Basic Electrical Technology
[ELE 1051]

SINGLE PHASE AC CIRCUITS

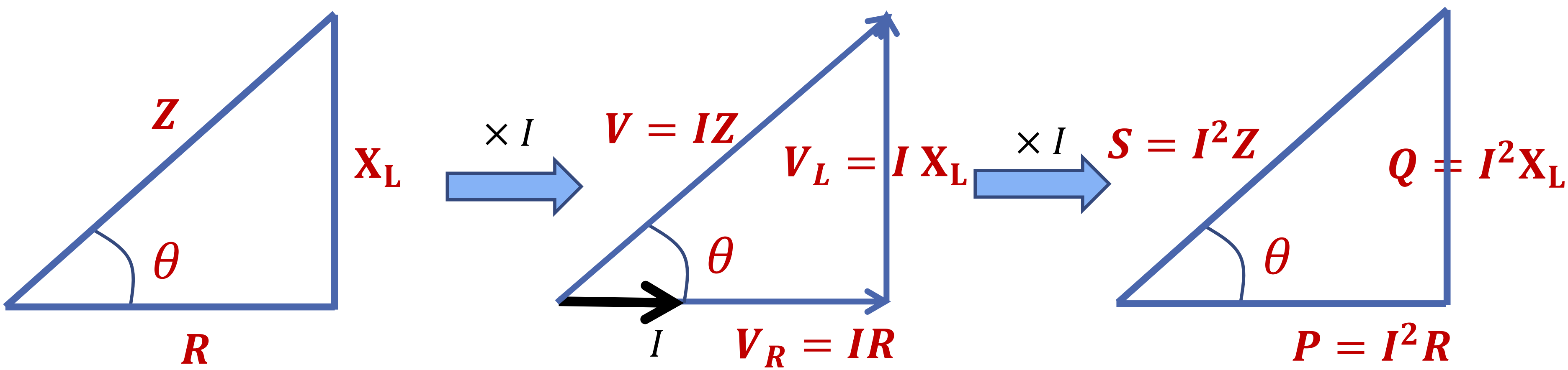
L19 – Power in AC circuits

Topics covered…

- Impedance, phasor & Power Diagram
- Concept of power factor and its significance
- Need for power factor improvement

Power associated in RL load

For RL load:



Impedance diagram

Phasor diagram

Power diagram

$$S = P + jQ$$

Where,

S = Apparent Power (VA)

P = Active Power (W)

Q = Reactive Power (var)

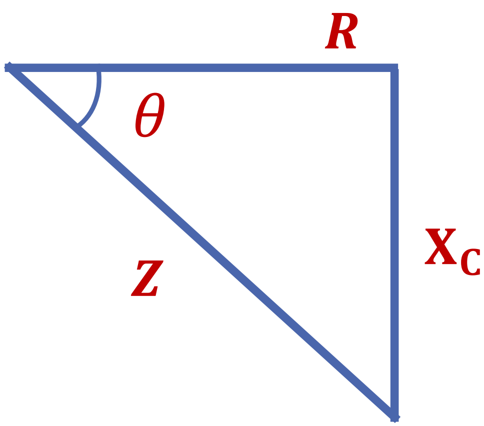
$$S = VI$$

$$P = VI \cos \emptyset$$

$$Q = VI \sin \emptyset$$

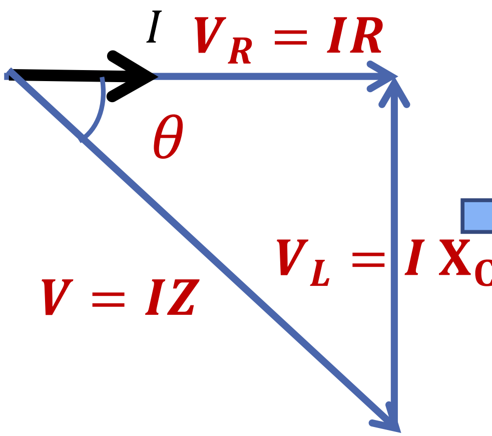
Power associated in RL load

For RC load:



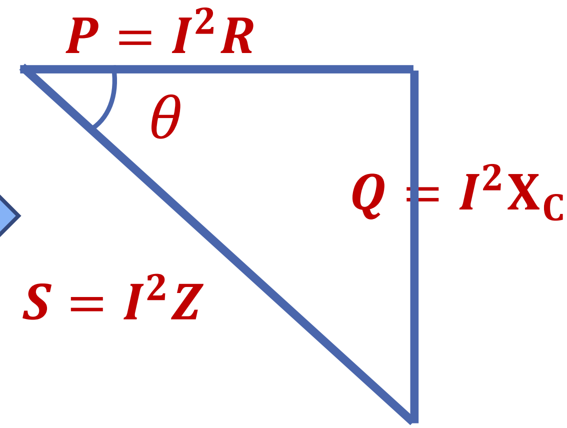
Impedance diagram

$\times I$



Phasor diagram

$\times I$



Power diagram

$$S = P - jQ$$

Where,
S = Apparent Power (VA)
P = Active Power (W)
Q = Reactive Power (var)

$$S = VI$$

$$P = VI\cos\emptyset$$

$$Q = VI\sin\emptyset$$

Power Factor

$$\textit{Power Factor} = \frac{\textit{Active Power P in watts}}{\textit{Apparent Power S in voltamperes}}$$

$$\cos\theta = \frac{P}{S} = \frac{P}{VI}$$

- For an impedance Z,

$$\cos\theta = \frac{IR}{V} = \frac{IR}{IZ} = \frac{resistance}{impedance}$$

- Power factor is *lagging* when the *current lags the supply voltage*
- Power factor is *leading* when the *current leads the supply voltage*
- For a resistive load, power factor is Unity

Disadvantages of Low Power Factor

1) Draws more reactive power
2) For supplying a certain amount of active power (consumed), the apparent power to be supplied increased
3) Cost of supply increases
4) Voltage drop occurs in the vicinity of consumer

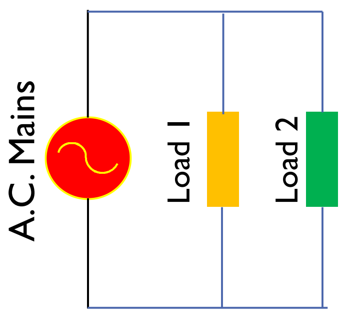
- Increased transmission losses
- Hence bulk consumers are advised to maintain the power factor close to unity by power utilities.

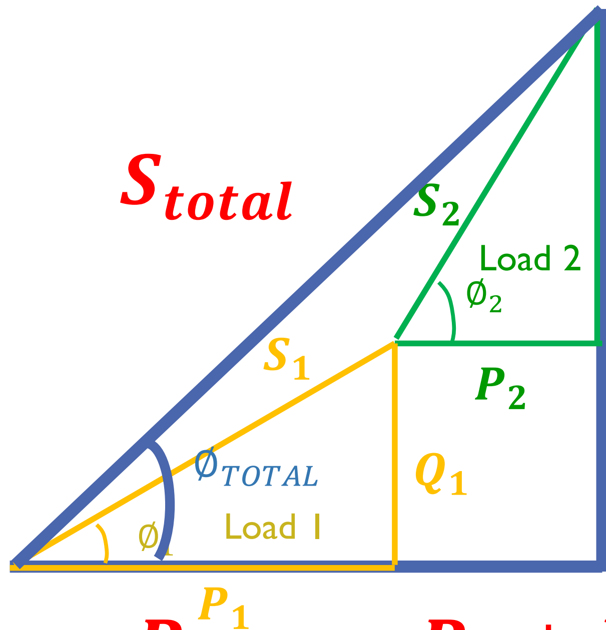
Remedial Measures

- Most of the industrial loads are inductive in nature
- Reactive power demand of Inductive loads can be compensated with capacitive loads
- Hence it is possible to localise reactive power requirement by connecting parallel capacitors across the load

Power Triangle

- Practically, loads are in connected parallel
- Majority of the loads are inductive in nature





