Experiment 45

Three-Phase Circuits

OBJECTIVE

- To study the relationship between voltage and current in three-phase circuits.
- To learn how to make delta and wye connections.
- To calculate the power in three-phase circuits.

DISCUSSION

Students tend to approach three-phase circuits with a certain apprehension which is not at all justified. Three-phase circuits, in the majority of cases, are symmetrical. They consist of three identical branches, each of which has the same impedance. Each of these branches can be treated exactly like a single-phase circuit. Consequently, three phase circuits are not necessarily harder to work with than single-phase circuits.

Unbalanced three-phase circuits represent an unnatural condition. Circuit analysis becomes somewhat difficult and will not be covered in this manual.

Three-phase systems are usually connected by either a delta or a wye configuration. Each of these connections has definite electrical characteristics and the designations delta and wye are derived from the method of connection.

EQUIPMENT REQUIRED

Refer to the Equipment Utilization Chart, in Appendix A of this manual, to obtain the list of equipment required to perform this exercise.

PROCEDURE

CAUTION!

High voltages are present in this Experiment! Do not make or modify any banana jack connections with the power on unless otherwise specified!

☐ 1. a. Using your Power Supply and AC Voltmeter connect the circuit shown in Figure 45-1.

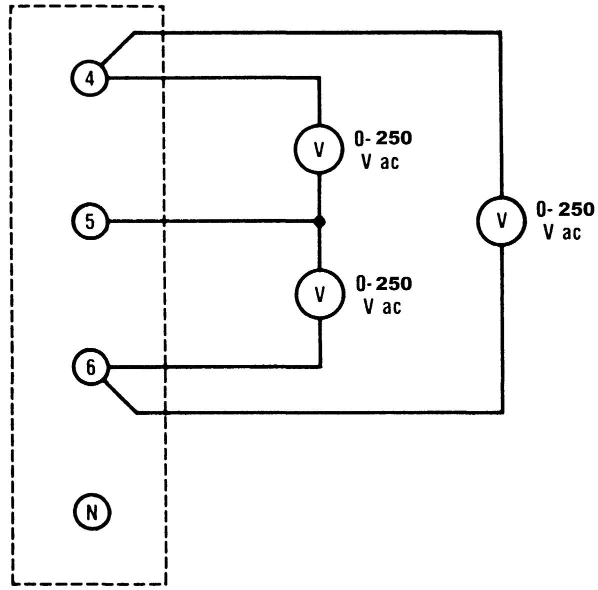

Figure 45-1.

b. Turn on the power supply and adjust the line-to-neutral voltage (as indicated by the power supply voltmeter) to exactly 120 V ac.

c. Measure and record each line-to-line voltage.

$E_{4\ to\ 5}$ = ______ V ac

$E_{5\ to\ 6}$ = ______ V ac

$E_{4\ to\ 6}$ = ______ V ac

d. Return the voltage to zero and turn off the power supply.

e. Calculate the average value of the line-to-line voltage.

____

____

____

$E_{line\text{-}to\text{-}line}$ = ______ V ac

☐ 2. a. Reconnect your three voltmeters in order to measure the voltage from each line-to-neutral.

b. Turn on the power supply and adjust the line-to-neutral voltage (as indicated by the power supply voltmeter) to exactly 120 V ac.

c. Measure and record each line-to-neutral voltage.

$E_{4\ to\ N}$ = ______ V ac

$E_{5\ to\ N}$ = ______ V ac

$E_{6\ to\ N}$ = ______ V ac

d. Return the voltage to zero and turn off the power supply.

e. Calculate the average value of the line-to-neutral voltage.

____

____

$E_{line-to-neutral}$ = ______ V ac

☐ 3. a. Calculate the ratio of the average line-to-line voltage to the average line-to-neutral voltage.

____

____

____

$E_{line-to-line}$ / $E_{line-to-neutral}$ = ______

b. Is this ratio approximately equal to the $\sqrt{3}$ **(1.73)?**

____

☐ 4. a. Repeat procedures 1 and 2 but this time measure the voltages from the fixed output terminals of your power supply.

$E_{1\ to\ 2}$ = ______ V ac $E_{1\ to\ N}$ = ______ V ac

$E_{2\ to\ 3}$ = ______ V ac $E_{2\ to\ N}$ = ______ V ac

$E_{1\ to\ 3}$ = ______ V ac $E_{3\ to\ N}$ = ______ V ac

b. Are the fixed line-to-line and the line-to-neutral voltages reasonably equal?

☐ Yes   ☐ No

c. Is the voltage between any two terminals a single-phase voltage or a three-phase voltage?

____

☐ 5. a. Using your Resistive Load, AC Ammeter and AC Voltmeter connect the WYE circuit shown in Figure 45-2. Use a separate resistance section for each of the loads R_1, R_2 and R_3. Do not connect the neutral of the resistance module to the neutral of the power supply.

b. Set each resistance section to 400 Ω.

c. Turn on the power supply and adjust for 208 V ac.

d. Measure and record the voltages across, and the currents through, the three load resistances R_1, R_2 and R_3.

E_1 = ______ V ac I_1 = ______ A ac

E_2 = ______ V ac I_2 = ______ A ac

E_3 = ______ V ac I_3 = ______ A ac

e. Return the voltage to zero and turn off the power supply.

f. Are the currents and voltages reasonably well balanced?

☐ Yes ☐ No

g. Calculate the average value of load voltage.

____

____

E_{load} = ______ V ac

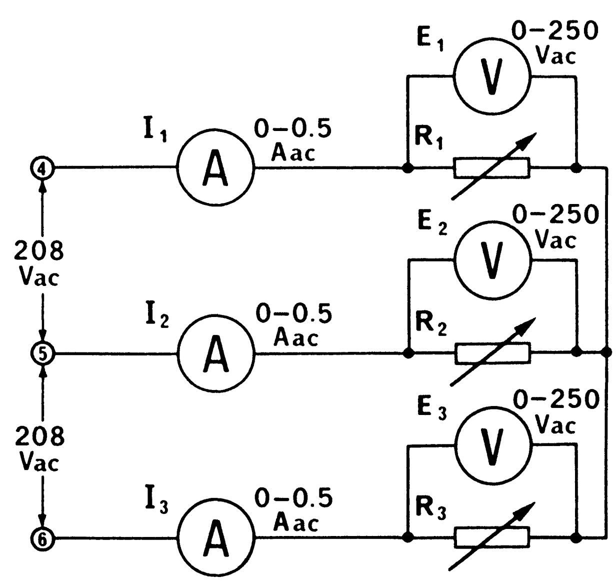

Figure 45-2.

h. What is the average value of the line-to-line voltage (from procedure 1 (e)):

$E_{line\text{-}to\text{-}line}$ = ______ V ac

i. Calculate the ratio of the average line-to-line voltage to the average load voltage.

