Basic Control Circuits

UNIT OBJECTIVE

Upon completion of this unit, you will be able to construct and analyze simple control circuits with various control devices.

DISCUSSION OUTLINE

The Discussion of Fundamentals covers the following points:

- Motor reversal
- Control voltage
- Brake motor

DISCUSSION OF FUNDAMENTALS

Different motor control circuits are chosen to suit particular needs. They can be simple, offering only manual on/off control. But they can also be more complex, permitting direction reversal, braking, or offering protection against sudden restarts or short-circuits.

When a motor needs to be operated from more than one location, multiple control stations can be used. Multiple push button stations, for instance, permit the starting and stopping of machinery at different places along a production line.

Each control circuit can be wired to restart automatically or not, following a voltage failure. **Two-wire control** allows a machine to restart automatically following a power outage, whereas **three-wire control** keeps the motor at rest until an operator accomplishes a restart procedure.

Motor reversal

To reverse the rotation direction of a motor, a cam switch can be employed to manually invert two power lines. Reversing the power lines can also be accomplished by using two magnetic contactors, one per motor rotation direction.

But when two reversing contactors are used, there is a risk of energizing both of them simultaneously, thus creating a short-circuit. To safely reverse the direction of a motor, interlocking means are employed. Mechanical interlock and push button interlock are two of these methods.

Control voltage

When control circuits are simple enough, the system designer may decide to use controls connected directly to power lines, or between a power line and the neutral. This approach proves to be less expensive because no voltage conversion device is required. Control elements must, however, be built to sustain higher voltages.

In many cases, though, motor control circuits are powered with a voltage different than that of the power circuit. In this manual, the technique used to provide low AC voltage suitable for control devices consists in utilizing a control transformer. This method also has the advantage of providing electrical isolation between power and control circuits.

Brake motor

In this unit, you will make use of the Brake Motor, Model 3176-A, shown in Figure 3-1. This is a general purpose, three-phase motor, coupled to a **friction disc brake**. The characteristics of the Brake Motor are shown on the motor nameplate and in Appendix F.

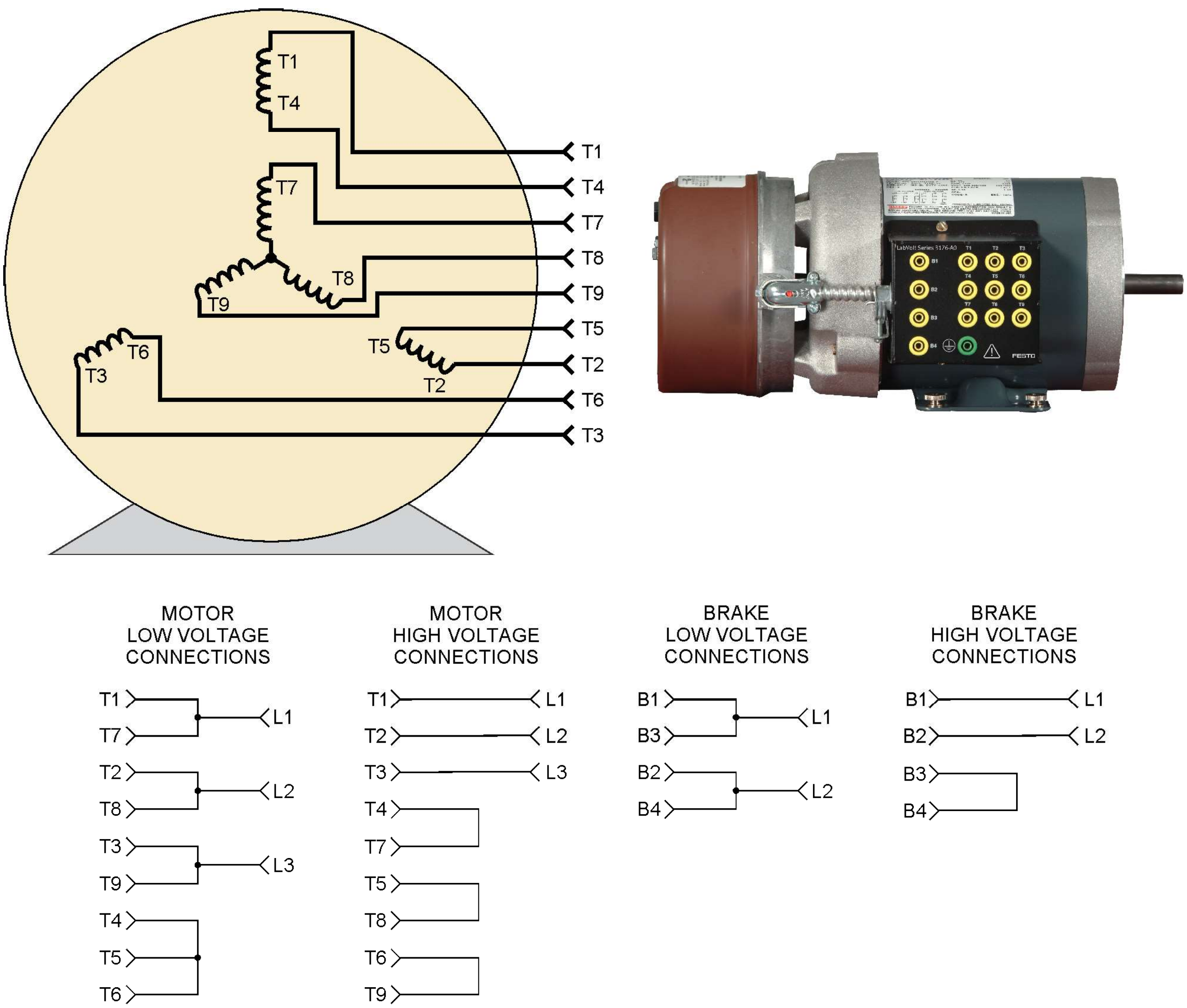


Figure 3-1. Brake Motor, Model 3176-A.

The labels on the motor and on the brake indicate how to make the connections, depending on the supplied voltage and frequency. Table 3-1 indicates the low and high voltage values for different network voltages and frequencies.

Table 3-1. Low and high voltage values for different network voltages and frequencies.

Low and high voltage values			
AC line voltage (V)	Frequency (Hz)	Low voltage (V)	High voltage (V)
120	60	208-230	460
220	50	190	380
240*	50	208	415
220*	60	190	380
* These values may not be indicated on the motor nameplate.			

To manually disengage the friction brake, set the knob on the brake cover to the RELEASE position as shown in Figure 3-2. The operation of the friction brake will be covered in Unit 4.

Figure 3-2. Release of friction brake on the Brake Motor.

Motor Starters

EXERCISE OBJECTIVE

- Set up and verify the operation of basic motor starters.
- Understand the purpose of a separate control circuit.

DISCUSSION OUTLINE

The Discussion of this exercise covers the following points:

- Inertia wheel
- Separate control

DISCUSSION

Motor starters are made out of contactors and overload protection devices. Full voltage can be applied directly to the motor, although this produces rather high inrush current.

The overload relay is chosen so as to protect the motor against a sustained, low level of excessive current. The contactor coil de-energizes when the overload relay trips.

Inertia wheel

Figure 3-3 shows the Inertia Wheel, Model 3147. This metal wheel can be coupled to a motor to increase its acceleration and deceleration time. In the following exercises, we will utilize the Inertia Wheel to observe the phenomena occurring while motors start and stop.

Figure 3-3. Inertia Wheel, Model 3147.

