Experiment 3	The University of Texas at Tyler Department of Electrical Engineering Electric Power Systems Lab (EENG 4110)	

Single-Phase Transformer Testing (2)

Objectives

By the end of this lab you will:

1. Determine the voltage regulation of a transformer.
2. Determine transformer efficiency.

Equipment and Components

1. Single-phase transformer
2. Wattmeter (2A/150-300V)
3. Voltmeter (150/300V)
4. Ammeter (2A)
5. Regulated power supply (0-120V, 60 Hz, 10A)
6. Resistive load (300/600/1200 Ω, 100 W)
7. Inductive load (0.8/1.6/3.2 H, 100 VAR)
8. Capacitive load (2.2/4.4/8.8 µF, 100 VAR)

Introduction

Most loads connected to the secondary of a transformer are designed to operate at essentially constant voltage. However, as the current is drawn from the transformer, the load terminal voltage changes because of the voltage drop in the internal impedance of the transformer. The load terminal voltage may go up or down depending on the nature of the load. The voltage regulation is defined as the change in magnitude of the secondary voltage as the load current changes from the no-load to the loaded condition. The voltage regulation depends on the power factor of the load. Voltage regulation can be formulated as:

$$\text{Voltage Regulation (\%)} = \frac{V_{\text{no load}} - V_{\text{full load}}}{V_{\text{no load}}} \times 100 \quad (1)$$

Losses in transformers are small, making transformers highly efficient static devices. The losses in a transformer are the core (iron) and copper losses. The core-loss is the sum of the hysteresis and eddy-current losses and manifests itself in the form of heat generated in the core. The copper losses are due to the resistance of the windings. Transformer efficiency is defined as:

$$\text{Efficiency (\%)} = \frac{P_{\text{out}}}{P_{\text{in}}} \times 100 = \frac{P_{\text{out}}}{P_{\text{out}} + \text{Losses}} \times 100 \quad (2)$$

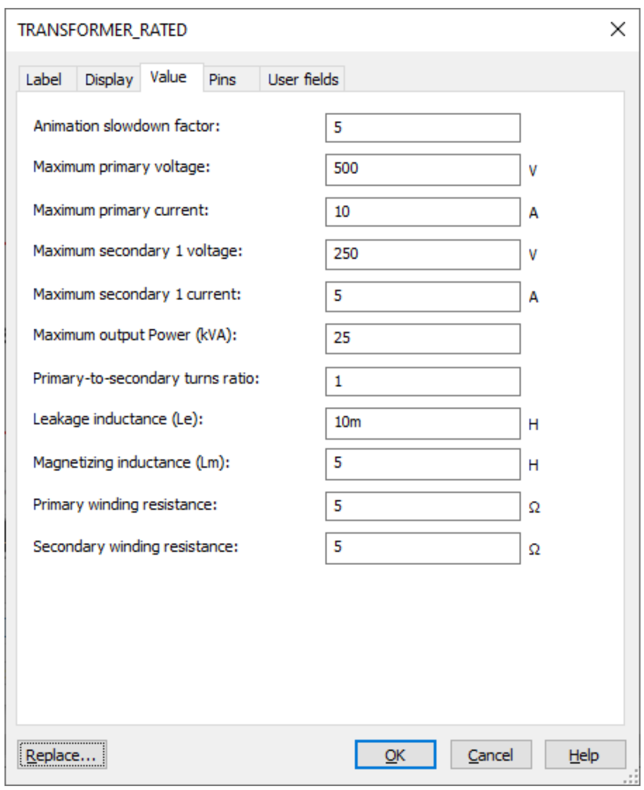
Procedure

Part A: Voltage Regulation Test

1. Make sure that the power supply is switched off, and the voltage control knob is turned fully to zero.
2. Connect the circuit as shown in Figure 1, <u>without placing any load</u>. To create the Multisim circuit, place the following components and instruments on your workspace and connect them as shown in Figure 1b:

Component/instrument	Name	Location	Settings
AC Power Supply	AC_POWER	Sources/POWER_SOURCES	120Vrms/60Hz/0°
Transformer	TRANSFORMER_RATED	Basic/RATED_VIRTUAL	See instructions
Ground	GROUND	Sources/POWER_SOURCES	None
Resistor (R_c)	Resistor	Basic/RESISTOR	10 kΩ
Resistor (R)	Resistor	Basic/RESISTOR	See instructions
Inductor (L)	Inductor	Basic/INDUCTOR	See instructions
Capacitor (C)	Capacitor	Basic/CAPACITOR	See instructions
Ammeter (I_{pri})	XMM1	Instrument Toolbar	AC current
Voltmeter (V_{sec})	XMM2	Instrument Toolbar	AC voltage

Set the transformer parameters to the following values:



3. After inspecting the circuit, turn the power supply on and gradually increase the voltage to the rated value of the winding connected to the power supply.
4. Measure the primary current and secondary voltage at no load and record the values in Table 1.
5. In steps, increase the resistive load to the full load and measure and record in Table 1 the primary current and secondary voltage for each load.

