PRINCIPLES OF ENERGY CONVERSION FINAL EXAM

Dr. Salih FADIL **June 11,2010**

#1) A three phase load draws 200 kW active power at 3 kV_{LL} and 0.65 lagging power factor from a power system. A capacitor bank, which is connected as Δ, is connected across the load and supplies an amount of reactive power so that the new power factor becomes 1.0. Assume that the voltage across the load is kept constant at 3 kV_{LL}. Frequency of the applied voltage is 50 Hz.

a) How much reactive power does the capacitor bank supply? What is the capacitance value of the capacitors located at each side of the Δ bank?

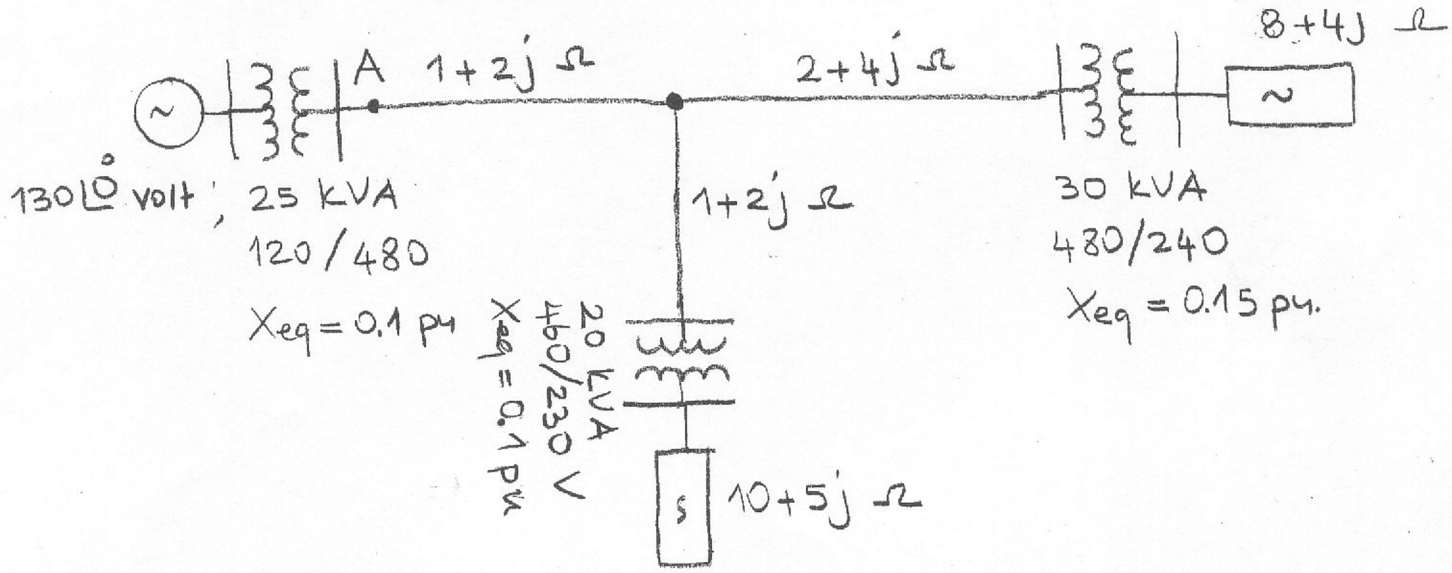
b) If the capacitors in the bank are connected as Y, what is the new power factor seen across the capacitor bank?

c) The load is fed through a three phase line whose series impedance is $4+j8\ \Omega$. Calculate the total active power loss on the line before and after the Δ connected capacitor bank connection.

#2) Consider the following single phase power system

a) Draw the <u>**actual**</u> equivalent circuit referred to line region.

b) Calculate the active and reactive power pumping to the system from point A shown in the figure.



#3) A parallel plate capacitor is connected to a source of voltage whose value is 100 sin(ωt) volts. If the average value of the electrostatic force of attraction between the plates, the plate area and the dielectric thickness values are 7×10^{-4} N, 100 cm^2 and 1 mm, respectively, calculate ε_r value of the dielectric.

