**LAB SESSION # 14**

# DETERMINE POWER FACTOR FOR INDUCTIVE AND CAPACITIVE LOADS

## OBJECTIVE:

1. To Study the Power Factor, Apparent Power, Reactive Power, Real Power.
2. To study and determine the Power factor for Inductive & Capacitive Loads.

## APPARATUS:

1. Resistor
2. Inductor
3. Capacitor
4. DMM
5. Connecting Wires
6. AC Power Supply
7. Oscilloscope

## Theory

**Power factor**:

The power factor of an AC electric power system is defined *as " The ratio **active (true or real) power** to **apparent power"***, where

- **Active (Real or True) Power** is measured in watts (*W*) and is "the *power drawn by the electrical resistance of a system doing useful work" It is denoted with **"P".***

- **Apparent Power** is measured in volt-amperes *(VA)* and is the voltage on an AC system multiplied by all the current that flows in it. It is the vector sum of the **active** and the **reactive power.** *It is denoted with **"S".***

- **Reactive Power** is measured in volt-amperes reactive (*VAR*). Reactive Power is power stored in and discharged by inductive motors, transformers and solenoids, *It is denoted with **"Q".***

$$\text{power factor} = \frac{P, \text{ real power}}{|S|, \text{ apparent power}}$$

$$\boldsymbol{P = S\ \cos\theta}$$

It is common to define the Power Factor - *PF* - as the cosine of the phase angle between voltage and current - or the "$\cos\theta$":

$$PF = \text{power factor } PF = \cos\theta$$

*OR*

**Power Factor** (PF) is defined as the cosine of angle between the inductive portion and the resistive portion of a coil. This angle is also called Phase Angle. In real world, ***Power Factor*** is *the ratio of real power over the available power from a AC system. Real Power (in KW) is the available power to do the work, and Available Power (in KVA) is the total delivered power*. The difference between Real Power and Available Power is the Reactive Power. Reactive Power (in KVAR) is the power needed to generate the magnetic fields in the inductive equipment, No useful work is performed by KVAR.

