~~AC Circuit Fundamentals~~

CHAPTER 2 AC Circuit Fundamentals

(*) AC machines:

AC machines, i.e. alternating current machines, are devices that generate or convert alternating current electrical energy.

AC generator operate on the principle of electromagnetic induction.

⇒ According to Faraday's law of electromagnetic induction, a change in magnetic field within closed of wire induces voltage in the wire.

(*) Components of AC generators

a) Stator:

Stationary part of generator that contains coils of wire that produces rotating magnetic field.

(b) Rotor:

Rotating part of generator that spins within the stator's magnetic field.

(c) Field Windings:

Coils of wire produces magnetic field when electrical current is applied.

(*) Generation of AC voltage:

When the armature is rotated within magnetic field, the magnetic flux through the coils of the armature changes.

According to Faraday's law, the change in magnetic flux induces voltage in armature coils.

Since polarity of voltage changes when armature rotates, the induced voltage is AC.

(*) Note:
In Nepal, AC = 50 Hz frequency.
$T = 0.02$ sec.

Time Period: (T)

The amount of time that takes to complete one complete cycle is called time period.
Mathematically,
$$T = \frac{1}{f}.$$

Frequency (f).

The number of cycles that occur in one second is called frequency.

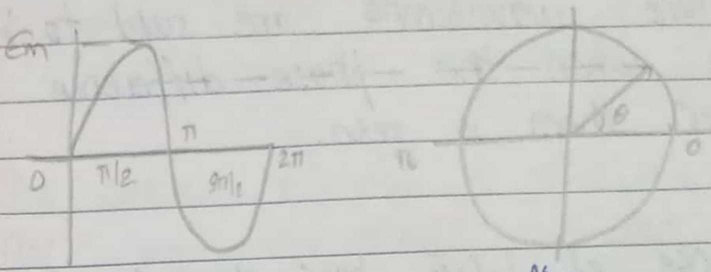
(*) Representation of ~~At~~ Alternating Quantity

An alternating ~~current~~ quantity can be represented using waveform, equation and phasor.

A sinusoidal alternating quantity can be represented by rotating line called phasor.

A phasor is a line of definite length rotating in anti-clockwise direction at constant angular velocity.

We know,



Waveform

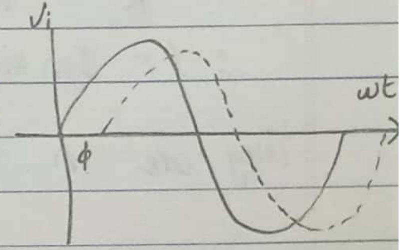
Phasor.

Eqn: ~~V_0~~ $v = V_0 \sin \omega t$
$i = I_0 \sin \omega t$

~~# Response of Basic R, L, C elements Due to Sinusoidal Voltage or Current.~~

~~(a): For Resistor only.~~

(*) Phase Difference.



When two alternating quantities of the same frequency have different zero points, they are said to have phase difference.

The angle between the zero points is the angle of phasor difference.

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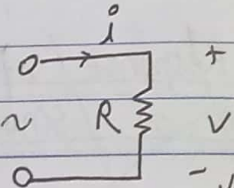
→ In-phase:

Two waveforms are said to be in-phase when the phase difference between them is zero.

Response of L,C,R basic elements Due to Sinusoidal voltage or current

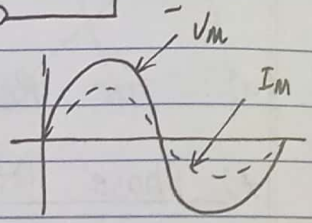
(a) For Resistor Only:



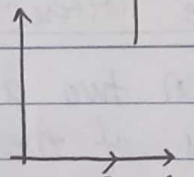
Let
$V = V_m \sin\omega t$.

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

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



They are in phase.



$\theta = 0$.

(b): For Inductor Only:

Consider a pure inductoive AC circuit L as in figure.

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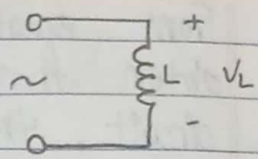
The alternating voltage is given by.

$V = V_m \sin(\omega t)$ —— (i)



The current flowing in the circuit is i.
The voltage across inductor is given by 'V_L' and $V = V_L$.