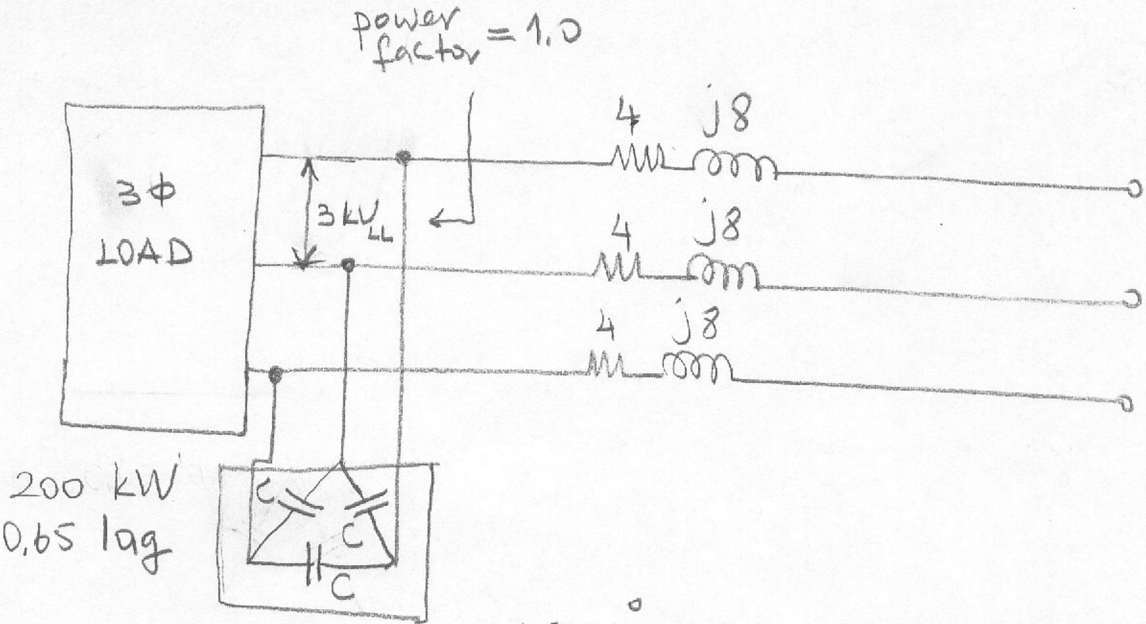
PRINCIPLES OF ENERGY CONVERSION FINAL EXAM

SOLUTION MANUAL

Dr. Salih FADIL June 11, 2010

#1)

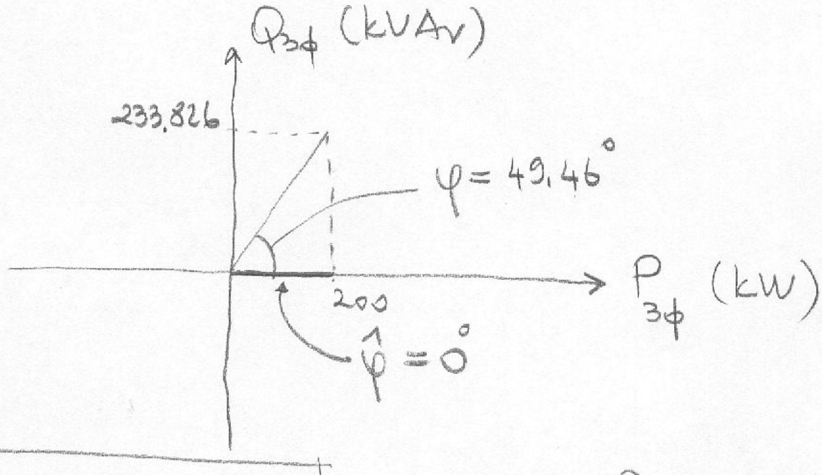
a)



$$P = 200 \text{ kW}$$

$$Q = P\tan\varphi = 200\tan\big(\underbrace{\cos^{-1}(0.65)}_{49.46^\circ}\big) = 233.826 \text{ kVAr}$$

