SNS COLLEGE OF TECHNOLOGY

Saravanampatti, Coimbatore – 641 035

Approved by AICTE, Recognized by UGC & Affiliated to Anna University, Chennai

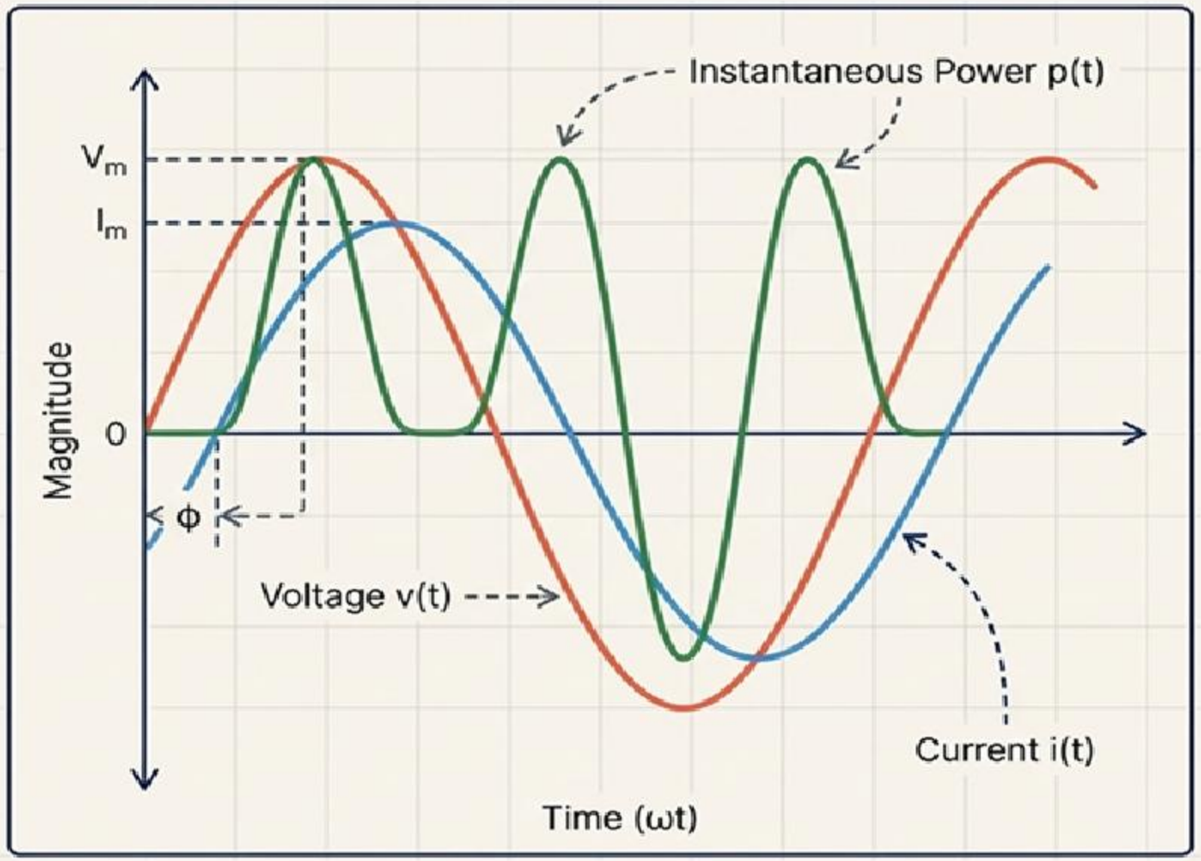
Department of Artificial Intelligence and Data Science

23EET103 – Electric Circuits and Electron Devices

I YEAR /II SEMESTER

UNIT -2 – Power and Power factor

Synthesizing Instantaneous Power



The Core Equation

$$p(t) = v(t) \times i(t)$$

The Physics

Power in AC circuits is not a flat constant; it dictates the exact rate of energy transfer at any given millisecond.

The Trigonometric Result

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

The product resolves into a constant term (average power) and an oscillating term, proving why the power wave cycles twice as fast.

