



Online Continuing Education for Professional Engineers
Since 2009

Creating Electrical Schematics

PDH Credits:

2 PDH

Course No.:

CES101

Publication Source:

US Dept. of Energy

"Fundamentals Handbook, Module 3 , Electrical Schematics"

Pub. # DOE-HDBK-1016/1-93

Release Date:

Jan. 1993

DISCLAIMER:

All course materials available on this website are not to be construed as a representation or warranty on the part of Online-PDH, or other persons and/or organizations named herein. All course literature is for reference purposes only, and should not be used as a substitute for competent, professional engineering council. Use or application of any information herein, should be done so at the discretion of a licensed professional engineer in that given field of expertise. Any person(s) making use of this information, herein, does so at their own risk and assumes any and all liabilities arising therefrom.

Department of Energy
Fundamentals Handbook

**ENGINEERING SYMBOLOGY, PRINTS,
AND DRAWINGS**

Module 3

Electrical Diagrams and Schematics

TABLE OF CONTENTS

LIST OF FIGURES	ii
LIST OF TABLES	iii
REFERENCES	iv
OBJECTIVES	v
ELECTRICAL DIAGRAMS AND SCHEMATICS	1
Symbology	2
Transformers	2
Switches	3
Fuses and Breakers	5
Relays, Contacts, Connectors, Lines, Resistors, and Miscellaneous Electrical Components	6
Large Components	7
Types of Electrical Diagrams or Schematics	9
Reading Electrical Diagrams and Schematics	14
Summary	17
ELECTRICAL WIRING AND SCHEMATIC DIAGRAM READING EXAMPLES	18
Examples	18
Summary	23

LIST OF FIGURES

Figure 1	Basic Transformer Symbols	2
Figure 2	Transformer Polarity	2
Figure 3	Switches and Switch Symbols	3
Figure 4	Switch and Switch Status Symbology	4
Figure 5	Fuse and Circuit Breaker Symbols	5
Figure 6	3-phase and Removable Breaker Symbols	6
Figure 7	Common Electrical Component Symbols	7
Figure 8	Large Common Electrical Components	8
Figure 9	Comparison of an Electrical Schematic and a Pictorial Diagram	9
Figure 10	Comparison of an Electrical Schematic and a Wiring Diagram	10
Figure 11	Wiring Diagram of a Car's Electrical Circuit	11
Figure 12	Schematic of a Car's Electrical Circuit	12
Figure 13	Example Electrical Single Line	13
Figure 14	Examples of Relays and Relay Contacts	14
Figure 15	Ganged Switch Symbology	15
Figure 16	Three-Phase Symbols	16
Figure 17	Example 1	19
Figure 18	Example 2	20

LIST OF TABLES

Table 1 Comparison Between Wiring and Schematic Diagrams 9

REFERENCES

- ANSI Y14.5M - 1982, Dimensioning and Tolerancing, American National Standards Institute.
- ANSI Y32.2 - 1975, Graphic Symbols for Electrical and Electronic Diagrams, American National Standards Institute.
- Gasperini, Richard E., Digital Troubleshooting, Movonics Company; Los Altos, California, 1976.
- Jensen - Helsel, Engineering Drawing and Design, Second Ed., McGraw-Hill Book Company, New York, 1979.
- Lenk, John D., Handbook of Logic Circuits, Reston Publishing Company, Reston, Virginia, 1972.
- Wickes, William E., Logic Design with Integrated Circuits, John Wiley & Sons, Inc, 1968.
- Naval Auxiliary Machinery, United States Naval Institute, Annapolis, Maryland, 1951.
- TPC Training Systems, Reading Schematics and Symbols, Technical Publishing Company, Barrington, Illinois, 1974.
- Arnell, Alvin, Standard Graphical Symbols, McGraw-Hill Book Company, 1963.
- George Mashe, Systems Summary of a Westinghouse Pressurized Water Reactor, Westinghouse Electric Corporation, 1971.
- Zappe, R.W., Valve Selection Handbook, Gulf Publishing Company, Houston, Texas, 1968.

TERMINAL OBJECTIVE

- 1.0 Given an electrical print, **READ** and **INTERPRET** facility electrical diagrams and schematics.

ENABLING OBJECTIVES

- 1.1 **IDENTIFY** the symbols used on engineering electrical drawings for the following components:

- | | | | |
|----|--|----|--------------------------|
| a. | Single-phase circuit breaker (open/closed) | m. | Electric motor |
| b. | Three-phase circuit breaker (open/closed) | n. | Meters |
| c. | Thermal overload | o. | Junctions |
| d. | "a" contact | p. | In-line fuses |
| e. | "b" contact | q. | Single switch |
| f. | Time-delay contacts | r. | Multiple-position switch |
| g. | Relay | s. | Pushbutton switch |
| h. | Potential transformer | t. | Limit switches |
| i. | Current transformer | u. | Turbine-driven generator |
| j. | Single-phase transformer | v. | Motor-generator set |
| k. | Delta-wound transformer | w. | Generator (wye or delta) |
| l. | Wye-wound transformer | x. | Diesel-driven generator |
| | | y. | Battery |

- 1.2 Given an electrical drawing of a circuit containing a transformer, **DETERMINE** the direction of current flow, as shown by the transformer's symbol.

- 1.3 **IDENTIFY** the symbols and/or codes used on engineering electrical drawings to depict the relationship between the following components:

- Relay and its contacts
- Switch and its contacts
- Interlocking device and its interlocked equipment

ENABLING OBJECTIVES (Cont.)

- 1.4 **STATE** the condition in which all electrical devices are shown, unless otherwise noted on the diagram or schematic.
- 1.5 Given a simple electrical schematic and initial conditions, **DETERMINE** the condition of the specified component (i.e., energized/de-energized, open/closed).
- 1.6 Given a simple electrical schematic and initial conditions, **IDENTIFY** the power sources and/or loads and their status (i.e., energized or de-energized).

ELECTRICAL DIAGRAMS AND SCHEMATICS

To read and interpret electrical diagrams and schematics, the basic symbols and conventions used in the drawing must be understood. This chapter concentrates on how electrical components are represented on diagrams and schematics. The function of the individual electrical components and the theory behind their operation is covered in more detail in the Electrical Science Handbook.

EO 1.1 IDENTIFY the symbols used on engineering electrical drawings for the following components:

- | | |
|---|--|
| <ul style="list-style-type: none"> a. Single-phase circuit breaker (open/closed) b. Three-phase circuit breaker (open/closed) c. Thermal overload d. "a" contact e. "b" contact f. Time-delay contacts g. Relay h. Potential transformer i. Current transformer j. Single-phase transformer k. Delta-wound transformer l. Wye-wound transformer | <ul style="list-style-type: none"> m. Electric motor n. Meters o. Junctions p. In-line fuses q. Single switch r. Multiple-position switch s. Pushbutton switch t. Limit switches u. Turbine-driven generator v. Motor-generator set w. Generator (wye or delta) x. Diesel-driven generator y. Battery |
|---|--|

EO 1.2 Given an electrical drawing of a circuit containing a transformer, DETERMINE the direction of current flow, as shown by the transformer's symbol.

EO 1.3 IDENTIFY the symbols and/or codes used on engineering electrical drawings to depict the relationship between the following components:

- a. Relay and its contacts
- b. Switch and its contacts
- c. Interlocking device and its interlocked equipment

EO 1.4 STATE the condition in which all electrical devices are shown, unless otherwise noted on the diagram or schematic.

EO 1.5 Given a simple electrical schematic and initial conditions, DETERMINE the condition of the specified component (i.e., energized/de-energized, open/closed).

Symbology

To read and interpret electrical diagrams and schematics, the reader must first be well versed in what the many symbols represent. This chapter discusses the common symbols used to depict the many components in electrical systems. Once mastered, this knowledge should enable the reader to successfully understand most electrical diagrams and schematics.

The information that follows provides details on the basic symbols used to represent components in electrical transmission, switching, control, and protection diagrams and schematics.

Transformers

The basic symbols for the various types of transformers are shown in Figure 1 (A). Figure 1 (B) shows how the basic symbol for the transformer is modified to represent specific types and transformer applications.

In addition to the transformer symbol itself, polarity marks are sometimes used to indicate current flow in the circuit. This information can be used to determine the phase relationship (polarity) between the input and output terminals of a transformer. The marks usually appear as dots on a transformer symbol, as shown in Figure 2.

