Portland State University
Electrical & Computer Engineering
EE 347 Power Systems I

- Lab 4: Single-Phase Transformers -

Introduction
This lab introduces students to single-phase power transformers, including autotransformers. Students design experiments to determine circuit models of transformers, which are then modeled using a scripting language[1]. Students also determine transformer efficiencies as well as maximum power configurations for autotransformers.

Objectives
Students learn how to:
- configure a test bench for performing open circuit and short circuit transformer testing
- perform the procedures for these two tests
- exercise precautions during testing, particularly during the short circuit test.

Analyze and interpret data, and draw conclusions
Develop engineering documentation:
- Bill of materials
- Points list
- One-line diagram

Part 1: Circuit Build and Data Gathering

Build a test bench for open-circuit testing of a single-phase transformer. The test bench shall include:

- The DUT: 8341 LabVolt 120-60/60 V transformer
- Open-circuit test: leave the secondary winding open
- LVDAC metering of voltage, current, and real power on the primary winding
- LVDAC metering of voltage on the secondary winding
- an 8821 LabVolt three-phase power supply
    - variable 120 V source, set initially to 0 V
    - source applied to the primary winding of the transformer

Perform the open-circuit testing procedure :
1. Follow the lock-out/tag-out start-up procedure
2. Energize the power supply
3. Adjust the power supply rheostat such that rated voltages are applied to the primary windings
4. Observe the metered voltage, current, and real power
5. De-energize the power supply
6. Follow the lock-out/tag-out shut-down procedure

Build a test bench for short-circuit testing of a single phase transformer. The test bench includes:

- The DUT: 8341 LabVolt 120-60/60 V transformer
- Short-circuit test: connect a short circuit across the 120 V terminals of the secondary
- LVDAC metering of voltage, current, and real power on the primary

[1] Python, Matlab, R, VB, etc. Students' choice.

- LVDAC metering of voltage and current on the secondary winding
- An 8821 LabVolt three-phase power supply
    - variable 120 V source, set initially to 0 V **(this is critical)**
    - source applied to the primary winding of the transformer

Perform the short-circuit testing procedure

1. Double-check to ensure that the 120 V variable source is initially set to 0 V
2. Follow the lock-out/tag-out start-up procedure
3. Energize the power supply
4. Continuously monitor the primary rated current
5. Slowly adjust the power supply rheostat until primary current equals the rated current
6. Double-check the current on the secondary, which should also be at rated
7. Observe the metered voltage, current, and real power
8. Adjusting the power supply rheostat to 0 V
9. De-energize the power supply
10. Follow the lock-out/tag-out shut-down procedure

Part 2. Data Analysis and Interpretation, Drawing Conclusions

2.1 Calculations, Analysis & Discussion

Use the test data collected in Part 1 to calculate the circuit parameters for a primary-side cantilever equivalent circuit model. Discuss findings; does the analysis agree with the theory as discussed in the lecture? Compare calculations to observations and explain discrepancies.

2.2 Engineering Design

Design a simulation model of the 8341 LabVolt 120-60/60 V transformer

1. Use a scripting language such as Python..
2. The model shall include a function for calculating load-regulated voltage regulation given a complex load
    a. function argument: $\mathbf{S}_{\mathbf{load}}$.
        i. $0 \leq |\mathbf{S}_{\mathbf{load}}| \leq 1.8\ S_{rated}$
        ii. $-90° \leq \theta \leq 90°$
    b. function return: voltage regulation, VR, expressed as a percentage
3. The model shall include a function for calculating efficiency given a complex load
    a. function argument: $\mathbf{S}_{\mathbf{load}}$.
        i. $0 \leq |\mathbf{S}_{\mathbf{load}}| \leq 1.8\ S_{rated}$
        ii. $-90° \leq \theta \leq 90°$
    b. function return: efficiency, η, expressed as a percentage
4. The model should include a function for flagging over current conditions
    a. function argument: $|I_{line}|$
    b. function argument: per-unit overcurrent factor C_I
    c. function return: overcurrent flag if $|I_{line}| \geq C_I\, I_{rated}$.
5. The model might include a function for flagging under- and overvoltage conditions,
    a. function argument: $|V_p|$
    b. function argument: per-unit under- and over-voltage factors $\mathbf{C_V} = [C_{Vu}, C_{Vo}]$
    c. function return: undervoltage flag if $|V_p| \leq C_{Vu}\, V_{rated}$.
    d. function return: overvoltage flag if $|V_p| \geq C_{Vo}\, V_{rated}$.

Part 3. Engineering Documentation Deliverables

1. Prepare a test report that includes the following:
    a. Brief description of the performed tests
    b. Test conditions
    c. Test results
    d. Calculations
    e. Analysis
    f. Engineering documents that describe the test benches
        i. one-line diagram
        ii. BoMs of equipment and supplies
        iii. Points lists for all equipment
2. For the simulation model
    a. In each function header, include a function description.
    b. In each function header, include instructions on how to use the function.
    c. Include comments throughout the code
    d. Demonstrate the functions by subjecting them to a series of tests, designed by the script authors.
    e. Present test results in a succinct and compelling manner.

The deliverables shall be submitted via Canvas as a single pdf file.