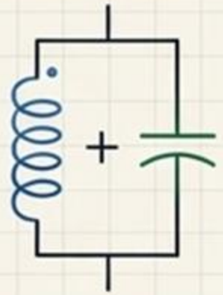
The Three Faces of AC Power

Real / Average Power (P)

The actual work done (heat, light, motion) by resistive components.

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

Measured in Watts (W)

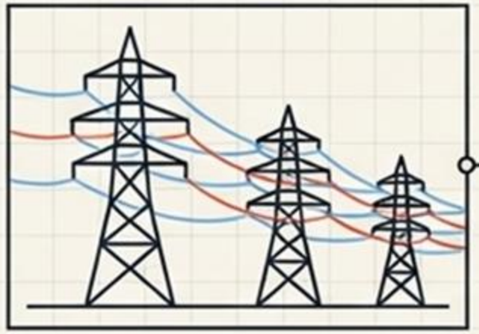


Reactive Power (Q)

The 'phantom' energy alternately stored and released by Inductors and Capacitors. Does no useful work.

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

Measured in Volt-Amps Reactive (VAR)



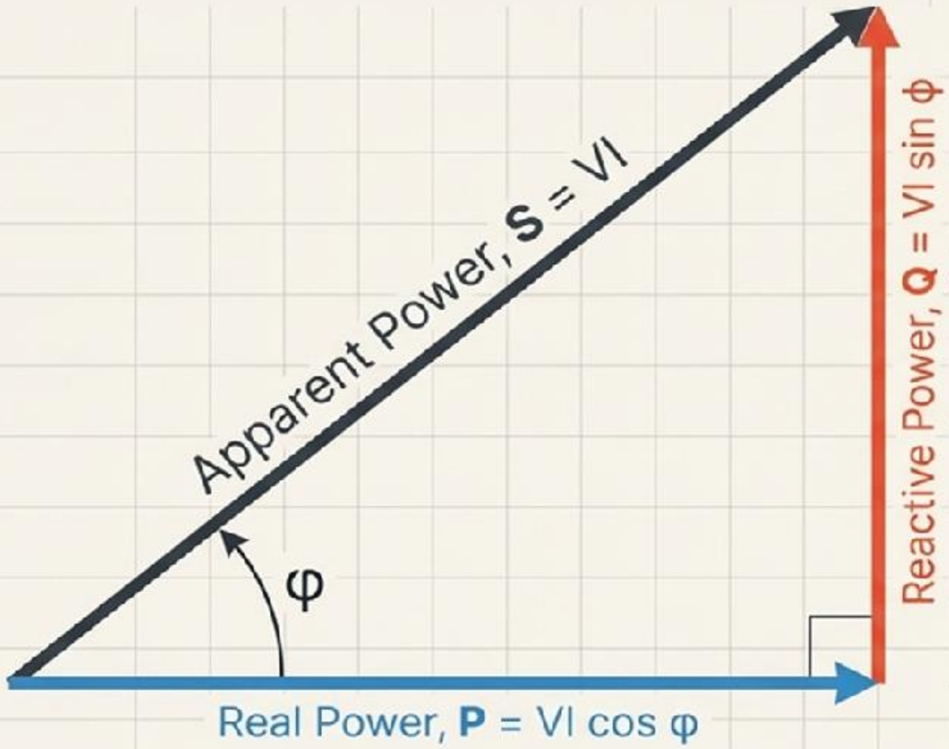
Apparent Power (S)

The absolute total power flow supplied to the circuit.

$$S = V_{rms} \cdot I_{rms}$$

Measured in Volt-Amps (VA)

The Power Triangle: Geometric Synthesis



Core Insight

The chaotic oscillation of AC circuits resolves into a perfect Pythagorean relationship.

