Hardware Engineer:	Basil Alsulami	Lab:	7
Software Engineer:	Andrew Struthers	Due:	March 7th, 2018

Lab 7: Three-Phase Motor Control

Purpose:

This lab represents the capstone project of the quarter, involving elements of Labs 1, 2, 3, 5 and 6. Groups will develop a complete control system of a three-phase motor using a low voltage, low current photovoltaic cell as an analog light sensor to control speed and pushbuttons to control Run/Stop/Reverse functions.

This lab requires each group to interface the motor to the VFD through the Motor Starter Relay, and the VFD to the PLC.

Objectives:

Upon completion of this lab, you should be able to:

- Interface analog sensors to the PLC
- Interface the PowerFlex 4 VFD to the PLC
- Implement control panel and 3Φ motor wiring solutions using NFPA 79
- Read and write data from the Analog module

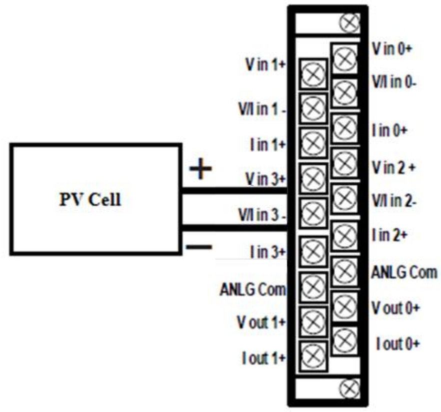
Materials:

1 *x*	PLC Trainer	1 *x*	Digital Multimeter
1 *x*	Photovoltaic Cell	1 *x*	¼ HP Three-Phase (3Φ) motor
3ft.	Red Wire	3ft.	Black Wire
3ft.	Blue Wire	3ft.	Orange Wire
2ft.	Yellow Wire	2ft.	White Wire
2ft.	Green Wire		

Procedure:
PV Cell Configuration

The Hardware Engineer should perform the following portion of the procedure

1. Before beginning any lab, always inspect the equipment to verify that all connections, including the chassis ground wires are secure and properly connected and that the equipment is safe to operate.



2. **Verify that the power is turned off to the unit.**

   Note: If the cabinet is still wired for Lab 6, skip to Step 6.

3. Route a brown wire from the **V in 3+** and a white wire from the **V/I in 3-** terminal on the 1769-IF4XOF2 analog module to two available terminal blocks on the upper terminal block rail.

   Note:
   The illustration to the right does not show the terminal block connections.

4. Use a DMM to verify the polarity of the leads connected to the photovoltaic cell. The red plug should be the positive lead and the black plug should be the negative lead.

5. Wire the **unshielded** red and black banana jacks on the right side of the cabinet to the terminal blocks where you made the connections in (Lab 6, Step 12). Make sure that the red jack is connected to the terminal block associated with **V in 3+** and the black jack is connected to the terminal block associated with **V/I in 3-**.

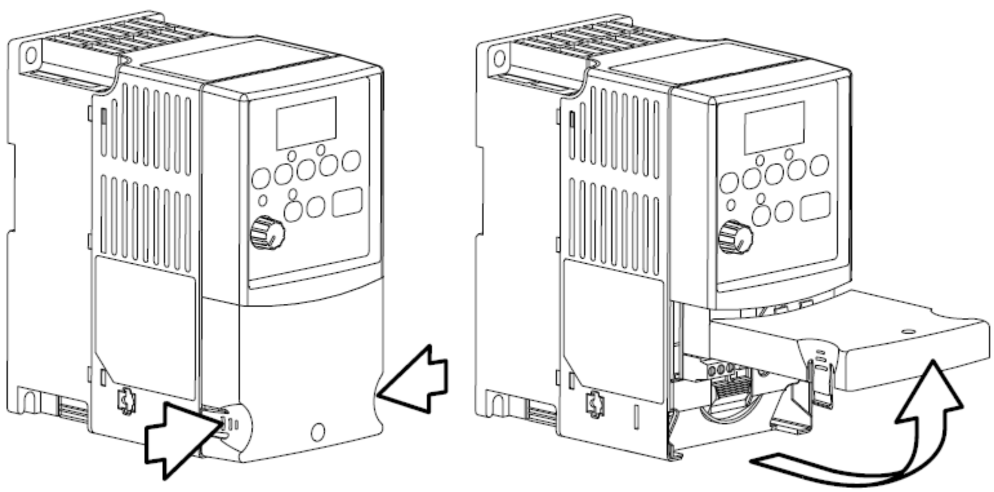
6. Connect the PV cell banana plugs to the jacks on the cabinet. Verify that the terminals of the PV cell are isolated from the case of the PLC unit and that all connections are securely connected before proceeding.

