UNIT-II AC Circuits

(1 Marks)

1.	**Taxonomy Level: Remember**	**CO: C114.2**	**PI: 3.2.3**

Define inductive reactance

Inductive reactance

The opposition offered by an inductor in an AC circuit for the flow of current through it is called inductive reactance. It is represented by X_L and the units are ohms.

$$X_L = \omega L$$

2.	**Taxonomy Level: Remember**	**CO: C114.2**	**PI: 3.2.3**

Define Impedance?

Impedance

The opposition offered by an AC circuit for the flow of current through it is called impedance. It is represented by Z and the units are ohms.

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

3.	**Taxonomy Level: Remember**	**CO: C114.2**	**PI: 3.2.3**

Define Power factor.

Power factor:

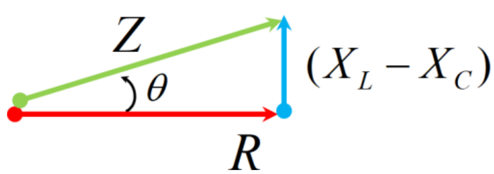
It is the cosine of angle between voltage phasor to current phasor in AC circuits.

Power factor, p.f = cosθ

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

4.	**Taxonomy Level: Remember**	**CO: C114.2**	**PI: 3.2.3**

Draw impedance triangle?



R =Resistance

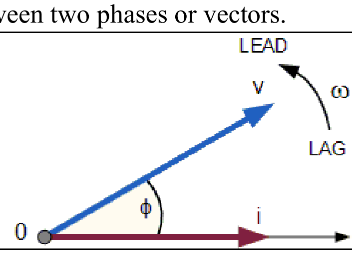
X_L= Inductive Reactance X_C=Capacitive Reactance

Z = Impedance

5.	**Taxonomy Level: Remember**	**CO: C114.2**	**PI: 3.2.3**

Define phase difference

It is the Difference between two phases or vectors.



(3 Marks)

1.	**Taxonomy Level: Remember**	**CO: C114.2**	**PI:3.2.3**

Define resonant frequency and derive the formula for it.

Resonant frequency

The frequency at which inductive reactance is equals to capacitive reactance that frequency is called as resonant frequency.

$$X_L = \omega L$$

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

At Resonance

$$X_L = X_C$$

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

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

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

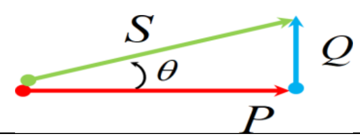
2.	**Taxonomy Level: Remember**	**CO: C114.2**	**PI: 3.2.3**

Mention the various types of powers in AC circuits& represent the power triangle.

There exist three powers in an AC circuit. Those are,

1. Real Power
2. Reactive Power
3. Apparent Power

Power triangle for capacitive load is,



3.	**Taxonomy Level: Remember**	**CO: C114.2**	**PI: 3.2.3**

A series RLC network consists of R=3Ω,L=2mHandC=0.4μF.Determine the Angular resonant frequency.

Given data

R=3Ω

L=2 mH=2×10^{-3}H C =

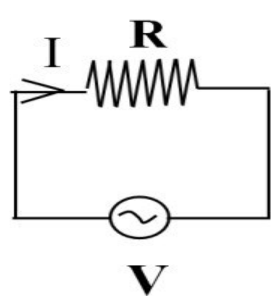
0.4μF

$$\omega_r = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{2\times10^{-3}\times0.4\times10^{-6}}} = 35355.33\,\text{rad/sec}$$

4.	**Taxonomy Level: Remember**	**CO: C114.2**	**PI: 3.2.3**

Find the impedance of R circuit with AC excitation

Circuit Diagram:



Voltage-Current-Impedance:

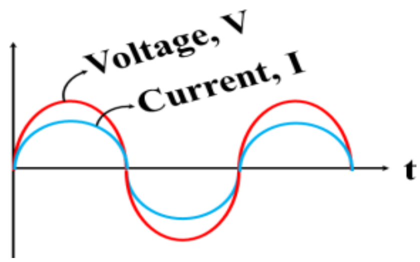
$$V = V_0 \sin\omega t$$

$$I = \frac{V_0 \sin \omega t}{R}$$

$$I = I_0 \sin \omega t$$

$$Z = R$$

Phasor Diagram



Vector Diagram:

5.		**Taxonomy Level: Remember**	**CO: C114.2**	**PI: 3.2.3**
		What is the relationship among the phase and line values in a i) star and ii) delta connected networks?		

