EEEE1028 Coursework 2

Simulation of a Single-Phase Transformer

Overview
In this coursework, you will undertake simulations using the PLECS software package to investigate the behaviour of a transformer.

The objective of this coursework is to use a simulation of a transformer to emulate experimental tests to:

- determine the turns ratio of the transformer;
- determine the "regulation" of the transformer;
- determine the "efficiency" of the transformer;
- determine the equivalent circuit parameters of the transformer.

Part 1. The Experimental System

The simulation work is emulating real measurements that you can make on a transformer to determine its various parameters. Before describing the simulation work it is worth briefly describing the experimental system you are emulating.

The experimental rig consists of a test transformer and various resistors which are used to load the transformer output. A "variac" or "autotransformer" is also used to provide an adjustable ac voltage to supply the primary winding of the test transformer. A Power Meter provides a measurement of the input rms voltage, input rms current, and both the active and reactive powers delivered from the supply to the transformer. The main components of the experiment can be seen in Figure 1. Two multimeters are also used for measurements on the secondary side: one configured as a voltmeter to measure load rms voltage, and one configured as an ammeter to measure load rms current.

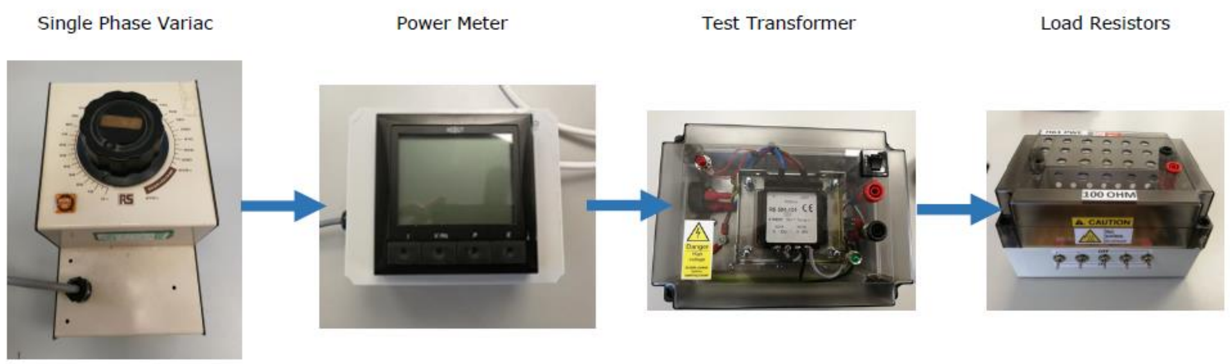

Figure 1: Main Components of the Experimental System

Part 2. Simulation Studies Using PLECs

The documentation for these transformer simulation studies is contained on the EEEE1028 Moodle page at the label “Coursework 2” in the “Transformers” section. There is one transformer modelled in PLECS - *transformer1.plecs*.

2.1 Introduction to PLECs for AC Systems

To begin this course work, follow the instructions in *PLECSforAC.pdf.* This provides an introduction to using PLECs for AC systems and has some hints for making the measurements needed in this coursework. You do not need to include any of the results from the work described in *PLECSforAC.pdf* in your final report.

2.2 Transformer Turns Ratio and Rated Load

This first exercise is to determine two fundamental parameters of the transformer. Carry out the following steps to set up your simulation model:

- Open the file containing your transformer in PLECs;
- Connect an ac voltage source to the input terminals of your transformer (terminals 1 and 2) and set the ac supply parameters according to the label in your PLECS file (note that the values in the label are RMS values, whereas the ac source requires a peak value);
- Create systems to allow you to measure the RMS voltage at the input and the output of the transformer (see *PLECSforAC.pdf* and *cwk2c*.plecs for examples);
- Run the simulation and measure the rms output voltage on no-load, and therefore determine the turns ratio of the transformer. (note – the simulation runs for a long time as the start up transient associate with the magnetizing current can be very long – you wll see this later when you measure supply current);
- Use the transformer MVA rating given on the transformer label and the measured no-load secondary voltage to calculate the rated current for the secondary side of the transformer and calculate the load resistance required to achieve this value (R_L).

2.3 Transformer Behaviour under Load: Measurement of Regulation and Efficiency

This exercise will examine the effects on the output voltage of a transformer as it is loaded – i.e. its regulation. Carry out the following steps:

- Add a resistance of value $4*R_L$ (R_L calculated in 2.2) to the secondary side;
- Connect ammeters to both the primary and secondary side of the transformer, together with systems to allow you to measure the RMS current.
- Add systems to measure Apparent Power and Active Power on the input side, and Active Power on the output side (see *PLECSforAC.pdf* and *cwk2c*.plecs for examples);
- Run the simulation and measure primary side active power, and the secondary side active power, rms current and rms voltage.
- Repeat for load resistances of $3*R_L$, $2*R_L$, $1*R_L$.
- Plot a graph of the secondary rms voltage against secondary side rms current. Calculate the slope of this graph – which transformer parameters is it related to?
- Calculate the efficiency and regulation of the transformer when operating at rated power.

You should save the PLECs file used for this load test and submit it as part of your final report.

2.4 Determine the Transformer Equivalent Circuit

To find the equivalent circuit parameters of a transformer (see figure 2), two tests must be carried out. The first is the open circuit (or no load) test and is used to determine the parallel components R_c and X_m. The other tests is the short circuit test that is used to determine the series components of the winding resistance R and winding leakage reactance X.