Since the new power factor is 1.0



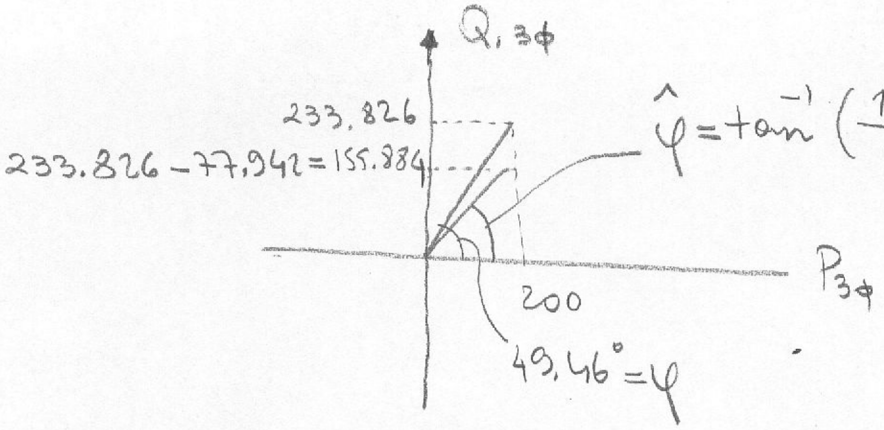
$$\boxed{Q_{c,3\phi} = 233.826 \text{ kVAr}} \quad , \quad Q_c = \omega C V^2$$

$$\hat{Q}_{c,3\phi} = 233.826\ 10^3 = 3\left(3\ 10^3\right)^2 100\pi\ C$$

$$C = \frac{233826}{3\times 9\times 10^6 \times 100\pi} = 27.566\ 10^{-6}\ F$$

$$= \boxed{27.566\ \mu F}$$

b) $Q^{Y}_{C,3\phi} = \frac{1}{3} Q^{\Delta}_{C,3\phi} = \frac{1}{3}\, 233.826 = 77.942$ kVAr.



$$\hat{\varphi} = \tan^{-1}\left(\frac{155.884}{200}\right) = 37.933$$

$$\boxed{\cos\hat{\varphi} = \cos(37.933) = 0.7887 \text{ lagging}}$$

c) Before Δ-connected capacitor bank connection

$$P_{3\phi} = \sqrt{3}\, V_{LL}\, I_L \cos\varphi \qquad I_L = \frac{200\; 10^3}{\sqrt{3}\; 3\; 10^3\; 0.65} = 59.215 \text{ A.}$$

$$\boxed{P_{loss,3\phi} = 3\,(59.215)^2 \cdot 4 = \underline{42.077 \text{ kW}}}$$