Separate control

It is sometimes possible to control motor circuits with the voltage between a power line and the neutral line, or between two power lines. However, there may be no neutral line available, or the provided voltage may not be desirable.

There is a considerable hazard in using high voltages for control circuits. Although push buttons and other pilot devices are often designed to withstand higher voltages, breaks in insulation and careless wiring may subject the operator to a serious shock. Therefore, it is common practice to use a control voltage transformer to provide low AC voltage suitable for control circuits. Figure 3-4 shows the Control Transformer, Model 3138 (208:120 version), used to provide AC control voltage compatible with coils and indicating lights of the Industrial Controls Training System.

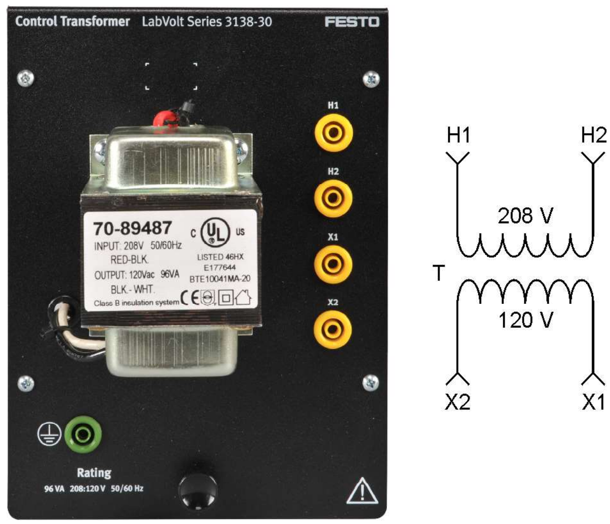
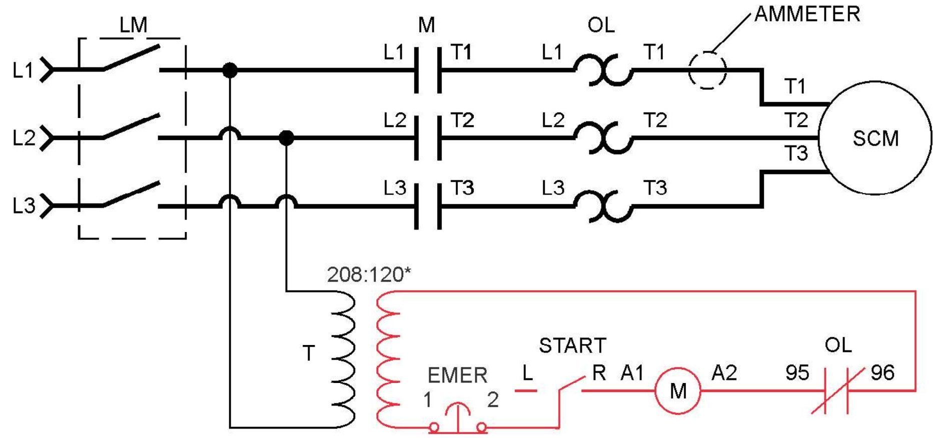


Figure 3-4. Control Transformer, Model 3138 (208:120 version).

Installing a DC power supply is another means of providing a safe control voltage. This method will be seen later in the Industrial Controls Training System student manuals.

Figure 3-5 is the schematic diagram of a separate motor control system. In this diagram, the control circuit is isolated from the power lines because of the control transformer, which takes voltage between two power lines to provide low control voltage. When power is applied to the circuit and the toggle switch is set to the START position, the contactor coil (M) is energized, actuating power contacts. If the NC overload contacts or the toggle switch open, the contactor coil (M) is de-energized and the power contacts are opened.



*208:120 FOR 120 V - 60 Hz NETWORK
380:110 FOR 220 V - 50 Hz NETWORK
415:110 FOR 240 V - 50 Hz NETWORK
380:120 FOR 220 V - 60 Hz NETWORK

LEGEND

EMER	=	EMERGENCY PUSH BUTTON (MAINTAINED CONTACT)
M	=	MAIN CONTACTOR
OL	=	OVERLOAD RELAY
SCM	=	SQUIRREL CAGE MOTOR
START	=	START TOGGLE SWITCH (MAINTAINED CONTACT)
T	=	CONTROL VOLTAGE TRANSFORMER
LM	=	LOCKOUT MODULE

Figure 3-5. Motor circuit with control transformer.

PROCEDURE OUTLINE

The Procedure is divided into the following sections:

- Basic setup
- Control transformer output voltage measurement
- Inrush current measurement

PROCEDURE

In this exercise, you will verify that the control transformer converts the line-line voltage from the power distribution system to a voltage compatible with the control pilot lights and coils.

You will then implement a basic motor starter circuit from a schematic diagram. This setup will use a control transformer and a toggle switch to activate a contactor. The instructor will be invited to verify your connections before power is applied to the circuit. When starting the motor, you will observe with the ammeter the inrush current phenomenon that was discussed in Exercise 1-5.

⚠ WARNING

The AC Power Supply provides high voltages. Do not change any AC connection with the power on.

Basic setup

1. Perform the Basic Setup and Lockout/Tagout procedures.

Control transformer output voltage measurement

2. Connect the Control Transformer to the Lockout Module as shown in Figure 3-5. Do not connect the other components for now.

   Connect the voltmeter between terminals X1 and X2 of the Control Transformer.

   Perform the Energizing procedure.

   What is the voltage provided by the Control Transformer?

   Voltage: ______

3. Is this voltage compatible with the pilot light rating of the Pilot Lights module?

   ❑ Yes ❑ No

4. Is this voltage compatible with the coil rating of the Contactor module?

   ❑ Yes ❑ No

5. Perform the Lockout/Tagout procedure.

Inrush current measurement

6. Install the Brake Motor, Inertia Wheel, and Safety Guard as described in Appendix E.

   Connect the circuit shown in Figure 3-5. Use the toggle switch O-R contact of the Selector Switches module.

Make sure that the motor is connected according to your distribution voltage.

7. Manually disengage the friction brake by setting the knob on the brake cover to the RELEASE position.

Set the START toggle switch of the Selector Switches to the O position.

Clamp an ammeter around a motor power lead.

Perform the Energizing procedure.

8. Observe the ammeter display as you set the START toggle switch to the R position. Repeat your observation if necessary.

How does the motor current level behave, when the motor is started?

❑ The current is maximum upon starting and decreases to become stable.

❑ The current is minimum upon starting and increases to become stable.

❑ The current level increases continuously.

9. Explain what happens in the circuit when the START toggle switch is reset to the O position.

____

10. Turn the individual power switch of the AC Power Supply off, disconnect the circuit, remove the magnetic labels, and return the equipment to the storage location.

Conclusion

The use of a control voltage transformer is a way to isolate control and power circuits. It provides suitable low voltage for the control circuit.

Motor starters are made of contactors and overload protection devices. When loads are coupled to the motor shaft, the motor accelerates and decelerates slower.

The current level is higher upon starting than during normal operation. This phenomenon, discussed in Exercise 1-5, is called inrush current.

Review Questions

1. How would you explain that direct line-neutral connection of a control circuit is often not desirable?

   a. High voltages present more risk for the operator.

   b. Power lines may conduct voltages too high for control.

   c. There is not always a neutral wire available.

   d. All of the reasons above are correct.

