PLC Control Circuits

UNIT OBJECTIVE

Upon completion of this unit, you will be able to interface AC and DC voltages within a motor starter circuit. You will also be able to implement PLC motor starters enabling reversing, jogging, and overload control.

DISCUSSION OF FUNDAMENTALS

A motor circuit can be made of subcircuits operating at different voltages. In the Industrial Controls Training System, there can be three different voltages:

- AC supply voltage from the AC Power Supply;
- AC control voltage from the Control Transformer;
- DC control voltage from the DC Power Supply.

Low AC and DC voltages are mainly used in control circuits to provide a safer working environment for the operator. A "bridge" must however be implemented between low and high voltage circuits. This bridge allows control devices to have an effect in a power circuit and feedback signals from the power circuit to be received by the control circuit.

In the manual *Basic Controls*, you have seen that the coil of a contactor can be actuated with AC control (low) voltage. You have also seen that the NO power contacts of the same contactor can switch motor supply (high) voltage on and off. This example shows that a relay-type device can take a signal of a given voltage to have an effect on a circuit of a different voltage. Relay-type devices can therefore act as bridges between two subcircuits operating at different voltages.

The same principle applies to the Interposing Relays module, Model 3129. This device provides a way of bridging AC and DC control voltages in both ways (AC to DC and DC to AC). This feature is useful in applications where the 24 V dc PLC interacts with the system's AC devices.

Motor Control Circuits using a PLC

PLCs can replace wired logic. When changes are made to a control circuit, there is usually not much rewiring necessary, except connecting the new devices to the PLC. The main job typically consists of modifying the PLC program.

In the manual *Basic Controls*, you implemented various motor control circuits to run or jog a motor in forward or reverse direction. Exercises 2 and 3 will concentrate on presenting alternative ways of implementing these circuits with the help of a PLC. The last exercise will also deal with the way to handle a motor overload condition within a PLC circuit.

Interfacing Voltages

EXERCISE OBJECTIVE

- Interface DC and AC voltages within a motor starter circuit.

DISCUSSION

In a single motor control circuit, some components may work at different voltages. For example, in the Industrial Controls Training System, the Programmable Logic Controller module operates at 24 V dc, whereas the Selector Switches module requires AC control voltage and the Brake Motor requires higher AC voltage.

The Interposing Relays module, Model 3129, ensures compatibility and logical continuity between 24 V dc and 110/120 V ac circuits. This module, shown in Figure 2-1, includes six relays: three for AC to DC (IR1, IR2, IR3) and three for DC to AC (IR4, IR5, IR6) logical conversion.

The terminals of the Interposing Relays module are as follows:

- Terminals A1-A2: supply voltage;
- Terminals 11-12: NC contacts;
- Terminals 11-14: NO contacts.

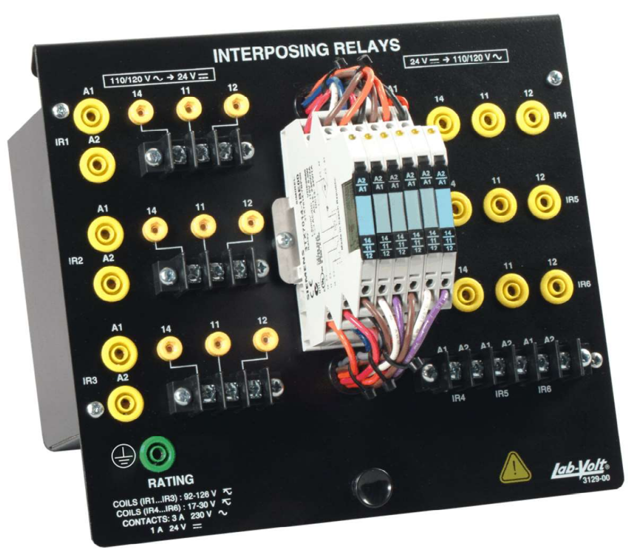
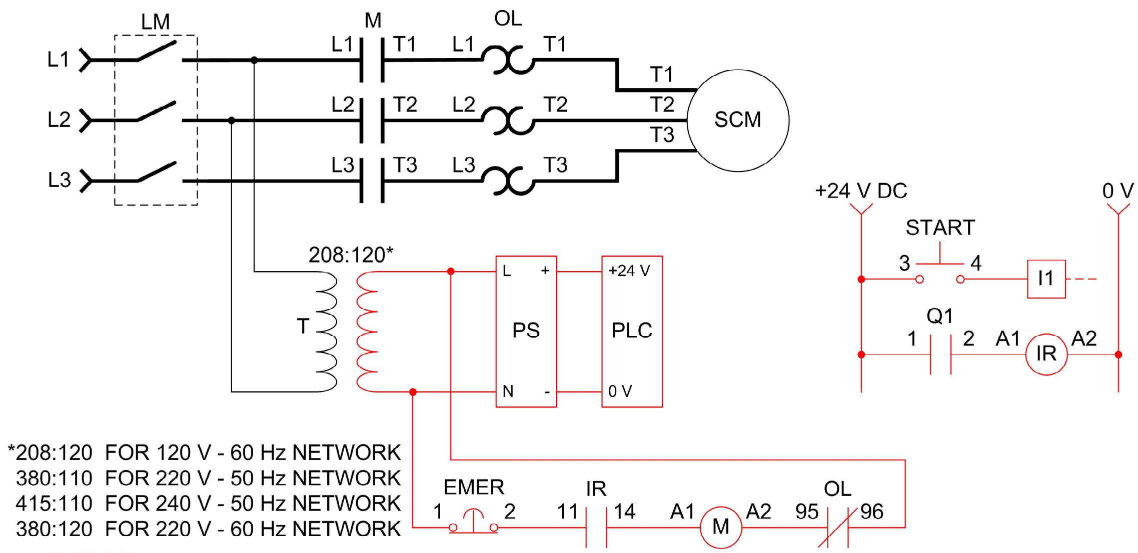


Figure 2-1. Interposing Relays, Model 3129.

Figure 2-2 shows how a 24 V dc control signal is transmitted from the Programmable Logic Controller module to the motor starting contactor through an interposing relay.

When the START push button is pressed, coil Q1 is energized, closing its related NO contact (Q1 terminals 1-2). This causes the interposing coil IR (DC coil) to be energized, closing its related NO contact (IR terminals 11-14). Because a 110/120 V ac source is connected to one end of the NO contact, a 110/120 V ac control signal is now provided at the other end of the contact. This last signal may, for instance, be used to start the motor via an AC contactor.



LEGEND

EMER	=	EMERGENCY PUSH BUTTON (MAINTAINED CONTACT)
Ix	=	PLC INPUT #x
IR	=	INTERPOSING RELAY (24 V DC COIL)
M	=	MAIN CONTACTOR
OL	=	OVERLOAD RELAY
PLC	=	PROGRAMMABLE LOGIC CONTROLLER
PS	=	DC POWER SUPPLY
Qx	=	PLC OUTPUT RELAY #x
SCM	=	SQUIRREL CAGE MOTOR
START	=	START PUSH BUTTON (MOMENTARY CONTACT)
T	=	CONTROL VOLTAGE TRANSFORMER
LM	=	LOCKOUT MODULE

LADDER DIAGRAM

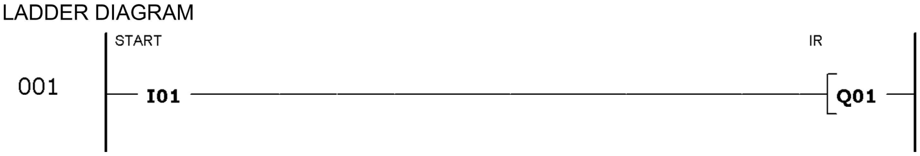
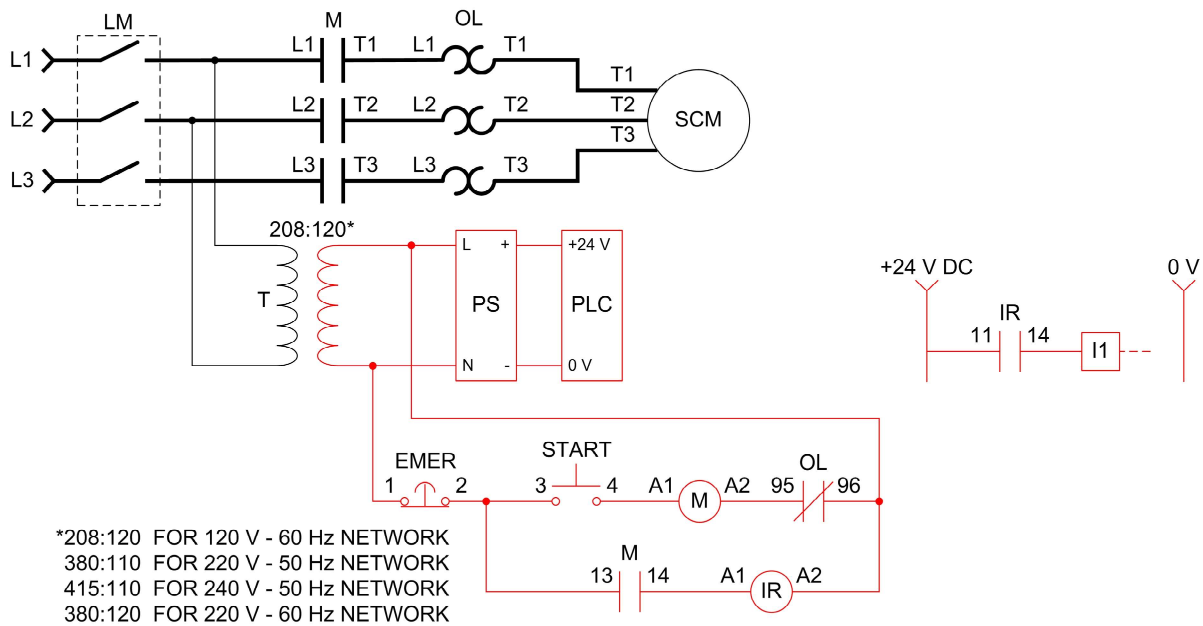


Figure 2-2. DC to AC conversion connection diagrams.

