ECE 320 & ECE 329

ENERGY SYSTEMS I

BACKGROUND STUDY IN ENERGY SYSTEMS

SESSION no. 12

ECE 320 / ECE 329 NAME ______________________

Quiz 3 8 February 2012

Transformers

1. (5 points) A small power system is configured as shown in Figure 1. The line reactance is j0.35 Ohms. Both ideal transformers have a 5:1 turns ratio. For an output of 1.0MVA, 480V AC rms, 0.94 power factor at full load, find the voltage regulation.

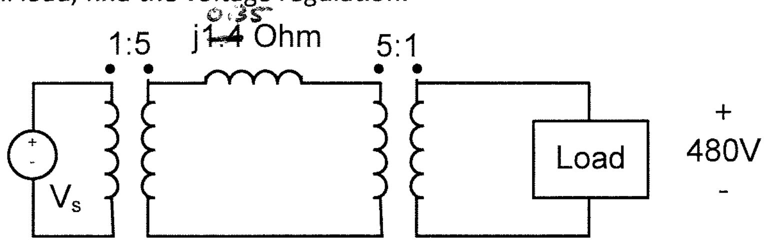

Figure 1. Small Electric Power System.

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ECE 320 / ECE 329
Quiz 3
Transformers

NAME ______________________________

8 February 2012

2. (5 points) A 50kVA, 4160V:480V transformer has the following parameters for its Steinmetz equivalent circuit:

R_{eq} = 13.8 Ohms	Series winding resistance referred to the high voltage side
X_{eq} = 41.5 Ohms	Series leakage reactance referred to the high voltage side
X_M = 92 Ohms	Magnetizing reactance referred to the low voltage side
R_C = 460 Ohms	Core loss resistance referred to the low voltage side

a. (1 points) Draw an appropriate equivalent circuit for this transformer. Label each circuit element.

b. (4 points) When a short circuit test is conducted according to the method prescribed in the textbook, what would you expect the voltage measurement to be?

ECE 320 / ECE 329 NAME ____________________

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Transformers

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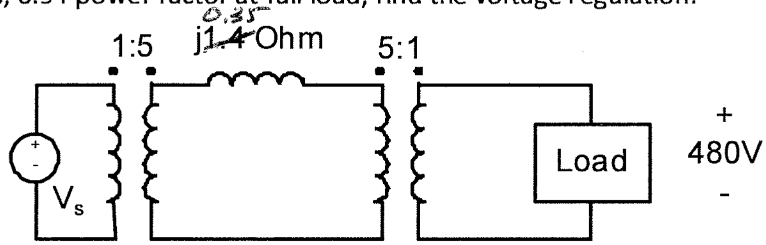

Figure 1. Small Electric Power System.

$MVA := 10^6 \cdot V \cdot A \quad j := \sqrt{-1}$

$V_L := 480 \cdot V \qquad pf_L := 0.94 \qquad S_L := 1.0 \cdot MVA \qquad N_t := 5 \qquad Z_{line} := 0.35 \cdot \Omega$

Find the current.

$\theta_L := \mathrm{acos}(pf_L) = 19.948\,deg \qquad I_L := \overline{\left(\frac{S_L \cdot e^{j \cdot \theta_L}}{V_L}\right)} = (1.958 \times 10^3 - 710.78i)\,A$

Reflect the line impedance and the source impedance to the load side. This divides the line impedance by the square of the turns ratio, but the offsetting transformers have no net effect on the reflected source voltage.

$$Z'_{line} := \frac{Z_{line}}{N_t^{\,2}} = 0.014\,\Omega$$

Calculate the source voltage.

$V_s := V_L + I_L \cdot j \cdot Z'_{line} = (489.951 + 27.417i)\,V \qquad |V_s| = 490.717\,V$

Find the voltage regulation. The no load voltage is equal to the source voltage.

$$V_{reg} := \frac{|V_s| - |V_L|}{|V_L|} = 2.233\,\%$$

2. (5 points) A 50kVA, 4160V:480V transformer has the following parameters for its Steinmetz equivalent circuit:

R_{eq} = 13.8 Ohms	Series winding resistance referred to the high voltage side
X_{eq} = 41.5 Ohms	Series leakage reactance referred to the high voltage side
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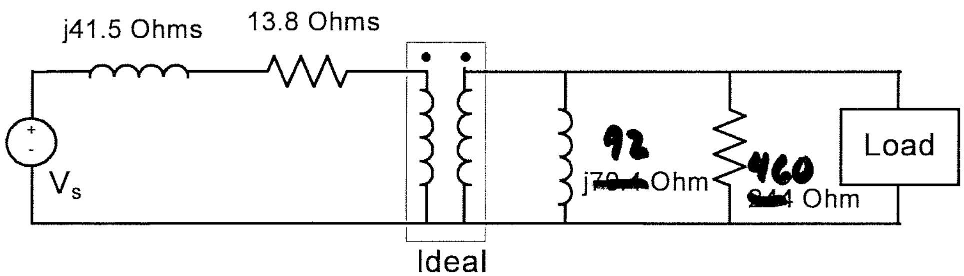
a. (1 point) Draw an appropriate equivalent circuit for this transformer. Label each circuit element.



Showing the source and load are optional in answering this problem.

b. (4 points) When a short circuit test is conducted according to the method prescribed in the textbook, what would you expect the voltage measurement to be?

