SNS COLLEGE OF TECHNOLOGY

An Autonomous Institution
Coimbatore-35

Department of Artificial Intelligence and Data Science

23EET103-Electrical Circuits and Electron Devices

I B.E IT / I SEMESTER

UNIT II : AC CIRCUITS

Topic 9: Impedance, power and power factor

Topicsfor discussion

- Fundamentals of AC Power
- Concept of Instantaneous Power
- Mathematical Derivation of Instantaneous Power
- Power in Resistive, Inductive, and Capacitive Loads
- Average, Reactive, and Apparent Power
- Power Triangle Representation
- Definition and Significance of Power Factor
- Types of Power Factor (Lagging, Leading, Unity)
- Effects of Low Power Factor on Systems
- Methods of Power Factor Improvement
- Measurement of Power and Power Factor
- Industrial and Real-World Applications
- Summary and Future Scope

Fundamentals of AC Power
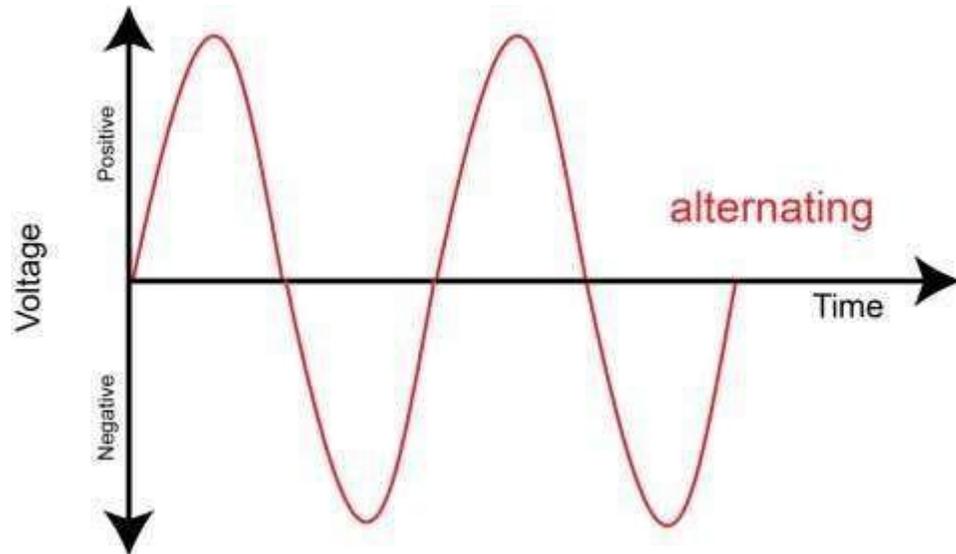
Alternating Current (AC) changes direction and magnitude with time.

AC voltage and current are sinusoidal in nature.

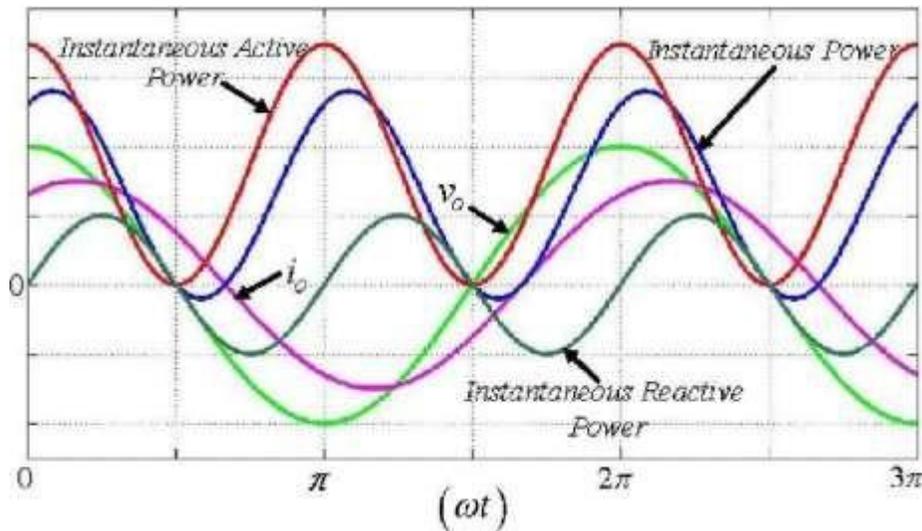Power in AC circuits is not constant — it varies with time.