VFD Configuration: Hardware

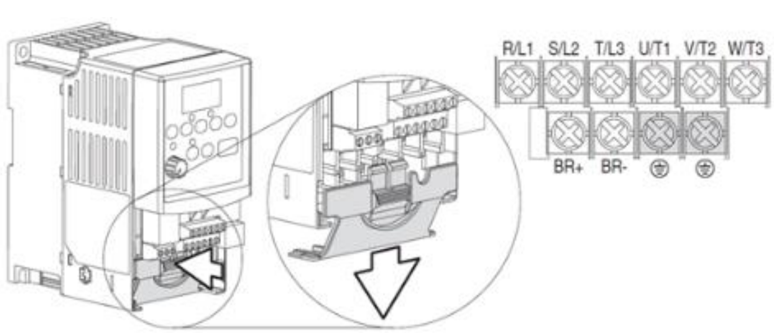
The following procedure will describe how to interface the VFD to three digital outputs and one analog output of the PLC. The Hardware Engineer should perform this procedure.

7. Press and hold in the tabs on each side of the VFD cover

8. Pull the cover out and up to release



9. The drive utilizes a finger guard over the power wiring terminals (shown below). To remove:
    a. Press in and hold the locking tab
    b. Slide finger guard down and out



Terminal	Description	
R/L1, S/L2	1-Phase Input	
R/L1, S/L2, T/L3	3-Phase Input	
U/T1	To Motor U/T1	Switch any two motor leads to change forward direction.
V/T2	To Motor V/T2	=
W/T3	To Motor W/T3	
BR+, BR-	Dynamic Brake Resistor Connection	
⏚	Safety Ground - PE	

10. Route one piece of green wire from the unused ground terminal on the VFD to the first unused terminal *to the left* of the +24V distribution point *created in* (Lab 2, Step 4).

Continuing *right to left*, complete steps 11-15:

11. Route one piece of **blue** wire from **W/T3** on the VFD to the next unused terminal…

12. …then route one piece of **red** wire from **V/T2** on the VFD to the next unused terminal…

13. …then route one piece of **black** wire from **U/T1** on the VFD to the next unused terminal.

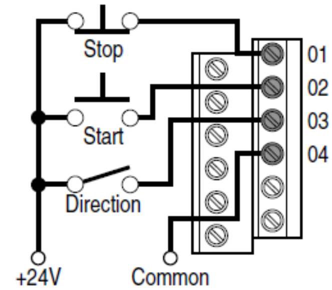
14. Replace the finger guard. Be careful not to break the latching tabs. If the guard does not install easily, **ask the instructor or a TA for help**.

