University of Utah
Electrical & Computer Engineering Department
ECE 3600 Lab 2
Model of a Power Transformer

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A. Stolp, 9/23/08, rev, 9/24/14, 9/11/18, 9/29/20, 2/12/23

Objectives
1. Find an equivalent circuit of an iron-core inductor.
2. From measurements and calculations, derive a model for a power transformer.
3. Measure the power efficiency of the transformer and compare the measurements to calculations made from the model.
4. Measure the voltage regulation of the transformer and compare the measurements to calculations made from the model.

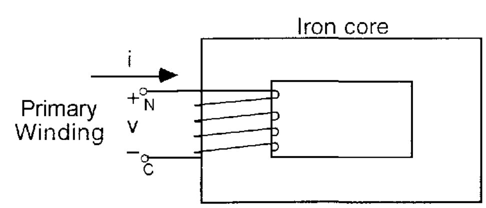
Equipment and materials to be checked out from stockroom:
- Power cable box
- 2 Wattmeters
- Power strip
- "Suicide" cord
- Vari-AC (Auto-transformer)
- MTC (Mountain Transformer Company) Transformer
- Panel with 3 lightbulbs

All work described below should be performed on the MTC transformer:

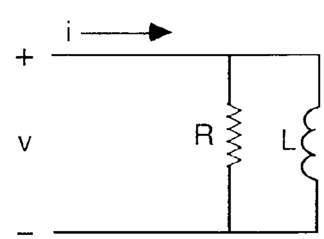
115/115 volts, 60 Hz, 250 VA
Effective cross-sectional area $A_c = 13.3\ \text{cm}^2$
Effective magnetic path length $l_m = 23.5$ cm
$N_1 = 260$ turns

The primary side of the transformer is labeled "P". You will use the "C" (common) and the "N" terminals of the transformer. ("N" refers to "normal" voltage, "H", and "-" are connections that can be used to get a higher or lower secondary voltage and will not be used in his lab.) Make sure that all other leads are free and clear because most of them are shock hazards when the primary is energized.

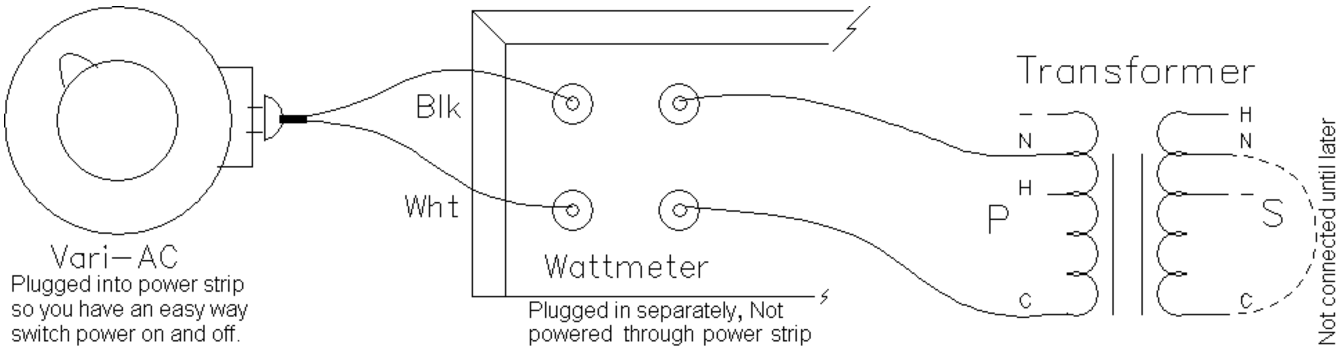
Experiment 1 (Equivalent circuit of an iron-core inductor)
If we ignore the nonlinearities, we can model (an equivalent circuit is a model) an iron-core inductor reasonably well with the parallel combination of a resistor and an ideal inductor. You will make measurements on the primary winding of the MTC transformer as though it was just an iron-core inductor.



Calculations will get you numerical values for the R and the L of the model. A series combination of a different R and different L could also be used as a model of the inductor; however, for this laboratory job, we will use the parallel combination. This has some advantages that are not necessarily obvious at this point.



Setup
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. Use the following hookup, WITHOUT the secondary shorted (dashed-line connection). The secondary winding should be left unconnected, so the transformer primary will look like a simple iron-core inductor. Draw your setup in your notebook (you should always do this, I will not always be specific in the future).



Measurements needed
1. Switch on the power and turn up the vari-AC, until you measure115 V at the primary of the transformer.

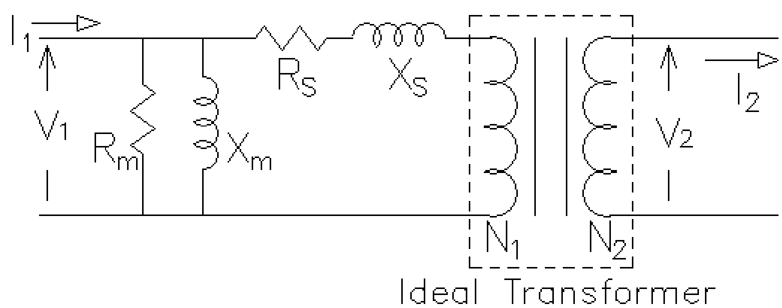
2. Record P, V, and I. Since you are looking for a linear model, assume a sinusoidal current.

