Lesson A4–5

Comparing Single-Phase and Three-Phase Systems

Unit A. Mechanical Systems and Technology

Problem Area 4. Electrical Systems

Lesson 5. Comparing Single-Phase and Three-Phase Systems

New Mexico Content Standard:

Pathway Strand: Power, Structural and Technical Systems

Standard: **X:** Use available power source to plan and apply control systems.

Benchmark: **X-A:** Measure with selected instruments to demonstrate knowledge of basic electricity.

Performance Standard: **1.** Show proficiency in use of various meters. **2.** Discuss importance of and techniques for grounding. **3.** Show understanding of codes and regulations.

Student Learning Objectives. Instruction in this lesson should result in students achieving the following objectives:

1. Describe the primary difference between single-phase and three-phase current.
2. Describe advantages and disadvantages of three-phase current as compared to single-phase current.
3. Explain the differences between delta-connected, open delta-connected, and wye-connected transformers and their resulting voltages.

List of Resources.

The following resources may be useful in teaching this lesson:

Recommended Resources. One of the following resources should be selected to accompany the lesson:

McKenzie, Bruce A., and Gerald L. Zachariah. *Understanding and Using Electricity.* Danville, Illinois: Interstate Publishers, Inc., 1982. (Textbook, Chapter 1)

VAS U3038. *Using Three-Phase Electrical Power On The Farm.* Urbana, Illinois: Vocational Agriculture Service.

Other Resources. The following resources will be useful to students and teachers:

Johnson, Donald M., et al. *Mechanical Technology in Agriculture.* Danville, Illinois: Interstate Publishers, Inc., 1998. (Textbook, Chapter 2)

Surbrook, Truman C., and Ray C. Mullin. *Agricultural Electrification*. Cincinnati, Ohio: South-Western Publishing Co., 1985. (Textbook Unit 3)

List of Equipment, Tools, Supplies, and Facilities

Writing surface

Overhead projector

Transparencies from attached masters

Copies of student lab sheet

Terms.

The following terms are presented in this lesson (shown in bold italics):

Delta-connected transformers

Open delta-connected transformers

Wye-connected transformers

Interest Approach.

Use an interest approach that will prepare the students for the lesson. Teachers often develop approaches for their unique class and student situations. A possible approach is included here.

Ask students if any of them have three-phase power at home. If so, ask those students what they use their three-phase power for. Ask them if they know how three-phase power is different from the more traditional single-phase power. This should generate some interest in finding out more about three-phase power and how and where it might be used. Consider having someone from the local power company come to speak to the class about three-phase power and cost differences as well as advantages and disadvantages of its use.

Summary of Content and Teaching Strategies

Objective 1: Describe the primary difference between single-phase and three-phase current.

Anticipated Problem: How is three-phase current different from single-phase current?

I. Electrical service can be available in single-phase current or three-phase current. Many years ago, single-phase current was sufficient to do the work that was necessary on nearly all farms. However, as farm sizes increased and the size of workloads for electric motors increased, single-phase current was not enough to meet the load demands. As a result, three-phase current at the local farm level became a viable solution for several farms.

A. With single-phase current, the voltage rises to a peak in one direction of flow, subsides to zero, reverses, rises to a peak in the opposite direction, subsides to zero, and so on. The cycle repeats itself 60 times every second, which is where we get the term 60-cycle or 60-hertz alternating current. Single-phase current requires the use of one transformer.

B. In the case of three-phase current, the same pattern exists, except that there are three separate and distinct single-phase currents, which are combined so they can be transmitted over three or four wires. The three currents rise to a peak in one direction, subside, reverse, and so on; however they do not peak at the same time. Each phase reaches its peak 120 degrees apart from the others. Three-phase current requires two or three transformers.

Review the concept of single-phase, 60-hertz current, using the Sine wave theory on TM: A4–5A. Build on that concept to introduce the idea of three-phase current. Use TM: A4–5A to illustrate how single-phase current and three-phase current are different.

