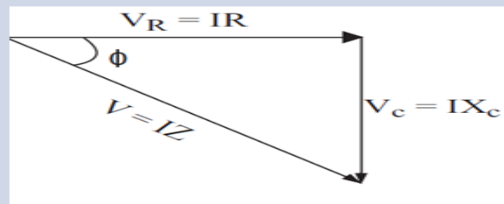
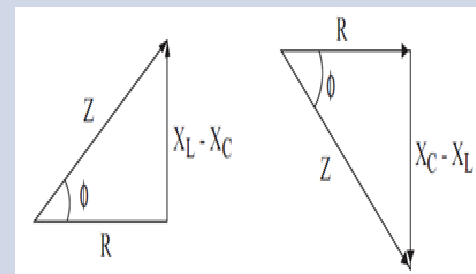
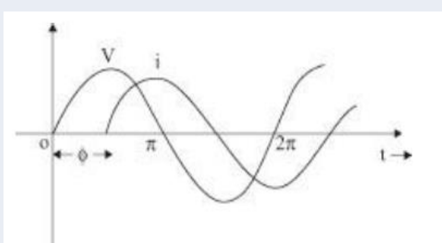
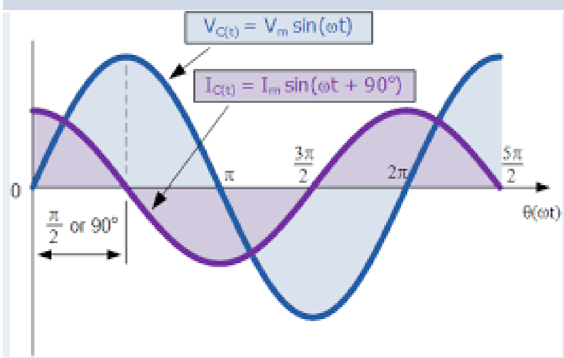
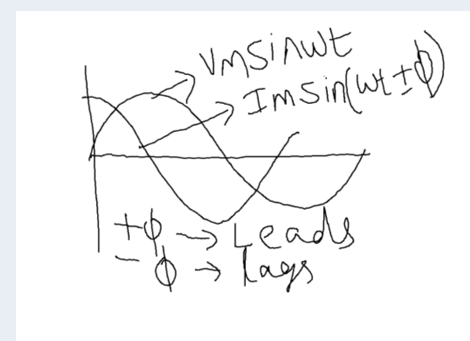
$$= 14.28\Omega (Inductive)$$

$$I = \frac{|V|}{|Z|} = \frac{200}{14.28} = 14 amps$$

e)

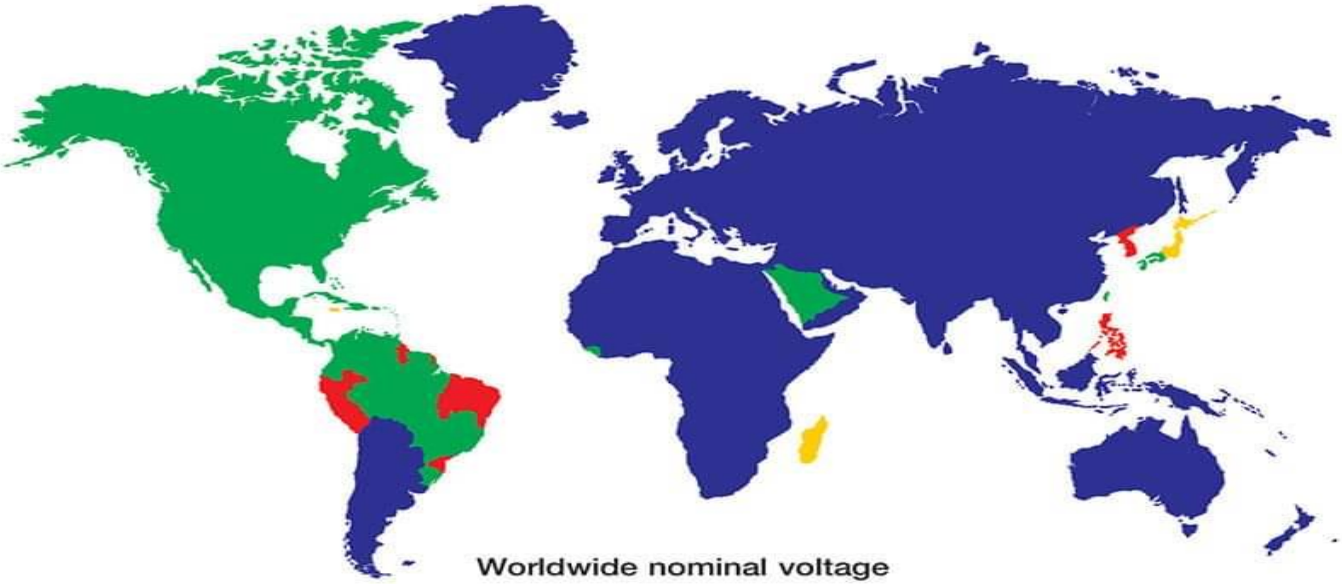
$$P.F = \cos\phi = \frac{R}{|Z|} = \frac{10}{14.28}$$

= 0.7 (lagging) (I lags behind V)

QUANTITY	SINUSOIDAL EXCITATION TO RL SERIES CIRCUITS	SINUSOIDAL EXCITATION TO RC SERIES CIRCUITS	SINUSOIDAL EXCITATION TO RLC SERIES CIRCUITS
Voltage & Current	V=VmSinwt I=ImSin(wt-ø) W=2πf	V=VmSinwt I=ImSin(wt+ø) W=2πf	V=VmSinwt I=ImSin(wt±ø) W=2πf
Circuit Diagram			
Phase Diagram			
Waveform Representation			

