Experiment		
2	**The University of Texas at Tyler** **Department of Electrical Engineering** **Electric Power Systems Lab (EENG 4110)**	UT TYLER

Single-Phase Transformer Testing (1)

Objectives

By the end of this lab you will:

1. Determine the correct polarity of a transformer.
2. Measure the iron losses and the components of the no-load current.
3. Measure the copper losses and determine the leakage impedance of the transformer.
4. Determine the approximate equivalent circuit of the transformer.

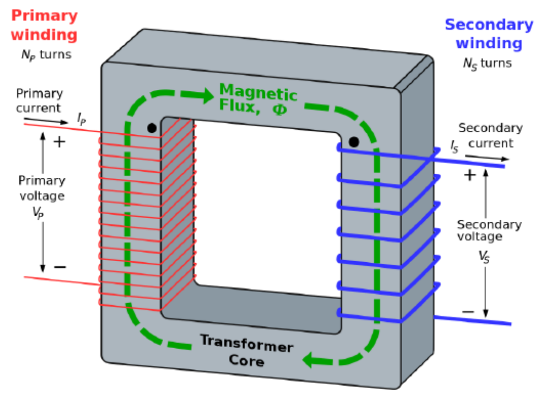
Equipment and Components

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)

Introduction

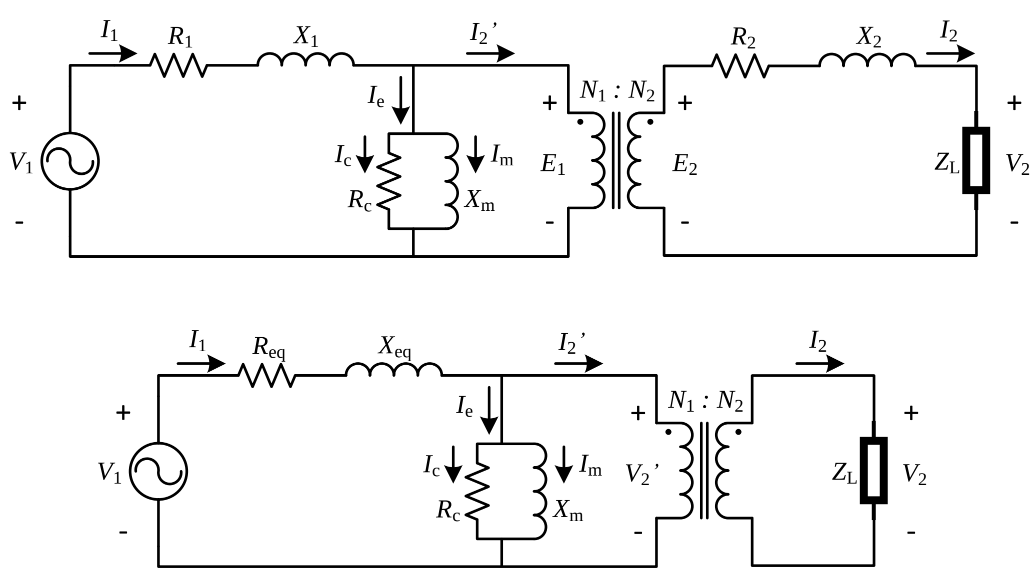
One of the most valuable apparatuses in electric systems is the transformer, for it enables us to utilize different voltage levels across the power system for the most economical value. Generation of power at the synchronous machine level is normally at a relatively low voltage, which is most economically desirable. Stepping up this generated voltage is achieved through power transformers to suit the power transmission requirement to minimize losses and increase the transmission capability of the lines. This transmission voltage level is then stepped down in many stages for distribution and utilization purposes. Transformers are used at all levels of the system. Besides voltage transformation, in electronic circuits, transformers are used for impedance matching. The main uses of electrical transformers are for changing the magnitude of an AC voltage, providing electrical isolation, and matching the load impedance to the source.

A transformer is usually considered to be a special form of inductive coupling between two or more coils. They are formed of two or more sets of stationary windings that are magnetically coupled with a high permeability core to maximize the coupling and increase mutual coupling. One of the most useful features of the transformer is its ability to relate the input voltage or current to its output voltage or current respectively (transformation ratio) while maintaining the power relationship the same (i.e. input power ≅ output power).



