Lesson 24:
Power Factor Correction

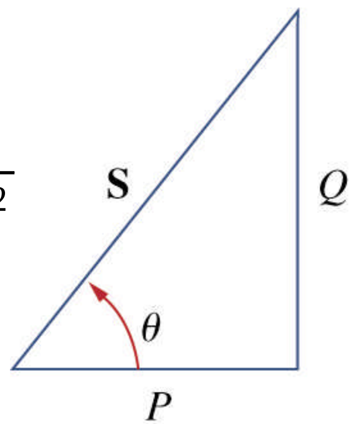
Power triangle

Complex Power

$$\mathbf{S} = P + jQ = \mathbf{V}_{\text{rms}}\mathbf{I}^*_{\text{rms}}$$
$$= V_{\text{rms}} I_{\text{rms}} \angle(\theta_v - \theta_i)$$

Apparent Power (VA)

$$S = |\mathbf{S}| = V_{\text{rms}} I_{\text{rms}} = \sqrt{P^2 + Q^2}$$



Reactive Power (VAR)

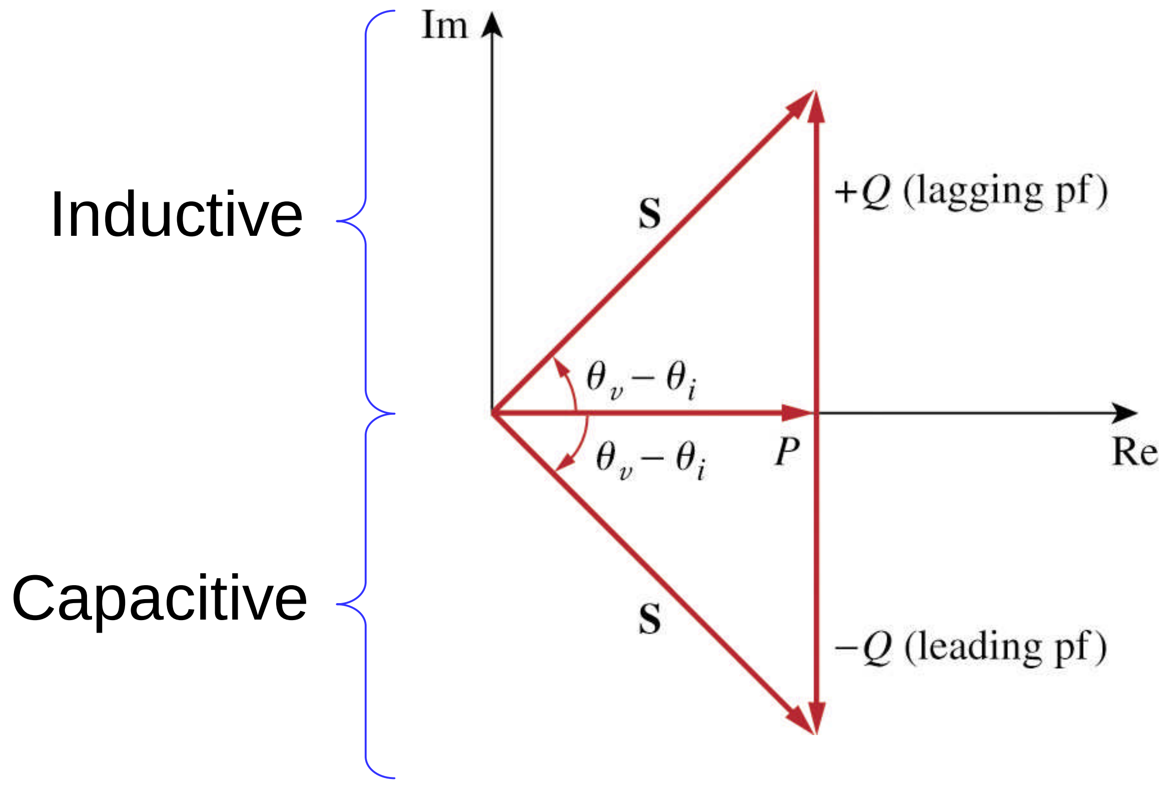
$$Q = \text{Im}(\mathbf{S}) = S\sin(\theta_v - \theta_i)$$

Real Power (watts)

$$P = \text{Re}(\mathbf{S}) = S\cos(\theta_v - \theta_i)$$

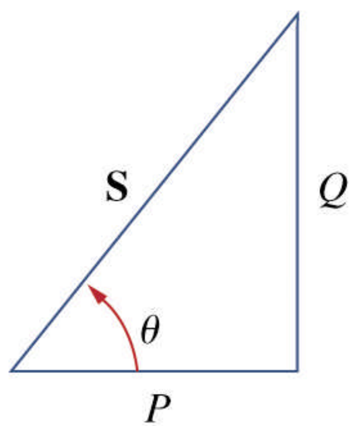
Leading/lagging in power triangle

- The power triangle's orientation depends on the sign of Q (which depends on the load $\mathbf{Z}$)



Power factor

- The amount of real power delivered a load is a function of apparent power S and the power factor.



$$P = \underbrace{V_{\text{rms}} I_{\text{rms}}}_{\textbf{apparent power}} \underbrace{\cos(\theta_v - \theta_i)}_{\textbf{power factor}}$$

- Why are electric utilities concerned with power factor?