Objective 2: Describe advantages and disadvantages of three-phase current as compared to single-phase current.

Anticipated Problem: What are some advantages and disadvantages of three-phase current as compared to single-phase current?

II. As with most choices, there are advantages and disadvantages that someone must consider. In order to choose three-phase current, one must know that the advantages outweigh the disadvantages.

A. Three-phase current offers a steadier source of power. Magnetic force which causes motor rotation is strongest when current flow is at its peak in the cycle. Single-phase current peaks twice during one cycle, whereas, three-phase current peaks six times during one cycle.

B. Three-phase motors are simpler, cheaper to buy and maintain, and safer to use around combustible materials since there is no sparking when they start. This is because three-phase current allows a motor to be self-starting since it produces a rotating field of mag-

netism in the motor. This eliminates the need for a separate starting winding, centrifugal switch, starting capacitor, or a system of brushes.

C. Three-phase motors are available in larger horsepower sizes than single-phase motors. Current is supplied to the motor with three conductors rather than two. This allowed the power supplied to larger three-phase motors to be on the same size conductor as that required for smaller single-phase motors. A balanced three-phase, three-wire circuit with equal voltages uses 75% of the copper required for conductors. They supply a single phase two-wire circuit of the same capacity, voltage rating, length of circuit, and transmission efficiency.

D. Three-phase motors are less expensive and usually lighter and smaller than single-phase motors of the same horsepower rating. There is also a wider choice of enclosures available than for single-phase motors.

E. Three-phase current service is much more expensive to have than single-phase current at a local farm. It requires more lines to be brought in and three transformers versus one transformer required for single-phase current.

Use the notes above and TM: A4–5B to outline advantages and disadvantages of three-phase current. Three-phase current is only necessary when needed horsepower of electric motors exceeds that which single-phase current can supply. In that case, three-phase motors are necessary, making three-phase current necessary.

Objective 3: Explain the differences between delta-connected, open delta-connected, and wye-connected transformers and their resulting voltages.

Anticipated Problem: What is the difference between delta-connected, open delta-connected, and wye-connected transformers and how do the voltages differ between them?

III. A three-phase farm installation requires at least three primary wires instead of two and generally two or three transformers rather than one. These transformers may be connected in one of three ways:

A. ***Delta-connected transformers*** require three transformers. They are connected in a configuration resembling the Greek letter delta. If only 240-volt service is needed, one connection is made to each transformer. However, if 120-volt and 240-volt services are needed, one of the transformers is center tapped to provide the 120-volt service. The center tap is grounded and becomes the neutral wire for the regular wiring system. Refer to the transparency master for the various connections. 240-volt three-phase current is achieved by connecting to A, B, and C. 240-volt single-phase current is achieved by connecting to A and B, B and C, or A and C. In order to achieve 120-volt single-phase current, connect A to N or B to N. Phase C is considered a "wild" or "foreign" phase and is not used with N as it will result in only 180 volts.

B. ***Open delta-connected transformers*** require only two transformers. This type of connection is therefore less costly, however you cannot obtain as much power from a given size transformer as you can with the delta connection. This connection is often used where

the power requirement is relatively low or intermittent. Refer to the transparency master for the diagram of connections. 240-volt three-phase current is achieved by connecting to A, B, and C. 240-volt single-phase is achieved by connecting A to B, B to C, or A to C. In order to achieve 120-volt single-phase current, connect B to N or C to N. Connecting A to N will result in 208 volts.

C. ***Wye-connected transformers*** require three transformers. They are connected in a configuration that resembles the letter "Y". This type of connection usually results in a 4-wire service, one wire being common to all transformers and grounded to form a neutral. The wye connection offers 120- and 208-volt currents. Refer to the transparency master for the various connections. The voltage obtained by connecting A to N, B to N, or C to N is 120. The voltage between A and B, B and C, or A and C is not 240, but 3 X 120, or 208 volts. Motors used on this system should be designed for 208 volts rather than for 240 volts. This system offers one major advantage, that the 120-volt load can be balanced on all three transformers and all three primary phases. This system is common in schools, office buildings, etc., where the principal load is for lighting and where three-phase power is necessary but incidental.