$E_{line\text{-}to\text{-}line} / E_{load}$ = ______

j. Is this ratio approximately equal to $\sqrt{3}$ (1.73)?

____

k. Calculate the power dissipated by each load resistance.

P_1 = ______ W

P_2 = ______ W

P_3 = ______ W

l. Calculate the total three-phase power P_T.

P_T = ______ W

☐ 6. a. Connect the DELTA circuit shown in Figure 45-3.

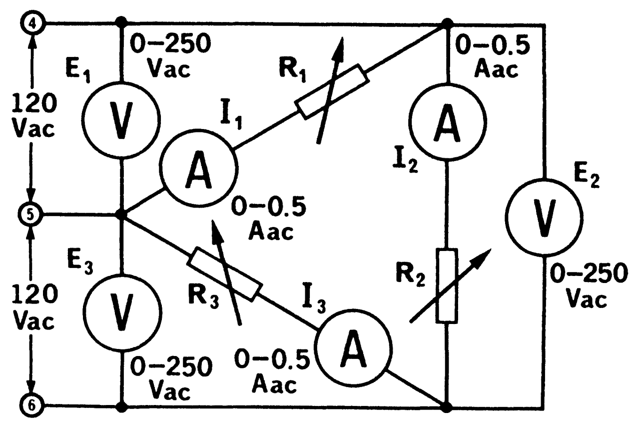

Figure 45-3.

b. Set each resistance section to 400 Ω.

c. Turn on the power supply and adjust for 120 V ac line-to-line.

d. Measure and record the voltages across, and the currents through, the three load resistances R_1, R_2 and R_3.

E_1 = ______ V ac I_1 = ______ A ac

E_2 = ______ V ac I_2 = ______ A ac

E_3 = ______ V ac I_3 = ______ A ac

e. Return the voltage to zero and turn off the power supply.

f. Are the currents and voltages reasonably well balanced?

☐ Yes ☐ No

g. Calculate the average value of load current.

____

____

____

I_{load} = ______ A ac

h. Disconnect the three current meters and insert them in series with power supply terminals 4, 5 and 6. Replace the removed current meters with connection leads as shown in Figure 45-4.

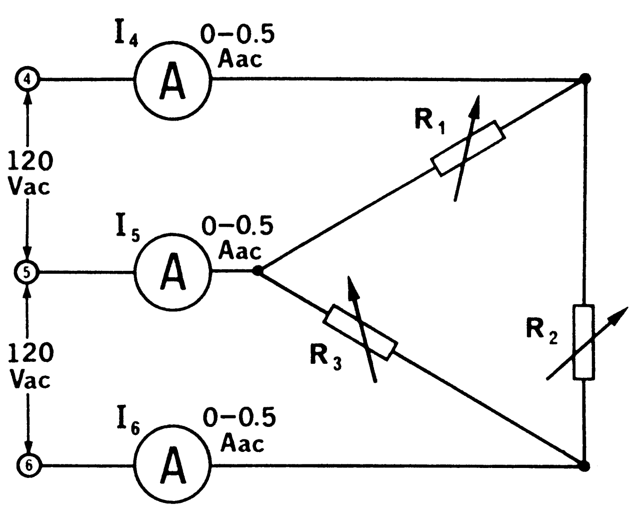

Figure 45-4.

i. Turn on he power supply and adjust for 120 V ac.

j. Measure and record the three line currents.

I_4 = ______ A ac

I_5 = ______ A ac

I_6 = ______ A ac

k. Return the voltage to zero and turn off the power supply.

l. Calculate the average value of line current.

____

____

I_{line} = ______ A ac

m. Calculate the ratio of the average line current to the average load current.

I_{line} / I_{load} = ______

n. Is this ratio approximately equal to $\sqrt{3}$ (1.73)?

☐ Yes ☐ No

o. Calculate the power dissipated by each load resistance.

P_1 = ______ W

P_2 = ______ W

P_3 = ______ W

p. Calculate the total three-phase power P_T.

P_T = ______ W

REVIEW QUESTIONS

1. In a wye connected circuit, if the line-to-line voltage is 346 V, what is the line-to-neutral voltage?

____

____

____

2. In a delta connected circuit, the current is 20 A in each resistance load. What is the line current?

3. In a wye connected circuit, the current is 10 A in each resistance load. What is the line current?

4. Three loads each having a resistance of 10 Ω are connected in wye. The total three-phase power is 3000 W. What is the line-to-line voltage of the power supply?

5. Three resistors each having a resistance of 11 Ω are connected in delta across a 3φ 440 V line.

   a) What is the line current?

   b) What is the total three-phase power?

Experiment 46

Three-Phase Watts, Vars, and Volt-Amperes

OBJECTIVE

- To determine the apparent, active and reactive power in three-phase circuits.
- To calculate the power factor in three-phase circuits.

DISCUSSION

In Experiment 45 you calculated active power in three-phase circuits. You will now learn that reactive power (either capacitive or inductive) can also be calculated in a similar manner. It therefore follows that apparent power and power factor can also be calculated for balanced three-phase circuits.

EQUIPMENT REQUIRED

Refer to the Equipment Utilization Chart, in Appendix A of this manual, to obtain the list of equipment required to perform this exercise.

PROCEDURE

CAUTION!

High voltages are present in this Experiment! Do not make or modify any banana jack connections with the power on unless otherwise specified!

☐ 1. a. Using your Inductive Load, Power Supply, AC Ammeter, and AC Voltmeter, connect the WYE circuit shown in Figure 46-1. Use a separate inductance section for each of the loads L_1, L_2 and L_3. Do not connect the neutral of the inductance module to the neutral of the power supply.