Three major types of power:

Real Power (P) – actual energy consumed

Reactive Power (Q) – energy stored and released

Apparent Power (S) – total supplied power

Concept of Instantaneous Power

Defined as the product of instantaneous voltage and current.

Formula: $p(t)=v(t)×i(t)$

p(t)=v(t)×i(t)

Represents the rate of energy transfer at any instant of time.

Varies continuously with the phase difference (φ) between voltage and c

Mathematical Derivation of Instantaneous Power

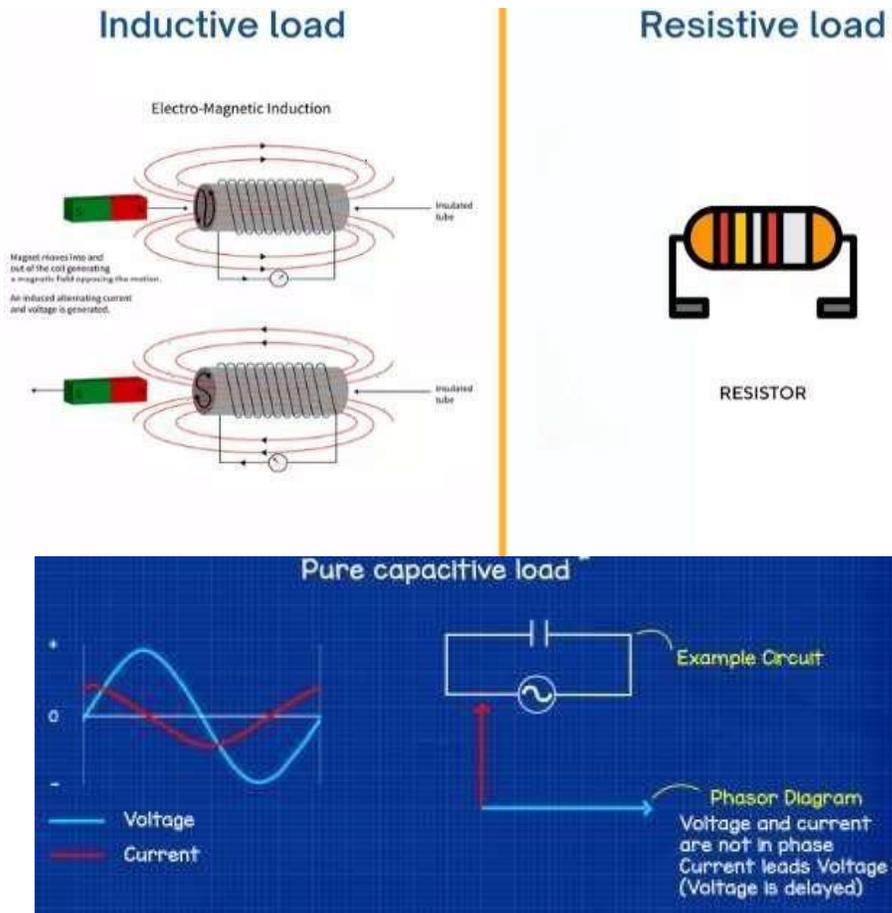- Let $v(t) = V_m \sin(\omega t)$ and $i(t) = I_m \sin(\omega t - \phi)$

- Then,

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

- Using trigonometric identities,

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

- The first term is constant (average power), and the second term is oscillating.