Figure 2-3 shows how a 110/120 V ac signal can be read by the PLC. When the motor is running, the power contacts of the contactor are closed, and therefore its NO contact (M terminals 13-14) is also closed. The 110/120 V ac voltage connected to one end of the NO contact is then provided at the other end of the contact, which is connected to the A1 terminal of the interposing relay IR. Because the A2 terminal of the relay IR is linked to the neutral line, the relay coil energizes, closing the corresponding NO contact. A 24 V dc signal, provided by the DC Power Supply, is then relayed to the PLC input.



LEGEND

EMER	=	EMERGENCY PUSH BUTTON (MAINTAINED CONTACT)
Ix	=	PLC INPUT #x
IR	=	INTERPOSING RELAY (110/120 V AC COIL)
M	=	MAIN CONTACTOR
OL	=	OVERLOAD RELAY
PLC	=	PROGRAMMABLE LOGIC CONTROLLER
PS	=	DC POWER SUPPLY
SCM	=	SQUIRREL CAGE MOTOR
START	=	START PUSH BUTTON (MOMENTARY CONTACT)
T	=	CONTROL VOLTAGE TRANSFORMER
LM	=	LOCKOUT MODULE

Figure 2-3. AC to DC conversion connection diagrams.

Procedure Summary

In this exercise, you will set up a basic motor control circuit (Figure 2-5) commanded by DC controls through a PLC.

In this circuit, when the START push button is pressed, an input signal is provided to the PLC. The PLC program uses this signal to activate an interposing relay connected to one of its outputs. This interposing relay in turn triggers the AC contactor to start the motor.

On the other hand, the NO contact of the contactor provides feedback to the DC subcircuit. When closed, this contact provides a PLC input signal via an AC to DC interposing relay. The PLC program reads this signal to turn on the RUN pilot light and to keep the motor running continuously.

Finally, the STOP push button, when pressed, de-energizes the motor circuit. When the RUN pilot light is off, the STOPL pilot light is on.

EQUIPMENT REQUIRED

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

PROCEDURE

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 procedure.

Basic motor control circuit commanded by DC controls through a PLC

☐ 2. Connect the Programmable Logic Controller module as described in Exercise 1-1.

Perform the Energizing procedure.

Enter the program shown in Figure 2-4.

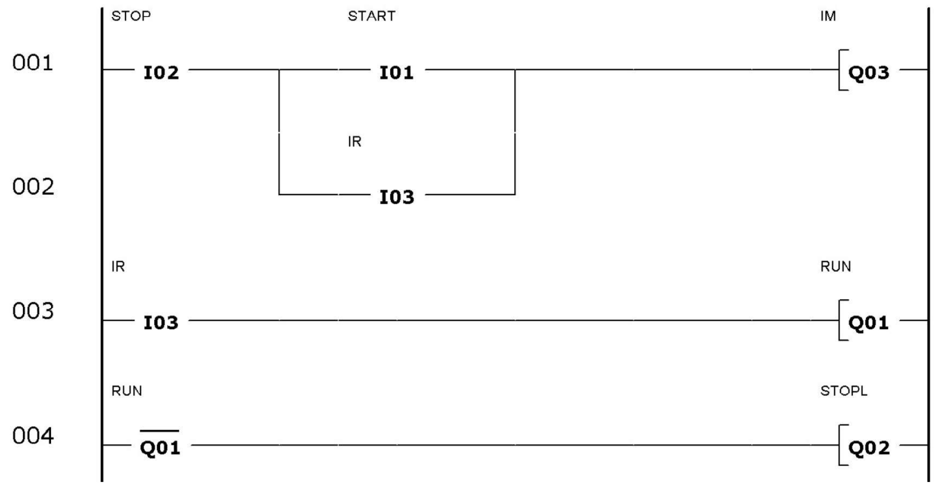
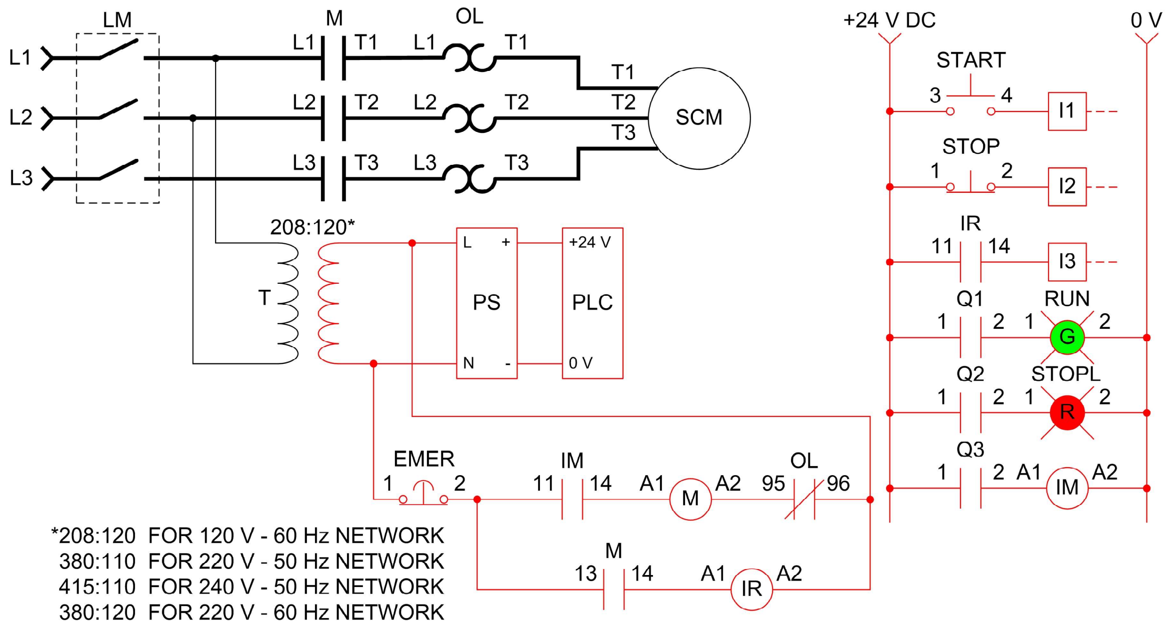


Figure 2-4. Basic motor control ladder program.

☐ 3. Install the Brake Motor, and Security Guard.

Set up the circuit shown in Figure 2-5.

Do not turn on the Lockout Module for now.



LEGEND

EMER	=	EMERGENCY PUSH BUTTON (MAINTAINED CONTACT)
Ix	=	PLC INPUT #x
IR	=	INTERPOSING RELAY (110/120 V AC COIL)
IM	=	INTERPOSING RELAY FOR MAIN CONTACTOR (24 V DC COIL)
M	=	MAIN CONTACTOR
OL	=	OVERLOAD RELAY
PLC	=	PROGRAMMABLE LOGIC CONTROLLER
PS	=	DC POWER SUPPLY
Qx	=	PLC OUTPUT RELAY #x
RUN	=	RUN PILOT LIGHT (GREEN)
SCM	=	SQUIRREL CAGE MOTOR
START	=	START PUSH BUTTON (MOMENTARY CONTACT)
STOP	=	STOP PUSH BUTTON (MOMENTARY CONTACT)
STOPL	=	STOP PILOT LIGHT (RED)
T	=	CONTROL VOLTAGE TRANSFORMER
LM	=	LOCKOUT MODULE

Figure 2-5. Basic motor control connection diagrams.

☐ 4. Fill out the Anticipated Status section of Table 2-1. Refer to the description of the circuit found in the PROCEDURE SUMMARY section to predict the status of the inputs and outputs, depending on the circuit operating mode.

CONTACT/COIL DESCRIPTION		ANTICIPATED STATUS			
		RUNNING MODE (MOTOR ON, NO PUSH BUTTON PRESSED)		STOPPED MODE (MOTOR OFF, NO PUSH BUTTON PRESSED)	
		ON	OFF	ON	OFF
I1	Start make contact				
I2	Stop brake contact				
I3	Motor run input				
Q1	Run pilot light				
Q2	Stop pilot light				
Q3	Motor output				

Table 2-1. Status of the contacts and coils in running and stopped modes.

☐ 5. Perform the Energizing procedure.

Note: *Make sure that the PLC is set to the RUN mode.*

☐ 6. Press the START push button. Is the I1 input energized while you press the START push button?

☐ Yes ☐ No

☐ 7. Does the motor start?

☐ Yes ☐ No

☐ 8. Verify that the circuit works in the RUNNING mode as predicted in Table 2-1. Does the circuit work as predicted?

☐ Yes ☐ No

☐ 9. Where does the holding contact in the PLC program of Figure 2-4 come from? Refer to Figure 2-5 if necessary.