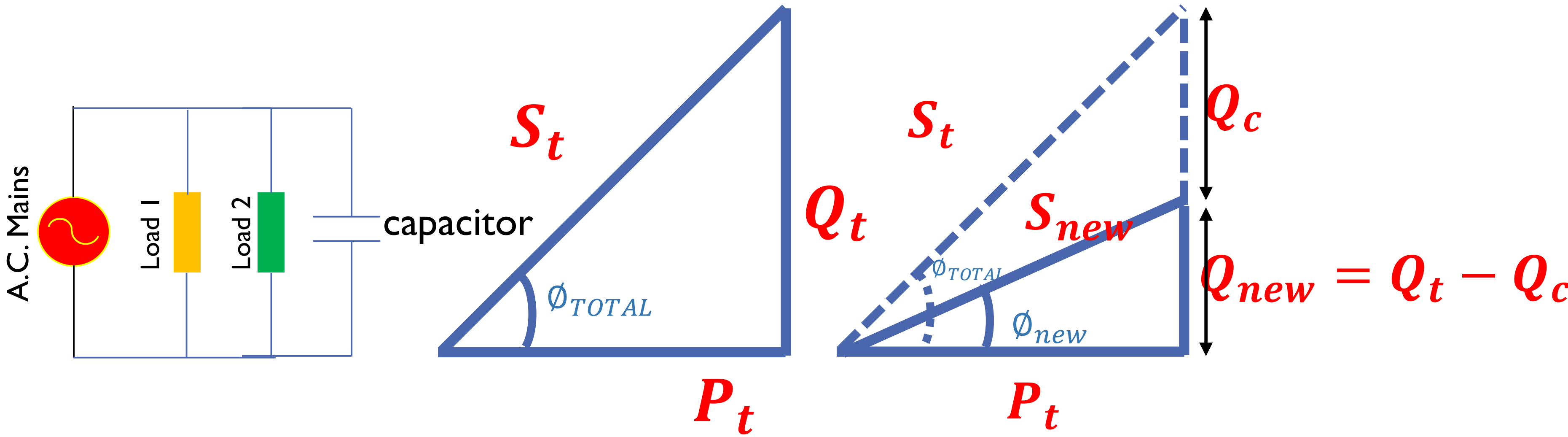
$$Q_{total} = Q_1 + Q_2$$

$$P_{total} = P_1 + P_2$$

$$S_{total} = P_{total} + jQ_{total}$$

Power Factor Improvement

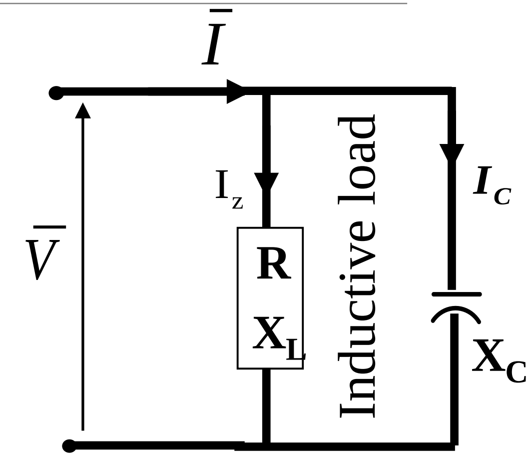
- Connect capacitor parallel to the load
- Energy stored by the capacitor provides the required reactive power by the load



<u>Calculation of capacitor value</u>

- Calculate Q_c needed to improve power factor to $cos\emptyset_{new}$
- Calculate $X_c = \frac{V^2}{Q_C}$ & $c = \frac{X_c}{2\pi f}$