The conditions of frequency, voltage, current, and volt-amperes product under which a transformer is designed to operate continuously are collectively termed the rating of the transformer. The open-circuit test gives information regarding the losses in the core, the parameters R_c, X_m, and the turns ratio. Rated voltage is applied at the terminals of one winding while the other winding terminals are open-circuited. Voltage, current, and power are measured. The current that flows in the primary winding during this test is called the excitation current, I_e. The excitation current component of the primary current is needed to produce the resultant mutual flux. This current has two components: the magnetizing current, I_m, and the core-loss current, I_c. Studying the transformer model in the figure below, we see that the primary and secondary winding resistances are R_1 and R_2, respectively. X_1 and X_2 are the leakage reactance of the resistive windings to account for the magnetic flux which does not couple all turns. R_c and X_m are the parameters related to core losses and the magnetization inductance, respectively.

The short-circuit test is used to determine the total winding resistance and leakage inductance losses in the windings at full-load current. In this test, one pair of terminals is short-circuited while the voltage of the other winding is raised until full load current flows in the short-circuited winding, and the voltage, current, and power input are recorded. The voltage that is required for the full-load current in the short-circuit test is determined by the low impedance of the windings and should be equal to about 5% of the rated voltage of the winding to which it is applied.



TRANSFORMER EQUIVALENT CIRCUIT MODEL

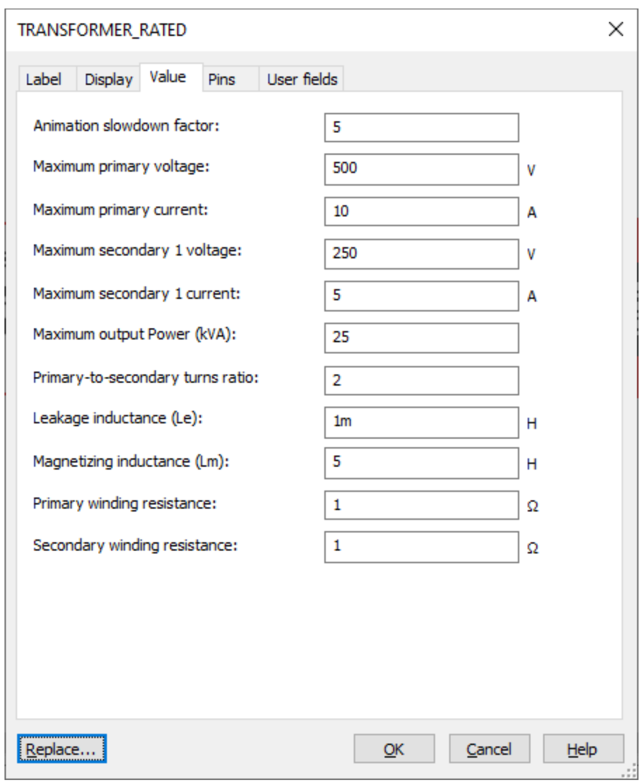
Procedure

Part A: Polarity 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. 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
Ammeter (I)	XMM1	Instrument Toolbar	AC current
Voltmeter (V_1)	XMM2	Instrument Toolbar	AC voltage
Voltmeter (V_2)	XMM4	Instrument Toolbar	AC voltage
Voltmeter (V_3)	XMM3	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 supply voltage to the rated value of the HV winding connected to the power supply (120 V for the Multisim circuit).
4. Record the measured values of the current I and the voltages V_1, V_2 and V_3 in Table 1.
5. Return the supply voltage to zero and then turn the power off.
6. Connect the circuit as shown in Figure 2 and repeat steps 3 to 5.
7. Determine the polarity of the transformer by inspecting the measured voltages V_1, V_2 and V_3.
   If $V_3 \cong V_1 + V_2$, the transformer is said to be connected in **additive polarity**.
   Conversely, if $V_3 \cong V_1 - V_2$, the transformer is said to be connected in **subtractive polarity**.

Part B: Open-Circuit Test (No-load Test)

8. Make sure that the power supply is switched off, and the voltage control knob is turned fully to zero.
9. Connect the circuit as shown in Figure 3. The open circuit is done using an AC voltmeter which when placed across the high voltage side of the transformer, creates an open circuit between them because of its high internal impedance.
10. To create the Multisim circuit, place the following components and instruments on your workspace and connect them as shown in Figure 3c. Note that the resistance R_c in Figure 3c is added to account for the core-loss resistance.

