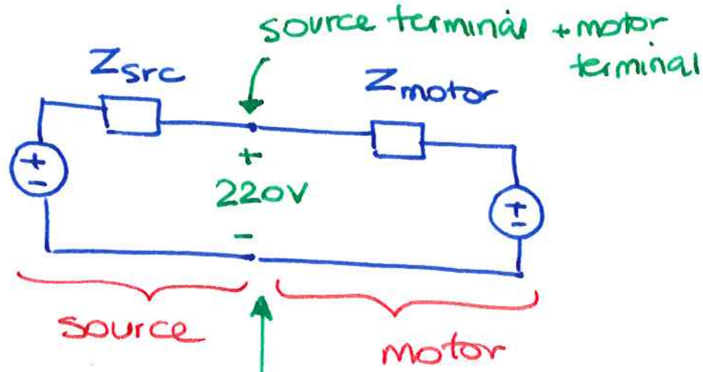
Tutorial 2

1) Let's draw the circuit:



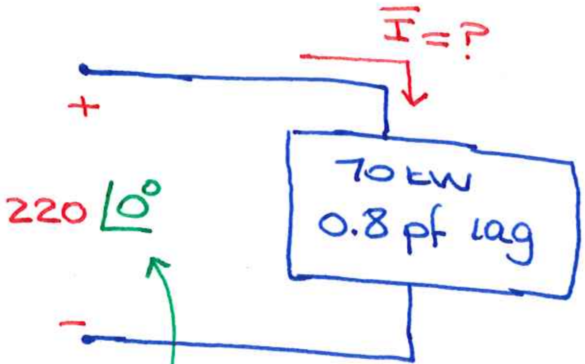
Unless otherwise stated, voltage of a generator (or motor) refers to the terminal voltages

. We can use the EMF behind an impedance model for motors & generators.

In this problem, we don't need to!

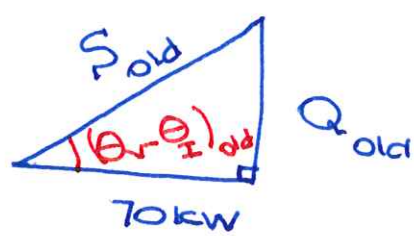
(We also don't know Z_{src}, Z_{motor} or internal EMF values).

. Let's redraw:



arbitrarily assigned

power triangle for existing configuration:



$(\theta_V - \theta_I) > 0$ for lagging PF

$$(\theta_V - \theta_I)_{old} = \cos^{-1}(0.8) = +36.87^\circ$$

$$Q_{old} = P_{old} \times \tan(\theta_V - \theta_I)_{old} = 52.5 \text{ kVAr}$$

$$S_{old} = \frac{P_{old}}{PF} = \frac{70 \text{ kW}}{0.8} = 87.5 \text{ kVA}$$

can calculate mag & phase of $\bar{I}$ separately:

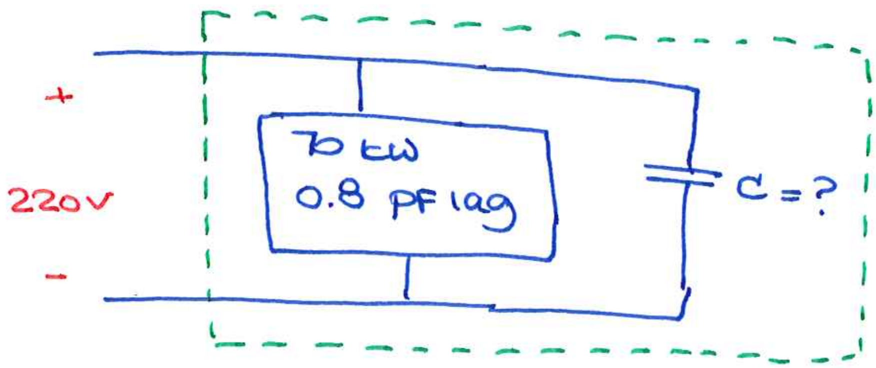
$$S = V \cdot I \qquad \therefore \quad I = \frac{S}{V} = \frac{87.5 \text{ kVA}}{220 \text{ V}} = 397.7 \text{ A}$$

$$\theta_V - \theta_I = 36.87^\circ \qquad \therefore \quad \theta_I = 0 - 36.87^\circ = -36.87^\circ$$

$$\bar{I} = 397.7 \angle -36.87^\circ \text{ A}$$

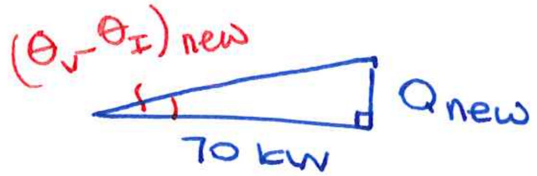
could have also used $\bar{S} = \bar{V}\bar{I}^*$ to find $\bar{I}$ in one shot

b.