If your school has three-phase current, take the students outside where the transformers are located to observe the type of connections at the transformers. If possible, follow those into the building and show how the various voltages are taken from the circuit breaker box. Use the notes above with each of the transparency masters to explain the differences between each of the types of connections of transformers to achieve three-phase current. Use TM: A4–5C to illustrate the schematic diagram of connections on a delta-connected transformer. Explain the different voltages achieved from connections to the different wires on the transformer. Use TM: A4–5D to illustrate the schematic diagram of connections on an open delta-connected transformer. Explain the different voltages achieved from connections to the different wires on the transformer. Use TM: A4–5E to illustrate the schematic diagram of connections on a wye-connected transformer. Explain the different voltages achieved from connections to different wires on the transformer. When finished explaining, have students complete LS: A4–5A to demonstrate that they know how to get the different voltages from each of the different connections of transformers.

Review/Summary. Use the student learning objectives to summarize the lesson. Have students explain the content associated with each objective. Student responses can be used in determining which objectives need to be reviewed or taught from a different perspective.

Application. Application can involve the following student activities using attached lab sheet:

Derived Voltages of Three-Phase Transformer Connections—LS: A4–5A

Evaluation. Evaluation should focus on student achievement of the objectives for the lesson. Various techniques can be used, such as student performance on the application activities. A sample written test is attached.

Answers to Sample Test:

Part One: Matching

1=b, 2=c, and 3=a

Part Two: Completion

1=120
2=less
3=sparking
4=more
5=wye

Part Three: Short Answer

1. a=180, single
   b=120, single
   c=120, single
   d=240, single
   e=240, single
   f=240, single
   g=240, three

Sample Test Name_____

Test

Lesson A4–5: Comparing Single-Phase and Three-Phase Systems

Part One: Matching

Instructions. Match the term with the correct response. Write the letter of the term by the definition.

a. delta-connected transformers
b. open delta-connected transformers
c. wye-connected transformers

_____ 1. This method of three-phase power requires only two transformers.

_____ 2. This method of three-phase power requires three transformers and results in 120-volt or 208-volt current.

_____ 3. This method of three-phase power contains a foreign or wild phase resulting in 180 volts.

Part Two: Completion

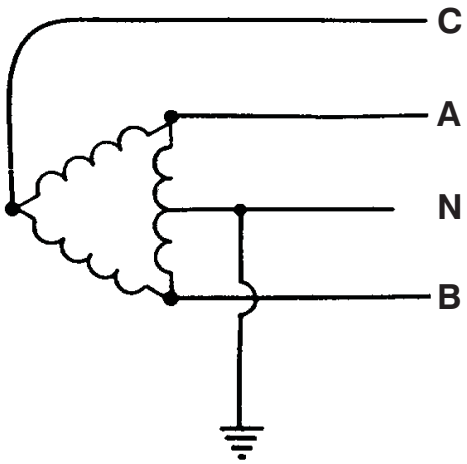
Instructions. Provide the word or words to complete the following statements.

1. Three-phase current has three distinct phases that reach peak voltages _____ degrees apart from each of the others.
2. Three-phase motors are (more or less) expensive than single-phase motors of the same horsepower rating.
3. Three-phase motors are safer to use around combustible materials since there is no _____ when they start.
4. Three-phase power is (more or less) expensive to have brought to a local farm.
5. _____-connected transformers are common in schools and office buildings since the 120-volt load can be balanced on all three transformers.

Part Three: Short Answer

Instructions. Provide information to answer the following questions.