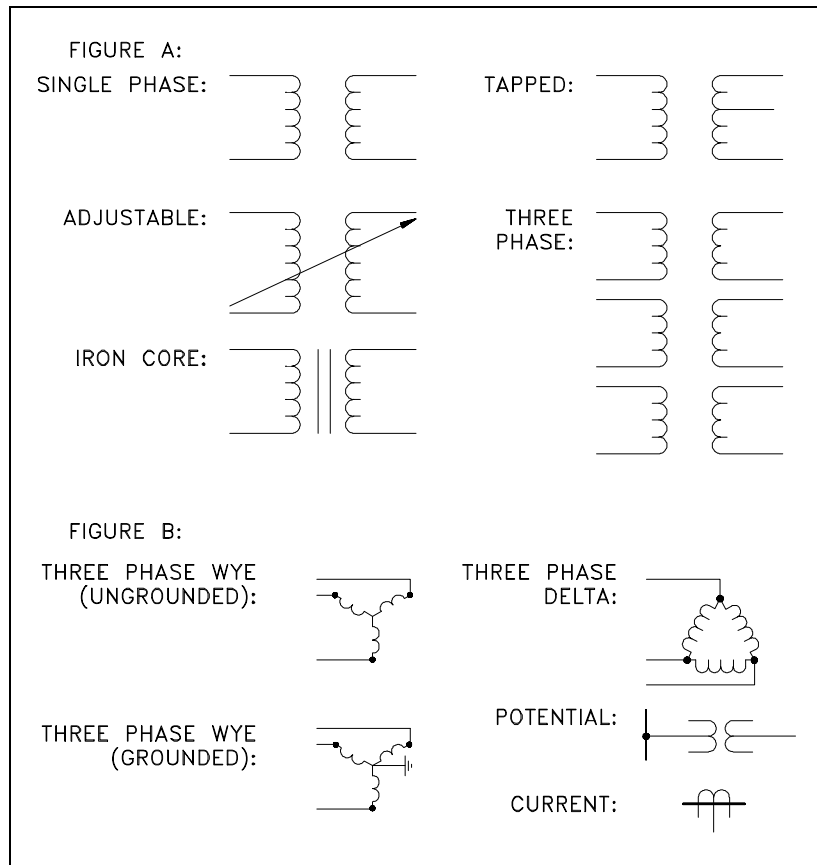


Figure 1 Basic Transformer Symbols

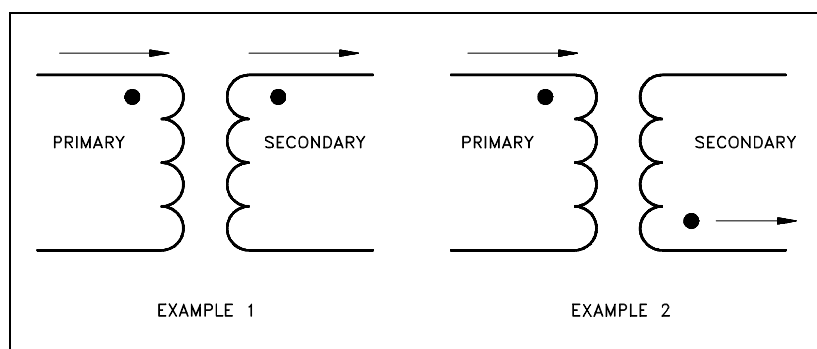


Figure 2 Transformer Polarity

On the primary side of the transformer the dot indicates current in; on the secondary side the dot indicates current out.

If at a given instant the current is flowing into the transformer at the dotted end of the primary coil, it will be flowing out of the transformer at the dotted end of the secondary coil. The current flow for a transformer using the dot symbology is illustrated in Figure 2.

Switches

Figure 3 shows the most common types of switches and their symbols. The term "pole," as used to describe the switches in Figure 3, refers to the number of points at which current can enter a switch. Single pole and double pole switches are shown, but a switch may have as many poles as it requires to perform its function. The term "throw" used in Figure 3 refers to the number of circuits that each pole of a switch can complete or control.

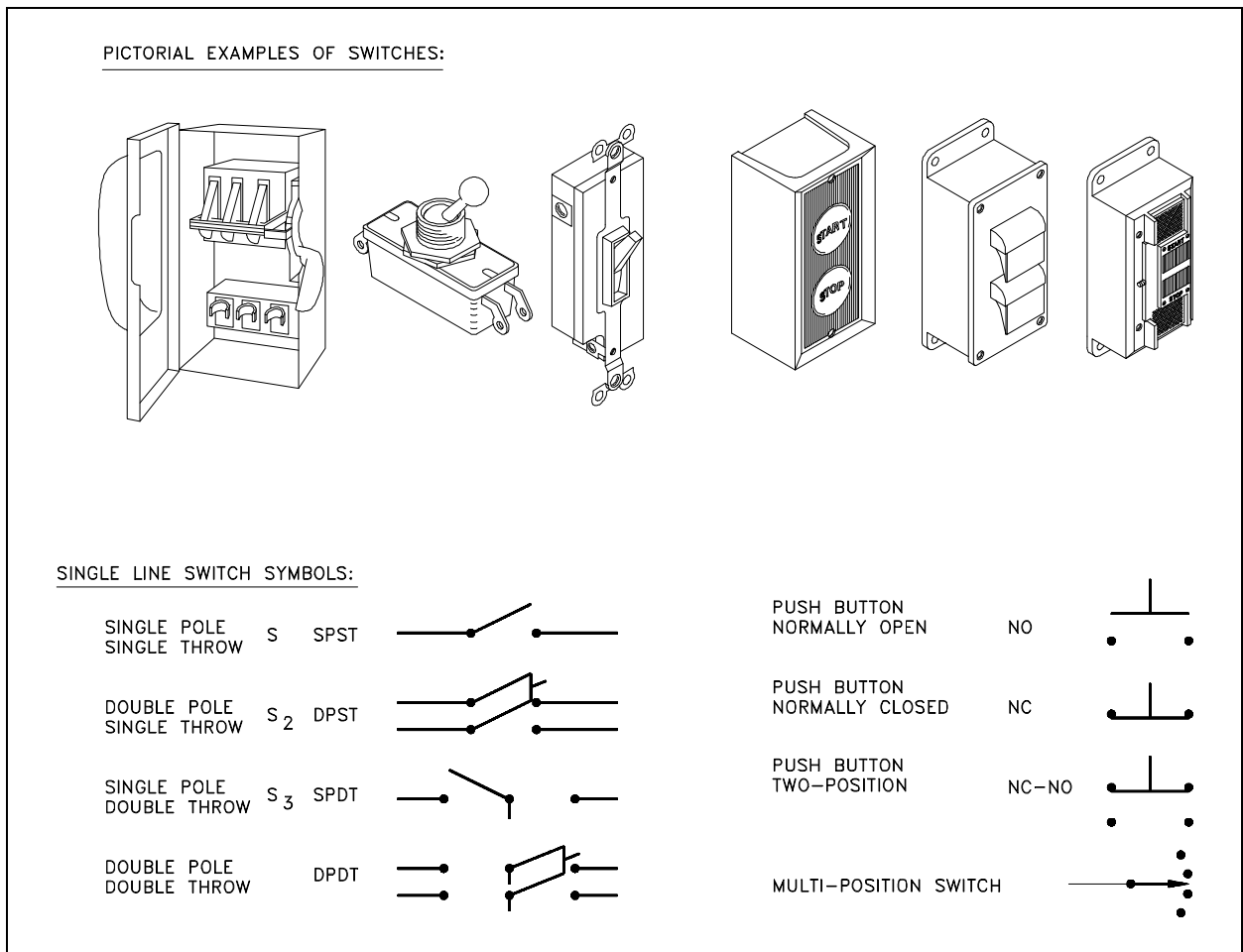


Figure 3 Switches and Switch Symbols

Figure 4 provides the common symbols that are used to denote automatic switches and explains how the symbol indicates switch status or actuation.

LIMIT SWITCH, DIRECT ACTUATED, SPRING RETURNED NORMALLY OPEN	
NORMALLY OPEN—HELD CLOSED	
NORMALLY CLOSED	
NORMALLY CLOSED—HELD OPEN	
OPEN SWITCH WITH TIME DELAY CLOSING (TDC) FEATURE	
CLOSED SWITCH WITH TIME DELAY OPENING (TDO) FEATURE	
OPEN SWITCH WITH TIME DELAY OPENING (TDO) FEATURE	
CLOSED SWITCH WITH TIME DELAY CLOSING (TDC) FEATURE	
FLOW ACTUATED SWITCH CLOSING ON INCREASE IN FLOW	
OPENING ON INCREASE IN FLOW	
LIQUID LEVEL ACTUATED SWITCH CLOSING ON RISING LEVEL	
OPENING ON RISING LEVEL	
PRESSURE OR VACUUM ACTUATED SWITCH CLOSING ON RISING PRESSURE	
OPENING ON RISING PRESSURE	
TEMPERATURE ACTUATED SWITCH CLOSING ON RISING TEMPERATURE	

Figure 4 Switch and Switch Status Symbolology

Fuses and Breakers

Figure 5 depicts basic fuse and circuit breaker symbols for single-phase applications. In addition to the graphic symbol, most drawings will also provide the rating of the fuse next to the symbol. The rating is usually in amps.

