СӘТБАЕВ УНИВЕРСИТЕТІ SATBAYEV UNIVERSITY

Lecture 10

Power in AC Circuits: Real, Reactive and Apparent Power

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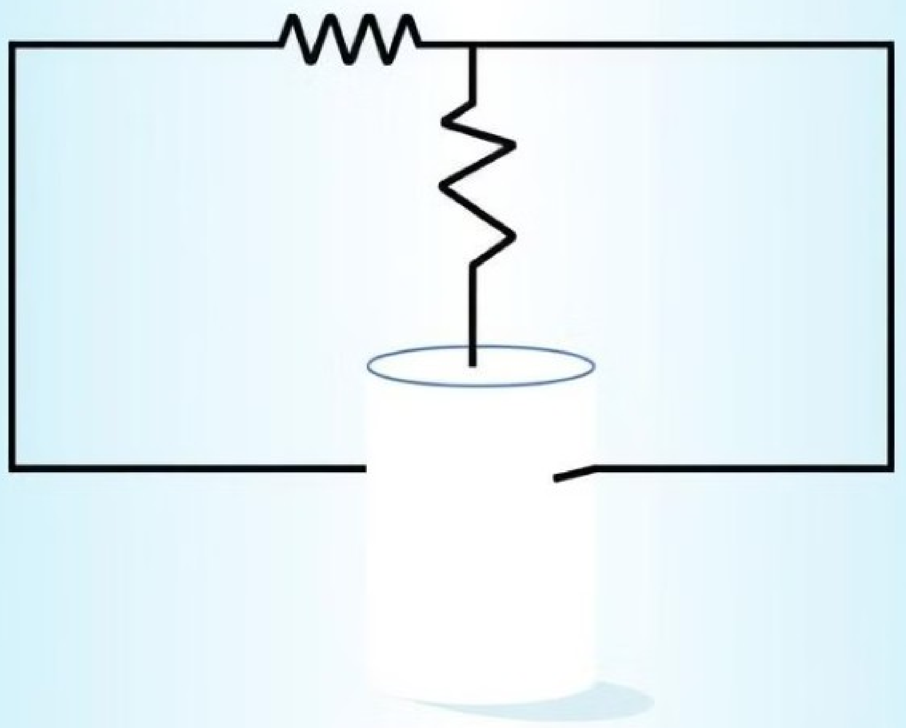


Introduction to AC Circuits

1

Alternating Current

AC circuits use alternating current, where the direction of current flow reverses periodically.

2

Sinusoidal Waveforms

AC voltage and current are typically represented by sinusoidal waveforms, characterized by their amplitude, frequency, and phase.

3

Circuit Elements

Common AC circuit elements include resistors, capacitors, and inductors, which interact differently with AC signals.

Voltage and Current in AC Circuits

1

Voltage

AC voltage varies over time, oscillating between positive and negative values.