1. Using the diagram for delta-connected transformers, complete the derived voltages and type of phase for each of the connections given:



a. C to N = _____ volts _____-phase

b. A to N = _____ volts _____-phase

c. B to N = _____ volts _____-phase

d. A to B = _____ volts _____-phase

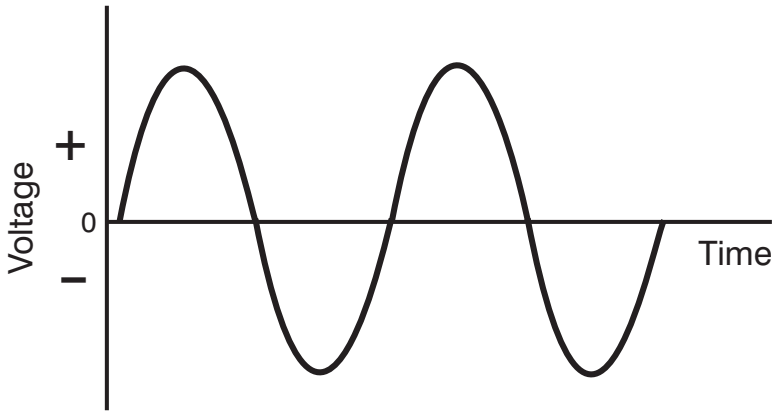
e. B to C = _____ volts _____-phase

f. A to C = _____ volts _____-phase

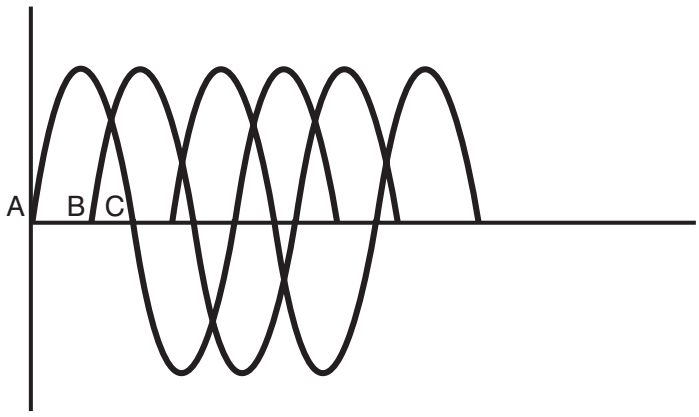
g. A to B to C = _____ volts _____-phase

TM: A4–5A

SINE WAVE PATTERN OF SINGLE-PHASE AND THREE-PHASE CURRENT



Sine Wave Pattern of Single-Phase



Sine Wave Pattern of Three-Phase

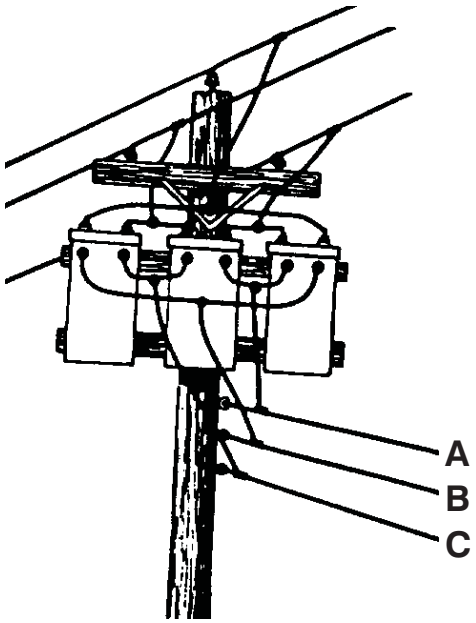
TM: A4–5B

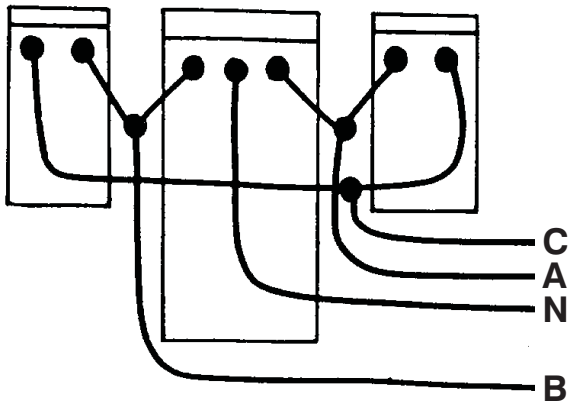
ADVANTAGES & DISADVANTAGES OF THREE-PHASE CURRENT

