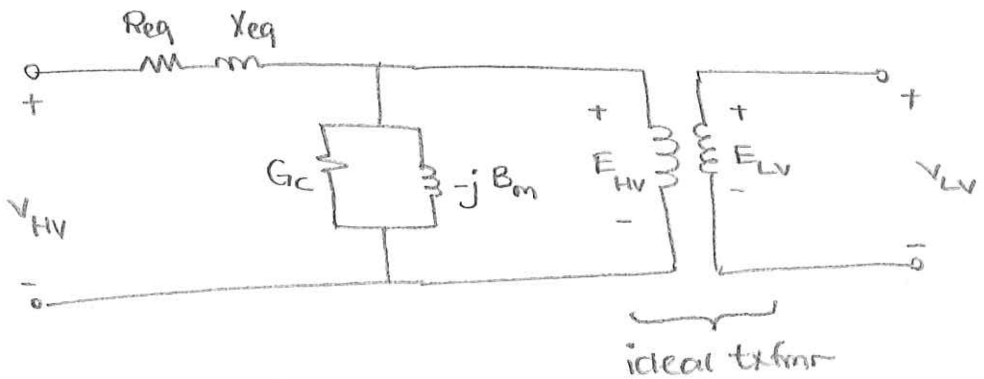
ENEL 487 | Winter 2020 | Quiz 2

Name: SOLUTION ID:

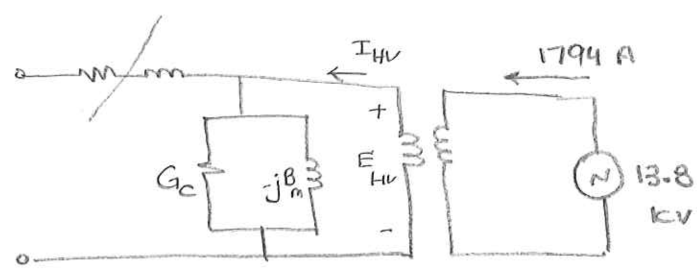
1a) Draw the equivalent circuit for a non-ideal transformer with all the impedances referred to the high voltage side. Your circuit should contain R_{eq}, X_{eq}, B_m, G_c, and an ideal transformer. Also, label the terminal voltages V_{HV} and V_{LV}, and winding voltages E_{HV} and E_{LV}. [3 marks]



1b) For a 200 MVA, 138 kV/13.8 kV single phase transformer, an open circuit test is performed to calculate the B_m and G_c, parameters in the model from part a). With the high voltage side open, the following measurements were taken on the low voltage side:
Voltage = 13.8 kV, current = 1794. A, power = 952.2 kW.
What are the B_m and G_c parameters for this transformer in Siemens? [3 marks]