Impedance (Z)	$Z=R+jXL$ $Z=\sqrt{R^2 + XL^2}$	$Z=R - jXc$ $Z=\sqrt{R^2 + Xc^2}$	$XL>Xc \quad Z=R + j(XL-Xc)$ $XL<Xc \quad Z=R - j(Xc-XL)$ $XL=Xc \quad Z=R$ $Z=\sqrt{R^2 + (XL-Xc)^2}$
Current	Im=Vm/Z	Im=Vm/Z	Im= Vm/Z
Phase angle	Ø=tan-1(XL/R)	Ø=tan-1(Xc/R)	Ø=tan-1(XL-Xc/R)
Power factor Cos ɸ	R/Z	R/Z	R/Z
Reactance	XL=LW	Xc=1/CW	XL=LW Xc=1/CW
Power	Real Power P=VI Cos ø(watts) Reactive Power Q=VI sinø(VAR) Apparent Power S=VI(VA)	Real Power P=VI Cos ø(watts) Reactive Power Q=VI sinø(VAR) Apparent Power S=VI(VA)	Real Power P=VI Cos ø(watts) Reactive Power Q=VI sinø(VAR) Apparent Power S=VI(VA)

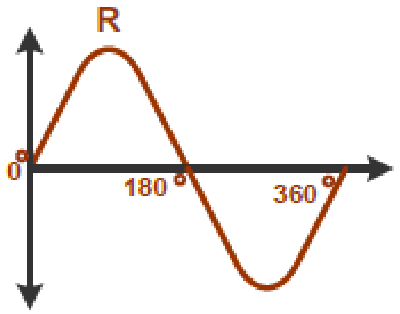
3 Phase Power Supply System



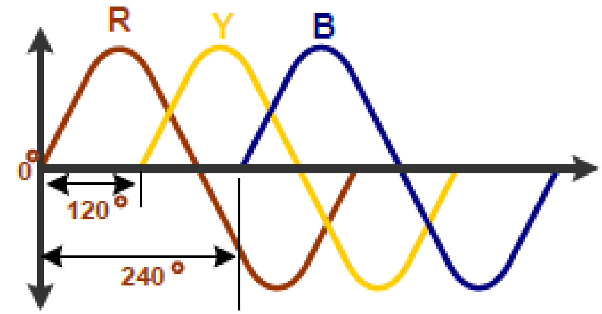
Worldwide nominal voltage

Single Phase	3 Phase
220-240 V - 50 Hz	380-415 V - 50 Hz
220-240 V - 60 Hz	380-415 V - 60 Hz
100-127 V - 60 Hz	170-220 V - 60 Hz
100-127 V - 50 Hz	170-220 V - 50 Hz

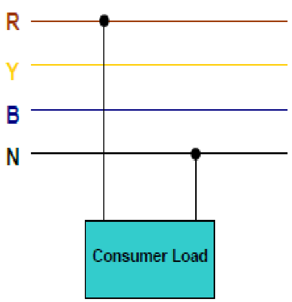
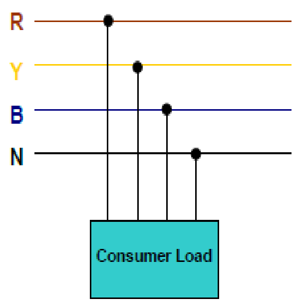
Single Phase Waveform

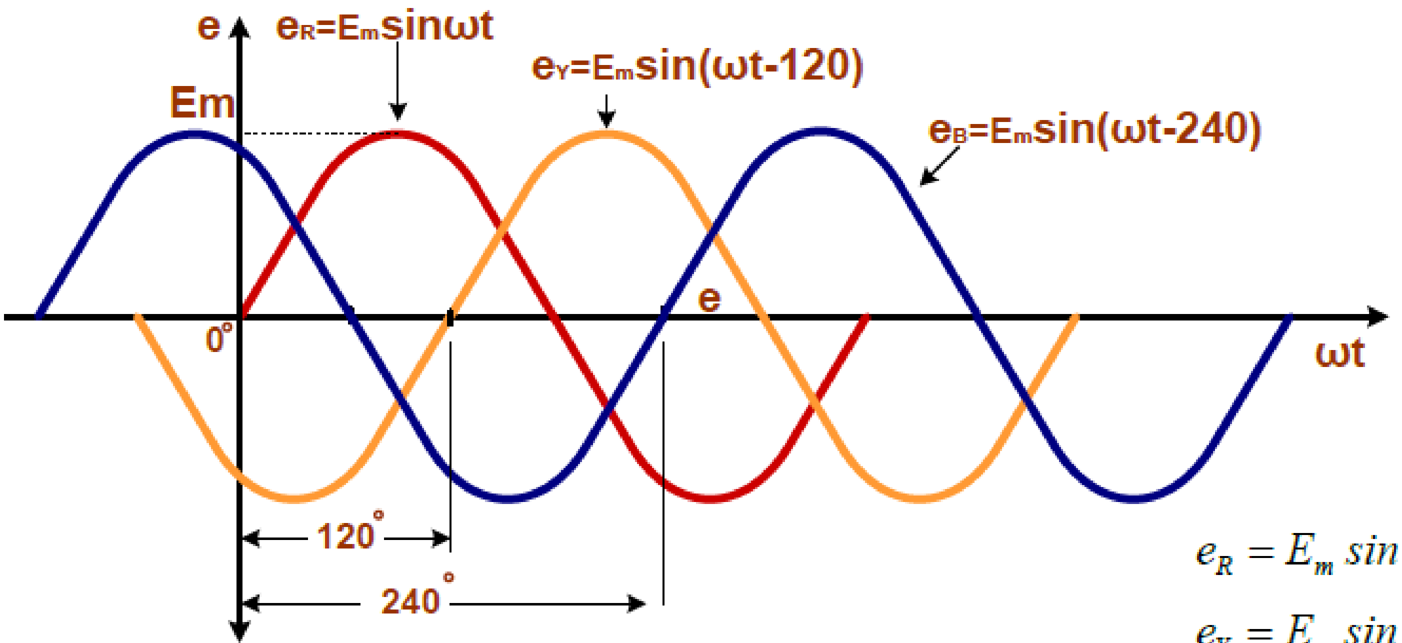


3 Phase Waveform



Comparison of Single & 3 Phase Power Supply

Number of wire	Require two wires for completing the circuit	Requires four wires for completing the circuit
Voltage	Carry 230V	Carry 415V
Phase Name	Split phase	No other name
Network	Simple	Complicated
Loss	Maximum	Minimum
Power Supply Connection		
Efficiency	Less	High
Economical	Less	More
Uses	For home appliances.	In large industries and for running heavy loads.



