Last Name: Solution

First Name: ____________________

SCHULICH
School of Engineering
UNIVERSITY OF CALGARY

ENEL 487 Midterm Examination

March 8, 2018

9:30 - 10:20 am

Instructor: Pouyan (Yani) Jazayeri

- Exam consists of 3 problems.
- Write answers in the space provided below each question.
- Show your work neatly in the work area. Otherwise, marks for partially correct answers cannot be given.
- Total marks for the exam is 30.
- Closed book exam. You may not refer to books or notes during the test.
- No wireless devices or earphones allowed during exam.
- Only scientific calculators without formulae storage and text display are allowed.

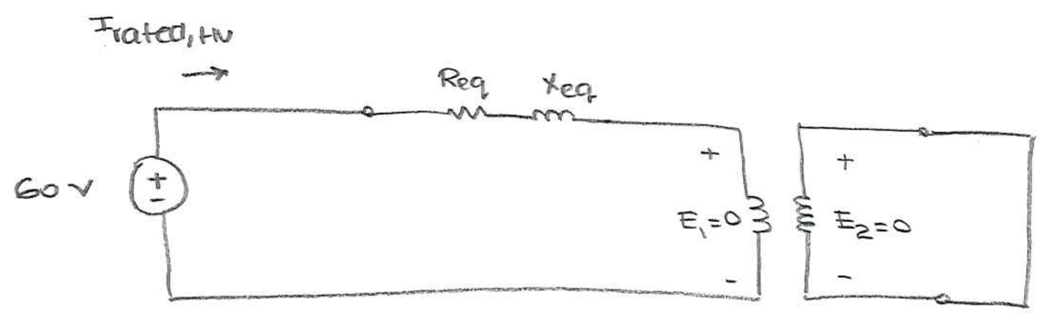
Problem 1:

A single phase, 96kVA, 2400/240 V distribution transformer is considered in this problem. We have been informed that the magnetization branch in this transformer is negligible.

a) What test (open circuit test or short circuit test) needs to be performed to calculate the transformer model parameters? Which parameters are calculated in this test? [1 mark]

Short circuit test to determine R_{eq}, X_{eq}

b) For the test in part a), the following measurements were made: applied voltage = 60V, real power consumed = 1.44 kW. Calculate the corresponding transformer model parameters. Draw the circuit for the test and label the elements and known voltages and currents on it. [5 marks]



$$I_{rated,HV} = \frac{S_{rated}}{V_{rated,HV}} = \frac{9600\ VA}{2400\ V} = 40\ A$$

$$R_{eq} = \frac{P_{SC}}{I_{rated,HV}^2} = \frac{1440\ W}{(40\ A)^2} = 0.9\ \Omega$$

$$|Z_{eq}| = \frac{V_{HV}}{I_{rated,HV}} = \frac{60\ V}{40\ A} = 1.5\ \Omega$$

$$X_{eq} = \sqrt{|Z_{eq}|^2 - R_{eq}^2} = 1.2\ \Omega$$

at unity pf

c) Calculate the efficiency of the transformer if it is delivering rated power and rated current is flowing in the HV side. [2 marks]

$$P_{out} = P_{rated} = 96 \text{ kW}$$

$$P_{in} = P_{out} + P_{loss} = P_{out} + \underbrace{I_{rated}^2 \cdot R_{eq}}_{P_{SC}} = 96 \text{ kW} + 1.44 \text{ kW}$$

$$= 97.44 \text{ kW}$$

$$\eta = \frac{P_{out}}{P_{in}} \times 100\% = 98.5\%$$

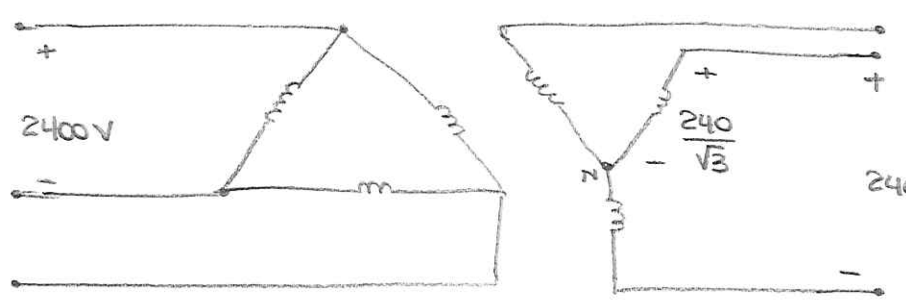
d) Suppose you are asked to build a three phase Δ-Y transformer with identical ratings (96kVA, 2400/240 V three phase transformer). You can also assume the transformer is ideal in this case. The HV side is Δ-connected and the LV side is Y-connected. If the rated voltage is applied to the HV side of the transformer,

The magnitude of the voltage across each HV winding is 2400 V [1 mark]