$$E_{HV} = 13.8\text{ kV} \times \frac{138}{13.8} = 138\text{ kV}$$

$$I_{HV} = 1794 \times \frac{13.8}{138} = 179.4\text{ A}$$



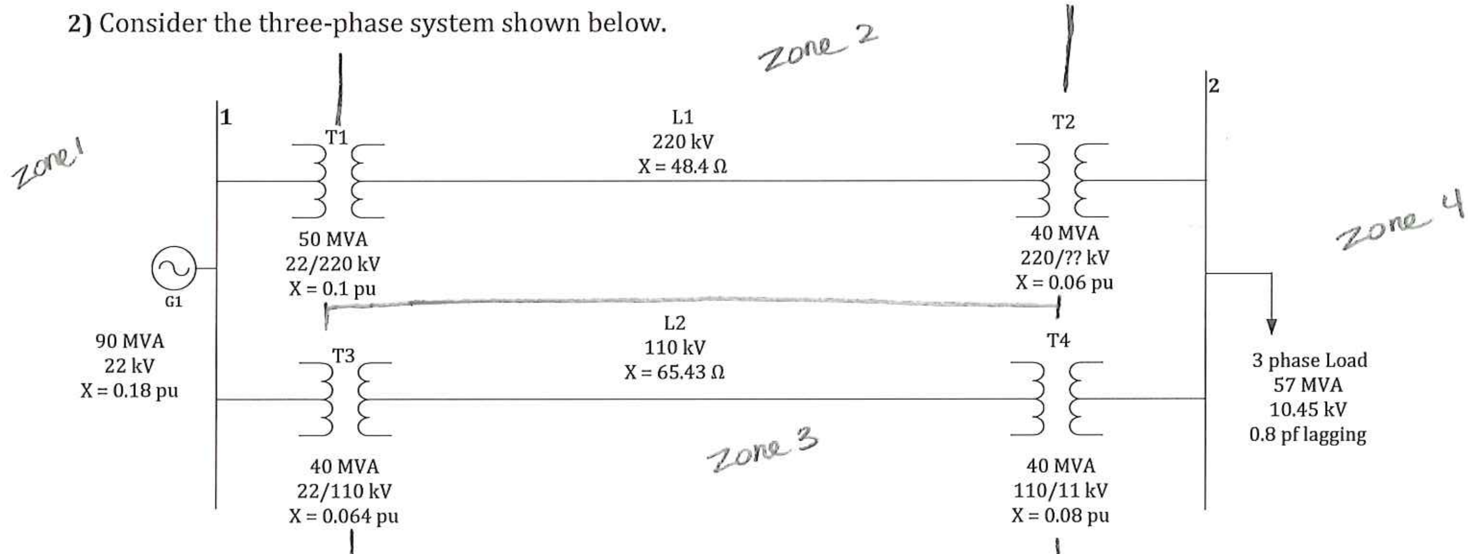
$$P_{oc} = E_{HV}^2 \cdot G_c$$

$$\therefore \quad G_c = \frac{P_{oc}}{E_{HV}^2} = \frac{952.2\text{ kW}}{(138\text{ kV})^2} = 5 \times 10^{-5}\text{ S}$$

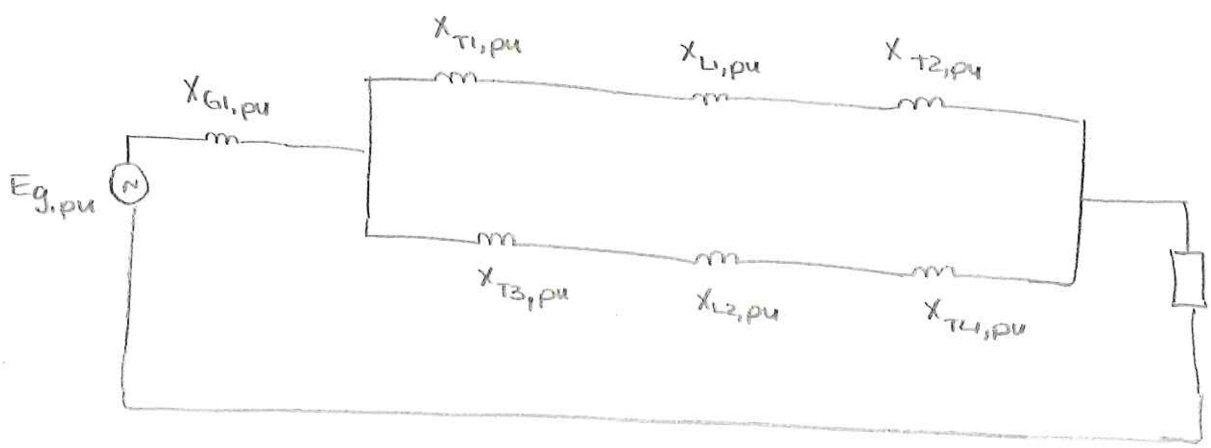
$$Y_{eq} = \frac{I_{HV}}{E_{HV}} = \frac{179.4\text{ A}}{138\text{ kV}} = 13 \times 10^{-4}\text{ S}$$

$$B_m = \sqrt{Y_{eq}^2 - G_c^2} \simeq 13 \times 10^{-4}\text{ S}$$

2) Consider the three-phase system shown below.



a) Draw the per unit impedance diagram for this system. Label (but do not calculate) all impedances on the diagram. For example, the per unit impedance of T1 should be labelled as $X_{T1,pu}$ on the diagram. [3 marks]



b) What should the voltage rating of T2 be? [2 marks]