6. Turn off the power supply and connect the inductive load. Repeat steps 2 to 5.
7. Turn off the power supply and connect the capacitive load. Repeat steps 2 to 5.
8. Return the supply voltage to zero and then turn the power off.
9. Use Equation (1) to calculate the voltage regulation of the transformer for each load type and record the values in Table 1.

Part B: Transformer Efficiency Test

10. Make sure that the power supply is switched off, and the voltage control knob is turned fully to zero.
11. Connect the circuit as shown in Figure 2. To create the Multisim circuit, place the following components and instruments on your workspace and connect them as shown in Figure 2b:

Component/instrument	Name	Location	Settings
AC Power Supply	AC_POWER	Sources/POWER_SOURCES	120Vrms/60Hz/0°
Transformer	TRANSFORMER_RATED	Basic/RATED_VIRTUAL	See instructions
Ground	GROUND	Sources/POWER_SOURCES	None
Resistor (R_c)	Resistor	Basic/RESISTOR	10 kΩ
Resistor (R)	Resistor	Basic/RESISTOR	See instructions
Ammeter (I_{pri})	XMM1	Instrument Toolbar	AC current
Ammeter (I_{sec})	XMM2	Instrument Toolbar	AC current
Wattmeter (P_{in})	XWM1	Instrument Toolbar	None

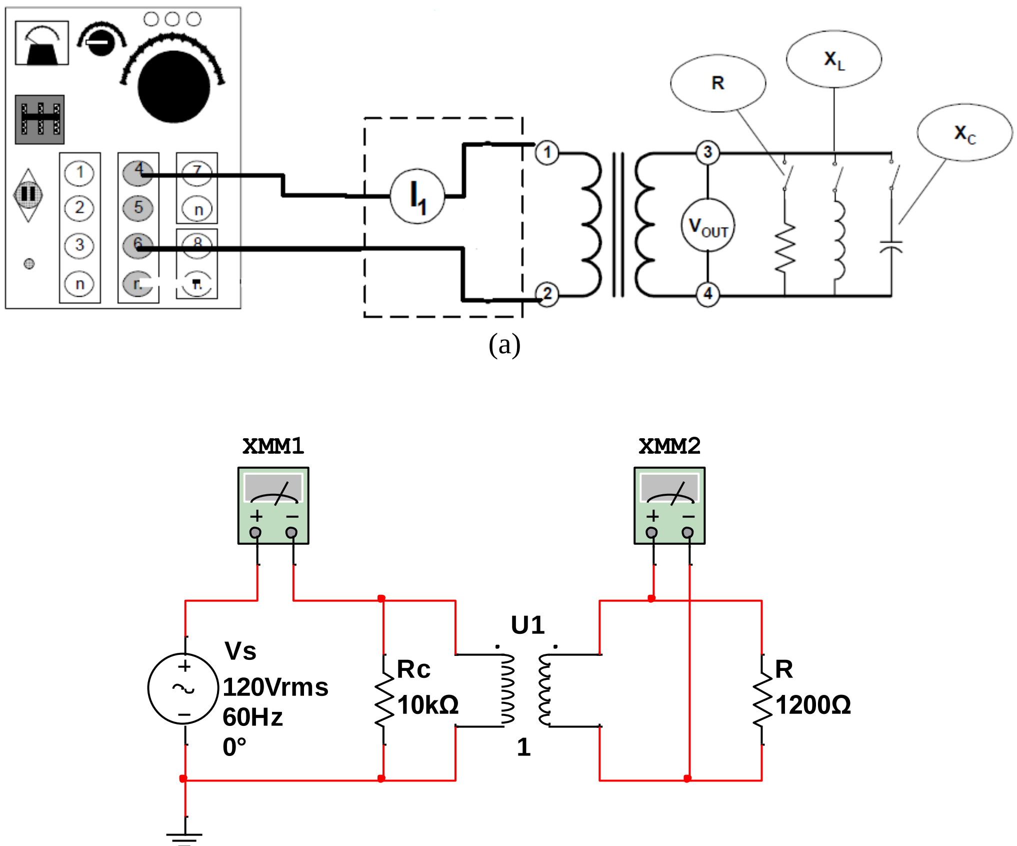
Keep the transformer parameters at the same values given in part A.

12. After inspecting the circuit, turn the power supply on and gradually increase the voltage to the rated value of the winding connected to the power supply.
13. Add resistive loads in steps and record the input current and power and the output current readings for each step in Table 2.
14. Return the supply voltage to zero and then turn the power off.
15. Calculate the output power for each load ($P_{\text{out}} = I_{\text{sec}}^2\, R$) and record the values in Table 2.
16. Calculate the efficiency of the transformer at each load using Equation (2). Record the values in Table 2.