2

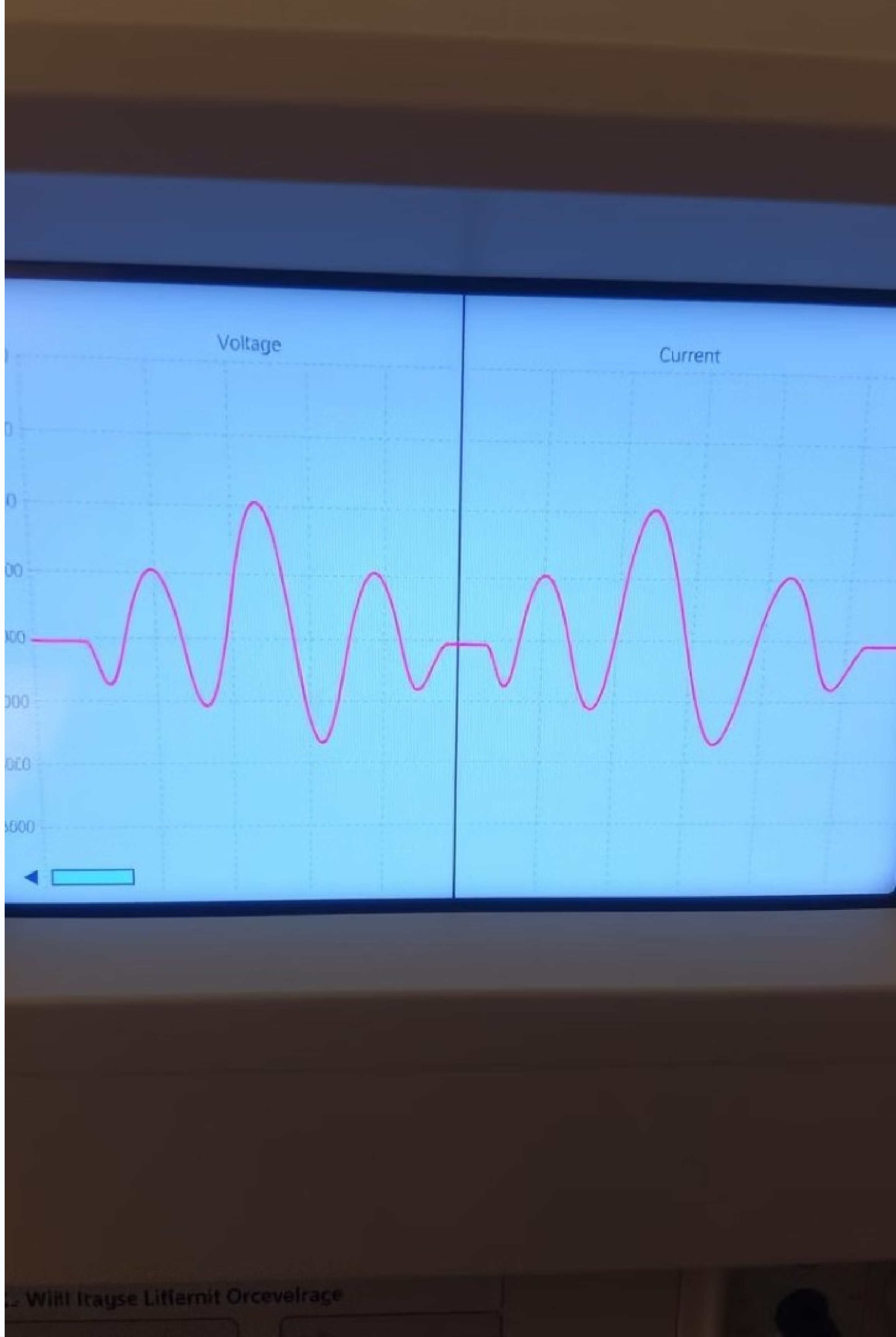
Current

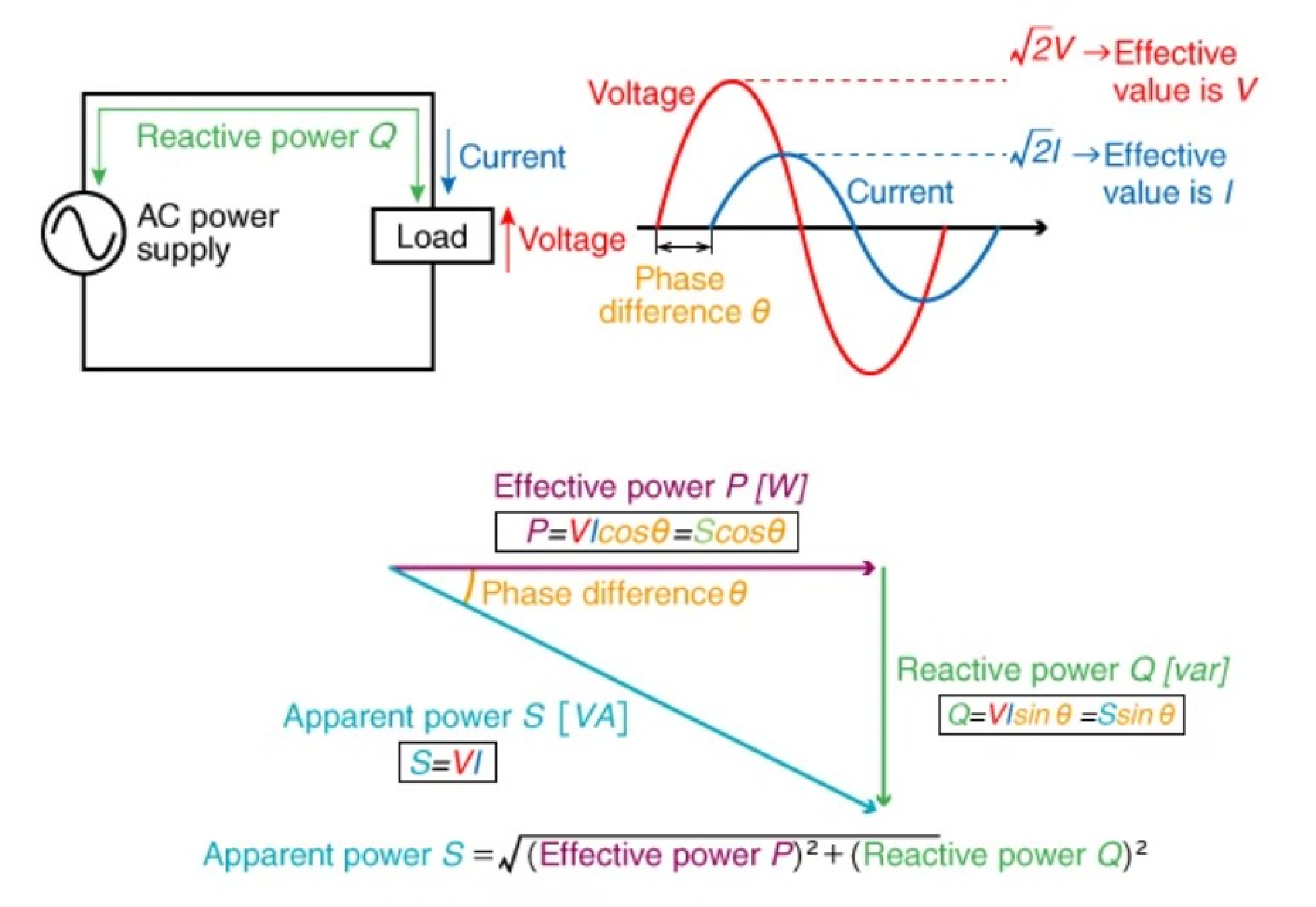
AC current also varies over time, following the voltage waveform but with a potential phase difference.