Component/instrument	Name	Location	Settings
AC Power Supply	AC_POWER	Sources/POWER_SOURCES	120Vrms/60Hz/0°
Transformer	TRANSFORMER_RATED	Basic/RATED_VIRTUAL	Same as part A
Resistor (R_c)	Resistor	Basic/RESISTOR	1 kΩ
Ground	GROUND	Sources/POWER_SOURCES	None
Voltmeter (V_{oc})	XMM1	Instrument Toolbar	AC voltage
Ammeter (I_{oc})	XMM2	Instrument Toolbar	AC current
Wattmeter (P_{oc})	XWM1	Instrument Toolbar	None

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

11. After inspecting the circuit, turn the power supply on and gradually increase the supply voltage to the rated value of the LV winding connected to the power supply (keep it at 120 V for the Multisim circuit).
12. Record the voltage (V_{oc}), current (I_{oc}) and power (P_{oc}) readings of the primary winding in Table 2. Measurements should be performed on the low-voltage side of the transformer.
13. Return the supply voltage to zero and then turn the power off.
14. Find the core parameters R_c and X_m of the transformer using the following formulas:

$$\text{pf} = \cos\phi = \frac{P_{oc}}{I_{oc}\,V_{oc}} \quad (1)$$

$$I_c = I_{oc}\cos\phi \quad (2)$$

$$I_m = I_{oc}\sin\phi \quad (3)$$

$$R_c = \frac{V_{oc}}{I_c} \quad (4)$$

$$X_m = \frac{V_{oc}}{I_m} \quad (5)$$

Part C: Short-Circuit Test

15. Make sure that the power supply is switched off, and the voltage control knob is turned fully to zero.
16. Connect the circuit as shown in Figure 4. The short circuit is done using an AC ammeter which when placed across the low voltage side of the transformer, creates a short-circuit between them because of its low internal impedance.
17. To create the Multisim circuit of Figure 4c, use the same components and instruments of part B. In Multisim, set the AC power supply to 5Vrms/60Hz/0° and keep the transformer parameters at the same values given in part A.
18. After inspecting the circuit, turn the power supply on and gradually increase the supply voltage to 5% of the rated value of the HV winding or when you are getting the rated current at the secondary side.
19. Record the voltage (V_{sc}), current (I_{sc}) and power (P_{sc}) readings of the primary winding in Table 3. Measurements should be performed on the high-voltage side of the transformer.
20. Return the supply voltage to zero and then turn the power off immediately when finished to avoid damaging the transformer.
21. Find the transformer parameters R_{eq} and X_{eq} using the following formulas:

$$R_{eq} = \frac{P_{sc}}{I_{sc}^2} \tag{6}$$

$$Z_{eq} = \frac{V_{sc}}{I_{sc}} \tag{7}$$

$$X_{eq} = \sqrt{Z_{eq}^2 - R_{eq}^2} \tag{8}$$

22. Use a digital multi-meter to measure the resistance of the primary winding (R_1) and the resistance of the secondary winding (R_2), and then verify the calculated value of R_{eq}.

$$R_{eq} \cong R_1 + a^2 R_2 \tag{9}$$

where a is the turns ratio of the transformer.

Report requirements

Your lab report must include:

1. Why is it important to know the polarity of a power transformer?
2. What is the difference between copper losses and iron losses in a power transformer?
3. Determine the iron losses of the transformer used in the lab.
4. Determine the copper losses of the transformer used in the lab.
5. Draw the approximate equivalent circuit of the transformer used in the lab.

