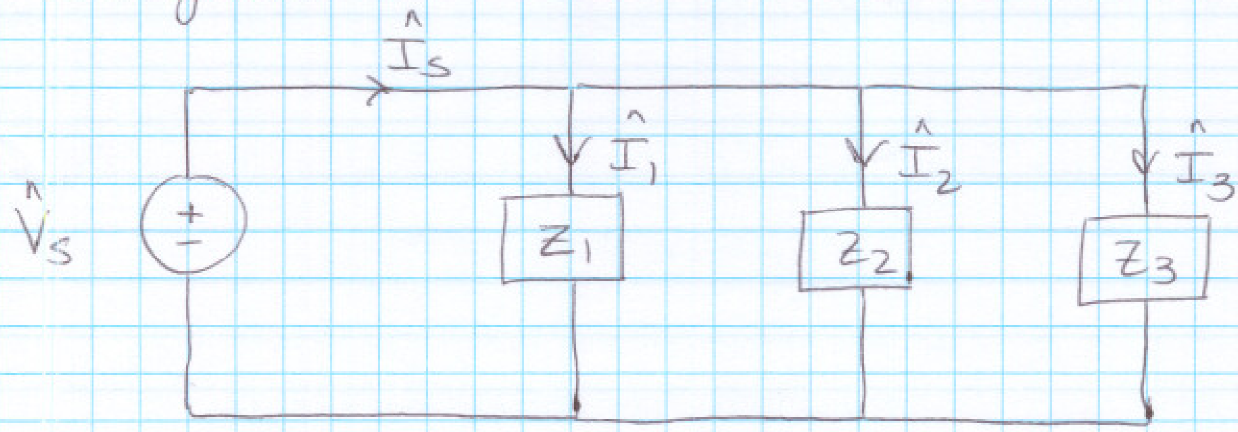
Example Power Factor Problem:

ckt diagram



assume 0° phase on $\hat{V}_s$ so $\hat{V}_s = 150\angle 0^\circ$ Vrms

a) & b) Impedances + Currents

Z_1: $P_1 = V_s I_1 PF_1$ $\qquad I_1 = \dfrac{25\times10^3}{(150)(.5)} = 333.33$ Arms

$\angle Z_1 = \cos^{-1}(0.5) = 60^\circ$

$|Z_1| = \dfrac{V_s}{I_1} = \dfrac{150}{333.33} = 0.45\,\Omega$

$\hat{Z}_1 = 0.45\angle 60^\circ\,\Omega \qquad \hat{I}_1 = 333.33\angle -60^\circ$ Arms

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Z_2: $\hat{S}_2 = P_2 + jQ_2 = 18 - j12$ kVA

$= 21.63\angle -33.69^\circ$ kVA

$\angle Z_2 = -33.69^\circ \qquad 21.63 = V_s \cdot I_2$

$|Z_2| = \dfrac{V_s}{I_2} = 1.04 \qquad I_2 = 144.20$ Arms

$Z_2 = 1.04\angle -33.69^\circ \qquad \hat{I}_2 = 144.20\angle +33.69^\circ$ Arms

Example Power Factor Problem

a&b) (cont)

Z_3 : $\angle Z_3 = \cos^{-1}(.75) = 41.41^\circ$

$|Z_3| = \frac{V_s}{I_3} = \frac{150}{60} = 2.5$

$\boxed{Z_3 = 2.5\angle 41.41^\circ\,\Omega \qquad \hat{I}_3 = 60\angle -41.41^\circ \text{ Arms}}$

c) option 1: $P_s = P_1 + P_2 + P_3$

$P_3 = V_s I_3 \cdot PF_3 = 6.75\,kW$

$\boxed{P_s = (25 + 18 + 6.75) = 49.75\,kW}$

~~or~~ option 2: $\hat{I}_s = \hat{I}_1 + \hat{I}_2 + \hat{I}_3$

$= 414.34\angle -36.83^\circ \text{ Arms}$

$\hat{S}_s = \hat{V}_s \cdot \hat{I}_s^* = (150\angle 0)(414.34\angle 36.83^\circ)$