The magnitude of the voltage across each LV winding is $240/\sqrt{3}$ V [1 mark]

or 138.6

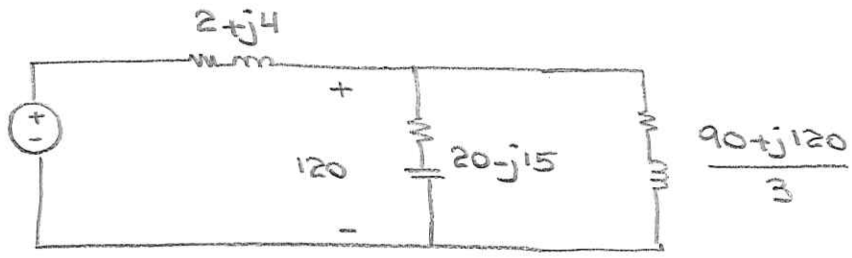
2400 V & 240V are now the line-to-line voltages on either side



Problem 2:

A three phase line, which has an impedance of (2+j4) Ω per phase, feeds two balanced three phase loads that are connected in parallel. One of the loads is Y-connected with an impedance of (20-j15) Ω per phase, and the other is Δ-connected with an impedance of (90+j120) Ω per phase. The line is energized from a 60 Hz, three phase, balanced voltage source. The line-to-neutral voltage at the load end of the line is 120 V (rms).

a) Draw the per-phase circuit for this system. In your diagram, label all known voltages [3 marks]

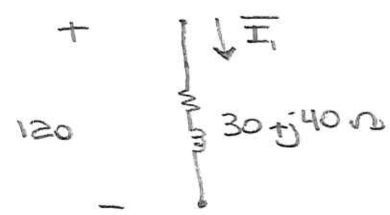


$\frac{90+j120}{3} = 30+j40\ \Omega$

b) Draw the power triangle for the Δ-connected load. Label all three sides of the triangle. Also, calculate the power factor for this load. [4 marks]

$I_1 = \frac{120}{30+j40} = 2.4\angle{-53.1^\circ}$ A

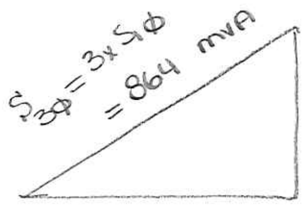
$= 1.44 - j1.92$ A



$\bar{S}_{1\phi} = \bar{V}\cdot\bar{I}_1^{\,*} = 120\,(2.4\angle{-53.1^\circ})^* =$

$= \underbrace{172.8}_{P_{1\phi}} + j\underbrace{230.4}_{Q_{1\phi}}$

$= \underbrace{288}_{S_{1\phi}}\angle{53.1^\circ}$



$Q_{3\phi} = 230.4 \times 3$

$= 691.2$ VAr

$P_{3\phi} = 172.8 \times 3$

$= 518.4$ W

$PF = \frac{P}{S} = 0.6$ lagging

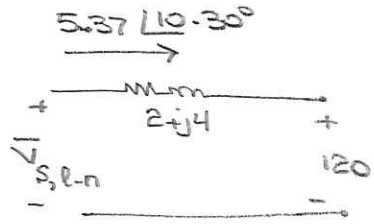
alternatives:

$\bar{S}_{1\phi} = \frac{V^2}{Z^*} = \frac{120^2}{(30+j40)^*} = 172.8 + j230.4$

OR

$\begin{cases} P_{1\phi} = I_1^2 \times 30 = 172.8 \text{ W} \\ Q_{1\phi} = I_1^2 \times 40 = 230.4 \text{ VAr} \end{cases}$

c) If the line current is 5.37∠10.30° A, what is the line-to-line voltage of the source? [2 marks]



$$\bar{V}_{S,l\text{-}n} = 120 + (5.37\angle 10.30^\circ)\times(2+j4)$$

$$= 126.7 + j\,23.05$$

$$= 128.8\angle 10.31^\circ \quad \checkmark$$

$$\bar{V}_{S,l\text{-}l} = \bar{V}_{S,l\text{-}n} \times \sqrt{3}\angle 30^\circ = 223.1\angle 40.31^\circ \quad \checkmark$$

d) In a few words, provide a practical suggestion for minimizing line losses. Explain why your suggestion would minimize line losses. You are not required to perform any calculations [1 mark]

The combined load appears capacitive

why? $Z_{eq} = \dfrac{(20-j15)(30+j40)}{(20-j15)+(30+j40)} = 22-j4$

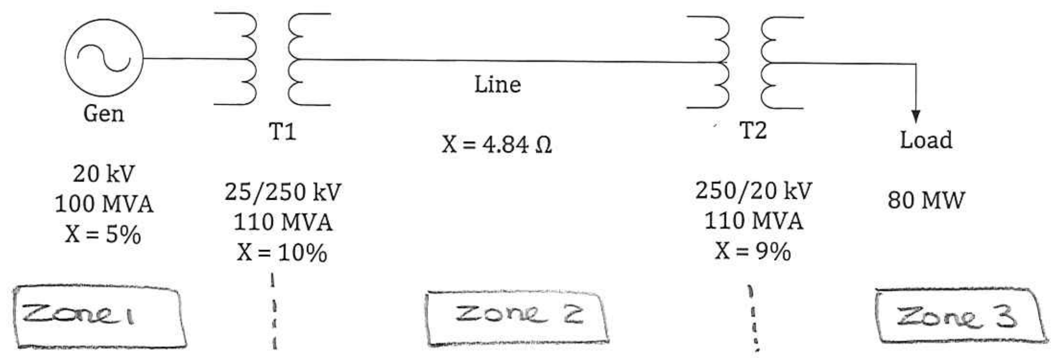
or $Q_{load\,1} = 230.4$ VAr & $Q_{load\,2} = -345.6$ VAr