i) Star connected Network:-

$$V_{Phase} = \frac{V_L}{\sqrt{3}}$$

$$I_{Phase} = I_{Line}$$

ii) Delta Connected Network:-

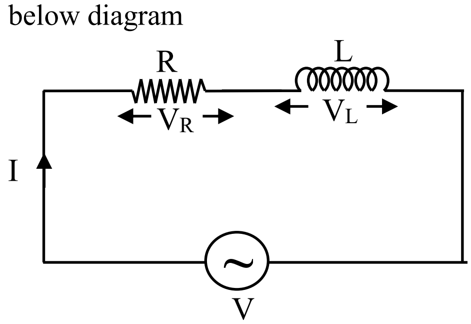
$$V_{Phase} = V_{Line}$$

$$I_{Phase} = \frac{I_L}{\sqrt{3}}$$

(5 Marks)

1.		**Taxonomy Level: Understand**	**CO: C114.2**	**PI: 3.2.3**
		Analyze series RL circuit and obtain the impedance triangle for the circuit if it is excited with ac supply		

Consider a series RL circuit connected with alternating voltage $V = V_m \sin \omega t$ as shown in below diagram



In the above diagram the current passes through the RL circuit then it causes two voltage drops. Those are,

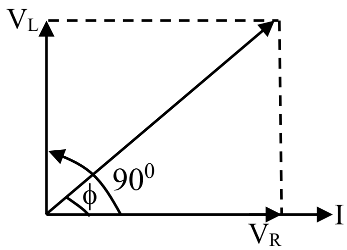
Voltage Drop across pure resistance , $V_R = I \times R$

Voltage drop across pure inductance, $V_L = I \times X_L$

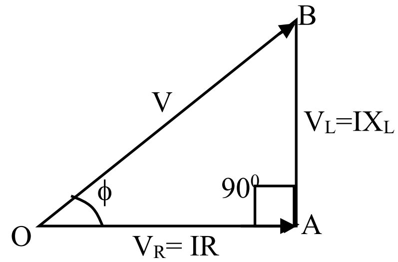
If we take voltage phasors then according to KVL, the addition of phasors is

$$\overline{V} = \overline{V_R} + \overline{V_L} = \overline{IR} + \overline{IX_L}$$

From the above equation the phasor diagram and voltage triangle are obtained as,



Phasor diagram



Voltage triangle

From the above diagram

V_R is inphase with I

I lags V_L by 90^0

from $\angle OAB$

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

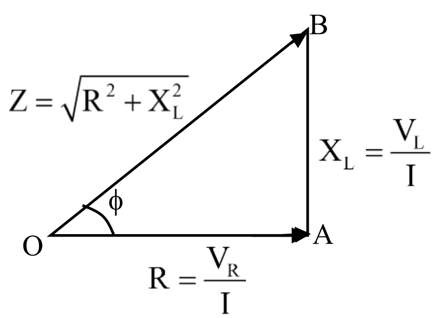
$$V = \sqrt{(IR)^2 + (IX_L)^2}$$

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

$$V = I.Z$$

<u>Impedance & Impedance triangle :-</u>

The impedance for RL-series circuit is $Z = R + jX_L$ where $X_L = 2\pi fL$



From $\angle OAB$

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

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

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

2.	**Taxonomy Level: Understand**	**CO: C114.2**	**PI: 3.2.6**

A Series RLC circuit has R=10Ω,L=25mH and C=60μF with frequency of 50Hz. Determine the impedance and power factor of the circuit.

Given data

R=10Ω

L=25 mH=25×$10^{-3}H$ C =

60μF

f=50Hz

$\omega=2\pi f=2\times3.14\times50=314\text{rad/sec}$

$X_L=\omega L=314\times25\times10^{-3}=7.85\Omega$

$$X_C=\frac{1}{\omega C}=\frac{1}{314\times60\times10^{-6}}=53.07\Omega$$

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

$$Z=\sqrt{10^2+\left(7.85-53.07\right)^2}$$

$$Z=53.43\Omega$$

$$\text{Power factor}, \cos\theta=\frac{R}{Z}$$

$$\cos\theta=\frac{10}{53.43}$$

$$\cos\theta=0.99$$

3.		**Taxonomy Level: Apply**	**CO: C114.2**	**PI: 3.2.6**
		A coil takes a current of 2 ampere at 0.6 lagging power factor from a 220 V, 50 Hz single phase source. If the coil is modeled by a series RL circuit, find the complex power in the coil and the values of R and L.		