2. Apart from a control transformer, what other device can be used to provide control circuit voltage?

   a. Lockout module

   b. Time relay

   c. DC power supply

   d. Cam switch

3. Which terminals of the Control Transformer must be connected to the system power lines, in the Figure 3-5 circuit?

   a. H2 and X1

   b. X1 and X2

   c. H1 and X2

   d. H1 and H2

4. In the Figure 3-5 circuit, what are the coil terminals of the main contactor?

   a. 1 L1 - 2 T2

   b. 3 L2 - 4 T2

   c. 5 L3 - 6 T3

   d. A1 - A2

5. In Figure 3-5, where does the Control Transformer take the voltage for the control circuit?

   a. Between lines 1 and 2.

   b. Between lines 2 and 3.

   c. Between lines 1 and 3.

   d. Between lines 1 and N.

Two-Wire and Three-Wire Controls

EXERCISE OBJECTIVE

Construct two-wire and three-wire control circuits and understand their principles.

DISCUSSION OUTLINE

The Discussion of this exercise covers the following points:

- Two-wire control
- Three-wire control

DISCUSSION

Electrical motor controls can be wired so that they restart the motor automatically or not, after power is removed from and returned to the circuit.

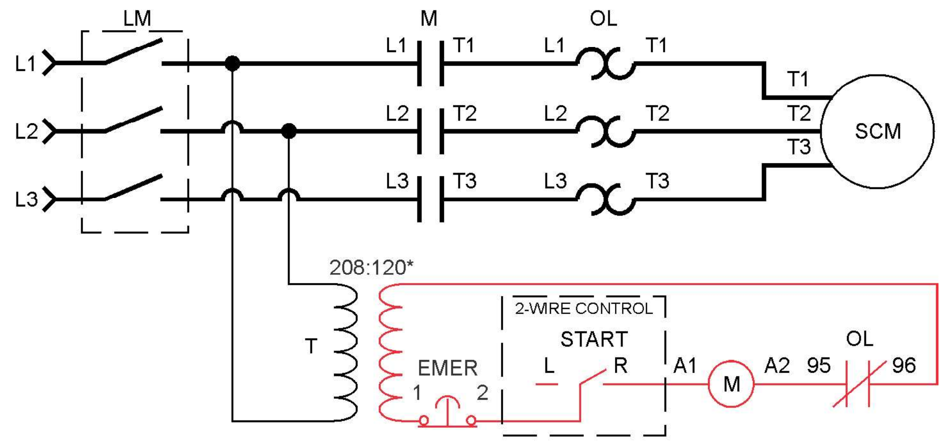
Two-wire control

Two-wire control of a starter means the starter drops out when there is a voltage failure and starts up by itself when the voltage returns. This type of control is often used on fans or exhaust blowers.

The two-wire control circuit is so named because only two wires are connected to the pilot device used to energize the magnetic controller. The pilot devices used can hold their contacts closed, even if there is a power failure. These controls may be thermostats, float switches, pressure switches, toggle switches, or **selector switches**. Two-wire control is also called **no-voltage release** or **low-voltage release**.

Two-wire control does not require an operator to be present to restart a machine following a voltage failure. However, this can be hazardous to personnel and machinery, due to the sudden restart of equipment.

Figure 3-6 shows a two-wire control circuit. When the control contact closes, the coil (M) is energized. The power contacts close, causing the motor to start. When the control contact opens, or power is removed from the circuit, the coil (M) de-energizes, which opens the power contacts and stops the motor. When power returns, the motor restarts automatically if the control contact is closed.



*208:120 FOR 120 V - 60 Hz NETWORK
380:110 FOR 220 V - 50 Hz NETWORK
415:110 FOR 240 V - 50 Hz NETWORK
380:120 FOR 220 V - 60 Hz NETWORK

LEGEND

EMER = EMERGENCY PUSH BUTTON (MAINTAINED CONTACT)
M = MAIN CONTACTOR
OL = OVERLOAD RELAY
SCM = SQUIRREL CAGE MOTOR
START = START TOGGLE SWITCH (MAINTAINED CONTACT)
T = CONTROL VOLTAGE TRANSFORMER
LM = LOCKOUT MODULE

Figure 3-6. Two-wire control circuit.

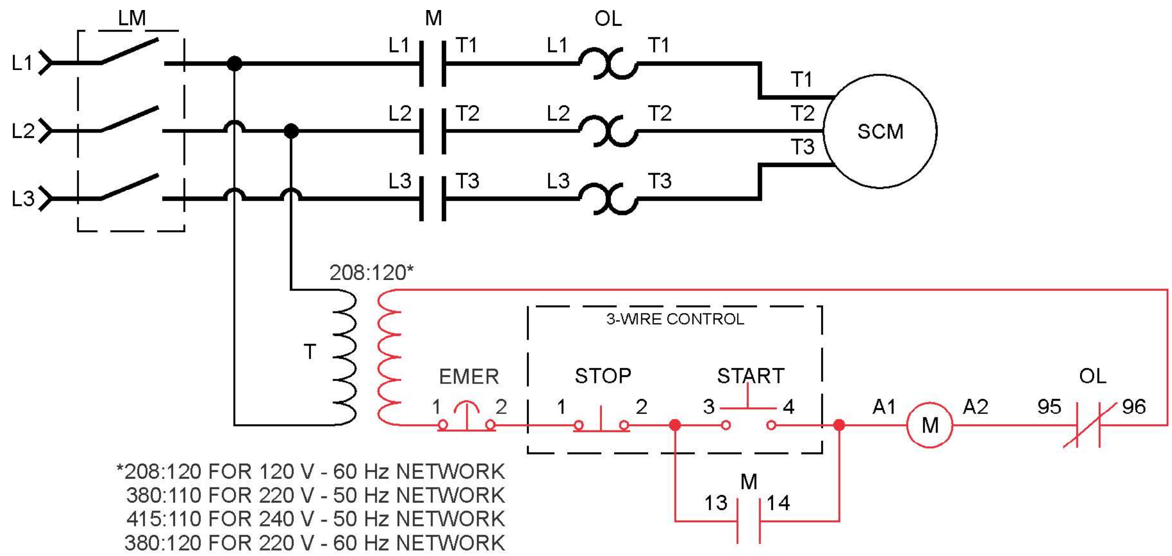
Three-wire control

Three-wire control of a starter means that the starter drops out when a voltage failure occurs, but does not restart when the voltage returns, therefore not constituting the same hazard as the two-wire control.

The three-wire control circuit gets its name from the three wires that must be connected to the pilot device. A holding contact must be used in addition to control devices that do not hold their state, like momentary contact push buttons. This method is also called **no-voltage protection** or **low-voltage protection**.

The circuit of Figure 3-7 is an example of three-wire control. It functions in the following manner:

- When the START push button is pressed, the coil (M) energizes and the holding contact (M) closes to keep the coil energized.
- When the STOP push button is pressed or power is removed, the circuit is broken, causing coil (M) to de-energize, and the holding contact to open.
- The START push button must be pressed again to energize the coil.



LEGEND

EMER	=	EMERGENCY PUSH BUTTON (MAINTAINED CONTACT)
M	=	MAIN CONTACTOR
OL	=	OVERLOAD RELAY
SCM	=	SQUIRREL CAGE MOTOR
START	=	START PUSH BUTTON (MOMENTARY CONTACT)
STOP	=	STOP PUSH BUTTON (MOMENTARY CONTACT)
T	=	CONTROL VOLTAGE TRANSFORMER
LM	=	LOCKOUT MODULE

Figure 3-7. Three-wire control circuit.

Procedure Outline

The Procedure is divided into the following sections:

- Basic setup
- Two-wire control circuit
- Three-wire control circuit

Procedure

In this exercise, you will implement a two-wire control circuit and verify that this circuit restarts automatically, after power is removed and restored.

After that, you will set up a three-wire control circuit to see that such a circuit does not restart by itself, after power is restored following a disruption.