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

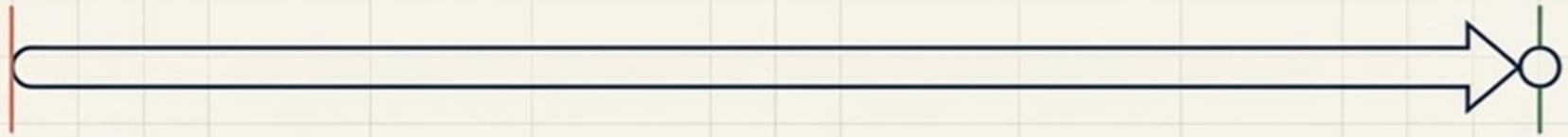
The Geometry

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

The Phase Angle (ϕ)

The angle between Apparent Power and Real Power is the exact physical representation of the phase difference between system voltage and current.

Power Factor: The Efficiency Metric



0.0 (Total Loss)

1.0 (Perfect Efficiency)

Definition

Power Factor (p.f.) is the cosine of the phase angle:

$$p.f. = \cos(\varphi) = \frac{P}{S}$$

It is the ratio of Real Power to Apparent Power.

Significance

It dictates the ratio of actual power utilized versus the total apparent power the grid must supply.

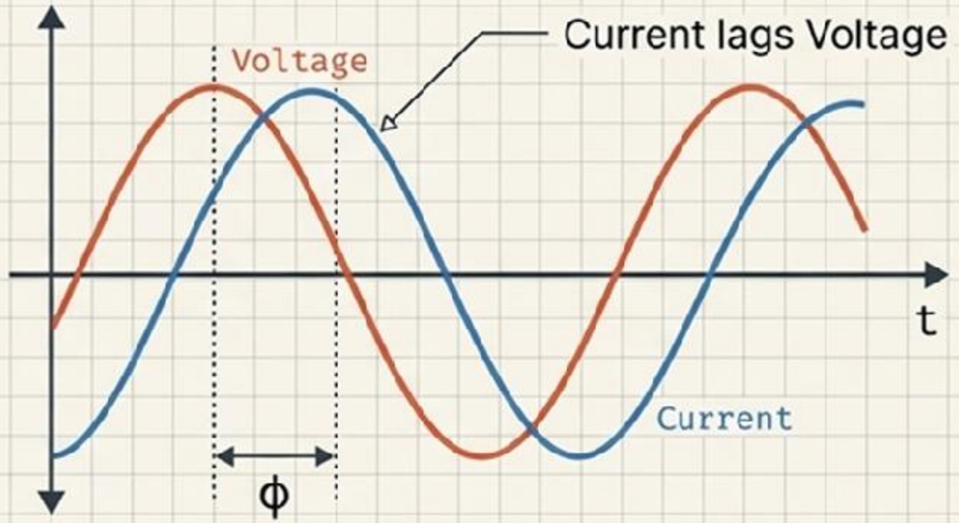
High p.f. means an efficient system; low p.f. indicates massive energy losses.

The Ideal State

A “Unity” power factor (1.0) means 100% of the supplied power is doing effective, real work, structurally equivalent to a purely resistive load.

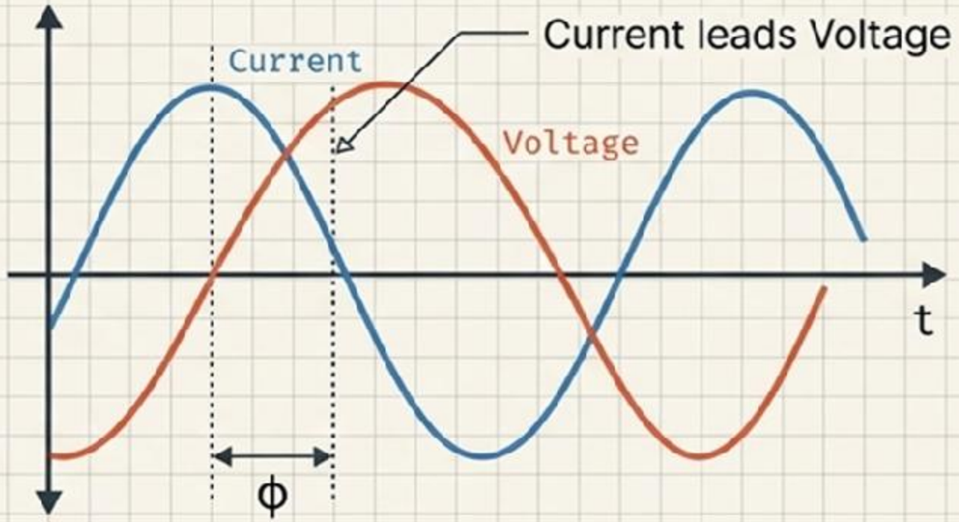
Diagnosing Inefficiency: Lagging vs. Leading