Given data

$I=2\text{A}$

$\cos\theta=0.6(lag)$

$V=220V$

$f=50\text{Hz}$

$S=?$

$R=?$

$L=?$

Solution

$$Z=\frac{V}{I}=\frac{220}{2}=110\Omega$$

$$R=Z\cos\theta=110\times0.6=66\Omega$$

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

$$X_L=\sqrt{(Z)^2-(R)^2}=88\Omega$$

$$X_L=\omega L$$

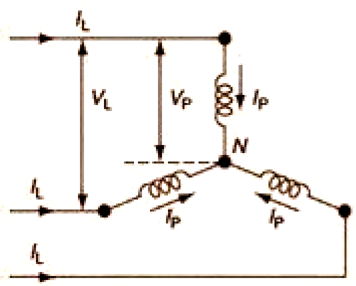
$$\omega=2\pi f=2\times3.14\times50=314\text{rad/sec}$$

$$L=\frac{X_L}{\omega}=\frac{88}{314}=0.28\text{H}$$

$$S=VI=220\times2=440\text{V}$$

4.		**Taxonomy Level: Understand**	**CO: C114.2**	**PI: 3.2.3**
		Compare star and delta connections in three phase circuits		

Star Connection



$$V_{Phase} = \frac{V_{Line}}{\sqrt{3}}$$

$$I_{Phase} = I_{Line}$$

Power in single phase,

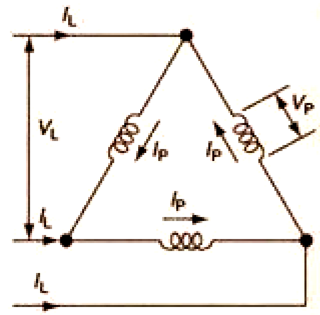
$$P_{ph} = V_{ph} I_{ph} \cos\theta$$

Power in three phase,

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

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

Delta Connection



$$V_{Phase} = V_{Line}$$

$$I_{Phase} = \frac{I_{Line}}{\sqrt{3}}$$

Power in single phase,

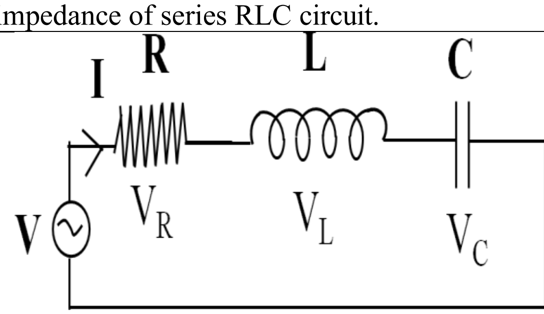
$$P_{ph} = V_{ph} I_{ph} \cos\theta$$

Power in three phase,

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

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

5.		**Taxonomy Level: Understand**	**CO: C114.2**	**PI: 3.1.6**
		Derive the formula for impedance of series RLC circuit.		



$$V_R = IR$$

$$V_L = IX_L$$

$$V_C = IX_C$$

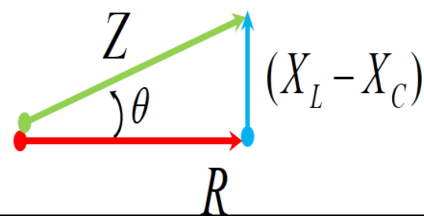
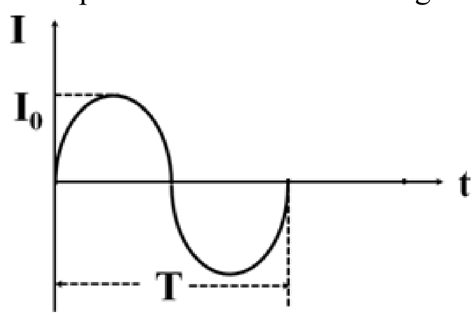
$$V = V_0 \sin(\omega t + \theta)$$

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

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

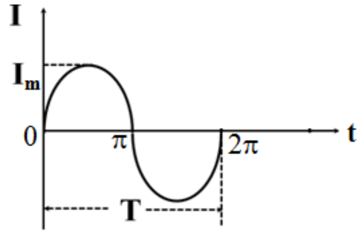
$$V = I\sqrt{(R)^2 + (X_L - X_C)^2}$$

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

<table>
<tr><td></td><td></td><td colspan="3">Impedance Triangle:

</td></tr>
<tr><td colspan="5">(10 Marks)</td></tr>
<tr><td>1.</td><td></td><td>Taxonomy Level: Understand</td><td>CO: C114.2</td><td>PI: 4.1.1</td></tr>
<tr><td></td><td></td><td colspan="3">Define Alternating quantity, Instantaneous value, Frequency, Time period and Cycle for a Full sine wave.</td></tr>
<tr><td></td><td></td><td colspan="3">Consider a full sine wave as represented in the below diagram,


Alternating quantity:
The magnitude of the wave form varies with respect to time is called as alternating quantity.
Instantaneous value:
The value of an alternating quantity at a particular time is called as instantaneous value
Frequency (f):
Number of cycles per second is called as frequency it is represented by f and the units are Hz
$f = \frac{1}{T}$
Time period (T):
The time taken to complete one cycle is called time period it is represented by T and the units are seconds.
Cycle:
The positive and negative portions of a wave form is called Cycle.</td></tr>
<tr><td>2.</td><td></td><td>Taxonomy Level: Understand</td><td>CO: C114.2</td><td>PI: 4.1.1</td></tr>
<tr><td></td><td></td><td colspan="3">Define the terms average value, rms value, form factor peak factor and derive them for full sine wave.</td></tr>
<tr><td></td><td></td><td colspan="3">Consider a full sine wave as represented below