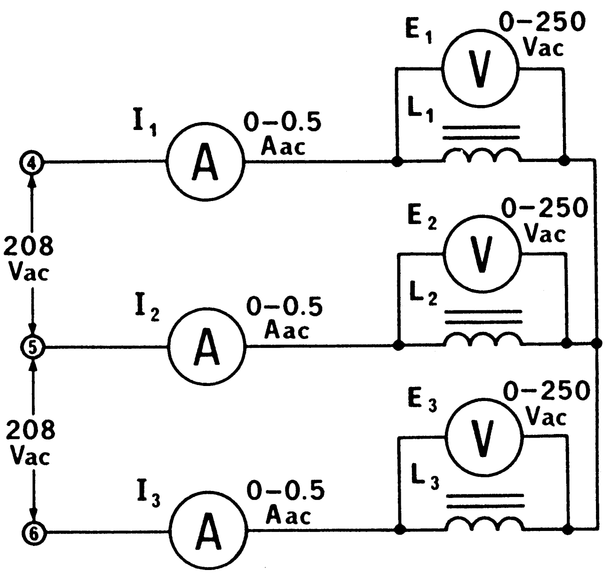

Figure 46-1.

b. Set each inductance section for a reactance of 300 Ω.

c. Turn on the power supply and adjust for 208 V ac.

d. Measure and record the voltages across, and the currents through, the three inductive loads L_1, L_2 and L_3.

E_1 = ______ V ac I_1 = ______ A ac

E_2 = ______ V ac I_2 = ______ A ac

E_3 = ______ V ac I_3 = ______ A ac

e. Return the voltage to zero and turn off the power supply.

f. Are the currents and voltages reasonably well balanced?

☐ Yes ☐ No

g. What is the average value of line current?

___

I_{line} = ______ A ac

h. What is the value of the line-to-line voltage?

$E_{line-to-line}$ = ______ V ac

i. Calculate the reactive power for each of the inductive loads.

$E_1 \times I_1$ = ______ var (L_1)

$E_2 \times I_2$ = ______ var (L_2)

$E_3 \times I_3$ = ______ var (L_3)

j. Calculate the total three-phase reactive power using the sum of (I)

$var_{L1} = var_{L2} = var_{L3}$ = ______ var

k. Calculate the total three-phase reactive power using the line values from (g) and (h).

$E_{line\text{-}to\text{-}line} \times I_{line} \times 1.73$ = ______ var

l. Does the total reactive power found in (j) compare well with the total found in (k)? ______

☐ 2. a. Using your Resistive Load add a resistance section in series with each of the inductive loads as shown in Figure 46-2. Do not connect the neutral of the resistance module to the neutral of the power supply.

b. Set each resistance section to 400 Ω while maintaining each inductance section at a reactance of 300 Ω.

c. Turn on the power supply and adjust for 208 V ac.

d. Measure and record the line currents and the voltages across each of the inductive loads L_1, L_2 and L_3.

E_1 = ______ V ac I_1 = ______ A ac

E_2 = ______ V ac I_2 = ______ A ac

E_3 = ______ V ac I_3 = ______ A ac

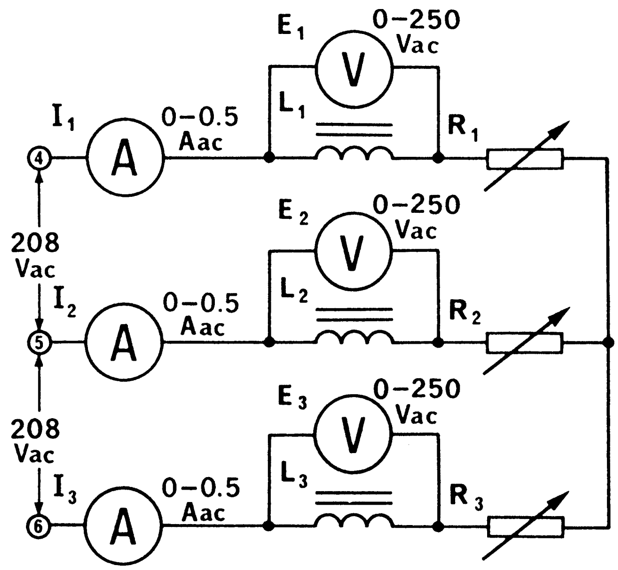

Figure 46-2.

e. Return the voltage to zero and turn off the power supply. Reconnect each of the voltmeters as shown in Figure 46-3.

f. Turn on the power supply and adjust for 208 V ac.

g. Measure and record the voltages across each of the resistive loads R_1, R_2 and R_3.

E_4 = ______ V ac

E_5 = ______ V ac

E_6 = ______ V ac

h. Return the voltage to zero and turn off the power supply.

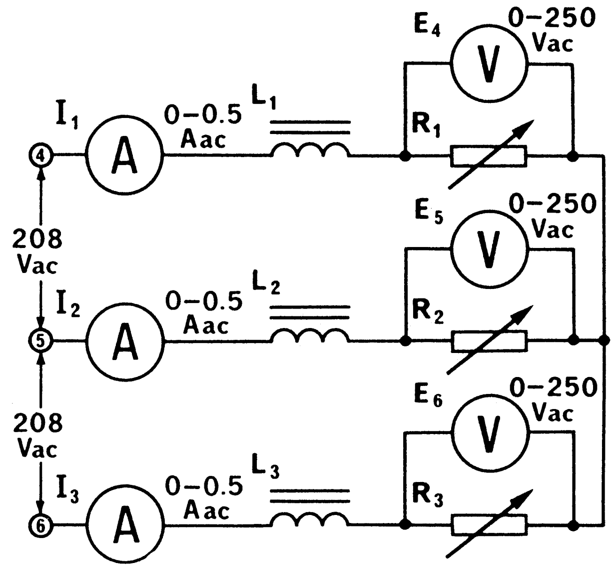

Figure 46-3.

i. Calculate the total active power dissipated in the three resistors using the results of (d) and (g)

E_4 ______ x I_1 ______ = ______ W

E_5 ______ x I_2 ______ = ______ W

E_6 ______ x I_3 ______ = ______ W

Total 3φ active power = ______ W

j. Calculate the total reactive power in the three inductors using the results of (d).

E_1 ______ x I_1 ______ = ______ var

E_2 ______ x I_2 ______ = ______ var

E_3 ______ x I_3 ______ = ______ var

Total 3φ reactive power = ______ var

k. Calculate the total 3φ apparent power using the results of (l) and (j).

(W ______ $)^2$ + (var ______ $)^2$ = (______ VA$)^2$

Total 3φ apparent power = ______ VA

l. Calculate the total 3φ apparent power using the formula:

$E_{line\text{-}to\text{-}line}$ x I_{line} x 1,73 = ______ VA

m. Does the total apparent power found in (k) compare well with the total found in (l)?