For current through inductor:

$$V = L \cdot \frac{di}{dt}$$

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

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

Integrating,

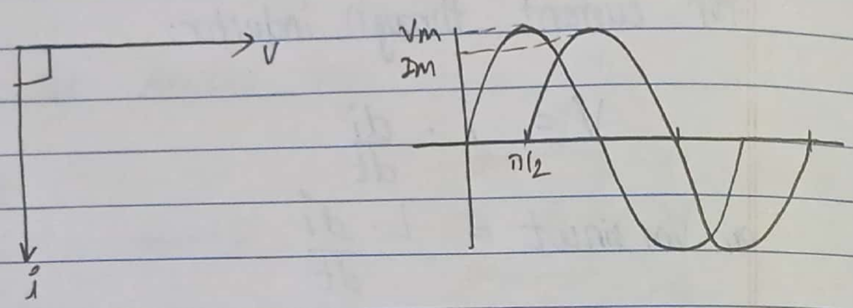
$$i = \frac{V_m}{\omega L}[-\cos\omega t]$$

$$= \frac{V_m}{X_L} \sin(\omega t - \pi/2)$$ [$\because$ Inductance $(X_L) = \omega L$

$\therefore i = I_m \sin(\omega t - \pi/2)$. —— (ii)

From equation (i) and (ii), we obtain that for an purely inductive circuit, the current lags behind the voltage by 90°

Hence, the voltage and current waveform and phasor can be drawn as.



Inductive reactance $(X_L) = \omega L = 2\pi f L$.

Instantaneous power $(P) = vi$

$= V_m \sin\omega t \times I_m \sin(\omega t - \pi/2)$

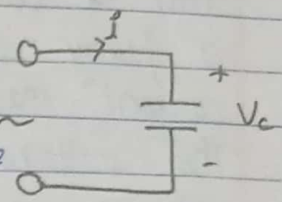
$= -\frac{V_m I_m}{2} . 2\sin\omega t \cos\omega t$

$\therefore P = -\frac{V_m I_m}{2} \sin 2\omega t$. —(iii)

The instantaneous power is fluctuating in nature.

(c): For capacitor only

Considers an AC circuit with a only ~~purely~~ capacitance as shown in figure.



The alternating voltage is given by

$V = V_m \sin\omega t$ — (i).

The current through the circuit is 'i'. The voltage across the capacitor is given by 'Vc' and $V = V_c$.

We can find current through the capacitor as follows:

$q = CV$

or $q = CV_m \sin\omega t$

Now,

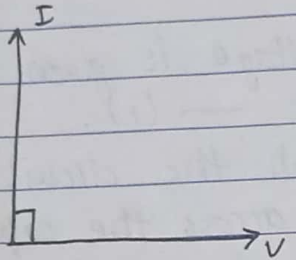
$i = \frac{dq}{dt} = \frac{d}{dt}(CV_m \sin\omega t)$

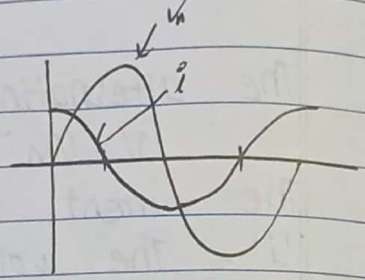
$= \omega C V_m \cos\omega t$

$= \frac{V_m}{X_C} \sin(\omega t + \pi/2)$ [$\because$ Capacitance $(X_C) = 1/\omega C$]

$\therefore i = I_m \sin(\omega t + \pi/2)$ —(ii)

From eqⁿ (i) and (ii), we observe that in a purely ~~induct~~ capacitive circuit, the current leads the voltage by 90°. The voltage and current represented as phasor and waveform:





Capacitive reactance $(X_C) = \frac{1}{\omega C} = \frac{1}{2\pi f C}$.

And

Instantaneous Power (P) = vi

$= V_m \sin\omega t \times I_m \sin(\pi/2 + \omega t)$

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

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

The nature is fluctuating in nature.

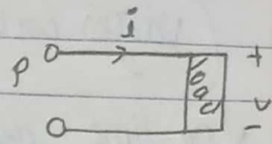
(*) Average Power & Power Factor

We know,

$v = V_m \cancel{\cos\omega t} \sin(\omega t + \theta_v)$

and

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



Power is expressed as:

$P = iv = V_m\sin(\omega t+\theta_v)\, I_m \sin(\omega t+\theta_i)$

We know,

$\sin A\sin B = \frac{\cos(A-B) - \cos(A+B)}{2}$

and

$\sin(\omega t+\theta_v)\sin(\omega t+\theta_i) = \frac{\cos(\theta_v-\theta_i) - \cos(2\omega t+\theta_v+\theta_i)}{2}$

Substituting,

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

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

The angle $(\theta_v - \theta_i)$ is the phase angle between v and i.

The first term,
$\left(\frac{V_m I_m}{2}\cos(\theta_v - \theta_i)\right)$ has constant magnitude
{no time dependency} and is
termed as average power or real power.

It is the power delivered to and dissipated by the load.

$\therefore P_{av} = \frac{V_m I_m}{2}\cos\phi$ where $\phi = |\theta_v - \theta_i|$.

It is measured in watts (W).