Lagging Power Factor



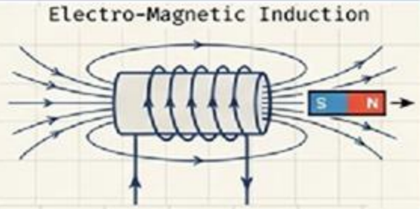
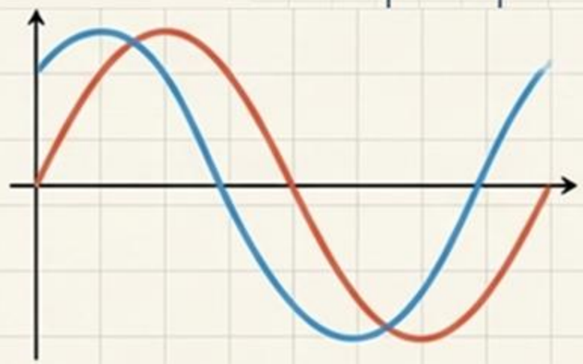
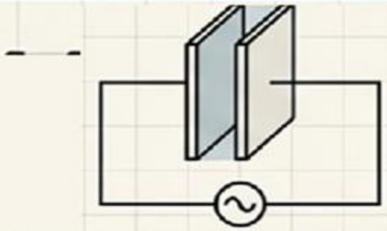
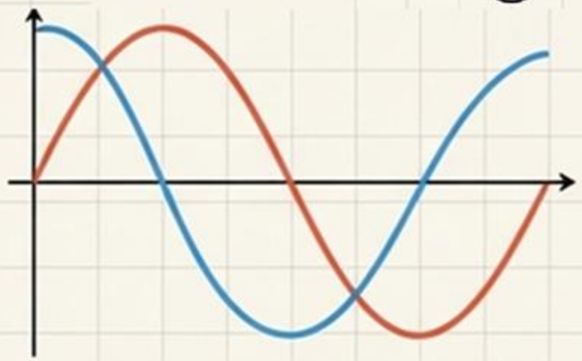
- **Symptom:** Current arrives after voltage.
- **Culprits:** Highly inductive industrial loads, such as large electric motors and transformers.

Leading Power Factor



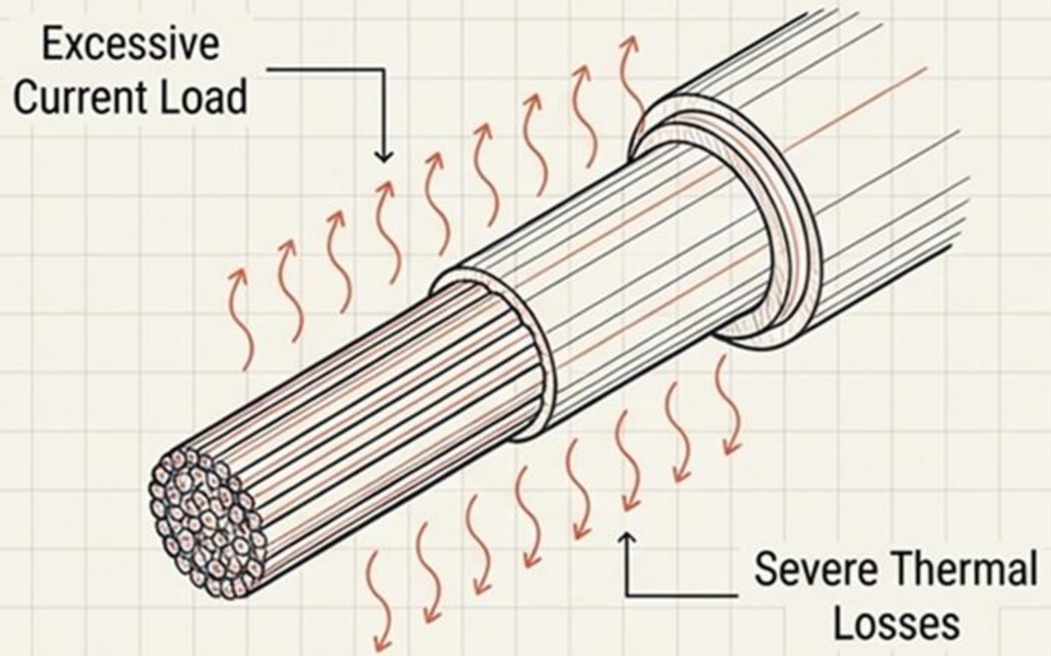
- **Symptom:** Current arrives before voltage.
- **Culprits:** Heavily capacitive loads, such as capacitor banks used in substation routing.