$R_{eq} := 13.8\cdot\Omega \quad X_{eq} := 41.5\cdot\Omega \qquad X_M := 92\cdot\Omega \qquad R_C := 460\cdot\Omega$

The short circuit input current should be the rated current, found by dividing the apparent power by the terminal voltage on the High Voltage side.

$$I_{SC} := \frac{50\cdot kV\cdot A}{4160\cdot V} = 12.019\,A$$

The voltage is found from a loop equation. The transformer is short circuited. The measurement will be the magnitude of this voltage.

$$V_{SC} := I_{SC}\cdot\left(R_{eq} + j\cdot X_{eq}\right) = (165.865 + 498.798i)\,V$$

$$\left|V_{SC}\right| = 525.653\,V$$

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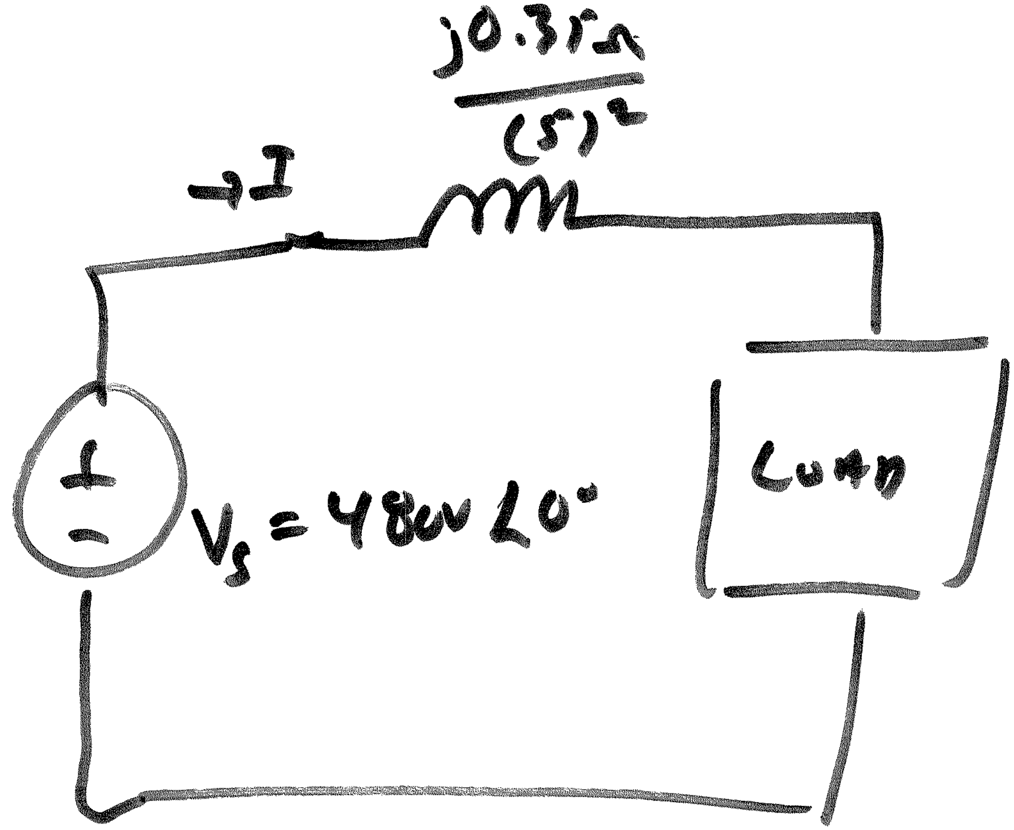


ECE 320 / ECE 329 Recitation Monday 13 February 2012
Homework 4
Per Unit Normalization

Do the following problems from the textbook:

1. 2.1 b on page 144

2. 2.1 c on page 144. Work the problem in per unit. Leave the answer in per unit.

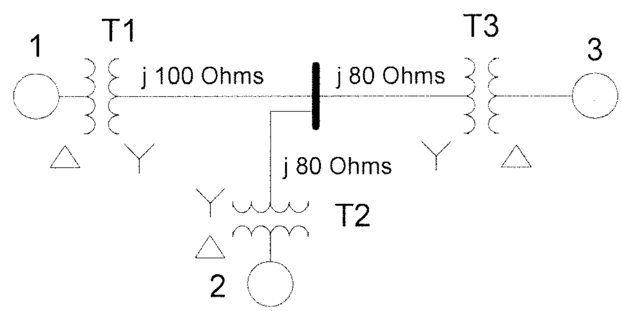
3. 2.24 a and 2.24 b on page 150. Set up the problem in per unit. Work the problem in per unit.

4. 2.14 on page 148. Work the problem in per unit this time, both without the effect of the transformers in the circuit (circuit (a)) and then with the effect of the transformers (circuit (b)).

5. A one-line diagram of an unloaded power system is shown below. Reactances of the two sections of transmission line are shown on the diagram. The generators and transformers are specified as follows:

Generator 1	20 MVA	6.9kV	X=0.15 per unit
Generator 2	10 MVA	6.9kV	X=0.15 per unit
Generator 3	30 MVA	13.8kV	X=0.15 per unit
Transformer 1	25 MVA	6.9kV : 115kV	X=10%
Transformer 2	12 MVA	6.9kV : 115kV	X=10%
Transformer 3	3 single phase transformers, each 10 MVA, 6.9 : 69kV, X=10%		

Draw a circuit diagram for one phase of this system with all reactances marked in per unit. Choose a base of 30 MVA and 6.9kV at generator 1.



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Energy Systems I

Lesson 12

Per Unit

Per unit: a mathematical system simplification or transformation of power circuits with all pertinent values being expressed in terms of a decimal fraction of conveniently chosen quantities.

Why?

*To make errors or unusual situations easier to identify because numbers appear in a narrow or predictable range

*To eliminate transformers from the circuit calculations

To set up the circuitry for per unit analysis

To perform per unit circuit analysis

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