⚠ WARNING

The AC Power Supply provides high voltages. Do not change any AC connection with the power on.

Basic setup

1. Perform the Basic Setup and Lockout/Tagout procedures.

Two-wire control circuit

2. Install the Brake Motor, Inertia Wheel, and Safety Guard.

   Connect the circuit shown in Figure 3-6.

3. Manually disengage the friction brake.

   Set the START toggle switch of the Selector Switches to the O position.

   How many leads (minimum) are connected to the Selector Switches module?

   Number of leads: ______

4. What type of control is this?

   ❑ No-voltage protection ❑ No-voltage release

5. Perform the Energizing procedure.

   Explain what happens as you turn on the Lockout Module.

   ____

   ____

   ____

6. Explain what happens as you set the START toggle switch to the R position.

   ____

   ____

   ____

7. While the Brake Motor is running, turn off the Lockout Module, then turn it on. Explain what happens.

   ____

   ____

   ____

8. Perform the Lockout/Tagout procedure.

Three-wire control circuit

9. Connect the circuit shown in Figure 3-7.

10. What type of control is this?

❑ No-voltage protection ❑ No-voltage release

11. Perform the Energizing procedure.

Explain what happens as you turn on the Lockout Module.

____

____

____

12. Press the START push button briefly. Explain what happens.

____

____

____

13. While the Brake Motor is running, turn off the Lockout Module, then turn it on. Explain what happens.

____

____

____

14. What do you have to do to restart the motor?

____

15. What happens if you press the STOP push button while the motor is running?

____

____

____

16. Turn the individual power switch of the AC Power Supply off, disconnect the circuit, remove the magnetic labels, and return the equipment to the storage location.

Conclusion

Two-wire control circuits restart a motor automatically when voltage returns, following a power failure. A two-wire controller can be a toggle switch, **float switch**, **limit switch**, or any other device with maintained on-off positions.

Three-wire control circuits require that an operator be present to restart the machine, following a power failure. Three-wire controls can be, for example, momentary contact push buttons.

Review Questions

1. What happens, following a power failure, in a two-wire control circuit?

   a. The motor starts up as soon as power is restored.

   b. The start push button must be pressed to restart the motor.

   c. An operator must be present to restart the machine.

   d. Two overload heaters are used to protect the motor.

2. Why are three-wire control circuits less hazardous to personnel in industries than two-wire control circuits?

   a. The machine does not have to be restarted.

   b. The personnel is less likely to stumble on the wires.

   c. The machine does not restart spontaneously after power is restored.

   d. All of the answers above are correct.

3. Which of the following words is a synonym for three-wire control circuit?

   a. Low-voltage release control circuit.

   b. No-voltage release control circuit.

   c. No-voltage protection control circuit.

   d. Overvoltage release control circuit.

4. Which of the following control devices can be used for three-wire control?

   a. Toggle switch

   b. Float switch

   c. Selector switch

   d. Push button

5. In three-wire control circuits, what path does the control current take when the momentary contact is released?

   a. Starting coil

   b. Holding contact

   c. Power contact

   d. Stop push button

Manual Reversing Starters

EXERCISE OBJECTIVE Build manual reversing starters and understand how they work.

DISCUSSION Reversing motor rotation direction is a common operation in industrial controls. For three-phase motors, this is done by interchanging any two power lines. Swapping two lines has the effect of shifting from a line sequence to another. Each sequence makes the motor turn in a specific direction, because the motor revolves according to the rotating magnetic field created by the voltages applied to the motor windings. There are two possible line sequences in a three-phase system:

- 1-2-3-1-2-3 (which can be expressed as 1-2-3, 2-3-1 or 3-1-2)
- 3-2-1-3-2-1 (which can be expressed as 3-2-1, 2-1-3 or 1-3-2)

The phase switching can be accomplished manually, with the help of a cam switch, or with magnetic devices, as will be seen later in this manual.

When the Cam Switch, shown in Figure 3-8, is set to the FORW (FWD) position, lines are connected in the usual order (L1 to T1, L2 to T2, and L3 to T3), so that the motor runs in the forward direction.

In the REV position, lines 1 and 2 are interchanged (L2 to T1, L1 to T2, and L3 to T3) to reverse the motor rotation direction. Placing the Cam Switch to the STOP position simply opens the three lines and shuts off the motor.

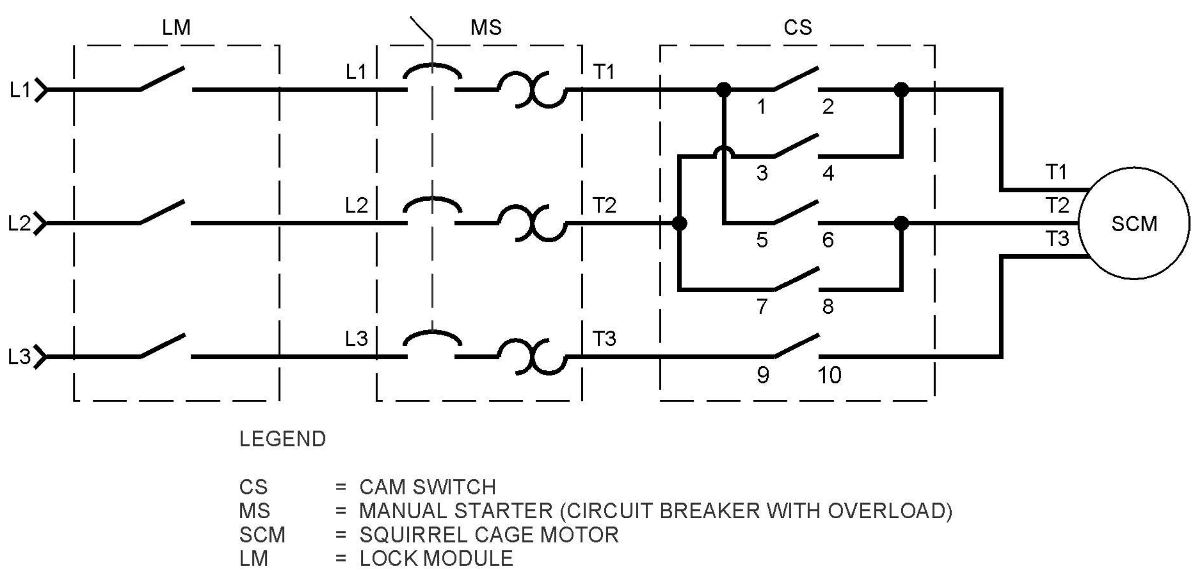


Figure 3-8. Manual reversing starter circuit with a cam switch.

PROCEDURE OUTLINE

The Procedure is divided into the following sections:

- Basic setup
- Reversing the rotation direction by manually changing the line sequence
- Reversing the rotation direction using a cam switch to change the line sequence

PROCEDURE

In this exercise, you will manually change the motor terminal connections to observe the relationship between line sequence and motor rotation direction. You will then use a cam switch to reverse the motor rotation direction without having to disconnect power leads.

⚠ WARNING

The AC Power Supply provides high voltages. Do not change any AC connection with the power on.

Basic setup

1. Perform the Basic Setup and Lockout/Tagout procedures.

Reversing the rotation direction by manually changing the line sequence

2. Install the Brake Motor, Inertia Wheel, and Safety Guard.

   Connect the circuit shown in Figure 3-8.

3. Manually disengage the friction brake.

   Set the Cam Switch to the FORW (FWD) position.

   Set the knob of the Manual Starter to the O position.

   Perform the Energizing procedure.