3. Turn down the vari-AC and switch off the power.

Calculate R and L and draw the model of the inductor (the transformer primary) with the part values.

Experiment 2 (Model of a Power Transformer)

Background
Refer to section 3.5 (esp. Starting p105) in your textbook and/or look at the transformer notes handed out in class. The transformer model we will use is shown at right. X_m represents the inductance of the primary and is called the "magnetizing reactance". R_m accounts for the no-load power losses. These "core losses" 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 experiment 1, you found the equivalent circuit of an iron-core inductor which happened to be the primary of a transformer. Thus, you essentially performed an open-circuit (OC) test on this transformer and found R_m and L_m, which can be translated to X_m. In this experiment you will perform a short-circuit (S.C.) test and find R_S and X_S to complete the transformer model. Finally, you will compare some lab measurements to calculations made using the model.

Setup for the Short-Circuit Test
Make sure POWER is OFF to the Vari-AC.
Use the same circuit as above, WITH the secondary shorted (dashed-line connection).

This MTC transformer is rated 115/115 volts, 250 VA, 60 Hz. Determine the rated primary current.

Measurements needed
1. With the vari-AC turned down to zero, turn on the power.

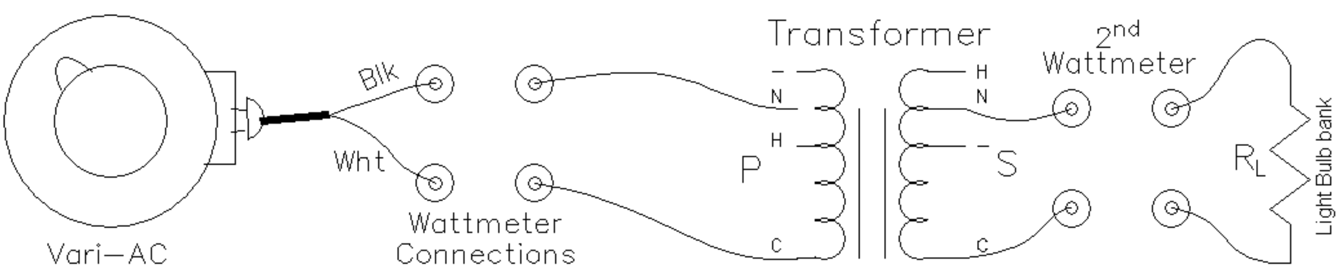
2. **Slowly** and **carefully** turn up the Vari-AC until the rated current flows in the primary. **DO NOT EXCEED 2.25 A.** Measure P, V, and I.

3. Turn vari-AC down and switch off the power.

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.

Experiment 3 (Voltage Regulation and Power Efficiency)
Change to the following hookup and unscrew all the bulbs enough that they can't light. Draw your setup in your notebook.



1. Make a table in your notebook with 5 rows, and columns for "Bulbs", P_{in} , V_1 , V_2 , I_2 , P_{out}, %VR and η. Note: you may also set up a spreadsheet to record the values. That would make later calculations and plots easier. If you use a spreadsheet, leave space in your notebook to paste the table in later.

2. Turn down the vari-AC, switch it on and turn it up to 115 V (measured).

3. Measure P_{in} , V_1 and V_2. I_2 and P_{out} are obviously zero (the 0 W measurement). V_2 is your no-load voltage (V_{NL}) for later voltage regulation calculations. Find the actual turns ratio from these initial no-load measurements.

4. The panel of 3 light bulbs is your load (R_L). Note the wattage numbers stamped on the bulbs. Unscrew the two highest-wattage bulbs so they don't light and tighten the lowest-wattage bulb so it is the only one lit.

5. Measure and record P_{in} , V_1 , V_2 , I_2 , P_{out}. Turn off the power before the bulb gets too hot. As a general practice, you should always look at your measurements as you take them and ask yourself if they make sense. If you see something like a P_{out} that's greater than P_{in} or a voltage that seems way off, check your setup and measuring equipment.

6. Use varying patterns of the (HOT) bulbs and repeat the step-5 measurements for at least 3 additional loads. Your 5 table rows should be approximately; 0 W, 50 W, 150 W, 200 W, and 250 W.

You are now done with the lab measurements. Assuming they were made correctly, you could leave the lab, just check-off now and do the calculations and plots later.

Calculations From the Data

Fill the other table columns with calculations as shown below. For the 0 W row and $V_{no\ load}$, well... if you don't know what to do it's time to look for a different major.

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

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

Plot %VR vs P_{out} and η vs P_{out}. (If you include the no-load condition in your efficiency plot, it will make the plot look bad, so you may wish to eliminate it.) Make nice plots (a computer is the recommended plot tool).

Calculations From the Model

For the load closest to 150 W, calculate the load resistance, 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 load closest to 250 W.

Check-off, Return Lab Materials and Conclude