Power in Resistive, Inductive, and Capacitive Loads

Inductive load

Electro-Magnetic Induction

Resistive load

RESISTOR

Pure capacitive load

Example Circuit

Voltage
Current

Phasor Diagram
Voltage and current are not in phase
Current leads Voltage (Voltage is delayed)

Resistive Load: Voltage and current are in phase → power always positive.

Inductive Load: Current lags voltage → power alternates between positive and negative.

Capacitive Load: Current leads voltage → similar alternating pattern. The **average power** for inductive/capacitive loads = 0 (no net energy consumption).

Average, Reactive, and Apparent Power

Average Power (P): $P = V_{rms}I_{rms}\cos\phi$

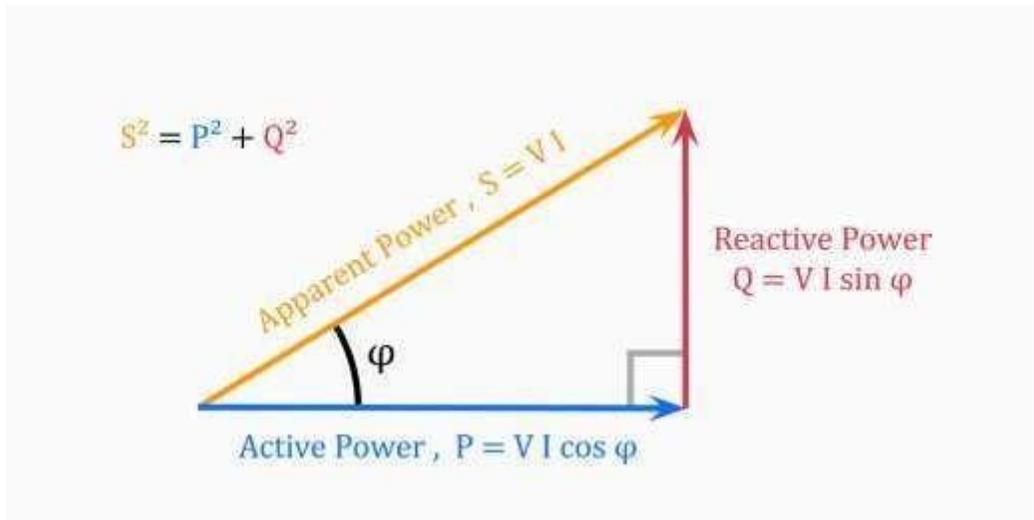$\rightarrow$ Actual power consumed by resistive components.

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

$\rightarrow$ Power alternately stored and released by L and C.

Apparent Power (S): $S = V_{rms}I_{rms}$

$\rightarrow$ Product of RMS voltage and current; represents total power flow.

Power Triangle Representation

$$S^2 = P^2 + Q^2$$

Apparent Power, $S = V\,I$

Reactive Power
$Q = V\,I \sin \varphi$
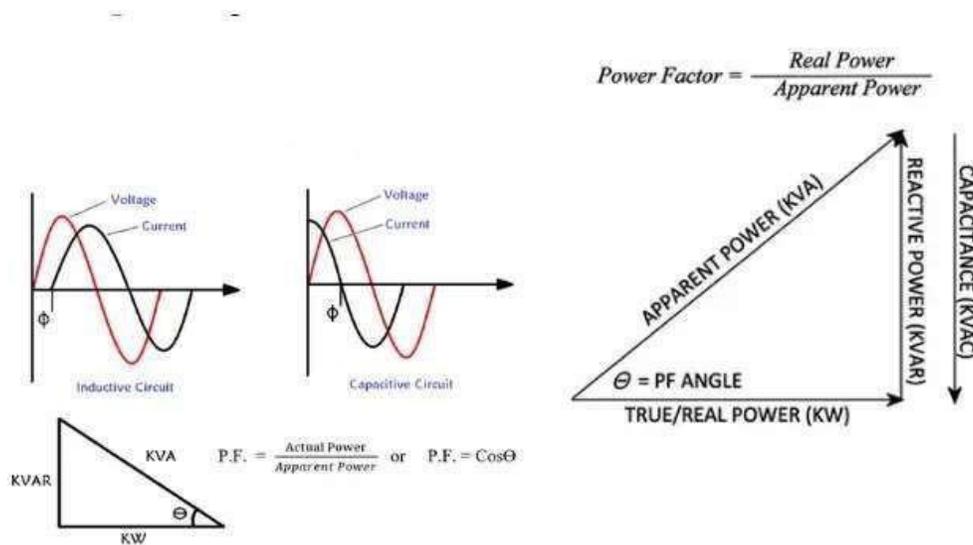
Active Power, $P = V\,I \cos \varphi$

