EELE 354 Lab Assignment 9: Single-Phase Transformers: Operation, Efficiency, and Connection Schemes

Lab Overview:

The electrical transformer is a device used to change the voltage in power systems, industrial plants, and electrical / electronic equipment from one level to another.

Thomas Edison, the inventor of the first commercially practical electric light (amongst other things; he held 1,093 patents), developed the early electrical supply system for generating and transmitting electricity. However, this electrical supply system, which was created to capitalize on his electric light invention, was a DC system. In those days, prior to the advent of power electronics, DC systems were impractical for long distance transmission of DC power, mostly because the DC voltage could not be raised high enough so that power losses (I^2R losses) in the transmission lines could be minimized.

Nikolai Tesla, the inventor of the induction motor (amongst other things; though he only held around 300 patents), and others including George Westinghouse, developed the AC transmission system, which is used all over the world today. They saw AC as the primary transmission medium due to the fact that AC voltages could easily and cheaply be raised and lowered using transformers. In their transmission system, voltages could be raised using step-up transformers so that the actual current flow in electricity transmission was lower. This lower current resulted in smaller I^2R losses in the conductors. Once transmitted, the voltages could then be lowered using step-down transformers for use with loads.

Objectives:

The objectives of this laboratory assignment are:

- Learn the operation of a small single-phase step-down transformer.
- Observe and measure the efficiency of the transformer as a function of load current.
- Become familiar with various transformer connections and operations.

Pre-lab Assignment:

Read through the entire lab assignment.

In this lab, you will be testing the operation of a 117/25 V transformer under a variety of connection configurations. For the pre-lab assignment, you need to draw the schematic diagrams for these tests.

- Draw the schematic diagram for testing the transformer in its standard configuration under resistive load (just draw a resistor for the load). In this schematic, show the connection of a power analyzer used to measure the source power (primary side of the transformer), and a power analyzer used to measure the load power (secondary side of the transformer).

- Draw the schematic diagrams for the transformer if the windings are connected to form an auto transformer with the following input and output voltage levels:

(a) 117/92 V Transformer **(a) 117/142 V Transformer**

Lab Experiment

1. Have your schematic diagrams drawn for the pre-lab approved by your instructor.

2. Assemble the circuit based on the diagram you drew for the efficiency testing of the transformer in its standard configuration. **Have your instructor approve your circuit.**

3. **Prior to energization**, find and record the nameplate current ratings of the transformer on its low-voltage (secondary) side:

$$I_s = \_\_\_\_\_\_\_\_\_\_ \text{ A}$$

4. Determine the corresponding current rating for the high-voltage (primary) side assuming an ideal transformer. Recall from class that the current-voltage relationship between the primary and secondary sides of an (ideal) transformer is given by:

$$V_p I_p = V_s I_s$$

$$I_p = \_\_\_\_\_\_\_\_\_\_ \text{ A}$$

5. Ensure that the testing schedule (see table below) will not cause excess current through the transformer by calculating the expected maximum secondary winding current during testing and comparing it to the recorded current rating, I_s. (Hint: You only need to calculate the expected currents for the case that will draw the most current.)

$$I_{s,max-test} = \_\_\_\_\_\_\_\_\_\_ \text{ A}$$

6. **With your instructor's permission, energize your circuit**, and make the following measurements for the different load resistance values given. Calculate the transformer efficiency for each case.

Load Resistance R_{load} (Ω)	Input Voltage V_{in} (V)	Input Current I_{in} (A)	Input Power P_{in} (W)	Output Voltage V_{out} (V)	Output Current I_{out} (A)	Output Power P_{out} (W)	Transformer Efficiency Eff (%)
Open Circuit							
100							
50							
33.3							
25							
16.7							

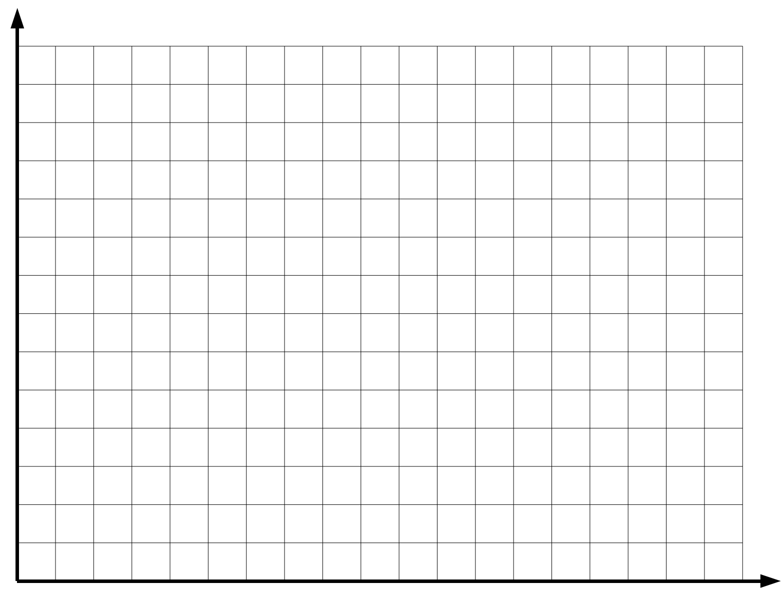
6. **De-energize your circuit and disassemble.**
7. Based on your circuit schematic from the pre-lab, connect the transformer windings so as to form an autotransformer with a voltage level transformation rating of 117/92 V. **Have your instructor approve your circuit and energize under no load conditions.**
8. Record the primary and secondary voltage for the transformer under this configuration in the table below.
9. **De-energize your circuit.**
10. Repeat steps 7 and 8 for an autotransformer with a voltage level transformation rating of 117/142 V. **Again, have your instructor test your circuit prior to energization.**

Transformer Configuration	Input Voltage V_{in} (V)	Output Voltage V_{out} (V)
117/92 V		
117/142 V		

11. De-energize your circuit and clean-up your lab station.

Lab Questions:

1. In the graph provided below, **neatly** plot the efficiency of the transformer as a function of load current.



2. Explain the reason for current flow (and thus power flow) on the primary side of the transformer even under no-load conditions on the secondary side.

3. Discuss why the efficiency increases as a function of load current. (Hint: Consider your answer to question 2).

4. Speculate as to why the efficiency of the transformer is not likely to be 100% even at its rated load. What are some sources of efficiency loss.

5. Explain why polarity markings (H_1, H_2, X_1, X_2) are needed on a transformer.

Name and initial of lab partners:

Lab Partner 1: ____________________________________

Lab Partner 2: ____________________________________

Lab Partner 3: ____________________________________