ELEC 302-81
Lab 2
Transformer Fundamentals

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Date Performed:	January 28, 2013
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1 Purpose of Experiment

In this experiment, the basic characteristics of transformers were studied. Various transformer circuits with different unknown turns ratios were constructed in order to study the different voltage ratios at each particular turns ratio. Other transformer circuits were constructed to observe the similarity between the current ratio and turns ratio, and to observe the saturation curve of a magnetic circuit.

2 Circuits Tested

2.1 Voltage Ratios

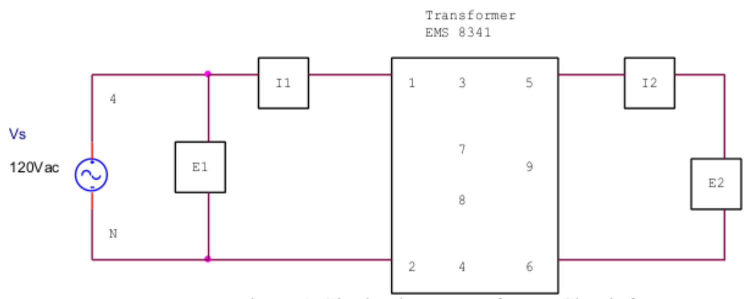

Figure 1: Single Phase Transformer Circuit

2.2 Current Ratio

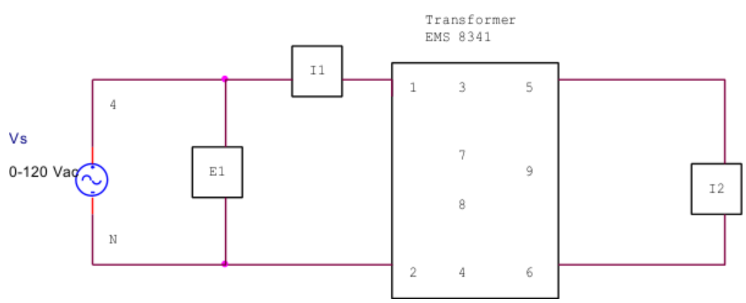

Figure 2: Single Phase Transformer Circuit

2.3 Saturation

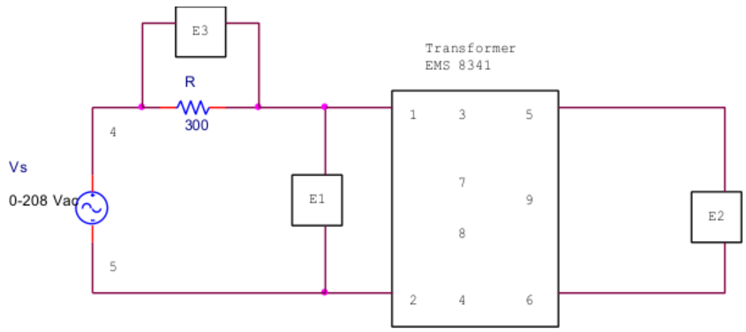

Figure 3: Single Phase Transformer Circuit

3 Procedure

3.1 EMS Workstation Set-up

At the Lab-Volt EMS workstation, a Fluke multi-meter was used to measure the DC resistance of each transformer winding. 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, E_3, I_1, and I_2 were opened. The metering windows were set to continuous refresh.

3.2 Voltage Ratios

With the main power switch to OFF and the voltage control knob fully counterclockwise (CCW), the voltmeter selector switch was set to position 4–N. The circuit shown in Figure 1 was then constructed. The main power switch was turned to ON and the voltage supply voltage was set to 120V. The primary voltage was recorded from E_1 and the secondary voltage was recorded from E_2. The values for E_1 and E_2 were then measured and recorded for each winding number listed in Table 3. The main power switch was set to OFF and the voltage control knob was set fully CCW before rewiring the circuit for each winding number. The respective turns ratio for each set of winding number, primary, and secondary voltages was calculated and also listed in Table 3. After completing the requisite measurements, the main power switch was set OFF and the voltage control to fully CCW.

3.3 Current Ratio

The circuit shown in Figure 2 was then constructed. The main power switch was set ON and the voltage control knob was slowly adjusted to read 0.4A from

I_2. It was noted that the ammeter I_2 shorted the windings 5–6. Hence, extreme care was given to not exceed the secondary winding current rating of 0.5A. The values for primary voltage E_1, primary current I_1, and secondary current I_2 were then measured and recorded, as shown in Table 5. The main power switch was set OFF and the voltage control knob fully CCW.

3.4 Saturation

The circuit shown in Figure 3 was then constructed. The voltage supply connection was set from 4–N to 4–5. Since the exciting current was small the 300Ω resistor was included and thus the voltage E_3 across the resistor was used to show the current variation. On the PC, the Data Table application was opened and set to record settings from the Options tab. E_1, E_2, and E_3 appeared as the columns in the data table. The main power switch was set ON and the supply voltage was then increased in 10V increments from 0–180 volts. At each increment, the Record Data tab was clicked to instantly enter the voltage measurements in the data table. After reaching 180V, the main power switch was set to OFF and the voltage supply control knob was fully CCW. On the PC, the Graph application was opened. E_3 (the exciting current) was set as the x-axis, and E_1 (the applied voltage) as the y-axis. The Line Graph tab was clicked to display the saturation curve of the transformer core.