15. Route one piece of orange wire from terminal **01** on the VFD to the next unused terminal.

16. Using information you recorded in Lab 2 and Lab 3, fill in the **first 6** entries in the table below:

Table: Output Module Addresses

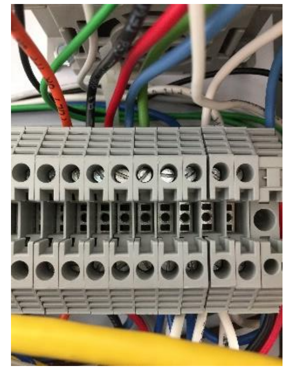
Output	Physical Location
Red Indicator	Local:2:O.Data.5
Yellow Indicator	Local:2:O.Data.2
Green Indicator	Local:2:O.Data.1
Blue Indicator	Local:2:O.Data.3
White Indicator	Local:2:O.Data.4
Motor Starter Relay (Motor Enable)	Local:2:O.Data.0
Start/Run Forward	Local:2:O.Data.6
Reverse	Local:2:O.Data.7



17. Route one piece of orange wire from terminal **02** on the VFD to the one of the unused terminals on the Output Module. **Record the address above as "Start/Run Forward".**

18. Route one piece of orange wire from terminal **03** on the VFD to the last unused terminal on the Output module. **Record the address above as "Reverse".**

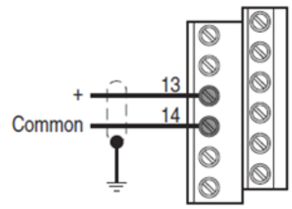
19. Route one piece of white wire from terminal **04** on the VFD to the common distribution point (Lab 2, Step 3). Your upper terminal block should look like the photo at upper right:



20. Route one piece of yellow wire from terminal **13** on the VFD to the first available terminal block next to the solar panel wiring installed in (Lab 6, Step 12).

21. Route one piece of white wire from terminal **14** on the VFD to the next available terminal block.

22. Route one piece of yellow wire from the terminal block in step 20 to **V out 0+** on the Analog Module.



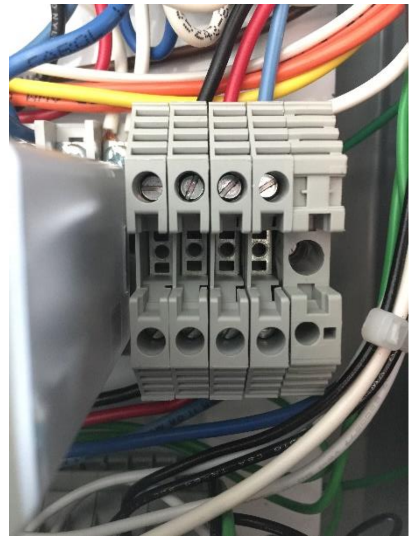
23. Route one piece of white wire from the terminal block in step 21 to the remaining **ANLG Com** terminal on the Analog Module. Your connections should look like the middle two images:

24. Route one piece of orange wire from the terminal block corresponding to terminal **01** on the VFD to terminal **53** on the auxiliary contact you used in (Lab 1 Part 2).

25. Route one piece of blue wire from terminal **54** on the auxiliary contact to the +24V DC Distribution point on the bottom of the cabinet.

26. Verify that terminal **A1** of the Motor Starter relay is still connected to the Output Module, and terminal **A2** is connected to the Common Distribution point on the bottom of the cabinet.

27. Route one piece of black wire from the upper terminal block corresponding to **U/T1** to terminal **L1** on the Motor Starter Relay.



28. Repeat Step 27 using a red wire to connect **V/T2** to **L2** and a blue wire to connect **W/T3** to **L3**.

29. Route a blue wire from **T3** on the Motor Starter Relay to the bottom side of the outermost (4th) slot in the terminal block to the right of the general purpose relays.

30. Repeat Step 29 using a red wire to connect **T2** to the 3rd slot and a black wire to connect **T1** to the 2nd slot in the same block. Your connections should look like the picture to the right:

31. Connect the black shielded banana plug lead to the terminal block corresponding to **T1**. Repeat for the red and blue shielded banana plugs. **Coil or tuck the excess length. Do not cut the wires.**

32. Connect the green banana plug to the upper terminal block corresponding to the ground point you created in step 10. **Coil or tuck the excess length. Do not cut the wire.**

<u>Before you continue, contact a TA or the Instructor to have your cabinet inspected. Do not plug it in without TA or instructor permission.</u>

DANGER

Do not proceed without Instructor or TA Authorization

VFD Configuration: Software

The following procedure will describe how to configure the VFD to control the motor used in this lab. The Software Engineer should perform this portion of the lab.