4. Observe the rotation direction of the motor shaft (viewed when facing the end of the motor shaft) as you set the knob of the Manual Starter to the I position.

   Enter the rotation direction and the line sequence in the appropriate row of Table 3-2.

   Set the knob of the Manual Starter to the O position.

5. Repeat the previous step for all the configurations shown in the Connections column of Table 3-2. Change configuration by modifying the connections at the Brake Motor terminals.

Turn off the Lockout Module while you modify the connections.

Table 3-2. Motor rotation directions and line sequences.

Connetions	Motor rotation directions		Line sequences	
	CW	CCW	1-2-3-1-2-3	3-2-1-3-2-1
L1 - T1 L2 - T2 L3 - T3 (M)				
L2 - T1 L1 - T2 L3 - T3 (M)				
L3 - T1 L2 - T2 L1 - T3 (M)				
L1 - T1 L3 - T2 L2 - T3 (M)				
L3 - T1 L1 - T2 L2 - T3 (M)				
L2 - T1 L3 - T2 L1 - T3 (M)				

6. Does the line sequence relate to the motor rotation direction?

❑ Yes ❑ No

Reversing the rotation direction using a cam switch to change the line sequence

7. Turn off the Lockout Module.

Set the knob of the Manual Starter to the I position.

Set the Cam Switch to the STOP position.

Connect the motor in the usual manner (L1 to T1, L2 to T2, and L3 to T3).

Turn on the Lockout Module.

Determine the motor rotation direction as you set the Cam Switch to the FORW (FWD) position.

❑ Clockwise ❑ Counterclockwise

8. Set the Cam Switch to the STOP position.

CAUTION

The Cam Switch module is AC-3 rated. Therefore, it is not recommended to reverse power lines while the motor is still rotating. Wait for the motor to come to a complete stop before changing switch direction.

9. Determine the motor rotation direction as you set the Cam Switch to the REV position.

   ❑ Clockwise ❑ Counterclockwise

10. Compared to the FORW (FWD) operation, does the motor turn in the other direction?

   ❑ Yes ❑ No

11. Does using the Cam Switch have the same effect as manually inverting motor connections of lines 1 and 2?

   ❑ Yes ❑ No

12. Turn the individual power switch of the AC Power Supply off, disconnect the circuit, remove the magnetic labels, and return the equipment to the storage location.

CONCLUSION

Changing the motor terminal's line sequence reverses the motor rotation direction. There are only two possible sequences in a three-phase system: one for the forward direction, and one for the reverse direction.

Instead of manually modifying the line sequence, a cam switch may be used to simplify the reversal of motor rotation direction.

REVIEW QUESTIONS

1. Which device can be used to directly reverse two power lines?

   a. Selector switch

   b. Toggle switch

   c. Push button

   d. None of the answers above is correct.

2. How many different line sequences exist for a three-phase system?

   a. 1

   b. 2

   c. 3

   d. 4

3. What phenomenon causes three-phase motors to turn in a specific direction?

   a. Rotating magnetic field

   b. Electrical hysteresis

   c. Windings resistivity

   d. Phase capacitance

4. What happens when the Cam Switch, Model 3140, is set to the STOP position?

   a. All three power contacts open.

   b. All three power lines are reversed.

   c. Two power lines are reversed.

   d. One power contact opens.

5. Which of the following power line terminal connection orders is part of a different line sequence?

   a. 3-1-2

   b. 2-3-1

   c. 3-2-1

   d. 1-2-3

Reversing Starters

EXERCISE OBJECTIVE

- Implement magnetic reversing starters.
- Understand the principles of mechanical and electrical interlocking.

DISCUSSION OUTLINE

The Discussion of this exercise covers the following points:

- Push button interlocking
- Mechanical interlocking

DISCUSSION

As you have seen in the previous exercise, reversing rotation direction of a three-phase motor is usually done by interchanging any two power lines. When the equipment is sufficiently rugged, motor line reversal can be accomplished while the motor is running at full speed. This has a major advantage: a counter torque is developed and the motor stops faster. This motor braking method is called **plugging**.

When phase reversal is executed in magnetic circuits, one contactor is used for each direction. But a short-circuit can occur if the two contactors are energized at the same time. Look at the power circuit in Figure 3-9, for example. If all contacts of the F and R contactors close, lines 1 and 2 will be short-circuited. That is the reason why forward and reverse contactors are usually electrically and/or mechanically interlocked together.

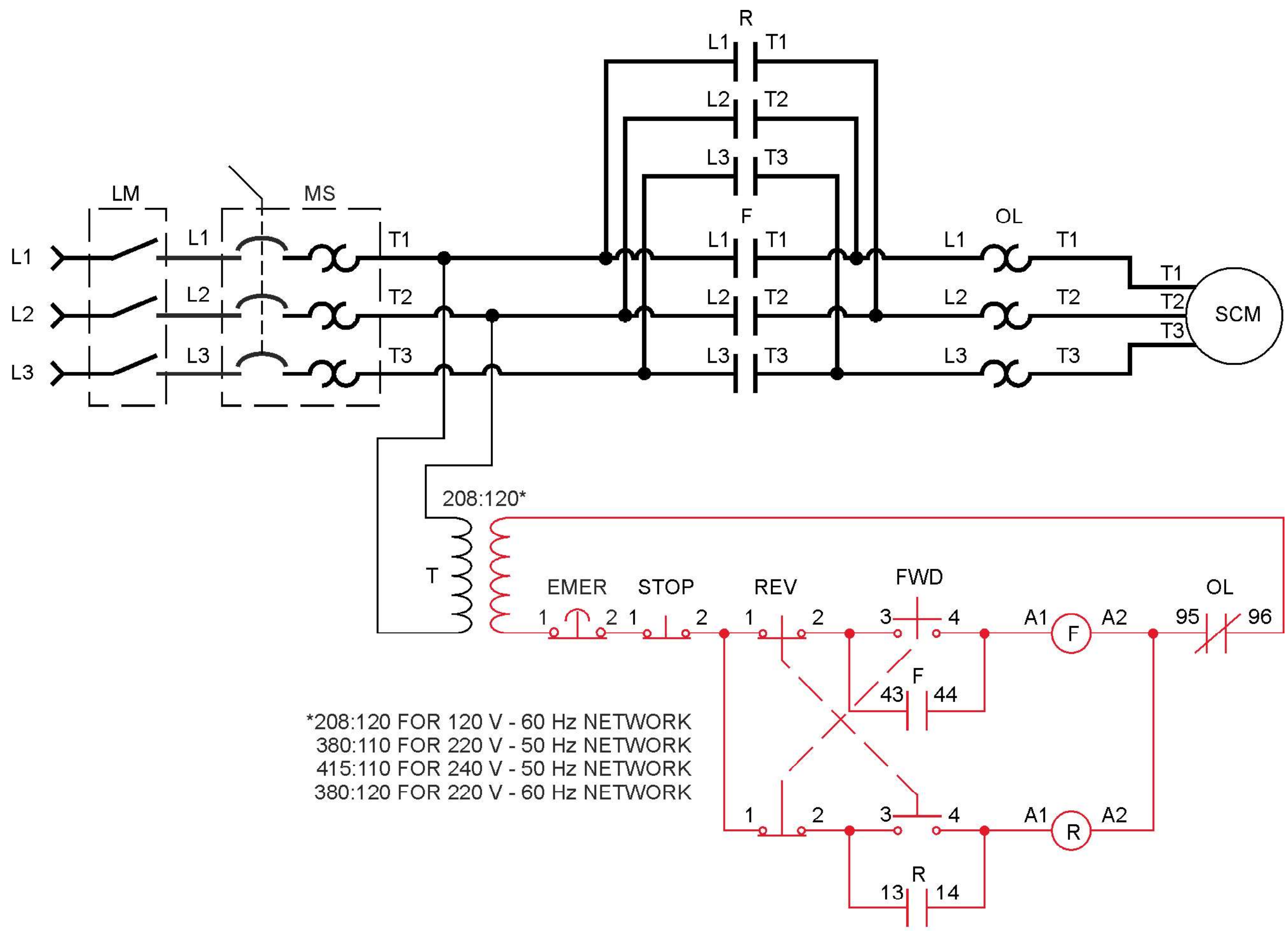
Push button interlocking

Avoiding simultaneous actuation of two contactors can be done electrically, by way of push button interlocking.

