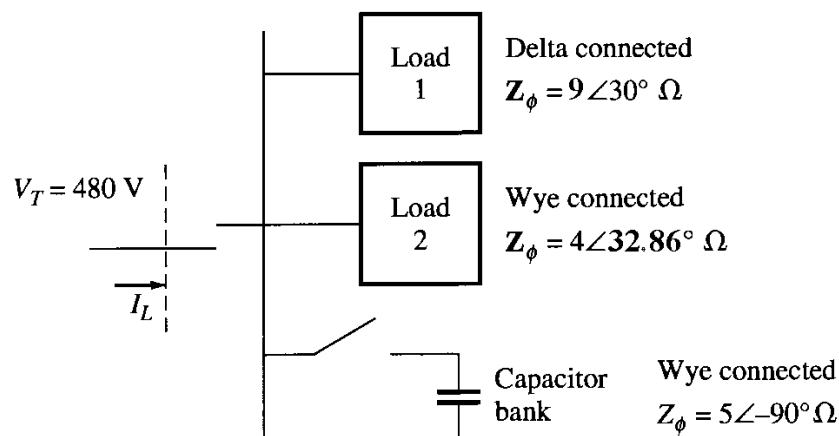


2-6. Figure P2-4 shows a one-line diagram of a small 480-V distribution system in an industrial plant. An engineer working at the plant wishes to calculate the current that will be drawn from the power utility company with and without the capacitor bank switched into the system. For the purposes of this calculation, the engineer will assume that the lines in the system have zero impedance.

- If the switch shown is open, find the real, reactive, and apparent powers in the system. Find the total current supplied to the distribution system by the utility.
- Repeat part (a) with the switch closed.
- What happened to the total current supplied by the power system when the switch closed? Why?

➤ **modified** so that $\bar{Z}_{\phi 1} = 9 \angle 30^\circ \Omega$ and $\bar{Z}_{\phi 2} = 4 \angle 32.86^\circ \Omega$

Figure P2-4 | The system in Problem 2-6.



a) Load 1 (Δ -conn) $V_{\phi} = V_{LL} = 480 \text{ V}_{rms}$
 $\bar{Z}_{\phi 1} = 9 \angle 30^\circ \Omega$

$$I_{\phi 1} = \frac{V_{\phi}}{Z_{\phi 1}} = \frac{480}{9} = 53.3 \text{ A}_{rms}$$

$$I_{L1} = \sqrt{3} I_{\phi 1} = 92.376 \text{ A}_{rms}$$

(2-29) $P_1 = \sqrt{3} V_{LL} I_{L1} \cos \theta_1 = \sqrt{3} (480) 92.376 \cos 30^\circ$

$$P_1 = 66,510.75 \text{ W} = \underline{\underline{66.51 \text{ kW}}}$$

(2-30) $Q_1 = \sqrt{3} V_{LL} I_{L1} \sin \theta_1 = \sqrt{3} (480) 92.376 \sin 30^\circ$

$$Q_1 = 38,400 \text{ VAR} = \underline{\underline{38.40 \text{ kVAR}}}$$

a) cont. Load 1 cont.

$$(2-31) \quad S_1 = \sqrt{3} V_{LL} I_{L1} = \sqrt{3} (480) 92.376$$

$$S_1 = 76,799.96 \text{ VA} = 76.80 \text{ KVA}$$

Load 2 (Y-conn) $V_{LL} = 480 \text{ V}_{\text{rms}} \rightarrow V_{\phi 2} = \frac{V_{LL}}{\sqrt{3}} = \frac{480}{\sqrt{3}} = 277.13 \text{ V}_{\text{rms}}$

$$\bar{Z}_{\phi 2} = 4 \angle 32.86^\circ \Omega$$

$$I_{L2} = I_{\phi 2} = \frac{V_{\phi 2}}{Z_{\phi 2}} = \frac{277.13}{4} = 69.282 \text{ A}_{\text{rms}}$$

