Power-Factor Correction – In Class Problem

THE LOADING OF A FACTORY ON A 1000V, 60HZ SYSTEM INCLUDES:

20kW HEATING ($F_p = 1$)
10kW INDUCTION MOTORS ($F_p = 0.7$ LAGGING)
5kW LIGHTING ($F_p = 0.85$ LAGGING)

(a) ESTABLISH THE POWER TRIANGLE FOR THE TOTAL LOADING ON THE SUPPLY

(b) FIND THE CAPACITOR REQUIRED TO CORRECT THE POWER FACTOR TO $F_p = 1$

(c) FIND $\vec{I}_s$ COMPENSATED & $\vec{I}_s$ UNCOMPENSATED (USE $\vec{S} = \vec{V}\vec{I}^*$)

Approach:

- (a) We know **S1** = 20kW + j0VAR, find **S2** and **S3** using the given Fp info and add to get **S**$_T$ and the power triangle
- (b) Use **S** = **V Is*** to find **Ic** and hence **Zc** and finally C
- (c) Use **S** = **V Is*** to find **Is** for each case

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(a) ESTABLISH THE POWER TRIANGLE FOR THE TOTAL LOADING ON THE SUPPLY

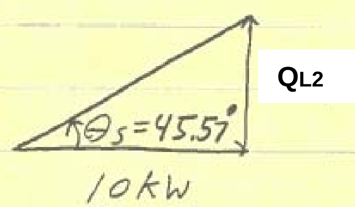
$\vec{S}_1 = 20kW + j0$
$\vec{S}_2 = 10kW + j\,\underline{Q_{L2}}$ — $F_p = 0.7$
$\vec{S}_3 = 5kW + j\,\underline{Q_{L3}}$ — $F_p = 0.85$

FILL IN THE BLANKS

LOAD 2

$\theta_S = \cos^{-1}(0.7)$

$= \underline{\underline{45.57^\circ}}$



$\tan(\theta_S) = \frac{OPP}{ADJ} = \frac{Q_{L2}}{10{,}000}$

$\therefore Q_{L2} = (10kW)(\tan(45.57^\circ))$

$\underline{Q_{L2} = 10.2kVAR}$

LOAD 3 $\theta_S = \cos^{-1}(0.85) = \underline{\underline{31.79^\circ}}$

$\therefore Q_{L3} = (5kW)(\tan(31.79^\circ))$

$\underline{Q_{L3} = 3.1kVAR}$

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10kW INDUCTION MOTORS ($F_p = 0.7$ LAGGING)
5kW LIGHTING ($F_p = 0.85$ LAGGING)

(a) ESTABLISH THE POWER TRIANGLE FOR THE TOTAL LOADING ON THE SUPPLY

$$\vec{S}_1 = 20\text{kW} + j0$$
$$\vec{S}_2 = 10\text{kW} + j\,\_\_\_ \quad - F_p = 0.7$$
$$\vec{S}_3 = 5\text{kW} + j\,\_\_\_ \quad - F_p = 0.85$$

FILL IN THE BLANKS

Becomes:

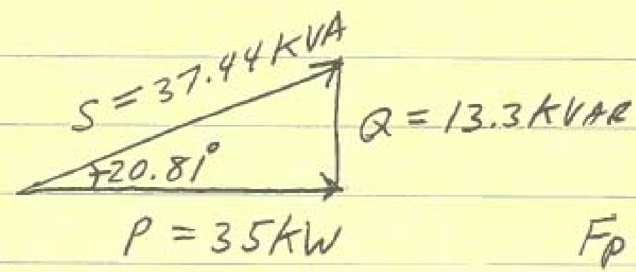
$$\vec{S}_1 = 20{,}000 + j0$$
$$\vec{S}_2 = 10{,}000 + j\,10{,}200$$
$$\vec{S}_3 = 5{,}000 + j\,3{,}100$$