When the FWD push button in Figure 3-9 is pressed, the coil (F) is energized and the related holding contact closes. If the REV push button is pressed while the motor is running in the forward direction, the forward control circuit de-energizes. At the same time, the reverse contactor (R) is energized and held closed, making the motor run in the reverse direction. Note that it is not necessary to press the STOP push button to reverse the direction. This fact facilitates plugging.

If the FWD and REV push buttons are simultaneously activated, both contactors will stay open. That is because the push button NC contacts open the control circuit completely, thereby forcing contactor coils to de-energize.

However, if a contactor coil is stuck closed or does not open fast enough, there can still be a short-circuit when the other coil is activated.



LEGEND

F	=	FORWARD DIRECTION CONTACTOR
FWD	=	FORWARD PUSH BUTTON (MOMENTARY CONTACT)
OL	=	OVERLOAD RELAY
R	=	REVERSE DIRECTION CONTACTOR
REV	=	REVERSE PUSH BUTTON (MOMENTARY CONTACT)
SCM	=	SQUIRREL CAGE MOTOR
STOP	=	STOP PUSH BUTTON (MOMENTARY CONTACT)
T	=	CONTROL VOLTAGE TRANSFORMER
EMER	=	EMERGENCY PUSH BUTTON (MAINTAINED CONTACT)
LM	=	LOCKOUT MODULE
MS	=	MANUAL STARTER

Figure 3-9. Push button interlocking circuit.

Mechanical interlocking

A mechanical lever is another manner of preventing both starter coils from being energized simultaneously. Figure 3-10 displays the mechanical interlock located between the two contactors of the Dual Contactors, Model 3119.

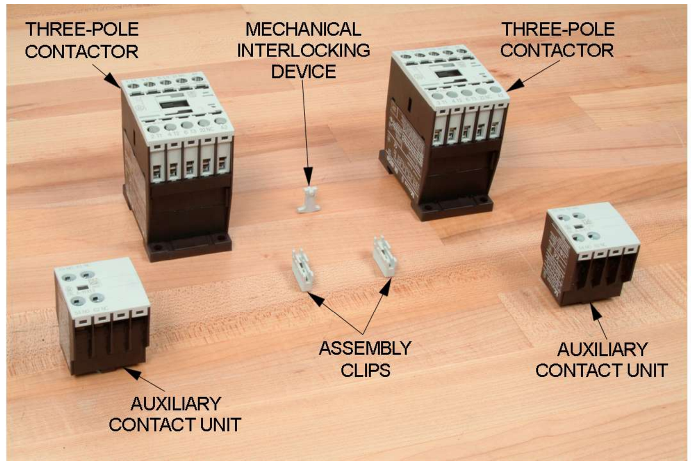
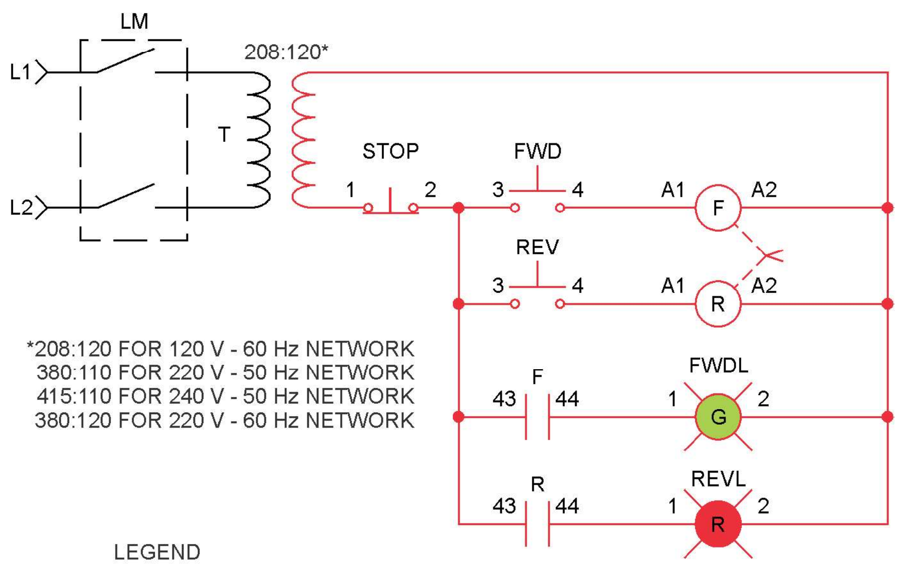


Figure 3-10. Mechanical interlocking.

Refer to the circuit of Figure 3-11. A mechanical interlock (in dashed lines) is located between the two contactor coils. When one of the two contactors is energized, the contacts of the other contactor are mechanically maintained, even if the second coil is energized. This method provides a level of security against short-circuits resulting from stuck contactors. This explains why mechanical interlocks are so common in the industry.



LEGEND

F = FORWARD DIRECTION CONTACTOR
FWD = FORWARD PUSH BUTTON (MOMENTARY CONTACT)
FWDL = FORWARD PILOT LIGHT
R = REVERSE DIRECTION CONTACTOR
REV = REVERSE PUSH BUTTON (MOMENTARY CONTACT)
REVL = REVERSE PILOT LIGHT
STOP = STOP PUSH BUTTON (MOMENTARY CONTACT)
T = CONTROL VOLTAGE TRANSFORMER
LM = LOCKOUT MODULE

Figure 3-11. Dual contactors testing circuit.

PROCEDURE OUTLINE

The Procedure is divided into the following sections:

- Basic setup
- Push button interlocking
- Mechanical interlocking
- Reversing starter with push button and mechanical interlock

PROCEDURE

In the first part of this exercise, you will set up a reversible starter circuit with push button interlocking and verify that this circuit enables changing the motor direction. You will also observe that motor direction reversing can be accomplished without having to press the STOP push button, to stop the motor faster. You will then verify that both contactors remain de-energized if the operator accidentally presses the two push buttons. Finally, you will simulate a stuck contactor to see that push button interlocking does not protect against short-circuits resulting from that type of trouble.

In the second part of this exercise, you will study, with the assistance of pilot lights, how a mechanical interlock operates. By manually applying pressure on the dual contactors plungers, you will check that it is not possible to activate both contactors at the same time. You will then visualize that, when both coils are powered, only the first contactor has its related contacts closed.

In the last part of this exercise, you will connect a reversing starter with push button and mechanical interlocks. You will see that this circuit, like the push button interlock circuit, enables motor direction reversal and opens completely when both push buttons are pressed. You will also discover that the mechanical interlock included adds protection against stuck contactors.

⚠ WARNING

The AC Power Supply provides high voltages. Do not change any AC connection with the power on.

Basic setup

1. Perform the Basic Setup and Lockout/Tagout procedures.

Push button interlocking

2. Install the Brake Motor, Inertia Wheel, and Safety Guard.

Connect the circuit shown in Figure 3-9.