☐ Yes ☐ No

n. Calculate the power factor using the total 3φ active and apparent powers:

W ______ / VA ______ = ______

REVIEW QUESTIONS

1. A three-phase motor draws a current of 10 A on a 440 V line, and its power factor is 80 percent.

a) Calculate the apparent power:

____

____

S = ______ VA

b) Calculate the active power:

____

____

P = ______ W

c) Calculate the reactive power:

____

____

Q = ______ var

2. A 3φ transformer delivers 120 kVA to a 3φ load at a line-to-line voltage of 2400 V. Calculate the current per line:

____

____

I = ______ A

Experiment 47

Three-Phase Power Measurement

OBJECTIVE

- To measure power in a three-phase circuit using the two wattmeter method.
- To determine the active and reactive power, and the power factor of a three-phase system.

DISCUSSION

A wattmeter, used for measuring power, is an electrodynamometer type instrument. This meter usually has two coils, one fixed, the other capable of turning in the magnetic field of the first. The fixed coil is connected in series with the line so as to carry the line current. The movable coil, which is of high resistance, is connected across the load (that portion of the circuit in which the power is to be measured). The small current in the coil is, therefore, proportional to the voltage between these terminals. This coil turns against a helical spring, and, since torque is proportional to the product of the values of the currents in the two coils, it is proportional to the product of the current I and the voltage E. The scale may, therefore, be graduated directly in watts.

See Figure 47-1. The fixed current coil A si in series with the load, and the movable voltage coil V is across load. The resulting deflection is directly proportional to the active power delivered to the load.

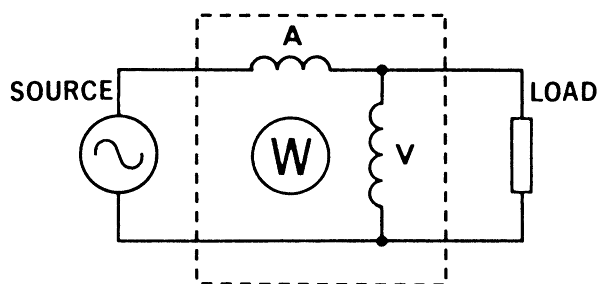

Figure 47-1.

If the power delivered by a three-phase, four-wire system is to be measured, we simply use three single-phase wattmeters connected as shown in Figure 47 -2 and take the sum of their individual readings.

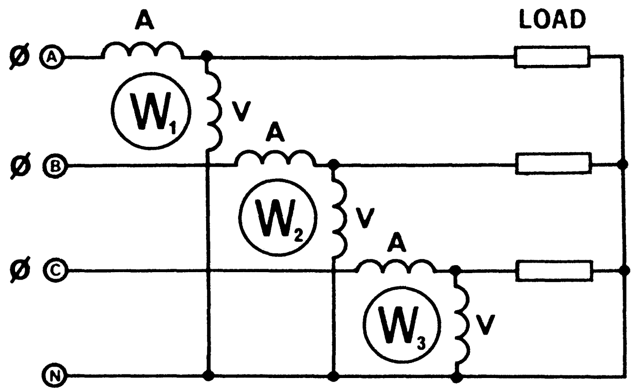

Figure 47-2.

However, on a three-phase, three-were system, only two single phase wattmeters are required to measure the power. See Figure 47-3. The two current coils carry the current in two of the lines and the two voltage coils are connected to the one remaining line. Note that no connection is made to the neutral. The total three-phase power is equal to the algebraic sum of the two wattmeter readings.

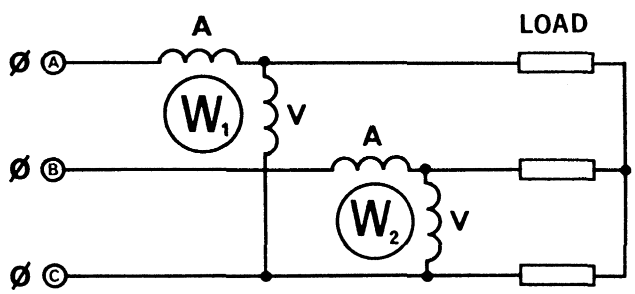

Figure 47-3.

For balanced loads at unity power factor, the indications of the two wattmeters will be identical. When the load power factor is 50 percent, one meter will indicate zero and the other will indicate the total three-phase power. At power factors between 50 and 100 percent, one meter will indicate higher power than the other. At power factors lower than 50 percent, the indication on one of the meters will be negative and the total three-phase power will be the power indicated by one meter less the negative indicate power of the other. At zero power factor, the wattmeters will have identical indications but of opposite signs, indicating zero power. Thus, there is a definite ratio of meter indications for each value of circuit power factor.

Your Three-Phase Wattmeter is provided with two wattmeters and is pre-wired so that you only have to connect the three-phase lines to input terminals 1, 2 and 3. The load connects to the output terminals 4, 5 and 6. Polarity-marked switches show whether the meter indications are positive or negative.

EQUIPMENT REQUIRED

Refer to the Equipment Utilization Chart, in Appendix A of this manual, to obtain the list of equipment required to perform this exercise.

PROCEDURE

CAUTION!

High voltages are present in this Experiment! Do not make or modify any banana jack connections with the power on unless otherwise specified!

☐ 1. Using your Three-Phase Wattmeter, Power Supply, Resistive Load, AC Ammeter, and AC Voltmeter, connect the circuit shown in Figure 47-4.

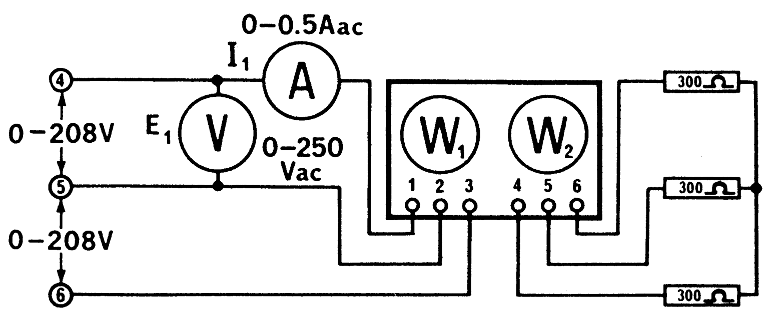

Figure 47-4.

☐ 2. a. Set the resistance of each section to 300 Ω.

b. Turn on the power supply and adjust the line voltage to 208 V ac as indicated by voltmeter V_1.

c. Measure and record the line current I_1 and the power indicated by W_1 and W_2.

I_1 = ______ A ac

P_1 = ______ W

P_2 = ______ W

d. Return the voltage to zero and turn off the power supply.

☐ 3. a. From the results of (c) calculate the 3φ:

Apparent power (E_1 x I_1 x 1,73) ____________________________________

____

S = ______ VA

Active power ____________________________________

____

P = ______ W

Power factor ____________________________________

____

PF = ______

b. Is the power factor close to unity? Explain.