$$(2-29) \quad P_2 = \sqrt{3} V_{LL} I_{L2} \cos \theta_2 = \sqrt{3} (480) 69.282 \cos 32.86^\circ$$

$$P_2 = 48,383.9 \text{ W} = 48.38 \text{ KW}$$

$$(2-30) \quad Q_2 = \sqrt{3} V_{LL} I_{L2} \sin \theta_2 = \sqrt{3} (480) 69.282 \sin 32.86^\circ$$

$$Q_2 = 31,253.1 \text{ VAR} = 31.25 \text{ KVAR}$$

$$(2-31) \quad S_2 = \sqrt{3} V_{LL} I_{L2} = \sqrt{3} (480) 69.282$$

$$S_2 = 57,600 \text{ VA} = 57.60 \text{ KVA}$$

To get total line current supplied, first determine overall complex power

$$\begin{aligned} \bar{S}_{\text{TOT},a} &= (P_1 + P_2) + j(Q_1 + Q_2) = (66.51 + 48.38) + j(38.41 + 31.25) \text{ KVA} \\ &= 114,894.65 + j69,653.1 \text{ VA} = 134,358.98 \angle 31.226^\circ \text{ VA} \\ &\quad \uparrow S_{\text{TOT}} \end{aligned}$$

$$\text{By (2-31)} \quad S_{\text{TOT}} = \sqrt{3} V_{LL} I_{L,\text{TOT}} \Rightarrow I_{L,\text{TOT}} = \frac{S_{\text{TOT}}}{\sqrt{3} V_{LL}}$$

$$I_{L,\text{TOT}} = \frac{134,358.98}{\sqrt{3} 480} = 161.61 \text{ A}_{\text{rms}}$$

b) * When switch is closed, the powers to loads 1 & 2 are unchanged.

* Find powers to capacitor bank & compute new $\bar{S}_{TOT,b}$ & $S_{TOT,b}$ to get new $I_{L,b}$

Capacitor Bank (Y-conn) $V_{LL} = 480 \text{ V}_{rms}$ & $V_{\phi} = 277.13 \text{ V}_{rms}$

$$\bar{Z}_{\phi, cap} = 5 \angle -90^{\circ} \Omega \quad I_{L, cap} = I_{\phi, cap} = \frac{V_{\phi}}{\bar{Z}_{\phi, cap}} = \frac{277.13}{5}$$

$$I_{L, cap} = 55.42563 \text{ A}_{rms}$$

$$(2-29) \quad P_{cap} = \sqrt{3} V_{LL} I_{L, cap} \cos \theta = \underline{\underline{0}} \quad (\cos -90^{\circ} = 0)$$

$$(2-30) \quad Q_{cap} = \sqrt{3} V_{LL} I_{L, cap} \sin \theta = \sqrt{3} (480) 55.43 \sin -90^{\circ}$$

$$Q_{cap} = -46,080 \text{ VAR} = \underline{\underline{-46.08 \text{ KVAR}}}$$

$$(2-31) \quad \underline{\underline{S_{cap} = \sqrt{3} V_{LL} I_{L, cap} = 46,080 \text{ VA} = 46.08 \text{ KVA}}}$$

$$\bar{S}_{TOT,b} = (P_1 + P_2 + P_{\phi, cap}^{\circ}) + j(Q_1 + Q_2 + Q_{cap})$$

$$= 114,894.65 + j(69,653.1 - 46,080)$$

$$= 114,894.65 + j23,573.1 \text{ VA} = 117,287.986 \angle 11.59455^{\circ} \text{ VA}$$

$$\text{By (2-31), } I_{L,b} = \frac{117,287.986}{\sqrt{3} (480)} = \underline{\underline{141.08 \text{ A}_{rms}}}$$

c) Total current decreased by $\sim 20 \text{ A}_{rms}$ because the total reactive power was greatly reduced by the capacitor bank.