33. Turn the power to the unit on. After the PLC has completed its self-test, continue.

34. Using the steps outlined on page 2-4 of the *PowerFlex 4 User Manual*, set (or verify) the following parameters:

Parameter Name	Value	Units/Significance
P031 – Nameplate Voltage	230	Volts
P032 – Nameplate Frequency	60	Hertz
P033 – Motor Overload Current	1.5	Amps
P034 – Minimum Frequency	30	Hertz
P035 – Maximum Frequency	90	Hertz
P036 – Start Source	2	“I/O-1 triggers Coast to Stop”
P037 – Stop Mode	0	“Ramp, Clear Faults”
P038 – Speed Reference	2	“0-10V Input”
P039 – Acceleration Time 1	10	Seconds
P040 – Deceleration Time 1	10	Seconds

PLC Configuration: Software

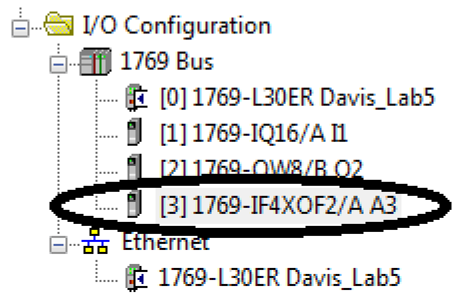
35. If necessary, use the **Network Connectivity and Configuration** procedure from Lab 2 to configure the network connection for your PLC from the PC that you plan to use for the remainder of this lab.

36. Launch **Studio 5000** and create a new Project named “Lab7_Unit#” where # corresponds to your Unit number.

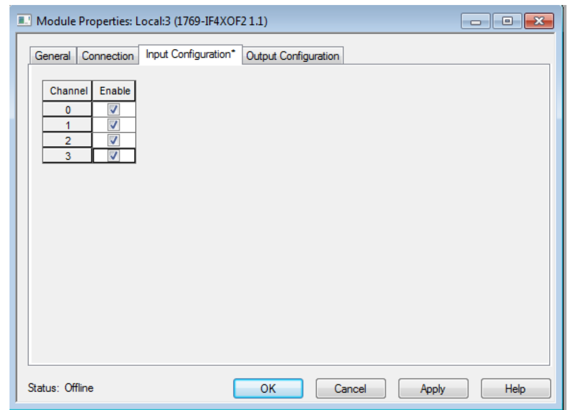
    Note: If a program template containing the default IO configuration, program tags, and the Machine_Active rung has been created, skip to Step 7.

37. Configure the Controller I/O Configuration as outlined in Lab 2.

38. Configure the Program Tags using the same tag labels as used outlined in Lab 3.
Right click on the 1769-IF4XOF2/A A3 module under the I/O Configuration folder and select “Properties”.



39. Open the **Input Configuration** Tab and verify that all channels are enabled. Verify that all output channels are likewise enabled in the **Output Configuration** Tab.

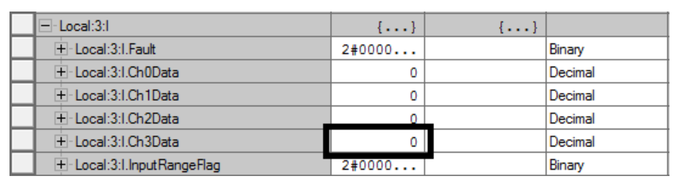


40. Implement the **Machine_Active** rung as described in lab 4 on the **MainRoutine** programming pane, EXCEPT use **Black_Mushroomhead_PB** instead of **Green_PB**.

