University of Utah
Electrical & Computer Engineering Department
ECE 3600 Lab 3

Model of a Power Transformer

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A. Stolp, 10/21/08, rev,

Objectives

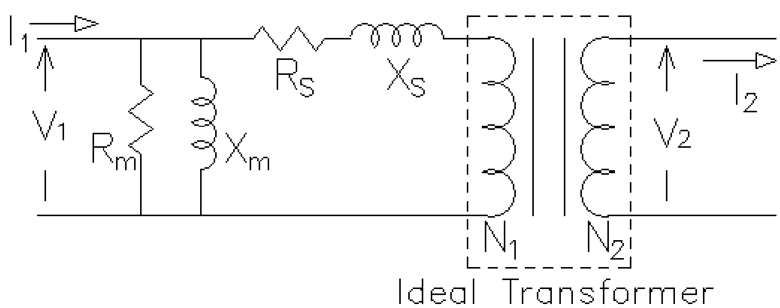
1. From measurements and calculations, derive a model for a power transformer.
2. Measure the power efficiency of the transformer and compare the measurements to calculations made from the model.
3. Measure the voltage regulation of the transformer and compare the measurements to calculations made from the model.

Equipment and materials to be checked out from stockroom:

- Power wire kit
- Wattmeter panel
- Two multimeters
- Power strip
- "Suicide" cord
- 3-prong to 2-prong adapter
- Vari-AC (Auto-transformer)
- MTC (Mountain Transformer Company) Transformer

Experiment background

Refer to section 6-2-3 (p.6-5) in your text. Let's simplify the model shown in Fig. 6-5 a bit. First, move R_1 and jX_{11} to the right of R_{he} and jX_m. This is reasonable because R_1 and jX_{11} are much smaller than R_{he} and jX_m and have virtually no effect unless there is an I_2. Next, move jX_{12} and R_2 from the right to the left side of ideal transformer as $jX_{12}(N_1/N_2)^2$ and $R_2(N_1/N_2)^2$ and add the results to R_1 and jX_{11}. Now the model looks like:



X_m represents the inductance of the primary and is called the "magnetizing reactance". R_m accounts for the no-load core power losses. These are due to the hysteresis in the B-H curve and to eddy-currents in the core. The series impedances, R_S and X_S account for winding resistance and leakage reactance. Both of these effects depend on the load current, I_2.

In this lab you will perform two tests on the same transformer that you used in the last lab. You'll find R_m and X_m with an open-circuit (O.C.) test and you'll find R_S and X_S with a short-circuit (S.C.) test. The secondary will shorted but not with full voltage on the primary.

Experiment Setup (check for hot & Neutral, just like last lab)

Switch off the power strip and plug it in. Switch off the vari-AC, turn it to 0V and plug it into the power strip. Make sure the suicide cord's leads are free and clear and plug it into the vari-AC using the adapter. Hook one lead of an AC voltmeter to a ground. There is a ground terminal on the bench power supply or use one of the oscilloscope grounds.) Switch on the power strip and check that both the suicide cord's leads are at near-ground potential. Switch on the vari-AC and check again. If you measure AC line voltage on either lead in either case something is wired incorrectly and is dangerous-- inform your TA. If there are no problems, turn up the vari-AC to about 30 V and see which lead is hot. If it's not the red lead, turn the plug over in the vari-AC. This will be your AC source for the rest of this lab. Turn the vari-AC back down to 0 V and switch it off. Always turn down the voltage before switching it off or on to avoid current surges in the transformer windings. Include some description in your lab notebook or refer back to last weeks lab.

Experiment description

All work described below should be performed on an MTC transformer (rated 115/115 volts, .25 kVA, 60 Hz). The primary side of the transformer is labeled "P" and the secondary is labeled "S". You will use the "C" (common) and the "N" (normal voltage, as opposed to "H" high and "-" low) terminals on both sides. Make sure that all other leads are free and clear.

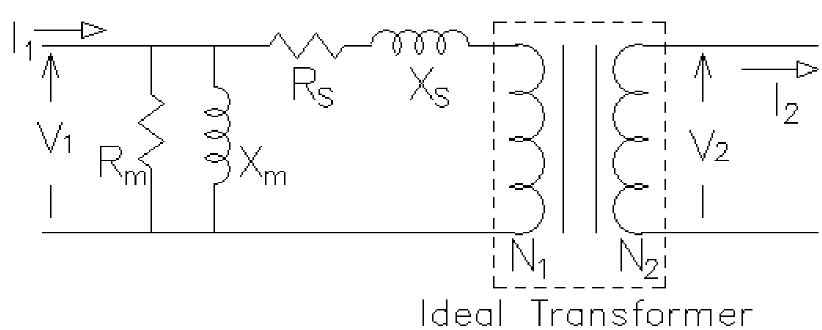
Open-Circuit Test

Leave the secondary unconnected to anything (open-circuit). Repeat what you did in the last lab to find the model of the inductor except now express the L as X_m and R as R_m . Leave the wattmeter, ammeter and voltmeter connected as is for the next test, but turn the Vari-AC down to zero.

Short-Circuit Test

Determine the rated primary current from the transformer data given above. Make sure that your ammeter can handle that current. If it can't, use another ammeter (or the 10 A connection). With the Vari-AC turned down to zero, short the secondary winding. **Slowly** and **carefully** turn up the Vari-AC until the rated current flows in the primary. Take measurements of P, V, and I. If you ignore the effects of X_m and R_m at this low voltage (very reasonable to do) then the transformer is just X_S in series with R_S. Find X_S in series with R_S from your measurements.

Draw the entire transformer model in your notebook with all the values that you have found.



Voltage Regulation and Power Efficiency

Prepare to connect various load resistors to the secondary of the transformer. Move ammeter from the primary side to the secondary side to measure I_2. Add the second multimeter to the secondary to measure V_2. Since you will connect resistors, you can simply calculate the P_{out} as I_2V_2. You will measure P_{in} , I_2 , and V_2 for 6 different loads, approximately; 0 W, 50 W, 100 W, 150 W, 200 W, and 250 W. Make a table with 6 rows and columns for P_{in} , I_2 , V_2 , P_{out} , VR and η.

VR is voltage regulation: $$VR = \frac{V_{noload} - V_{load}}{V_{load}} 100\%$$

η is power efficiency: $$\eta = \frac{P_{out}}{P_{in}} 100\%$$

For the 0 W, well... if you don't know what to do it's time to look for a different major. Turn the primary up to 115 V (measured) and record P_{in} , I_2 , and V_2 in the table. Turn down the primary voltage. Calculate P_{out} , VR and η.

For all the other loads, your TA will have some large resistors preset and labeled for the loads. Take one at a time, not necessarily in order. Repeat the measurements and calculations for each.

Plot VR vs P_{out} and η vs P_{out} . Make nice plots (a computer is the recommended plot tool).

Calculations From the model

For the ~100 W load, calculate the load resistor, R_L. Draw your model with this R_L transformed to the primary side in place of the ideal transformer. Use your model to calculate VR and η. Compare these numbers to those you found from measurements.

Repeat for the ~250 W load.

Check-off and Conclude