After Δ-connected capacitor bank connection

$$\hat{I}_L = \frac{200\; 10^3}{\sqrt{3}\; 3\; 10^3\; 1} = 38.49 \text{ A}$$

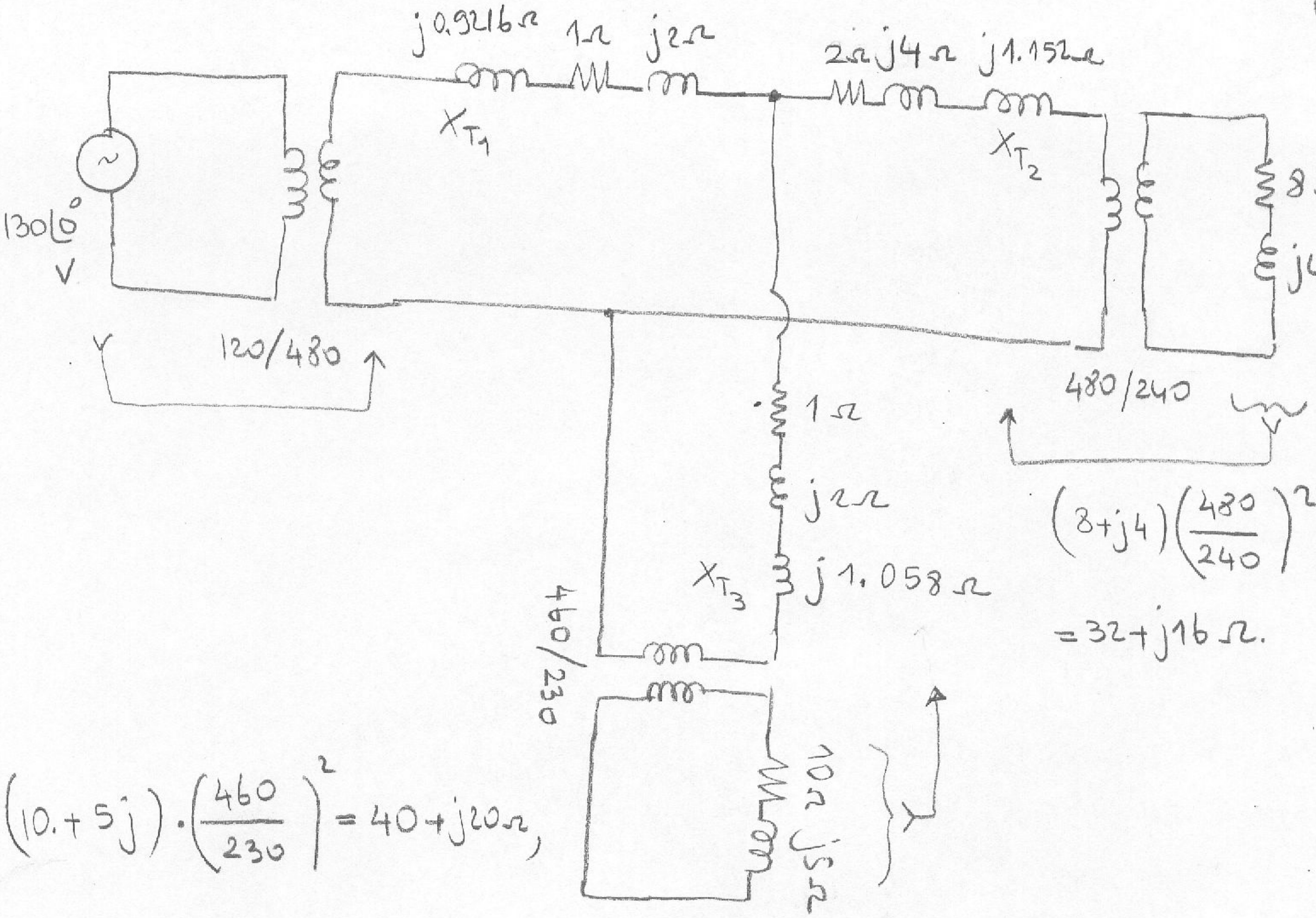
$$\boxed{\hat{P}_{loss,3\phi} = 3\,(38.49)^2\, 4 = \underline{17.777 \text{ kW}}}$$

#2)
a)

$$X_{T_1} = 0.1\,\frac{(480)^2}{25.\,10^3} = 0.9216\ \Omega \quad \text{on the line region. (on the left)}$$

$$X_{T_2} = 0.15\,\frac{(480)^2}{30\; 10^3} = 1.152\ \Omega \quad \text{" " " " (on the right)}$$

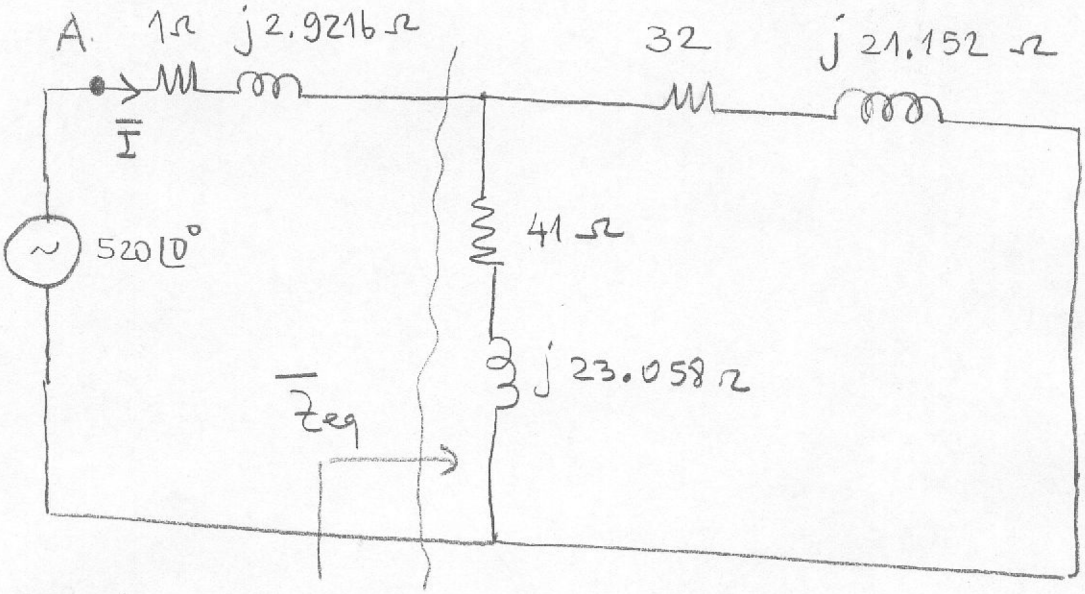
$$X_{T_3} = 0.1\,\frac{(460)^2}{20\; 10^3} = 1.058\ \Omega \quad \text{(at the bottom)}$$