____

____

☐ 10. What is the purpose of the PLC program holding contact?

____

____

☐ 11. Press the STOP push button. Is the I2 input energized while you press the STOP push button?

☐ Yes ☐ No

☐ 12. Does the motor stop?

☐ Yes ☐ No

☐ 13. Verify that the circuit works in the STOPPED mode as predicted in Table 2-1. Does the circuit work as predicted?

☐ Yes ☐ No

☐ 14. Explain how the contactor coil (M) is linked to the PLC output Q3. Refer to Figures 2-4 and 2-5 if necessary.

____

____

____

☐ 15. Set the PLC to the STOP mode.

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

CONCLUSION

In this exercise, you used a PLC to control a motor. Because the PLC and the motor circuits operate at different voltages, you used interposing relays to make them interact with each other.

REVIEW QUESTIONS

1. In Figure 2-4 ladder program, which contact is part of the motor holding circuit?

   a. I1
   b. I3
   c. Q1
   d. Q3

2. When are interposing relays useful?

   a. When two subcircuits operate at different voltages.
   b. Every time control and motor circuits are connected.
   c. When a different voltage has to be produced from a given voltage.
   d. None of the above is correct.

3. In the Figure 2-5 connection diagram, which voltage type is connected to the motor terminals?

   a. DC Power Supply voltage
   b. AC Power Supply line-neutral voltage
   c. AC Power Supply line-line voltage
   d. None of the above is correct.

4. Refer to Figure 2-5. To what device is PLC input I3 directly connected?

   a. Push button
   b. Selector switch
   c. Contactor
   d. Interposing relay

5. If an interposing relay is connected to a device providing an incoming signal, which part of the interposing relay will be receiving this incoming signal?

   a. Relay coil
   b. Relay NC contact
   c. Relay NO contact
   d. It depends on the situation.

Motor Starters with Jogging

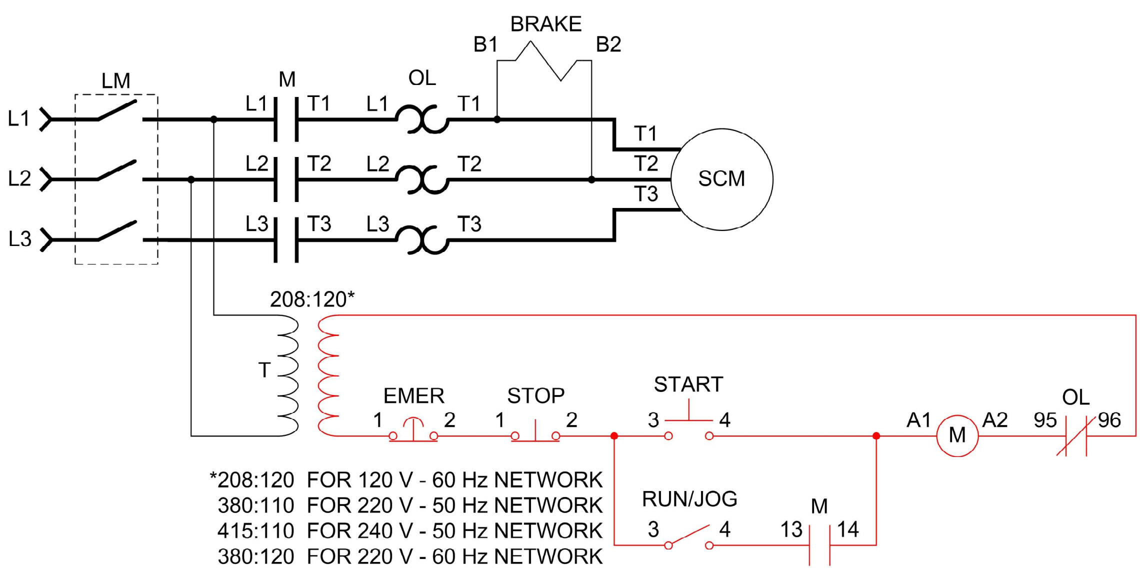
EXERCISE OBJECTIVE

- Implement motor starter circuits with jogging to demonstrate the flexibility of PLCs.

DISCUSSION

PLCs can be configured in a variety of ways. The use of PLCs in motor control circuits has the advantage of allowing changes to the circuit easily, without much rewiring. This is particularly useful when new features or controls must be added to the circuit. In the manual *Basic Controls*, you implemented two different motor jogging circuits:

- A circuit where a selector switch enables alternation between the running and the jogging modes (see Figure 2-6).

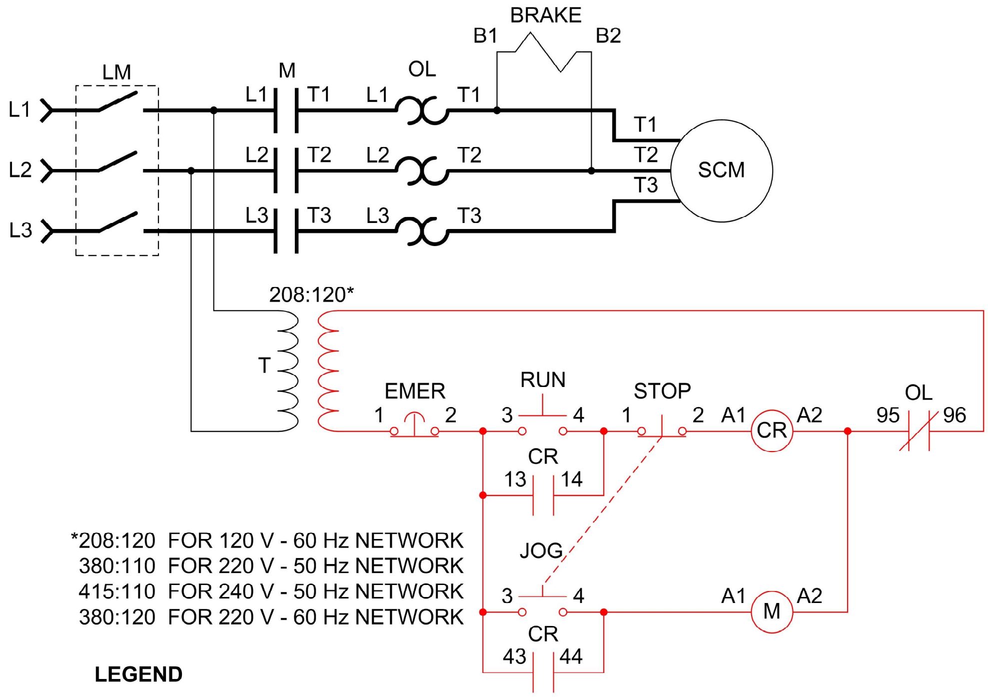


LEGEND

BRAKE	=	SOLENOID ACTUATED BRAKE COIL
EMER	=	EMERGENCY PUSH BUTTON (MAINTAINED CONTACT)
M	=	MAIN CONTACTOR
OL	=	OVERLOAD RELAY
RUN/JOG	=	RUN/JOG SELECTOR SWITCH (MAINTAINED CONTACT)
SCM	=	SQUIRREL CAGE MOTOR
START	=	START PUSH BUTTON (MOMENTARY CONTACT)
STOP	=	STOP PUSH BUTTON (MOMENTARY CONTACT)
T	=	CONTROL VOLTAGE TRANSFORMER
LM	=	LOCKOUT MODULE

Figure 2-6. Jog/Run circuit with selector switch.

- A circuit where push buttons and a control relay are used to control the run and jog functions independently (see Figure 2-7).



LEGEND

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

Figure 2-7. Jogging circuit with control relay.

In a situation where a circuit has to be modified after it has been implemented, a PLC really is very useful.

Procedure Summary

In the first part of this exercise, you will be asked to set up a JOG/RUN circuit where the position of a selector switch makes the START push button work in the run or jog mode. Both the EMERGENCY and JOG/STOP push buttons make the motor stop.

In the second part of the exercise, your client wants you to put into operation a circuit where two push buttons are used: START and JOG/STOP. In this circuit, when the motor is at rest, the JOG/STOP pushbutton makes the motor start momentarily. Both the EMERGENCY and JOG/STOP push buttons make the motor stop. To obtain this circuit from the last one, all you will have to do is to modify the inputs and the ladder program of the PLC.

EQUIPMENT REQUIRED

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

PROCEDURE

⚠ 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 procedure.

Jog/Run with selector switch

☐ 2. Connect the Programmable Logic Controller module as described in Exercise 1-1.

Perform the Energizing procedure.

Enter the program shown in Figure 2-8.