To get the same V_{base} for load zone (zone 4 in diagram above), whether we calculate it from L1 side or L2 side, T2 should be $\boxed{220 / 11 \text{ kV}}$

e.g. Let's say $V_{base_1} = 22$ kV $\rightarrow$ $V_{base_2} = 22 \times \frac{220}{22} = 220$ kV

$V_{base_3} = 22 \times \frac{110}{11} = 110$ kV

$V_{base_4} = V_{base_3} \times \frac{11}{110} = 11$ kV , $V_{base_4} = V_{base_2} \times \frac{??}{220} = 11$ kV $\therefore ?? = 11$ kV

c) If a power base of 100 MVA and voltage base of 10kV on the load side is chosen, what is the per unit impedance of T4? [2 marks]

$$S_{base} = 100 \text{ MVA}$$

$$V_{base_4} = 10 \text{ kV}$$

$$X_{T4,pu,new} = 0.08 \times \frac{100 \text{ MVA}}{40 \text{ MVA}} \times \left(\frac{11 \text{ kV}}{10 \text{ kV}}\right)^2$$

$$= 0.242 \text{ pu}$$

d) If the generator is operating at rated power and a line-to-line terminal voltage of 20 kV, calculate the <u>magnitude</u> of the line current entering bus 1 from the generator side. [2 marks]

in Amps

Let's use Gen <u>rated</u> values as <u>base</u> values :

$$S_{gen,pu} = 1 \text{ pu}$$

$$V_{gen,pu} = \frac{20 \text{ kV}}{22 \text{ kV}} = 0.91 \text{ pu}$$

$$|I_{gen,pu}| = \frac{S_{gen,pu}}{V_{gen,pu}} = \frac{1}{0.91} = 1.1 \text{ pu}$$

$$|I_{gen}| = 1.1 \text{ pu} \times I_{rated} = 1.1 \times \frac{90 \text{ MVA}}{\sqrt{3} \times 22 \text{ kV}} = 2598 \text{ A}$$

. If using base values from part c) :

$$V_{base_1} = 20 \text{ kV} \quad , \quad S_{base} = 100 \text{ MVA}$$

$$S_{gen,pu} = \frac{90 \text{ MVA}}{100 \text{ MVA}} = 0.9 \text{ pu}$$

$$V_{gen,pu} = \frac{20 \text{ kV}}{V_{base_1}} = 1 \text{ pu}$$

$$|I_{gen,pu}| = \frac{S_{gen,pu}}{V_{gen,pu}} = 0.9 \text{ pu}$$

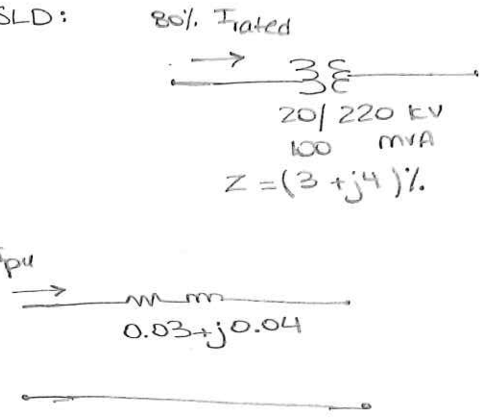
$$|I_{gen}| = 0.9 \text{ pu} \times I_{base_1} = 0.9 \times \frac{100 \text{ MVA}}{\sqrt{3} \times 20 \text{ kV}} = 2598 \text{ A}$$

For Q2d, you could also simply re-arrange S3Ø=√3.Vll.Il to solve for I!

in %

3) Consider a three phase, 100 MVA, 20kV/200 kV transformer with a per unit impedance of 3+j4. You can ignore the excitation branch. If the transformer is drawing 80% of its rated current, calculate the total power losses in the transformer in p.u. and in Watts. [4 marks]

SLD:



using rated values as base values :

$$I_{pu} = \frac{I_{actual}}{I_{base}} = \frac{0.8 \times I_{rated}}{I_{rated}}$$

$$= 0.8 \text{ pu}$$

$$P_{pu} = I_{pu}^2 \times R_{pu} = 0.8^2 \times 0.03 = 0.0192 \text{pu}$$

$$P_{actual} = P_{pu} \times S_{base} = 0.0192 \times 100 \text{ MW} = 1.92 \text{ MW}$$