$$e_R = E_m \sin \omega t$$

$$e_Y = E_m \sin\left(\omega t - 120^0\right)$$

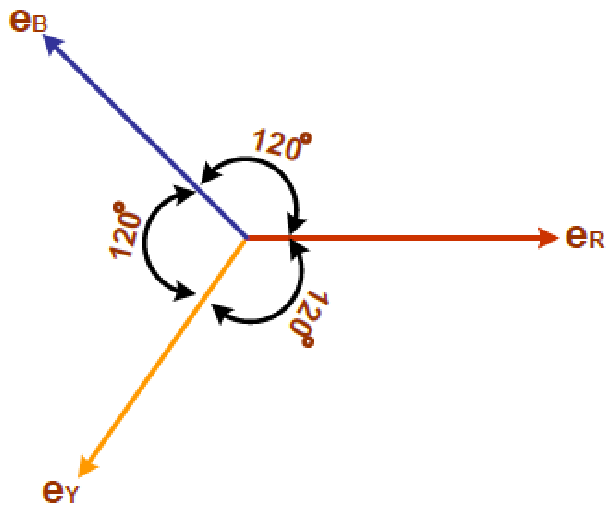
$$e_B = E_m \sin\left(\omega t - 240^0\right)$$

Vector Representation of 3Phase Voltage

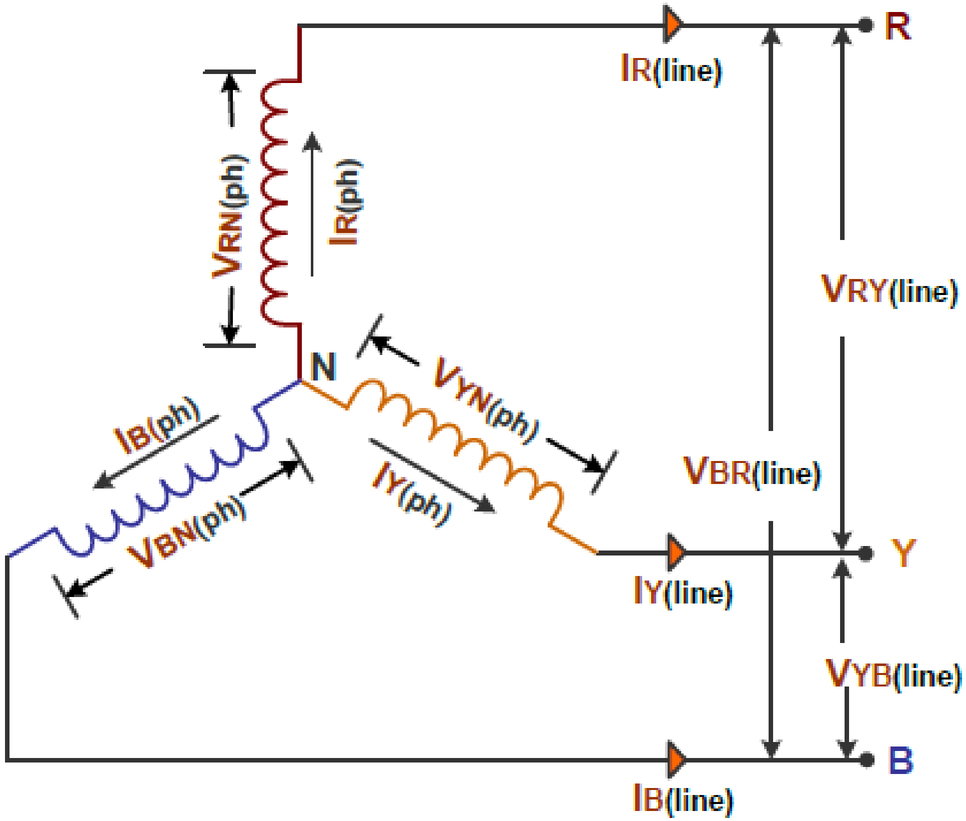
$$e_R = E_m \sin \omega t$$

$$e_Y = E_m \sin\left(\omega t - 120^0\right)$$

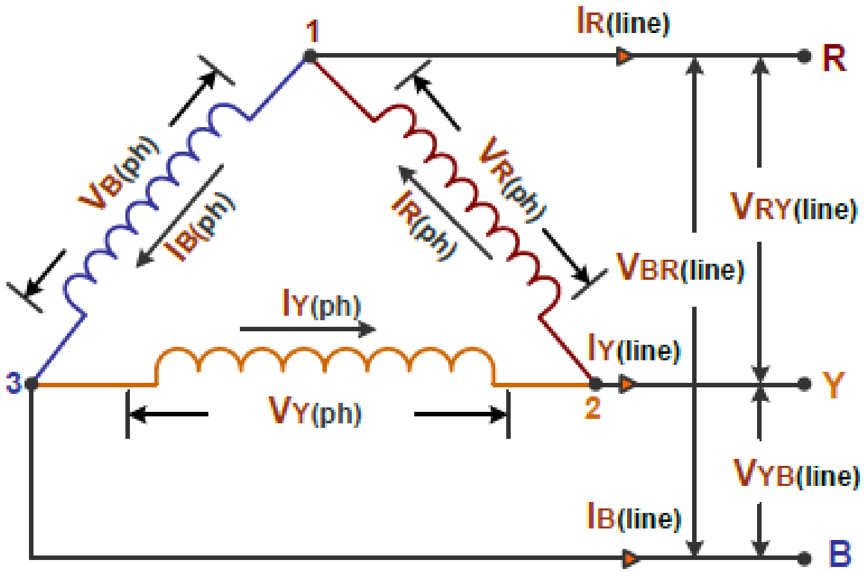
$$e_B = E_m \sin\left(\omega t - 240^0\right)$$



Star Connection



Delta Connection



Basic Definition of 3 Phase System

- **Phase current**

  It is defined as the current flowing through each phase winding or load. It is denoted by I_{ph}.