$\therefore Q_{load,total} < 0$

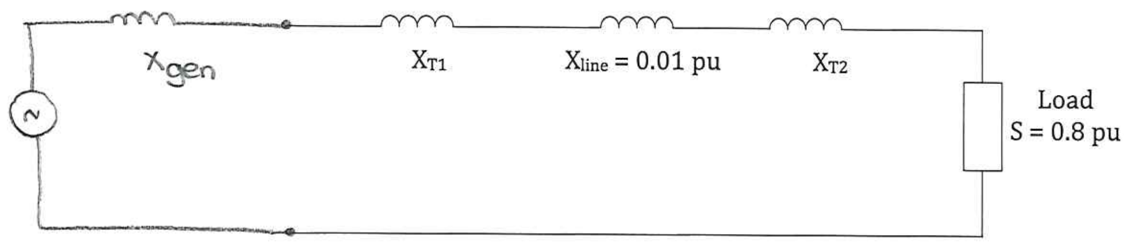
therefore, adding a power factor correction inductor on the load side will "absorb" the extra reactive power "supplied" by the load thereby reducing the reactive power coming from the source. This will reduce the line current & therefore reduce line losses.

Problem 3:

The following is a single line diagram of a three phase system:



Your fictitious classmate, Wil Lehman, started working on the per unit circuit (impedance diagram) for this system and has asked you to finish it. His per unit circuit (impedance diagram) is shown below:



a) Complete the per unit circuit shown above. You are not required to calculate the unknown impedance values yet. [2 marks]

b) Wil forgot to tell you the V_{base} and S_{base} values he used in creating the per unit circuit. Based on the information available on his circuit, what should the value of X_{T1} be? What S_{base} did Wil use? What is V_{base} in the line zone? [4 marks]

$$S_{base} = \frac{S_{load,\,actual}}{S_{load,\,pu}} = \frac{80 \text{ MVA}}{0.8 \text{ pu}} = 100 \text{ MVA}$$

$$Z_{base_2} = \frac{X_{line,\,actual}}{X_{line,\,pu}} = \frac{4.84\ \Omega}{0.01 \text{ pu}} = 484\ \Omega$$

$$Z_{base2} = \frac{(V_{base2})^2}{S_{base}} \quad \therefore \quad V_{base_2} = \sqrt{Z_{base2} \cdot S_{base}} = 220 \text{ kV}$$

$$X_{T_1} = X_{T_1,old} \times \frac{(250 \text{ kV})^2}{(V_{base_2})^2} \times \frac{S_{base}}{110 \text{ MVA}}$$

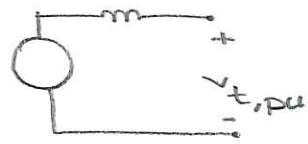
$$= 0.1 \times \left(\frac{250}{220}\right)^2 \times \frac{100}{110} = 0.117 \text{ pu}$$

alternatively, $X_{T_1} = X_{T_1,old} \times \dfrac{Z_{base,old}}{Z_{base,2}} = 0.1 \times \dfrac{\frac{(250 \text{ kV})^2}{110 \text{ MVA}}}{484\ \Omega} = 0.117$

c) If the generator is operating at rated voltage, what is the per unit voltage at the generator terminals? [2 marks]

gen terminal voltage = 20 kV (line-to-line)

$$V_{t,pu} = \frac{\text{gen terminal voltage}}{V_{base_1}}$$



$$= \frac{20\ kV}{V_{base_2} \times \frac{25}{250}} = \frac{20\ kV}{22\ kV}$$

$$= 0.91\ pu$$

d) If the current through T1 is calculated to be 1 pu, what is the load current in pu and Amps? For this part, you can assume that V_{base} in the load zone is 17.6 kV. [2 marks]

Everything is in series! $\therefore I_{load,pu} = I_{T1,pu} = 1$ pu

$$I_{load} = I_{load,pu} \times I_{base_3} = 1 \times \frac{S_{base}}{\sqrt{3}\, V_{base_3}}$$

$$= 1 \times \frac{100\ MVA}{\sqrt{3} \times 17.6\ kV}$$

$$= 3280.4\ A$$

Name:____

Question	1	2	3	Total
Mark	/10	/10	/10	/30