**<u>Power Triangle</u>**

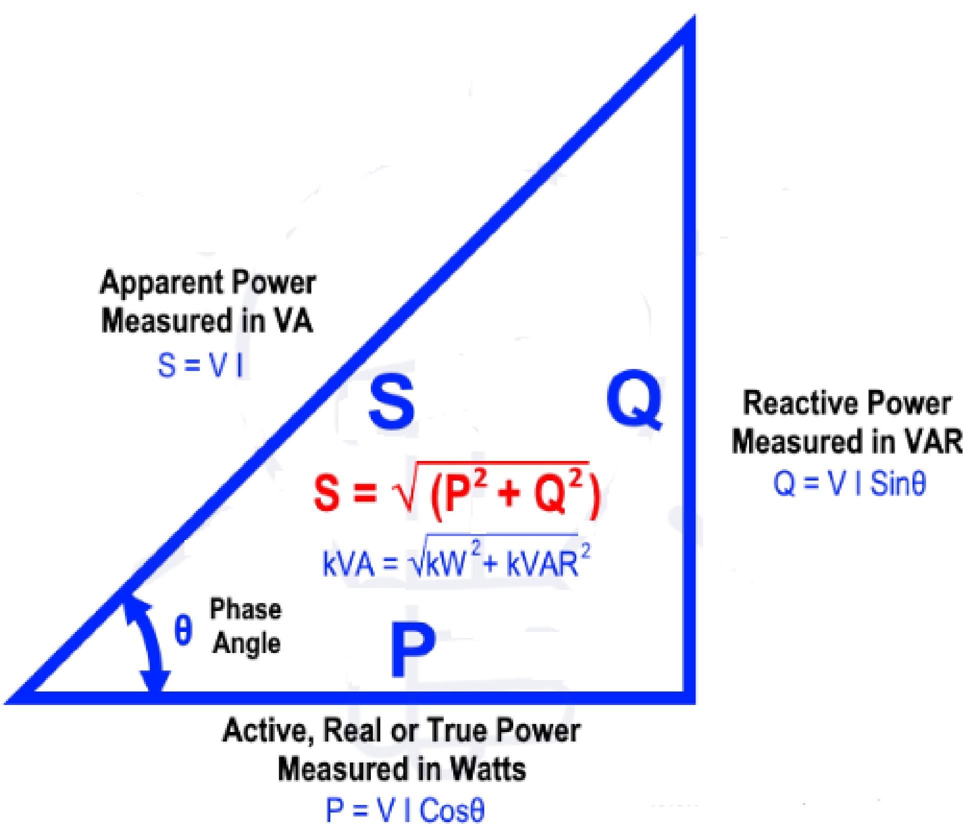


Figure 14.1 ( Power Triangle )

**"Leading" or "Lagging" Power Factors**

A Power Factor is usually stated as "leading" or "lagging" to show the sign of the phase angle.

- With a purely resistive load the current and voltage changes polarity in step and the power factor will be **1**. Electrical energy flows in a single direction across the network in each cycle.

- **Inductive loads** - transformers, motors and wound coils - consumes reactive power with current waveform lagging the voltage.

- **Capacitive loads** - capacitor banks or buried cables - generates reactive power with current phase leading the voltage.

There is also a difference between a lagging and leading power factor. The terms refer to whether the phase of the current is lagging or leading the phase of the voltage.

A lagging power factor signifies that the load is inductive, as the load will "consume" reactive power, and therefore the reactive component **Q** is positive as reactive power travels through the circuit and is "consumed" by the inductive load.

A leading power factor signifies that the load is capacitive, as the load "supplies" reactive power, and therefore the reactive component **Q** is negative as reactive power is being supplied to the circuit as shown in figure 14.2 .

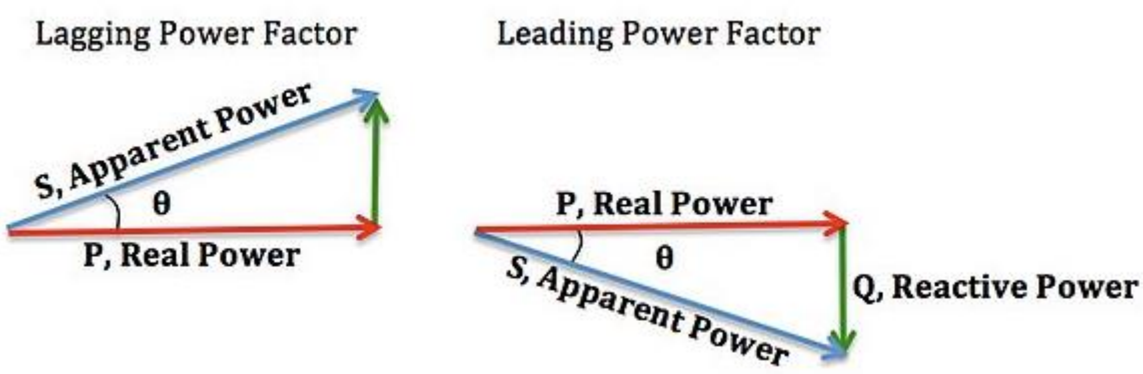


Figure 14.2 (Power Triangle "Leading" or "Lagging")

If **θ** is the phase angle between the current and voltage, then the power factor is equal to

the cosine of the angle, :

$$P = S \cos\theta$$

## 1. Inductive Load

**Inductive** reactance resists the change to current, causing the circuit current to lag voltage. **Examples** of devices producing reactive / **inductive loads** include motors, transformers and chokes. **Inductive Loads**, also called Lagging **Loads**.

Consider a simple RL circuit as shown in figure 14.3 below in which resistor, R and inductor, L (as a load ) are connected in series with a voltage supply of V volts.

Let $V_R$ and $V_L$ be the voltage drop across resistor and inductor.

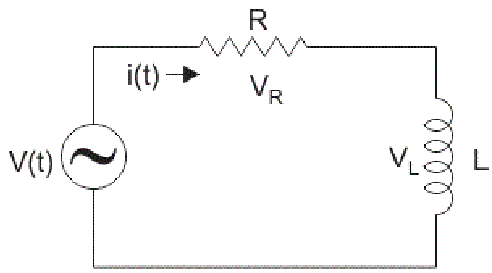


Fig 14.3 RL Series Circuit

**In inductor**, the voltage and the current are not in phase. The voltage leads that of current by 90° or in other words, voltage attains its maximum and zero value 90° before the current attains it.