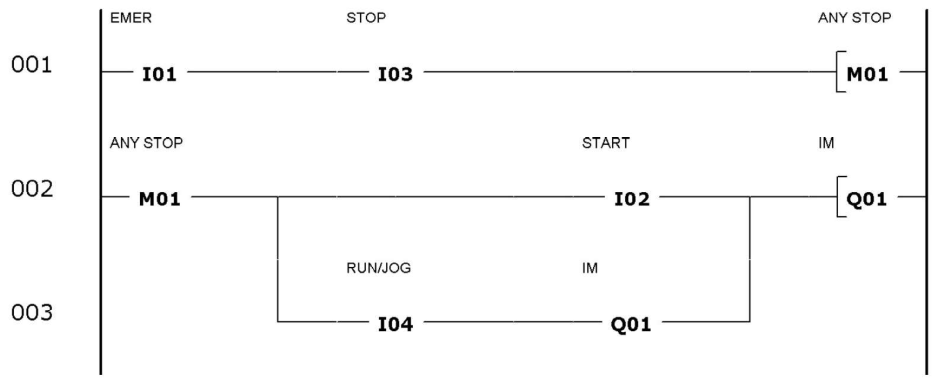
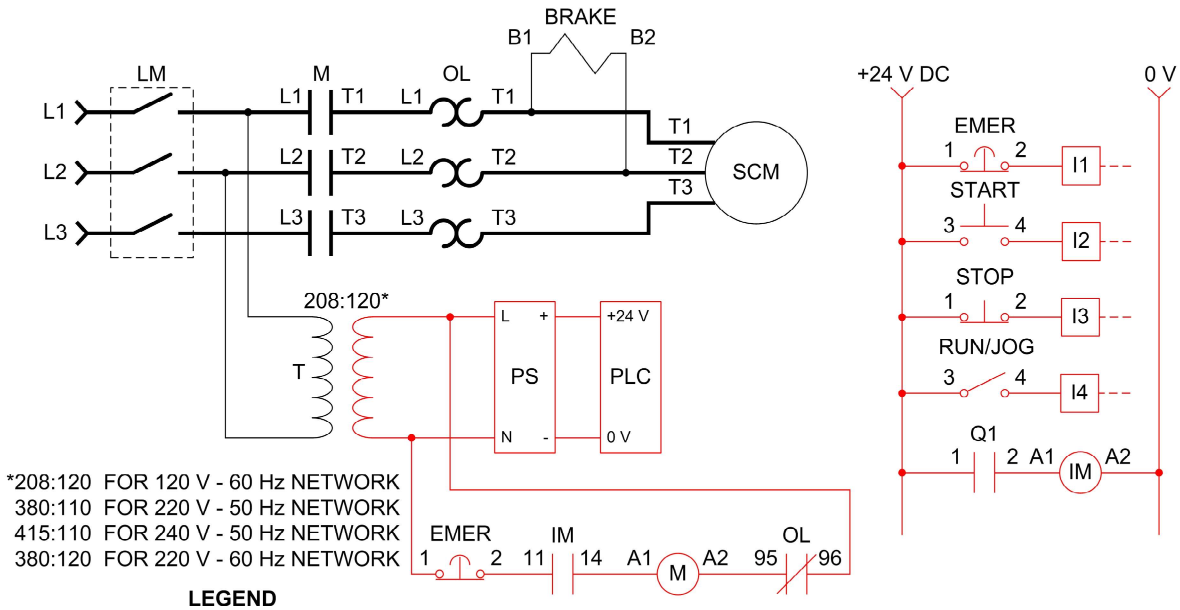


Figure 2-8. Jog/Run with selector switch ladder program.

Perform the Lockout/Tagout procedure.

☐ 3. Install the Brake Motor, Inertia Wheel, and Security Guard.

Set up the circuit shown in Figure 2-9.



LEGEND

BRAKE	=	SOLENOID ACTUATED BRAKE COIL
EMER	=	EMERGENCY PUSH BUTTON (MAINTAINED CONTACT)
Ix	=	PLC INPUT #x
IM	=	INTERPOSING RELAY FOR MAIN CONTACTOR (24 V DC COIL)
M	=	MAIN CONTACTOR
OL	=	OVERLOAD RELAY
PLC	=	PROGRAMMABLE LOGIC CONTROLLER
PS	=	DC POWER SUPPLY
Qx	=	PLC OUTPUT RELAY #x
RUN/JOG	=	RUN/JOG SELECTOR SWITCH (MAINTAINED CONTACT)
SCM	=	SQUIRREL CAGE MOTOR
START	=	START PUSH BUTTON (MOMENTARY CONTACT)
STOP	=	STOP PUSH BUTTON (MOMENTARY CONTACT)
T	=	CONTROL VOLTAGE TRANSFORMER
LM	=	LOCKOUT MODULE

Figure 2-9. Jog/Run with selector switch connection diagrams.

Set the JOG/RUN selector switch to the O position (JOG).

Perform the Energizing procedure.

Note: *Make sure that the PLC is set to the RUN mode.*

☐ 4. Which PLC inputs/outputs are energized?

☐ I1 ☐ I2 ☐ I3 ☐ I4 ☐ Q1

☐ 5. Press the START push button. Which PLC's inputs/outputs are energized while the START push button is pressed?

☐ I1 ☐ I2 ☐ I3 ☐ I4 ☐ Q1

☐ 6. Which PLC's inputs/outputs are energized after the START push button is released?

☐ I1 ☐ I2 ☐ I3 ☐ I4 ☐ Q1

☐ 7. Does latching occur?

☐ Yes ☐ No

☐ 8. Set the JOG/RUN selector switch to the L position (RUN).

Which PLC's inputs/outputs are energized?

☐ I1 ☐ I2 ☐ I3 ☐ I4 ☐ Q1

☐ 9. Press the START push button. Which PLC's inputs/outputs are energized while the START push button is pressed?

☐ I1 ☐ I2 ☐ I3 ☐ I4 ☐ Q1

☐ 10. Which PLC's inputs/outputs are energized after the START push button is released?

☐ I1 ☐ I2 ☐ I3 ☐ I4 ☐ Q1

☐ 11. Does latching occur?

☐ Yes ☐ No

☐ 12. Does the selector switch control the operating mode (JOG or RUN) of the START push button?

☐ Yes ☐ No

☐ 13. Press the STOP push button to stop the Brake Motor.

☐ 14. Set the Programmable Logic Controller module to the STOP mode.

Jog/Run with independent push buttons

☐ 15. Enter the program shown in Figure 2-10.

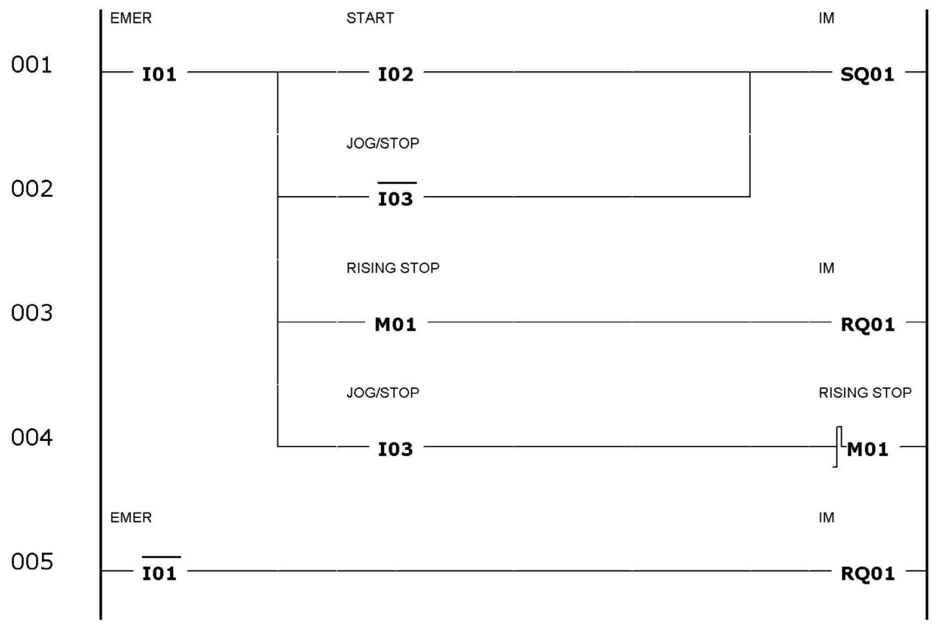
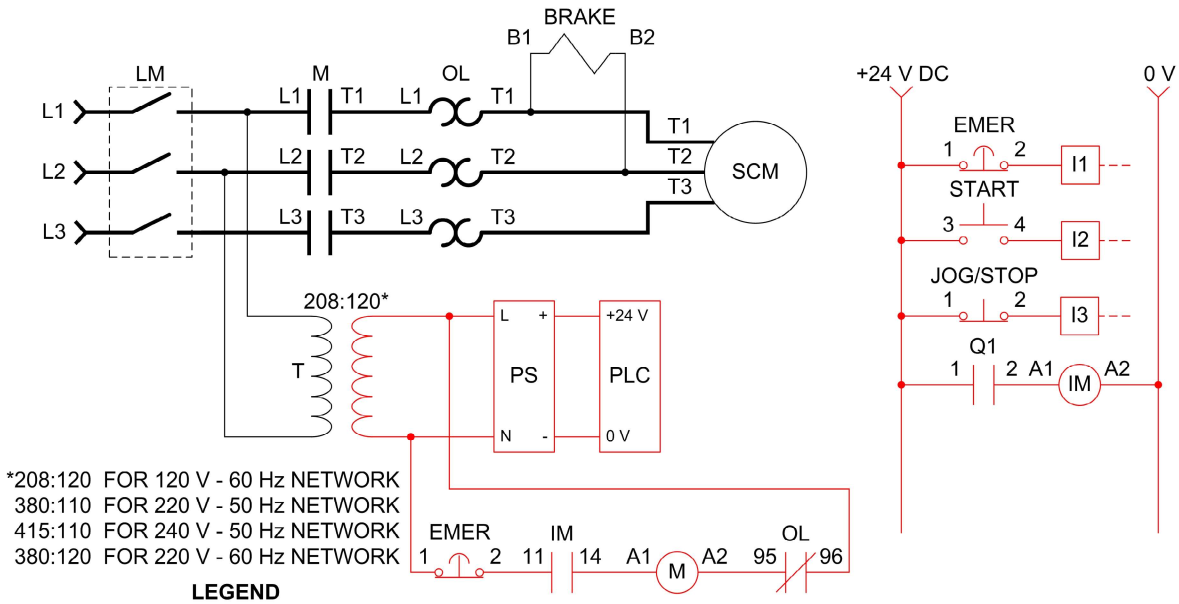


Figure 2-10. Jog/Run with independent push buttons ladder program.

