B.Tech First Year: Regular Course Lecture Plan Session 2022-23

Subject Name	Electrical Engineering

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4	Electrical Machines	DC machines:Principle & Construction	27
		DC Generator-e.m.f equation,types ,applications	28
		DC Motor- Working,torque equation,back e.m.f	29
		DC Motor- Types, characteristics of series and shunt motors ,applications	30
		Three Phase Induction Motor:Construction and working	31
		Slip, Slip-torque characteristics of three phase induction motor	32,33
		Single Phase Induction motor - Working & starting	34,35
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5	Electrical Installation	LT Switchgears : Switch Fuse Unit (SFU), MCB	37
		LT Switchgears : ELCB, MCCB,ACB	38
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Signature	
Name of Subject Head	Mr. Ashok Kumar Rajput

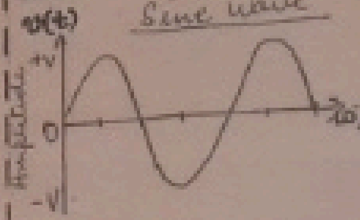
Unit - 2 STEADY STATE ANALYSIS OF AC CIRCUIT

ALTERNATING QUANTITY (AC)

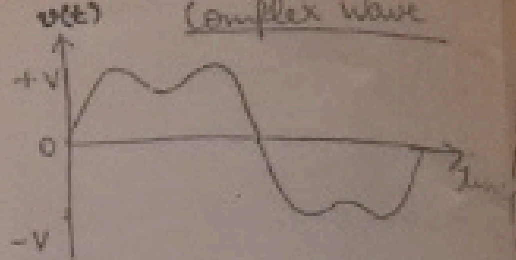
An alternating quantity is that which acts in alter. direction & whose magnitude undergoes a definite cycle of changes in definite intervals of time.

In India, the frequency of a.c is 50Hz.

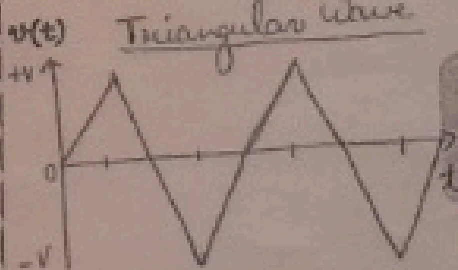
Sine wave



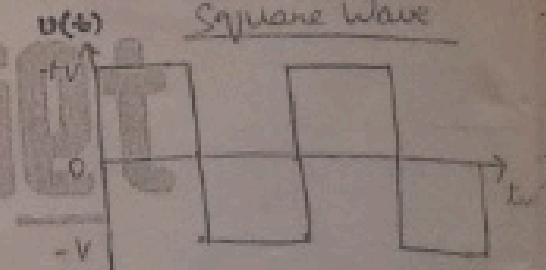
Complex wave



Triangular wave



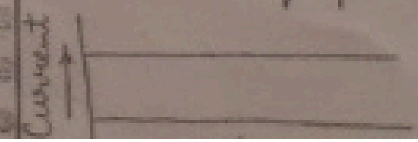
Square Wave

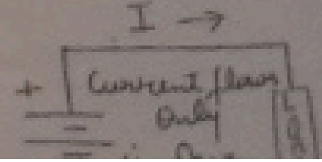


DIRECT CURRENT (DC)

When the electric charge inside the conductor flows in one direction, then such type of current is called direct current. The magnitude of direct current always remains constant and the frequency of current is zero.

It is used in cell phones, electric vehicles, electronic equipment etc.





SOME IMPORTANT DEFINITIONS — AKTU (2019-18)

1) **Waveform** :- The graph of instantaneous values of an alternating quantity plotted against time is called its waveform.

2) **Instantaneous value** :- The value of an alternating quantity at a particular instant is called its instantaneous value.

3) **Cycle** :- One complete set of positive & negative values & zero values of an alternating quantity is called a cycle. Sometimes, a cycle is specified in terms of angular measure. In that case, one complete cycle is said to spread over 360° or 2π radians.

4) **Time Period** :- Time taken by an alternating quantity to complete one cycle is called its time period 'T'.

$$\boxed{T = \frac{1}{F}} \text{ seconds}$$

5) **Frequency** :- No. of cycles/second is called frequency of an alternating quantity. Its unit is Hertz (H_z)

$$\boxed{F = \frac{1}{T}} \ sec^{-1} \text{ or Hertz.}$$

6) **Amplitude** :- Maximum positive or negative value of an alternating quantity is known as its amplitude.

Eg. $i = 100 \sin \omega t$

Amplitude is $\boxed{i_0 = 100 \text{ Amp}}$

7) **Angular Frequency** :- It is the frequency expressed in electrical radians per second.

One cycle is of alternating quantity corresponds to 2π radians, the angular frequency is $\boxed{\omega = 2\pi f}$ rad/sec

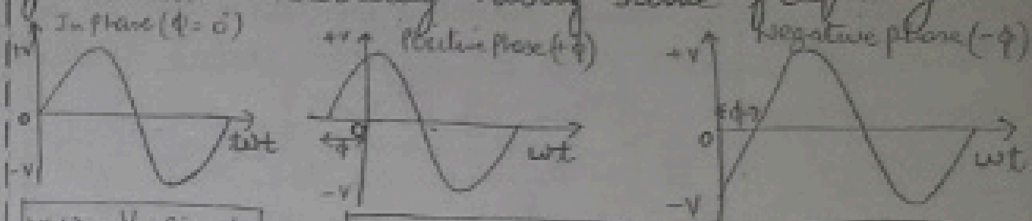
$\omega = \frac{2\pi}{T}$ (rad/sec)

8) **Phase** :- Phase of an alternating quantity is the fractional part of time period which shows that ac quantity has which displaced from time zero-axis.

$e = E_m \sin(\omega t + 90)$

i.e. the phase 90 degree (leading)

9) **Phase difference** :- It is defined as angular displacement b/w two zero values or two maximum values of the two alternating having same frequency.



$\boxed{V(t) = V_m \sin \omega t}$ $\boxed{V(t) = V_m \sin(\omega t + \phi)}$ $\boxed{V(t) = V_m \sin(\omega t - \phi)}$

* **Leading phase difference**
A quantity which attains its zero or positive maximum value before the compared to other quantity.

* **Lagging phase difference**
A quantity which attains its zero or positive maximum value after the other quantity.

Imp.
AVERAGE VALUE :- The average value of an alternating current is expressed by that steady current which transfers across any circuit the same charge as is transferred by that alternating current during the same time.

\# In case of symmetrical alternating current (i.e. whose two half-cycles are exactly similar, whether sinusoidal or non-sinusoidal), the average value over a complete cycle is zero.

\# But in case of unsymmetrical alternating current (like half-wave rectified current), average value must always be taken over the whole cycle.

$$\boxed{V_{avg} = \frac{1}{T}\int f(t) \cdot dt}$$

Imp.
R.M.S Value :- It is defined as that steady current which when flows through a resistor of known resistance for a given period of time as a result the same quantity of heat is produced by an alternating current when flows through the same resistor for the same period of time is called R.M.S or effective value of alternating current.

$$\boxed{V_{rms} = \sqrt{\frac{1}{T}\int_0^T f(t)^2 dt}}$$

FORM FACTOR :- It is defined as the ratio of R.M.S value to the Average value of an alternating waveform.

$$\text{Form Factor } (K_f) = \frac{\text{R.M.S value}}{\text{Average Value}} = \frac{V_{max}/\sqrt{2}}{2V_{max}/\pi}$$

$K_f = 1.11$ For sinusoidal waveform

V. Imp.
PEAK FACTOR or **CREST FACTOR** or **AMPLITUDE FACTOR**

It is the ratio of maximum value to the R.M.S value of an alternating wave.
For sinusoidal wave of voltage, peak factor is 1.4142.

$$\text{Peak factor} = \frac{\text{Maximum Value}}{\text{R.M.S Value}}$$

For sinusoidal waveform

$$\text{Peak factor } (K_P) = \frac{V_{max}}{V_{max}/\sqrt{2}}$$

$$\boxed{K_P = \sqrt{2} = 1.414}$$

Ques:- An alternating voltage is given by $v = 141.4 \sin 314 t$

Find out :-
(i) Frequency (ii) Instantaneous value when $t = 3ms$ (iii) Amplitude (iv) Time taken for the voltage to reach 100V for the first time after passing the
(a) Zero value (b) max. positive value.
(v) Rms value & average value.
AKTU (19-20, 17-18, 15-16)

Sol^n:
Given :- $v = 141.4 \sin 314 t$, Compare it with
$v = V_m \sin \omega t$

1) $\omega = 314$ rad/sec
$\omega = 2\pi f = 314$
$\boxed{F = 50Hz}$

2) Put $t = 3ms$ in the equation
$v = 141.4 \sin(314 \times .003) = 114.4$ volt

4) time taken from $t = 0$ to reach 100V
a) $100 = 141.4 \sin 314 t$
$t = \frac{1}{314}\sin^{-1}\left(\frac{100}{141.4}\right) = (2.5\ ms)$ {Use radian mode in calculator}

b) From max. positive value
$v = 141.4 \sin(314 t + \pi/2)$
$v = 141.4 \cos 314 t$
$100 = 141.4 \cos 314 t$
$t = \frac{1}{314}\cos^{-1}\left(\frac{100}{141.4}\right) = (2.5\ ms)$ {radian mode

3) Amplitude $\boxed{V_m = 141.4\ Volt}$ {On comparing

5) $V_{rms} = V_m/\sqrt{2} = 141.4/\sqrt{2} = 100V$
$V_{avg} = .637 V_m = .637 \times 141.4 = 90V$
Form factor $K_F = 100/90 = 1.11$
Peak factor $K_P = 141.4/100 = 1.414$

R.M.S and Average Values of different waveform

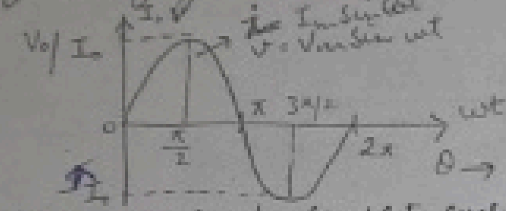
1) Sinusoidal Current | Voltage (AKTU 17-18)

OR

Derive an expression for average value & r.m.s value of a sinusoidally varying AC voltage.

2π (Length of the Base)

Wave eq^n $\left\{ \begin{array}{l} I = I_m \sin\theta \\ V = V_m \sin\theta \end{array} \right\}$



R.m.s Value

$$V_{rms}^2 = \frac{1}{2\pi}\int_0^{2\pi} v^2(\theta)\cdot d\theta$$

$$V_{rms}^2 = \frac{1}{2\pi}\int_0^{2\pi} \frac{2V_m^2 \sin^2\theta \cdot d\theta}{2}$$

$$= \frac{1}{4\pi} V_m^2 \left[\int_0^{2\pi} (1-\cos 2\theta) d\theta\right]$$

$$= \frac{V_m^2}{4\pi}\left[\theta - \frac{\sin 2\theta}{2}\right]_0^{2\pi}$$

$$V_{rms}^2 = \frac{V_m^2}{4\pi}\left[2\pi - 0\right]$$

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

$$\boxed{V_{rms} = .707\, V_m}$$

Average value for complete cycle is zero.

So for half cycle

Average Value

$$V_{avg} = \frac{1}{\pi}\int_0^{\pi} v(\theta)\cdot d\theta$$

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

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

$$= \frac{V_m}{\pi}\left[-\cos\pi - \cos 0\right]$$

$$= \frac{V_m}{\pi}\left[-(-1) + 1\right]$$

$$\boxed{V_{avg} = \frac{2V_m}{\pi}}$$

or $\boxed{V_{avg} = .637 V_m}$

Form factor $K_F = \frac{V_{rms}}{V_{avg}} = \frac{.707 V_m}{.637 V_m} = 1.11$

Peak factor $K_P = \frac{V_{max}}{V_{rms}} = \frac{V_m}{V_m/\sqrt{2}} = \sqrt{2} = 1.414$

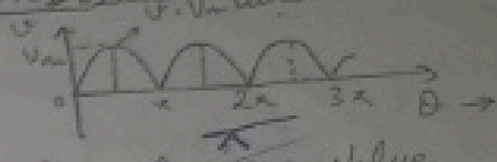
$\frac{V_{avg}}{V_{rms}}$

$\frac{V_{rms}}{V_{avg}}$

2) FULL WAVE RECTIFIED SINUSOIDAL WAVE FORM

$\pi \rightarrow$ Length of Base

Wave eq^n $\{ v = V_m \sin\theta \}$



Rms Value

$$V_{rms}^2 = \frac{1}{\pi}\int_0^{\pi} v^2(\theta)\cdot d\theta$$

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

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

$$= \frac{V_m^2}{2\pi}\int_0^{\pi}(1-\cos 2\theta)\, d\theta$$

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

$$= \frac{V_m^2}{2\pi}\left[\pi - 0\right]$$

$$= \frac{V_m^2}{2}$$

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

Average Value

$$V_{avg} = \frac{1}{\pi}\int_0^{\pi} v(\theta)\cdot d\theta$$

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

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

$$= \frac{V_m}{\pi}\left[-\cos\pi - \cos 0\right]$$

$$= \frac{V_m}{\pi}\left[-(-1)+1\right]$$

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

$$\boxed{V_{avg} = .637 V_m}$$

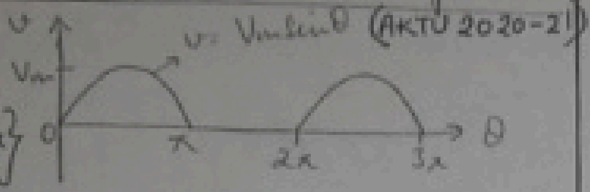
K_F (Form factor) $= \frac{V_{rms}}{V_{avg}} = 1.11$

K_P (Peak factor) $= \frac{V_m}{V_{rms}} = \sqrt{2} = 1.414$

3.) Half Wave Rectified Sinusoidal Waveform (AKTU 2020-21)

$2\pi \rightarrow$ length of base

Wave Eq^n :- $\begin{cases} v = V_m \sin\theta, & 0 \text{ to } \pi \\ v = 0, & \pi \text{ to } 2\pi \end{cases}$



R.M.S Value

$$V_{rms}^2 = \frac{1}{2\pi}\int_0^{2\pi} v^2(\theta)\cdot d\theta$$

$$= \frac{1}{2\pi}\left[\int_0^{\pi} V_m^2 \sin^2\theta\, d\theta + \int_{\pi}^{2\pi} 0 \cdot d\theta\right]$$

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

$$= \frac{V_m^2}{4\pi}\left[\int_0^{\pi}(1-\cos 2\theta)\, d\theta\right]$$

$$= \frac{V_m^2}{4\pi}\left[\theta - \frac{\sin 2\theta}{2}\right]_0^{\pi}$$

$$= \frac{V_m^2}{4\pi}(\pi - 0)$$

$$= \frac{V_m^2}{4}$$

or $\boxed{V_{rms} = \frac{V_m}{2}}$

Average Value

$$V_{avg} = \frac{1}{2\pi}\int_0^{2\pi} v(\theta)\cdot d\theta$$

$$= \frac{1}{2\pi}\left[\int_0^{\pi} V_m \sin\theta\, d\theta + \int_{\pi}^{2\pi} 0\, d\theta\right]$$

$$= \frac{1}{2\pi}\left[\int_0^{\pi} V_m \sin\theta\, d\theta\right]$$

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

$$= \frac{V_m}{2\pi}\left[-\cos\pi - \cos 0^\circ\right]$$

$$= \frac{V_m}{2\pi}\left[-(-1)+1\right]$$

$\boxed{V_{avg} = \frac{V_m}{\pi}} = .637 V_m$

Form factor $K_f = \frac{(V_m/2)}{(V_m/\pi)} = 1.57$

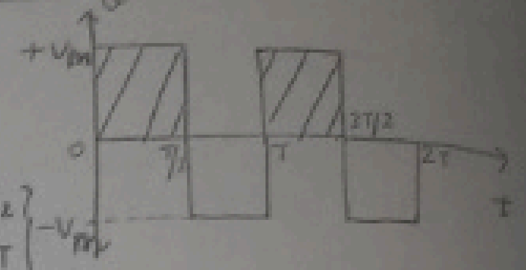
Peak factor $(K_p) = \frac{V_m}{V_{rms}} = \frac{V_m}{V_m/2} = 2$

4.) SQUARE WAVE FORM :-

Time Period

$T = T$ sec

Wave Eq^n $\begin{cases} v = +V_m, & 0 \text{ to } T/2 \\ v = -V_m, & T/2 \text{ to } T \end{cases}$



Rms Value

$$V_{rms}^2 = \frac{1}{T}\int_0^{T} v(t)\cdot dt$$

$$= \frac{1}{T}\left[\int_0^{T/2} V_m^2\, dt + \int_{T/2}^{T}(-V_m)^2\, dt\right]$$

$$= \frac{V_m^2}{T}\left[\int_0^{T/2} 1\cdot dt + \int_{T/2}^{T} 1\cdot dt\right]$$

$$= \frac{V_m^2}{T}\left[(t)_0^{T/2} + (t)_{T/2}^{T}\right]$$

$$= \frac{V_m^2}{T}(T)$$

or $\boxed{V_{rms} = V_m}$

Average Value

For a complete Cycle,

$= 0$

$\therefore$ For Half Cycle

$$V_{avg} = \frac{1}{T/2}\int_0^{T/2} V_m\, dt$$

$$V_{avg} = \frac{1}{T/2}\cdot V_m\left[t\right]_0^{T/2}$$

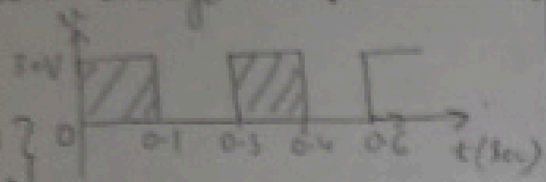
$$V_{avg} = \frac{1}{T/2} V_m\left[T/2 - 0\right]$$

