# Chapter 15

# A.C Circuit

* Alternating Voltage

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

* Average Value or Mean Value

$$\langle V \rangle = 0$$

(For one cycle)

* Power

$$P = I^2 R$$

$$= (I_m \sin \omega t)^2 R$$

$$P = I_m^2 R \sin^2 \omega t$$

* Average Power Dissipated

$$P = \frac{1}{2} I_m^2 R$$

or

$$P = I_{rms}^2 R$$



* Irms

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

or

$$I_{rms} = 0.707 I_m$$

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

* $V_{rms}$

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

* The ratio of instantaneous voltage to instantaneous current is always equal to ratio of $V_{max}$ and $I_{max}$

$$\frac{V}{I} = \frac{V_{max}}{I_{max}} = \frac{V_{rms}}{I_{rms}}$$

* Instantaneous Power

$$P = IV$$

Power may be :

a) Positive → Power flows from source to load

b) Negative → Power flows from load to source

* AC Through Resistance

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

$$I = I_m \sin\omega t$$

$$P = \frac{V_m}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}} = V_{rms} I_{rms}$$

* AC Through Pure Inductance

$$I = I_m \sin\omega t$$

$$V = V_m \sin(\omega t + 90^\circ)$$

$$X_L = \omega L = 2\pi f L$$

$$P = 0$$

* AC Through Capacitance

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

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

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

$$P = 0$$

# * RL SERIES AC CIRCUIT

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

Z : Impedence (opposition offered to current flow)

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

$$I = I_m \sin(\omega t - \phi) \qquad 0^\circ < \phi > 90^\circ$$

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

$$\cos\phi = \frac{R}{Z} \qquad \cos\phi : \text{Power Factor}$$

# * RC SERIES AC CIRCUIT

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



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

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

$$\tan\phi = \frac{-V_C}{R} = \frac{-X_C}{R}$$

$$P = VI\cos\phi$$

* The impedence of a circuit containing inductance L and resistance R is given by:

$$Z = \sqrt{R^2 + \omega^2 L^2}$$

## * RLC SERIES AC CIRCUIT

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

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

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

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

$$P = VI\cos\phi$$

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



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

(1) When $X_L - X_C$ is positive (i.e $X_L > X_C$) phase angle $\phi$ is positive and the circuit will be inductive.

In such case, current I will lag behind applied voltage by $\phi$

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(ii) When $X_L - X_C$ is negative (i-e $X_C > X_L$) phase angle $\phi$ is negative and circuit will be capacitive.

In such case, the current I will lead the applied voltage by $\phi$.

(iii) When $X_L - X_C = 0$ (i-e $X_L = X_C$), the circuit is purely resistive.

In such case current I and voltage V will be in phase

* In RLC AC circuit, voltage across inductor L leads current by 90° and voltage across capacitor lags behind the current by 90°. So voltage across L-C combination will be zero.

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## POWER FACTOR $\cos\phi$

* For a pure resistive circuit : $\cos\phi = 1$
* For a pure L or C circuit : $\cos\phi = 0$
* For RLC circuit, $\cos\phi$ lies b.w 0 and 1.

## CHOKE COIL

In electronics, a choke coil is an inductor used to block higher-frequency A.C while passing direct current and lower-frequencies of an A.C in an electrical circuit

## Q - FACTOR

The quality factor or Q-factor of a component is its energy storing ability. The Q-factor of a circuit is a ratio of energy stored in the circuit to the energy dissipated in one cycle.

$$\text{Q-Factor} = \frac{X_L}{R} = \frac{\omega L}{R}$$

$$\text{Q-Factor} = 2\pi \times \frac{\text{Max. Energy stored}}{\text{Energy Dissipated per cycle}}$$

The Q-Factor is used to describe the quality or effectiveness of a coil. A coil is usually designed to have high value of L compared to resistance R. The greater the value of Q-factor of a coil, the greater is its Inductance (L) as compared to its resistance (R)

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# RESONANCE IN AC CIRCUIT

Resonance in an AC circuit refers to that state of the circuit in which the inductive reactance of the circuit is equal to its capacitive reactance.