☐ 16. Perform the Lockout/Tagout procedure.

Connect the PLC inputs and outputs according to Figure 2-11.



LEGEND

BRAKE = SOLENOID ACTUATED BRAKE COIL
EMER = EMERGENCY PUSH BUTTON (MAINTAINED CONTACT)
Ix = PLC INPUT #x
IM = INTERPOSING RELAY FOR MAIN CONTACTOR (24 V DC COIL)
JOG/STOP = JOG/STOP PUSH BUTTON (MOMENTARY CONTACT)
M = MAIN CONTACTOR
OL = OVERLOAD RELAY
PLC = PROGRAMMABLE LOGIC CONTROLLER
PS = DC POWER SUPPLY
Qx = PLC OUTPUT RELAY #x
SCM = SQUIRREL CAGE MOTOR
START = START PUSH BUTTON (MOMENTARY CONTACT)
T = CONTROL VOLTAGE TRANSFORMER
LM = LOCKOUT MODULE

Figure 2-11. Jog/Run circuit with independent push buttons connection diagrams.

☐ 17. If you refer to Figures 2-9 and 2-11, do you have to change any other connection than the PLC inputs to convert the last circuit into the new one?

☐ Yes ☐ No

☐ 18. Perform the Energizing procedure.

☐ 19. Set the Programmable Logic Controller module to the RUN mode.

☐ 20. Which PLC's inputs/outputs are energized?

☐ I1 ☐ I2 ☐ I3 ☐ Q1

☐ 21. Press the START push button. Which PLC's inputs/outputs are energized while the START push button is pressed?

☐ I1 ☐ I2 ☐ I3 ☐ Q1

☐ 22. Which PLC's inputs/outputs are energized after the START push button is released?

☐ I1 ☐ I2 ☐ I3 ☐ Q1

☐ 23. Does latching occur?

☐ Yes ☐ No

☐ 24. Press and release the JOG/STOP push button. Which PLC's inputs/outputs are energized?

☐ I1 ☐ I2 ☐ I3 ☐ Q1

☐ 25. Which PLC's inputs/outputs are energized while the JOG/STOP push button is pressed?

☐ I1 ☐ I2 ☐ I3 ☐ Q1

☐ 26. Which PLC's inputs/outputs are energized after the JOG/STOP push button is released?

☐ I1 ☐ I2 ☐ I3 ☐ Q1

☐ 27. Does latching occur?

☐ Yes ☐ No

☐ 28. Is the JOG/STOP push button independent from the START push button?

☐ Yes ☐ No

☐ 29. Set the PLC to the STOP mode.

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

CONCLUSION

In this exercise, you used a PLC to implement two motor JOG/RUN circuits. These circuits operated in the same manner as their hardwired counterparts. However, changing from one circuit to another required much less rewiring; only the PLC program and the inputs were changed.

REVIEW QUESTIONS

1. What advantages does a PLC circuit have over a hardwired circuit?

   a. Configurability
   b. Ease of expandability
   c. Less hardwiring
   d. All of the above are correct.

2. What are the differences between the connection diagrams in Figures 2-9 and 2-11?

   a. PLC inputs
   b. PLC outputs
   c. Schematic diagrams
   d. All of the above are correct.

3. In the Figure 2-8 ladder program, which programming method was used to circumvent the PLC rung length limitation?

   a. Using a marker
   b. Using equivalent Boolean logic circuit
   c. Using backwards wiring
   d. None of the above is correct.

4. In the Figure 2-10 ladder program, which programming unit is the logical equivalent of the Control Relay in Figure 2-7?

   a. RQ1
   b. I3
   c. SQ1
   d. M1

5. In the Figure 2-8 ladder program, under which circumstance is the motor jogging?

   a. START push button is pressed.
   b. State of the M marker is true.
   c. JOG/RUN selector is at the JOG position.
   d. All of the above are correct.

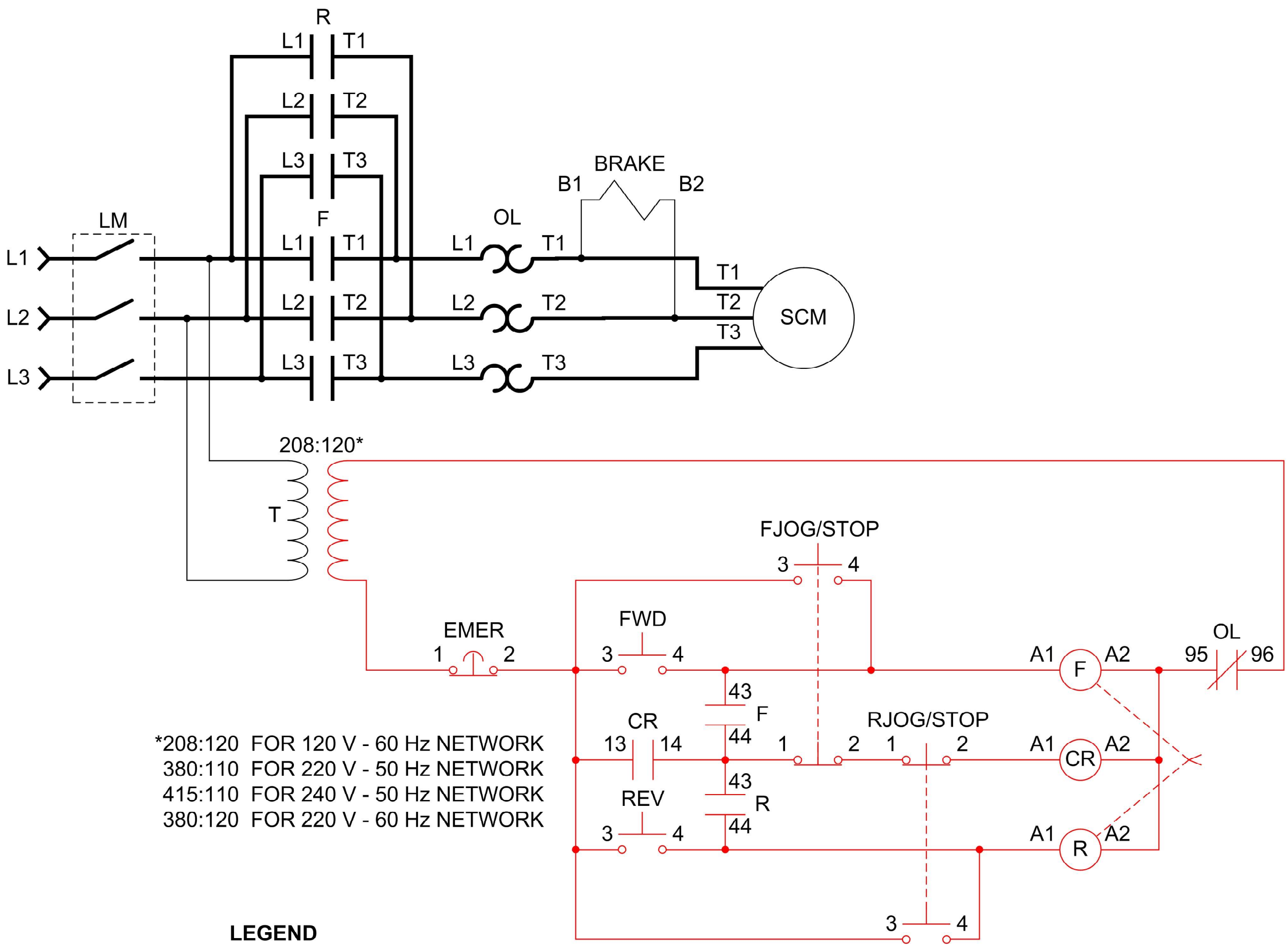
Reversing Motor Starters with Jogging

EXERCISE OBJECTIVE

- Implement a PLC reversing motor starter.
- Add a tripped overload relay light indicator to a circuit.

DISCUSSION

Some applications, in particular in position control, require a motor to run and jog in both forward and reverse directions. To meet these requirements a jogging control circuit with a reversing motor starter can be implemented. Figure 2-12 is an example of a hardwired motor reversing circuit with jogging. This setup includes a control relay to form the holding circuits.



LEGEND

BRAKE = SOLENOID ACTUATED BRAKE COIL
CR = CONTROL RELAY
EMER = EMERGENCY PUSH BUTTON (MAINTAINED CONTACT)
F = FORWARD DIRECTION CONTACTOR
FJOG/STOP = FORWARD JOG/STOP PUSH BUTTON (MOMENTARY CONTACT)
FWD = FORWARD PUSH BUTTON (MOMENTARY CONTACT)
OL = OVERLOAD RELAY
R = REVERSE DIRECTION CONTACTOR
REV = REVERSE PUSH BUTTON (MOMENTARY CONTACT)
RJOG/STOP = REVERSE JOG/STOP PUSH BUTTON (MOMENTARY CONTACT)
SCM = SQUIRREL CAGE MOTOR
T = CONTROL VOLTAGE TRANSFORMER
LM = LOCKOUT MODULE

Figure 2-12. Reversing motor starter circuit with jogging.