$\boxed{V_{avg} = V_m}$

Form factor $(K_F) = \frac{V_{rms}}{V_{avg}} = \frac{V_m}{V_m} = 1$

Peak factor $(K_p) = \frac{V_m}{V_{rms}} = \frac{V_m}{V_m} = 1$

Ques Find Rms Value, Average Value, form factor, Peak factor of the given waveform. (AKTU 2013-14)



Sol: Time Period $T = 0.3\,sec$

$$\begin{cases} v = 30V, & 0 < t < 0.1 \\ v = 0, & 0.1 < t < 0.3 \end{cases}$$

$$V_{rms}^2 = \frac{1}{T}\int_0^T v^2(t)\,dt$$

$$= \frac{1}{0.3}\left[\int_0^{0.1}(30)^2 dt + \int_{0.1}^{0.3} 0 \cdot dt\right]$$

$$= \frac{1}{0.3} \times 900\,[t]_0^{0.1}$$

$$= \frac{900}{0.3}(0.1)$$

$$\boxed{V_{rms} = \sqrt{300} = 17.32\ Volt}$$

$$V_{avg} = \frac{1}{T}\int_0^T v(t)\,dt$$

$$= \frac{1}{0.3}\left[\int_0^{0.1} 30\,dt + \int_{0.1}^{0.3} 0 \cdot dt\right]$$

$$= \frac{30}{0.3}(t)_0^{0.1}$$

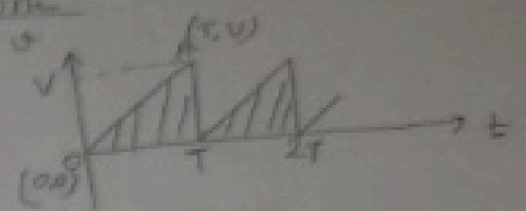
$$= \frac{30}{0.3}(0.1 - 0)$$

$$\boxed{V_{avg} = 10\ Volt}$$

Form factor $K_f = \frac{V_{rms}}{V_{avg}} = \frac{17.32}{10}\ 1.732$

Peak factor $K_p = \frac{V_m}{V_{rms}} = \frac{30}{17.32} = 1.732$

Imp 5) Sawtooth Waveform



$T = T\,sec$

equation of wave is equation of line (OA)

$$y = mx,\ y = \frac{(y_2 - y_1)}{(x_2 - x_1)} \cdot x$$

$$\boxed{v = \frac{V}{T} \cdot t} \quad -(1)$$

R.M.S Value

$$V_{rms}^2 = \frac{1}{T}\int_0^T v^2(t) \cdot dt$$

$$= \frac{1}{T}\int_0^T \frac{V^2}{T^2} \cdot t^2\,dt$$

$$= \frac{V^2}{T^3} \cdot \left[\frac{t^3}{3}\right]_0^T$$

or $\boxed{V_{rms} = \frac{V_m}{\sqrt{3}}}$

Average Value

$$V_{avg} = \frac{1}{T}\int_0^T v(t)\,dt$$

$$= \frac{1}{T}\int_0^T \frac{V}{T} \cdot t\,dt$$

$$= \frac{V}{T^2}\left[\frac{t^2}{2}\right]_0^T$$

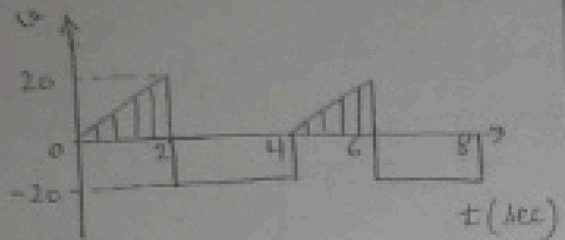
or $\boxed{V_{avg} = \frac{V}{2} \text{ or } \frac{V_m}{2}}$

$$K_f = \frac{V_{rms}}{V_{avg}} = \frac{V_m/\sqrt{3}}{V_m/2} = 1.15$$

$$K_p = \frac{V_m}{V_{rms}} = \frac{V_m}{V_m/\sqrt{3}} = \sqrt{3} = 1.73$$

Imp

Ques-2 Find V_{rms}, V_{avg}, K_f, K_p for the given waveform.



Sol^n Time Period (T) = 4 sec

Wave eq^n
$$\begin{bmatrix} v = \frac{V}{T} \cdot t = \frac{20t}{2} \\ = 10t \text{ for } t = 0 \text{ to } 2 \text{ sec} \\ v = -20 \text{ for } t = 2 \text{ to } 4 \text{ sec} \end{bmatrix}$$

$$V_{rms}^2 = \frac{1}{T}\int_0^T v^2(t)\cdot dt = \frac{1}{4}\left[\int_0^2 (10t)^2 dt + \int_2^4 (-20)^2 \cdot dt\right]$$

$$= \frac{1}{4}\left[\int_0^2 100 t^2 dt + \int_2^4 400\, dt\right]$$

$$= \frac{1}{4}\left[100\left[\frac{t^3}{3}\right]_0^2 + 400\,[t]_2^4\right]$$

$$V_{rms}^2 = \frac{1}{4}\left[\left(100 \times \frac{8}{3}\right) + (400 \times 2)\right]$$

$$V_{rms} = \sqrt{266.66} = 16.32 \text{ Volt}$$

$$V_{avg} = \frac{1}{T}\int_0^T v(t)\,dt = \frac{1}{4}\left[\int_0^2 10(t)\,dt + \int_2^4 (-20)\,dt\right]$$

$$= \frac{1}{4}\left[10 \times \left[\frac{t^2}{2}\right]_0^2 + (-20)(t)_2^4\right]$$

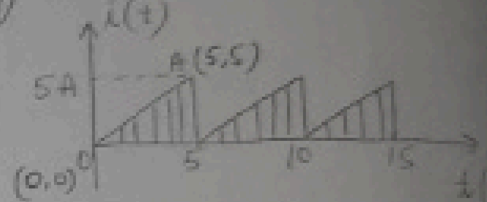
$$= \frac{1}{4}\left[\left(10 \times \frac{4}{2}\right) - 20 \times 2\right]$$

$$= \frac{1}{4}\left[20 - 40\right] = -5 \text{ Volt}$$

$$K_f = \frac{V_{rms}}{V_{avg}} = \frac{16.32}{5} = 3.26$$

$$K_p = \frac{V_m}{V_{rms}} = \frac{20}{16.32} = 1.22$$

Ques Find i_{rms}, i_{avg}, K_f & K_p. AKTU (2014-15)



Sol^n
$$\boxed{I(t) = \frac{I}{T}\cdot t = \frac{5}{5}\cdot t = t}$$

Eq^n of wave

$y = mx$

$$i(t) = \frac{5-0}{5-0}\cdot t$$

$$\boxed{i(t) = t}$$

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

$$= \frac{1}{5}\int_0^5 t^2 dt = \frac{1}{5}\left[\frac{t^3}{3}\right]_0^5$$

$$I_{rms}^2 = \frac{1}{5}\left[\frac{125}{3}\right]$$

$$\boxed{I_{rms} = 2.88 \text{ A}}$$

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

$$= \frac{1}{5}\int_0^5 t \cdot dt$$

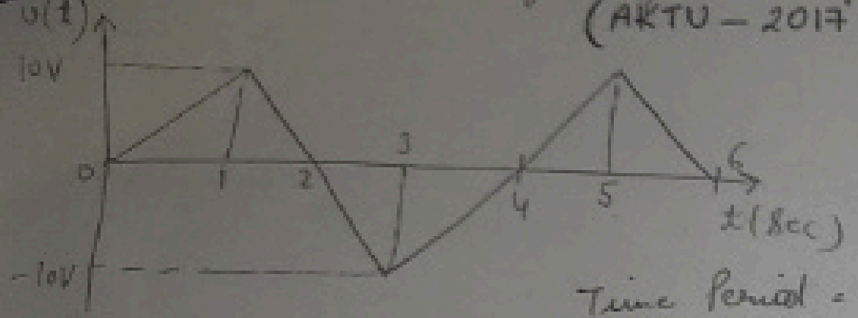
$$= \frac{1}{5}\cdot\left(\frac{t^2}{2}\right)_0^5$$

$$\boxed{I_{avg} = 2.5 \text{ A}}$$

form factor $K_f = \frac{I_{rms}}{I_{avg}} = \frac{2.88}{2.5} = 1.152$

Peak factor $K_p = \frac{I_{max}}{I_{rms}} = \frac{5}{2.88} = 1.73$

Determine form factor of the given waveform (AKTU – 2017 - 18)

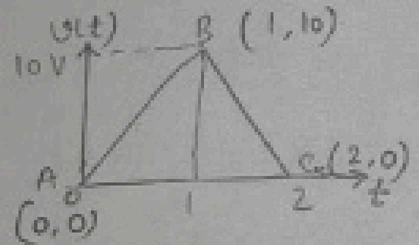


Time Period = 4 sec

For a symmetrical waveform, average value over a complete cycle is Zero.
So for Half cycle –

$V_{avg} = \frac{\text{Area Under the Curve for Half Cycle}}{\text{base of Half cycle}} = \frac{\frac{1}{2}\times 2\times 10}{2}$

$\boxed{V_{avg} = 5\,Volt}$



$V_{rms} = \sqrt{\frac{1}{T}\int_0^T v^2(t)\cdot dt}$

$= \sqrt{\frac{1}{4}\int_0^4 v^2(t)dt} = \frac{1}{2}\sqrt{2\times\int_0^2 v^2(t)\cdot dt}$ — (1)

line AB, eq^n of line is $y = mx$

$v(t) = \frac{10-0}{1-0}\cdot t$

$\boxed{v(t) = 10t}$ — (2)

For line BC, $v(t) = mx + C$

$v(t) = \frac{(10-0)}{(1-2)}\cdot t + C$

$\boxed{v(t) = -10t + C}$ — (3)

For point (2,0)

$0 = -10\times 2 + C$

$(C = 20)$

Hence line BC, $\boxed{v(t) = -10t + 20}$ — (4)

From eq^n (1) $\left\{\int_0^2 v^2(t)\cdot dt\right\} = \int_0^1 (10t)^2\cdot dt + \int_1^2 (-10t+20)^2\cdot dt$

$= \int_0^1 100t^2 dt + \int_1^2 (100t^2 - 400t + 400)\cdot dt$

$= 100\left[\frac{t^3}{3}\right]_0^1 + \left[100\frac{t^3}{3} - 400\frac{t^2}{2} + 400t\right]_1^2$

$= \frac{100}{3} + \frac{100}{3}(2^3 - 1^3) - 200(2^2 - 1^2) + 400(2-1)$

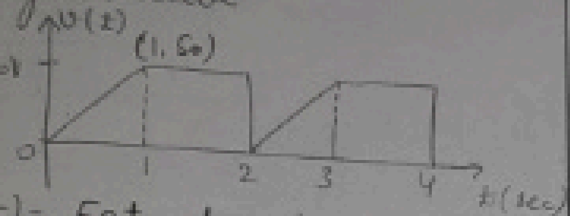
$= 66.67$

So, $V_{rms} = \frac{1}{2}\sqrt{2\times 66.67}$

or $\boxed{V_{rms} = 5.77\ Volt}$

Form factor $K_f = \frac{V_{rms}}{V_{avg}} = \frac{5.77}{5} = 1.154$

Ques Find out r.m.s value, average value, form factor, peak factor for the given wave



Solⁿ Time Period = 2 sec

Eqⁿ of wave

$v(t) = \frac{(50-0)}{(1-0)} \cdot t$, $v(t) = 50t$ for $(t = 0 \text{ to } 1)$

$v(t) = 50$ for $(t = 1 \text{ to } 2 \text{ sec})$

$V_{rms} = \sqrt{\frac{1}{T}\int_0^T v^2(t)\,dt}$

$V_{rms}^2 = \frac{1}{2}\left[\int_0^1 (50t)^2\,dt + \int_1^2 (50)^2\,dt\right]$

$= \frac{1}{2}\left[(50)^2 \left|\frac{t^3}{3}\right|_0^1 + 2500\,|t|_1^2\right]$

$= \frac{1}{2}\left[\frac{2500}{3} + 2500\right] = \frac{10000}{6}$

or $\boxed{V_{rms} = 40.8 \text{ Volt}}$

$V_{avg} = \frac{1}{T}\int_0^T v(t)\cdot dt = \frac{1}{2}\left[\int_0^1 50t\cdot dt + \int_1^2 50\,dt\right]$

$= \frac{1}{2}\left[50\left|\frac{t^2}{2}\right|_0^1 + 50\,|t|_1^2\right]$

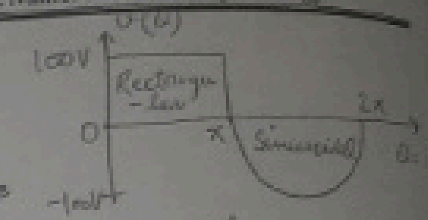
$= \frac{1}{2}[25 + 50] = \frac{75}{2}$

or $\boxed{V_{avg} = 37.5 \text{ Volt}}$

$K_f = \frac{V_{rms}}{V_{avg}} = \frac{40.8}{37.5} = 1.088$

$K_p = \frac{V_{max}}{V_{rms}} = \frac{50}{40.8} = 1.225$

Ques Find form factor of the given waveform -



Solⁿ $2\pi \to$ length of the base

Eqⁿ of wave - (Unsymmetrical)

$\begin{cases} v(\theta) = 100 , & \text{for } \theta = 0 \text{ to } \theta = \pi \\ v(\theta) = +100\sin\theta , & \text{for } \theta = \pi \text{ to } \theta = 2\pi \end{cases}$

↳ For Function take +ve sign.

$V_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} v^2\theta . d\theta}$

$V_{rms}^2 = \frac{1}{2\pi}\left[\int_0^\pi (100)^2 d\theta + \int_\pi^{2\pi} (100\sin\theta)^2 d\theta\right]$

$= \frac{1}{2\pi}\left[100^2\int_0^\pi 1\,d\theta + \frac{100^2}{2}\int_\pi^{2\pi} 2\sin^2\theta\,d\theta\right]$

$= \frac{1}{2\pi}\left[100^2\int_0^\pi 1\,d\theta + \frac{100^2}{2}\int_\pi^{2\pi}(1-\cos 2\theta)\,d\theta\right]$

$= \frac{100^2}{2\pi}\left[[\theta]_0^\pi + \frac{1}{2}\left\{[\theta]_\pi^{2\pi} - \left|\frac{\sin 2\theta}{2}\right|_\pi^{2\pi}\right\}\right]$

$= \frac{100^2}{2\pi}\left[\pi + \frac{1}{2}[\pi - 0]\right]$

$\boxed{V_{rms} : 50\sqrt{3} = 86.60 \text{ Volt}}$

$V_{avg} : \frac{1}{2\pi}\int_0^{2\pi} v(\theta)\cdot d\theta$

$= \frac{1}{2\pi}\left[\int_0^\pi 100\,d\theta + \int_\pi^{2\pi} +100\sin\theta\cdot d\theta\right]$

$= \frac{100}{2\pi}\left[\int_0^\pi 1\cdot d\theta + \int_\pi^{2\pi}\sin\theta\cdot d\theta\right]$

$= \frac{100}{2\pi}\left[|\theta|_0^\pi - |\cos\theta|_\pi^{2\pi}\right]$

$= \frac{100}{2\pi}\left[(\pi - 0) - (\cos 2\pi - \cos\right.$

$= \frac{100}{2\pi}\left[\pi - (1 - (-1))\right] = \frac{100}{2\pi}$

$\boxed{V_{avg} = 18.15 \text{ Volt}}$

$K_f = \frac{V_{rms}}{V_{avg}} = \frac{86.60}{18.15} = 4.9$

R.M.S Value of Combined waveform -

$i = 10A$ d.c

$i(t) = 12\sin\omega t + 6\sin\left(3\omega t - \frac{\pi}{6}\right) + 4\sin\left(5\omega t + \frac{\pi}{2}\right)$ a.c

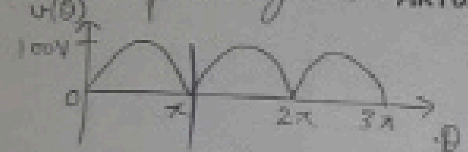
R.M.S value of combined a.c & d.c is -

$I^2_{rms} = (10)^2 + \left(\frac{12}{\sqrt{2}}\right)^2 + \left(\frac{6}{\sqrt{2}}\right)^2 + \left(\frac{4}{\sqrt{2}}\right)^2 = 198$

or $\boxed{I_{rms} = 14.07 \text{ Amp}}$

Ques Find form factor of the waveform given - AKTU(14-15)

