

AC Theory

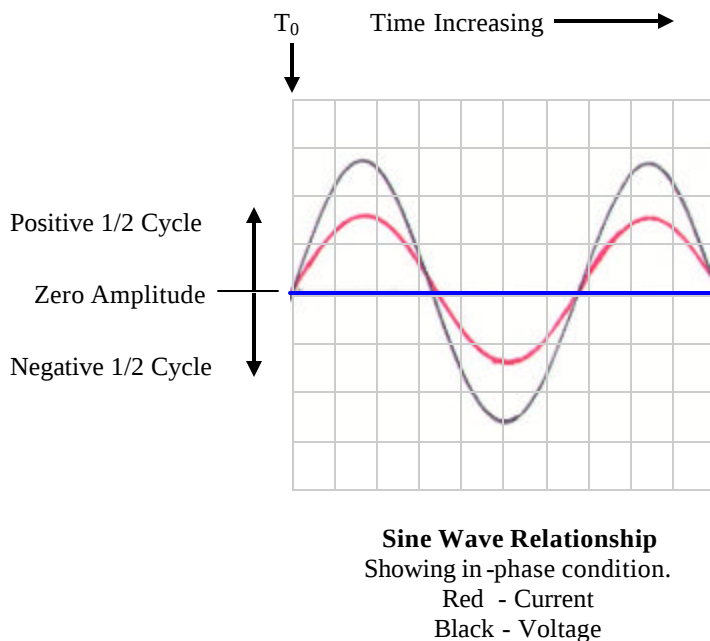
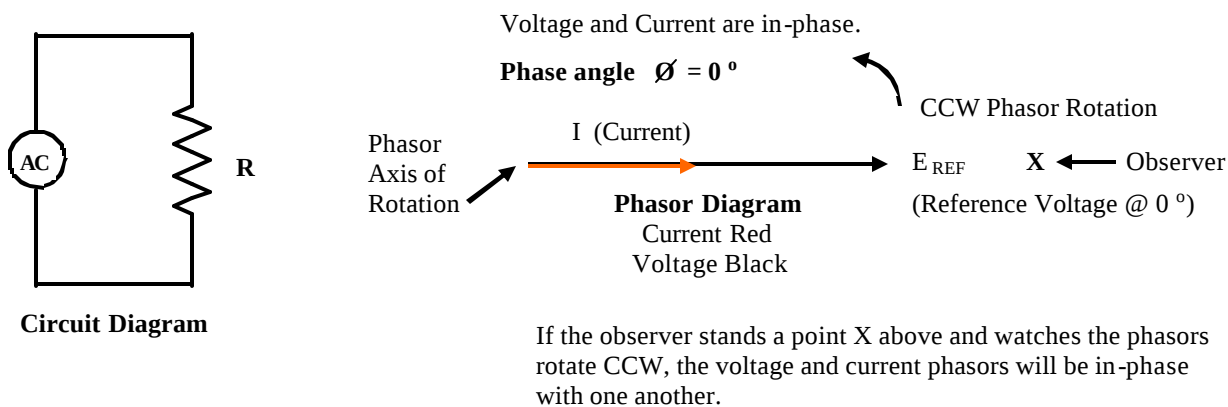
Power is a Resistive Circuit

In a purely resistive circuit (such as electric heaters or incandescent lighting), the circuit voltage and the current will be in-phase.

In this circuit, because the current is in-phase with the voltage, the maximum amount of power in watts will be produced. Single-phase power in watts in an AC circuit is: $P = E \times I \times \cos \theta$. The phase angle in this case is 0° . Since $\cos 0^\circ = 1$, the circuit power is therefore $P = E \times I \times 1$. All power is true power in watts.

Remember:

- There are 360 degrees in a sine wave.
- Electrical Phasors rotate counter-clockwise (CCW).
- Phasors (electrical vectors) show two things: (1) magnitude, and (2) direction.