  Phase current $I_{R(ph)}$, $I_{Y(ph)}$ and $I_{B(Ph)}$ measured in each phase of star and delta connection. respectively.

- **Line current**

  It is defined as the current flowing through each line conductor. It denoted by I_L.

  Line current $I_{R(line)}$, $I_{Y(line)}$, and $I_{B((line)}$ are measured in each line of star and delta connection.

- **Phase sequence**

  The order in which three coil emf or currents attain their peak values is called the phase sequence. It is customary to denoted the 3 phases by the three colours. i.e. red (R), yellow (Y), blue (B).

- **Balance System**

  A system is said to be balance if the voltages and currents in all phase are equal in magnitude and displaced from each other by equal angles.

Basic Definition of 3 Phase System

- **Unbalance System**

  A system is said to be unbalance if the voltages and currents in all phase are unequal in magnitude and displaced from each other by unequal angles.

- **Balance load**

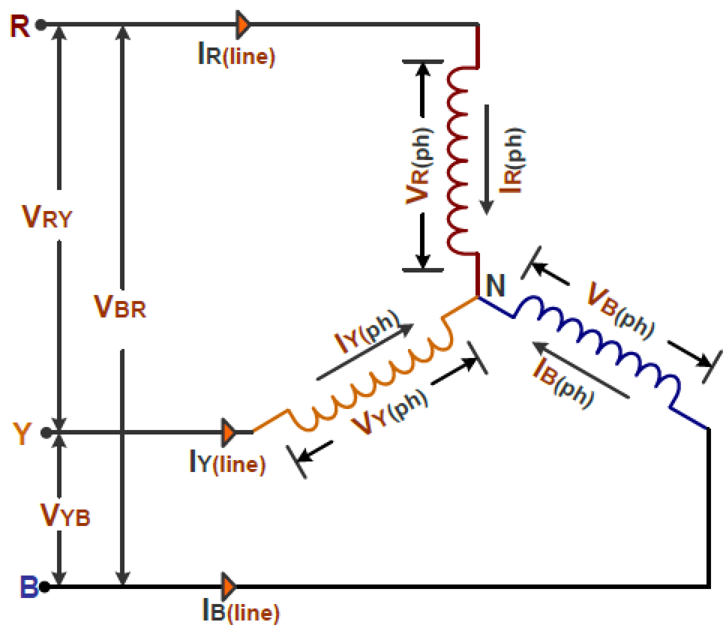
  In this type the load in all phase are equal in magnitude. It means that the load will have the same power factor equal currents in them.

- **Unbalance load**

  In this type the load in all phase have unequal power factor and currents.

Relation between line and phase values for voltage and current in case of balanced star connection.

Circuit Diagram



Let,

line voltage, $V_{RY} = V_{BY} = V_{BR} = V_L$

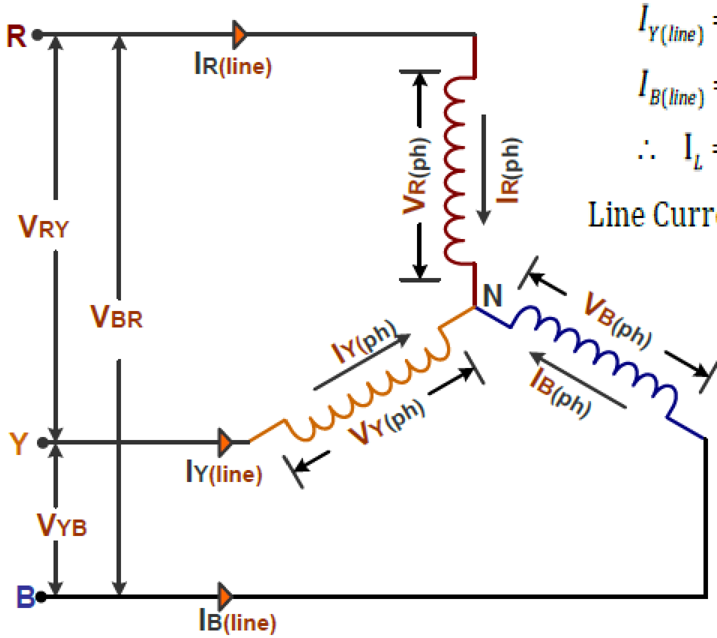
phase voltage, $V_{R(ph)} = V_{Y(ph)} = V_{B(ph)} = V_{ph}$

line current, $I_{R(line)} = I_{Y(line)} = I_{B(line)} = I_{line}$

phase current, $I_{R(ph)} = I_{Y(ph)} = I_{B(ph)} = I_{ph}$

Relation between line and phase current

Circuit Diagram



For star connection, line current I_L and phase current I_{ph} both are same.