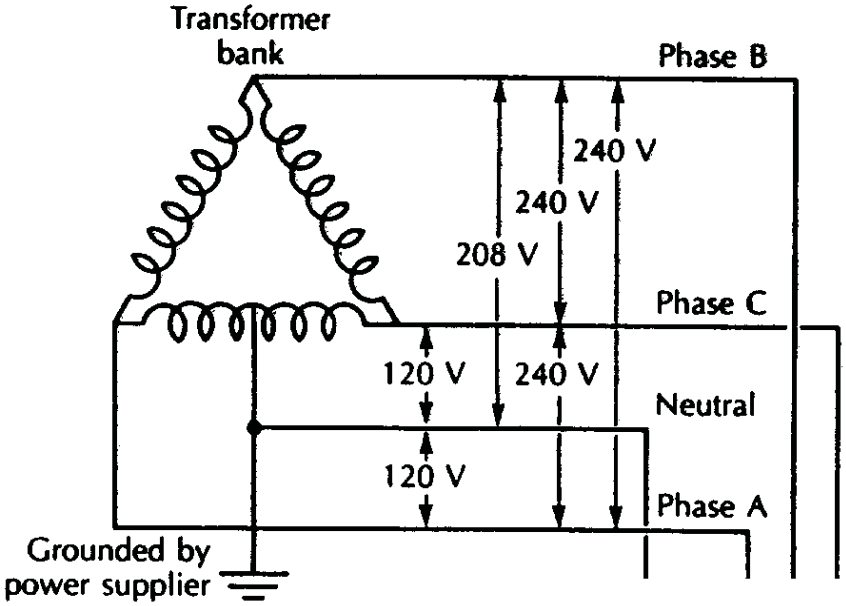
1. Steadier source of power.
2. Three-phase motors are simpler, cheaper to maintain, and safer around combustible materials.
3. Three-phase motors are available in larger horsepower sizes.
4. Three-phase motors are less expensive and usually lighter and smaller than single-phase motors of same horsepower rating.
5. Three-phase current is more expensive to run to local farms.