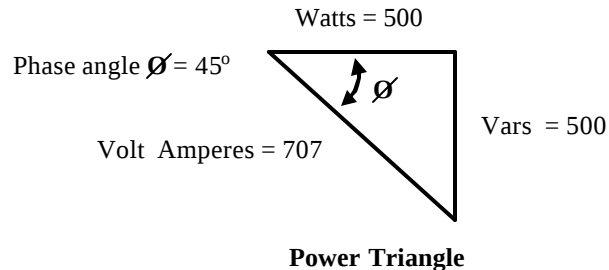
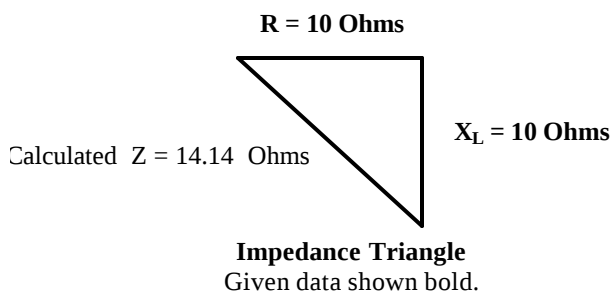
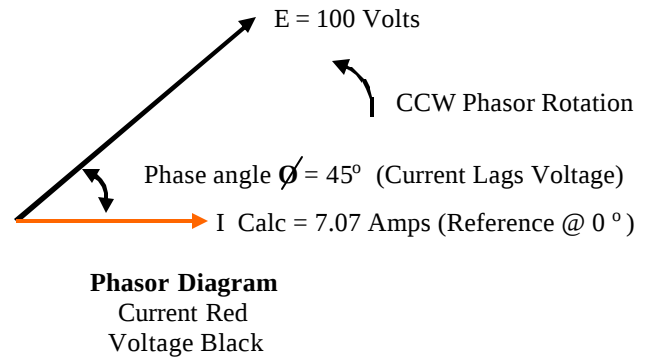
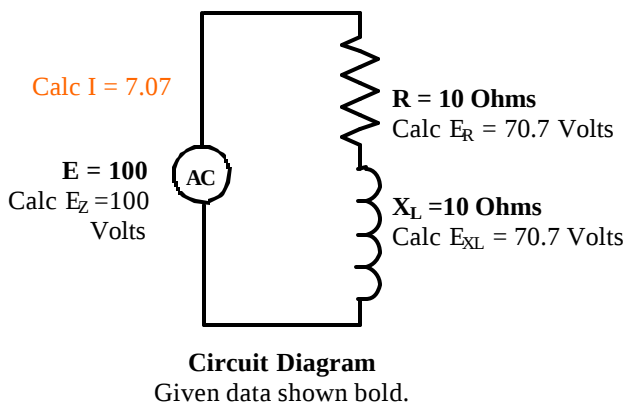
In the above drawing, the zero crossing for both the current and voltage occurs at the same time.

AC Theory Power in an RL Circuit

This series circuit combines resistance and reactance. Given: System Voltage = 100, $R = 10$ Ohms, $X_L = 10$ Ohms. Because this is a series circuit, the current is the same through both circuit elements and current becomes the reference phasor. The circuit is inductive, so the current will lag the voltage.

Steps to solving this circuit:

- Find system impedance - Use Trig or Pythagorean Theorem to find Z .
- Calculate system current - Divide given system voltage (100) by Z .
- Calculate voltage drops - Multiply calculated current times R , X_L , and Z .
- Calculate values for power triangle - Multiply current (I) times E_R , E_{XL} , and E_Z . (Or you can use $P = I^2 R$.)
- Calculate phase angle - There are several ways to do this, shown is Trig calculation using Watts and Vars.
- Calculate system power factor - This is the Cosine of the phase angle expressed as a percent.