$$I_{R(line)} = I_{R(ph)}$$

$$I_{Y(line)} = I_{Y(ph)}$$

$$I_{B(line)} = I_{B(ph)}$$

$$\therefore \quad I_L = I_{ph}$$

Line Current = Phase Current

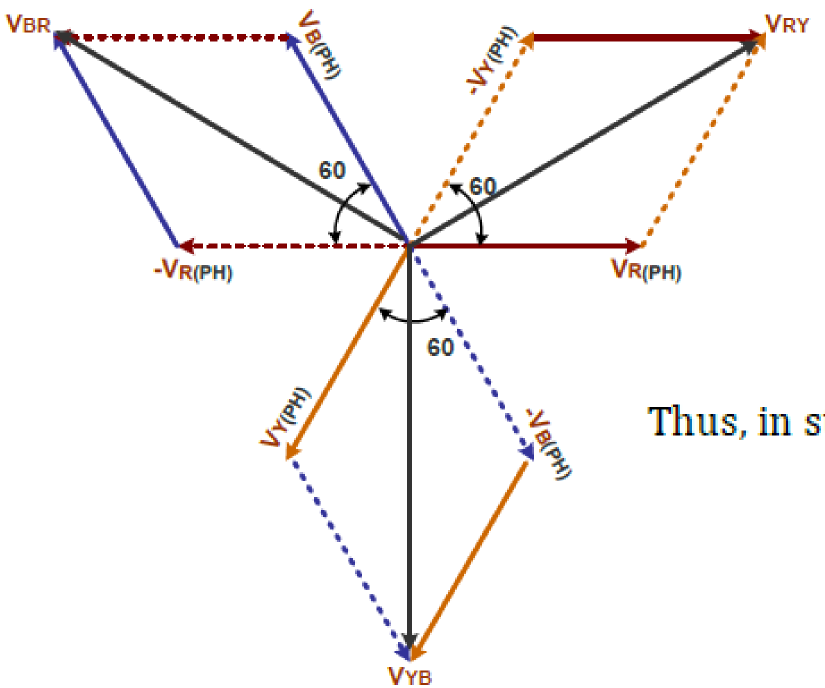
Relation between line and phase voltage

For star connection,

$$V_{RY} = V_{R(ph)} - V_{Y(ph)}$$

$$V_{YB} = V_{Y(ph)} - V_{B(ph)}$$

$$V_{BR} = V_{B(ph)} - V_{R(ph)}$$



From parallelogram,

$$V_{RY} = \sqrt{V_{R(ph)}^{2} + V_{Y(ph)}^{2} + 2V_{R(ph)}V_{Y(ph)}\cos\theta}$$

$$\therefore V_L = \sqrt{V_{ph}^{2} + V_{ph}^{2} + 2V_{ph}V_{ph}\cos 60^\circ}$$

$$\therefore V_L = \sqrt{V_{ph}^{2} + V_{ph}^{2} + 2V_{ph}^{2} \times \left(1/2\right)}$$

$$\therefore V_L = \sqrt{3V_{ph}^{2}}$$

$$\therefore V_L = \sqrt{3}V_{ph}$$

Similarly, $V_{YB} = V_{BR} = \sqrt{3}\ V_{ph}$

Thus, in star connection Line voltage = $\sqrt{3}$ Phase voltage

Relation between line and phase voltage

For star connection,

$$V_{RY} = V_{R(ph)} - V_{Y(ph)}$$

$$V_{YB} = V_{Y(ph)} - V_{B(ph)}$$

$$V_{BR} = V_{B(ph)} - V_{R(ph)}$$

Power

$$P = V_{ph}I_{ph}\cos\phi + V_{ph}I_{ph}\cos\phi + V_{ph}I_{ph}\cos\phi$$

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

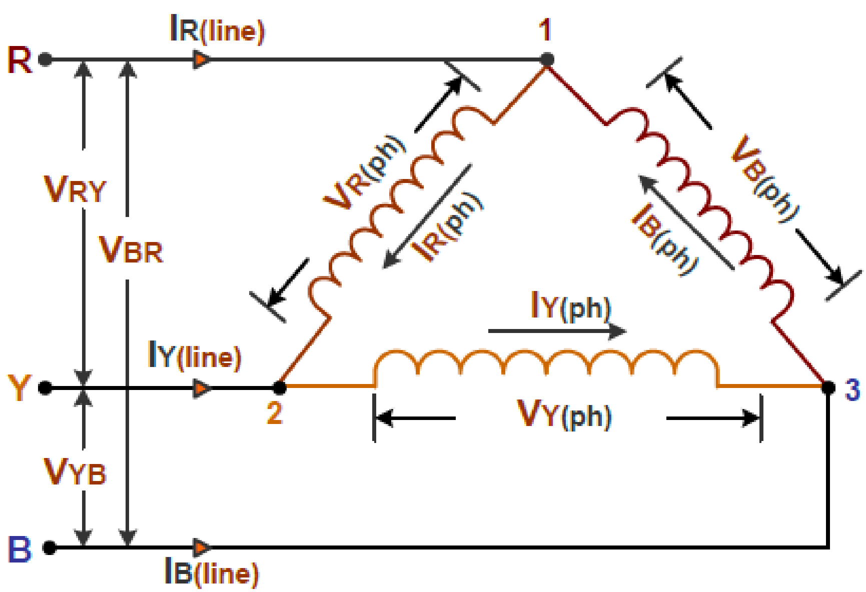
$$P = 3\left(\frac{V_L}{\sqrt{3}}\right)I_L\cos\phi$$

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

2^{nd} Derivation

Relation between line and phase values for voltage and current in case of balanced delta connection.

Relation between line and phase values for voltage and current in case of balanced delta connection.



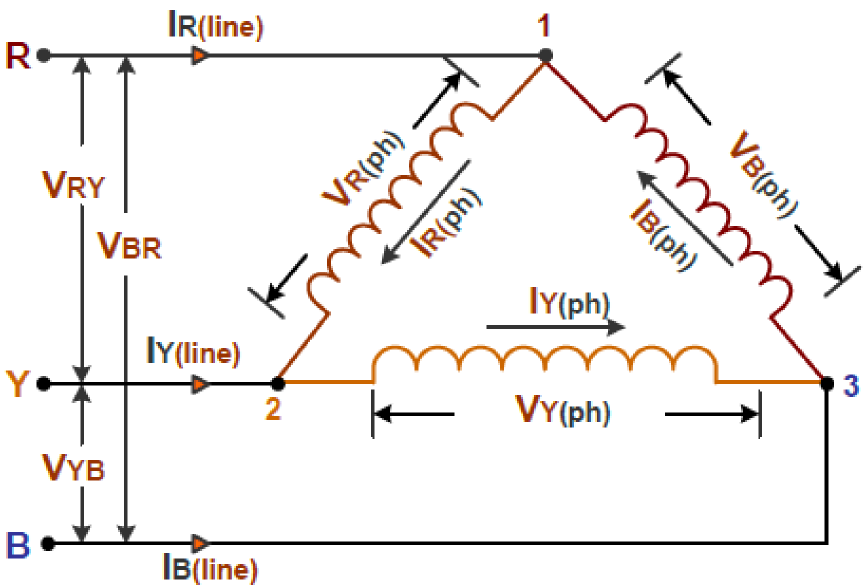
Let,

Line voltage, $V_{RY} = V_{YB} = V_{BR} = V_L$

Phase voltage, $V_{R(ph)} = V_{Y(ph)} = V_{B(ph)} = V_{ph}$

Line current, $I_{R(line)} = I_{Y(line)} = I_{B(line)} = I_{line}$

Phase current, $I_{R(ph)} = I_{Y(ph)} = I_{B(ph)} = I_{ph}$



Relation between line and phase current

- For delta connection,

$$I_{R(line)} = I_{R(ph)} - I_{B(ph)}$$

$$I_{Y(line)} = I_{Y(ph)} - I_{R(ph)}$$

$$I_{B(line)} = I_{B(ph)} - I_{Y(ph)}$$

Relation between line and phase voltage

- For delta connection line voltage V_L and phase voltage V_{ph} both are same.