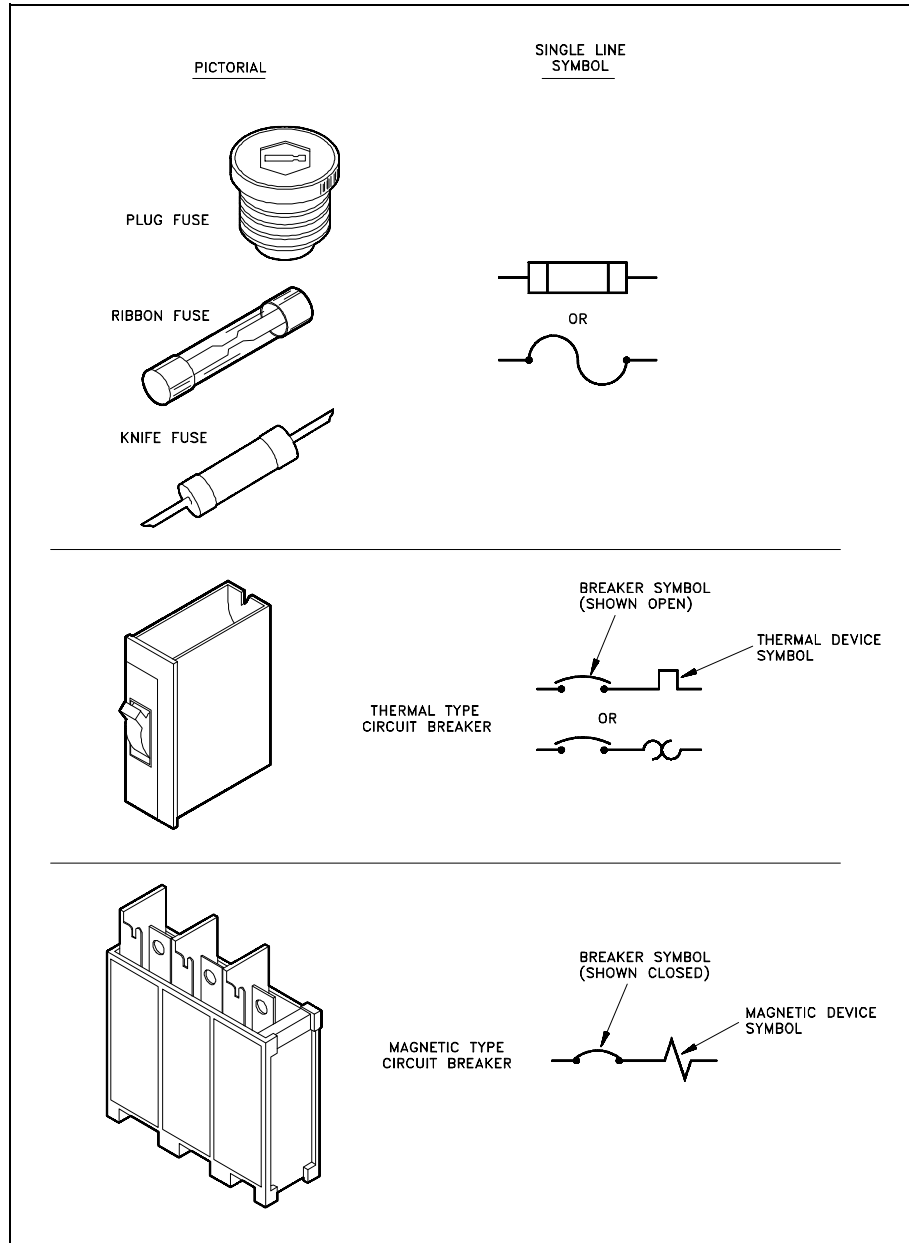


Figure 5 Fuse and Circuit Breaker Symbols

When fuses, breakers, or switches are used in three-phase systems, the three-phase symbol combines the single-phase symbol in triplicate as shown in Figure 6. Also shown is the symbol for a removable breaker, which is a standard breaker symbol placed between a set of chevrons. The chevrons represent the point at which the breaker disconnects from the circuit when removed.

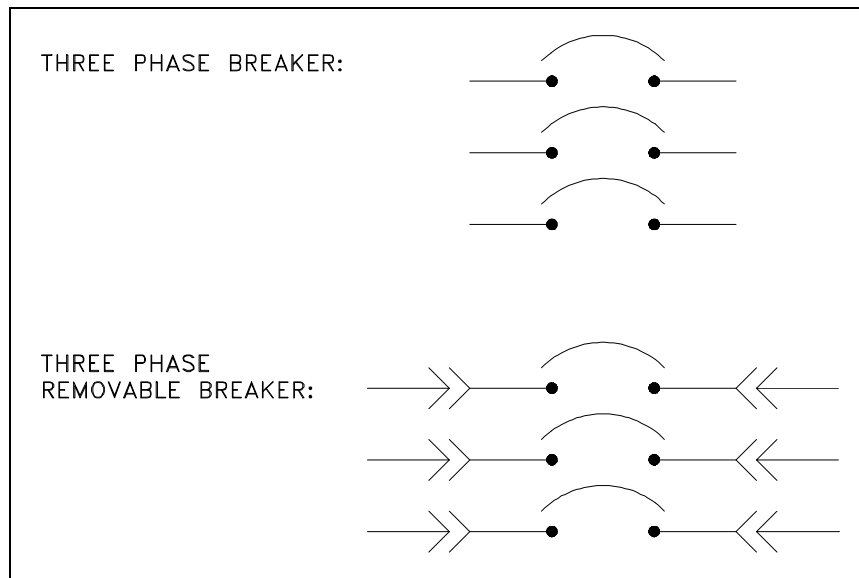


Figure 6 Three-phase and Removable Breaker Symbols

Relays, Contacts, Connectors, Lines, Resistors, and Miscellaneous Electrical Components

Figure 7 shows the common symbols for relays, contacts, connectors, lines, resistors, and other miscellaneous electrical components.