Calculations

Impedance:

$$Z^2 = R^2 + X^2 \quad \text{or} \quad Z = \sqrt{R^2 + X^2}$$

$$Z = \sqrt{10^2 + 10^2} = \sqrt{100 + 100} = \sqrt{200} = 14.14 \text{ Ohms}$$

Current: $I = E / Z$

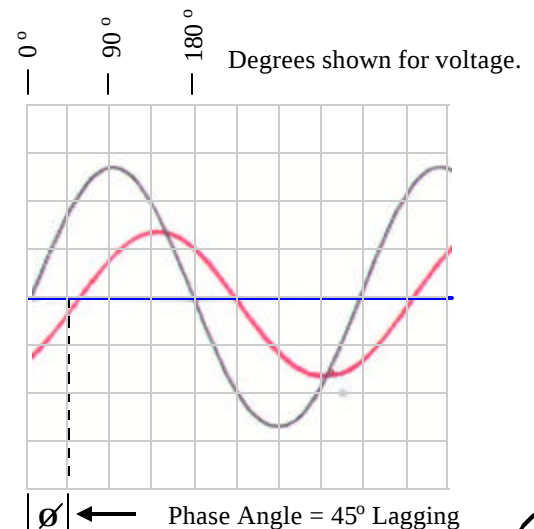
$$I = E / Z = 100 \text{ volts} / 14.14 \text{ ohms} = 7.07 \text{ Amps}$$

Voltage $E_R = I \times R = 7.07 \times 10 = 70.7$ Volts
 $E_{XL} = I \times X_L = 7.07 \times 10 = 70.7$ Volts
 $E_Z = I \times Z = 7.07 \times 14.14 = 100$ Volts

Power: Watts = $E_R \times I = 70.7 \times 7.07 = 500$ Watts
 Vars = $E_{XL} \times I = 70.7 \times 7.07 = 500$ Vars
 Volt Amperes = $E_Z \times I = 100 \times 7.07 = 707$ VA

Phase Angle: $\tan \phi = \text{Opp} / \text{Adj} = \text{Vars} / \text{Watts} = 500 / 500 = 45^\circ$

Power Factor = $\cos \phi \times 100 = \cos 45^\circ \times 100 = .707 \times 100 = 70.7 \%$



Sine Wave Relationship
Red - Current
Black - Voltage

AC Theory Power in an RLC Circuit

This parallel circuit combines resistance, inductance, and capacitance. Because capacitive reactance X_C and inductive reactance X_L are opposite one another, the two reactances can be vectorally (algebraically) added to obtain a single reactance with the magnitude of the resultant vector being equal to the difference between the quantities and the vector direction being that of the larger quantity. Because it is a parallel circuit, the voltage is the same across each circuit element and is chosen as the reference phasor.

A practical application of this principle is power factor correction. Primarily because of induction motor load, electrical systems are generally inductive and have a lagging power factor. Power factor correction capacitors can be added to the system to supply leading vars and offset some of the lagging system vars.

To simplify the application of power factor correction capacitors to electrical systems, manufacturers rate these capacitors in kilovars (kVAR) rather than in microfarads. The correlation between microfarads and kVARs is given by the formula: $\text{kVAR} = 2\pi FCE^2 / 10^9$ Where: $2\pi = 6.28$, F = Frequency in hertz, C = Capacitance in microfarads, and E^2 = Voltage².

The Circuit Diagram shown below represents a typical distribution system. The resistance element represents resistive loads such as incandescent lighting, electric heat, and the resistive component of inductive loads such as motors and transformers. The inductance symbol represents the inductive component of motors, transformers, and other magnetic circuits, and the capacitance represents a bank of power factor correction capacitors of 300 kVAR.

The Original System Power Triangle, below left, shows a system with a 500 kW (true power) load, 500 kVAR of reactive (wattless) power, and a kVA (apparent power) of 707. The system phase angle $\phi = 45^\circ$, resulting in a system power factor of 70% ($\cos 45^\circ = .707$). The Phasor Diagram and the Resultant Power Triangle, bottom right, illustrate the system improvement by the addition of a 300 kvar power factor correction capacitor.