☐ Yes ☐ No

____

☐ 4. a. Replace the resistance module with the capacitance module.

b. Set the reactance of each section to 300 Ω.

c. Repeat procedure 2.

I_1 = ______ A ac

P_1 = ______ W

P_2 = ______ W

$P_1 + P_2$ = ______ W

d. From the results of (c) calculate the 3φ:

Apparent power ____________________________________

____

S = ______ VA

Active power ____________________________________

____

P = ______ W

Power factor ____

____

PF = ______

Reactive power ____

____

Q = ______ var

☐ 5. a. Replace the capacitance module with the inductance module.

b. Set the reactance of each section to 300 Ω.

c. Repeat procedure 2.

I_1 = ______ A ac

P_1 = ______ W

P_2 = ______ W

$P_1 + P_2$ = ______ W

d. From the results of (c) calculate the 3φ:

Apparent power ____

____

S = ______ VA

Active power ____

____

P = ______ W

Power factor ____

____

PF = ______

Reactive power ____

____

Q = ______ var

REVIEW QUESTIONS

1. If two wattmeters are used to measure total power in a three-phase three-wire system does each meter measure single-phase power? Explain.

   ☐ Yes ☐ No

   ____

   ____

2. What is the significance of a negative indication on a wattmeter?

   ____

   ____

3. Would only one wattmeter be needed to measure the total three-phase power on a balanced three-phase four-wire system? Explain.

   ☐ Yes ☐ No

   ____

   ____

4. Must you use two wattmeters to measure the total three-phase power on a balanced three-phase three-wire system? Explain.

   ☐ Yes ☐ No

   ____

   ____

5. Can a wattmeter that has current through its current coil and a potential across its voltage coil, indicate zero? Explain

   ☐ Yes ☐ No

   ____

   ____

Experiment 48

Three-Phase Transformer Connections

OBJECTIVE

- To connect transformers in delta and wye configurations.
- To study the current and voltage relationships.

DISCUSSION

The three-phase transformer may be a single transformer or three separate single-phase transformers connected in delta or wye. Sometimes only two transformers are used.

Commercial three-phase voltage from the power lines is generally 208 V, and the standard values of single-phase voltage (120 V) can be supplied from the line as shown in Figure 48-1.

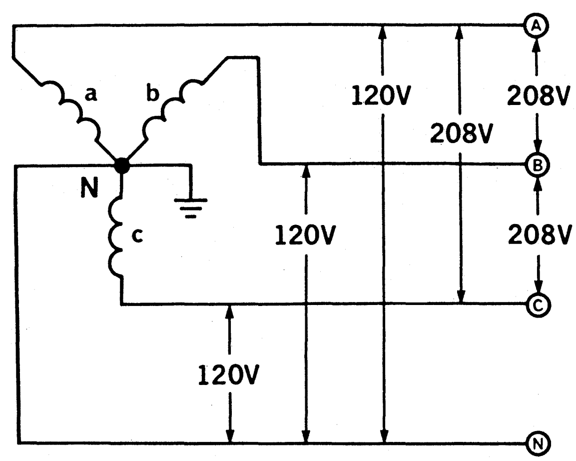

Figure 48-1.

The windings a, b and c, represent the three wye-connected transformer secondaries. The three-phase lines are designated A, B and C, and the single-phase connections are from A, B or C to neutral (ground). Three-phase transformers must be properly connected to these lines in order to operate. Four of the most widely used transformer connections (see Figure 48-2) are:

a) Primary windings in delta, secondary windings in delta, or delta-delta (Δ - Δ)

b) Primary windings in wye, secondary windings in wye, or wye-wye (Y - Y)

c) Primary windings in wye, secondary windings in delta, or wye-delta (Y - Δ)

d) Primary windings in delta, secondary windings in wye, or delta-wye (Δ - Y)