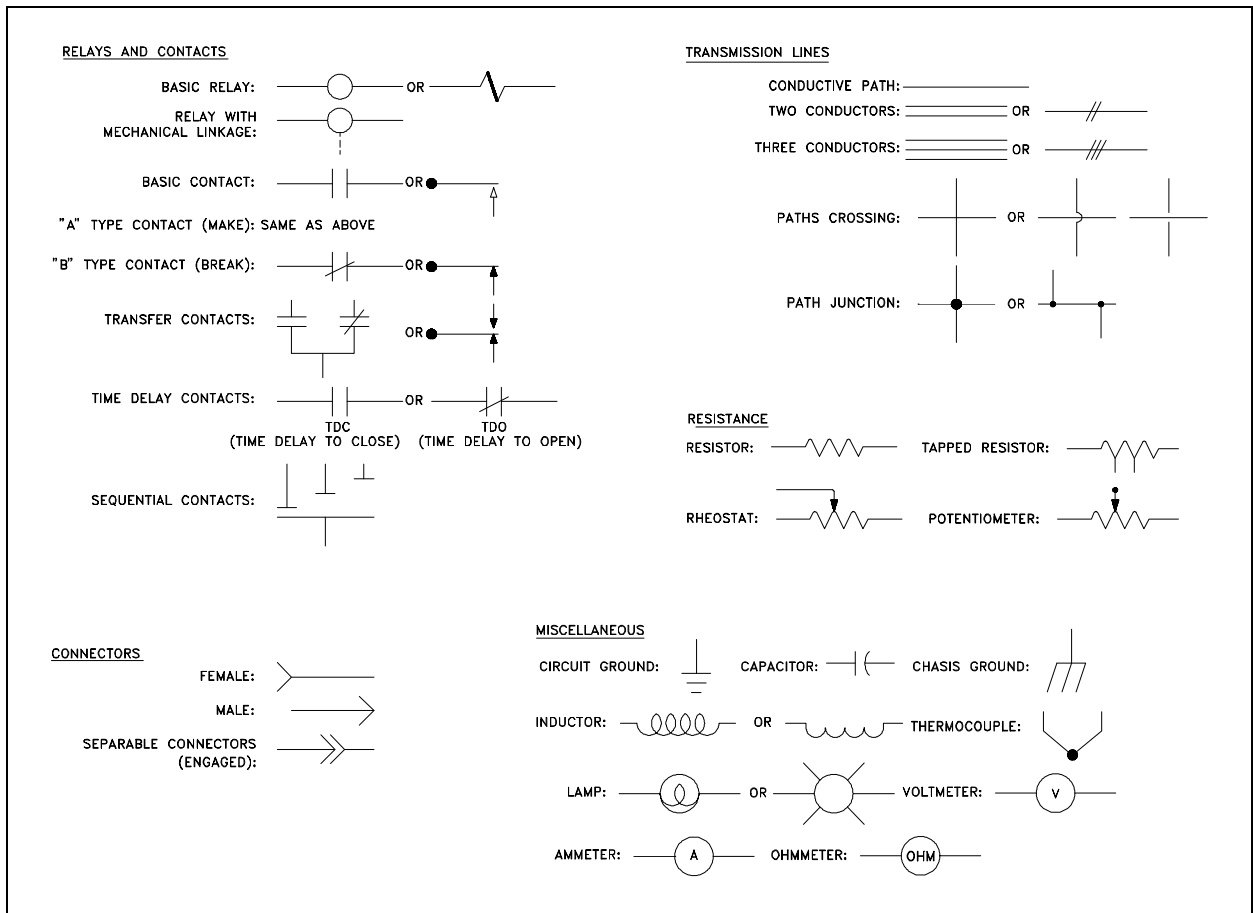


Figure 7 Common Electrical Component Symbols

Large Components

The symbols in Figure 8 are used to identify the larger components that may be found in an electrical diagram or schematic. The detail used for these symbols will vary when used in system diagrams. Usually the amount of detail will reflect the relative importance of a component to the particular diagram.

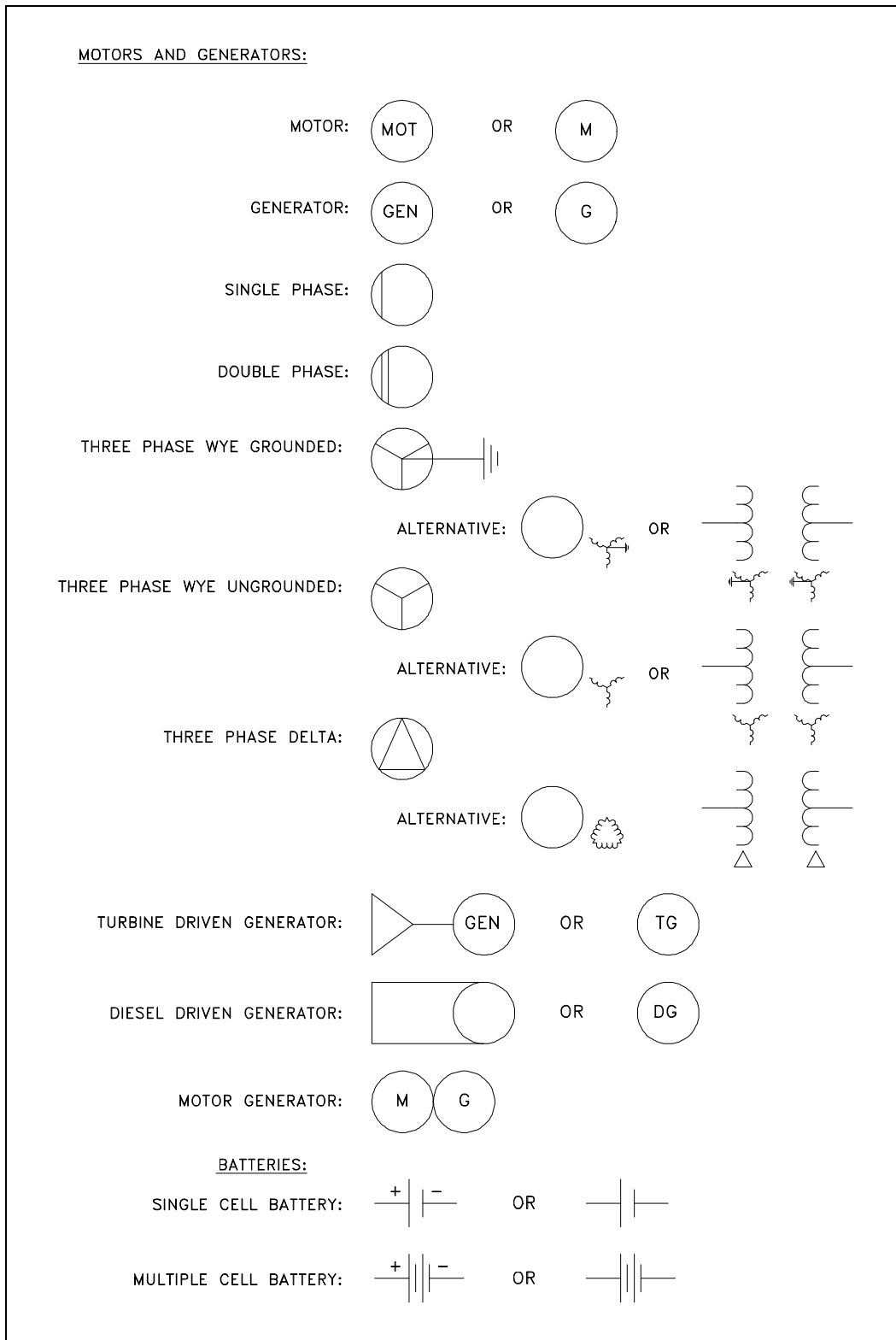


Figure 8 Large Common Electrical Components

Types of Electrical Diagrams or Schematics

There are three ways to show electrical circuits. They are wiring, schematic, and pictorial diagrams. The two most commonly used are the wiring diagram and the schematic diagram. The uses of these two types of diagrams are compared in Table 1.

TABLE 1	
Comparison Between Wiring and Schematic Diagrams	
Wiring Diagrams	Schematic Diagrams
<ol style="list-style-type: none"> 1. Emphasize connections between elements of a circuit or system 2. Use horizontal and vertical lines to represent the wires 3. Use simplified pictorials that clearly resemble circuit/system components 4. Place equipment and wiring on drawing to approximate actual physical location in real circuit 	<ol style="list-style-type: none"> 1. Emphasize "flow" of system 2. Use horizontal and vertical lines to show system flow 3. Use symbols that indicate function of equipment, but the symbols do not look like the actual equipment 4. Drawing layout is done to show the "flow" of the system as it functions, not the physical layout of the equipment

The pictorial diagram is usually not found in engineering applications for the reasons shown in the following example. Figure 9 provides a simple example of how a schematic diagram compares to a pictorial equivalent. As can be seen, the pictorial version is not nearly as useful as the schematic, especially if you were trying to obtain enough information to repair a circuit or determine how it operates.

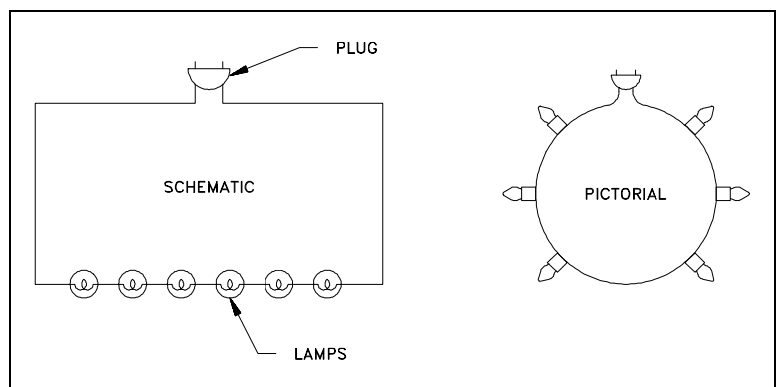


Figure 9 Comparison of an Electrical Schematic and a Pictorial Diagram

Figure 10 provides an example of the relationship between a schematic diagram (Figure 10A) and a wiring diagram (Figure 10B) for an air drying unit. A more complex example, the electrical circuit of an automobile, is shown in wiring diagram format in Figure 11 and in schematic format in Figure 12. Notice that the wiring diagram (Figure 11), uses both pictorial representations and schematic symbols. The schematic (Figure 12) drops all pictorial representations and depicts the electrical system only in symbols.