TM: A4–5C

DELTA-CONNECTED TRANSFORMERS

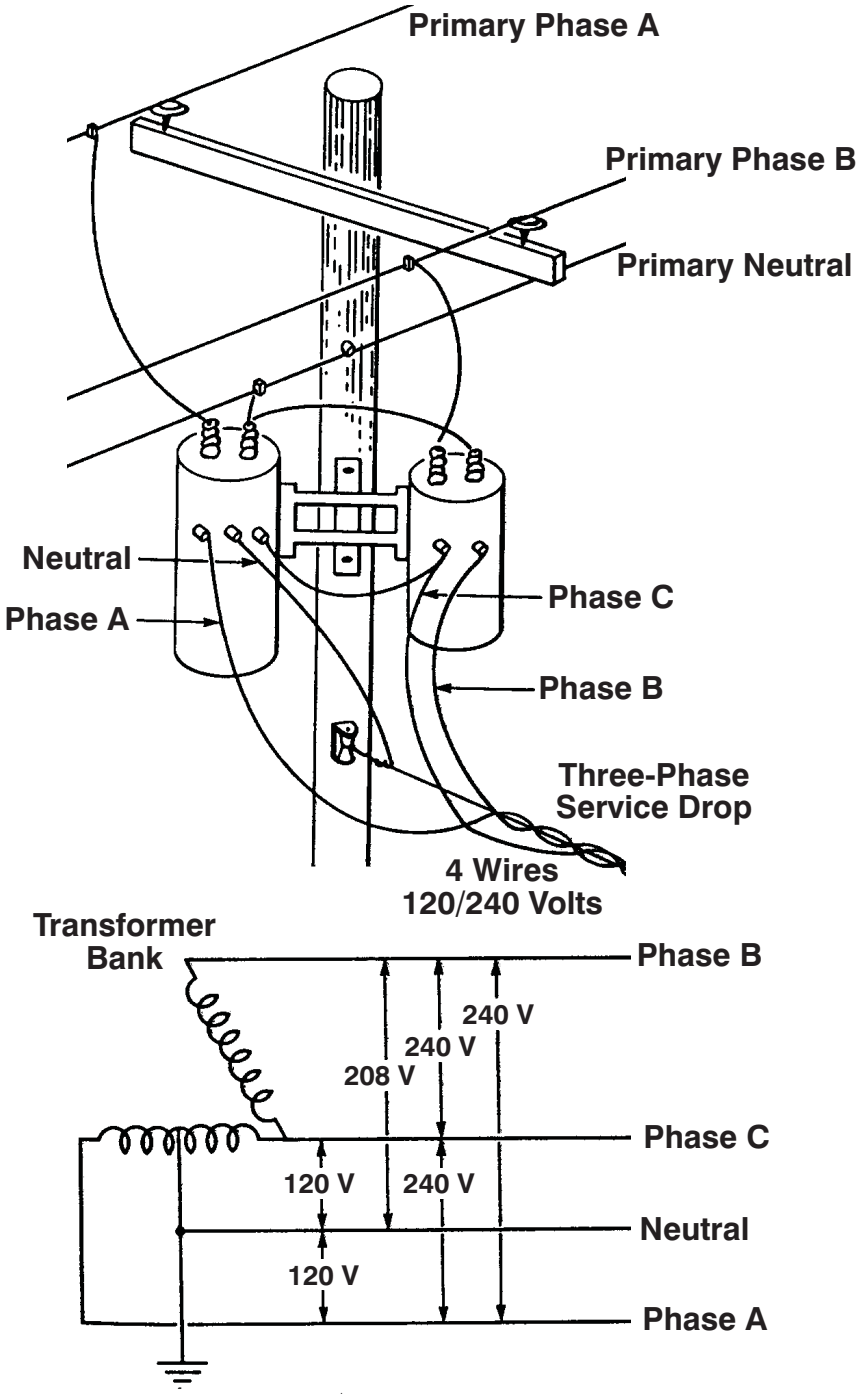






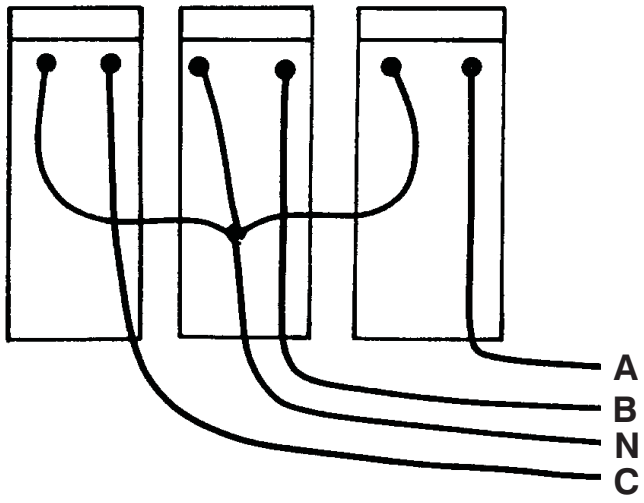
TM: A4–5D

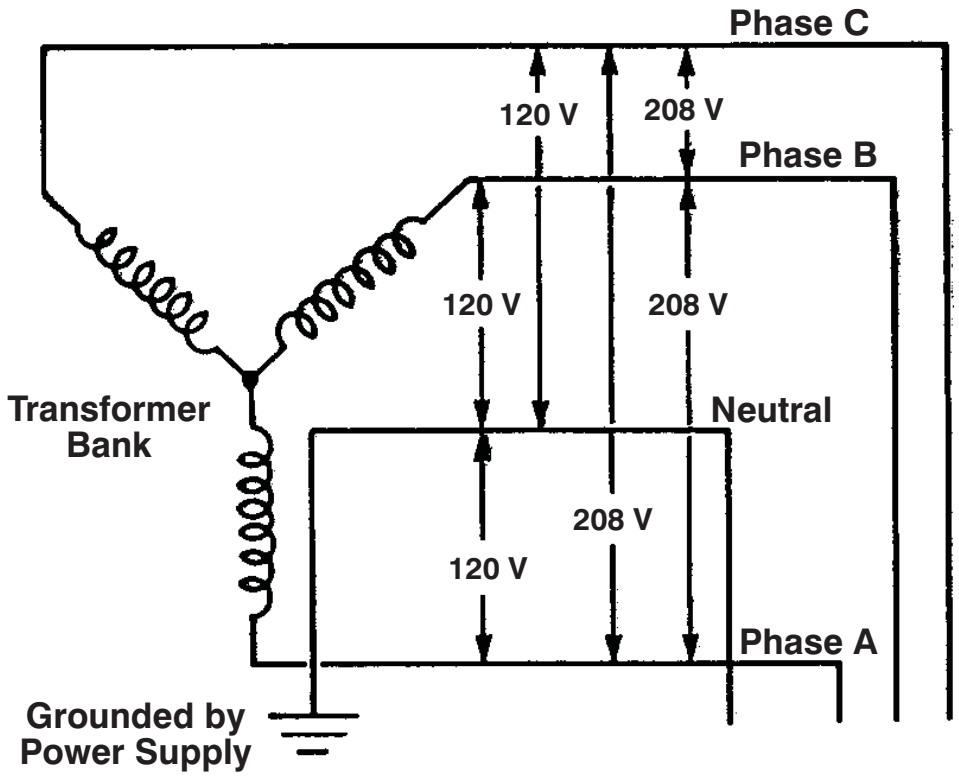
OPEN DELTA-CONNECTED TRANSFORMERS



TM: A4–5E

WYE-CONNECTED TRANSFORMERS





Name _____

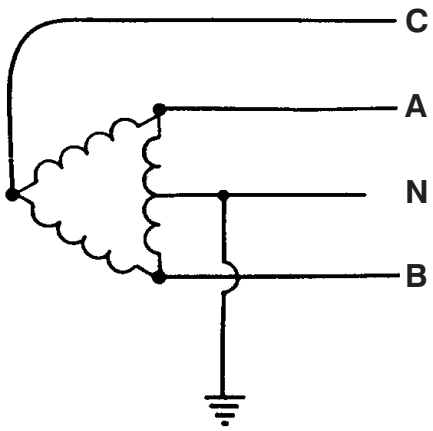
Lab Sheet

Derived Voltages of Three-Phase Transformer Connections

Purpose: Students will enhance their knowledge of three-phase power and their understanding of the available voltages depending on the connection used.

Instructions: Determine the derived voltages for each of the three transformer connections for each connection of wires from the transformer.