$v(\theta) = 100\sin\theta$



Sol^n $V_{rms} = \sqrt{\frac{1}{\pi}\int_0^{\pi} v^2(\theta).d\theta}$

$V_{rms} = \frac{1}{\pi}\int_0^{\pi}(100\sin\theta)^2 d\theta$

$= \frac{100^2}{2\pi}\int_0^{2\pi} 2\sin^2\theta \, d\theta$

$= \frac{100^2}{2\pi}\int_0^{\pi}(1-\cos 2\theta)d\theta$

$= \frac{100^2}{2\pi}\left[\theta - \frac{\sin 2\theta}{2}\right]_0^{\pi}$

$= \frac{100^2}{2\pi}[\pi - 0]$

$\boxed{V_{rms} = \frac{100}{\sqrt{2}}}$

$V_{avg} = \frac{1}{\pi}\int_0^{\pi} v(\theta).d\theta$

$= \frac{1}{\pi}\int_0^{\pi}(100\sin\theta)d\theta$

$= \frac{100}{\pi}\left|(-\cos\theta)\right|_0^{\pi}$

$= \frac{100}{\pi}\left[-\cos\pi + \cos 0^\circ\right]$

$= \frac{100}{\pi}\left[-(-1)+1\right]$

$\boxed{V_{avg} = \frac{200}{\pi}}$

$K_F = \frac{V_{rms}}{V_{avg}} = \frac{100/\sqrt{2}}{200/\pi} = 1.11$

$K_P = \frac{V_m}{V_{rms}} = \frac{100}{(100/\sqrt{2})} = \sqrt{2} = 1.414$

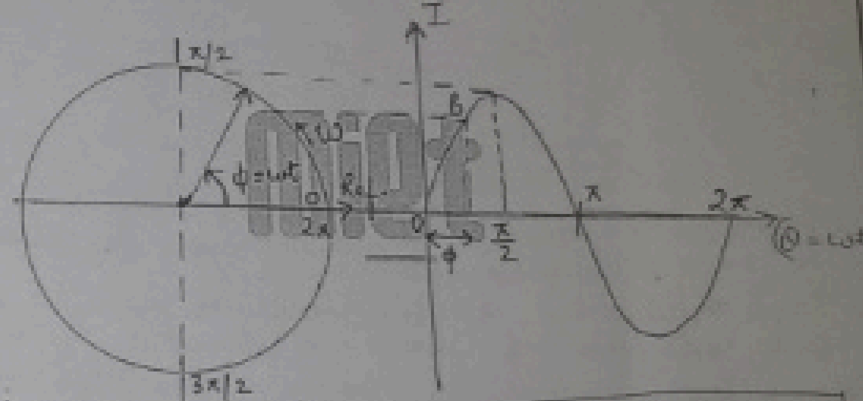
Concept of Phase and Phase difference

a.c → $A\angle\phi$ → angle (Phase), ↓ Magnitude

$A\angle\phi$

[Polar Form - $A\angle\theta$ → Phase, ↳ r.m.s
Rectangular = $A + jB$, ↓ Real, ↳ Imaginary]

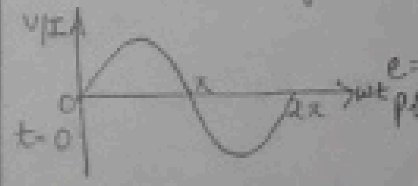
Phase : Phase of an alternating quantity at any instant is the angle (ϕ) travelled by the phasor representing that alternating quantity upto the instant of consideration, measured from the reference.



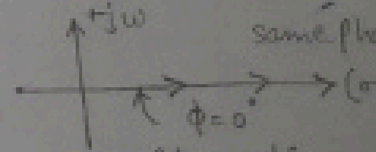
Equation of ac is given by $\boxed{e = E_m\sin(\omega t \pm \phi)}$

Three Cases are -:

Case I ($\phi = 0^\circ$) → Zero phase means at $t=0$, instantaneous value of ac quantity is zero.

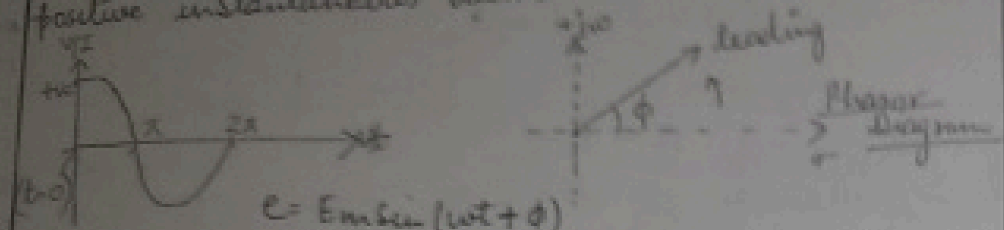


$e = E_m\sin\omega t$
Phase $\phi = 0^\circ$



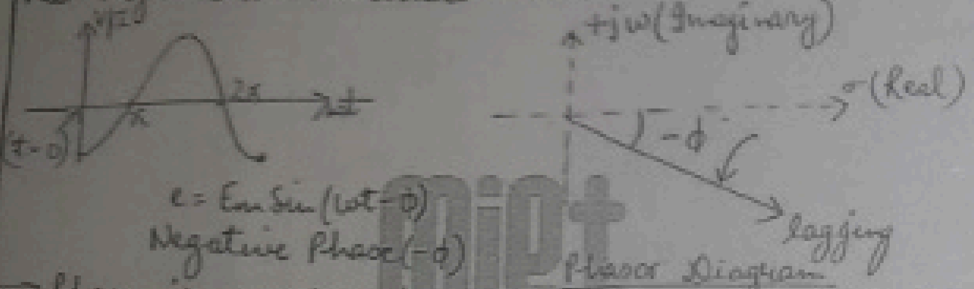
Phasor diagram

Case 2 Positive Phase :- If at $t=0$, alternating quantity has positive instantaneous value.



$e = E_m \sin(\omega t + \phi)$
positive phase ϕ

Case 3 Negative Phase :- If at $t=0$, alternating quantity has negative instantaneous value.



$e = E_m \sin(\omega t - \phi)$
Negative Phase $(-\phi)$

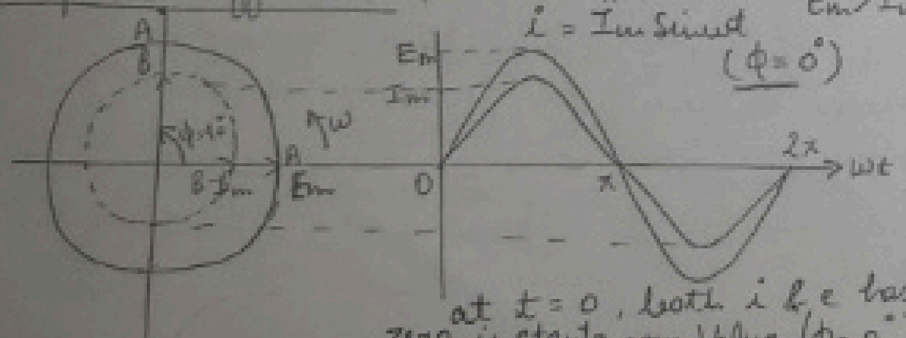
Phasor Diagram

→ Phase is measured w.r.t. reference direction i.e. +ve x-axis direction.

→ Phase measured in anticlockwise direction is +ve while measured in clockwise direction is negative.

The difference b/w the phases of the two alternating quantities is called the Phase difference.

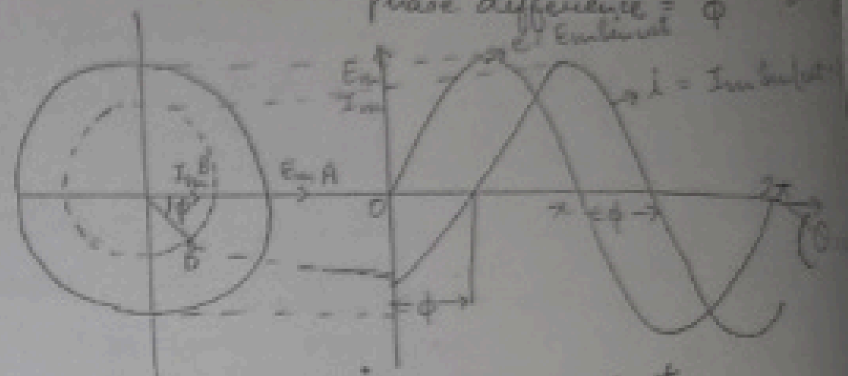
1-) Zero Phase Difference :- $e = E_m \sin\omega t$, $i = I_m \sin\omega t$ $(\phi = 0^\circ)$, $E_m > I_m$

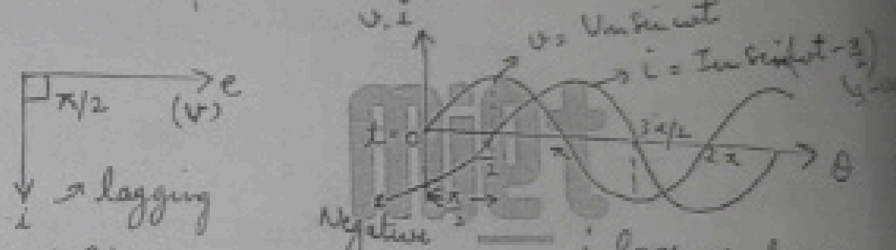


at $t=0$, both i & e has zero instantaneous value. $(\phi = 0^\circ)$

* Lagging Phase Difference :- $e = E_m \sin\omega t$, $i = I_m \sin(\omega t - \phi)$

e leads i by 'φ', or i lags e
Phase difference = ϕ

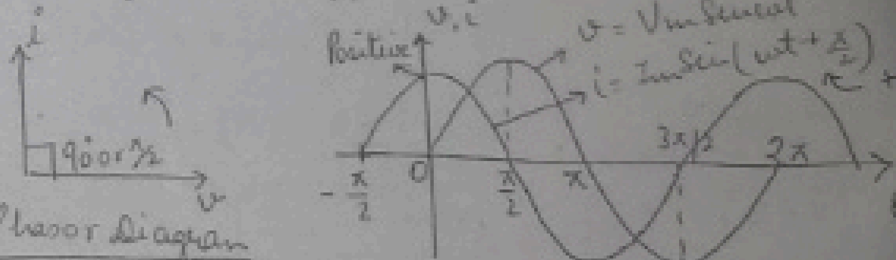




Phasor Diagram

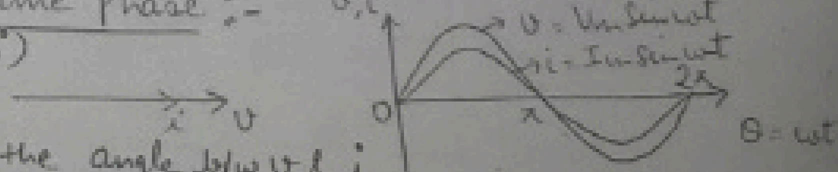
i lags v by $\frac{\pi}{2}$
Phase difference $= \frac{\pi}{2}$

* Leading Phase Difference



Phasor Diagram

* Same Phase :- $(\phi = 0^\circ)$



φ is the angle b/w v & i

 AKTU (2016-17)

Ques Draw the phasor diagram of the following voltages & find rms value of resultant voltage

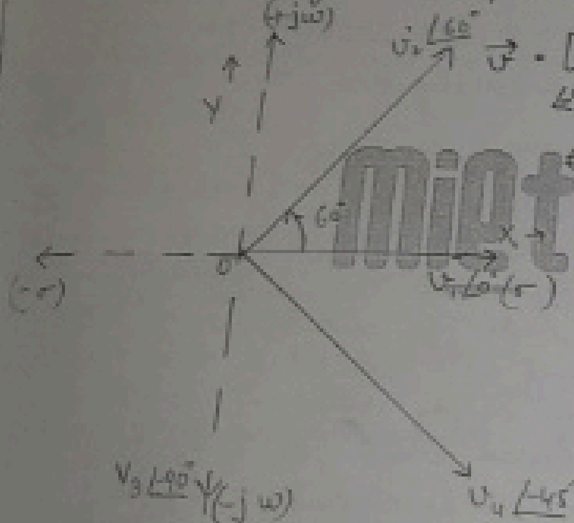
$v_1 = 100 \sin \omega t$, r.m.s $100/\sqrt{2}$, Polar form $70.71 \angle 0^\circ$

$v_2 = 200 \sin(500t + \frac{\pi}{3}) = 200/\sqrt{2}$, $141.4 \angle 60^\circ$

$v_3 = -50 \cos 500t$
$= +50 \sin(500t - \frac{\pi}{2}) = \frac{50}{\sqrt{2}}$, $35.35 \angle -90^\circ$

$v_4 = 50 \sin(500t - \frac{\pi}{4}) = \frac{150}{\sqrt{2}}$, $106.06 \angle -45^\circ$

Resultant Voltage $\vec{v} = \vec{v_1} + \vec{v_2} + \vec{v_3} + \vec{v_4}$



$\vec{v} = [70.71 \angle 0^\circ + 141.42 \angle 60^\circ + 35.35 \angle -90^\circ + 106.06 \angle -45^\circ]$

Convert to Rectangular form

$\vec{v} = [(70.71 + j0) + (70.71 + j122.47) + (0 - j35.35) + (75 - j75)]$

$\vec{v} = (216.421 + j12.118)$

Polar form

$\vec{v} = 216.76 \angle 3.205^\circ$

r.m.s +ve phase

Phasor Diagram

$\therefore \boxed{V_{rms} = 216.76 \text{ volt}}$

$\boxed{V_{max} = V_{rms}/\sqrt{2} = 306.54V}$

$\therefore$ Resultant Voltage waveform

$\boxed{\vec{v} = 306.54 \sin(500t + 3.205^\circ)}$

Multiplication and Division of Phasors -

Ques For the two phasors $A = a_1 + jb_1$ and $B = a_2 + jb_2$. Obtain their multiplication & division using polar form.

Solⁿ $A = a_1 + jb_1$ $B = a_2 + jb_2$

For multiplication & division, use polar co-ordinates

$\therefore A = |A| \angle \phi_1 = \sqrt{a_1^2 + b_1^2} \angle \tan^{-1} \frac{b_1}{a_1}$

$\therefore B = |B| \angle \phi_2 = \sqrt{a_2^2 + b_2^2} \angle \tan^{-1} \frac{b_2}{a_2}$

$\therefore A \times B = |A||B| \angle \phi_1 \angle \phi_2$

$\frac{A}{B} = \frac{|A| \angle \phi_1}{|B| \angle \phi_2} = \frac{|A|}{|B|} \angle \phi_1 - \phi_2$

Imp.

Ques Three currents are represented by $i_1 = 10 \sin \omega t$, $i_2 = 20 \sin(\omega t - \frac{\pi}{6})$, $i_3 = 30 \sin(\omega t + \frac{\pi}{4})$. Find magnitude & phase angle of resultant current of their addition.

Solⁿ $i_1 = 10 \sin \omega t$ i.e. $I_1 = 10 \angle 0^\circ$

$i_2 = 20 \sin(\omega t - \frac{\pi}{6})$ i.e. $I_2 = 20 \angle -\frac{\pi}{6}$ or $20 \angle -30^\circ$

$i_3 = 30 \sin(\omega t + \frac{\pi}{4})$ i.e. $I_3 = 30 \angle \pi/4$ or $30 \angle 45^\circ$

$\therefore I_1 = (10 + j0)A$, $I_2 = (17.32 - j10)A$, $I_3 = (21.21 + j21.21)A$

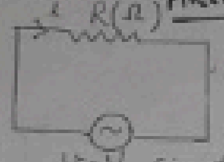
$\therefore I_R = I_1 + I_2 + I_3$
$= 48.53 + j11.21$

$\boxed{I_R = 49.81 \angle 13^\circ A}$

$\therefore$ Magnitude $= 49.81A$, Phase Angle $= 13^\circ$

PURELY RESISTIVE CIRCUIT (R Only) :- AKTU(18-19)

Let 'Z' be the impedance of the circuit.



∴ current flowing through the circuit-

$i = \frac{v}{Z} = \frac{V_m \sin \omega t}{Z} = \frac{V_m \sin \omega t}{R}$

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

or $I_m = \frac{V_m}{Z} = \frac{V_m}{R}$

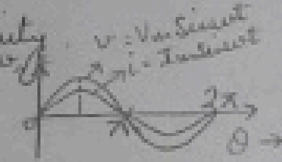
∴ $\boxed{Z = R}\ \Omega$

i) Impedance $\boxed{(Z = R)\ \Omega}$

ii) ϕ = Angle b/w v & i. $\phi = \hat{v\,i} = 0°$

iii) Power Factor ($\cos\phi = \cos 0 = 1$) i.e unity

iv) v & i are in same phase



$\xrightarrow{v}$

$\phi = 0°$ (Same phase)

$v = V\angle 0°$ $\{v = V_m \sin \omega t$
$i = I\angle 0°$ $\{i = I_m \sin \omega t$

IMPEDANCE :-

The opposition offered by an a.c ckt in the path of current is called Impedance (Z).

$Z = \frac{v}{i} = \frac{V\angle 0°}{I\angle 0°} = R\angle 0°$

$Z = R\angle 0°$ (Polar form)

$Z = R + j0$ (Rectangular form)

$|Z| = R\ \Omega$, $(\angle\phi = 0°)$

[Power factor ($\cos\phi$) = Unity]

i.e. $\cos\phi = \cos 0°$

$\boxed{\cos\phi = 1}$ (Unity)

POWER :

$p = v \cdot i$

$p = V_m \sin \omega t \cdot I_m \sin \omega t$

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

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

$p = \left\{ \underbrace{\frac{V_m I_m}{2}}_{\text{Constant Part}} - \underbrace{\frac{V_m I_m \cos 2\omega t}{2}}_{\text{Variable Part}} \right\}$

Over a complete Cycle.