Example Problem 1

Air conditioning for Rickover Hall requires a 40-ton unit which draws 85-kW. Assuming V = 460 V_{rms}, determine the required current I for the following three cases (all lagging): (a) pf = 0.6, (b) pf = 0.85, and (c) pf = 1.0. What is the percentage increase in transmission line losses (I^2R) suffered by the utility for cases a & b relative to pf = 1.0.

[Trane IntelliPak specs]

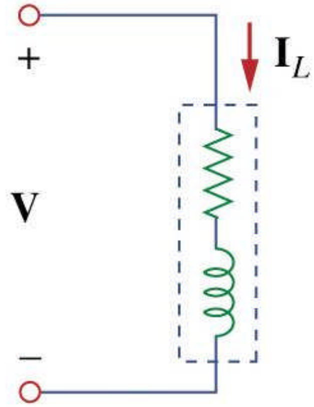
Power factor correction

- Most all practical loads are inductive (motors, fluorescent lights, etc.) and operate at a lagging power factor.

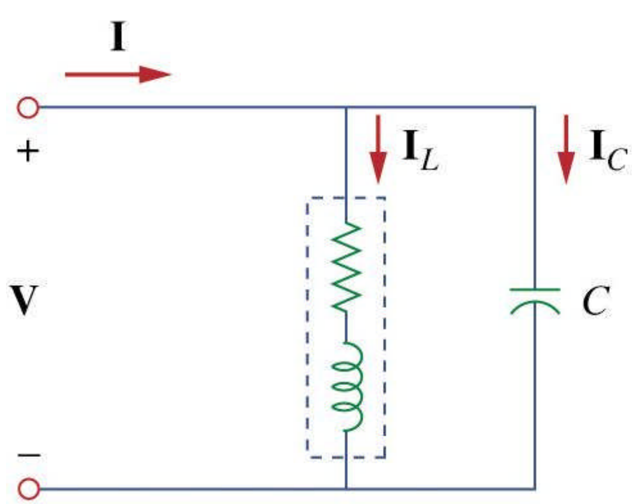
The process of increasing power factor without altering the voltage or current to the original load is known as **power factor correction**.

Power factor correction

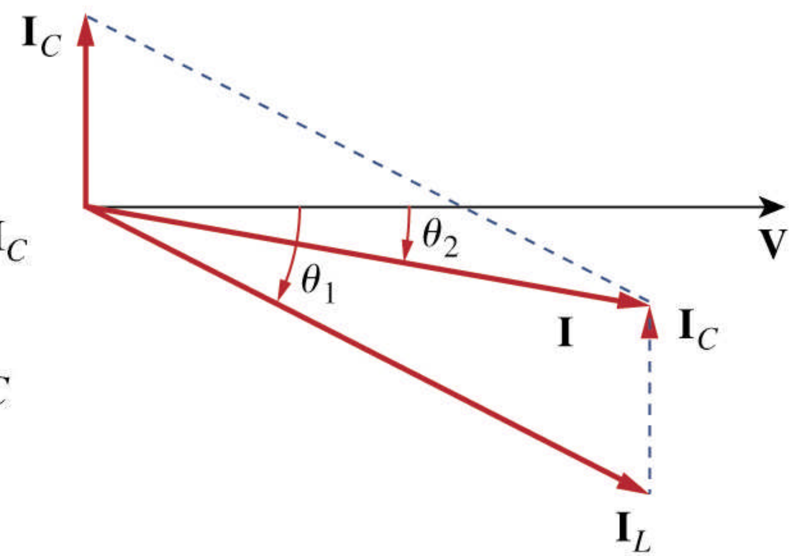
- Because most loads are inductive, power factor can be corrected by installing a capacitor in parallel with the load.