Use one of the two contactors from the Dual Contactors, Model 3119, as the forward direction contactor, and the Contactor, Model 3127, as the reverse direction contactor, to make sure that there is no mechanical link between contactors.

3. On the Manual Starter, set the overload potentiometer according to the motor FLA, and the O/I button to the I position.

Manually disengage the friction brake.

Perform the Energizing procedure.

Determine the motor rotation direction as you press the FWD push button.

❑ Clockwise ❑ Counterclockwise

4. Press the STOP push button and observe the time taken by the motor to stop.

5. Determine the motor rotation direction as you press the REV push button.

❑ Clockwise ❑ Counterclockwise

6. Compared to the forward operation, does the motor turn in the other direction?

❑ Yes ❑ No

The contactors are all AC-4 rated. This class allows for plugging operation (reversing direction of rotation from other than off condition).

7. While the motor is running in the reverse direction, press the FWD push button until the motor halts. Press the STOP push button before the motor starts rotating in the opposite (forward) direction. Repeat if necessary.

Repeated motor starts and stops may cause the Overload Relay to trip.

Did the motor stop slower or faster than with the STOP push button only?

❑ Slower ❑ Faster

8. When the FWD push button was pressed, why were both contactors (F and R) not activated at the same time, thereby causing a short-circuit?

9. What happens when you keep the FWD and REV push buttons pressed simultaneously?

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10. Describe how the circuit operates while you simultaneously keep the FWD and REV push buttons pressed.

____

____

11. What happens if you do not release both push buttons simultaneously? Explain why.

____

____

12. Press the FWD push button to start the motor.

To simulate a stuck contactor, manually hold the forward contactor plunger down (using the tip of a pen), then press the REV push button. What happens?

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13. Describe how the circuit operates while you simultaneously hold the forward contactor plunger down and press the REV push button.

____

____

14. Does push button interlocking offer a good protection against stuck contactors?

❑ Yes ❑ No

15. Perform the Lockout/Tagout procedure.

Mechanical interlocking

16. Connect the circuit shown in Figure 3-11.

Use the two contactors from the Dual Contactors module.

17. Perform the Energizing procedure.

18. Can you (manually) hold down completely the two contactor plungers simultaneously? Explain why.

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19. When you press the FWD push button alone, which contactor coil is energized? (Refer to the respective pilot lights.)

❑ F ❑ R

20. When you press the REV push button alone, which contactor coil is energized? (Refer to the respective pilot lights.)

❑ F ❑ R

21. Does pressing the FWD and REV push buttons energize both contactor coils simultaneously?

❑ Yes ❑ No

22. When both push buttons are pressed, which contactor coil(s) energize(s), in regard to the order in which the corresponding push buttons were pressed?

❑ The first ❑ The second ❑ Both ❑ None

23. Perform the Lockout/Tagout procedure.

Reversing starter with push button and mechanical interlock

24. Connect the circuit shown in Figure 3-9, this time using the two contactors from the Dual Contactors module.

25. Perform the Energizing procedure.

Determine the motor rotation direction as you press the FWD push button.

❑ Clockwise ❑ Counterclockwise

26. Press the STOP push button and wait for the motor to stop.

27. Determine the motor rotation direction as you press the REV push button.

❑ Clockwise ❑ Counterclockwise

28. While the motor is running in the reverse direction, press the FWD push button. Does the motor direction change? Explain what happens, considering that the circuit now contains a mechanical interlock.

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29. Press both push buttons simultaneously, and determine which contactor(s) energize(s), in regard to the order in which the corresponding push buttons were pressed.

❑ The first ❑ The second ❑ Both ❑ None

30. Press the FWD push button to start the motor. To simulate a stuck contactor, manually hold the forward contactor plunger down (using the tip of a pen). Press the REV push button.

Does the motor still run in the forward direction? Explain why.

____

____

31. Does mechanical interlocking offer protection against stuck contactors?

❑ Yes ❑ No

32. Turn the individual power switch of the AC Power Supply off, disconnect the circuit, remove the magnetic labels, and return the equipment to the storage location.

CONCLUSION

Reversing magnetic starters are built with two contactors, one per rotation direction. If both contactors are actuated at the same time, a short-circuit can occur. This is why electrical and/or mechanical interlocks are used.

Push button interlocking is an electrical means of preventing two contactors from being actuated simultaneously. When a push button is pressed, the circuit controlling the other motor direction is automatically opened.

Mechanical interlocking uses a lever to artificially keep the second contactor de-energized, while the first coil is actuated. This method is more rugged in the way that it prevents short-circuits resulting from a stuck contactor.

Plugging is a method of making the motor brake faster. It is accomplished by reversing phases while the motor is running.

Review Questions

1. What is the purpose of interlocking in reversing starters?

   a. Prevent any contactor from being energized.

   b. Prevent any contactor from being de-energized.

   c. Stop the motor in case of electrical overload.

   d. Prevent two contactor coils from being energized at the same time.

2. How many contactors are necessary for reversing starters?

   a. 2

   b. 3

   c. 4

   d. 5 or more

3. What is the motor braking method that uses the counter torque produced by reversing connections?

   a. Inching

   b. Plugging

   c. Jogging

   d. DC injection

4. In mechanical interlocking, which item prevents both coils from being actuated simultaneously?

   a. Coil

   b. Lever

   c. Push button

   d. Diode

5. In the Figure 3-9 circuit, which lines have been interchanged in the reverse mode compared to the forward mode?

   a. Line 1 and line 2

   b. Line 1 and line 3

   c. Line 2 and line 3

   d. Line 1 and line N

Multiple Push Buttons

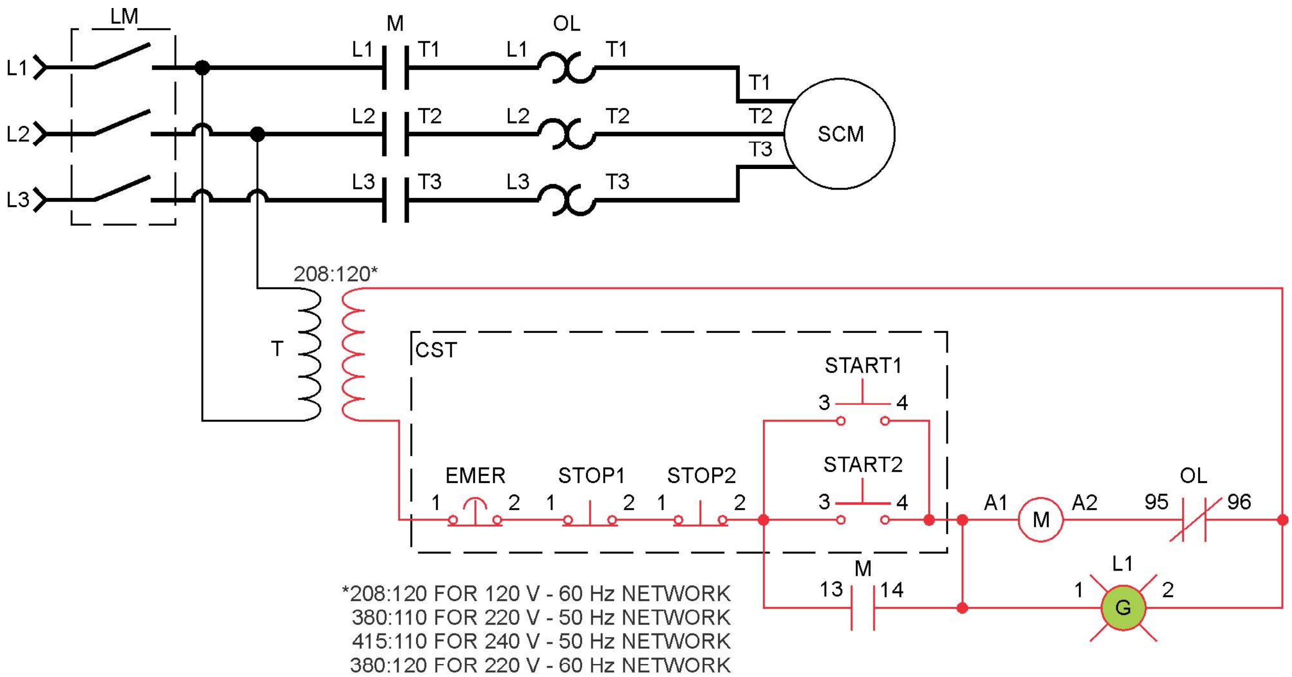
EXERCISE OBJECTIVE

- Implement multiple push button control circuits.
- Understand the differences between stop push button and emergency button.