$\int_0^{\pi} -\frac{V_m I_m}{2} \cos 2\omega t \, (d\omega t) = 0$

Average Power over a complete Cycle is

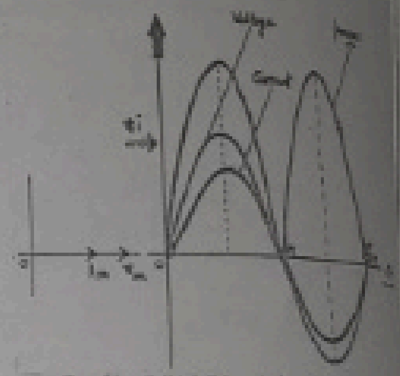
$P_{avg} = \frac{V_m I_m}{2} = \frac{V_m}{\sqrt{2}} \cdot \frac{I_m}{\sqrt{2}}$

$P_{avg} = V_{rms} \cdot i_{rms}$ (Watt)

$P_{avg} = i^2_{rms} \cdot R$ $\{v = iR\}$

$P_{avg} = \frac{V^2_{rms}}{R}$ $\{i = \frac{v}{R}\}$

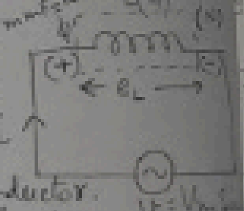
So a pure resistance dissipates energy in the form of heat.



V. Imp. **PURELY INDUCTIVE CIRCUIT (L Only)** AKTU

Ques:- Prove that in a purely Inductive circuit Power is Zero.

Solⁿ When an alternating current i flows through an inductor L(H) having N Turns, it sets up an alternating magnetic field (φ), $\boxed{MMF = NI\ (AT)}$ around the inductor.



→ This changing flux links the coil & due to self inductance, e.m.f gets induced in the coil which opposes the supply voltage.

Self Induced E.M.F $\left(e_L = -L\frac{di}{dt}\right)$

applied voltage 'v' is opposite in polarity to

∴ $v = -e_L = -\left(-L\frac{di}{dt}\right)$

or $v = \left(L\frac{di}{dt}\right)$ — ①

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

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

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

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

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

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

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

$i_m = \frac{V_m}{Z} = \frac{V_m}{X_L}$

or $\boxed{Z = X_L = \omega L = 2\pi f L}\ (\Omega)$

1) Impedance $(Z = X_L)\ \Omega$
2) $\because$ 'i' lags 'v' by $\frac{\pi}{2}$ or 90° $(\therefore \phi = 90^\circ)$
3) Power factor $\cos\phi = \cos\frac{\pi}{2} = 0$
4) Power (P) = $VI\cos\phi$

$\boxed{P = 0}$ $[\because \cos\phi = 0]$

$v = V_m \sin\omega t = V\angle 0^\circ$
$i = I_m \sin(\omega t - 90^\circ) = I\angle -90^\circ$

Impedance $Z = \frac{V\angle 0^\circ}{I\angle -90^\circ}$

$Z = X_L \angle +90^\circ$ or $(0 + jX_L)\ \Omega$
↳ (+)ve sign shows the P.F. is lagging.

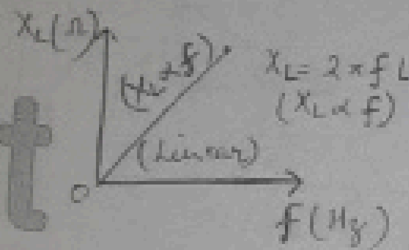
X_L = Inductive Reactance is defined as the opposition offered by inductance of a ckt to the flow of alternating sinusoidal current.

* POWER :-

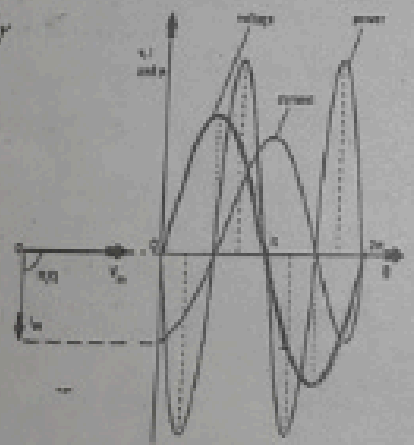
$p = v \cdot i$
$p = V_m \sin\omega t \cdot I_m \sin(\omega t - \frac{\pi}{2})$
$p = -\frac{V_m I_m}{2}\, 2(\sin\omega t \cdot \cos\omega t)$
$p = -\frac{V_m I_m}{2} \sin 2\omega t$

$P_{avg} = \left[\frac{1}{\pi}\int_0^{2\pi} -\frac{V_m I_m}{2} \sin 2\omega t\, d\omega t\right]$

$\boxed{P_{avg} = 0}$

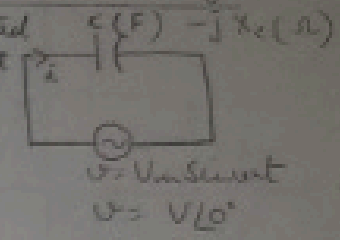


$X_L = 2\pi f L$
$(X_L \propto f)$



PURELY CAPACITIVE CIRCUIT (C Only) {15-16}

Let a pure capacitance (C)F is connected to an a.c sinusoidal voltage $v = V_m \sin\omega t$. Instantaneous charge 'q' on plates of the capacitor is



$\boxed{q = Cv}$

Current $i = \frac{dq}{dt} = \frac{d}{dt}(Cv)$

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

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

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

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

$\therefore$ i leads 'v' by $\frac{\pi}{2}$ or 90°

$i = \frac{V_m}{Z} = \frac{V_m}{1/\omega C} = \frac{V_m}{X_C}$

or $\boxed{Z = X_C} = \frac{1}{2\pi f C}\ (\Omega)$
↳ Capacitive Reactance

2) $\phi = 90^\circ$, i leads 'v' by 90°
3) $\cos\phi = \cos 90^\circ = 0$
4) Power (P) = 0 as $\cos\phi = 0$

IMPEDANCE :- (Z)

$v = V_m \sin\omega t = V\angle 0^\circ$
$i = I_m \sin(\omega t + \frac{\pi}{2}) = I\angle 90^\circ$

$Z = \frac{V\angle 0^\circ}{I\angle 90^\circ} = X_C \angle -90^\circ = (0 - jX_C)\ \Omega$
↳ -ve leading P.F

Capacitive reactance (X_C) is the opposition offered by the capacitance of the ckt to the flow of alternating sinusoidal current.

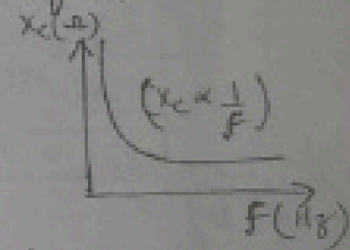
POWER

$p = v \cdot i$
$p = V_m \sin\omega t \cdot I_m \sin(\omega t + \frac{\pi}{2})$
$p = \frac{V_m I_m}{2}\, 2(\sin\omega t \cdot \cos\omega t)$
$p = \frac{V_m I_m}{2} \sin 2\omega t$

$P_{avg} = \frac{1}{\pi}\int_0^{\pi} \frac{V_m I_m}{2} \sin 2\omega t\, (d\omega t) = 0$

{over a complete cycle of power.}

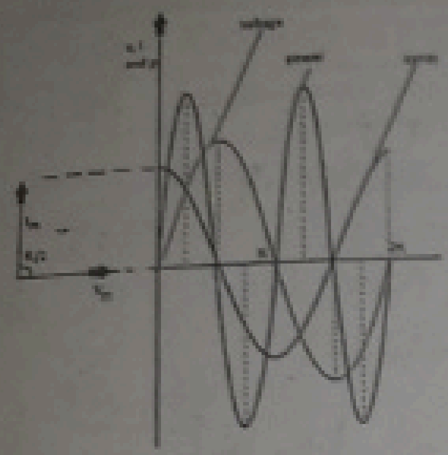
$\boxed{P_{avg} = 0}$ → Average Power in a purely capacitive ckt is zero.



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

$\therefore \boxed{X_C \propto \frac{1}{f}}$

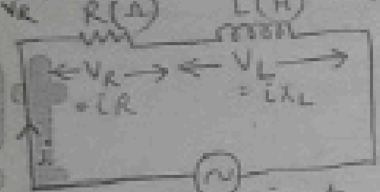
$\therefore$ Graph is Rectangular Hyperbola.



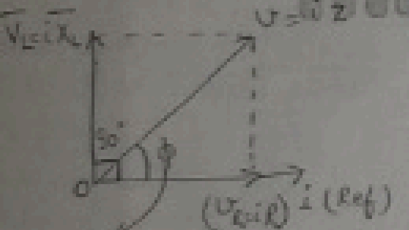
Series R-L Circuit (Inductive ckt)

$\vec{v} = \vec{v_R} + \vec{v_L}$ — (1)

$v_R \to$ is in phase with 'i' for 'R'
$v_L \to$ leads 'i' by 90° for 'L'



$v = V_m \sin\omega t$
$v = V\angle 0°$



$(0° < \phi < 90°)$

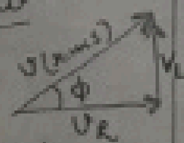
From phasor diagram -
'i' lags 'v' by φ.

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

From the fig. below -

$v^2 = v_R^2 + v_L^2$

$(iZ)^2 = (iR)^2 + (iX_L)^2$



or $\boxed{|Z| = \sqrt{R^2 + X_L^2}}$ Impedance

$\tan\phi = \frac{v_L}{v_R} = \frac{\cancel{i}X_L}{\cancel{i}R}$

$\therefore \boxed{\phi = \tan^{-1}\frac{X_L}{R}}$

* $\cos\phi$ (Power Factor) $= \frac{v_R}{v} = \frac{iR}{iZ}$

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

$\boxed{R = Z\cos\phi}$

$\sin\phi = \frac{v_L}{v} = \frac{\cancel{i}X_L}{\cancel{i}Z}$

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

or $\boxed{X_L = Z\sin\phi}$

* Impedance (Z) :-

$v = V\angle 0°$
$i = I\angle\phi°$

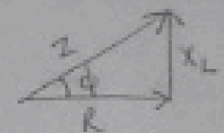
$Z = \frac{V\angle 0°}{I\angle\phi°} = |Z|\angle{+\phi}$

$|Z| = \sqrt{R^2 + X_L^2}$
$\angle\phi = \tan^{-1}\left(\frac{X_L}{R}\right)$

$\cos\phi$ is lagging $(0° < \phi < 90°)$ R-L ckt

$\boxed{Z = (R + jX_L)}\ \Omega$

IMPEDANCE TRIANGLE



POWER :-

$p = v \cdot i$

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

$p = \frac{V_m I_m}{2}\{2\sin\omega t \cdot \sin(\omega t - \phi)\}$ (A) (B)

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

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

Constant Part — Variable Part (Double Freq.)

Avg Power over a complete cycle

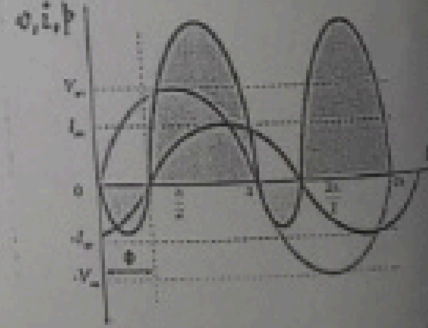
$P_{avg} = \frac{1}{\pi}\int_0^{\pi}\left\{\frac{V_m I_m}{2}\cos\phi - \frac{V_m I_m}{2}\cos(2\omega t - \phi)\right\}$

$\int_0^{\pi}\frac{V_m I_m}{2}\cos(2\omega t - \phi) \cdot d\omega t = 0$ Over a complete cycle.

$\therefore P_{avg} = \frac{V_m I_m}{2}\cos\phi$

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

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

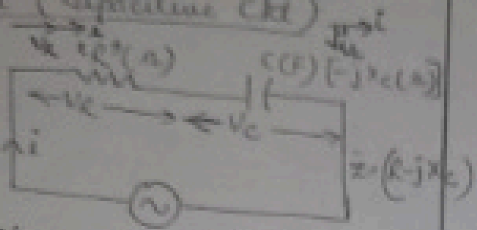


R-C Series Circuit (Capacitive Ckt)

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

$V_R = iR$ Volt {voltage drop across R}

$V_C = iX_C$ Volt {voltage drop across C}



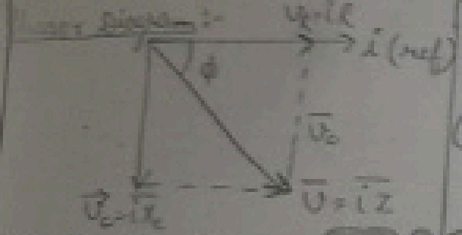
$V_R \to$ is in phase with 'i' for 'R'

$V_C \to$ lagging by 90° for 'C'.

$v = V_m \sin\omega t$

$v = V\angle 0°$

Phasor Diagram :-



i leads v by 90°

$v = V_m \sin\omega t = V\angle 0°$

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

Impedance $(Z) = \dfrac{V\angle 0°}{I\angle \phi} = |Z|\angle\phi$ (P.f. leading)

$Z = (R - jX_C)$ Ω

$$\left.\begin{aligned}|Z| &= \sqrt{R^2 + X_C^2}\\ \angle\phi &= \tan^{-1}\left(\frac{X_C}{R}\right)\end{aligned}\right\}$$

From Phasor Diagram -

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

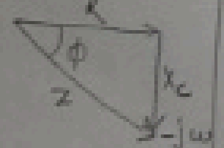
$(iZ)^2 = (iR)^2 + (iX_C)^2$

$|Z| = \sqrt{R^2 + X_C^2}$ (Ω)

$\tan\phi = \dfrac{-V_C}{V_R} = \dfrac{-iX_C}{iR}$

$\boxed{\tan\phi = -\dfrac{X_C}{R} \text{ or } \angle\phi = \tan^{-1}\left(\dfrac{-X_C}{R}\right)}$

Impedance Triangle :-



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

$\boxed{R = Z\cos\phi}$

$\sin\phi = \dfrac{X_C}{Z}$

$\boxed{X_C = Z\sin\phi}$

POWER

$p = v \cdot i$

$p = V_m \sin\omega t \cdot I_m \sin(\omega t + \phi)$

$p = \dfrac{V_m I_m}{2}\left[\underset{(A)}{2\sin\omega t} \cdot \underset{(B)}{\sin(\omega t + \phi)}\right]$

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

$p = \underbrace{\dfrac{V_m I_m \cos\phi}{2}}_{\text{Constant Part}} - \underbrace{\dfrac{V_m I_m \cos(2\omega t + \phi)}{2}}_{\text{Variable Part (Double Freq.)}}$

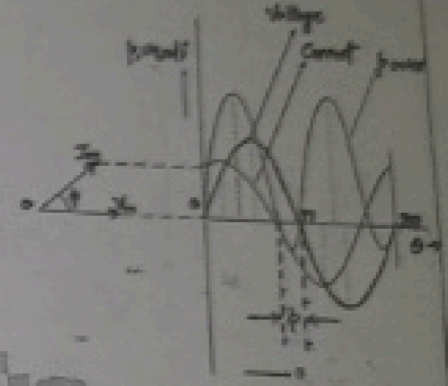
Avg Power over a Complete Cycle

$P_{avg} = \dfrac{1}{\pi}\displaystyle\int_0^{\pi}\left\{\dfrac{V_m I_m \cos\phi}{2} - \dfrac{V_m I_m}{2}\cos(2\omega t + \phi)\right\} d\omega t$

But $\displaystyle\int_0^{\pi} -\dfrac{V_m I_m}{2}\cos(2\omega t + \phi) \cdot d\omega t = 0$

$\therefore P_{avg} = \dfrac{V_m I_m}{2}\cos\phi = \dfrac{V_m}{\sqrt{2}} \cdot \dfrac{I_m}{\sqrt{2}}\cos\phi$

or $\boxed{P_{avg} = V_{rms} \cdot I_{rms} \cdot \cos\phi}$



Imp.

Ques In a series ckt voltage & current are given by

$v = 283 \sin 314 t$ and $i = 4\sin(314t - 45°)$

Find (a) Impedance (b) ckt parameters (c) Power factor & Power (d) Phasor Diagram. [AKTU-2013-14]

Sol^n $v = \dfrac{283}{\sqrt{2}}\angle 0°$

$i = \dfrac{4}{\sqrt{2}}\angle -45°$ (r.m.s)

a) $\therefore Z = \dfrac{v}{i} = \dfrac{283/\sqrt{2}\angle 0°}{4/\sqrt{2}\angle -45°}$

$\therefore \boxed{Z = 70.75\angle 45°}$ +ve sign i.e P.f. is lagging

or $Z = (50 + j50)$ Ω

$Z = (R + jX_L)$

(b) $\boxed{R = 50\,\Omega}$

$X_L = 50\,\Omega$

$X_L = \omega L$

$50 = 314 \times L$

$\boxed{L = 0.159\,H}$

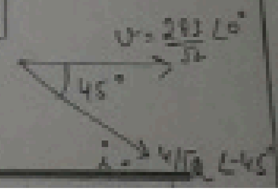
(c) $\phi = 45°$ $\therefore \cos\phi = \cos 45° = .707$ (lag)

$P = V_{rms} \cdot I_{rms}\cos\phi$

$= \dfrac{283}{\sqrt{2}} \times \dfrac{4}{\sqrt{2}} \times .707$

$\boxed{P = 400.16 \text{ Watt}}$

(d) Phasor Diagram

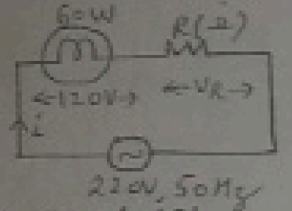


Imp.