$$\vec{S}_T = 35{,}000 + j\,13{,}300$$

35kW   13.3kVAR (L)

$$\vec{S}_T = 37.44\text{kVA} \angle 20.81^\circ$$

So the power triangle for the uncompensated system is:



$$F_p = \cos(\theta_s) = 0.93$$

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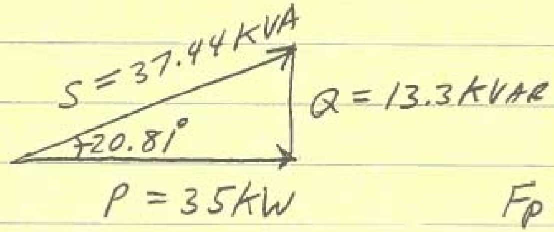
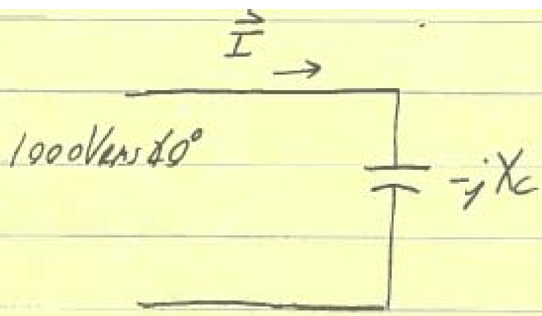


$F_p = \cos(\theta_s) = 0.93$

(b) FIND THE CAPACITOR REQUIRED TO CORRECT THE POWER FACTOR TO $F_p = 1$

We need a 13.3KVAR (C) load to correct for or compensate for the 13.3KVAR (L):



$\vec{I}^* = \dfrac{\vec{S}}{\vec{V}}$

$$\vec{I}^* = \frac{(0 - j13{,}300)\,VA}{1000V_{RMS}\angle 0^\circ} = 13.3A_{RMS}\angle -90^\circ$$

$$\therefore \vec{I} = 13.3A_{RMS}\angle 90^\circ$$

Using **I** and **V** to find **Zc**:

$$Z_C = \frac{\vec{V}}{\vec{I}} = \frac{1000V_{RMS}\angle 0^\circ}{13.3A_{RMS}\angle 90^\circ}$$

$$= -j75.19\,\Omega$$

Using **Zc** to find C:

$$X_C = 75.19\,\Omega = \frac{1}{2\pi f C}$$

$$= \frac{1}{2\pi(60Hz)(C)}$$

$$C = \frac{1}{2\pi(60HZ)(75.19\,\Omega)} = \boxed{35.28\,\mu F}$$

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(c) FIND $\vec{I}_S$ COMPENSATED & $\vec{I}_S$ UNCOMPENSATED
(USE $\vec{S} = \vec{V}\vec{I}^*$)

Uncompensated System (no C)

$$\vec{S}_T = 37.44\,kVA \angle 20.81^\circ$$

$$\therefore \vec{I}_S^* = \frac{37.44\,kVA \angle 20.81^\circ}{1000\,V_{RMS} \angle 0^\circ}$$

$$= 37.44\,A_{RMS} \angle 20.81^\circ$$

$$\boxed{\vec{I}_S = 37.44\,A_{RMS} \angle -20.81^\circ}$$

Compensated System (C = 35.28uF)

$$\vec{S}_T = (37.44\,kVA \angle 20.81^\circ) + (0 - j\,13.3 \times 10^3)$$

$$\therefore \vec{S}_T = 35\,kVA \angle 0^\circ$$

$$\vec{I}_S^* = \frac{35\,kVA \angle 0^\circ}{1000\,V_{RMS} \angle 0^\circ} = \underline{35\,A_{RMS} \angle 0^\circ}$$

Hence **Is** = 35ARMS < 0º

Note the reduction in supply current from 37.44ARMS to 35ARMS while the loads experienced no differences in voltage or current.