Tripped overload indicator

An electric overload occurs when a motor draws a current that is above its nominal value. Standard motor starters include an overload relay that detects sustained, abnormally high currents to prevent damage to the motor. Under these irregular conditions, the overload relay trips, causing the motor to be de-energized.

The motor stopping and its origin might not be readily apparent to the operator. Therefore, a pilot light can be added into the motor control circuit to display the overload condition. Also, the overload signal can be used to keep the PLC from restarting the motor as soon as the overload relay is reset.

Procedure Summary

In this exercise, you will set up a PLC motor reversing circuit with jogging capabilities. You will test that the ladder program, shown in Figure 2-13, functions like the hardwired circuit in Figure 2-12.

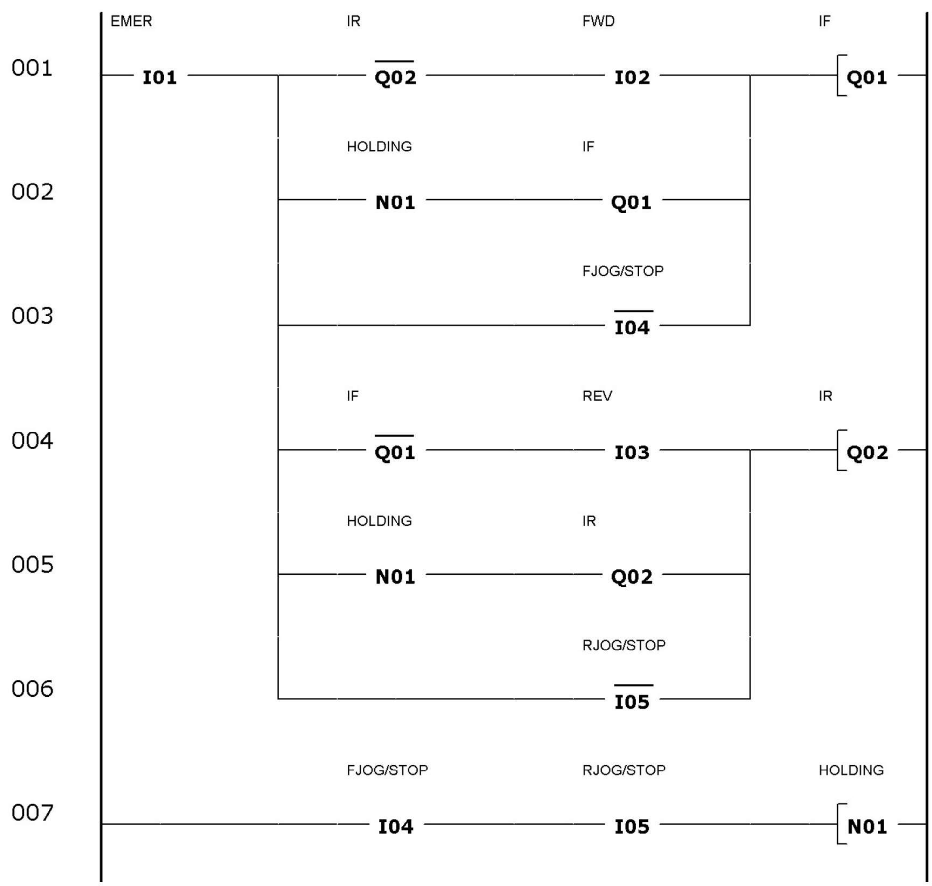


Figure 2-13. Reversing motor starter with jogging ladder program.

In the second part of the exercise, you will add a pilot light that uses the NO contact of the Overload Relay module to indicate the overload condition of the circuit. Figure 2-14 represents the new ladder program including an input for the NO contact of the Overload Relay module and an output for the pilot light. A timing relay is added to the program to make the pilot light flash.

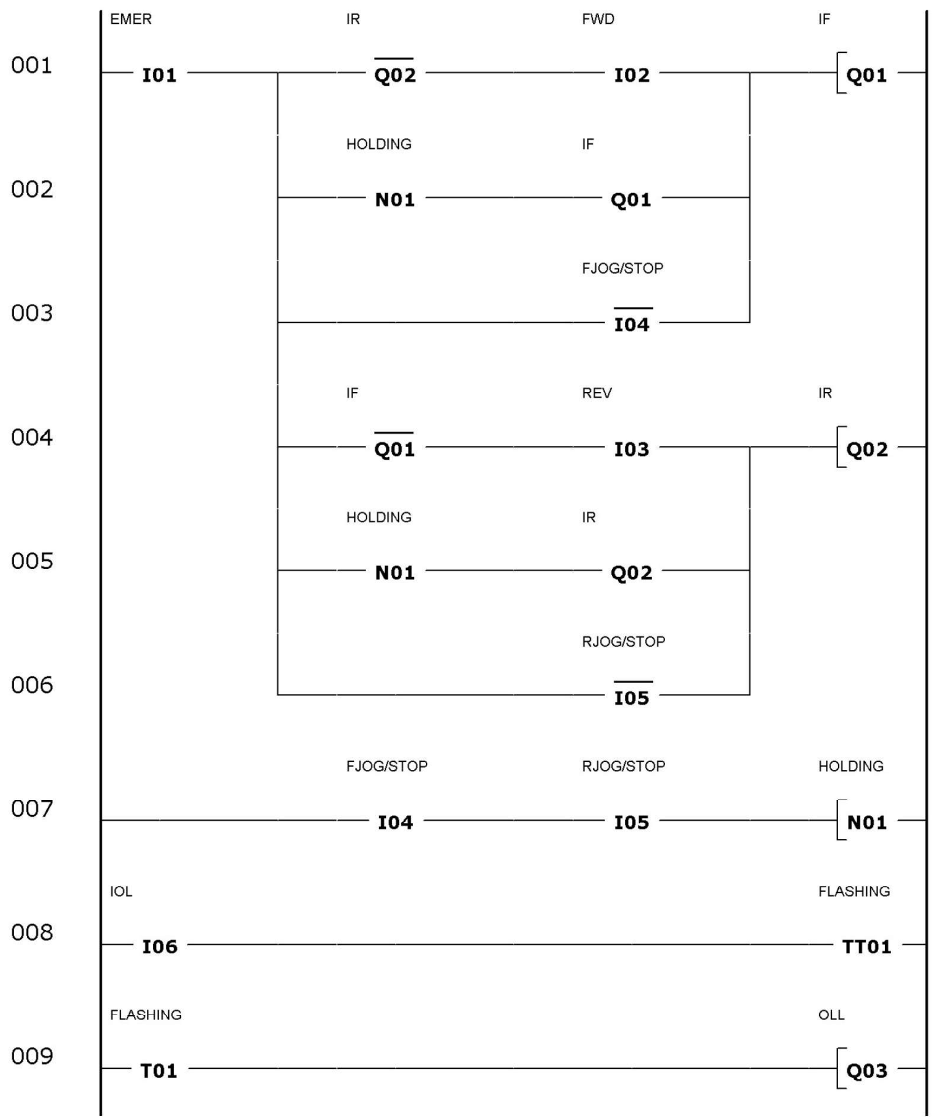


Figure 2-14. Reversing motor starter with jogging and overload indicator ladder program.

To verify that this new feature functions correctly, you will use the Overload Relay's TEST button to simulate a motor overload condition. You will notice that the system can restart automatically if the overload signal is not used to reset the PLC program. To increase the system safety, you will modify your program so that an operation is required from the operator to restart the motor, following an overload.

EQUIPMENT REQUIRED

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

PROCEDURE

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 procedure.

Reversing motor starter with jogging

☐ 2. Connect the Programmable Logic Controller module as described in Exercise 1-1.

Perform the Energizing procedure.

Enter the ladder program shown in Figure 2-13.

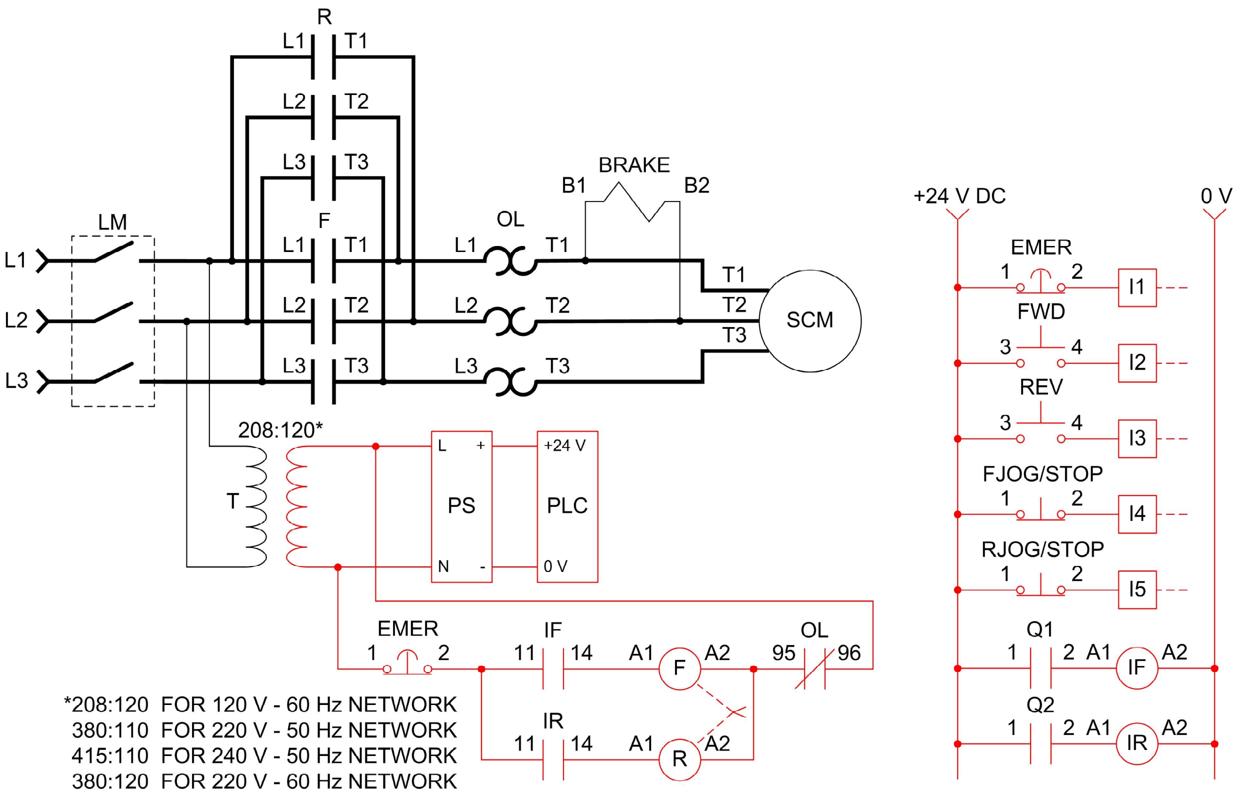
Perform the Lockout/Tagout procedure.