Ques: A 120 V, 60 W lamp is to be operated on 220 V, 50 Hz supply mains. In order that lamp should operate on correct voltage, calculate the value of (a) Non-Inductive resistance (b) Pure Inductance.

(AKTU 2013-14)

Sol^n (a)



Lamp is purely 'R'.

$\therefore i = \frac{P}{V_{lamp}} = \frac{60}{120} = 0.5$ Amp

$\vec{V}_{supply} = \vec{V}_{Lamp} + \vec{V}_R$ (same Phase)

$220 = 120 + V_R$

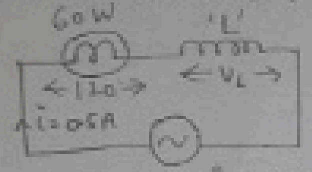
$\boxed{V_R = 100V}$

$V_R = iR$

$100 = 0.5\,R$

$\boxed{R = 200\,\Omega}$

(b) Pure Inductance (L)



$\vec{V}_{supply} = \vec{V}_{Lamp} + \vec{V}_L$

$V^2 = V_{Lamp}^2 + V_L^2$

$(220)^2 = (120)^2 + (V_L)^2$

or $V_L = \sqrt{(220)^2 - (120)^2}$

$\boxed{V_L = 184.3908}$ Volt

$V_L = iX_L$

$184.39 = 0.5\,X_L$

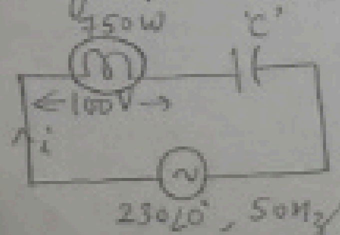
$X_L = 368.78\,\Omega$

$L = \frac{X_L}{2\pi f} = \frac{368.78}{314}$

$\boxed{L = 1.1738\,H}$

Ques: A metal filament lamp rated at 750W, 100V is to be connected in series with a capacitance across a 230V, 50Hz supply. Cal. the value of Capacitance required. Draw phasor diagram.

Sol^n Lamp is purely resistive.

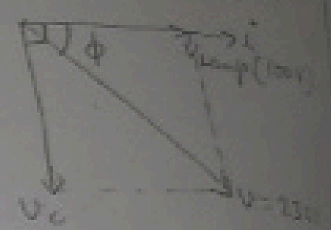


$P = VI$

$I = \frac{P}{V_{lamp}} = \frac{750}{100} = 7.5$ amp

$\therefore \boxed{I = 7.5\text{ Amp}}$

From Phasor Diagram-



$V^2 = V_{Lamp}^2 + V_C^2$

$(230)^2 = (100)^2 + V_C^2$

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

$\boxed{V_C = 207.12\text{ Volt}}$

$V_C = iX_C$

$X_C = \frac{V_C}{i} = \frac{207.12}{7.5} = 27.616\,\Omega$

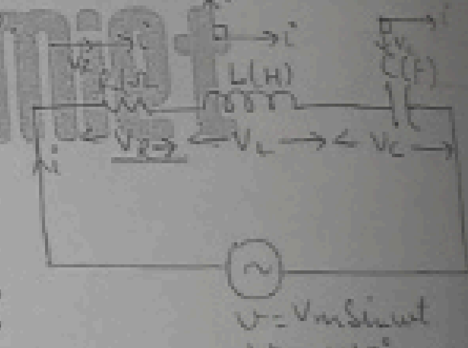
$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$

$\boxed{C = 115.261\,\mu F}$

V. Imp. **Series R-L-C Circuit** (AKTU 2017-18)

According to Kirchoff's law

$\vec{V} = \vec{V_R} + \vec{V_L} + \vec{V_C}$ — (1)



$V_R = iR$ Volt

$V_L = iX_L$ Volt

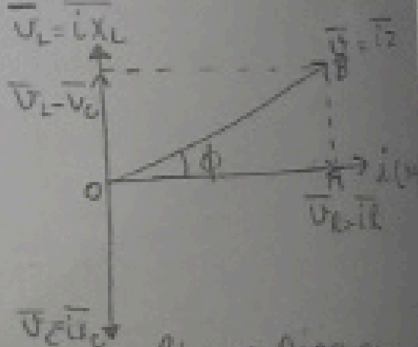
$V_C = iX_C$ Volt

V_R is in phase with i;

V_L leads 'i' by 90°

V_C lags 'i' by 90°

From Phasor Diagram-



Phasor Diagram

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

$\{Z = R + j(X_L - X_C)\}\,\Omega$

In $\triangle OAB$

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

$(iZ)^2 = (iR)^2 + (iX_L - iX_C)^2$

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

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

There are three possible cases –

Case 1 When $X_L = X_C$ $(V_L = V_C)$

Impedance $Z = R + j(X_L - X_C)\,\Omega$

$\because X_L = X_C$

$\therefore \boxed{Z = R}\,\Omega$

ckt is purely resistive.

v & i are in same phase

$\phi = 0^\circ \therefore \cos\phi = 1$ (Unity)

$P = V_{rms} \cdot I_{rms}$ watt

or $P = I_{rms}^2 \cdot R$ watt

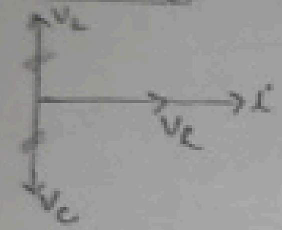
$\vec{V} = \vec{V_R} + j(\vec{V_L} - \vec{V_C})$

$X_L = X_C$

$iX_L = iX_C$

$\boxed{V_L = V_C}$

$\therefore \boxed{V = V_R}$



Case 2 When $X_L > X_C$, $V_L > X_C$

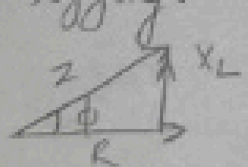
$Z = R + j(X_L - X_C)\,\Omega$

If $X_L >>> X_C$

$\boxed{Z = R + jX_L}\,\Omega \rightarrow$ Inductive ckt

$\left.\begin{array}{l} |Z| = \sqrt{R^2 + X_L^2} \\ \angle\phi = \tan^{-1}\left(\frac{X_L}{R}\right) \end{array}\right\}$ $\boxed{Z = |Z| \angle\phi}$

Power Factor is lagging.



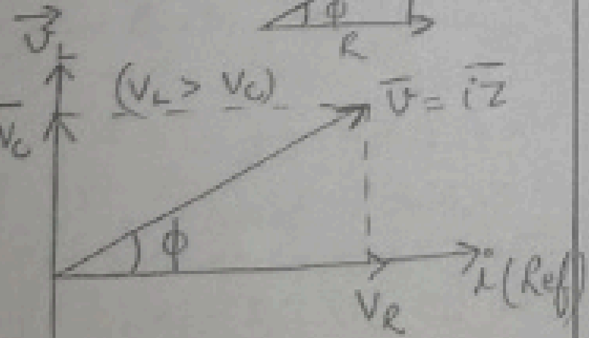
i lags v by ϕ $(0^\circ < \phi < 90^\circ)$

$\cos\phi = \frac{R}{Z}$ & $\sin\phi = \frac{X_L}{Z}$

$P = V_{rms} \cdot I_{rms} \cdot \cos\phi$ (watt)

$Q = V_{rms} I_{rms} \sin\phi$ (VAR)

$S = V_{rms} \cdot I_{rms}$ (VA)



behaves as an Inductive

Case 3 When $X_L < X_C$, $V_L < V_C$

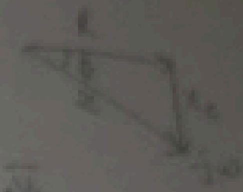
Impedance $Z = R + j(X_L - X_C)\,\Omega$

as $X_L < X_C$

$\boxed{Z = R - jX_C}\,\Omega$

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

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

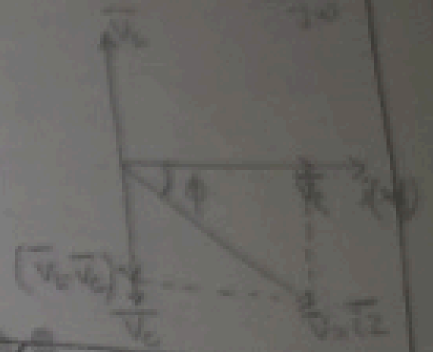


1) $Z = (R - jX_C)\,\Omega \rightarrow$ R-C circuit

2) i leads v by ϕ $(0^\circ < \phi < 90^\circ)$

3) $\cos\phi = \frac{R}{Z}$ & $\sin\phi = \frac{X_C}{Z}$

4) $P = V_{rms} \cdot I_{rms} \cdot \cos\phi$ watt



Imp. **A.C. POWER :-** (AKTU 2015-16)

In an a.c. circuits, power is represented differently. Total Power is "Volt - Amp" VA. It's real & reactive components are represented by "watts" and "Volt - Amp reactive" (VAR). Hence –

$S > VR$

AC Total Power $\boxed{S = VI^*} = \boxed{P + jQ}$ $P + j$

where $P = VI\cos\phi$ (Watt) ; $Q = VI\sin\phi$ (VAR)

V & I are rms val...

* **APPARENT POWER (S) :-**

Total Power drawn by the ckt from the supply is called "Apparent Power".

$\boxed{S = V_{rms} \cdot I_{rms}}$ (VA)

$\left\{\begin{array}{l} S = P + jQ \\ S^2 = P^2 + Q^2 \end{array}\right\}$

* Active (Real / True) Power (P) :-

→ It is the power utilized by the ckt. It is the power dissipated in pure resistance.

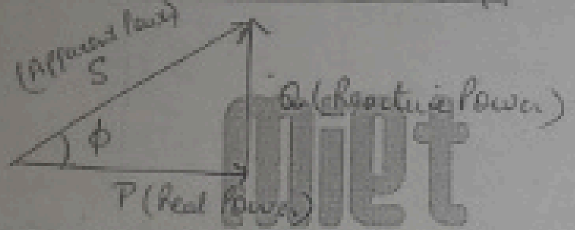
→ It is the multiplication of voltage & real component of current.

→ Real Power flows from source to load.

$\boxed{P = V_{rms} I_{rms} \cos\phi}$ watt

* Reactive Power (Q) :- Power which is not utilized by the ckt is called Reactive Power. It is the multiplication of voltage & reactive component of current.

$\boxed{Q = V_{rms} \cdot I_{rms} \sin\phi}$ VAR



Ques Given $v = 200 \sin 377t$ Volt, $i = 8 \sin(377t - 30°)$ A for an ac ckt. Determine :- (a) Impedance (b) Ckt elements (c) Power Factor (d) P, Q, S (e) Phasor Diagram.

Solⁿ $V_{rms} = 200/\sqrt{2} = \frac{200}{\sqrt{2}} \angle 0° \ V$

$I_{rms} = \frac{8}{\sqrt{2}} = \frac{8}{\sqrt{2}} \angle -30° \ A$

$\omega = 377$ rad/sec

a) $Z = \frac{V}{I} = \frac{200/\sqrt{2} \angle 0°}{8/\sqrt{2} \angle -30°} = 25\angle 30° \ \Omega$

$\boxed{Z = (21.65 + j\,12.5)}\ \Omega$

b) $R = 21.65\ \Omega$

$X_L = 12.5\ \Omega$

$X_L = \omega L$

$L = \frac{X_L}{\omega} = \frac{12.5}{377} = .0331$ H

$\boxed{L = .0331\text{ H}}$

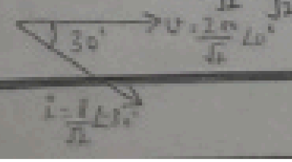
$Z = 25\angle 30°$

c) $\cos\phi = \cos 30° = .866$ (lagging)

$S = V_{rms} I_{rms} = \frac{200}{\sqrt{2}} \cdot \frac{8}{\sqrt{2}} = 800$ (VA)

$P = V_{rms} I_{rms} \cos\phi = \frac{200}{\sqrt{2}} \times \frac{8}{\sqrt{2}} \times .866 = 692.8$ (W)

$Q = V_{rms} I_{rms} \sin\phi = \frac{200}{\sqrt{2}} \times \frac{8}{\sqrt{2}} \times 0.5 = 400$ (VAR)

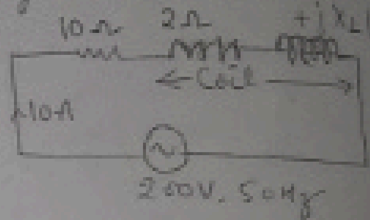
e) 

Imp

Ques: A non-inductive resistance of 10 Ω is connected in series with an inductive coil across 200V, 50Hz ac supply. The current drawn by the series combination is 10A. The resistance of the coil is 2 Ω. Determine (AKTU 2017-18)

(a) Inductance of the coil

(b) Power factor (c) Voltage across the coil.



Solⁿ $Z = (R + r) + jX_L = (12 + jX_L)\ \Omega$

$|Z| = \sqrt{(12)^2 + X_L^2}$

$I = 10$A

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

$10 = \frac{200}{\sqrt{12^2 + X_L^2}}$ i.e $(12)^2 + (X_L)^2 = \left(\frac{200}{10}\right)^2$

or $X_L^2 = 256$

$\boxed{X_L = 16\ \Omega}$

a) $X_L = 2\pi f L$

$16 = 2 \times \pi \times 50 \times L$

$\boxed{L = .0509\text{ H}}$

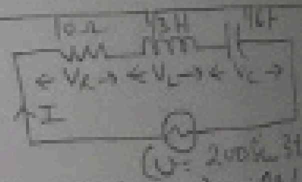
b) $\cos\phi = \frac{(R+r)}{Z} = \frac{12}{\sqrt{12^2 + (16)^2}} = 0.6$ (lag)

c) $V_{coil} = I \cdot Z_{coil}$

$Z_{coil} = r + jX_L = (2 + j16)\ \Omega = 16.12\angle 82.87°\ \Omega$

$\boxed{V_{coil} = 10 \times 16.12 = 161.245}$ Volt

Ques Find (i) Z (ii) I (iii) $\cos\phi$ (iv) V_R, V_L, V_C (v) P, Q, S



Solⁿ $v = \frac{200}{\sqrt{2}} \angle 0°$, $\omega = 3$ rad/sec

$X_L = \omega L = 3 \times \frac{1}{3} = 1\ \Omega$

$X_C = 1/\omega C = \frac{1}{3 \times 1/6} = 2\ \Omega$

$\therefore R = 10\ \Omega$, $X_L = 1\ \Omega$, $X_C = 2\ \Omega$

$Z = R + j(X_L - X_C) = 10 + j(1 - 2)$

(i) $Z = (10 - j1) = 10.04\angle -5.71°$

(ii) $I = \frac{V}{Z} = \frac{200/\sqrt{2} \angle 0°}{10.04\angle -5.71°}$

$I = \underline{14.08\sqrt{2}\sin(3t + 5.71°)}$ Amp

(iii) $\cos\phi = \cos(-5.71) = .99$ (leading)

(iv) $V_R = iR = 14.08 \times 10 = 140.8$ ...

$V_L = iX_L = 14.08 \times 1 = 14$ ...

$V_C = iX_C = 14.08 \times 2 = 2$ ...

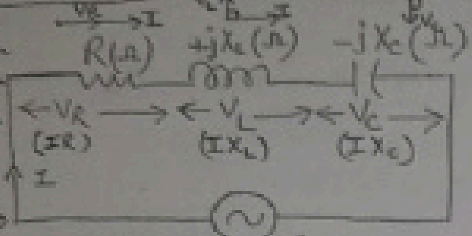
(v) $S = V_{rms} I_{rms} = 1991.21$ ...

$P = V_{rms} \cdot I_{rms} \cos\phi = 198$ ...

$Q = V_{rms} \cdot I_{rms} \sin\phi = 198$ ...

RESONANCE IN SERIES R-L-C CIRCUIT :-

Resonance is the condition in a series R-L-C ckt that when frequency of supply is varied then at a particular freq. called resonant frequency (f_r), the current is maximum and net reactance of the ckt is zero. Ckt behaves as a purely resistive ckt and power factor is unity.



$V = V_m \sin\omega t$, $f = f_r$, Variable freq.

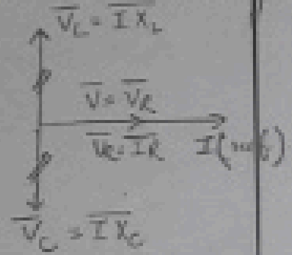
At Resonant Freq. f_r,

$V_L = V_C$

$X_L - X_C = 0$

→ $\boxed{X_L = X_C}$ (Ω)

$IX_L = IX_C$



→ ∴ $\boxed{V_L = V_C}$

→ $\boxed{Z = R}$ (Ω), minimum → Purely Resistive

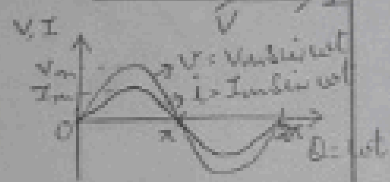
→ $\boxed{V = V_R}$ (Volt)

→ Current is maximum $\boxed{I_{max} = \frac{V}{R}}$ (amp)

→ Voltage & current are in same phase.