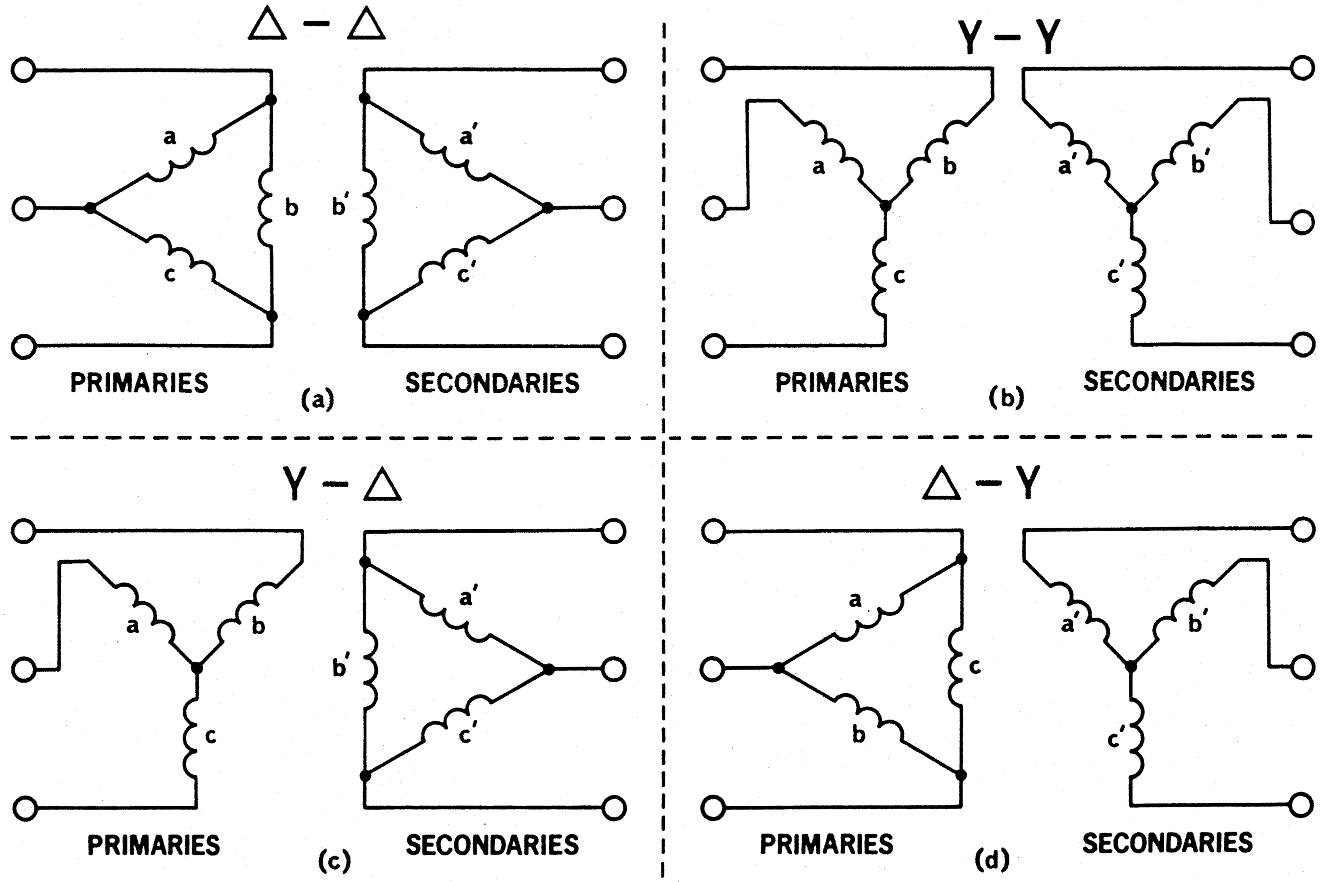

Figure 48-2.

Of these four combinations, the one used most extensively is the last one listed, the delta-wye.

Regardless of what method of connection is used, the windings must be connected in the proper phase relationships. To determine these in a wye-connected secondary, the voltage is measured across two windings as shown in Figure 48-3 (a). The voltage A to B should be equal to $\sqrt{3}$ times the voltage across either winding. If the voltage is equal to that across either winding, then one of the windings must be reversed. The third winding c is then connected as shown in Figure 48-3 (b), and the voltage C to A or B should also equal $\sqrt{3}$ times the voltage across any one winding. If not, the winding c must be reversed.

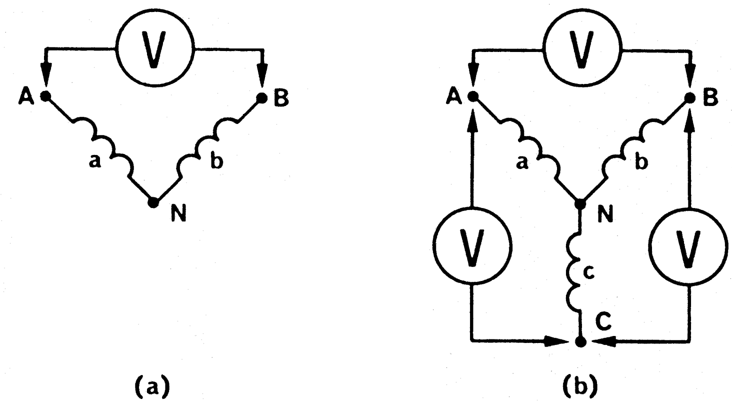

Figure 48-3.

To determine the proper phase relationships in a delta-connected secondary, the voltage is measured across two windings as shown in Figure 48-4 (a). The voltage A to C should equal the voltage across either winding. If not, one of the windings must be reversed. The winding c is then connected as shown in Figure 48-4 (b), and the voltage across the three windings C^1 to C should equal zero. If not, winding c must be reversed. The open ends (C^1 & C) are then joined and the transformer has the proper phase relationships for delta connection as shown in Figure 48-4 (c).

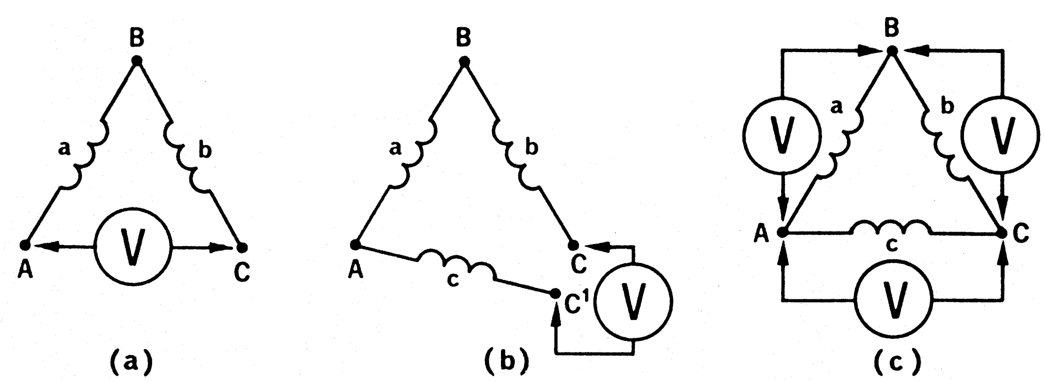

Figure 48-4.

CAUTION!

The delta should never be closed until a test is first made to determine that the voltage within the delta is zero. If not, and the delta is closed on itself, the resulting current will be of short-circuit magnitude, with resulting damage to the transformers.

The wye-wye connection has the same volts per turn ratio between primary and secondary windings as that of an individual single-phase transformer. The voltage output of the delta-delta is also dependent on the turn ratio of the primary and secondary windings. The delta-wye connection has a higher 3φ voltage ratio than either the delta-delta or wye-wye connection. This is because the voltage across any two windings of the wye secondary is equal to $\sqrt{3}$ times the 3φ primary line voltage. The wye-delta connection is the opposite of the delta-wye connection.

EQUIPMENT REQUIRED

Refer to the Equipment Utilization Chart, in Appendix A of this manual, to obtain the list of equipment required to perform this exercise.

PROCEDURE

CAUTION!

High voltages are present in this Experiment! Do not make any connections with the power on! The power should be turned off after completing each individual measurement!

☐ 1. a. The circuit shown in Figure 48-5 has three transformers connected in a ______ ______ configuration.

b. Calculate the expected voltages and record the values in the spaces provided.

c. Connect the circuit as shown.

d. Turn on the power supply and slowly increase the output for a line-to-line voltage of 120 V ac.

e. Measure the indicated voltages and record the values in the spaces provided.

f. Return the voltage to zero and turn off the power supply. Repeat (d), (e) and (f) until all of the listed voltages have been measured.