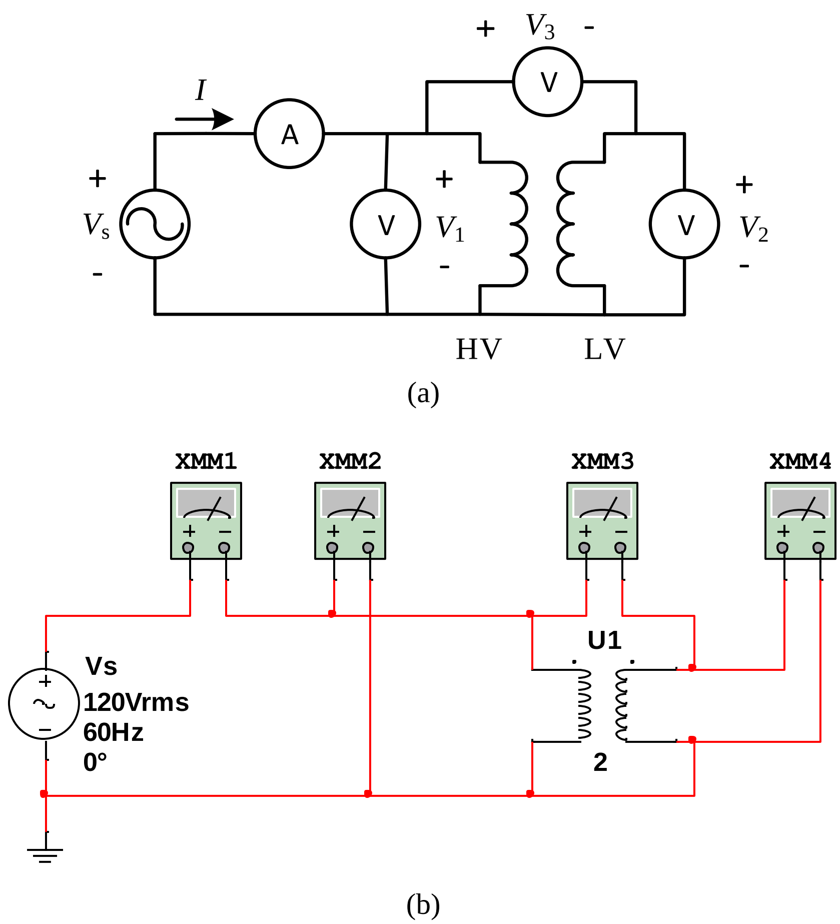


Figure 1: Polarity test connection 1.
(a) Schematic diagram and (b) Multisim circuit.

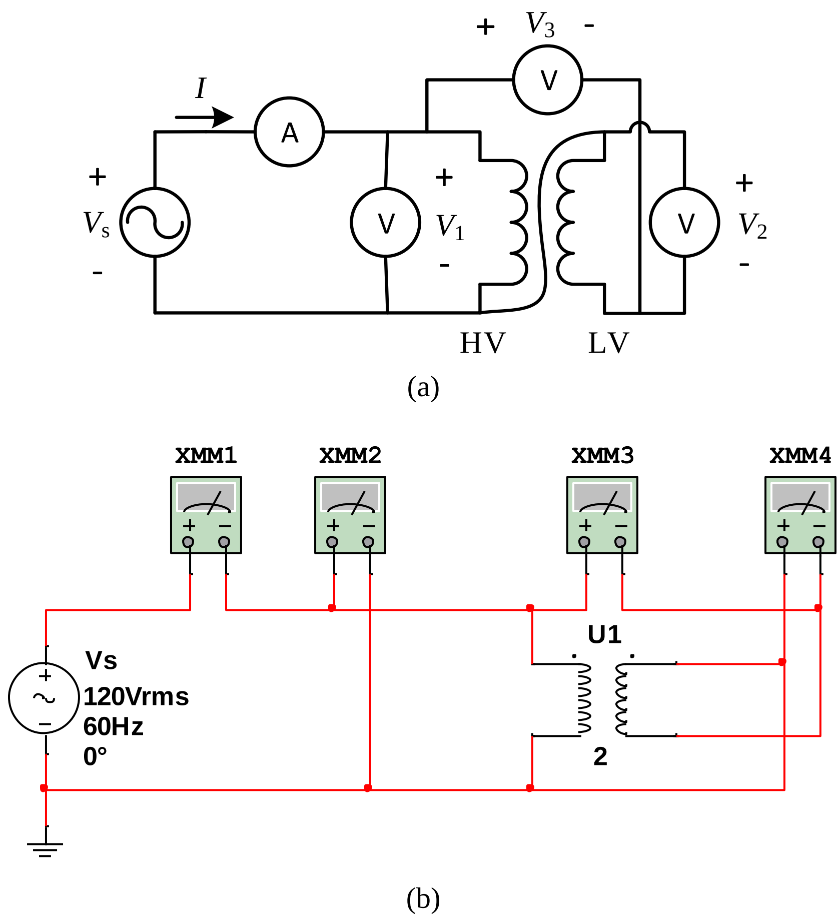
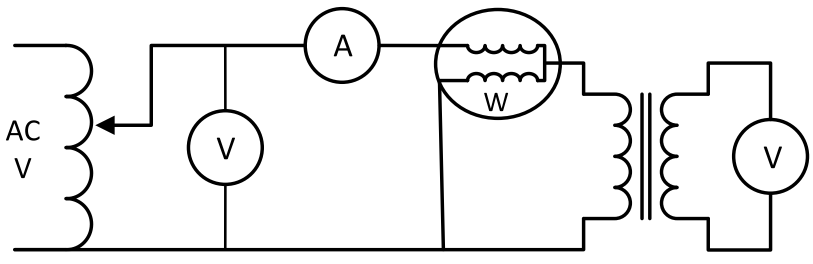
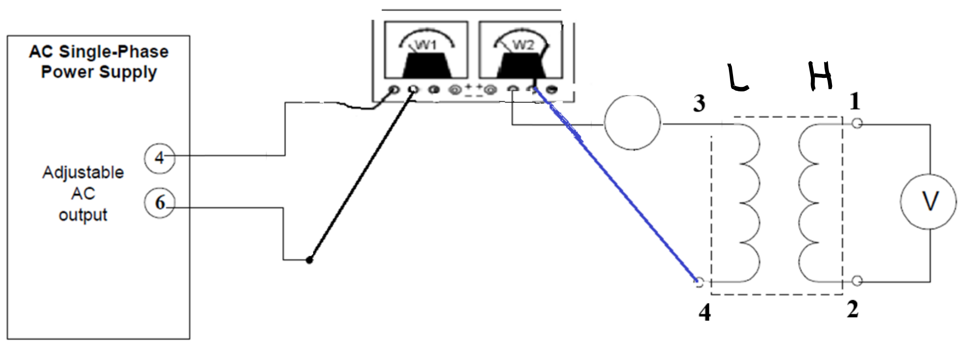