$\phi = V \wedge I = 0°$

→ $\boxed{\cos\phi = 1}$ = Unity



RESONANT FREQUENCY :- (f_r)

Frequency at which resonance occurs is called Resonant Frequency (f_r).

At f_r,

$X_L - X_C = 0$

$X_L = X_C$

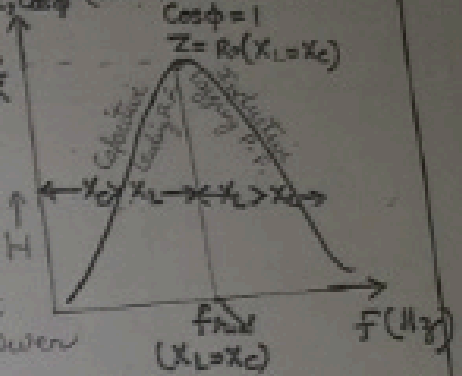
$\omega_r L = \frac{1}{\omega_r C}$

$\omega_r = \frac{1}{\sqrt{LC}}$ (rad/sec)

as $\omega = 2\pi f$

∴ $\boxed{f_r = \frac{1}{2\pi\sqrt{LC}}}$ (Hz)

RESONANCE CURVE :-



→ At resonance frequency (f_r) Impedance is minimum & current is maximum. Power factor is unity & ckt behaves as a purely resistive ckt.

→ On L.H.S of f_r, for lower frequencies $X_C > X_L$ ($X_C \propto \frac{1}{f}$) so ckt behaves as a capacitive ckt & Power Factor is leading.

→ On R.H.S of f_r for higher frequencies $X_L > X_C$ ($X_L \propto f$) so ckt behaves as an inductive ckt & power factor is mainly lagging.

Ques:- Why in series resonance, voltage across 'L' & 'C' is very high?

Solⁿ In series resonance, current is maximum 'I_{max}' & $V_L = I_{max} \cdot X_L$ and $V_C = I_{max} \cdot X_C$, so at f_r, $V_L = V_C$ and V_L & V_C are very high than supply voltage.

Ques:- Why series R-L-C ckt at resonance is called acceptor ckt?

Solⁿ:- In series R-L-C ckt, at resonant frequency, impedance is minimum $\boxed{Z = R}$ (Ω) and current is maximum $\boxed{I_{max} = \frac{V}{R}}$. So, it accepts the signals of a particular frequency. Hence it is called acceptor ckt.

Ques:- What are the applications of series resonant ckt?

Solⁿ:- → In radio transmitters and receivers.
→ In Inverters.
→ Tuning circuits in t.v receivers.
→ As a wave trap.

Imp: (AKTU 2013-14)

Ques:- Derive the Quality factor of series resonant ckt.

Sol^n:- Q-factor is defined as the voltage magnification in a series resonance (voltage resonance) ckt.

$$\boxed{Q = \frac{\text{Voltage across L or C}}{\text{Supply voltage}}}$$

$Q = \frac{V_L}{V}$ | $Q = \frac{V_C}{V}$

$Q = \frac{I_{max} \cdot X_L}{I_{max} \cdot R}$ | $Q = \frac{I_{max} \cdot X_C}{I_{max} \cdot R}$

$Q = \frac{\omega_r L}{R}$ | $Q = \frac{1}{\omega_r \cdot C \cdot R}$

$Q = \frac{1}{\sqrt{LC}} \cdot \left(\frac{L}{R}\right)$ | $Q = \frac{\sqrt{LC}}{CR}$

$$\boxed{Q = \frac{1}{R}\sqrt{\frac{L}{C}}} \qquad \boxed{Q = \frac{1}{R}\sqrt{\frac{L}{C}}}$$

Ques:- In a series R-L-C ckt, $R = 10\Omega$, $L = 0.2H$, $C = 40\mu F$. It is supplied with a 100V supply at variable freq. Find the following w.r.t series resonant ckt:

(i) The frequency at resonance (ii) Current (iii) Power factor (iv) Power (v) Voltage across R, L, C at resonance (vi) Q-factor (vii) Half Power Frequencies (viii) Phasor Diagram. (AKTU 2014-15)

Sol^n Given:- $R = 10\Omega$, $L = 0.2H$, $C = 40\mu F$, $V = 100$ (Volt)

(i) $f_r = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2 \times 3.14\sqrt{0.2 \times 40 \times 10^{-6}}} = 56.269$ (Hz)

(ii) $I_{max} = \frac{V}{R} = \frac{100}{10} = 10$ (Amp)

(iii) $\cos\phi = \cos 0° = 1$ (Unity) as V & I are in same phase.

(iv) $P = I^2_{max} \cdot R = (10)^2 \times 10 = 1000$ (Watt)

(v) $V_R = I_{max} R = 10 \times 10 = 100$ (Volt)

$V_L = V_C$

$V_L = I_{max} \cdot X_L = 10 \times (2 \times 3.14 \times 56.269 \times 0.2)$

$\boxed{V_L = 707.105}$ Volt.

$V_C = I_{max} \cdot X_C = 10 \times \frac{1}{2 \times 3.14 \times 56.269 \times 40 \times 10^{-6}}$

$\boxed{V_C = 707.105}$ Volt

(vi) $Q = \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{1}{10}\sqrt{\frac{0.2}{40 \times 10^{-6}}} = 7.07$

(vii) $f_1 = f_r - \frac{R}{2\pi L}$

$f_1 = 56.269 - 3.9788$

$\boxed{f_1 = 52.2909}$ (Hz)

$f_2 = f_r + \frac{R}{2\pi L}$

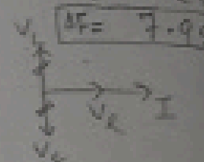
$f_2 = 56.269 + 3.9788$

$\boxed{f_2 = 60.2485}$ Hz

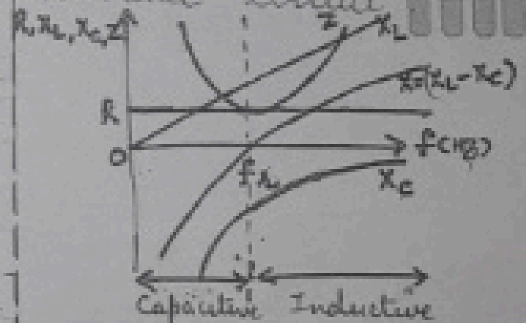
(viii) Bandwidth $\Delta F = f_2 - f_1$

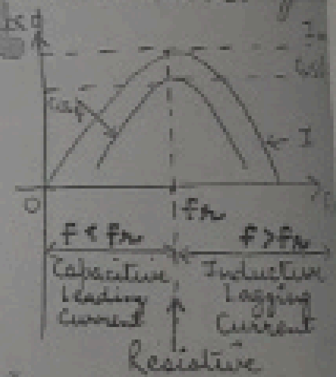
$= 60.248 - 5$

$\boxed{\Delta F = 7.95}$ (Hz)



Ques:- Draw and explain the characteristics of resonance circuit.





Characteristics of Series Resonance

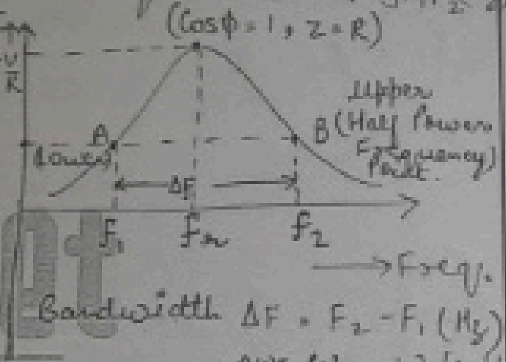
* As $X_L = 2\pi f L$ i.e. $\boxed{X_L \propto f}$ & is represented by a straight line from origin.
* As $X_C = \frac{1}{2\pi f C}$ i.e. $\boxed{X_C \propto \frac{1}{f}}$ & is represented by rectangular hyperbola in fourth Quadrant.
* R is independent of supply freq. & is represented by line ‖ to freq. axis.

- At $f = f_r$, value of $X_L = X_C$ & the net reactance (X) curve lies in b/w X_L & X_C.
- At $f = f_r$, $\cos\phi = 1$
  At $f < f_r$, $\cos\phi$ is leading in nature
  At $f > f_r$, $\cos\phi$ is lagging in nature.

$*$ Imp.

Ques Define bandwidth of series R-L-C ckt. Prove that the resonant frequency is the geometric mean of upper & lower Half Power Frequencies. $f_r = \sqrt{f_1 f_2}$ (Hz).
AKTU 2017-18, 16-17, 14-15, 13-14)

Sol^n bandwidth is defined as the band of frequencies that lie on either side of resonant freq. where current falls $\frac{1}{\sqrt{2}}$ times of its Max. value.



Bandwidth $\Delta F = F_2 - F_1$ (Hz)
$\Delta\omega = \omega_2 - \omega_1$ (rad/sec)

At Half Power Points,
Power $\rightarrow$ $P_A = P_B = (I_m/\sqrt{2})^2 \cdot R$
$P_A = P_B = \frac{I_m^2 R}{2} = \frac{P}{2}$

Proof $\rightarrow$ Impedance of R-L-C ckt is given by -:

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

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

At Half Power Points $I = \frac{I_m}{\sqrt{2}} = \frac{V}{\sqrt{R^2 + (X_L - X_C)^2}}$

as $I_m = \frac{V}{R}$ so $\frac{V}{\sqrt{2} \cdot R} = \frac{V}{\sqrt{R^2 + (X_L - X_C)^2}}$

Squaring both sides -
$2R^2 = R^2 + (X_L - X_C)^2$
$R^2 = (X_L - X_C)^2$
$R = \pm (X_L - X_C) (\Omega)$ — (A)

Case I when $R = +(X_L - X_C)(\Omega)$
or $R = (\omega L - \frac{1}{\omega C})$
$R = \frac{\omega^2 LC - 1}{\omega C}$
$\omega^2 LC - \omega CR - 1 = 0$
$Ax^2 + Bx + C = 0$
By Shreedharacharya Formula,
$\omega = \frac{+CR \pm \sqrt{C^2R^2 + 4LC}}{2LC}$
$\omega = \frac{R}{2L} \pm \sqrt{\frac{R^2}{4L^2} + \frac{1}{LC}}$
As $\frac{1}{L} >>>> \frac{R^2}{4L^2}$ so, $\frac{R^2}{4L^2}$ is neglected
$\therefore \omega = (\frac{R}{2L} \pm \omega_r)$ ($\because \omega_r = \frac{1}{\sqrt{LC}}$ rad/sec)

Case II when $R = -(X_L - X_C)(\Omega)$
Similarly as of Case I,
$(\omega = -\frac{R}{2L} \pm \omega_r)$
so there are 4 roots of ω
$\{\omega = \frac{R}{2L} + \omega_r, \frac{R}{2L} - \omega_r, -\frac{R}{2L} + \omega_r, -\frac{R}{2L} - \omega_r\}$
as ω_r can't be negative, so there are two roots of ω:
$\{\omega = \omega_r + \frac{R}{2L}$ & $\omega_r - \frac{R}{2L}$

Let ω_1 = Lower Half Power Freq.
ω_2 = Upper Half Power Frequency.

$$\left.\begin{aligned}\omega_1 &= \omega_r - \frac{R}{2L}\\ \omega_2 &= \omega_r + \frac{R}{2L}\end{aligned}\right\} \text{rad/sec} \rightarrow (1)$$

as $\omega = 2\pi f$, so,

$$\left.\begin{aligned}f_1 &= f_r - \frac{R}{4\pi L}\\ f_2 &= f_r + \frac{R}{4\pi L}\end{aligned}\right\} \text{cycle/sec} \rightarrow (2)$$

$\Delta\omega = \omega_2 - \omega_1 = \frac{R}{L}$ (rad/sec) – (3)

$\Delta f = f_2 - f_1 = \frac{R}{2\pi L}$ (cycle/sec) – (4)

Put eq^n (3) in eq^n (1) & eq^n (4) in eq^n (2).

$$\left.\begin{aligned} \omega_1 &= \omega_r - \frac{\Delta\omega}{2} \\ \omega_2 &= \omega_r + \frac{\Delta\omega}{2} \end{aligned}\right\} \text{(rad/sec)} - (5)$$

$$\left.\begin{aligned} f_1 &= f_r - \frac{\Delta f}{2} \\ f_2 &= f_r + \frac{\Delta f}{2} \end{aligned}\right\} \text{(cycle/sec)} - (6)$$

To Prove that :- $f_r = \sqrt{f_1 f_2}$

We have, $\boxed{X_L - X_C = \pm R}$ {from eq^n (A)}

$\therefore X_L - X_C = +R$ [For Upper Half Power Freq]

$\omega_2 L - \frac{1}{\omega_2 C} = +R \rightarrow (7)$

$X_L - X_C = -R$ [For Lower Half Power Freq.]

$\omega_1 L - \frac{1}{\omega_1 C} = -R \rightarrow (8)$

Adding eq^n (7) & (8),

$(\omega_1 + \omega_2)L - \frac{1}{C}\left[\frac{1}{\omega_1} + \frac{1}{\omega_2}\right] = 0$

$\therefore (\omega_1 + \omega_2)L = \frac{1}{C}\left[\frac{\omega_1 + \omega_2}{\omega_1\omega_2}\right]$

$\therefore \omega_1\omega_2 = \frac{1}{LC}$

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

$\therefore \omega_1\omega_2 = \omega_r^2$

$$\boxed{f_1 f_2 = f_r^2}$$

This shows that Resonant freq. f_r is geometric mean of two Half Power frequencies.

Ques :- In a series R-L-C ckt, $R = 2\Omega$, $L = 2$ mH, $C = 10\,\mu F$. Find out (i) Resonant Freq (ii) Q-factor (iii) Bandwidth (iv) Half Power Frequencies. (AKTU 2018-19)

Sol^n (i) $f_r = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\times 3.14\sqrt{.002\times 10\times 10^{-6}}} = 1125.4$ (Hz)

(ii) Q-Factor $= \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{1}{2}\sqrt{\frac{0.002}{10\times 10^{-6}}} = 7.07$

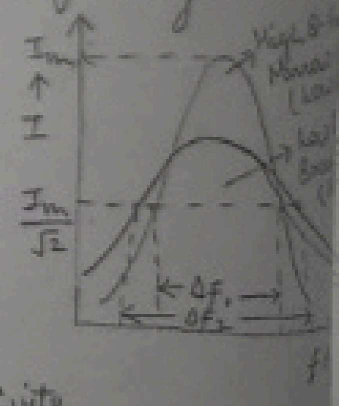
(iii) Bandwidth $\Delta f = \frac{R}{2\pi L} = \frac{2}{2\times 3.14\times 0.002} = 159.15$

(iv) $f_1 = f_r - \frac{R}{4\pi L} = 1125.4 - \frac{2}{4\times 3.14\times 0.002} = 1045.1$

$f_2 = f_r + \frac{R}{4\pi L} = 1125.4 + \frac{2}{4\times 3.14\times 0.002} = 1204.9$

Imp.

SELECTIVITY :- It is the ability to select the signal of a particular Frequency & discriminates other frequencies.



Q-Factor & Bandwidth :-

$Q = \frac{f_r}{\Delta f}$ or $\frac{\omega_r}{\Delta\omega}$

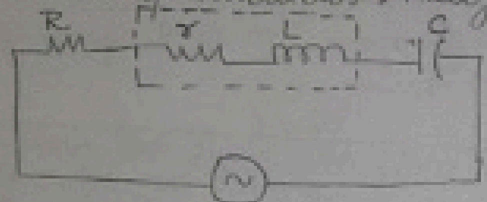
$\therefore$ Q-Factor $\propto \frac{1}{\text{Bandwidth}(\Delta f)}$

If ΔF is narrow → Q-High → High Selectivity

If ΔF is broad → Q-Low → Low Selectivity

For large values of 'R', Curve becomes flatter.

Ques: A 20Ω resistor is connected in series with an inductor and a capacitor, across a variable Freq. 25V supply. When the frequency is 400 Hz, the current is at its maximum value of 0.5 A & the potential difference across the capacitor is 150V. Calculate the resistance & inductance of inductor. Also find 'C'.



Solⁿ $V_L = V_C = 150V$

$I_{max} = 0.5A \{Z = R + r\}$

$I_{max} = \frac{V}{R+r}$

$0.5 = \frac{25}{20+r}$

$\boxed{r = 30\Omega}$

$V_C = I_{max} \cdot X_C$

$150 = 0.5 \times \frac{1}{2\pi \times 400 \times C}$ {as F_r (400 Hz)}

$\boxed{C = 1.322\ \mu F}$

$V_L = V_C = 150V$

$V_L = I_{max} \cdot X_L$

$150 = 0.5 \times (2 \times 3.14 \times 400 \times L)$

$\boxed{L = 0.1193\ H}$

Ques:- Calculate the power factor if $v(t) = V_m \sin(\omega t - 45°)$ and $i(t) = I_m \sin(\omega t - 135°)$.

Solⁿ $v(t) = \frac{V_m}{\sqrt{2}} \angle -45°$

$i(t) = \frac{I_m}{\sqrt{2}} \angle -135°$

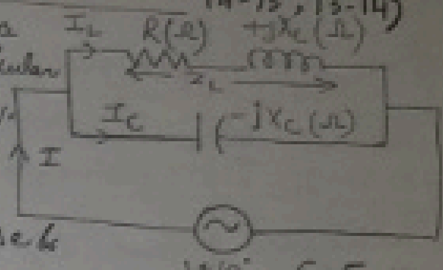
$\phi = V \wedge I = (-45° + 135°) = 90°$

$\boxed{\cos\phi = \cos(90°) = 0}$

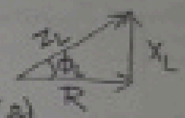
V. Imp.