Inductive load



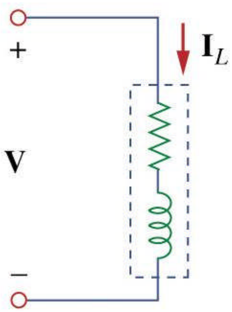
Inductive load with improved pf

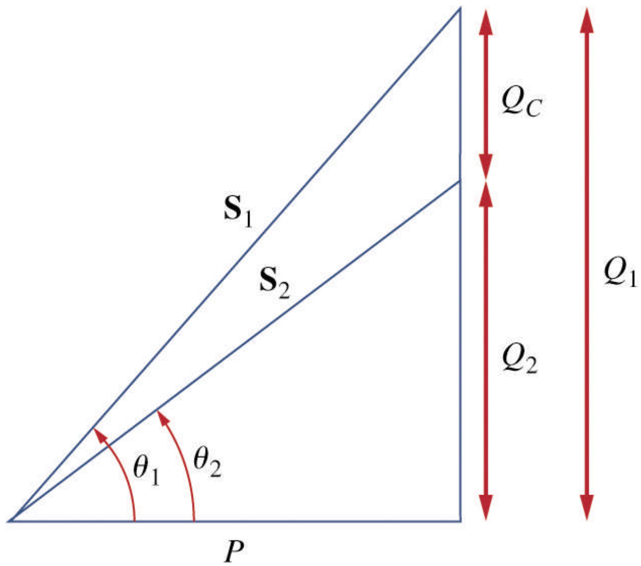


Phasor diagram of currents relative to **V**

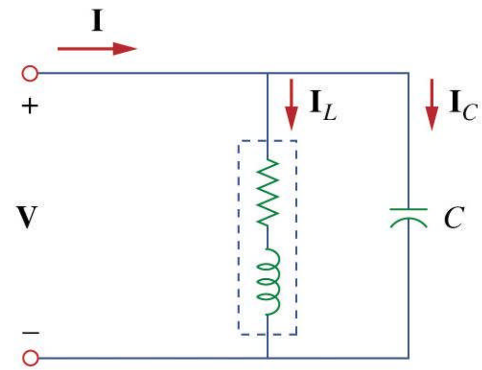
Power factor correction

Before correction





After correction



$$P = S_1 \cos\theta_1$$

$$Q_1 = S_1 \sin\theta_1 = P \tan\theta_1$$

$$P = S_2 \cos\theta_2$$

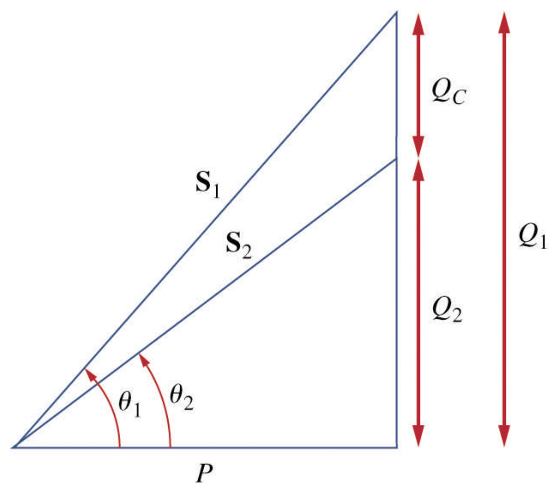
$$Q_2 = S_2 \sin\theta_2 = P \tan\theta_2$$

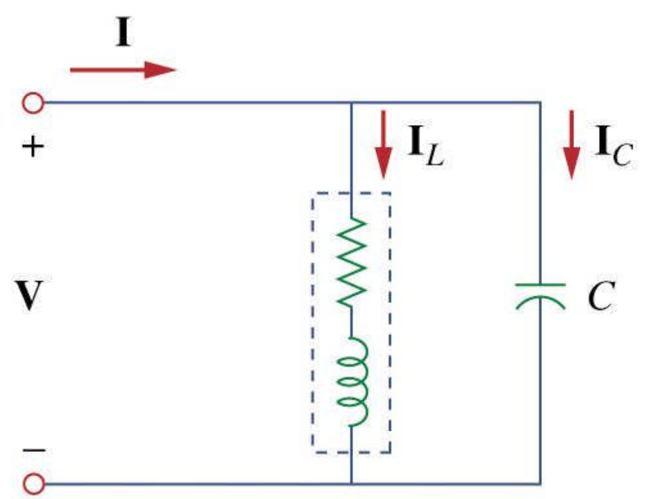
$$Q_C = Q_1 - Q_2 = P(\tan\theta_1 - \tan\theta_2)$$

Shunt capacitor

- The value of the required shunt capacitance is given by

$$C = \frac{Q_C}{\omega V_{\mathrm{rms}}^2} = \frac{P(\tan\theta_1 - \tan\theta_2)}{\omega V_{\mathrm{rms}}^2}$$





Example Problem 2

When connected to a 120-Vrms, 60-Hz power line, a load absorbs 4 kW at a lagging power factor of 0.8. Find the value of capacitance necessary to raise the pf to 0.95.

Fixed capacitors for power factor correction