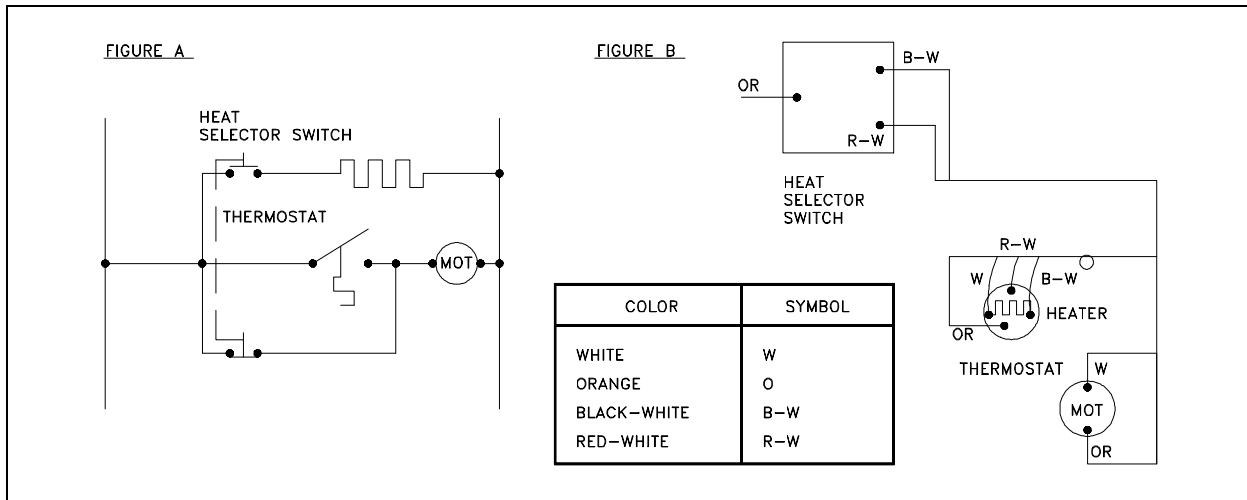


Figure 10 Comparison of an Electrical Schematic and a Wiring Diagram

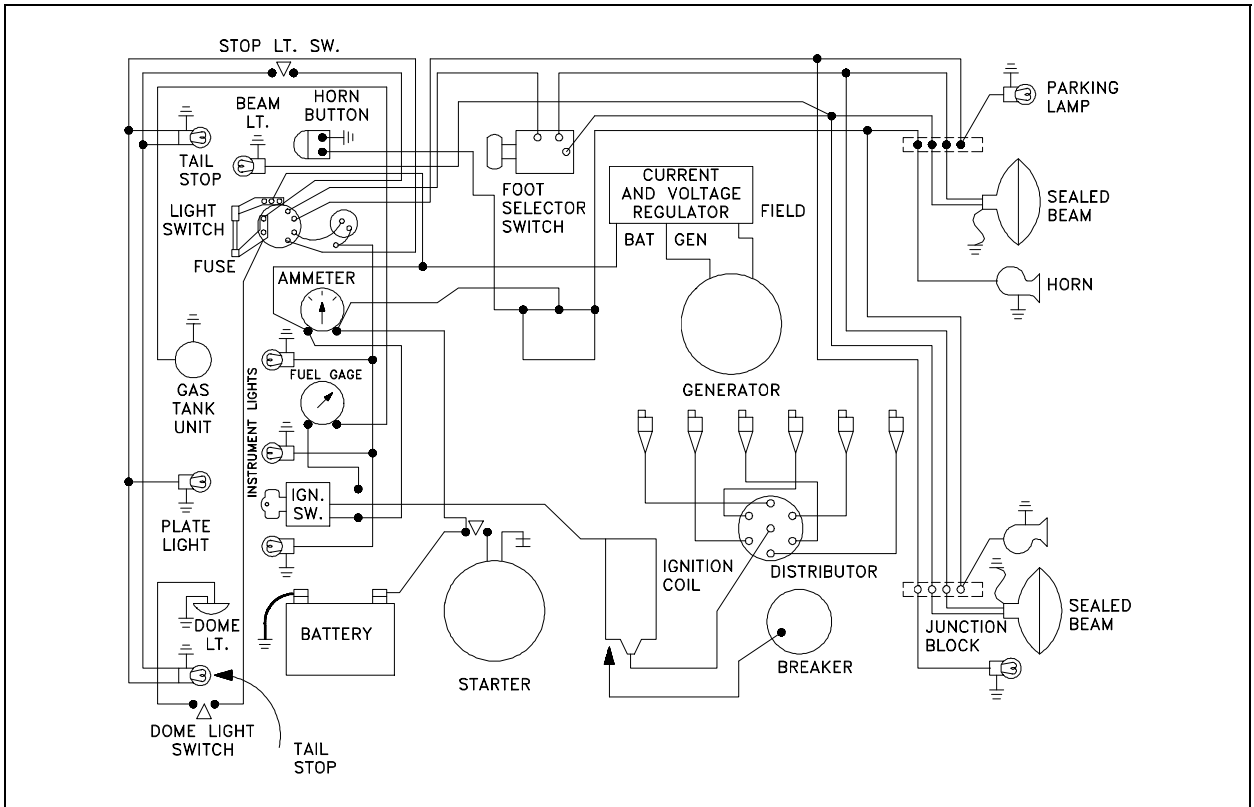


Figure 11 Wiring Diagram of a Car's Electrical Circuit

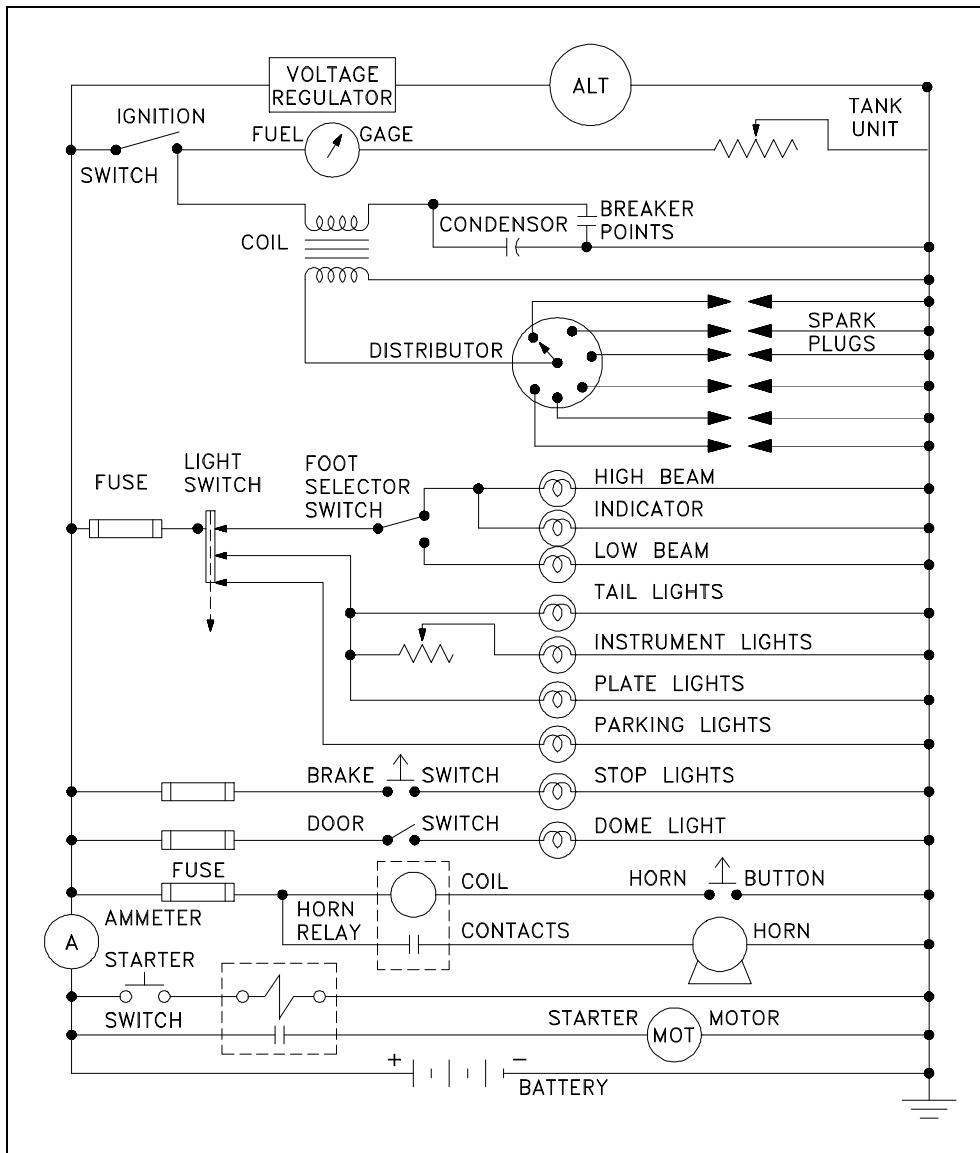


Figure 12 Schematic of a Car's Electrical Circuit

When dealing with a large power distribution system, a special type of schematic diagram called an electrical single line is used to show all or part of the system. This type of diagram depicts the major power sources, breakers, loads, and protective devices, thereby providing a useful overall view of the flow of power in a large electrical power distribution system.