$$V_{RY} = V_{R(ph)}$$

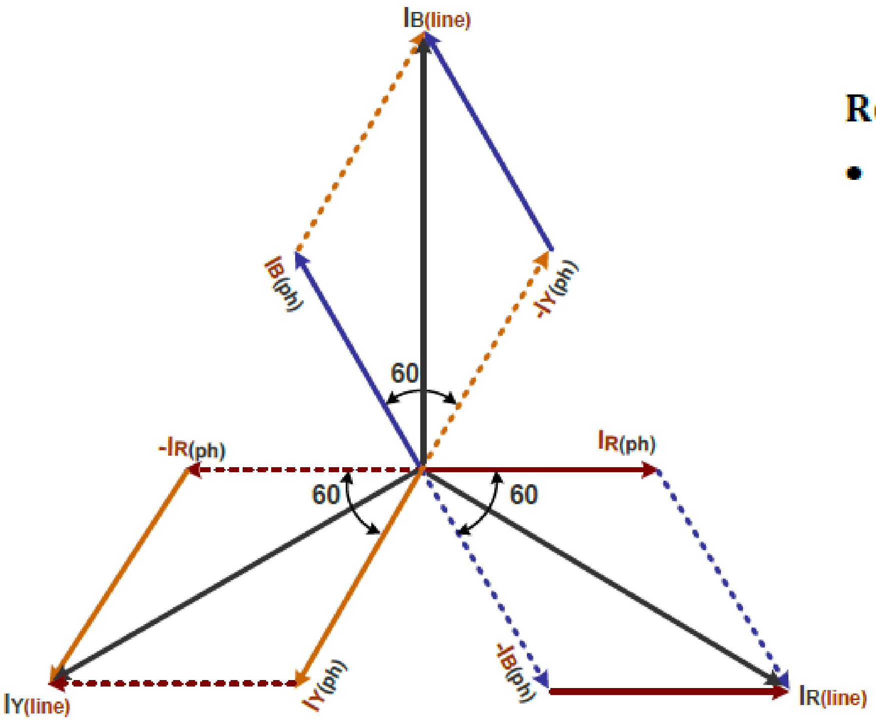
$$V_{YB} = V_{Y(ph)}$$

$$V_{BR} = V_{B(ph)}$$

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

Line voltage = Phase Voltage

Phasor Diagram



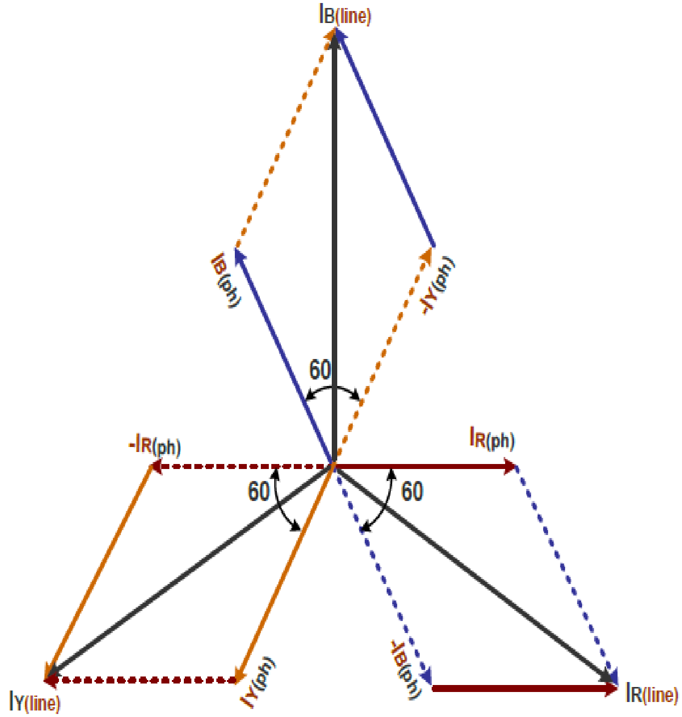
Relation between line and phase current

- For delta connection,

$$I_{R(line)} = I_{R(ph)} - I_{B(ph)}$$

$$I_{Y(line)} = I_{Y(ph)} - I_{R(ph)}$$

$$I_{B(line)} = I_{B(ph)} - I_{Y(ph)}$$



So, considering the parallelogram formed by I_R and I_B.

$$I_{R(line)} = \sqrt{I_{R(ph)}^2 + I_{B(ph)}^2 + 2I_{R(ph)}I_{B(ph)}\cos\theta}$$

$$\therefore I_L = \sqrt{I_{ph}^2 + I_{ph}^2 + 2I_{ph}I_{ph}\cos 60^\circ}$$

$$\therefore I_L = \sqrt{I_{ph}^2 + I_{ph}^2 + 2I_{ph}^2 \times \left(\frac{1}{2}\right)}$$