4 Results

4.1 Voltage Ratios

Winding #	Resistance Ω
1–2	7.9
3–4	24.9
5–6	7.9
7–8	9.4
3–7	12.1
8–4	3.6
5–9	3.8
9–6	4.2

Table 1: Winding Resistances

Winding #	Primary Voltage E_1 V (1–2)	Secondary Voltage E_2 V	Turn Ratio N_P:N_S
3–4	120.3	207.2	0.58
5–6	120.2	119.2	1.01
7–8	120.2	75.8	1.59
3–7	120.3	103.6	1.16
8–4	120.3	27.8	4.33
5–9	120.2	59.8	2.01
9–6	120.1	59.7	2.01

Table 2: Primary and Secondary Voltages

Winding	Nameplate Voltage	Measured Voltage	Percent Difference
3–4	208	207.2	0.38
5–6	120	119.2	0.67
7–8	76	75.8	0.26
3–7	104	103.6	0.38
8–4	28	27.8	0.71
5–9	60	59.8	0.33
9–6	60	59.7	0.50

Table 3: Comparison of Nameplate Secondary Voltages with Measured Values

$$\text{Percent Difference} = \frac{\text{measured} - \text{nameplate}}{\text{nameplate}} \times 100\%$$

4.2 Current Ratio

E_1 V	I_1 A	I_2 A
11.75	0.403	0.399

Table 4: Winding Resistances

4.3 Saturation

Primary Voltage E_1 V (1–2)	Secondary Voltage E_2 V	Exciting Voltage E_2 V
10.56	10.42	2.12
19.61	19.39	2.84
30.90	30.60	3.57
40.77	40.39	4.11
50.02	49.60	4.59
60.76	60.27	5.12
70.54	70.03	5.62
80.48	79.90	6.04
91.36	90.73	6.59
99.36	98.66	7.02
110.57	109.78	7.63
119.85	119.07	8.20
130.03	129.16	8.91
140.67	139.77	9.76
149.73	148.70	10.70
160.85	159.70	12.25
171.55	170.27	14.50
180.38	178.92	17.11

Table 5: Data for Fig 3

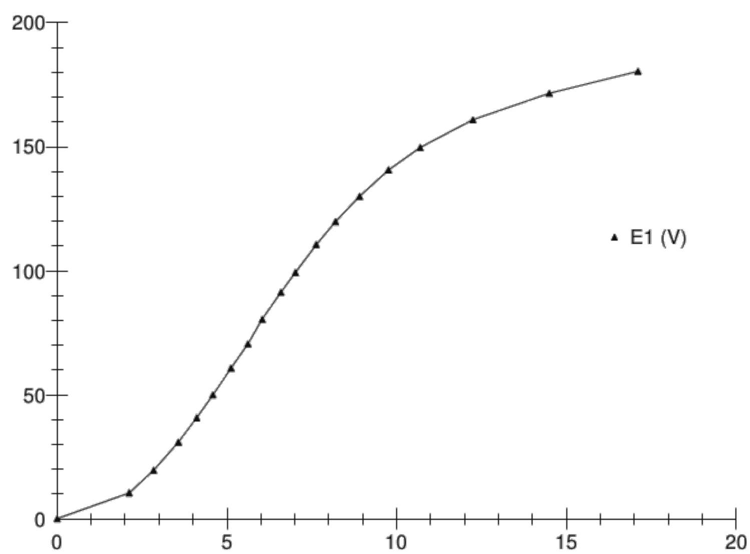

Figure 4: Saturation Curve

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 transformer windings had no faults and the integrity of the windings were intact.

By measuring the voltage ratios for each particular transformer winding, the turns ratio for that winding was calculated by taking the primary voltage over the secondary voltage. This was one method to determine the turns ratio of an unspecified transformer.

By measuring the current ratio for one set of transformer windings, another method to determine the turns ratio was implemented. By referring to the text *Electric Machinery Fundamentals*, the current ratio of a transformer is inversely proportional to the turns ratio. The relationship states: $\frac{I_p}{I_s} = \frac{N_s}{N_p}$, where $\mathrm{I_p}$ is the primary current, $\mathrm{I_s}$ the secondary current, $\mathrm{N_p}$ the primary winding, and $\mathrm{N_s}$ the secondary winding. The ratio of secondary current $\mathrm{I_2}$ over primary current $\mathrm{I_1}$ was the same as the turns ratio calculated and recorded in row 2 of Table 3 pertaining to winding number 5–6. Therefore, the additional method of determining a transformer turns ratio was verified.

By analyzing the saturation curve, it was determined that the transformer core did indeed become saturated. From an applied voltage of 10V to approximately 110V, the saturation curve was linear and the transformer core was unsaturated at this time. A small increase in the magneto-motive force (represented as $\mathrm{E_3}$) resulted in a very large increase in the flux produced (represented as $\mathrm{E_1}$). Then the saturation curve started to level off after an applied voltage of 110V (termed the *knee* of the curve), and therefore the core started to become saturated. In the saturated region, increases in magneto-motive force produce smaller and smaller increases in flux.