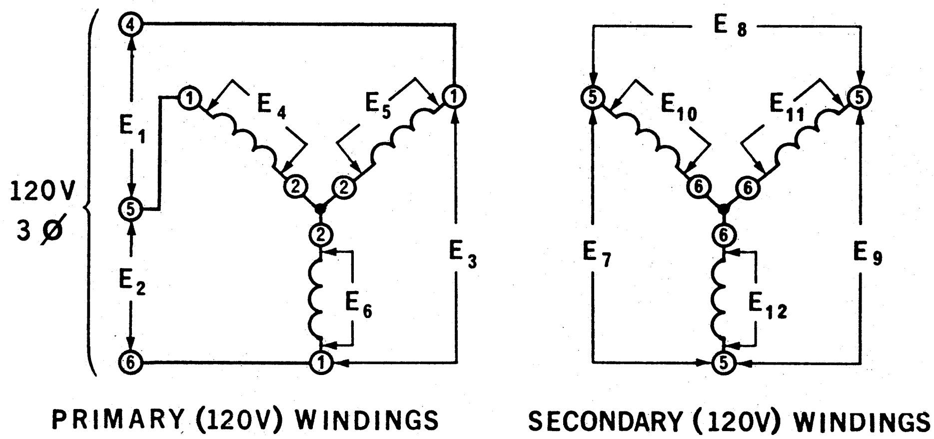

Figure 48-5.

CALCULATED VALUES			MEASURED VALUES		
E_1 = ______ V,	E_2 = ______ V,	E_3 = ______ V	E_1 = ______ V,	E_2 = ______ V,	E_3 = ______ V
E_4 = ______ V,	E_5 = ______ V,	E_6 = ______ V	E_4 = ______ V,	E_5 = ______ V,	E_6 = ______ V
E_7 = ______ V,	E_8 = ______ V,	E_9 = ______ V	E_7 = ______ V,	E_8 = ______ V,	E_9 = ______ V
E_{10} = ______ V,	E_{11} = ______ V,	E_{12} = ______ V	E_{10} = ______ V,	E_{11} = ______ V,	E_{12} = ______ V

☐ 2. a. The circuit shown in Figure 48-6 has three transformers connected in a ______ ______ configuration.

b. Calculate the expected voltages and record the values in the spaces provided.

c. Connect the circuit as shown.

d. Turn on the power supply and slowly increase the output for a line-to-line voltage of 90 V ac.

e. Measure the indicated voltages and record the values in the spaces provided.

f. Return the voltage to zero and turn off the power supply. Repeat (d), (e) and (f) until all of the listed voltages have been measured.

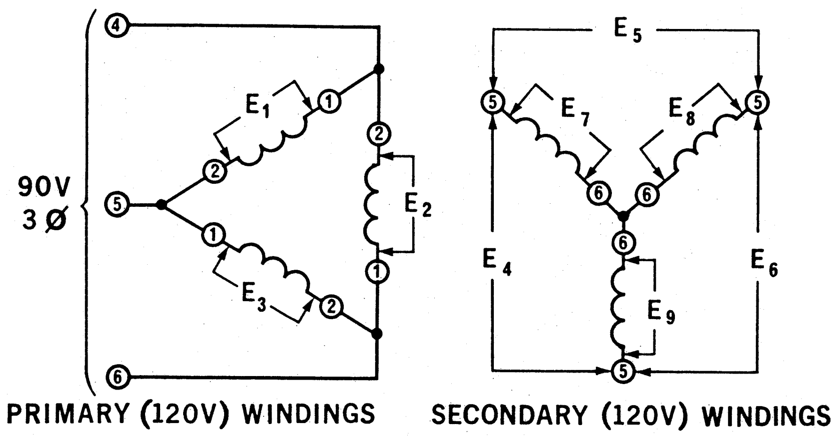

Figure 48-6.

CALCULATED VALUES			MEASURED VALUES		
E_1 = ______ V,	E_2 = ______ V,	E_3 = ______ V	E_1 = ______ V,	E_2 = ______ V,	E_3 = ______ V
E_4 = ______ V,	E_5 = ______ V,	E_6 = ______ V	E_4 = ______ V,	E_5 = ______ V,	E_6 = ______ V
E_7 = ______ V,	E_8 = ______ V,	E_9 = ______ V	E_7 = ______ V,	E_8 = ______ V,	E_9 = ______ V

☐ 3. a. The circuit shown in Figure 48-7 has three transformers connected in a ______ ______ configuration.

b. Calculate the expected voltages and record the values in the spaced provided.

c. Connect the circuit as shown. Open the delta connected secondary at point “A” and place a voltmeter across the opened loop.

d. Turn on the power supply and slowly increase the output voltage. The voltmeter across the open delta, at point “A”, should not indicate any appreciable voltage if your delta connections are phased properly. Some small voltage will be present because the normal 3φ supply does not have all 3φ voltages equal and the three transformers also have small differences.

e. Return the voltage to zero and turn off the power supply.

f. Remove the voltmeter and close the delta loop at point “A”.

g. Turn on the power supply and slowly increase the output for a line-to-line voltage of 120 V ac.

h. Measure the indicated voltages and record the values in the spaces provided.

i. Return the voltage to zero and turn off the power supply. Repeat (g), (h) and (I) until all of the listed voltages have been measured.

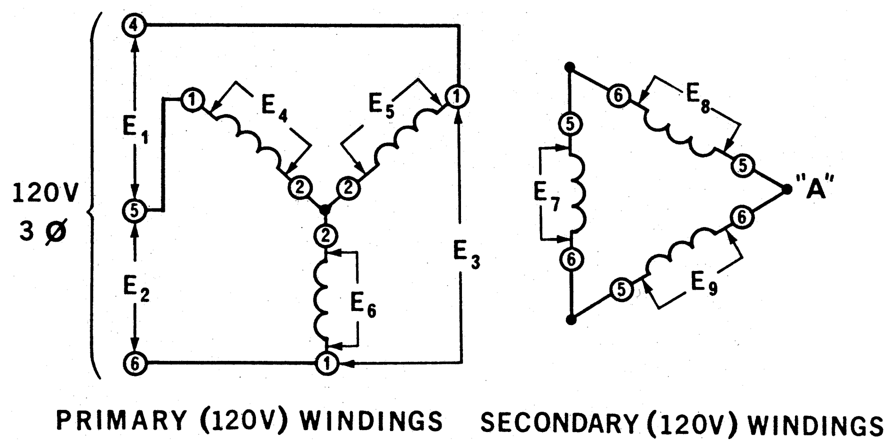

Figure 48-7.