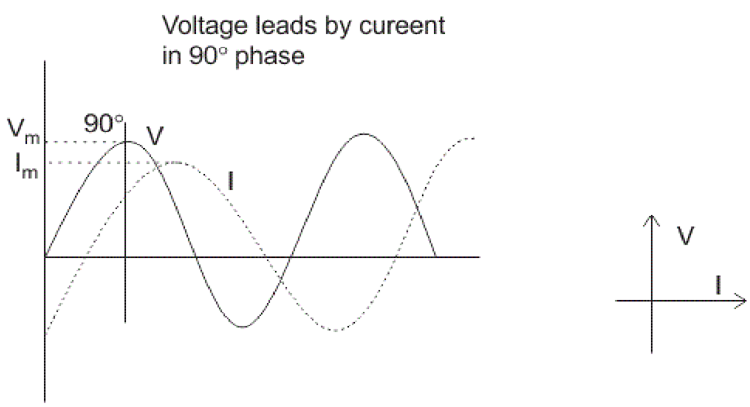


Fig. 14.4 (Voltage leads by Current in 90° in Inductive Circuit)

**Power in RL Circuit:**

In series RL circuit, some energy is dissipated by the resistor and some energy is alternately stored and returned by the inductor-

1. The instantaneous power deliver by voltage source V is P = VI (watts).
2. Power dissipated by the resistor in the form of heat, $P = I^2R$ (watts).

3. The rate at which energy is stored in inductor. $XL = 2\pi f L$

**Related Terms:**

**Impedance** $$Z = \sqrt{R^2 + X_L^2}$$

**Current in a circuit** $$I = \frac{V}{Z}$$

**Phase Angle** $$\theta = \tan^{-1}\frac{XL}{R}$$

**Apparent Power** $$S = VI$$

**Average power,** $$P = S \cos\theta$$

**or**

$$P = VI \cos\theta$$

**Reactive power,**

$$Q = VI \operatorname{Sin}\theta$$

**Power factor** $$\text{pf} = \cos\theta$$

or

$$\cos\theta = \frac{R}{Z}$$

Simulation results ( Sine wave, Amplitude = 5 and frequency = 1 Hz )