Right-angled triangle linking P, Q, and S.

Base = Real Power (P), Perpendicular = Reactive Power (Q), Hypotenuse = Apparent Power (S).

Relationship: $S^2 = P^2 + Q^2$.

The angle (φ) between S and P denotes the phase difference.

Definition and Significance of Power Factor

$$\text{Power Factor} = \frac{\text{Real Power}}{\text{Apparent Power}}$$

- Power Factor (p.f.) = cos(φ) = P / S
- Indicates efficiency of power utilization.
- High p.f. → efficient system, low p.f. → energy losses.
- Unity power factor (1.0) means all supplied power is effectively used.

Types of Power Factor (Lagging, Leading, Unity)
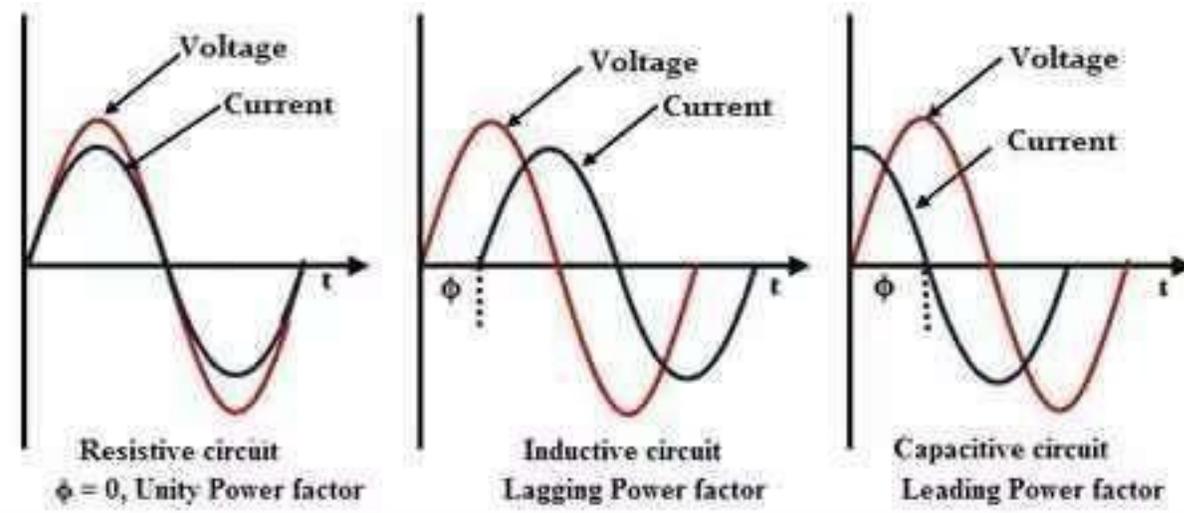
- Lagging Power Factor: Current lags voltage → Inductive loads (motors, transformers).
- Leading Power Factor: Current leads voltage → Capacitive loads (capacitor banks).
- Unity Power Factor: Voltage and current in phase → purely resistive load.

Summary and Future Scope

Looking ahead, **future trends** involve integrating power factor monitoring with **AI- based smart systems**, enabling **real-time analysis, predictive maintenance, and automatic power factor correction**. Such intelligent systems can optimize energy usage dynamically, improve grid stability, and enhance overall energy efficiency in industrial and commercial setups.