The wave form is represented in the equation form as,
$i(t) = I_m \sin \omega t$</td></tr>
</table>



1. Average value:

The algebraic sum of all the instantaneous values over a period of time is called as average value. The average value can be obtained as,

$$I_{avg} = \frac{1}{\pi}\int_0^{\pi} i(t)dt$$

$$I_{avg} = \frac{1}{\pi}\int_0^{\pi} I_m \sin\omega t\, d\omega t$$

$$I_{avg} = \frac{I_m}{\pi}\int_0^{\pi} \sin\omega t\, d\omega t$$

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

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

2. RMS value:

It is the DC equivalent of AC current. The rms value can be obtained as,

$$I_{rms} = \sqrt{\frac{1}{T}\int_0^{T} i^2(t)dt}$$

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

$$I_{rms} = \sqrt{\frac{I_m^2}{2\pi}\int_0^{2\pi} \sin^2\omega t\; d\omega t}$$

$$\text{We know}, \sin^2\theta = \frac{1-\cos 2\theta}{2}$$

$$I_{rms} = \sqrt{\frac{I_m^2}{2\pi}\int_0^{2\pi}\left(\frac{1-\cos 2\omega t}{2}\right)d\omega t}$$

$$I_{rms} = \frac{I_m}{\sqrt{2\pi}}\sqrt{\int_0^{2\pi}\left(\frac{1-\cos 2\omega t}{2}\right)d\omega t}$$

$$I_{rms} = \frac{I_m}{\sqrt{2\pi}}\sqrt{\left[\frac{1}{2}\int_0^{2\pi} d\omega t - \frac{1}{2}\int_0^{2\pi}\cos 2\omega t\; d\omega t\right]}$$

$$I_{rms} = \frac{I_m}{\sqrt{2\pi}}\sqrt{\left[\frac{1}{2}\left[\omega t\right]_0^{2\pi} - \frac{1}{2}\left[\sin 2\omega t\right]_0^{2\pi}\right]}$$

$$I_{rms} = \frac{I_m}{\sqrt{2\pi}}\sqrt{\pi - 0}$$

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

		3. from factor: The ratio of rms value to average value is called as form factor. $\text{form factor} = \dfrac{\text{RMS value}}{\text{Average value}}$ The form factor for the sine wave is, $\text{form factor} = \dfrac{I_{rms}}{I_{avg}}$ $\text{form factor} = \dfrac{I_m/\sqrt{2}}{2I_m/\pi}$, $\text{form factor} = 1.11$ **4. Peak factor:** The ratio of peak value to rms value is called as peak factor. $\text{peak factor} = \dfrac{\text{peak value}}{\text{rms value}}$ The peak factor for the sine wave can be obtained as, $\text{peak factor} = \dfrac{I_m}{I_m/\sqrt{2}}$ $\text{Peak factor} = 1.41$
3.		**Taxonomy Level: Analyze** — **CO: C114.2** — **PI: 4.1.1**
		Three similar coils each of resistance 40Ω and the inductance 2 H are connected in i) star and ii)delta to the three phase 50Hz and 440Vsupply. Calculate the line current and total Power absorbed.
		Given data R = 40Ω, L = 2H F = 50Hz, ω = 314 rad/sec $X_L = \omega L = 314 \times 2 = 628\Omega$ $Z_{ph} = \sqrt{(R)_L + (X_L)} = 629.27\,\Omega$ **i) Star connected** $V_{Phase} = \dfrac{V_{Line}}{\sqrt{3}} = \dfrac{440}{\sqrt{3}} = 254.03V$ $I_{phase} = \dfrac{V_{phase}}{Z_{phase}} = \dfrac{440}{629.27} = 0.699A$ $I_{Line} = I_{Phase} = 0.403\,A$ $P = 3 \times 440 \times 0.699 \times 0.063 = 58.12W$ $\cos\theta = \dfrac{R}{Z} = \dfrac{40}{629.27} = 0.063$ $P = 3 \times 254.03 \times 0.403 \times 0.063 = 19.34W$ **ii) Delta connected** $V_{Phase} = V_{Line} = 440V$ $I_{Phase} = \dfrac{V_{Phase}}{Z_{Phase}} = \dfrac{254.03}{629.27} = 0.403\,A$ $P = 3V_{ph}I_{ph}\cos\theta$ =3X440X0.403X0.063=33.5W