RESONANCE IN PARALLEL R-L-C CKT :- (AKTU 2018-19, 17-18, 14-15, 13-14)

Resonance is the condition in a parallel ckt (R-L-C) that at a particular frequency called resonant Freq. (F_r), the power factor of the ckt is unity. The supply voltage & total current are in same phase & current is minimum.



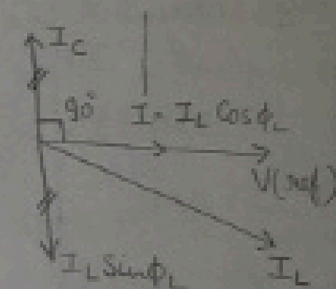
Impedance of Inductive Branch :- $Z_L = \sqrt{R^2 + X_L^2}$



Impedance of Capacitive Branch :- X_C (Ω)

From Phasor Diagram :-

I_L lags 'V' by ϕ_L & 'I_C' leads 'V' by 90°.



At Resonant Freq. F_r, the reactive component of current is zero

$\therefore I_C - I_L \sin\phi_L = 0$ — ①

Total Current $I = I_L \cos\phi_L$ — ②

From Impedance Δ :-

$\cos\phi_L = \frac{R}{\sqrt{R^2+X_L^2}}$, $\sin\phi_L = \frac{X_L}{\sqrt{R^2+X_L^2}}$

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

$I_L = \frac{V}{Z_L} = \frac{V}{\sqrt{R^2+X_L^2}}$

$I_C = \frac{V}{X_C}$

From eqⁿ ①, $I_C = I_L \sin\phi_L$

$\frac{V}{X_C} = \frac{V}{\sqrt{R^2+X_L^2}} \cdot \frac{X_L}{\sqrt{R^2+X_L^2}}$

or $Z_L^2 = X_L \cdot X_C$

$Z_L^2 = \omega_r L \cdot \frac{1}{\omega_r C}$

or $Z_L^2 = \frac{L}{C}$

Let $\omega_r \rightarrow$ resonant Freq.

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

$R^2 + (\omega_r L)^2 = \frac{L}{C}$

$\omega_r^2 = \frac{L}{L^2 C} - \frac{R^2}{L^2}$

$\omega_r = \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$ (rad/sec)

or $\omega_r = 2\pi f_r$

$\boxed{F_r = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}}$ (Hz) if $\frac{1}{LC} >>>> \frac{R^2}{L^2}$, then $\frac{R^2}{L^2} \rightarrow$ neglected.

$\therefore$ $\boxed{f_r = \frac{1}{2\pi\sqrt{LC}}}$ Hz (For Ideal Case)

DYNAMIC IMPEDANCE :- (Z_D)

(AKTU 2019-20)

The impedance offered by the parallel ckt at resonance is called Dynamic Impedance of the ckt.

At resonance,

Total Current $I = I_L \cos\phi_L$

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

$$I = \frac{V \cdot R}{Z_L^2}$$

or $I = \frac{V \cdot R}{\frac{L}{C}}$ $\{$as $Z_L^2 = \frac{L}{C}\}$

or $I = \frac{V}{\boxed{\frac{L}{RC}}} \rightarrow Z_D$ (Dynamic Impedance)

$\therefore$ $\boxed{Z_D = \frac{L}{RC}}$ Ω

as I is minimum at resonance, Z_D is High.

Important Points :-

* Impedance is max. $Z_D = \frac{L}{RC}$ Ω
* Current is minimum $I = \frac{V}{Z_D}$
* Power Factor is unity ($\cos\phi = 1$)
* Admittance is minimum.
* Current Magnification
* $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$

APPLICATIONS :-

1.) R-F Oscillators.
2.) Complex Communication Ckt.
3.) Impedance Transformation
4.) In Filters.

Q-FACTOR OF PARALLEL R-L-C CKT AT RESONANCE OR CURRENT MAGNIFICATION

Q = Current in inductive/Capacitive Branch / Total current at resonance

$$Q = \frac{I_L}{I} = \frac{(V/Z_L)}{(V/Z_D)}$$

$$Q = \frac{Z_D}{Z_L} = \frac{(L/RC)}{\sqrt{L/C}}$$

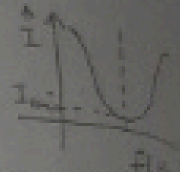
$$\boxed{Q = \frac{1}{R}\sqrt{\frac{L}{C}}}$$

Imp.

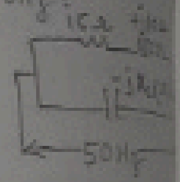
Ques:- Why Parallel ckt at resonance is called a rejector ckt? (2018-19)

Ans:- In Parallel resonance, at resonant Frequency, current is minimum and impedance is maximum. So, it rejects the signals of a particular Frequency. Hence is called a rejector ckt and is used in Filters.

$\{$as 'F' increases, $Z_L = \sqrt{R^2 + X_L^2} \rightarrow$ inc. & $\cos\phi_L = \frac{R}{Z_L} \rightarrow$ dec. so $I = I_L \cos\phi_L \rightarrow$ Minimum at f_r.



Ques: A series a-c circuit has resistance of 15Ω & inductive reactance of 10Ω. Cal. the value of 'C' which is connected across this series combination so that the system has unity power factor. Frequency of a-c supply is 50Hz.



Soln $R = 15\Omega$, $X_L = 10\Omega$

This is Parallel Resonance with $\boxed{f_r = 50Hz}$

$X_L = 2\pi f_r L$

$L = \frac{10}{314} = 0.03183$ H

$$\boxed{f_r = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}}$$

$$50 = \frac{1}{2\times3.14}\sqrt{\frac{1}{.03183C} - \frac{15^2}{(.03183)^2}}$$

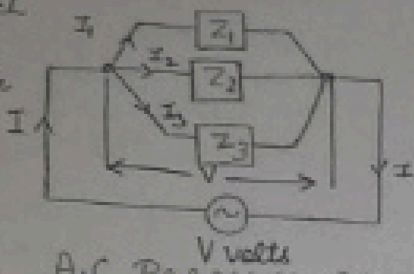
$\boxed{C = 97.94}$ (µF)

Comparision B/W Series and Parallel Resonance

S.No.	Parameter	Series Resonant	Parallel Resonant
1.)	Circuit		
2.)	Type of circuit	Purely Resistive	Purely Resistive
3.)	Power Factor	Unity	Unity
4.)	Impedance	Minimum Z = R	Dynamic but Hi (ZD) = L/RC
5.)	Frequency (f_r)	$f_r = \frac{1}{2\pi\sqrt{LC}}$	$f_r = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$
6.)	Current (I)	Maximum $I = \frac{V}{R}$	Minimum $I = \frac{V}{Z_D}$
7.)	Magnification	Voltage Magnification	Current Magnification
8.)	Quality factor (Q)	$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$	$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$

AC PARALLEL CIRCUIT

A Parallel ckt is one in which two or more impedances are connected in Parallel across the supply voltage.



A.C PARALLEL CKT

$$\boxed{\vec{I} = \vec{I_1} + \vec{I_2} + \vec{I_3}}$$

$$\frac{\vec{V}}{\vec{Z}} = \frac{\vec{V}}{\vec{Z_1}} + \frac{\vec{V}}{\vec{Z_2}} + \frac{\vec{V}}{\vec{Z_3}}$$

or
$$\boxed{\frac{1}{\vec{Z}} = \frac{1}{\vec{Z_1}} + \frac{1}{\vec{Z_2}} + \frac{1}{\vec{Z_3}}}$$

TWO IMPEDANCES IN PARALLEL

If two impedances are in Parallel and I_T is the total current, then for calculating individual branch current, Apply Current Division Rule -

$$\boxed{\vec{I_1} = \vec{I_T} \times \frac{\vec{Z_2}}{\vec{Z_1} + \vec{Z_2}}}$$

$$\boxed{\vec{I_2} = \vec{I_T} \times \frac{\vec{Z_1}}{\vec{Z_1} + \vec{Z_2}}}$$

ADMITTANCE :- is defined as the reciprocal of Impedance.

Let $Z = R \pm jX$

$$\boxed{\text{Admittance}(Y) = \frac{1}{Z\,(\text{Impedance})}}$$

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

Rationalising the above expression -

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

$$\boxed{Y = \left(\frac{R}{R^2+X^2}\right) \mp j\left(\frac{X}{R^2+X^2}\right) = \frac{R}{Z^2} \mp j\frac{X}{Z^2}}$$

$$\therefore \boxed{Y = G \mp jB}$$

where G = Conductance $= \frac{R}{Z^2}$

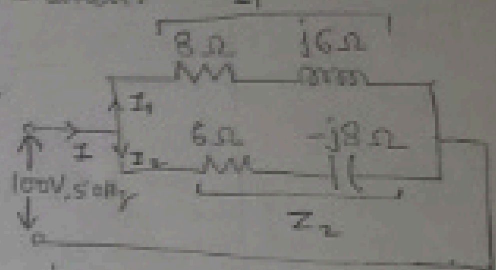
B = Susceptance $= \frac{X}{Z^2}$

In Polar form,
$Y = G + jB = |Y| \angle\phi$ Siemens
$|Y| = \sqrt{G^2 + B^2}$, $\phi = \tan^{-1} B/G$

Imp.

Ques:- The Parallel circuit is connected across a single phase 100V, 50 Hz a.c. supply. Calculate :-

1) The Branch currents
2) The total Current
3) Supply Power factor
(4) Active Power, Reactive Power & Total Power of the ckt.
(5) Power dissipated by each branch.



Solⁿ

i) $Z_1 = (8 + j6)\,\Omega = 10 \angle 36.86°\,\Omega$

$$\vec{I_1} = \frac{\vec{V}}{\vec{Z_1}} = \frac{100\angle 0°}{10\angle 36.86°}$$

$$\boxed{\vec{I_1} = 10 \angle -36.86°\ \text{Amp}}$$

$$\vec{I_2} = \frac{\vec{V}}{\vec{Z_2}}$$

$Z_2 = (6 - j8)\,\Omega$

$\vec{Z_2} = 10 \angle -53.13°\,\Omega$

$$\therefore \vec{I_2} = \frac{100\angle 0°}{10 \angle -53.13°}$$

$$\boxed{\vec{I_2} = 10 \angle 53.13°\ \text{Amp}}$$

ii) Total Current $\vec{I} = \vec{I_1} + \vec{I_2}$

$\vec{I} = 10\angle -36.86° + 10 \angle 53.13°$

$= (8 - j6) + (6 + j8)$

$\vec{I} = 14 + j2$ Amp

$$\boxed{\vec{I} = 14.14 \angle 8.13°\ \text{Amp}}$$

iii) Power factor $(\cos\phi) = \cos(8.13°)$

$$\boxed{\cos\phi = .989\ (\text{leading})}$$

(iv) Active Power(P) : $V_{rms} I_{rms} \cos\phi$

$P = 100 \times 14.14 \times .989$

$\boxed{P = 1399.71\ \text{Watt}}$

Reactive Power (Q): $V_{rms} I_{rms} \sin\phi$

$Q = 100 \times 14.14 \times \sin(8.13°)$

$\boxed{Q = 199.96\ \text{VAR}}$

Total Power (S): $V_{rms} \times I_{rms}$

$S = 100 \times 14.14$

$\boxed{S = 1414\ \text{VA}}$

(v) Power dissipated by Branch I

$P_1 = I_1^2 R_1$

$P_1 = (10)^2 \times 8$

$\boxed{P_1 = 800\ \text{Watt}}$

Power dissipated by Branch II

$P_2 = I_2^2 R_2$

$P_2 = (10)^2 \times 6$

$\boxed{P_2 = 600\ \text{Watt}}$

Que POWER FACTOR IMPROVEMENT (AKTU 19-20, 16-17, 15-16, 13-14)

What is Power factor? What are the disadvantages and causes of low power factor. Explain any one method to improve Power factor. (AKTU 2016-17, 15-16, 12-13)

Sol^n Power FACTOR :-

$$\cos\phi = \frac{\text{Active Power}}{\text{Apparent Power}} = \frac{VI\cos\phi}{VI} = \cos\phi$$

also $\cos\phi = \frac{R}{Z}$ $\qquad \cos\phi = \frac{\text{Active power}}{\text{Apparent power}}$

* It shows that how much percentage of Total Power is consumed by the ckt.
* It's a practical measure of the efficiency of Power distribution system. $\boxed{P = VI\cos\phi}$ watt

or $I = \frac{P}{V\cos\phi}$ as P & V are constant. So $I \propto \frac{1}{\cos\phi}$

If P.F. is low, I is very high & vice versa.

Disadvantages of Low Power factor :

* Large generators and transformers are required to deliver same load but at a low Power factor.
* More conductor material is required for Transmission lines due to large current.
* Due to high current, more Cu loss occurs at low power factor.
* Low lagging power factor results in large voltage drop in transformers, generators, Tx lines which results in poor regulation.

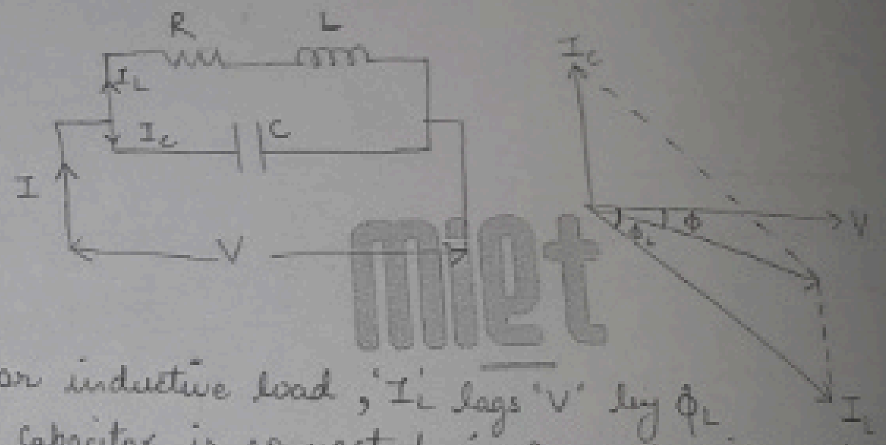
Causes of Low Power factor :-

* All a.c motors and transformers operate at lagging Power factor. Power factor decreases with decrease in load.
* Industrial heating furnaces such as arc and induction furnaces operate on very low lagging Power factor.

Power Factor can be improved by :-

* Using induction motors with phase advancers.
* Connecting the static capacitors in Parallel with the equipment operating at lagging power factor.
* By using synchronous condenser like shunt capacitor connected across the supply.

Power factor can be improved by Shunt Capacitor



* For inductive load, 'I_L' lags 'V' by ϕ_L
* If capacitor is connected in parallel with inductor, 'I_c' leads 'V' by 90°.

Current $\vec{I} = \vec{I_L} + \vec{I_c}$

$\because$ 'I' lags 'V' by ϕ

$\therefore$ $\boxed{\phi < \phi_L}$

$\therefore$ $\boxed{\cos\phi > \cos\phi_L}$

Hence, Power factor is improved.

THREE PHASE A.C. CIRCUIT

ADVANTAGES OF THREE PHASE SYSTEM OVER SINGLE PHASE SYSTEM :-

* The rating of a machine increase with increase in number of phases.
* Power Factor of a 1ϕ motor is lower than that of a three-phase motor of same rating.
* Three-phase motor has more output (> 1.5 times) than single phase motor.
* 3ϕ system is more reliable & capable than single phase system.
* 3ϕ system having higher efficiency as compared to 1ϕ system.

SOME BASIC TERMS RELATED TO 3ϕ AC SYSTEM :-

1) Phase Voltage (V_P) - It is defined as the voltage across either phase winding or load terminal.
V_R, V_Y & V_B are the phase voltages across R, Y & B phase of Star & Delta connection respectively.

2) Line Voltage (V_L) : It is defined as the voltage across any two line terminals.
V_{RY}, V_{YB} & V_{BR} are the line voltages measured b/w R-Y, Y-B & B-R terminal for Star & Delta connections.

3) Phase Current (I_P): It is defined as the current flowing through each phase winding or load.

Line Current (I_L) : It is defined as the current flowing through each line wire.

Phase Sequence :- The order in which three coil emf's or currents attain their maximum values one after the other is called Phase sequence.

Ques: A 3ϕ voltage source has a phase voltage of 120V and supplies star connected load having impedance $(36+j48)\Omega$ per phase. Calculate :-
a) line voltage (b) line current (c) Power factor (d) Total 3ϕ Power supplied to the load. (AKTU 2013-14, 14-15)

Sol^n a) For Star or Y connected System :

$V_L = \sqrt{3} V_P$, $I_L = I_P$

(a) $V_L = \sqrt{3} V_P$
$V_L = \sqrt{3} \times 120$
$\boxed{V_L = 207.8V}$

(b) $Z_P = (36+j48)\Omega = 60\angle 53.13^\circ \Omega$

$I_P = \frac{V_P}{Z_P} = \frac{120\angle 0^\circ}{60\angle 53.13^\circ} = 2\angle -53.13^\circ$ Amp

$\boxed{I_P = I_L = 2\angle -53.13^\circ}$ Amp

(c) $\cos\phi = \cos(-53.13^\circ)$
$\boxed{\cos\phi = 0.6 (\text{lagging})}$

(d) $P = \sqrt{3} V_L I_L \cos\phi$ Watt
$P = \sqrt{3} \times 207.8 \times 2 \times .6$
$\boxed{P = 432 \text{ Watt}}$

Ques: A Δ-connected balanced 3-phase load is supplied from 400V 3ϕ mains. The line current is 20A and the Power taken by the load is 10KW. Find :
(i) Impedance in each branch (ii) Power factor of the load (iii) line current & Power consumed if same load is connected in star.