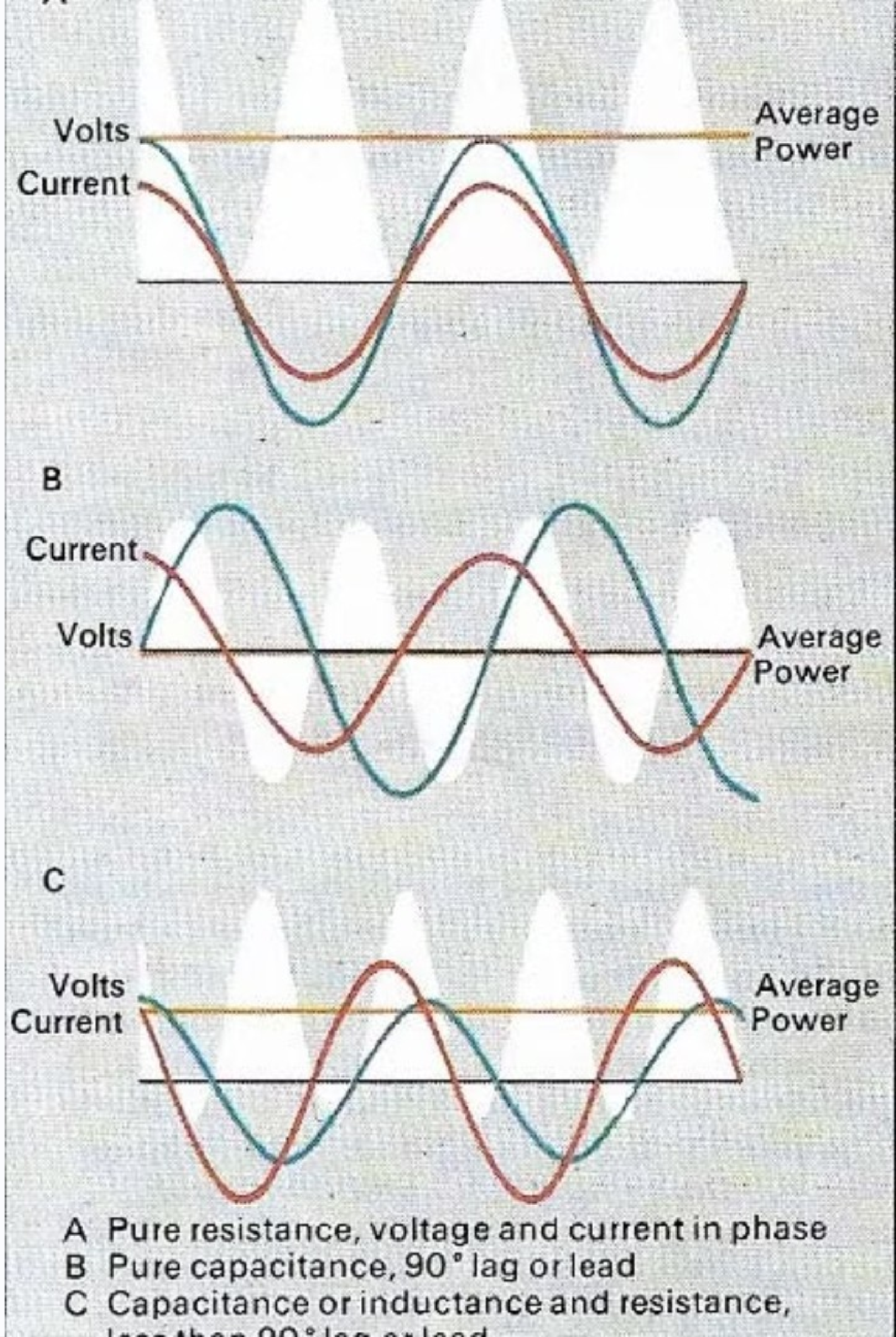
3

Phase Difference

The phase difference between voltage and current in an AC circuit is critical for understanding power.







In AC (alternating current) circuits, power is not simply the product of voltage and current as in DC circuits, due to the phase difference between voltage and current caused by reactive components (inductors and capacitors). Here’s an overview of the three main types of power in AC circuits:

Real Power (P)

Definition

Real power is the power actually consumed by a circuit, measured in watts (W). In a single-phase AC circuit, active power is:

$$P = V \times I \times cos\theta$$

Energy Conversion

Real power is the energy converted into useful forms like **heat, light, motion, or sound**. In resistive components, such as resistors, heaters, and light bulbs, it directly becomes **heat and light**. In **electric motors**, real power generates **motion** by converting electrical energy into kinetic energy. In **speakers**, it is transformed into **sound** by moving diaphragms to produce sound waves.

Resistive Loads

Real power is primarily associated with resistive loads, where voltage and current are in phase.

Power flows from source to load

Reactive Power (Q)

Definition

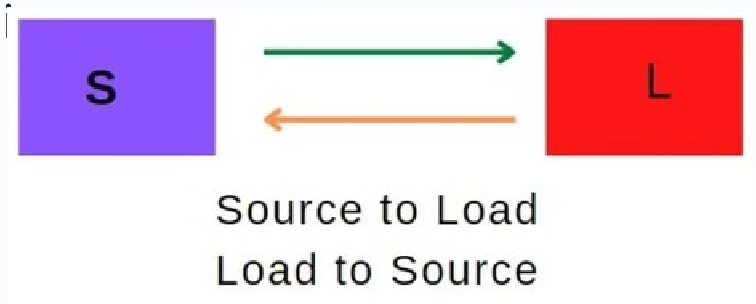
Reactive power, often denoted by **Q** and measured in **volt-amperes reactive (VAR)**, is a type of electrical power that flows back and forth between the source and the reactive components of a circuit, such as **inductors** and **capacitors**. Unlike real power, reactive power does not contribute directly to energy conversion in the form of heat, light, or motion, but instead facilitates the maintenance of voltage levels necessary for the transmission of active power across electrical networks.

$$Q = V \times I \times sin\theta$$

Energy Storage

Reactive power is closely associated with **energy storage** in electric and magnetic fields, created by the properties of **capacitors** and **inductors**.