$$\therefore I_L = \sqrt{3I_{ph}^2}$$

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

Similarly, $I_{Y(line)} = I_{B(line)} = \sqrt{3}\ I_{ph}$

Thus, in delta connection Line current = $\sqrt{3}$ Phase current

Power

$$P = V_{ph} I_{ph} \cos\phi + V_{ph} I_{ph} \cos\phi + V_{ph} I_{ph} \cos\phi$$

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

$$P = 3 V_L \left(\frac{I_L}{\sqrt{3}} \right) \cos\phi$$

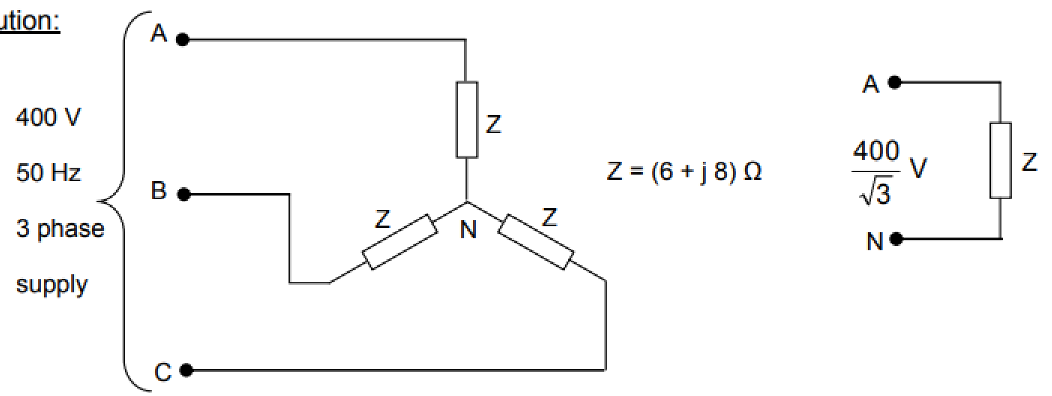
$$\therefore P = \sqrt{3} V_L I_L \cos\phi$$

SYSTEM	STAR CONNECTION	DELTA CONNECTION
LINE VOLTAGE AND PHASE VOLTAGE	$VL=\sqrt{3}\ VPH$	$VL=VPH$
LINE CURRENT AND PHASE CURRENT	$IL= IPH$	$IL=\sqrt{3}\ IPH$
THREE PHASE POWER	$P=\sqrt{3}\ VL\ IL\ COS\ ø$	$P=\sqrt{3}\ VL\ IL\ COS\ ø$

A balanced three-phase load connected in star consists of (6 + j 8) Ω impedance in each phase. It is connected to a three-phase supply of 400 V, 50 Hz. Find (a) magnitude of phase current and line current (b) per phase power and (c) total power

Problem No.2

<u>Solution:</u>



(a) (b)

Given three-phase circuit and its single-phase equivalent are shown above. Referring to Fig. (b), Voltage $E_{ph} = 400 / \sqrt{3} = 230.94$ V; $Z = (6 + j\,8)\ \Omega = 10\angle 53.13^0\ \Omega$

(a) Phase current, $I_{ph} = 230.94 / 10 = 23.094$ A

Line current, $I_\ell = I_{ph} = 23.094$ A

(b) Per phase power, $P = E_{ph}\, I_{ph} \cos\theta = 230.94 \times 23.094 \times \cos 53.13^0 = 3200$ W

(c) Total power, $P_T = \sqrt{3}\ E_\ell\, I_\ell \cos\theta = \sqrt{3} \times 400 \times 23.094 \times \cos 53.13^0 = 9600$ W

Alternatively, total power, $P_T = 3\,P = 9600$ W

Problem No.3

Each phase of a three-phase alternator, generates a voltage of 3810.5 V and can carry a maximum current of 30 A. Find the line current, line voltage and total kVA capacity, if the alternator is connected in (a) star (b) delta.

Solution: Given data: E_{ph} = 3810.5 V; I_{ph} = 30 A

Star

Line current $I_\ell = I_{ph}$ = 30 A

Line voltage $E_\ell = \sqrt{3}\ E_{ph}$ = 6600 V

Total kVA = $\sqrt{3}\,E_\ell\, I_\ell$

= $\sqrt{3} \times 6600 \times 30 \times 10^{-3}$

= 342.95

Delta

Line current $I_\ell = \sqrt{3}\ I_{ph}$ = 51.9615 A

Line voltage E_ℓ = 3810.5 V

Total kVA = $\sqrt{3}\,E_\ell\, I_\ell$

= $\sqrt{3} \times 3810.5 \times 51.9615 \times 10^{-3}$

= 342.95

PART-A

1.In a series RLC circuit, the applied voltage is 5v, drop across resistance and inductance are 3v and 1v respectively. Calculate the voltage across the capacitor.

$$V = V_R + V_L + V_C$$

$$5 = 3 + 1 + V_C$$

$$\boxed{V_C = 1V}$$

2.Write the formulae for calculating the total power in 3-Phase circuit.

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

3. Define RMS value.

7. R.M.S value [Root Mean Square]

The steady current when flowing through a given resistor for a given time produces the same amount of heat as produced by an alternating current when flowing through the same resistor for the same time is called R.M.S value of the alternating current.

4. Write the demerits of low power factor.

Real Power get reduced. The usual reason for the low power factor is because of the inductive load. The current in the inductive load lag behind the voltage. The power factor is therefore lagging. Since both the capital and running cost are increased. efficiency of the system is reduced.

6. The voltage and current sinusoid of an element are i(t) = 10Sin314t and v (t) = 100Cos314t. What is the frequency of the sinusoid.

v (t) = 100Cos314t, i(t) = 10Sin314t

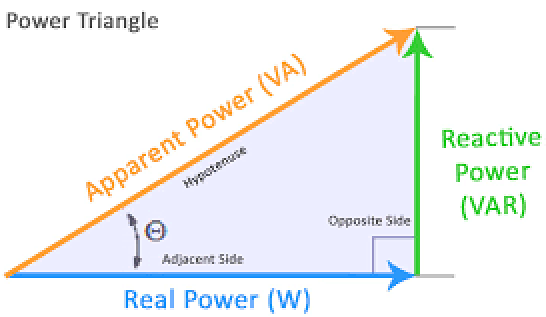
W=2*pi*f

314=2*pi*f

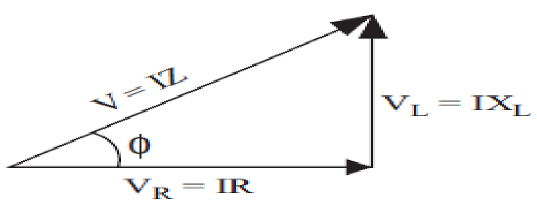
F=50 Hz

7. Differentiate between apparent power, active power and reactive power with help of power triangle.

- Real Power P=VI Cos ø(watts)
- Reactive Power Q=VI sinø(VAR)
- Apparent Power S=VI(VA)



8. Draw the phasor relationship between voltage and current in a RL circuit.



PART-B

1.For the case derive the instantaneous value of V and I, Impedance, Average power, Power factor, Instantaneous power and the relevant phasors. Explain the behavior of AC through R-L series circuit

2. Discuss the effect of R-C series circuit of V, I, power and power-factor in a single phase AC circuit with relevant expression.