On power distribution single lines, even if it is a 3-phase system, each load is commonly represented by only a simple circle with a description of the load and its power rating (running power consumption). Unless otherwise stated, the common units are kilowatts (kW). Figure 13 shows a portion of an electrical distribution system at a nuclear power plant.

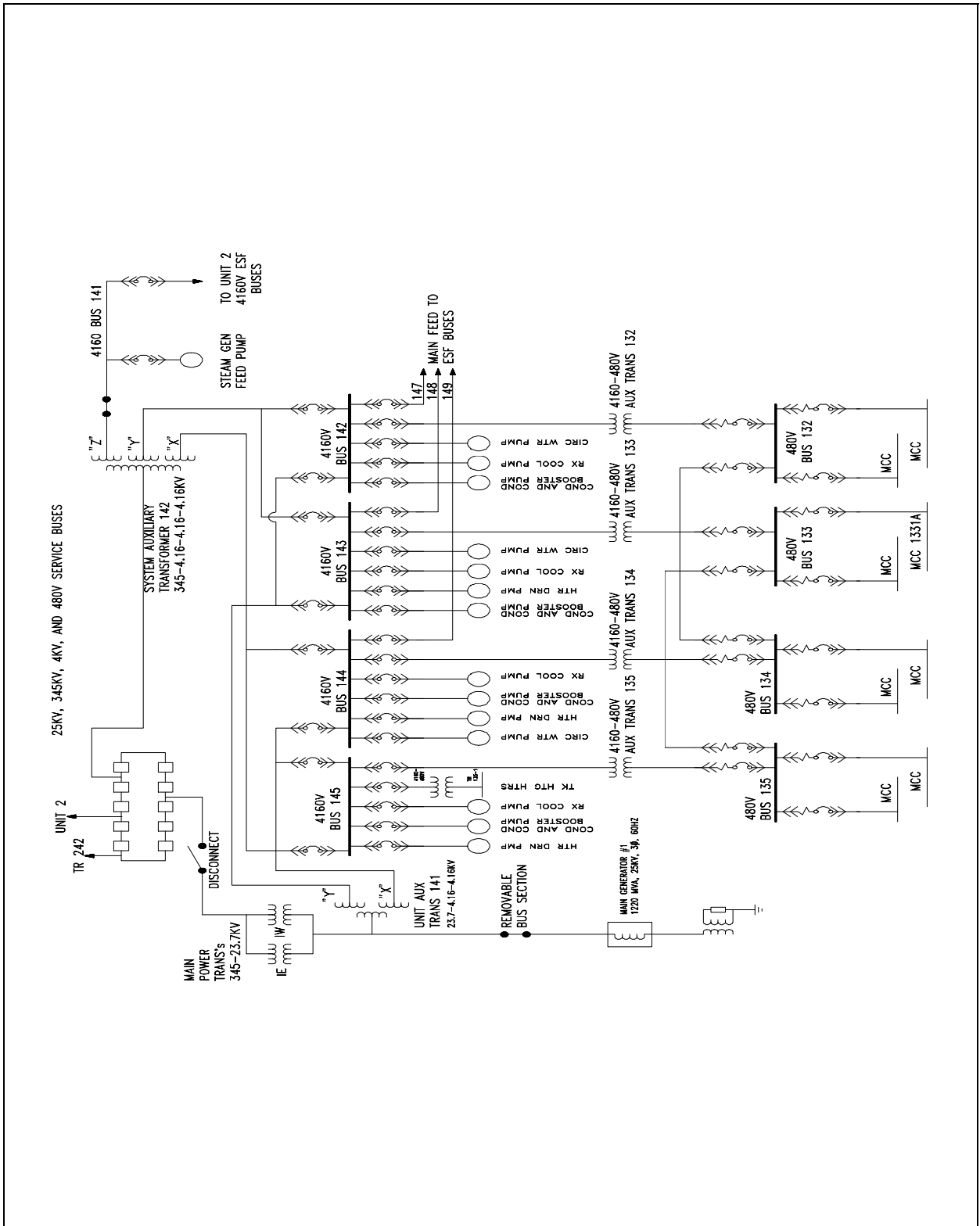


Figure 13 Example Electrical Single Line

Reading Electrical Diagrams and Schematics

To read electrical system diagrams and schematics properly, the condition or state of each component must first be understood. For electrical schematics that detail individual relays and contacts, the components are always shown in the de-energized condition (also called the shelf-state).

To associate the proper relay with the contact(s) that it operates, each relay is assigned a specific number and/or letter combination. The number/letter code for each relay is carried by all associated contacts. Figure 14 (A) shows a simple schematic containing a coil (M1) and its contact. If space permits, the relationship may be emphasized by drawing a dashed line (symbolizing a mechanical connection) between the relay and its contact(s) or a dashed box around them as shown in Figure 14 (B). Figure 14 (C) illustrates a switch and a second set of contacts that are operated by the switch.