The value of angular frequency of alternating emf for which resonance is established in the circuit is called resonance frequency

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

or

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

# MAXIMUM POWER TRANSFER

To transfer the maximum amount of power from a source to the load, the load impedence should match the source impedence.

Transfer of maximum power is only 50% efficient

* The impedence of the circuit at resonance is only resistive so the current and voltage are in phase. The power factor is 1

* The impedence of the circuit is minimum at resonant frequency and it is equal to R.

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# MAXWELL'S EQUATION

Maxwell's Equation predict the existance of electromagnetic waves and that such waves are radiated by accelerating charges

## EQUATIONS

#1

$$\mathcal{E} = \frac{\Delta\phi}{\Delta t}$$

$$\mathcal{E} = \frac{\Delta}{\Delta t}(B.A)$$

#2

$$\mathcal{E} = \frac{W}{q} = 2\pi r E$$

$$E = \frac{1}{2\pi r}\frac{\Delta\phi}{\Delta t}$$

$$E = \frac{A}{2\pi r}\frac{\Delta B}{\Delta t}$$

#3

For Capacitor:

$$Q = CV$$

$$Q = \frac{\varepsilon_0 A}{d} V$$

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$$Q = \varepsilon_0 A E \qquad \because V/d = E$$

$$I = \varepsilon_0 \frac{\Delta \phi}{\Delta t}$$

#4 $$c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$$

* A changing electric flux gives rise to a magnetic field
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→ It was first conceived by Maxwell a change in the electric field is the cause of current in capacitor

* DISPLACEMENT CURRENT:

The type of current which is due to changing electric flux is called displacement current

* CONDUCTION CURRENT

The electric current which exists in a conductor when the electrons flow in the conductor at a uniform rate.

# WAVELENGTHS OF ELECTROMAGNET... RADIATIONS

1. Gamma Rays : Less than 10pm
2. X-Rays : 0.01 nm - 10nm
3. Ultraviolet : 1nm - 400 nm
4. Visible Light : 400 nm - 700nm
5. Infrared : 710nm - 1mm
6. Microwaves : 1mm - 1m
7. Radio waves : Longer than 1m

Roman Men Invented Very Unusual X-Ray Guns

## ECG

* P-deflection → contraction of the atria at the start of the heartbeat
* QRS → contraction of ventricles
* T-deflection → Repolarization or recovery of the heart cells in preparation for next beat

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# * PRINCIPLE OF METAL DETECTORS

→ Coil (L) and capacitor (c) are coupled to produce oscillations of currents

→ L-C circuit behaves like an oscillating mass-spring system

→ Energy oscillates b/w capacitor and inductor called an electrical oscillator

⇒ LC circuit produces beats phenomenon for metal detection

* If L and R denote the inductance and resistance respectively, then dimentional formula for R/L is same as that of:

Frequency

* For Transformer:

$$\frac{V_s}{V_p} = \eta \frac{I_p}{I_s}$$

* Power In An AC Circuit

$$P = \frac{V_m I_m}{2} \cos\phi$$

* CRO can be used as voltmeter, frequency meter and phase meter.

* A capacitor act as perfect insulator for direct current

* In RLC series AC circuit, $V_L$ and $V_C$ are:
  out of phase by 180°

* Due to AC, capacitor behaves as conductor

* In a pure inductor:
  Energy gained = Energy given out

* $\text{Admittance} = \frac{1}{\text{Impedence}}$

* $\text{Susceptance} = \frac{1}{\text{Reactance}}$

* In an ideal choke, ratio of its inductance L to its DC Resistance R is infinity

* Displacement current is produced in dielectrics

* At resonance, a parallel LCR circuit offers maximum impedence.

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* The argument of AC current function is:

$\omega t$ or $2\pi f t$

Explanation: Arguement is the variable on which the function operates

* If $V_0 = 100V$ and capacitance of the circuit is 70 ohms. Current as measured by AC meter is?

Ans: 1A

Sol:

$$V_{rms} = (V_0)\ 0.707$$
$$= 70\ V_{rms}$$

$$I_{rms} = \frac{V_{rms}}{X_c}$$
$$= \frac{70}{70} = 1A$$