Report requirements

Your lab report must include:

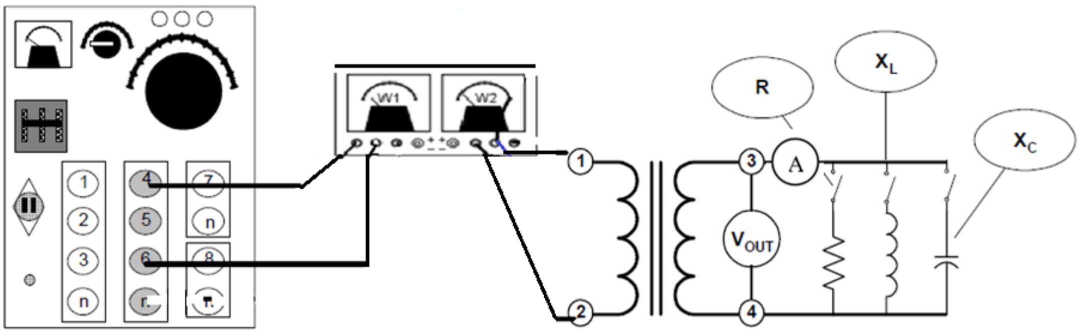
1. Inspect the influence of resistive, inductive, and capacitive loads on the voltage regulation.
2. Prove that the maximum efficiency of a transformer is achieved when the copper loss is equal to the iron loss.
3. What is the maximum efficiency of your transformer? At what load the maximum efficiency occur?
4. Plot the percent efficiency versus the secondary current, and indicate the full-load current and the maximum-efficiency current on the plot.



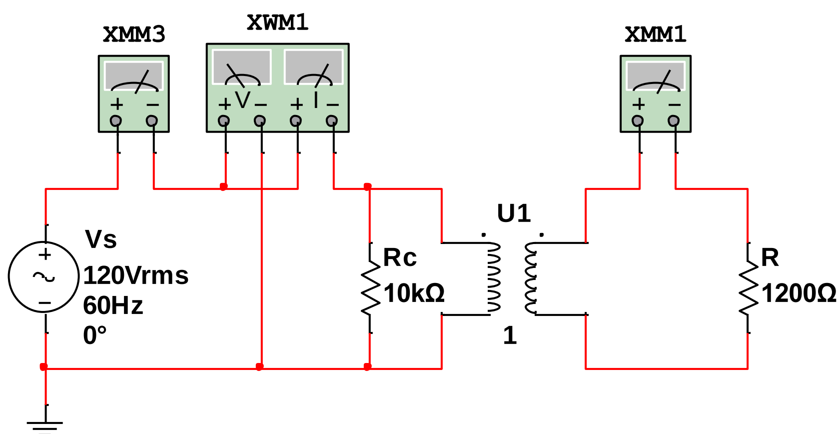
(a)

(b)

Figure 1: Voltage regulation test connection.
(a) Circuit wiring and (b) Multisim circuit.



(a)



(b)

Figure 2: Transformer efficiency test connection.
(a) Circuit wiring and (b) Multisim circuit.

Table 1: Voltage regulation test.

Multisim			Actual circuit		
Resistive load	I_{pri}	V_{sec}	**Resistive load**	I_{pri}	V_{sec}
No load			No load		
1200 Ω			1200 Ω		
600 Ω			600 Ω		
400 Ω			400 Ω		
300 Ω			300 Ω		
240 Ω (Full load)			240 Ω (Full load)		
Voltage Regulation (%)			**Voltage Regulation (%)**		

Inductive load	I_{pri}	V_{sec}	**Inductive load**	I_{pri}	V_{sec}
1200 Ω			1200 Ω		
600 Ω			600 Ω		
400 Ω			400 Ω		
300 Ω			300 Ω		
240 Ω (Full load)			240 Ω (Full load)		
Voltage Regulation (%)			**Voltage Regulation (%)**		

Capacitive load	I_{pri}	V_{sec}	**Capacitive load**	I_{pri}	V_{sec}
1200 Ω			1200 Ω		
600 Ω			600 Ω		
400 Ω			400 Ω		
300 Ω			300 Ω		
240 Ω (Full load)			240 Ω (Full load)		
Voltage Regulation (%)			**Voltage Regulation (%)**		

Table 2: Transformer efficiency test.

Multisim					
Resistive load	$\boldsymbol{I_{\mathrm{pri}}}$	$\boldsymbol{P_{\mathrm{in}}}$	$\boldsymbol{I_{\mathrm{sec}}}$	$\boldsymbol{P_{\mathrm{out}} = I_{\mathrm{sec}}^2\, R}$	**Efficiency (%)**
1200 Ω					
600 Ω					
400 Ω					
300 Ω					
240 Ω					
200 Ω					
Actual circuit					
Resistive load	$\boldsymbol{I_{\mathrm{pri}}}$	$\boldsymbol{P_{\mathrm{in}}}$	$\boldsymbol{I_{\mathrm{sec}}}$	$\boldsymbol{P_{\mathrm{out}} = I_{\mathrm{sec}}^2\, R}$	**Efficiency (%)**
1200 Ω					
600 Ω					
400 Ω					
300 Ω					
240 Ω					
200 Ω					