3. Draw and discuss the current, power and power factor in a RLC series circuit.

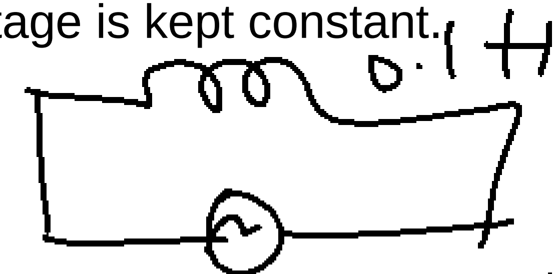
4. Explain the behavior of ac through (a) Pure R (b) Pure L (c) Pure C circuits.

5. Derive RMS,average value,form factor and Peak factor of Sinusoidal Voltage/Full wave Rectifier current.

6. Derive RMS,average value,form factor and Peak factor of halfwave Rectifier voltage/current

7.Derive three phase power in a balanced three phase star or delta connected load

8. An alternating voltage of 200V, 50Hz is applied to a coil of negligible resistance and inductance of 0.1H. Find the current draw by the coil. What will be the effect on the current drawn if (i) frequency is reduced to half (ii) frequency is doubled. The supply voltage is kept constant.



200V, 50 HZ

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

$$X_L = 31.4\,\Omega$$

$$I = \frac{V}{Z} = \frac{200}{31.4} = 6.3\,A$$

(i) $f = 25\,Hz$

$$X_L = 15.7\,\Omega$$

$$I = \frac{200}{15.7} = 12.7\,A$$

(ii) $f = 100\,Hz$

$$X_L = 62.8\,A\Omega$$

$$I = 3.18\,A$$

9.A series R-L circuit has R = 5Ω and L = 12mH connected to 230V, 50Hz power supply. Calculate (i) Reactance (ii) Impedence (iii) Current drawn from the circuit (iv) p.f. of the circuit

(v) Draw the power triangle

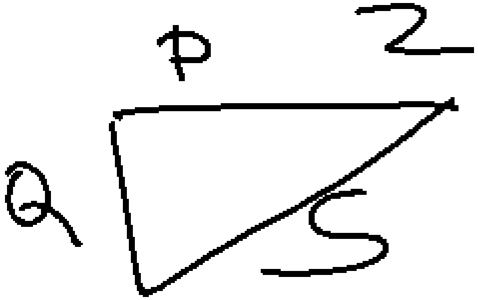
(i) $X_L = L\omega = 3.7\Omega$

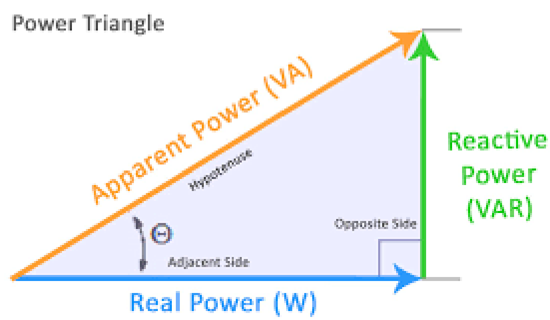
(ii) $Z = \sqrt{R^2 + X_L^2} = 6.22\Omega$

(iii) $I = \frac{V}{Z} = \frac{230}{6.22} = 36.9A$

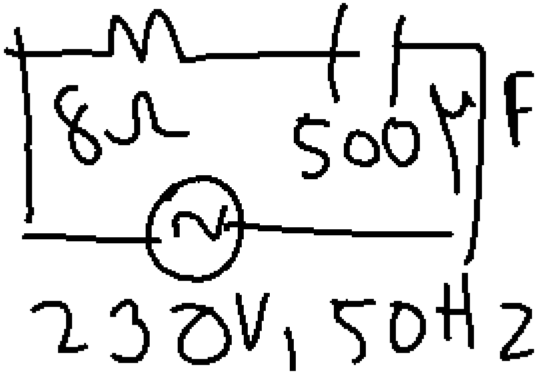
(iv) $\cos\phi = \frac{R}{Z} = \frac{25}{} = 0.677$ (lag)

(v)





10 A voltage of 230 V,50 HZ is applied to a series RC circuit (R=8 ohms, C=500 microfarads). Determine the current, power and power factor. Draw the phasor diagram also.



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

$$Z = \sqrt{R^2 + \left(\frac{1}{C\omega}\right)^2}$$

$$Z = \sqrt{8^2 + (6.3)^2}$$

$$Z = 10.14\,\Omega$$

(i) $I = \frac{V}{Z} = \frac{230}{10.14} = 22.68A$

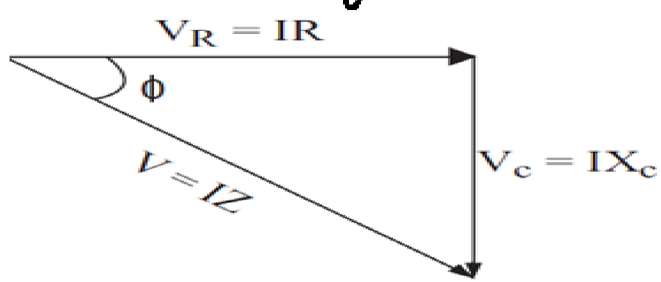
(ii) $\cos\theta = \frac{R}{Z} = \frac{8}{10.14} = 0.78$ (Lead)

(iii) $P = VI\cos\theta$

$= 230 * 22.68 * 0.78$

$P = 4068.7$ watts

(iv) Phasor diagram



THANK YOU