7. ALTERNATING CURRENT

Single Page Simple Synopsis

Alternating Current (AC) is an electric current that periodically reverses direction and continuously changes its magnitude with time, following a sinusoidal (sine wave) pattern, whereas Direct Current (DC) flows in only one direction. AC is used to efficiently transmit power over long distances. AC circuits are governed by a specific set of rules, key concepts, and formulas.

1. **Mathematical Representation of AC:**

   An alternating current or voltage changes is a wave-like pattern over time:

   AC Current $I = I_0 \sin(\omega t)$; **AC Voltage** $V = V_0 \sin(\omega t)$

   Here I_0 and V_0 represent the maximum values, ω is the angular frequency, and t is time.

2. **Average and RMS Current:** Because AC changes constantly. We use specific averages to calculate its power and effective values,

   • **RMS (Root Mean Square) Current (I_{rms}):** $I_{rms} = \frac{I_0}{\sqrt{2}} \approx 0.707 I_0$

   • **Average current(I_{Avg}) over a half cycle:** $I_{avg} = \frac{2I_0}{\pi} \approx 0.637 I_0$

3. **Circuit Elements** When AC passes through different components like capacitor, resistor, inductor it experiences unique resistance, known as Reactance.

   • **In a purely Resistive Circuit** current and voltage are *in phase*.

   • **In a purely Inductive Circuit** current ***lags*** voltage by $\pi/2=90^\circ$ Here $X_L = \omega L$.

   • **In a purely Capacitive Circuit** current ***leads*** voltage by $\pi/2=90^\circ$. Here $X_C = \frac{1}{\omega C}$

4. **Series LCR Circuit:** When a inductor (L), capacitor (C), and resistor (R) are connected in series to an AC source, the **total opposition** to the current is called Impedance (Z).

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

5. **Resonance in LCR Circuits:** When $X_L = X_C$, the impedance (Z) equals the resistance (R) allowing maximum current to flow. **Formula: Resonant Frequency** $\omega_r = \frac{1}{\sqrt{LC}}$

6. **Power Factor:** Power consumed in an AC circuit is calculated as $P = VI\cos\phi$ where $\cos\phi$ is the power factor. Also $\cos\phi = R/Z$

Real Life Examples

- **Household Electricity:** Electric Fans and Motors, Air Conditioners and Refrigerators AC Generators (Alternators) Mobile & Laptop Chargers, Power Transmission

IMP. IPE POINTS

1. Alternating **current** $I = I_m \sin \omega t$

---

2. Alternating **voltage** $v = v_m \sin \omega t$

---

3. Root mean square current $I_{rms} = \frac{I_m}{\sqrt{2}}$

---

4. Root mean square voltage $v_{rms} = \frac{v_m}{\sqrt{2}}$

---

5. In a **pure inductive circuit:**

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

- Amplitude of current $I_m = \frac{v_m}{X_L}$

- Inductive reactance $X_L = \omega L$

- Current **lags behind** the voltage by $\pi/2$

---

6. In a **pure capacitive circuit:**

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

- Amplitude of current $I_m = \frac{v_m}{X_C}$

- Capacitive reactance $X_C = \frac{1}{\omega C}$

- Current **leads ahead** the voltage by $\pi/2$

---

7. In series LCR circuit,
the current is $I = I_m \sin(\omega t + \phi)$

- Amplitude of current is $I_m = \frac{v_m}{Z}$

- Impedance is $Z = \sqrt{R^2 + (X_C - X_L)^2}$
  Resonance condition $X_C = X_L$; $Z = R$

- Phase difference is $\phi = \tan^{-1}\left[\frac{X_C - X_L}{R}\right]$

- Resonating angular frequency $\omega_0 = \frac{1}{\sqrt{LC}}$

---

8. **Power Factor :** The average power loss over a complete cycle is given by
$P = V I \cos \phi$
In this the term $\cos \phi$ is called **power factor**.
Also $\cos \phi = R/Z$

---

9. **Transformer** is based on the principle of mutual induction.

- Transformer ratio is the ratio between turns in secondary and primary .

- **Transformer ratio** $= \frac{N_s}{N_p} = \frac{V_s}{V_p} = \frac{i_p}{i_s}$

- If $\frac{N_s}{N_p} > 1$, the transformer is called **step-up transformer.**

- If $\frac{N_s}{N_p} < 1$, the transformer is called **step-down transformer.**

Resistor Vs Inductor Vs Capacitor

- **Resistor** regulates the flow of current. It opposes AC and DC.
- **Inductor** stores energy in magnetic field and releases/ regulates electric current . It opposes AC and allows DC.
- **Capacitor** stores energy in electric field and releases/ regulates electrical energy(voltage) It allows AC and opposes DC when charged fully.