Lecture 06: Power (continued)

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February 5, 2003

Abstract

Continuation of the discussion on power in R-L-C circuits.

1 Example

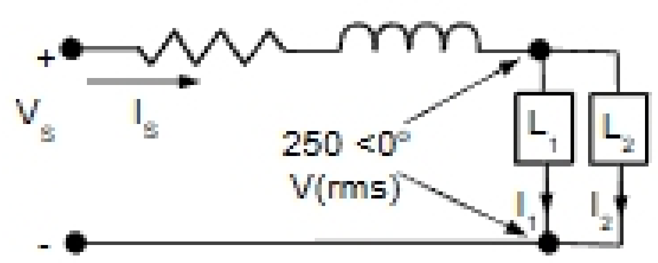

Figure 1: The circuit for the example.

Given

- Load L_1 (8 kW at pF of 0.8) leading
- Load L_2 (20 kVA at pF of 0.6) lagging
- L_1 and L_2 are in parallel with each other and the voltage across them is $250\angle(0)$ (rms).

Find the power factor (pF) of the total load.

1. For load L_1:

$$S_1 = P_1 + jQ_1$$

$$\theta_1 = \cos^{-1}(0.8) = 36.87^\circ$$

$$|S_1| = \frac{P_1}{\cos\theta_1} = \frac{8\text{ kW}}{0.8} = 10\text{ kVA}$$
$$|Q_1| = 6\text{ kVAR}$$

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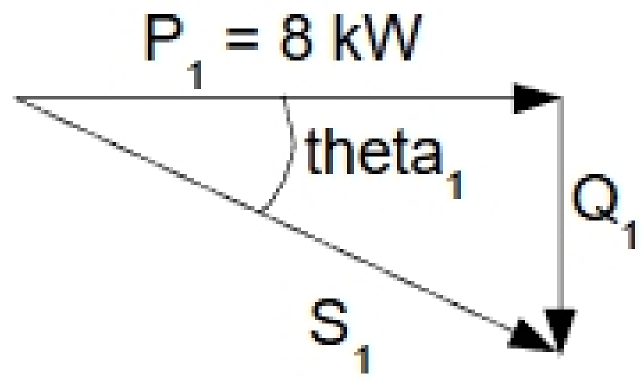

Figure 2: Complex power diagram for load L_1.

2. Similarly for load L_2:

$$S_2 = P_2 + jQ_2$$
$$|S_2| = 20 \text{ kVA}$$
$$\theta_2 = \cos^{-1}(0.6)$$

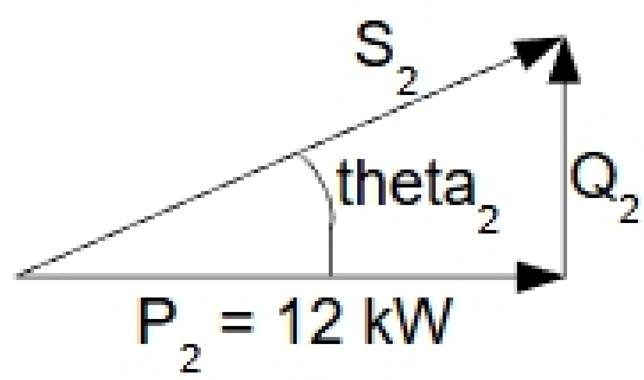

Figure 3: Complex Power diagram for load L_2.

$$|P_2| = |S_2| \cos\theta_2 = 20(0.6) = 12 \text{ kW}$$
$$|Q_2| = 20 \sin\theta_2 = 16 \text{kVAR}$$

3. Complex Power:

$$S_1 = 8000 - j6000$$
$$S_2 = 12000 + j16000$$

Therefore, total power is

$$S = S_1 + S_2 = (20000 + j10000) \text{ VA}$$

But,

$$S = V_s I_s^*$$

Therefore,

$$I_s^* = \frac{20000 + j10000}{250\angle(0)} = 80 + j40 \text{ A}$$

$$I_s = 80 - j40 = 89\angle(-26.57°)$$

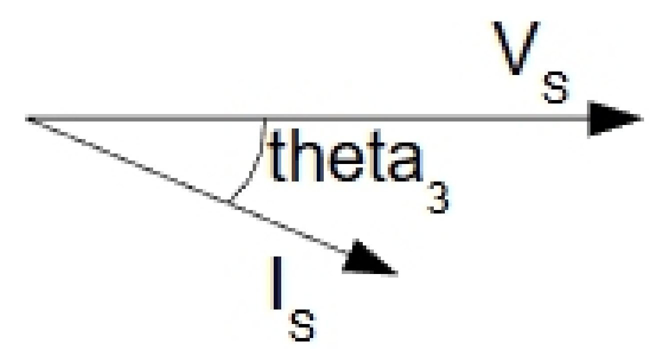

Figure 4: Illustration for θ_3.

Thus, $\theta_3 = 26.57°$.

Power factor of the combined load is

$$\cos(\theta_v - \theta_i) = \cos(26.57°)$$

lagging.

$$pF = 0.8944 \text{ lagging}$$

that is, current lags the voltage.

4.

$$\begin{aligned} |S| &= \text{Apparent Power} \\ &= |(20000 + j10000)| = 22.36 \text{ kVA} \end{aligned}$$

Magnitude of current supplied is

$$|80 - j40| = 89.89 \text{ A}$$

5. Average power lost in the line is:

$$I_s^2 R = (89.89)^2(0.05) = 404 \text{ watts}$$

Thus the power company must supply a real power of 20000 + 404 = 20404 watts of which only 20000 W is useful.

Also it must supply an apparent power of (22360 + ...) VA.

6. If we put a capacitor in parallel to the two loads such that the power in the capacitor is −10 kVAR, then the net power factor will be 1.

We want $Q = -10000$ VAR.

But,

$$Q = \frac{(V_{eff})^2}{1/(\omega C)}$$

or,

$$\frac{1}{\omega C} = \frac{250^2}{10000} = 6.25\Omega$$