$\hat{S}_s = 62.15\angle 36.83^\circ\,kVA$

$\boxed{P_s = Re[\hat{S}_s] = 49.75\,kW}$

or option 3: combined loads $= z_1 \| z_2 \| z_3$

$= 0.362\angle 36.83^\circ$

$PF_{1,2,3} = \cos(36.83) = 0.8 \text{ lag}$

$P_s = V_s I_s \cdot PF_{1,2,3} = (150)(414.34)(.8)$

$\boxed{P_s = 49.75\,kW}$

Example Power Factor Problem

d) $\hat{S}_1 = V_S I_1 \angle Z_1 = (150)(333.33)\angle 60^\circ = 50\angle 60^\circ$ kVA

or $\hat{S}_1 = \hat{V}_S \cdot \hat{I}_1^* = (150\angle 0)(333.33\angle 60^\circ) = 50\angle 60^\circ$ kVA

or $Q_1 = V_S I_1 \sin(60^\circ) = 43.30$ kVAR

$\hat{S}_1 = P_1 + jQ_1 = 25 + j43.30$ kVA $\Rightarrow 50\angle 60^\circ$ kVA

$\hat{S}_2 = P_2 + jQ_2 = 18 - j12$ kVA $\Rightarrow 21.63\angle -33.69$ kVA

or $\hat{S}_2 = \hat{V}_S \hat{I}_2^* = 21.63\angle -33.69^\circ$ kVA

or $\hat{S}_2 = V_S I_2 \angle Z_2 = 21.63\angle -33.69^\circ$ kVA

$\hat{S}_3 = V_S I_3 \angle Z_3 = (150)(60)\angle 41.41^\circ = 9\angle 41.41$ kVA

or $\hat{S}_3 = \hat{V}_S \cdot \hat{I}_3^* = 9\angle 41.41^\circ$ kVA

or $Q_3 = V_S I_3 \sin(\angle Z_3) = 5.95$ kVAR

$P_3 = V_S I_3 \cdot PF_3 = 6.75$ kW

$\hat{S}_3 = P_3 + jQ_3 = 9\angle 41.40^\circ$ kVA

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e) option 1 $\quad Z_1 \| Z_2 \| Z_3 = 0.362\angle 36.83^\circ$

$PF_{1,2,3} = \cos(36.83) = 0.8$ lagging

option 2 $\quad \hat{S}_S = \hat{V}_S \cdot \hat{I}_S^* = 62.15\angle 36.83$ kVA

angle of combined loads

$PF_{123} = \cos(36.83) = 0.8$ lagging

f) $|\hat{I}_S| = |\hat{I}_1 + \hat{I}_2 + \hat{I}_3| = |414.34\angle{-36.83}|$

$= 414.34$ Arms

note: $|\hat{I}_S| \neq |\hat{I}_1| + |\hat{I}_2| + |\hat{I}_3|$

g) The larger the power factor of the combined loads, the smaller the source current magnitude.

Note $P_S = V_S I_S \cdot PF_{CL}$, where $PF_{CL} = Z_1 || Z_2 || Z_3 || Z_C$

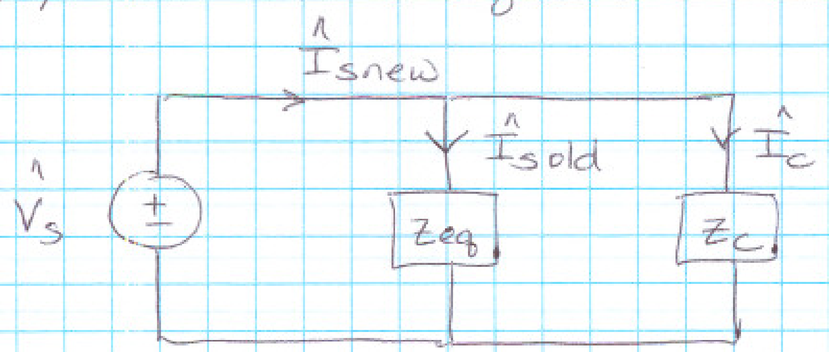
Corrective load

$$I_S = \frac{P_S}{V_S \cdot PF_{CL}}$$

when $PF_{CL} = 1$, I_S is mimimized.

$$I_S = \frac{49.75\,kW}{150} = 331.67 \text{ Arms}$$

h) new ckt diagram



$P_S = 49.75\,kW$

$\hat{I}_{sold} = 414.34\angle 36.83^\circ$ Arms

$PF_{CL} = 0.952$ lag

power factor of all 4 loads

$\angle Z_{CL} = \cos^{-1}(.952) = 17.82^\circ$

$$I_{snew} = \frac{P_S}{V_S \cdot PF_{CL}} = \frac{49.75 \times 10^3}{(150)(.952)} = 348.39 \text{ Arms}$$

$\hat{I}_{snew} = 348.39\angle{-17.82^\circ}$ Arms

h) cont

$$\hat{I}_{snew} = \hat{I}_{sold} + \hat{I}_C \quad \text{so} \quad \hat{I}_C = 141.76 \angle 90^\circ \text{ Arms}$$

$$Z_C = \frac{\hat{V}_S}{\hat{I}_C} = 1.06 \angle -90^\circ \,\Omega$$

$$\frac{1}{\omega C} = 1.06 \qquad \omega = 2\pi(60) \cong 377 \text{ rad/s}$$

$$C = 2.51 \text{ mF}$$

$$|\hat{I}_{snew}| = 348.39 \text{ Arms}$$