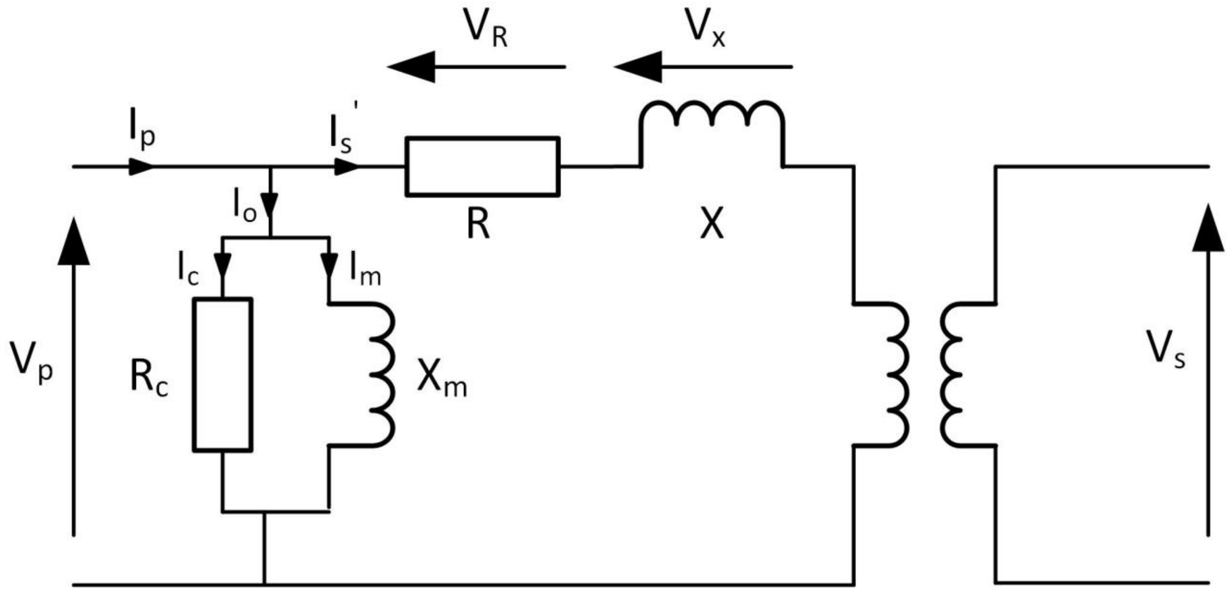

Figure 2 Transformer Equivalent Circuit

<u>Open Circuit Test</u>

This test aims to measure the components of the magnetizing branch.

- Disconnect any resistance connected to the secondary of your transformer so that it is open circuit (no-load)
- Run the simulation - note the primary rms voltage, current, and the primary active power.

For the "Open Circuit" test, with reference to Figure 2, I_s' is zero as there is no load, and therefore $I_p = I_o$). Draw the phasor diagram for the open circuit test using your measurements (including the voltage V_p and the currents I_o, I_m and I_c.). Use this, and the theory that you have covered in class to calculate values for the parallel components R_c and X_m.

<u>Short Circuit Test</u>

For this test, the resistance connected in the secondary side is replaced by a short circuit (do this!). We must limit the output current to its rated value (calculated in 2.1 above) and in the actual experiment we use the variac to reduce the input voltage. In the simulation work here we can simply reduce the supply voltage by changing the voltage in the input ac source.

- Start by changing it to 10% of its rated value;
- Run the simulation and measure the output current. If it is not within 10% of the rated output current, change the voltage source amplitude until it is.
- Note the primary rms voltage and current, and the primary active power.

For the "Short Circuit" test, with reference to the circuit diagram of Figure 2, I_s' is much larger than I_o and therefore the magnetizing branch can be ignored to simplify calculations (i.e. assume $I_s' = I_p$). Draw up the phasor diagram for the short circuit test using your measurements (including the voltage V_p, the current I_s', and the voltages across R and X). Use this, and the theory that you have covered in class to calculate values for the winding resistance *R* and leakage reactance *X*.

2.5 Phasor Diagram for the Full Load Condition

For the maximum loading condition (ie lowest load resistance value) use the various scopes in the simulation to measure the phase angle between currents and voltages and draw to scale the phasor diagram for this condition. You may want to draw two diagrams – one for currents and one for voltages – as there is a big difference in scaling between volts and amps measured.

REPORT REQUIREMENTS

The mark scheme given in a separate document is based upon both correctly undertaking the required simulations and correctly interpreting the results. Be sure to follow clearly, what you are asked to do and to include all relevant calculations and explanations in your final coursework document.

The report must be typed (not handwritten), and presented to a professional standard i.e. neat, well-structured and organized. The report should include:

- An introduction to the report – summarising briefly what is contained in the report;
- Your measurements for the three simulated experiments together with associated graphs, tables and any calculations requested, all organised in a logical manner with comments and brief discussion alongside the relevant results presented;
- A conclusion summarising the important findings from this work e.g. does the theory match the simulation findings?). Please add comments about how easy/difficult it was to follow these instructions and do these simulations.

You do not need to repeat method statements or instructions given in this handout.

<u>Report Submission</u>

Your submission will consist of a **single PDF file**, containing relevant outputs (such as graphs measurements, phasor diagrams) and your interpretation of these results when requested. You must name your file "**H61PWE_CW2_########.pdf**", where ######## is your student ID number. You should also submit the PLECs file you developed for the load test of section 2.3, with the name **H61PWE_CW2_########.plecs**.