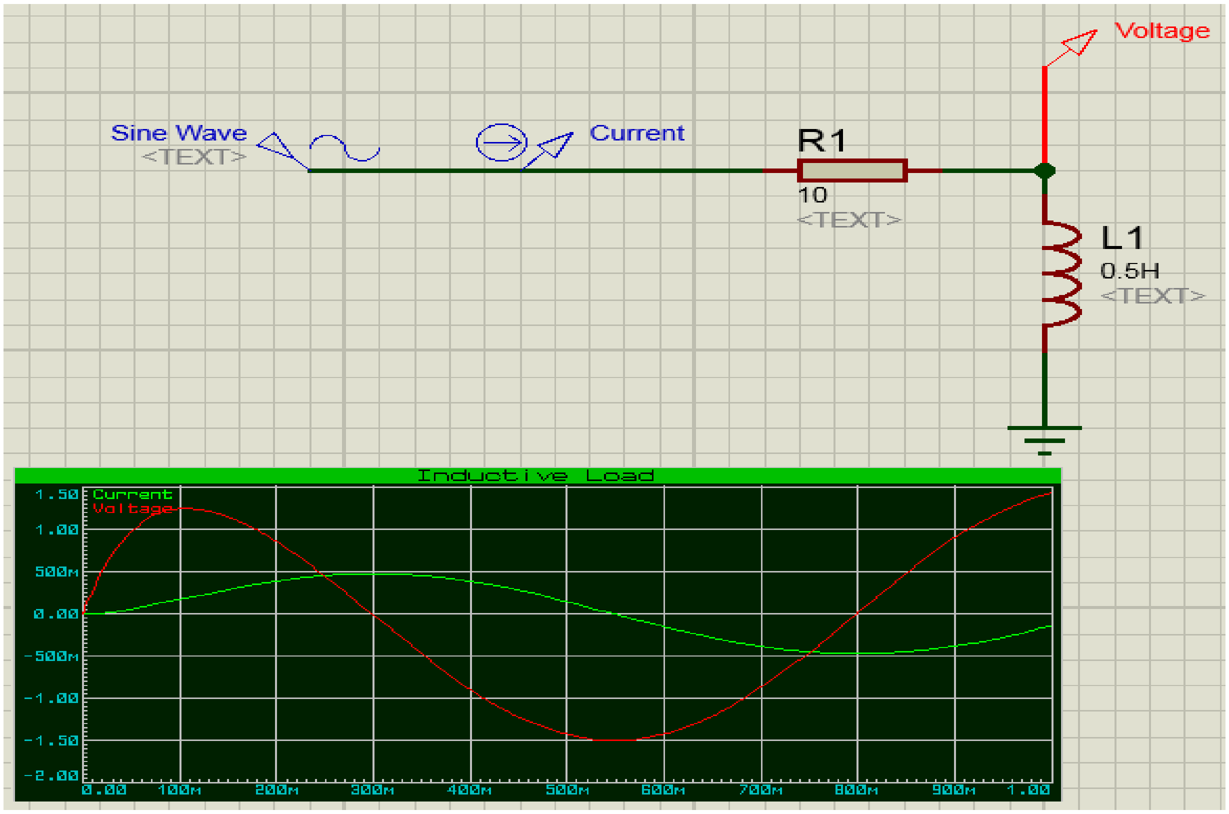


Figure 14.5 (Simulation Results of RL Series Circuit)

Observation Table 14.1

| V (V) | R (Ω) | $X_L$ (Ω) | ϴ | PF | P (W) | S (VA) | Q (VAR) |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

2. Capacitive Load

Consider a simple RC circuit as shown in fig.14.6 in which resistor, R and capacitor, C as load are connected in series with a voltage supply of V volts. Let us think the current flowing in the circuit is I (amp) and current through resistor and capacitor is IR and Ic respectively. Since both resistance and capacitor are connected in series, so the current in both the elements and the circuit remains the same. i.e IR = Ic = I. Let VR and Vc be the voltage drop across resistor and capacitor. When the resistor is connected in series to the capacitor in AC circuit, this results the in-phase between the load current I and voltage VR while the current at capacitor is 90° leads applied Voltage Vc.

The total voltage is presented by the summation of Vectors as

$$V_T = V_R + V_C.$$

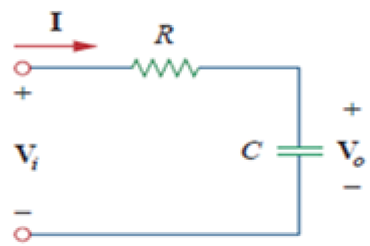


Fig. 14.6  RC Series Circuit

Z is the total opposition offered to the flow of alternating current by an RC series circuit and is called **impedance** of the circuit. It is measured in ohms (Ω).

$$Z = \sqrt{R^2 + X_c^2}$$

**Power in RC Circuit:**

1. The instantaneous power deliver by voltage source V is P = VI (watts).
2. Power dissipated by the resistor in the form of heat, $P = I^2R$ (watts).
3. The rate at which energy is stored in capacitor is. $XC = 1/2\pi f C$