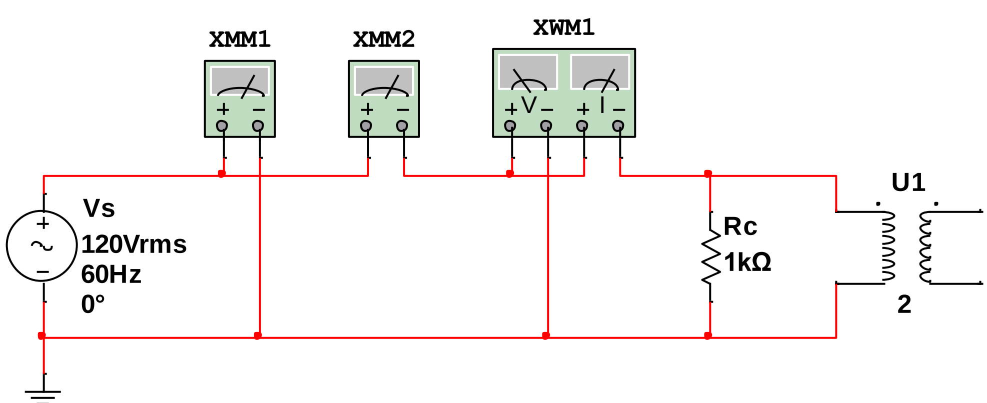
Figure 2: Polarity test connection 2.
(a) Schematic diagram and (b) Multisim circuit.



(a)



(b)



(c)

Figure 3: Open-circuit test connection.
(a) Schematic diagram, (b) circuit wiring, and (c) Multisim circuit.
(Measurements are taken on the low-voltage side with the high-voltage winding open)

