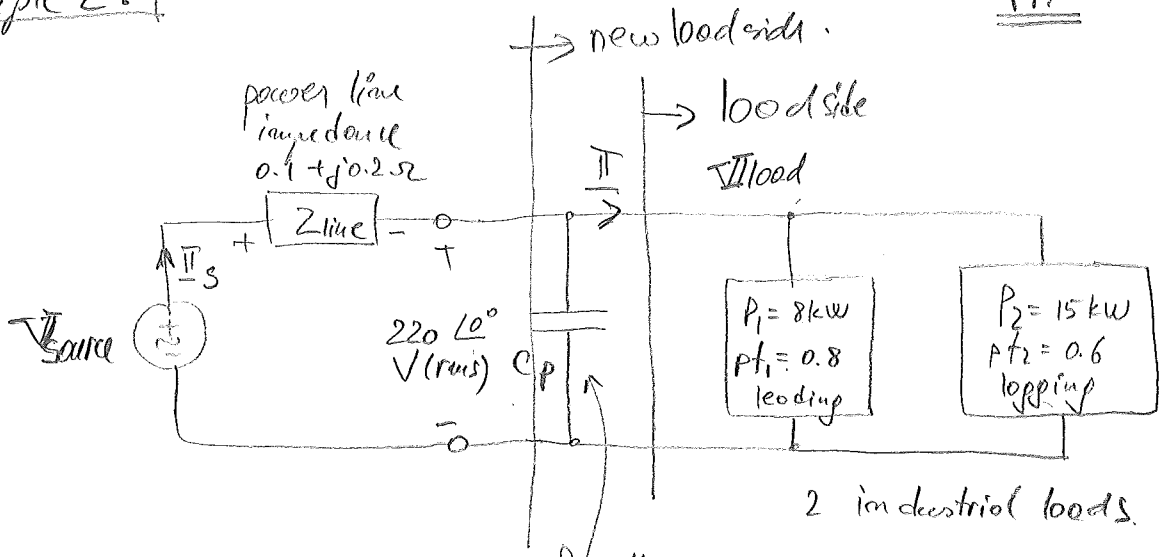
Example 2.6



(a) Assuming $C_p = 0$ find voltage and current capacity required to ensure 220 V (rms) across the load. Find efficiency of the system.

(b) Specify a suitable value for C_p to ensure $pf = 0.95$ lagging. Recompute source capacity and efficiency and compare w/ the uncorrected case.

(a) At the load we have (eq. 7):

$$Q_1 = P_1 \cdot \tan\varphi_1 = 8 \tan(-\cos^{-1} 0.8) = -6 \text{ kVAR}$$

$$Q_2 = P_2 \cdot \tan\varphi_2 = 15 \tan(\cos^{-1} 0.6) = 20 \text{ kVAR}$$

By "ac power conservation principle"

$$S_{load} = S_1 + S_2 = (8 - j6) + (15 + j20) = 23 + j14 \text{ kVA}$$
$$= P_{load} + j Q_{load}$$

Also

$$\bar{I}_{rms} = (\bar{I}_{rms}^*)^* \overset{(10)}{=} \left(\frac{S_{load}}{\bar{V}_{rms}}\right)^* = \frac{(23 - j14)\times 10^3}{220} =$$

phasor

$$= 104.5 - j63.64 = 122.4 \angle -31.33° \text{ A}$$

By KVL:

$$\mathbb{V}_{s(rms)} = 220\angle 0^\circ + Z_{line}\cdot \mathbb{I}_{rms}$$

(phasor)

$$= 220 + (0.1+j0.2)(104.5 - j63.64)$$

$$= 243.2 + j14.53 \text{ V}$$

$$= \underline{243.6 \angle 3.42^\circ} \text{ V}$$

By eq. 10:

$$S_{source} = \mathbb{V}_{s(rms)}\cdot \mathbb{I}_{rms}^{*} = (243.6\angle 3.42^\circ)\times(122.4\angle 31.33^\circ)$$

$$= 29.82\angle 34.75^\circ = 24.50 + j17.00 \text{ kVA}$$
$$= P_{source} + j\,Q_{source}.$$

Finally the efficiency of the system:

$$\boxed{\eta \triangleq \frac{P_{load}}{P_{source}} = \frac{23}{24.50} = 93.9\ \%}$$

(b) Before power-factor correction:

$$pf \triangleq \cos\varphi = \cos\left(\tan^{-1}\left(\frac{14}{23}\right)\right) = 0.854$$
$$= \frac{Q_{load}}{P_{load}}$$

- To raise pf to 0.95 we need $C_p = -\frac{1}{\omega X_p}$, where X_p is found with equation (14). Hence:

$$C_p = -\frac{\tan(\cos^{-1}0.95) - \tan(\cos^{-1}0.854)}{377\times 220^2/(23\times 10^3)} = 353\ \mu F$$

- with C_p in place, complex power of the load becomes (eq. (7)):

$$S_{load} = 23 + j\,23\tan(\cos^{-1}0.95) = 23 + j\,7.56 \text{ kVA}.$$

- Repeating calculations we find:

all phasors:

$$\mathbb{I}_{rms} = 110.0 \angle -18.20^\circ \text{ A}$$

$$\mathbb{V}_{s(rms)} = 238.0 \angle 4.21^\circ \text{ V}$$

$$S_{source} = 24.21 + j\,9.98 \text{ kVA}$$

$$\eta = 95\%$$

- In summary, with C_p in place, the required source capacity is decreased from 243.6 V, 122.4 A to 238.0 V, 110.0 A (rms)
- Also, system efficiency is increased from 93.9% to 95%!