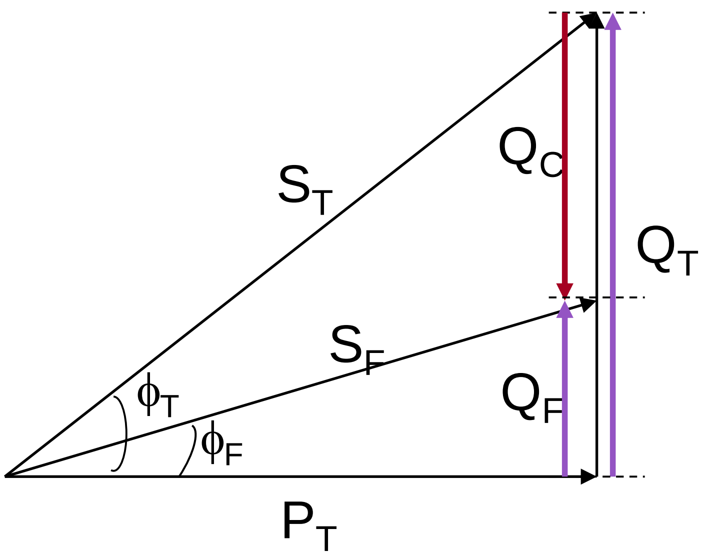
Power Factor Improvement



Since most of the loads are inductive in nature, a capacitor connected in parallel to the inductive load improves the power factor

Determination of Capacitor Value:

- ϕ_T is the over all power angle
- ϕ_F is the final power angle after connecting the capacitor across the load



- $S_T = P_T/\text{Cos}\phi_T$ & $S_F = P_T/\text{Cos}\phi_F$
- $Q_T = (P_T/\text{Cos}\phi_T) * \text{Sin } \phi_T$
- $Q_F = (P_T/\text{Cos}\phi_F) * \text{Sin } \phi_F$
- $Q_C = (Q_T - Q_F) = P_T(\text{Tan } \phi_T - \text{Tan } \phi_F)$
- $X_C = V^2/ Q_C$

Illustration 1

A single-phase motor takes 8.3 A at a power factor of 0.866 lagging when connected to a 230 V, 50 Hz supply. Capacitance bank is now connected in parallel with the motor to raise the power factor to unity. Determine the capacitance value

Ans: $\mathbf{57.4\ \mu F}$

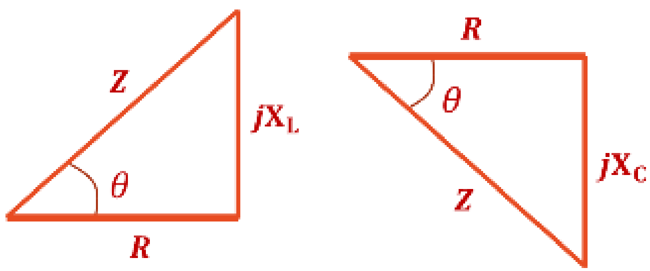
Illustration 2

A single-phase load of 5 kW operates at a power factor of 0.6 lagging. It is proposed to improve this power factor to 0.95 lagging by connecting a capacitor across the load. Calculate the kvar rating of the capacitor

Ans: 5.02 kvar

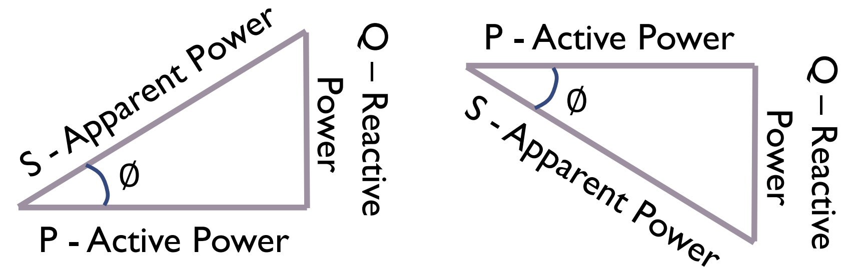
Summary

Impedance diagram



RL Load RC Load

Power diagram



RL Load RC Load

- Power in AC circuit is given by, $\boldsymbol{S = VI}$
- For any load with impedance Z,
  - Active Power (watt), $\boldsymbol{P = VI\cos\theta = I^2 Z\cos\theta = I^2 R}$
  - Reactive Power (var), $\boldsymbol{Q = VI\sin\theta = I^2 Z\sin\theta = I^2 X}$
  - Apparent Power (VA), $\boldsymbol{S = VI = I^2 Z}$
- $\boldsymbol{Power\ Factor} = \dfrac{\boldsymbol{Active\ Power}}{\boldsymbol{Apparent\ Power}} = \dfrac{P}{S} = \dfrac{R}{Z} = \cos\theta$

Summary

- Low power factor loads must be avoided

- Capacitor bank connected parallel to the load serves as the source of reactive power for the load
  - Improves load power factor
  - Reduces transmission and distribution losses