A. Delta-connected transformer



a. C to N = _____ volts _____-phase

b. A to N = _____ volts _____-phase

c. B to N = _____ volts _____-phase

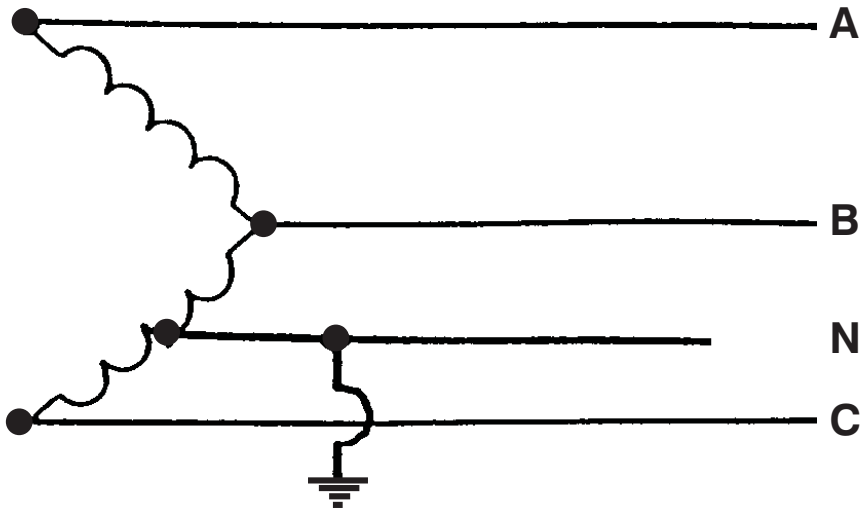
d. A to B = _____ volts _____-phase

e. B to C = _____ volts _____-phase

f. A to C = _____ volts _____-phase

g. A to B to C = _____ volts _____-phase

B. Open delta-connected transformer



a. C to N = _____ volts _____-phase

b. A to N = _____ volts _____-phase

c. B to N = _____ volts _____-phase

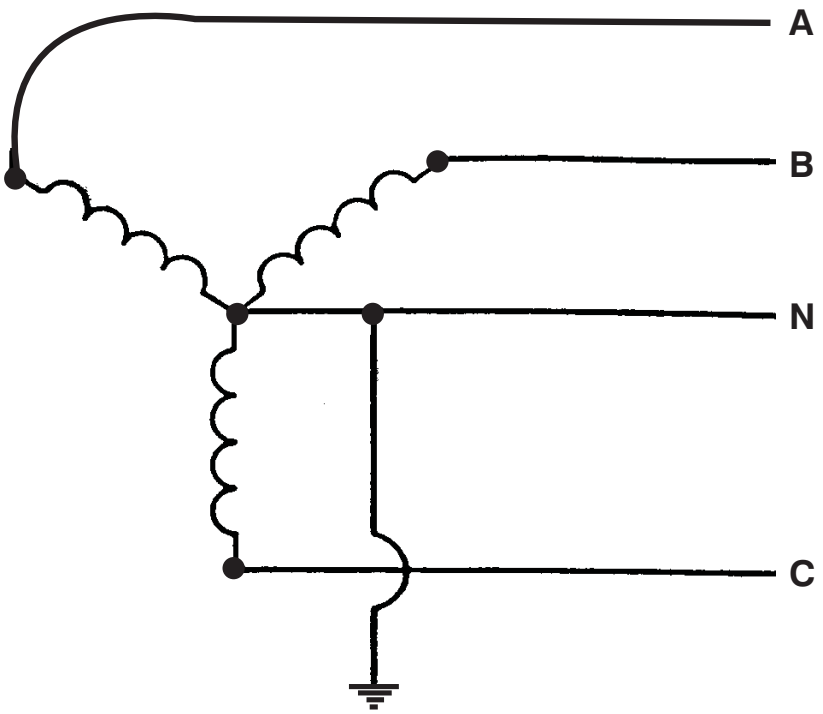
d. A to B = _____ volts _____-phase

e. B to C = _____ volts _____-phase

f. A to C = _____ volts _____-phase

g. A to B to C = _____ volts _____-phase

C. Wye-connected transformer



a. C to N = _____ volts _____-phase

b. A to N = _____ volts _____-phase

c. B to N = _____ volts _____-phase

d. A to B = _____ volts _____-phase

e. B to C = _____ volts _____-phase

f. A to C = _____ volts _____-phase

g. A to B to C = _____ volts _____-phase