$$(8+j4)\left(\frac{480}{240}\right)^2$$

$$=32+j16\ \Omega.$$

$$(10.+5j)\cdot\left(\frac{460}{230}\right)^2=40+j20\ \Omega,$$



b) ideal transformers are not shown in the figure!

$$\bar{Z}_{eq}=\underbrace{(32+j21.152)}_{38.359\angle 33.4^\circ}\parallel\underbrace{(41+j23.058)}_{47.04\angle 29.3^\circ}=\frac{1804.4\angle 62.7}{\underbrace{73+j44.21}_{85.34\angle 31.2}}$$

$$\bar{Z}_{eq}=21.1436\angle 31.5=18.027+j11.047\ \Omega$$

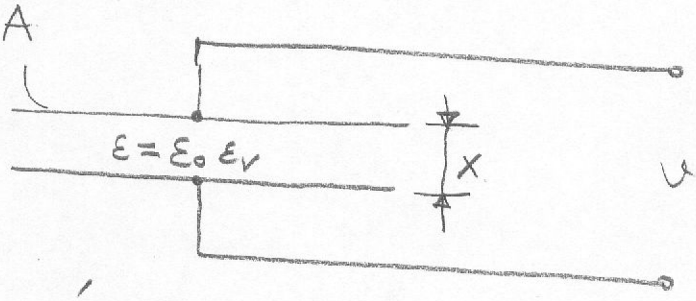
$$\bar{I} = \frac{520\angle 0^\circ}{\underbrace{19.027 + j\,13.9686}_{23.604\angle 36.28}} = 22.030\angle{-36.28^\circ}\ A.$$

$$\bar{S}_s = 520 \times 22.030\angle{+36.28} = 9234.76 + j\,6778.64\ VA$$

$$P_s = 9234.76\ W$$

$$Q_s = 6778.64\ VAr$$

#3)



$$v(t) = 100 \sin(\omega t)\ \text{volt}.$$

$$f_e = + \left.\frac{\partial W_s'}{\partial x}\right|_{v=\text{const.}} \qquad W_s' = \frac{1}{2} C v^2 = \frac{1}{2}\,\frac{\varepsilon A}{x}\left[100 \sin(\omega t)\right]^2$$

$$f_e(t) = -\frac{1}{2}\,\frac{\varepsilon A}{x^2}\,(100)^2\,\frac{1}{2}\left[1 - \cos(2\omega t)\right]$$ instantenous force..!

$$f_{e,avg} = -\frac{\varepsilon A\,(100)^2}{4x^2}$$

$$|f_{e,avg}| = 7\,10^{-4} = \varepsilon_r\,\frac{\varepsilon_0\,100\,\cancel{10^{-4}}\,\cancel{10^{4}}}{4\,(10^{-3})^2} = \varepsilon_r\,\frac{\frac{10^{-9}}{36\pi}\cdot 100}{4\,10^{-6}}$$

$$7\times 10^{-4} = \varepsilon_r\,\frac{\cancel{10^{-9}}^{\,10^{-3}}\,100}{36\pi\,4\,\cancel{10^{-6}}} = \frac{\varepsilon_r}{4\times 36\pi}\,10^{-1}$$

$$7\times 10^{-3} \times 4 \times 36\pi = \varepsilon_r$$

$$\boxed{\varepsilon_r = 3.1667}$$