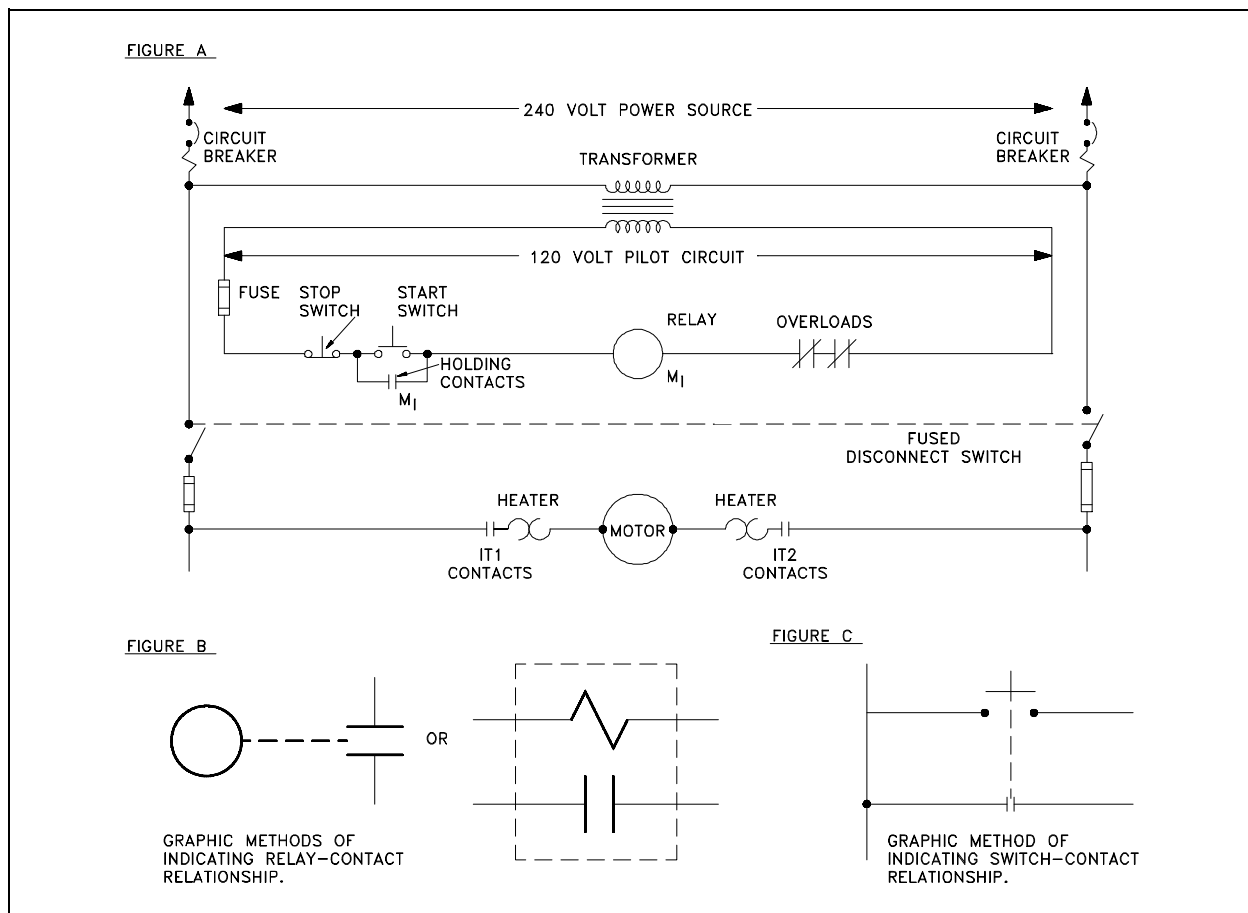


Figure 14 Examples of Relays and Relay Contacts

When a switch is used in a circuit, it may contain several sets of contacts or small switches internal to it. The internal switches are shown individually on a schematic. In many cases, the position of one internal switch will effect the position of another. Such switches are called *ganged* switches and are symbolized by connecting them with a dashed line as shown in Figure 15 (A). In that example, closing Switch 1 also closes Switch 2. The dashed line is also used to indicate a mechanical interlock between two circuit components. Figure 15 (B) shows two breakers with an interlock between them.

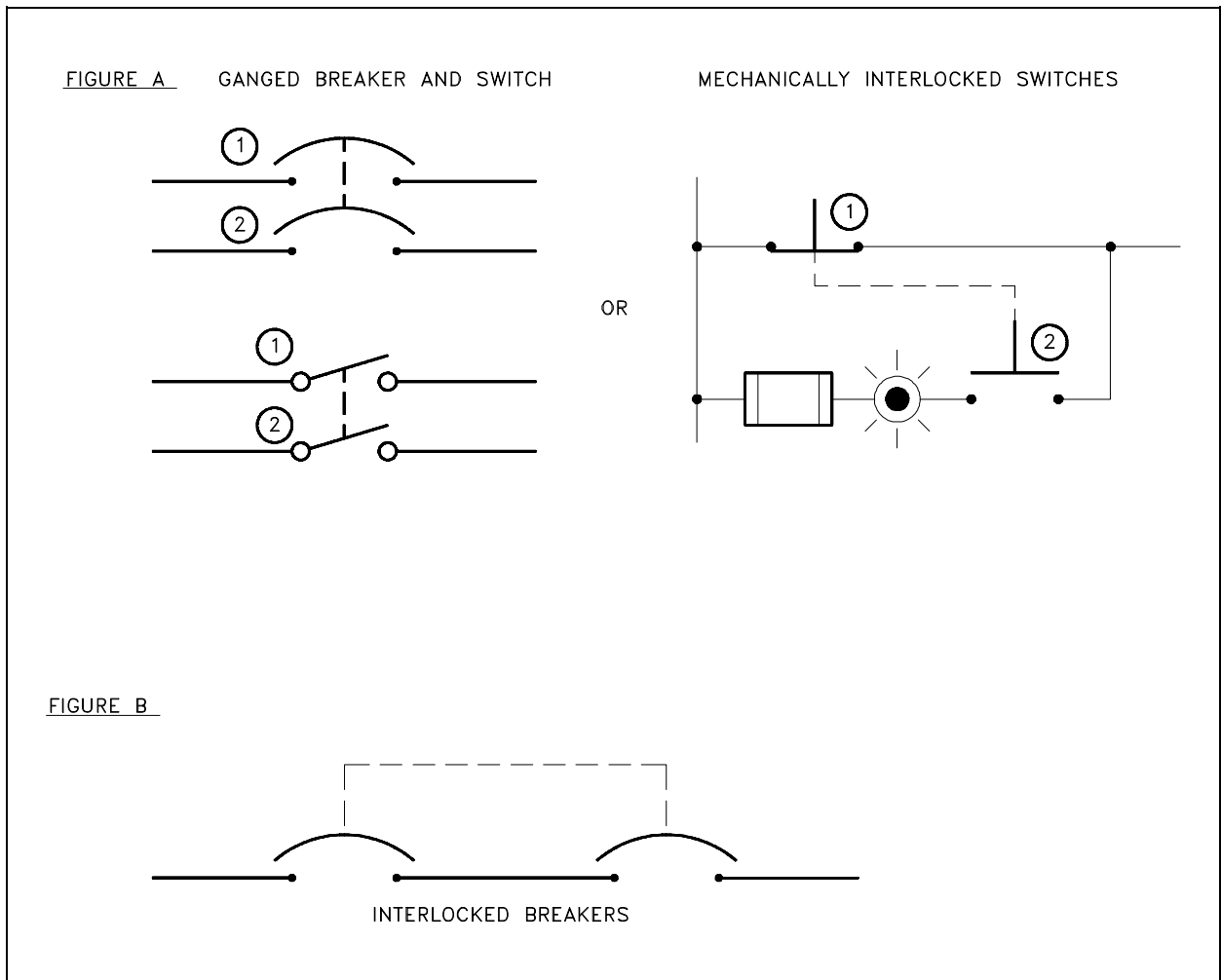


Figure 15 Ganged Switch Symbology

In system single line diagrams, transformers are often represented by the symbol for a single-phase air core transformer; however, that does not necessarily mean that the transformer has an air core or that it is single phase. Single line system diagrams are intended to convey only general functional information, similar to the type of information presented on a P&ID for a piping system. The reader must investigate further if more detail is required. In diagrams

depicting three-phase systems, a small symbol may be placed to the side of the transformer primary and secondary to indicate the type of transformer windings that are used.

Figure 16 (A) shows the most commonly used symbols to indicate how the phases are connected in three-phase windings. Figure 16 (B) illustrates examples of how these symbols appear in a three-phase single line diagram.

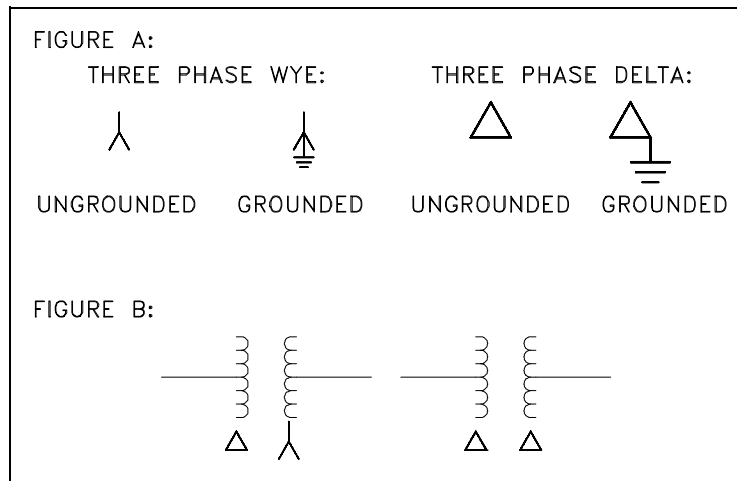


Figure 16 Three-Phase Symbols

Summary

The important information in this chapter is summarized below.

Electrical Diagrams and Schematics Summary

- This chapter covered the common symbols used on electrical diagrams and schematics to represent the basic electrical components.
- Polarity on a transformer is defined by dots placed on the primary and secondary windings. On the primary side, the dot indicates current in; on the secondary, the dot indicates current out.
- Switches, relays, and interlocked equipment commonly use dashed lines or boxes to indicate the relationship between them and other components.
- Electrical components, such as relays, are drawn in the de-energized state unless otherwise noted on the diagram.

ELECTRICAL WIRING AND SCHEMATIC DIAGRAM READING EXAMPLES

This chapter contains several examples that will help to build, through practice, on the knowledge gained in reading electrical wiring and schematic diagrams.

- 1.6 Given a simple electrical schematic and initial conditions, IDENTIFY the power sources and/or loads and their status (i.e., energized or de-energized).**
-

Examples

To aid in understanding the symbology and diagrams discussed in this module refer to Figure 17 and Figure 18. Then answer the questions asked about each. The answers for each example are given on the page following the questions.

Referring to Figure 17:

1. What type of diagram is it?
2. What is the rating on the fuses protecting the motor controller circuit?

Refer to the number at the far left to locate the following lines.