41. Create a rung that will enable the **White_Indicator** only if **Machine_Active**=0 on the **MainRoutine** programming pane.

42. Go online.

43. Open the **Controller Tags** tab and verify that the **Local:3:I.Ch3Data** value is non-zero (i.e., the panel is gathering light).



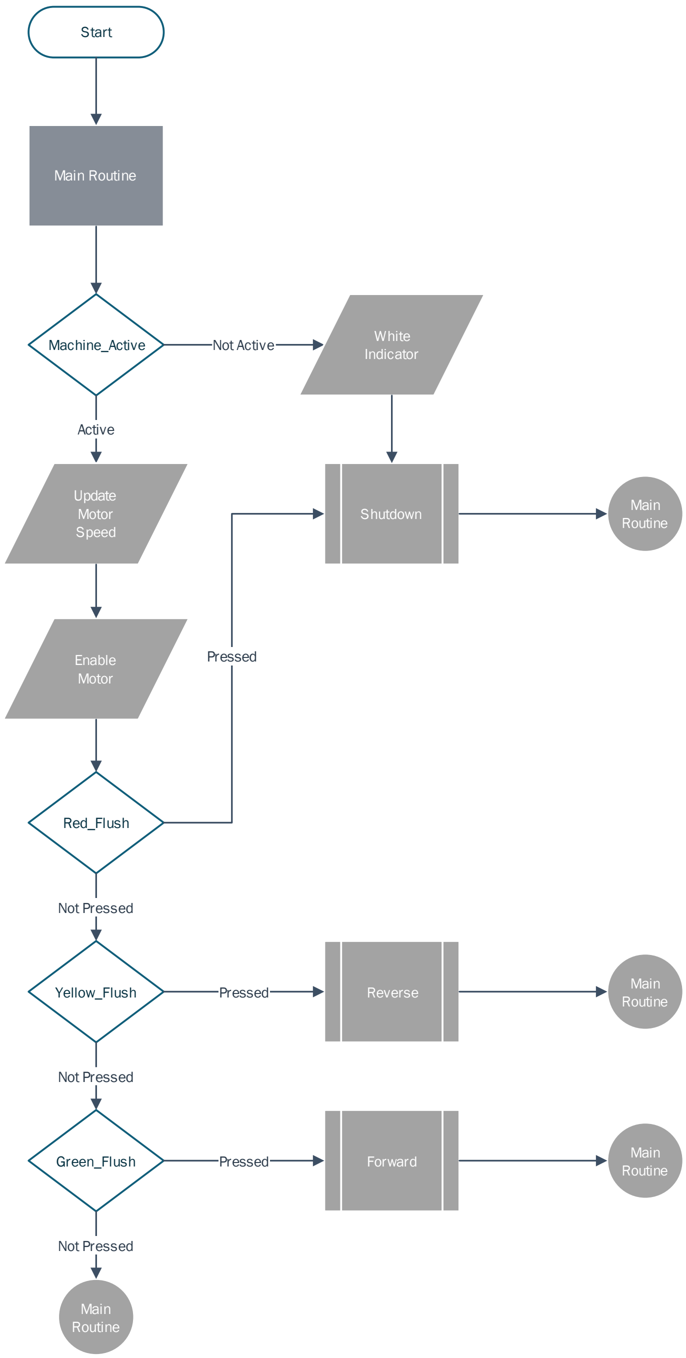
44. Partially block the light to the PV Cell. The value stored in **Local:3:I.Ch3Data** should change. If it does not, verify that the electrical connections are secure and that the controller is Online.