☐ 3. Install the Brake Motor, Inertia Wheel, and Security Guard.

Set up the circuit shown in Figure 2-15.

Perform the Energizing procedure.

Note: *Make sure that the PLC is set to the RUN mode.*



LEGEND

BRAKE	=	SOLENOID ACTUATED BRAKE COIL
EMER	=	EMERGENCY PUSH BUTTON (MAINTAINED CONTACT)
F	=	FORWARD DIRECTION CONTACTOR
FJOG/STOP	=	FORWARD JOG/STOP PUSH BUTTON (MOMENTARY CONTACT)
FWD	=	FORWARD PUSH BUTTON (MOMENTARY CONTACT)
Ix	=	PLC INPUT #x
IF	=	INTERPOSING RELAY FOR FORWARD CONTACTOR (24 V DC COIL)
IR	=	INTERPOSING RELAY FOR REVERSE CONTACTOR (24 V DC COIL)
M	=	MAIN CONTACTOR
OL	=	OVERLOAD RELAY
PLC	=	PROGRAMMABLE LOGIC CONTROLLER
PS	=	DC POWER SUPPLY
Qx	=	PLC OUTPUT RELAY #x
R	=	REVERSE DIRECTION CONTACTOR
REV	=	REVERSE PUSH BUTTON (MOMENTARY CONTACT)
RJOG/STOP	=	REVERSE JOG/STOP PUSH BUTTON (MOMENTARY CONTACT)
SCM	=	SQUIRREL CAGE MOTOR
T	=	CONTROL VOLTAGE TRANSFORMER
LM	=	LOCKOUT MODULE

Figure 2-15. PLC reversing motor starter with jogging circuit connection diagrams.

☐ 4. Which PLC's inputs/outputs are energized?

☐ I1 ☐ I2 ☐ I3 ☐ I4 ☐ I5 ☐ Q1 ☐ Q2

☐ 5. Test the PLC circuit and note in Table 2-1 if it has the same characteristics as the hardwired version in Figure 2-12.

CHARACTERISTICS OF THE HARDWIRED CIRCUIT	**PLC circuit**	
	Yes	**No**
FWD button makes the motor run continuously		
REV button makes motor run continuously in reverse direction		
FJOG/STOP can make a motor running continuously (F and R) stop		
RJOG/STOP can make a motor running continuously (F and R) stop		
FJOG/STOP makes motor run only as long as it is pressed		
RJOG/STOP makes motor run in reverse direction only as long as it is pressed		
The EMER button de-energizes the control circuit until it is reset		

Table 2-1. Characteristics of the hardwired circuit.

☐ 6. What are $\overline{\textbf{Q1}}$ and $\overline{\textbf{Q2}}$ contacts used for in the ladder program?

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☐ 7. Do your observations confirm that the PLC version is equivalent to the hardwired version in terms of functionalities?

☐ Yes ☐ No

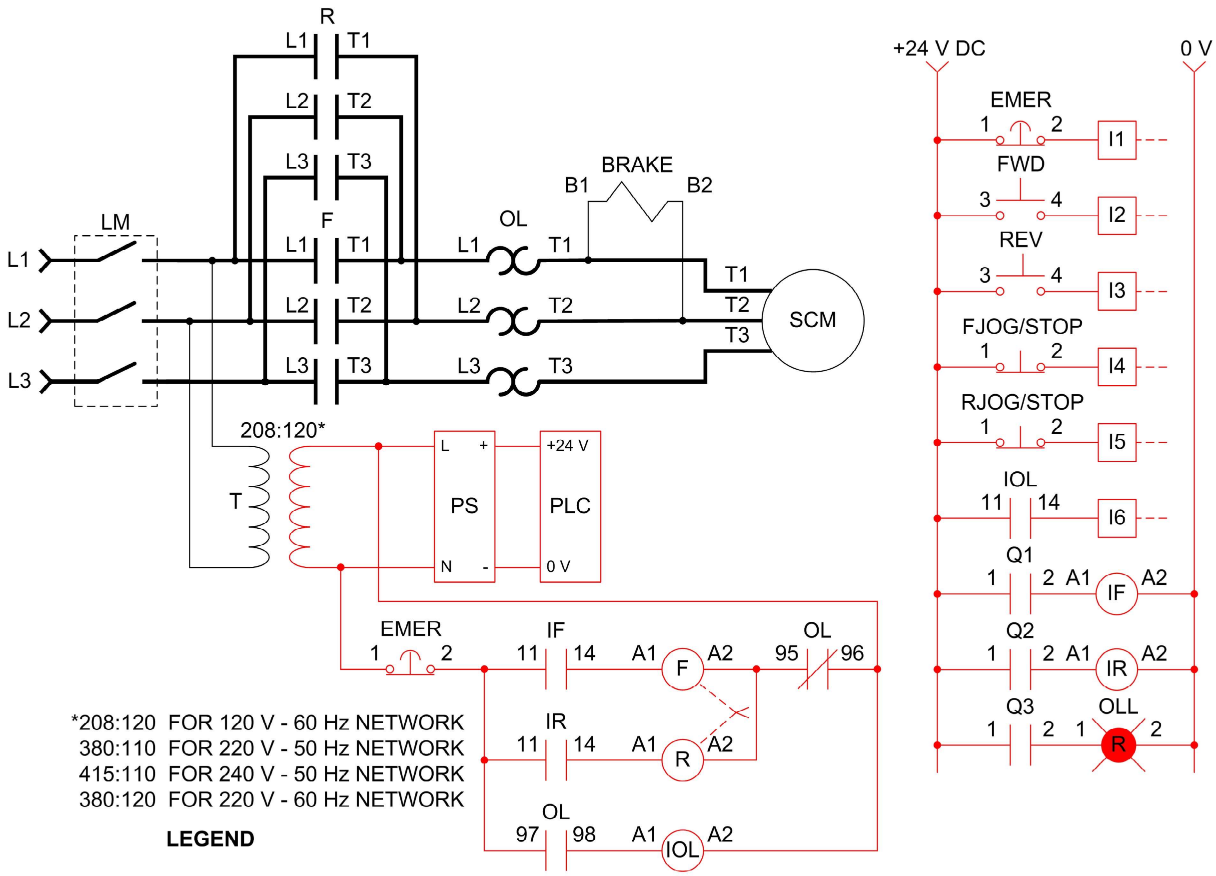
☐ 8. Set the Programmable Logic Controller module to the STOP mode.

Enter the program shown in Figure 2-14, with the following timing relay (T1) parameter values:

- Coil function: trigger
- Mode: flash switching
- Setpoint I1: 0.5 s
- Setpoint I2: 0.5 s

☐ 9. Perform the Lockout/Tagout procedure.

Set up the circuit according to Figure 2-16.



LEGEND

BRAKE	=	SOLENOID ACTUATED BRAKE COIL
EMER	=	EMERGENCY PUSH BUTTON (MAINTAINED CONTACT)
F	=	FORWARD DIRECTION CONTACTOR
FJOG/STOP	=	FORWARD JOG/STOP PUSH BUTTON (MOMENTARY CONTACT)
FWD	=	FORWARD PUSH BUTTON (MOMENTARY CONTACT)
Ix	=	PLC INPUT #x
IF	=	INTERPOSING RELAY FOR FORWARD CONTACTOR (24 V DC COIL)
IOL	=	INTERPOSING RELAY FOR OVERLOAD SIGNAL (110/120 V AC COIL)
IR	=	INTERPOSING RELAY FOR REVERSE CONTACTOR (24 V DC COIL)
M	=	MAIN CONTACTOR
OL	=	OVERLOAD RELAY
OLL	=	OVERLOAD PILOT LIGHT (RED)
PLC	=	PROGRAMMABLE LOGIC CONTROLLER
PS	=	DC POWER SUPPLY
Qx	=	PLC OUTPUT RELAY #x
R	=	REVERSE DIRECTION CONTACTOR
REV	=	REVERSE PUSH BUTTON (MOMENTARY CONTACT)
RJOG/STOP	=	REVERSE JOG/STOP PUSH BUTTON (MOMENTARY CONTACT)
SCM	=	SQUIRREL CAGE MOTOR
T	=	CONTROL VOLTAGE TRANSFORMER
LM	=	LOCKOUT MODULE

Figure 2-16. Reversing motor starter with jogging and overload indicator connection diagrams.