CALCULATED VALUES			MEASURED VALUES		
E_1 = ______ V,	E_2 = ______ V,	E_3 = ______ V	E_1 = ______ V,	E_2 = ______ V,	E_3 = ______ V
E_4 = ______ V,	E_5 = ______ V,	E_6 = ______ V	E_4 = ______ V,	E_5 = ______ V,	E_6 = ______ V
E_7 = ______ V,	E_8 = ______ V,	E_9 = ______ V	E_7 = ______ V,	E_8 = ______ V,	E_9 = ______ V

☐ 4. a. The circuit shown in Figure 48-8 has three transformers connected in a ______ ______ configuration.

b. Calculate the expected voltages and record the values in the spaced provided.

c. Connect the circuit as shown. Open the delta connected secondary at point “A” and place a voltmeter across the opened loop.

d. Turn on the power supply and slowly increase the output voltage. The voltmeter across the open delta, at point “A”, should not indicate any appreciable voltage if your delta connections are phased properly.

e. Return the voltage to zero and turn off the power supply.

f. Remove the voltmeter and close the delta loop at point “A”.

g. Turn on the power supply and slowly increase the output for a line-to-line voltage of 120 V ac.

h. Measure the indicated voltages and record the values in the spaces provided.

i. Return the voltage to zero and turn off the power supply. Repeat (g), (h) and (I) until all of the listed voltages have been measured.

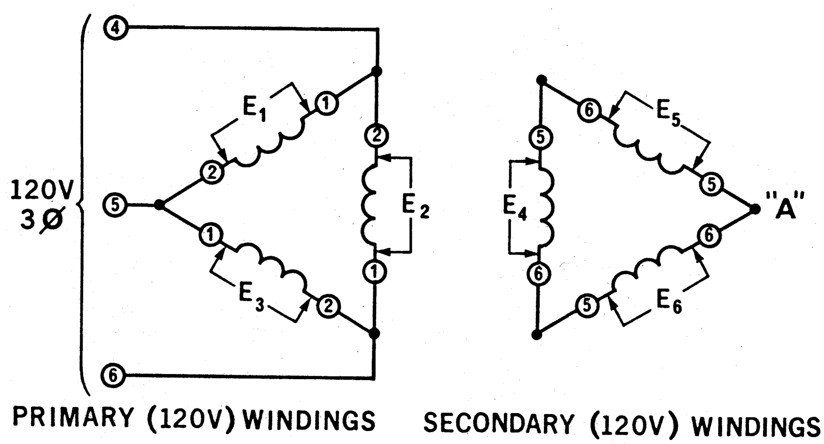

Figure 48-8.

CALCULATED VALUES			MEASURED VALUES		
E_1 = ______ V,	E_2 = ______ V,	E_3 = ______ V	E_1 = ______ V,	E_2 = ______ V,	E_3 = ______ V
E_4 = ______ V,	E_5 = ______ V,	E_6 = ______ V	E_4 = ______ V,	E_5 = ______ V,	E_6 = ______ V

☐ 5. a. The circuit shown in Figure 48-9 has two transformers connected in a open-delta configuration.

b. Calculate the expected voltages and record the values in the spaces provided.

c. Connect the circuit as shown.

d. Turn on the power supply and slowly increase the output for a line-to-line voltage of 120 V ac.

e. Measure the indicated voltages and record the values in the spaces provided.

f. Return the voltage to zero and turn off the power supply. Repeat (d), (e) and (f) until all of the listed voltages have been measured.

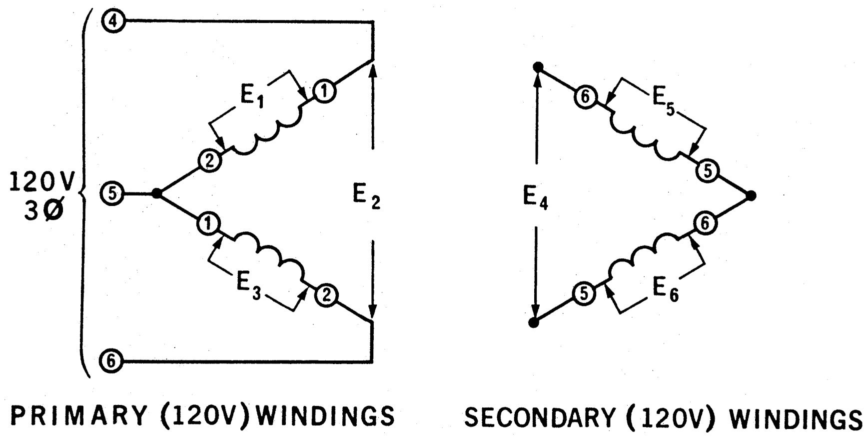

Figure 48-9.

CALCULATED VALUES			MEASURED VALUES		
E_1 = ______ V,	E_2 = ______ V,	E_3 = ______ V	E_1 = ______ V,	E_2 = ______ V,	E_3 = ______ V
E_4 = ______ V,	E_5 = ______ V,	E_6 = ______ V	E_4 = ______ V,	E_5 = ______ V,	E_6 = ______ V

REVIEW QUESTIONS

1. Compare the results of procedure 4 and 5.

   a) Is there a voltage difference in a delta-delta vs open-delta configuration?

   ☐ Yes ☐ No

   b) Is the VA rating of the delta-delta configuration the same as for the open-delta configuration? Explain.

   ☐ Yes ☐ No

   ____

   ____

   c) If the current ratings for each winding were increased, could the open-delta configuration work as well as the delta-delta configuration? Explain.

   ☐ Yes ☐ No

   ____

   ____

   ____

2. If each transformer has a capacity of 60 kVA what total 3φ power can be obtained in each of the five types of configurations.

   a) wye-wye ____________________

   ____

   ____

   ____________________ = ____________ kVA

   b) wye-delta ____________________

   ____

   ____

   ____________________ = ____________ kVA

   c) delta-wye ____________________

   ____

   ____

   ____________________ = ____________ kVA

   d) delta-delta ____________________

   ____

   ____

   ____________________ = ____________ kVA

   e) open-delta ____________________

   ____

   ____

   ____________________ = ____________ kVA

3. If one of the secondary winding polarities were reversed, in procedure 1:

   a) Would there be a dead short?

   ☐ Yes ☐ No

   b) Would the transformer heat up?

   ☐ Yes ☐ No

c) Would the primary voltages become unbalanced?

☐ Yes ☐ No

d) Would the secondary voltages become unbalanced?

☐ Yes ☐ No

4. If one of the secondary winding polarities were reversed in procedure 4:

a) Would there be a dead short?

☐ Yes ☐ No

b) Would the transformer heat up?

☐ Yes ☐ No

c) Would the primary voltages become unbalanced?

☐ Yes ☐ No

d) Would the secondary voltages become unbalanced?

☐ Yes ☐ No