$$Xc = \frac{1}{2\pi f C}$$

**Related Terms:**

**Impedance** $$Z = \sqrt{R^2 + X_c^2}$$

**Current in a circuit** $$I = \frac{V}{Z}$$

**Phase Angle** $$\theta = \tan^{-1}\frac{Xc}{R}$$

**Apparent Power** $$S = VI$$

**Average power,** $$P = S\ \cos\theta$$

$$P = VI\ \cos\theta$$

**Reactive power,**

$$Q = VI\,\text{Sin}\,\theta$$

**Power factor** $$\text{pf} = \cos\theta$$

**or**

$$\cos\theta = \frac{R}{Z}$$

**Simulation Result of Capacitive Load**

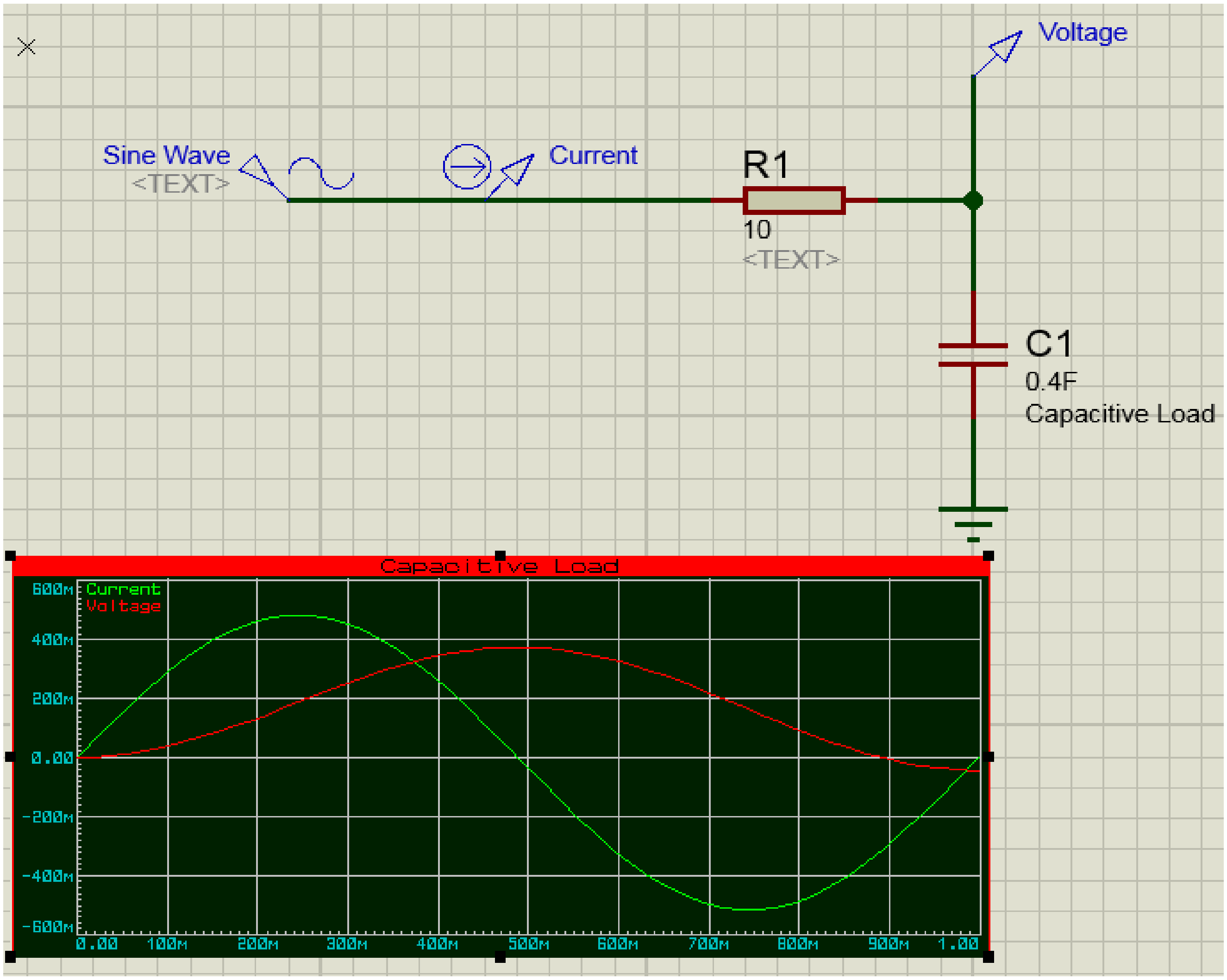


Figure 14.7 ( Simulation Result of Capacitive Load )

Observation Table 14.2

| V (V) | R (Ω) | $X_c$ (Ω) | Θ | PF | P (W) | S (VA) | Q (VAR) |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |

Comments & Discussion