☐ 10. Perform the Energizing procedure.

Note: *Make sure that the PLC is set to the RUN mode.*

☐ 11. Which PLC's inputs/outputs are energized?

☐ I1 ☐ I2 ☐ I3 ☐ I4 ☐ I5 ☐ I6 ☐ Q1 ☐ Q2 ☐ Q3

☐ 12. Press the FWD push button. Does the motor start running continuously?

☐ Yes ☐ No

☐ 13. Pull the red TEST button located on the Overload Relay module. This will simulate an overload condition where the Overload Relay is triggered.

Does the motor stop?

☐ Yes ☐ No

☐ 14. Does the red OLL (overload) pilot light start flashing?

☐ Yes ☐ No

☐ 15. Release the TEST button. Does the red OLL (overload) pilot light keep on flashing?

☐ Yes ☐ No

☐ 16. Does the motor restart automatically?

☐ Yes ☐ No

☐ 17. Set the PLC to the STOP mode.

To increase the system safety, modify the program according to Figure 2-17. This modification prevents the motor from automatically restarting.

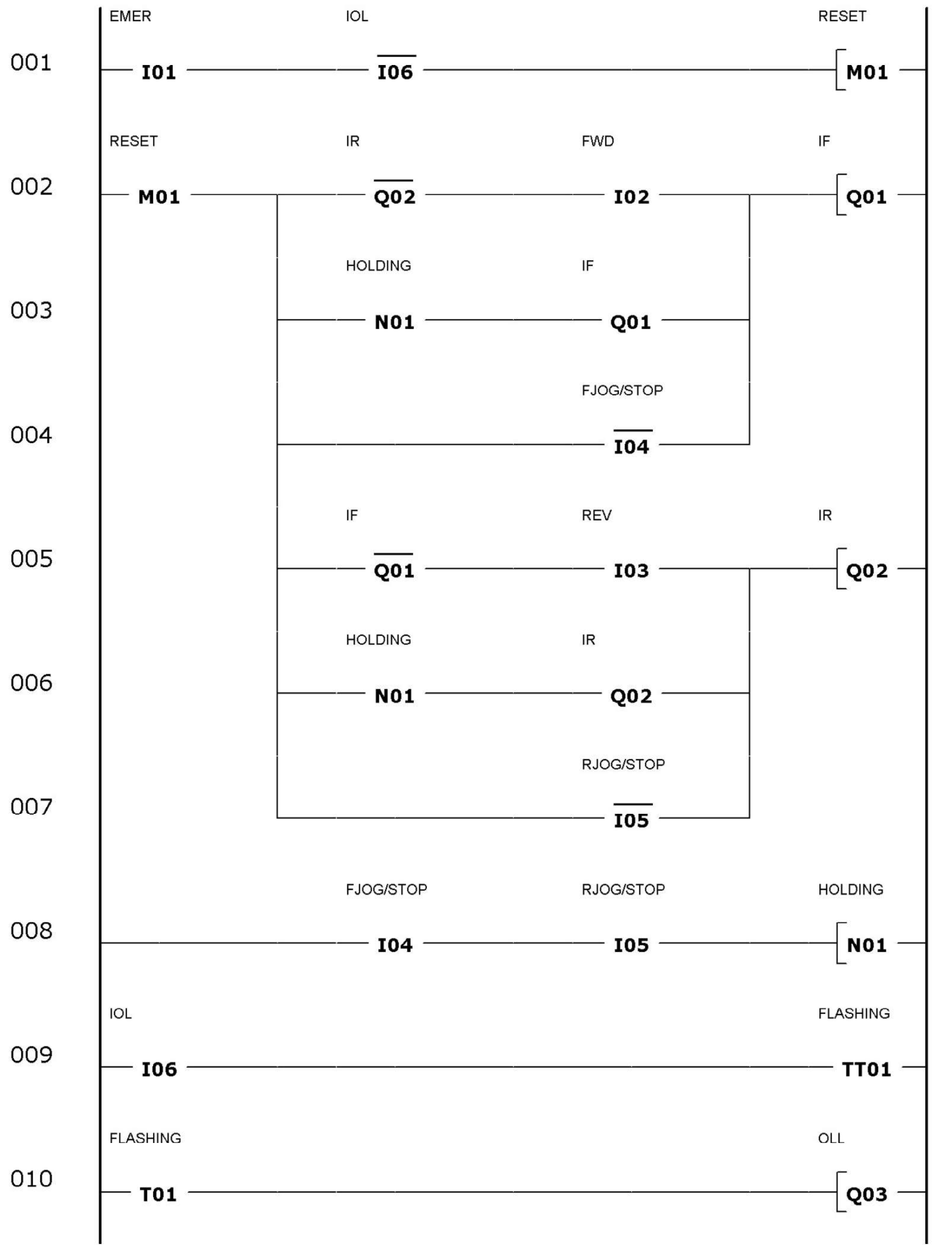


Figure 2-17. Reversing motor starter with jogging and overload indicator and reset connection diagrams.

☐ 18. Set the PLC to the RUN mode.

Press the FWD push button. Does the motor start running continuously?

☐ Yes ☐ No

☐ 19. Simulate an overload condition by pulling the red TEST button of the Overload Relay module.

Does the motor stop and the red OLL (overload) pilot light start flashing?

☐ Yes ☐ No

☐ 20. Release the TEST button. Does the red OLL (overload) pilot light keep on flashing?

☐ Yes ☐ No

☐ 21. Does the motor restart automatically? Explain why.

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☐ 22. Set the PLC to the STOP mode.

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

CONCLUSION

In this exercise, you programmed three different ladder programs to obtain a reversing motor starter with jogging. The first program could run and jog in both directions. However, it did not provide any feedback from the Overload Relay module.

The second program was similar to the first one, except that the PLC had an input connected to the Overload Relay module to make a pilot light flash in case of an overload. But this setup caused the motor to restart as soon as the Overload Relay module was reset.

The third program prevents the motor from restarting automatically by unlatching the motor output (forward or reverse) when an overload condition is detected.

REVIEW QUESTIONS

1. Which PLC programming unit in Figure 2-13 is logically equivalent to the control relay in Figure 2-12?

   a. Q1
   b. N1
   c. Q2
   d. I1

2. For what reason would a tripped overload pilot light be implemented in a motor control circuit?

   a. To suggest the operator to stop the motor manually.
   b. To make use of the overload relay NO contact.
   c. Because the motor overload might not be readily apparent.
   d. None of the above are correct.

3. Why is the circuit of Figures 2-14 and 2-15 likely to restart automatically, following an overload?

   a. The PLC is powered continuously.
   b. The signal from the overload relay NO contact does not reset the PLC program.
   c. The overload relay can be reset automatically.
   d. All of the above are correct.

4. In Figure 2-14, which PLC input triggers the flashing timing relay?

   a. I1
   b. I4
   c. I5
   d. I6

5. In Figure 2-17, which conditions cause the program to reset?

   a. False (make) I1
   b. True (break) I6
   c. True (make) T1
   d. None of the above is correct.

Unit Test

1. What is connected to the coil of the Interposing Relays?

   a. Output signal
   b. Incoming signal
   c. Overload relay
   d. None of the above is correct.

2. What is needed to one side of the contact of the Interposing Relays?

   a. Supply voltage
   b. Push buttons
   c. Overload relay
   d. None of the above is correct.

3. Which device needs an interposing relay for AC to DC bridging?

   a. DC Power Supply, Model 3139
   b. Switches, Model 3112
   c. Overload Relay module, Model 3131
   d. None of the above is correct.

4. Which device needs an interposing relay for DC to AC bridging?

   a. DC Power Supply, Model 3139
   b. Switches, Model 3112
   c. Overload Relay module, Model 3131
   d. None of the above is correct.

5. Which device delivers appropriate voltage for the Programmable Logic Controller, Model 3128?

   a. DC Power Supply, Model 3139
   b. Control Transformer, Model 3138
   c. AC Power Supply, Model 3196
   d. None of the above is correct.

6. Which device delivers appropriate voltage for the Brake Motor, Model 3176-A?

   a. DC Power Supply, Model 3139
   b. Control Transformer, Model 3138
   c. AC Power Supply, Model 3196
   d. None of the above is correct.

7. Which device delivers appropriate voltage for the Selector Switches, Model 3111?

   a. DC Power Supply, Model 3139
   b. Control Transformer, Model 3138
   c. AC Power Supply, Model 3196
   d. None of the above is correct.

8. Why are low AC and DC voltages widely used in control circuits?

   a. Simplify circuits
   b. Increase electrical power in control circuits
   c. Make the working environment of the operator safer
   d. None of the above is correct.

9. How is the tripped overload status used in the Figure 2-17 PLC program?

   a. Digital input signal
   b. Analog input signal
   c. Output signal
   d. None of the above is correct.

10. Why would the tripped overload signal be used to reset the PLC motor control program?

   a. To suggest the operator to stop the motor manually.
   b. To prevent the motor from restarting automatically.
   c. Because the motor overload might not be readily apparent.
   d. None of the above is correct.