Sol^n For Delta Connection :
$V_L = 400V$, $I_L = 20A$, $P = 10kW$

$P = \sqrt{3} V_L I_L \cos\phi$ i.e $10 \times 10^6 = \sqrt{3} \times 400 \times 20 \times \cos\phi$

$\therefore$ $\boxed{\cos\phi = .721}$ i.e $\phi = 43.8^\circ$.

(i) $V_P = V_L = 400V$
$I_P = \frac{I_L}{\sqrt{3}} = \frac{20}{\sqrt{3}} = 11.54$ Amp

(i) $Z_P = \frac{V_P}{I_P}$
$Z_P = \frac{400}{11.54} = 34.64\ \Omega$

(2.) $\cos\phi = \cos 43.8^\circ$

$\boxed{\cos 43.8^\circ = .721}$ (lagging)

(3.) For star connected system

$V_L = \sqrt{3}\, V_p$

& $I_L = I_p$

$\therefore V_p = \frac{V_L}{\sqrt{3}} = 230.94V$

$I_p = \frac{V_p}{Z_p} = \frac{230.94}{34.64}$

$\boxed{I_p = 6.667 \text{ Amp} = I_L}$

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

$P = \sqrt{3} \times 400 \times 6.66 \times .721$

$\boxed{P = 3.33KW}$

Ques A balanced 3ϕ star-connected load of 18KW taking a leading current of 60 amp when connected across a 3ϕ 440V, 50Hz supply. Find the values and nature of load & power factor of the load. AKTU (2015 - 16)

Soln for Y Connection

$V_L = \sqrt{3} V_p$ & $I_L = I_p$

$V_L = 440V$, $P = 18 \times 10^3$ Watt

$I_L = 60$ Amp

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

$18 \times 10^3 = \sqrt{3} \times 400 \times 60 \times \cos\phi$

$\boxed{\cos\phi = .39}$

or $\boxed{\phi = -66.81}$

$V_p = \frac{V_L}{\sqrt{3}} = \frac{440}{\sqrt{3}} = 254.03$ Volt

$\boxed{I_L = I_p = 60 Amp}$

$Z_p = \frac{V_p}{I_p} = \frac{254.03}{60}$

$\boxed{Z_p = 4.23\Omega}$

$R_p = Z_p \cos\phi$

$R_p = 4.23 \times .39$

$\boxed{R_p = 1.66\Omega}$

$X_{cp} = Z_p \sin\phi$

$X_{cp} = 4.23 \times \sin(-66.81)$

$\boxed{X_{cp} = 3.89\Omega}$

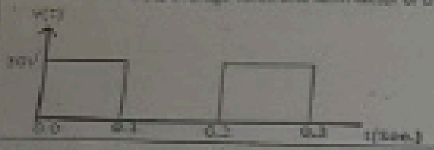
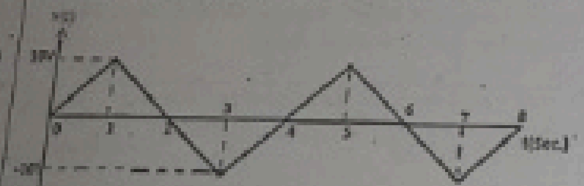
or $X_{cp} = \frac{1}{\omega C_p} = \frac{1}{2\pi F C_p}$

$\boxed{C_p = .81 mF}$

5 Year's

University Paper Questions

(AKTU Question Bank)

5 Years University Examination Questions		Unit-2	
S. No	Questions	Session	Lec No.
1	Write a note on: Amplitude, mechanical degrees and angular velocity.	(2017-18)EVEN	11
2	The equation of an alternating current is $i = 141.4 \sin 314t$. What is the r.m.s. value of current and frequency?	(2015-16)EVEN	11
3	The equation of an alternating current $i = 42.42 \sin 628\, t$. Determine (i) maximum value (ii) frequency (iii) rms value (iv) average value (v) form factor	(2017-18)EVEN	11,12,13
4	Find the r.m.s. value, average value and form factor of the given waveforms. 	((2013-14) ODD	11,12,13
5	Derive expression for average value and r.m.s. value of Half wave rectifier voltage output.	(2020-21)ODD	12,13
6	Determine the form factor of AC current $i = 200 \sin(157\, t + \pi/6)$.	(2019-20)ODD	12,13
7	Derive expressions for average value and r.m.s. value of a sinusoidally varying AC voltage.	(2017-18)EVEN	12,13
8	Explain the form factor and peak factor	(2017-18)EVEN	12,13
9	Calculate average value, rms value, form factor and peak factor of the following waveform shown in figure. 	(2017-18)ODD	12,13
10	The instantaneous values of two alternating voltages are represented by $V_1 = 60 \sin\theta$ and $V_2 = 5\sin(\theta - \pi/3)$. Derive expressions for the instantaneous values of (i) the sum and (ii) the difference of these voltages.	(2019-20)ODD	14
11	The two voltage waves are given: $V_a = 150\sin(\omega t + 45°)$ and $V_b = 75\sin(\omega t - 15°)$ Which voltage wave is leading with other and what will be the phase angle between V_a and V_b.	(2016-17)ODD	14
12	Draw the phasor diagram for the following voltages. Calculate the resultant voltage. Also find the r.m.s. voltage. $V_1 = 100\sin 500t$ $V_2 = 200\sin(500t + \pi/3)$ $V_3 = -50\cos 500t$ $V_4 = 150\sin(500t - \pi/4)$	(2016-17)ODD	14

13	Draw a Phasor diagram showing the following voltages: $v_1 = 100 \sin 500\, t$ $v_2 = 200 \sin(500\, t + 45°)$ $v_3 =$ [illegible] $\cos 500\, t$ Find rms value of resultant voltage	(2013-14) EVEN	14
14	What is phase angle difference between the voltage and current phasor in a purely capacitive circuit?	(2018-19)EVEN	15
15	Derive the expression for the average power in a single phase purely resistive circuit. Also draw the phasor diagram and waveform diagram for this circuit.	(2018-19)EVEN	15
16	A 120V, 100W lamp is to be connected to 220 volt, 50Hz supply. In order that lamp should operate on correct voltage, calculate the value of a). Non inductive resistance b). Pure inductance.	((2013-14) ODD	16
17	A coil and non-inductive resistor are connected in series across a 200V, 50 Hz supply. The voltage across the coil and resistor is 120V and 140V respectively. If the supply current is 0.5 A, calculate— 1.) The resistance and inductance of the coil 2.) The power dissipated in the coil. 3.) The power factor of the coil. 4.) The power factor of the circuit.	(2015-16) ODD	16
18	A resistance and inductance are connected in series with voltage $v = 283 \sin 314\, t$. The current expression is found to be $i = 4 \sin(314\, t - 45°)$. Find the value of resistance, inductance and power factor.	(2013-14) EVEN	16
19	If load draws a current of 10A at 0.8 p.f. lagging when connected to 100 V supply, calculate the values of real, reactive and apparent powers. And also find the resistance of load.	(2020-21)ODD	16,17
20	What is the power factor of a circuit having impedance of 3+j4 ohms.	(2017-18)ODD	16,17
21	A non inductive resistance of 10 ohm is connected in series with an inductive coil across 200 V, 50 Hz ac supply. The current drawn by the series combination is 10 Amp. The resistance of coil is 2 ohms. Determine: (i) Inductance of the coil (ii) Power factor (iii) Voltage across the coil.	(2017-18)ODD	16,17
22	Derive expressions for impedance, current and power factor for an R-L-C series circuit when applied with AC voltage. Draw also the vector diagram.	(2017-18)EVEN	17
23	A 46 mH inductive coil has a resistance of 10 ohm. How much current will it draw, if connected across 100 V, 50 Hz source? Also determine the value of capacitance that must be connected across the coil to make the power factor of the circuit to be unity.	(2016-17)EVEN	17
24	A series ac circuit has a resistance of 15Ω and inductive reactance of 10 Ω. Calculate the value of a capacitor which is connected across this series combination so that system has unit power factor. The frequency of ac supply is 50Hz	(2016-17)ODD	17
25	What do you mean by apparent power, active power and reactive power?	(2015-16) EVEN	17
26	A 40 V d.c. source has internal resistance of 1 ohm and supplies a resistive load. What can be maximum power drawn by the load?	(2015-16)EVEN	17
27	A coil having a resistance of 30 ohm and inductance of 0.05 H is connected in series with a capacitor of 100 μF. The whole circuit has	(2014-15)EVEN	17

B. Tech I Year [Subject Name: Fund. Of Electrical Engineering]

	been connected to a single phase 230 V, 50 Hz supply. Calculate impedance, current, power factor, power and apparent power of the circuit.		
28	A series RLC circuit is composed of 10 Ω resistance, 0.1 H inductance and 50 μF capacitance. A voltage V(t)= 141.4 Cos(100 π t) V is impressed upon the circuit. Determine (i) the expression for instantaneous current, (ii) the voltage drops V_R, V_L and V_C (iii)draw the phasor diagram using all the voltage relations.	(2014-15)ODD	17
29	Voltages across R.L.C connected in series are 5.6 and 10 volt respectively. Calculate the value of supply voltage at 50 Hz. Also find the frequency at which this ckt would resonate.	(2013-14) ODD	17
30	Derive an expression of resonance frequency in series resonance circuit. If the bandwidth of a resonant circuit is 10 KHz and the lower half power frequency is 120 KHz, find out the value of the upper half power frequency and the quality factor of the circuit.	(2019-20)ODD	18
31	Derive expression of resonance frequency for series RLC circuit. A series circuit consists of a resistance of 10Ω, and inductance of 50mH and a variable capacitance in series across a 100V, 50Hz supply. Calculate- (i) The value of capacitance to produce resonance. (ii) Voltage across the capacitance. (iii) Q-factor	(2018-19)ODD	18
32	Why series resonant circuit is known as acceptor circuit & parallel resonant circuit as rejecter circuit?	(2017-18)ODD	18
33	Explain series resonance in RLC circuit. What are the bandwidth and quality factor of the circuit? Derive expressions for lower and upper half power frequencies for a series RLC circuit.	(2016-17)EVEN	18
34	Explain resonance in a series RLC circuit with the help of impedance v/s frequency diagram and derive an expression for resonant frequency. Write properties of series resonance circuit.	(2015-16)EVEN	18
35	Derive resonance conditions in series circuit. Also derive the expression for Bandwidth.	(2014-15)EVEN	18
36	Derive the condition for resonance in series RLC circuit. What are the different applications of resonance ?	(2013-14) EVEN	18
37	A series circuit has R= 10Ω, L= 0.02H and C= 3μF. Calculate Q-factor of the circuit.	(2018-19)ODD	19
38	Derive the expression of Bandwidth of a series RLC circuit. Explain the relationship between bandwidth and quality factor.	(2017-18)ODD	19
39	A series circuit has R = 10 ohm, L = 0.05 H and C = 10μf Calculate Q-factor of the circuit.	(2014-15)EVEN	19
40	Explain the concepts of bandwidth and quality factor for aseriesR-L-C Circuit.Derivetheirexpressions	(2013-14) EVEN	19
41	Derive the quality factor Q of the series R-L-C ckt at resonance. Define the bandwidth for the same.	(2013-14) ODD	19
42	Explain the term "Dynamic impedance" in AC circuits. OR Derive mathematically dynamic impedance (Z_D) offered by RLC parallel	(2019-20)ODD-(2021-	20,21

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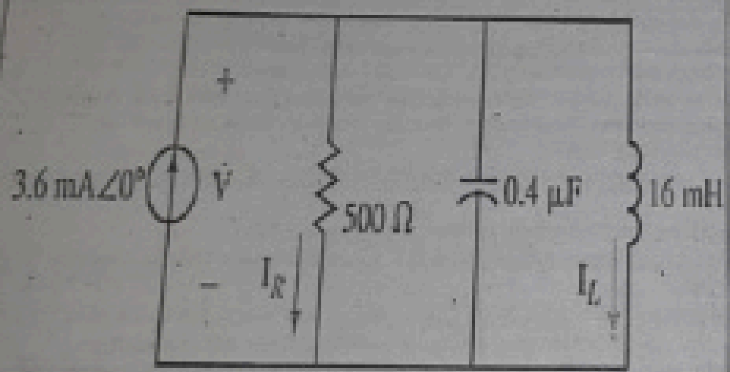
	circuit underresonance.Also, draw its phasor diagram.	22)ODD	
43	Derive the expression for resonant frequency & quality factor for an ac circuit under the condition of parallel resonance.	(2018-19), 17-18, 14-15, 13-14	20,21
44	Explain Parallel Resonance. A circuit of a resistance of 20 Ω , and inductance of 0.3 H and a variable capacitance in series across a 220 V,50 Hz supply. Calculate: (i)The value of capacitance to produce resonance (ii)The voltage across the capacitance and inductance (iii)The Q-factor of the circuit.	(2014-15)EVEN	20,21
45	Define power factor. Discuss reasons for poor power factor. How can power factor beimproved?	21-22)ODD(19-20, 16-17, 15-16, 13-14	21
46	A balanced star connected load of (6+j8) ohm per phase connected to abalance 3 phase, 400V supply. Find the line current, power factor, powerand total volt-amperes.	(2020-21)ODD	[illegible]
47	Derive the relation between line current & phase current in case of three phase delta connected balanced load. Three identical coils of resistance 8Ωand inductive reactance 6Ωare connected in delta across 400V mains. Determine power, power factor and line current. Draw phasor diagram.	20-21, 19-20, 18-19, 17-18, 16-17, 15-16, 14-15, 13-14	[illegible]
48	A balanced star-connected load of (8+j6) Ω per phase is connected to a balanced 3-phase, 400 V supply. Find the line current, power factor, power and total volt-amperes.	(2017-18)EVEN	[illegible]
49	Derive the relationship between line current and phase current for delta connected 3-phase load when supplied from 3-phase balanced supply.	19-20, 18-19, 17-18, 16-17, 15-16, 14-15, 13-14	[illegible]
50	A balanced star connected load of (8 + j6) Ω per phase is connected to a 3-phase 400 V supply. Find the line current, power factor, 3-phase power and 3-phase volt-amperes. Also draw the phasor diagram.	(2016-17)EVEN	[illegible]
51	Three similar coils each having a resistance of 10 ohm and an inductance of0.0318 H in series are connected in delta. The line voltage is 400V, 50 HZ. Calculate: phase current, line current, power factor, total power in the circuit.	(2015-16) EVEN	[illegible]
52	Obtain the relation between line & phase voltages in balanced Star connected load system. Also draw its Phasor diagram. A 3-phase, star connected balanced load is supplied by 400 V, 50 Hz. The load takes a leading current of 100√3 A & power 20 kW. Calculate power factor of load and Resistance & Inductance per phase.	(2015-16) ODD	[illegible]
53	Abalanceddeltaconnectedloadimpedance(16+j 12) Ω/phase is connected to a three phase 400V supply. Find the phase current, line current, power factor, active power, reactive power and total power. Also draw the phasor diagram.	(2014-15)ODD	[illegible]
54	A three-phase load consists of three similar inductivecoils,eachofresistance50Ωandinductance 0.3 H. the supply is 415 V,	(2013-14) EVEN	[illegible]

	50 Hz. Calculate: (i) the line current,(ii) the power factor; and (iii) the total power when the load is (a) star connected and (b) delta connected		
55	Show that in a 3-phase star connected system, the line voltage is 3 times of the phase voltage.	(2013-14) ODD	23,24
56	A balanced delta connected load of (12+j9) Ω/ phase is connected to 3-phase 400 V supply. Calculate line current, power factor and power drawn by it.	(2013-14) ODD	23,24
57	A series R – L – C circuit consists of R = 1000 Ohm, L = 100 mH and C = 10 μF. The applied voltage across the circuit is 100 V. (i) Find the resonant frequency of the circuit. (ii) Find the quality factor of the circuit at the resonant frequency. (iii) At what angular frequencies do the half power points occur? Calculate the bandwidth of the circuit.	(2021-22) ODD	
58	Three impedances of (70.7 + j 70.7) Ohm, (120 + j 160) Ohm and (120 + j 90) Ohm are connected in parallel across a 250 V supply. Determine (i) admittance of the circuit (ii) supply current and (iii) circuit power factor.	(2021-22) ODD	
59	Why the average power consumed in purely inductive circuit is zero?	(2021-22) EVEN	12
60	Consider the circuit shown in figure below and calculate the following.  a. Determine the resonant frequencies, ω(rad/s) and f(Hz) of the tank circuit. b. Find the Q of the circuit at resonance. c. Calculate the voltage across the circuit at resonance. d. Solve for currents through the inductor and the resistor at resonance.	(2021-22) EVEN	
61	Two coils having resistance 5 Ω and 10 Ω and inductances 0.04 H and 0.05 H respectively are connected in parallel across a 200 V, 50 Hz supply. Calculate: i. Conductance, susceptance and admittance of each coil. ii. Total current drawn by the circuit and its power factor. Power absorbed by the circuit.	(2021-22) EVEN	

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