Load Environments: Resistive, Inductive, and Capacitive

Resistive Load (R)	Inductive Load (L)	Capacitive Load (C)
  Current and Voltage are perfectly In-Phase. Power is always positive. Net energy is consumed.	  Current Lags Voltage. Power alternates between positive and negative. Average power equals zero.	  Current Leads Voltage. Power similarly alternates. Average power equals zero (no net energy consumption).

The Real-World Impact of Low Power Factor

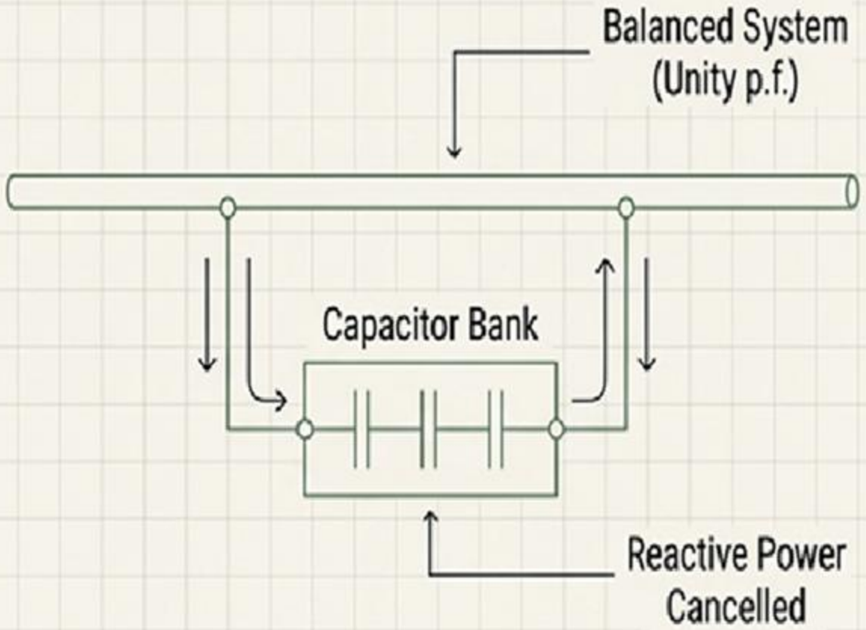
The Problem: Grid Strain



A low p.f. forces the grid to supply massive amounts of apparent power to accomplish a small amount of real work. This results in higher currents, requiring thicker transmission wires, and generating severe thermal energy losses.