DISCUSSION

A standard three-wire push button control circuit may be expanded by adding one or more push button stations. With start push buttons connected in parallel and stop push buttons connected in series, the motor may be started or stopped from a number of separate locations. Figure 3-12 represents a multiple push button station.

Although they are both designed to stop a motor, stop push buttons and emergency buttons have one major difference. Contrary to the stop push button, the emergency button maintains its contact open after it has been pressed. It is also more accessible, with a larger contact surface.



LEGEND

CST = CONTROL STATION
EMER = EMERGENCY PUSH BUTTON (MAINTAINED CONTACT)
L1 = MOTOR STARTED PILOT LIGHT (GREEN)
M = MAIN CONTACTOR
OL = OVERLOAD RELAY
SCM = SQUIRREL CAGE MOTOR
START1 = START PUSH BUTTON #1 (MOMENTARY CONTACT)
START2 = START PUSH BUTTON #2 (MOMENTARY CONTACT)
STOP1 = STOP PUSH BUTTON #1 (MOMENTARY CONTACT)
STOP2 = STOP PUSH BUTTON #2 (MOMENTARY CONTACT)
T = CONTROL VOLTAGE TRANSFORMER

Figure 3-12. Multiple push button, three-wire control circuit.

PROCEDURE OUTLINE

The Procedure is divided into the following sections:

- Basic setup
- Multiple push button circuit
- Emergency button

PROCEDURE

In this Exercise, you will implement a multiple push button circuit including an emergency button. You will apply power to the circuit to verify that any start or stop push button can make the motor run or come to a halt.

You will then short-circuit the start push buttons to make the motor run inadvertently. This will help you discover how useful an emergency button can be in this type of situation.

⚠ WARNING

The AC Power Supply provides high voltages. Do not change any AC connection with the power on.

Basic setup

1. Perform the Basic Setup and Lockout/Tagout procedures.

Multiple push button circuit

2. Install the Brake Motor, Inertia Wheel, and Safety Guard.

   Connect the circuit shown in Figure 3-12.

3. Manually disengage the friction brake.

   Perform the Energizing procedure.

4. Determine the motor operation for the following conditions:

   - The motor starts when the START1 push button is pressed.

     ❑ Yes ❑ No

   - The motor stops when the STOP1 push button is pressed.

     ❑ Yes ❑ No

   - The motor starts when the START2 push button is pressed.

     ❑ Yes ❑ No

   - The motor stops when the STOP2 push button is pressed.

     ❑ Yes ❑ No

5. What conclusion about start and stop controls in a multiple push button circuit can you draw from the preceding manipulations?

   ____

   ____

⚠ WARNING

In the next procedure step, a fault will be added to the circuit, making the motor start automatically as power is turned on.

6. Turn off the Lockout Module.

Emergency button

7. Install a lead connecting terminals 13NO and 14NO of the Contactor module.

   Stay alert as you turn on the Lockout Module. Describe and explain what happens.

   ____

   ____

   ____

8. What happens when you press and release a stop push button?

   ____

   ____

9. What happens when you press the Emergency Button?

   ____

   ____

10. Turn the individual power switch of the AC Power Supply off, disconnect the circuit, remove the magnetic labels, and return the equipment to the storage location.

CONCLUSION

A motor can be started or stopped from more than one location by using multiple push buttons. To implement such a circuit, the stop push buttons are connected in series and the start push buttons in parallel.

Emergency buttons are easily accessible and maintain their contact open after they have been pressed.

Review Questions

1. What reasons can motivate the use of multiple push button stations?

   a. There is more than one operator for the same circuit.

   b. The circuit has to be stopped from different locations.

   c. The circuit has to be started from different locations.

   d. All of the answers above are correct.

2. Name a characteristic of an emergency button.

   a. Its size is typically smaller than that of a same-circuit stop push button.

   b. When pressed, the contact is momentarily opened.

   c. It is located where is it not easily accessible.

   d. When pressed, the contact is maintained open.

3. What type of contact is commonly used with start push buttons?

   a. Power contacts

   b. Normally open contacts

   c. Normally closed contacts

   d. Emergency contacts

4. What type of contact is commonly used with stop push buttons?

   a. Power contacts

   b. Normally open contacts

   c. Normally closed contacts

   d. Emergency contacts

5. What is the color associated with stop push buttons?

   a. Yellow

   b. Orange

   c. Red

   d. Green

Unit Test

1. Which of the following statements is a characteristic of a control transformer?

   a. Permits switching off the load.
   b. Prevents motor overload.
   c. Provides control voltage compatible with relay coils.
   d. Enables motor phase reversal.

2. Which contactor utilization category permits plugging operation?

   a. AC-1
   b. AC-2
   c. AC-3
   d. AC-4

3. What happens as power returns, in a three-wire motor circuit, following a power failure?

   a. The motor restarts automatically.
   b. The motor remains de-energized.
   c. The motor starts in the opposite direction.
   d. The overload relay trips.

4. What should be taken care of, when servicing a two-wire control circuit?

   a. There is a risk of seeing the motor start inadvertently.
   b. Three wires must be connected to the pilot device.
   c. An operator must be present to restart the machine.
   d. All of the answers above are correct.

5. Push button interlocking is a type of:

   a. Electrical interlocking
   b. Mechanical interlocking
   c. Braking method
   d. Lockout/tagout procedure

6. What is the effect of reversing the power line sequence of a three-phase squirrel-cage motor?

   a. Stops motor rotation
   b. Accelerates motor rotation
   c. Reverses motor rotation direction
   d. Slows down motor rotation

7. What happens if two contactors are energized at the same time in a reversing circuit without interlocking?

   a. Open circuit
   b. Short-circuit
   c. Nothing happens
   d. The motor starts turning in the opposite direction.

8. If a mechanical interlock is implemented in a reversing starter, what happens if the forward coil is energized, as you try to energize the reverse coil as well?

   a. The forward coil remains the only coil energized.
   b. The reverse coil becomes the only coil energized.
   c. Both coils are energized simultaneously.
   d. No coil is energized.

9. In push button interlocking, what happens if the motor is running in the forward direction and you push both forward and reverse push buttons?

   a. The forward coil remains the only coil energized.
   b. The reverse coil becomes the only coil energized.
   c. Both coils are energized simultaneously.
   d. No coil is energized.

10. What circuit configuration can be used to allow motor control from more than one location?

   a. Two-wire control
   b. Three-wire control
   c. Multiple push buttons
   d. Push button interlock