3. What is the component labeled ITDR in line 13?
4. Which lines contain limit switches?
5. Which lines contain pushbutton switches?
6. How many contacts are operated from relay 8CR?
7. What component is represented by the symbol on the far right of line 4?

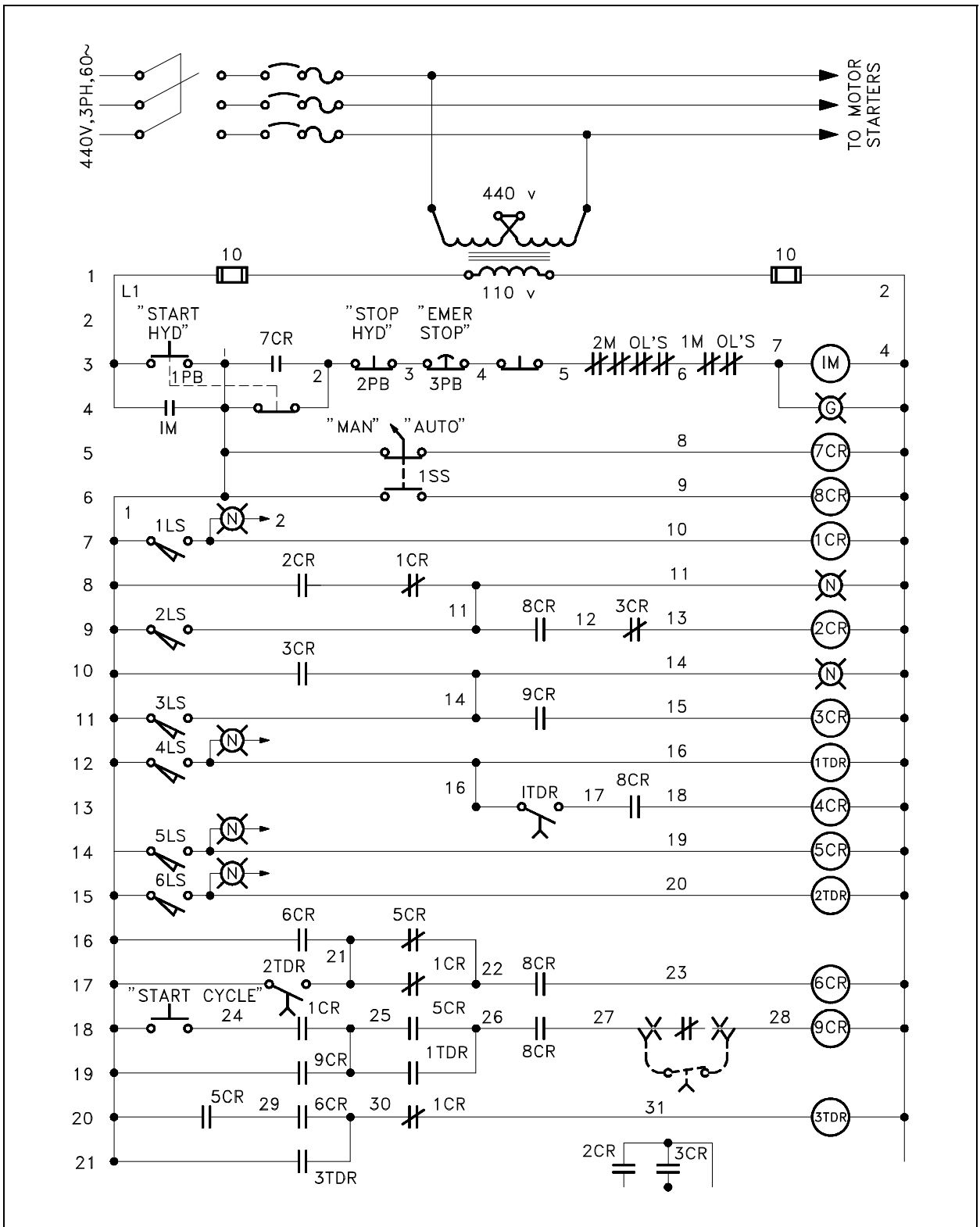


Figure 17 Example 1

Answers to questions on Figure 17.

1. Schematic
2. 10 amps
3. A time delay closing switch
4. Lines 7, 9, 11, 12, 14, and 15
5. Lines 3, 4, 5, 6, and 18
6. 4.
7. A green lamp

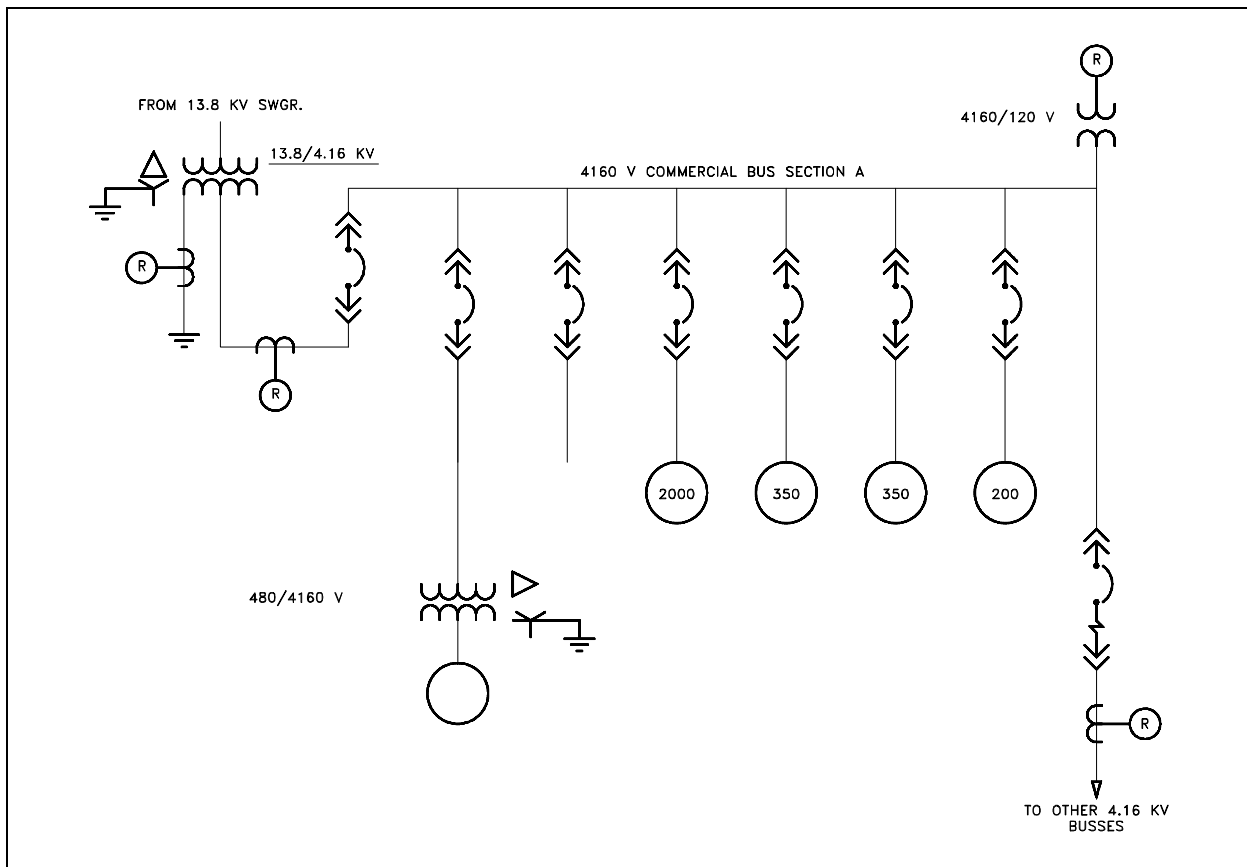


Figure 18 Example 2

Referring to Figure 18.

1. What type of diagram is Figure 18?
2. How many current transformers are in the diagram?
3. What type of circuit breakers are shown?
4. What is the voltage on the main bus?
5. What is the voltage entering the transformer in the lower left corner?
6. Classify the transformer in the upper left corner.
7. What is the component in the lower left corner?

Answers to questions on Figure 18.

1. System diagram
2. 3. If you said 4, the one in the upper right is a potential transformer.
3. Drawout type.
4. 4.16 kV or 4160 V.
5. 480 V.
6. Delta primary, grounded wye secondary.
7. (Emergency) diesel generator

Summary

The important information in this chapter is summarized below.

Electrical Wiring and Schematic Diagram Reading Example Summary

- This chapter reviewed the material presented in this module through the practice reading examples.