ELEC 302-81
Lab 3
Non-Ideal Transformer Properties

February 11, 2013

Date Performed:	February 4, 2013
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1 Purpose of Experiment

In this experiment, the non-ideal properties of a transformer were examined. The performance of the transformer at the Lab-Volt station was first analyzed by measuring the primary and secondary: voltages, currents, and powers. Then the transformer was subjected to an open-circuit test and a short-circuit test in order to generate the equivalent circuit components. These results were then compared to the original performance specifications to show the transformer's non-ideal properties.

2 Procedure

2.1 EMS Workstation Set-up

At the Lab-Volt EMS workstation, a Fluke multi-meter was used to measure the DC resistance of the transformer windings. These values are recorded in Table 1. The DAI 24V supply was turned on, and the DAI USB connector was connected between the EMS workstation and the PC. On the LVDAM EMS application software, the metering windows for E_1, E_2, I_1, and I_2 were opened and set to continuous refresh.

2.2 Transformer Performance

With the main power switch turned off and the voltage control knob fully counter-clockwise, the voltmeter selector switch was set to position 4–N. The circuit represented by Figure 1 was constructed with the secondary voltmeter E_2 open-circuited at first to simulate an infinite load. The main power supply was turned on, and the supply voltage was adjusted to 120V. The primary voltage, primary current, input power, secondary voltage, secondary current, and output power were then measured for each of the four loads listed in Table 2. Prior to changing each load, the voltage supply knob was set fully counter-clockwise and the main power switch turned off.

2.3 Open Circuit Test

The circuit shown in Figure 2 was then constructed. The main power switch was turned on and the voltage control knob was adjusted to 120V. The values of the primary voltage, primary current, and input power were measured. These values were recorded in Table 3. The main power switch was turned off and the voltage control knob fully counter-clockwise.

2.4 Short Circuit Test

The circuit shown in Figure 3 was then constructed. It was noted that I_2 short circuited the secondary windings 5–6. Then the voltage supply knob was slowly adjusted until a secondary current of 0.4A was obtained. The primary voltage, primary current, input power, and the secondary current were measured and recorded in Table 4. The main power switch was turned off and the voltage control knob turned fully counter-clockwise.

3 Results

3.1 Transformer Performance

Winding #	**Resistance** Ω
1–2	7.9
5–6	7.9

Table 1: Winding Resistances

Load	**Primary Voltage**	**Primary Current**	**Input Power**	**Secondary Voltage**	**Secondary Current**	**Output Power**
Z_L Ω	E_1 V	I_1 A	P_1 W	E_2 V	I_2 A	P_2 W
∞	119.9	0.027	2.453	119.0	0.003	0
300	119.3	0.388	46.01	112.4	0.368	41.35
300 + j300	119.5	0.270	23.63	112.4	0.244	20.20
300 - j300	119.5	0.281	27.30	120.0	0.276	23.52

Table 2: Primary and secondary voltages and currents

3.2 Open Circuit Test

Primary Voltage	**Primary Current**	**Input Power**
E_1 V	I_1 A	P_2 W
119.7	0.027	2.44

Table 3: Open Circuit

3.3 Short Circuit Test

Primary Voltage	**Primary Current**	**Input Power**	**Secondary Current**
E_1 V	I_1 A	P_1 W	I_2 A
11.7	0.403	2.607	0.398

Table 4: Data for Fig 3

4 Analysis

4.1 Transformer Equivalent Circuit Component Values

$\mathbf{R}_C$ kΩ	$\mathbf{X}_M$ kΩ	$\mathbf{R}_{eq}$ Ω	$\mathbf{X}_{eq}$ Ω
5.85	6.80	16.05	24.19

Table 5: Equivalent Transformer Components

Equivalent circuit components found from the following equations:

$$\text{Admittance} = Y_E = \frac{I_{OC}}{V_{OC}}\angle{-\theta} = \frac{1}{R_C} - \frac{1}{X_M}$$

$$\text{Series Impedance} = Z_{SE} = \frac{V_{SC}}{I_{SC}}\angle\theta = R_{eq} + jX_{eq}$$

4.2 Transformer Losses

	Losses	
Load Ω	$\mathbf{P_{Cu}}$ W	$\mathbf{P_{core}}$ W
∞	0.0014	2.453
300	2.162	2.433
300 + j300	0.956	2.441
300 - j300	1.223	2.437

Table 6: Copper and Core Losses

Equations Used:

$$P_{Cu} = I_S^2 * R_{eq}$$

$$P_{core} = (\frac{V_P}{a})^2 * \frac{1}{R_C}$$

4.3 Voltage Regulation VR and Efficiency Comparison

Load Ω	**VR** Part 1	**VR** R_{eq}	**Percent Difference**
∞	0.00	0.00	0.00
300	5.97	6.39	7.0
300 + j300	6.16	6.69	8.6
300 - j300	-0.92	-1.25	35.9