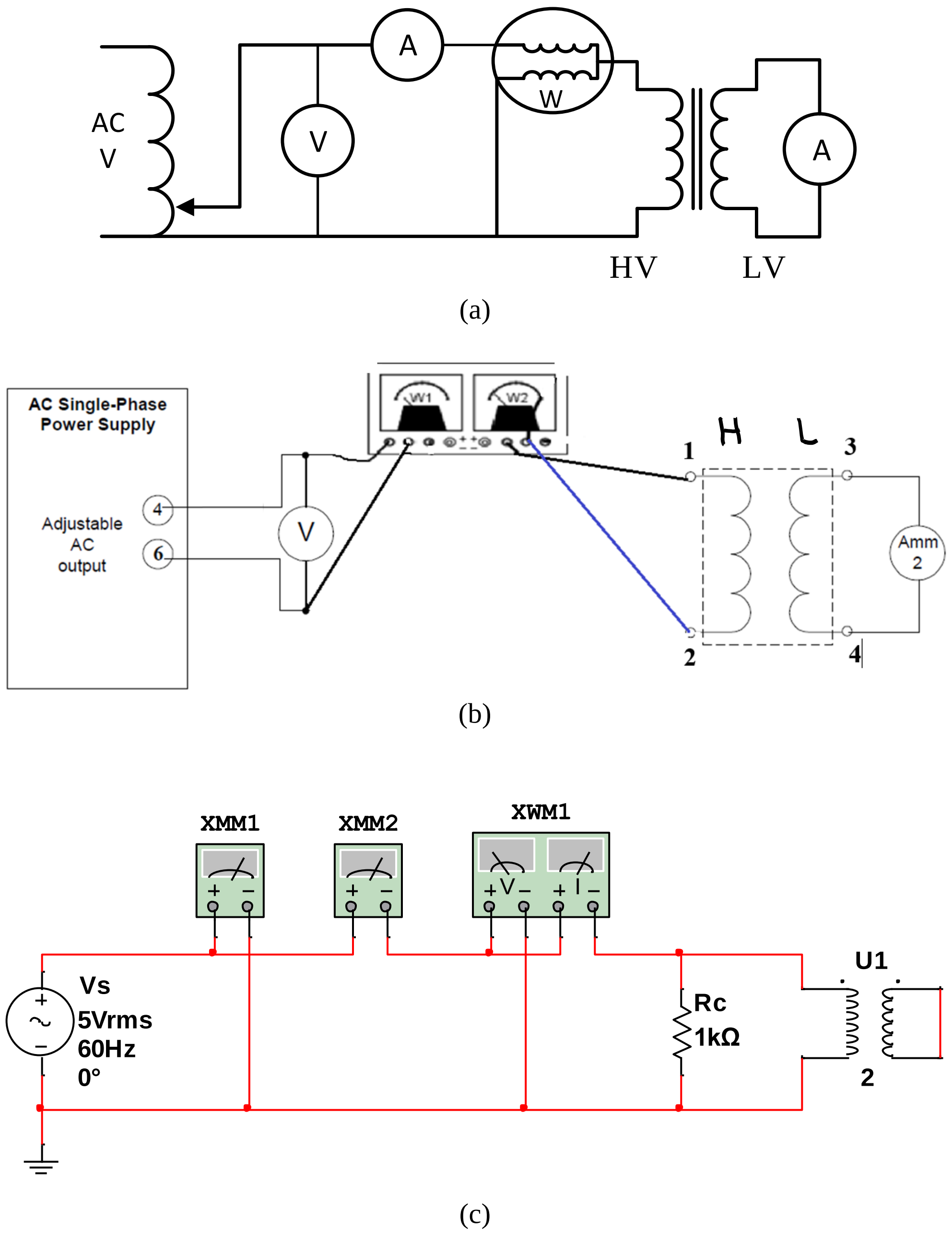


Figure 4: Short-circuit test connection.
(a) Schematic diagram, (b) circuit wiring, and (c) Multisim circuit.
(Measurements are taken on the high-voltage side with the low-voltage winding shorted)

Table 1: Transformer polarity test.

Circuit of Figure 1			
	Multisim	**Actual circuit**	**Transformer polarity**
I			
V_1			
V_2			
V_3			
Circuit of Figure 2			
I			
V_1			
V_2			
V_3			

Table 2: Open-circuit test.

Measured values		
	Multisim	**Actual circuit**
V_{oc}		
I_{oc}		
P_{oc}		
Calculated values		
pf		
ϕ		
R_{c}		
X_{m}		

Table 3: Short-circuit test.

Measured values		
	Multisim	**Actual circuit**
V_{sc}		
I_{sc}		
P_{sc}		
Calculated values		
R_{eq}		
Z_{eq}		
X_{eq}		