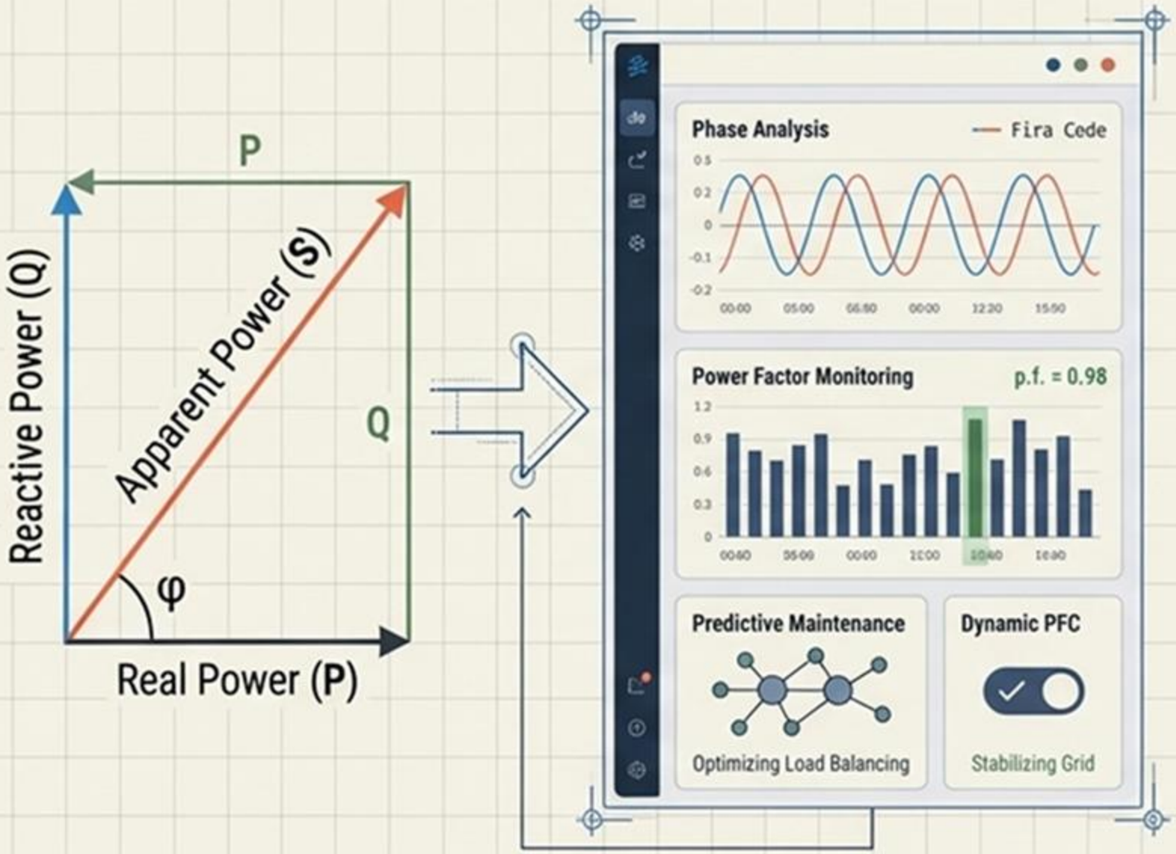
The Real-World Impact of Low Power Factor

The Solution: Power Factor Correction



By deliberately introducing capacitive loads (capacitor banks) into a motor-heavy (inductive) system, engineers can cancel out reactive power, pulling the system's p.f. back toward a perfect 1.0.

The Future Scope: Smart Grids & AI Integration



The Evolution of Power Management

While the fundamental physics of AC power remain constant, grid infrastructure is shifting from static formulas to dynamic, software-driven management.

Next-Generation Capabilities

- Real-time phase analysis and **Power Factor** monitoring.
- **Predictive maintenance** algorithms for load balancing.
- **Dynamic, automatic power factor correction** to stabilize the grid and maximize commercial energy efficiency without human intervention.

Summary Cheat Sheet: Multipliers & Formulas

The Core Equations	
Angular Frequency:	$\omega = 2\pi f$
Instantaneous Power:	$p(t) = v(t) \times i(t)$
Power Geometry:	$S^2 = P^2 + Q^2$
Real Power:	$P = V_{rms} \cdot I_{rms} \cdot \cos(\varphi)$
Power Factor:	$p.f. = \cos(\varphi) = \frac{P}{S}$

REFERENCES

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THANK YOU