- **Capacitors** store energy in an electric field when voltage is applied across their plates, charging and discharging as the AC current alternates.
- **Inductors** store energy in a magnetic field when current flows through them. When the current reverses, the magnetic field collapses, releasing the stored energy back into the circui



Phase Difference

Reactive power only exists in AC circuits where there is a **phase difference** between the voltage and current waveforms. This phase shift is typically caused by **inductive** or **capacitive loads**:

- In **inductive loads** (such as motors, transformers, and inductors), the current lags behind the voltage, creating **positive reactive power**.
- In **capacitive loads** (such as capacitor banks), the current leads the voltage, resulting in **negative reactive**

Apparent Power (S)

Definition	The total power in an AC circuit, measured in volt-amperes (VA), where S = Apparent Power measured in kVA, Q = Reactive Power in kVAR and P = Active Power in kW $S^2 = P^2 + Q^2$
Relationship	Apparent power is the vector sum of real power and reactive power. This equation shows how real power PPP and reactive power QQQ relate to apparent power SSS. It indicates that apparent power represents the vector sum (not a direct addition) of the active and reactive components.
Significance	Apparent power plays a key role in the design and operation of power systems because it indicates the **total capacity** a system must support to handle both active and reactive demands. For instance: • **Transformer and Generator Sizing**: Apparent power determines the size and capacity of transformers, generators, and other components. • **Cable Sizing**: Since cables must carry the total current associated with apparent power, their sizing depends on SSS, not just PPP. • **Power Factor Correction**: By understanding SSS, engineers can implement power factor correction to reduce QQQ and make more efficient use of the system's capacity, minimizing losses.

Power Factor (PF)

Definition

Power factor is the ratio of real power to apparent power, a dimensionless value between 0 and 1. A power factor of 1.0 is called a “unity power factor” or 100 percent power factor, which means that the current and voltage is “in phase”.

$$Power\ Factor = \frac{Active\ Power}{Apparent\ Power}$$

Significance

Power factor (PF) is a measure of how effectively electrical power is being used in an AC circuit. It is defined as the ratio of real power (P), which performs useful work, to apparent power (S), which is the total power supplied by the source. When the power factor is high (closer to 1), a larger portion of the apparent power is being converted into useful work, minimizing energy losses. In contrast, a lower power factor indicates that a significant portion of the power is reactive, resulting in inefficiency and additional demand on the power supply.

Improving PF

To improve **power factor**, capacitors or synchronous condensers are often added to the circuit. Capacitors can offset the inductive effects of motors and other inductive loads, thus increasing the PF. In industrial setups, power factor correction equipment is often used to automatically adjust reactive power, keeping the system's power factor near optimal levels.

Importance of Power Factor Correction

1

Reduced Energy Loss

A lower power factor leads to increased current flow, resulting in higher energy losses due to resistive heating.

2

Improved System Efficiency

Power factor correction reduces losses in the power system, improving overall efficiency and reducing wasted energy.

3

Lower Electricity Bills

By reducing energy consumption and losses, power factor correction can contribute to lower electricity bills.

Methods of Power Factor Correction

1 **Capacitors**

Capacitors are commonly used to improve power factor by providing leading reactive power to compensate for lagging reactive power.

2 **Synchronous Motors**

Synchronous motors can be operated at leading power factor, providing reactive power compensation for inductive loads.

3 **Power Factor Controllers**

Automatic controllers can adjust the amount of reactive power compensation based on real-time power system conditions.

Conclusion

Understanding power in AC circuits is crucial for optimizing system efficiency and reducing energy waste. Power factor correction is an essential practice for improving the performance of AC power systems and reducing energy consumption. By implementing appropriate methods for power factor correction, we can enhance energy efficiency, lower electricity costs, and contribute to a more sustainable energy future. Real power represents the portion of energy that does useful work, while reactive power oscillates between source and load, contributing to inefficiencies but necessary for certain devices. Apparent power combines these components, and power factor indicates how effectively the electrical power is used. Improving power factor enhances energy efficiency, reduces costs, and minimizes strain on the power grid. By managing these elements, both energy providers and consumers can achieve more sustainable and cost-effective power usage.

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