Table 7: Transformer Voltage Regulation (VR)

Load Ω	η Part 1	η R_{eq}	**Percent Difference**
∞	0.00	0.00	0.00
300	89.72	87.41	2.6
300 + j300	85.57	86.02	0.5
300 - j300	86.11	86.93	0.9

Table 8: Transformer Efficiencies (η)

Equations Used:

$$VR = \frac{V_P - V_S}{V_S} * 100\%$$

$$V_P = V_S + R_{eq} * I_S + \mathrm{j}X_{eq} * I_S$$

$$\eta = \frac{P_{out}}{P_{\text{in}}} * 100\%$$

$$\text{Percent Diff} = \frac{\text{difference}}{\text{average}} * 100\%$$

5 Conclusions

By measuring the resistance of each transformer winding and not getting any extremely high resistance readings similar to an open circuit, it was determined that the windings were intact and had integrity.

In Table 5, the component values for the transformer equivalent circuit are listed. These values were needed to accurately model the equivalent circuit due to the imperfections in real transformers. The resistance R_{eq} was made up of R_P + R_S. R_P was a resistance in the primary circuit that represented the resistive losses in the primary windings of the transformer core. Similarly, R_S was a resistance in the secondary circuit that represented the resistive losses in the secondary windings of the transformer core. The reactance X_{eq} was made up of X_P + X_S. These reactances represented the leakage inductances of the primary and secondary coils. The core excitation losses were modeled with a resistance R_C in parallel with a reactance X_M.

In Table 6 the copper and core excitation losses for each load are listed. These losses were accounted for by the component values for the equivalent circuit found in Table 5.

In Table 7 and Table 8, the transformer voltage regulation and efficiencies for the transformer modeled in Part 1 and the equivalent circuit are compared. On average small percent differences were obtained, thus the equivalent circuit constructed was an accurate model of the transformer in Part 1.

Circuits Tested

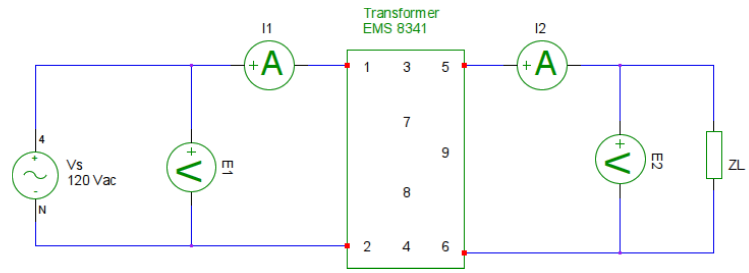

Figure 1: Single Phase Transformer Circuit for part one

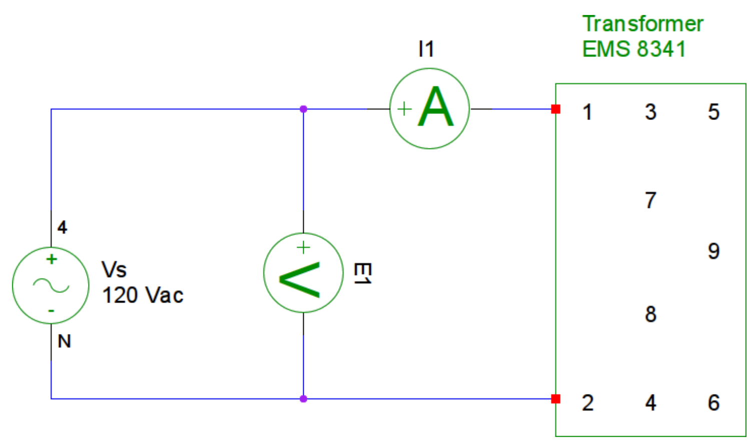

Figure 2: Single Phase Transformer Circuit for part two (open circuit test)

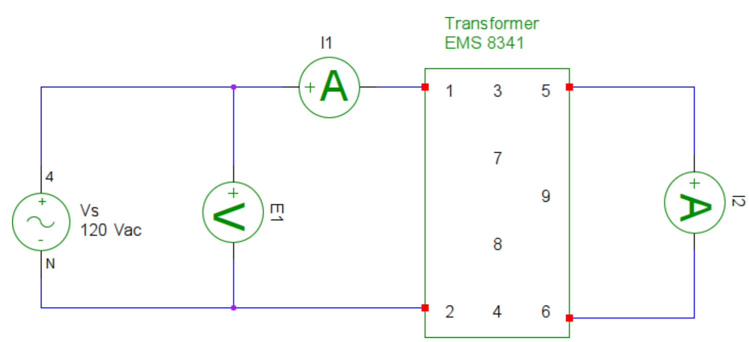

Figure 3: Single Phase Transformer Circuit for part two (short circuit test)