PF = 0.95 lagging

After adding cap:



$$(\theta_V - \theta_I)_{new} = \cos^{-1}(0.95) = \pm 18.19^\circ$$

still lag

$$Q_{new} = \underbrace{P_{new}}_{\text{still 70 kW}} \times \tan(\theta_V - \theta_I)_{new} = 23 \text{ kVAr}$$

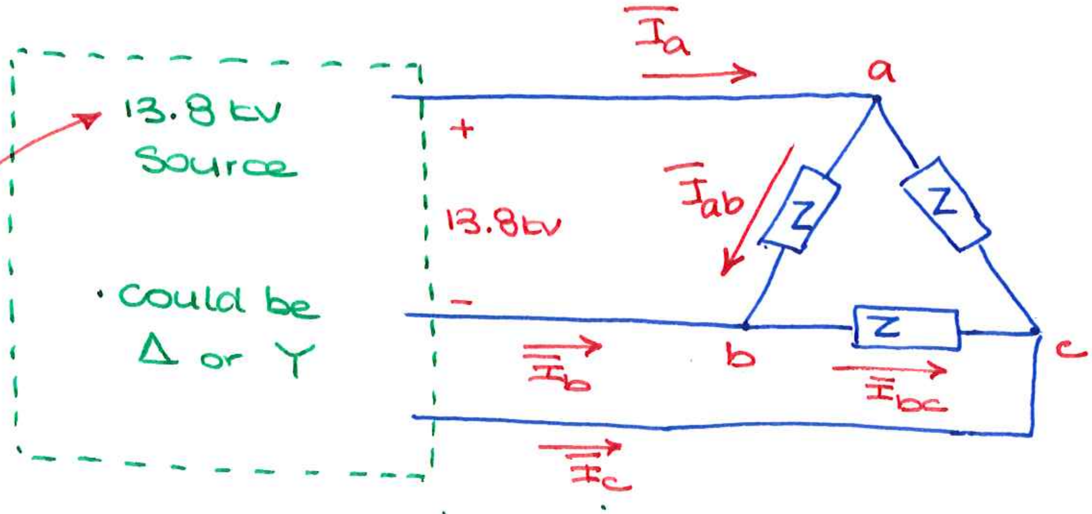
$$Q_{cap} = Q_{new} - Q_{old} = -29.5 \text{ kVAr}$$

using the same procedure as tutorial 1, we can find

$$C = 1.62 \times 10^3 \ \mu F$$

2)

line_to_line voltage at source terminals



arbitrarily assigned since phase angle information about voltages or currents is provided

$$\overline{V_{ab}} = 13.8\angle 0^\circ \text{ kV}$$

$$\overline{V_{bc}} = 13.8\angle -120^\circ \text{ kV}$$

$$\overline{V_{ca}} = 13.8\angle +120^\circ \text{ kV}$$

From Ohm's Law: $\overline{I_{ab}} = \dfrac{\overline{V_{ab}}}{Z_\Delta} = \dfrac{13.8\angle 0^\circ \text{ kV}}{100\angle 20^\circ\ \Omega} = 138\angle -20^\circ$ A

To calculate power:

option 1) $\overline{S_{3\phi}} = 3 \cdot \overline{S_{1\phi}} = 3 \cdot \underbrace{\overline{V_{ab}}}_{\overline{V_\phi}} \cdot \underbrace{\overline{I_{ab}}^*}_{\overline{I_\phi}^*}$

$$= 3\ (13.8\angle 0^\circ \text{ kV})(138\angle +20^\circ \text{ A})$$

$$= 5.7\angle 20^\circ \text{ MVA} = \underbrace{5.37}_{P_{3\phi}\ (\text{MW})} + j\ \underbrace{1.95}_{Q_{3\phi}\ (\text{MVAr})}$$

option 2) $S_{3\phi} = \sqrt{3}\ V_{ll} \cdot I_l = \sqrt{3} \cdot (13.8 \text{ kV}) \underbrace{(138 \times \sqrt{3})}_{I_l = \sqrt{3} \cdot I_\phi \text{ for } \Delta}$

$$= 5.7 \text{ MVA}$$

$$PF = \cos(\theta_{V_\phi} - \theta_{I_\phi}) = \cos(\theta_Z) = \cos(20^\circ) = 0.94$$

$$P_{3\phi} = S_{3\phi} \cdot PF = 5.37 \text{ MW}$$

$$Q_{3\phi} = \sqrt{S_{3\phi}^2 - P_{3\phi}^2} = 1.95 \text{ MVAr}$$

Aside : $\overline{I}_{bc} = 138 \angle -20^\circ - 120^\circ$ A $\overline{I}_{bc}$ lags $\overline{I}_{ab}$ by 120°

$\overline{I}_{ca} = 138 \angle -20^\circ + 120^\circ$ A

$\overline{I}_a = \sqrt{3} \times 138 \angle -20^\circ - 30^\circ = \sqrt{3} \times 138 \angle -50^\circ$ A

$\overline{I}_b = \sqrt{3} \times 138 \angle -50^\circ - 120^\circ$

$\overline{I}_c = \sqrt{3} \times 138 \angle -50^\circ + 120^\circ$