45. Create three subtasks using the process outlined in Lab 5. Name them **Forward, Reverse**, and **Shutdown**.

46. Using the following flowcharts as a guide, finish **MainRoutine, Forward, Reverse,** and **Shutdown**.

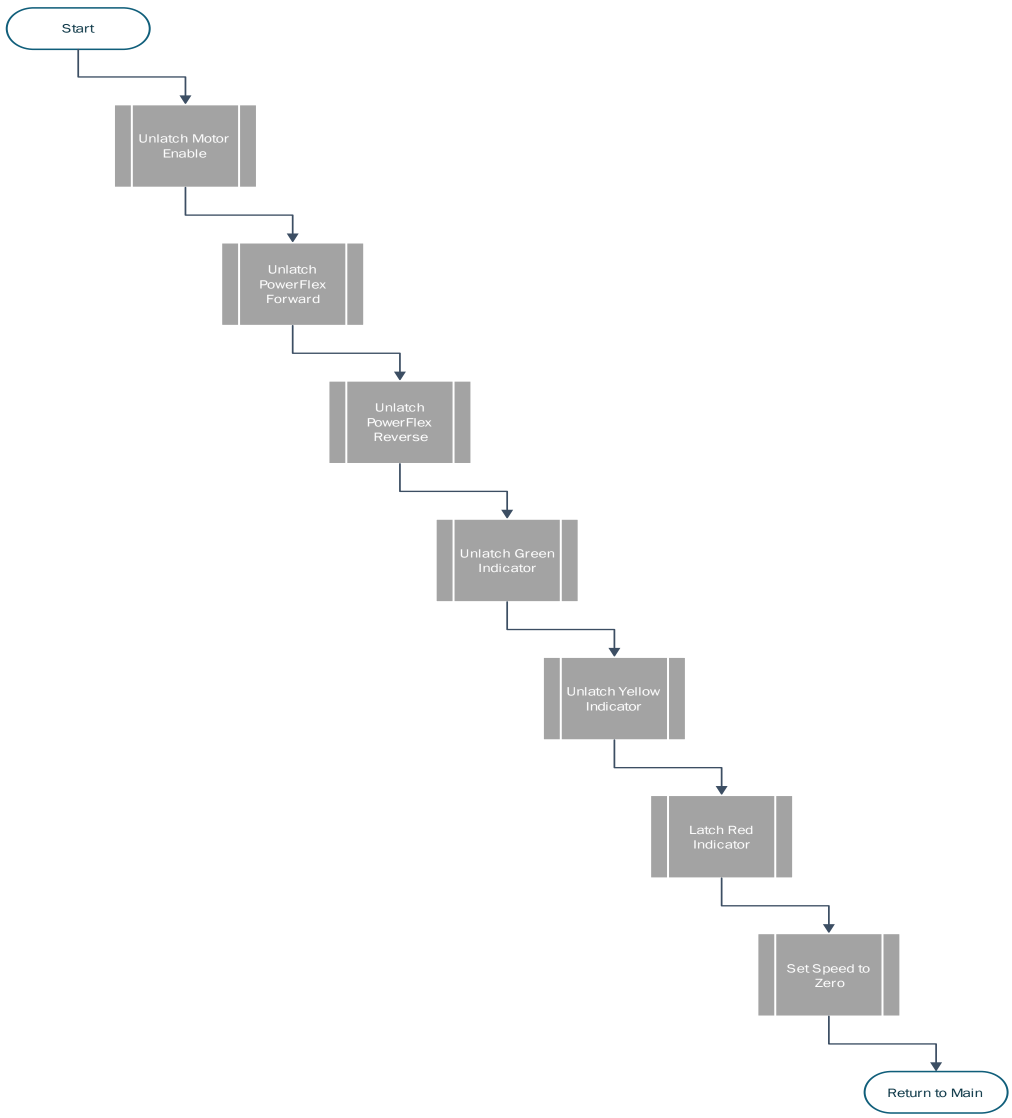
Main Routine:

This routine will control the system as a whole, managing the current state of Machine_Active as well as the motor speed. "Button listeners" allow Shutdown, Forward and Reverse to be called from MainRoutine. NOTE: Don't forget that Red_Flush is ***normally-closed****.*



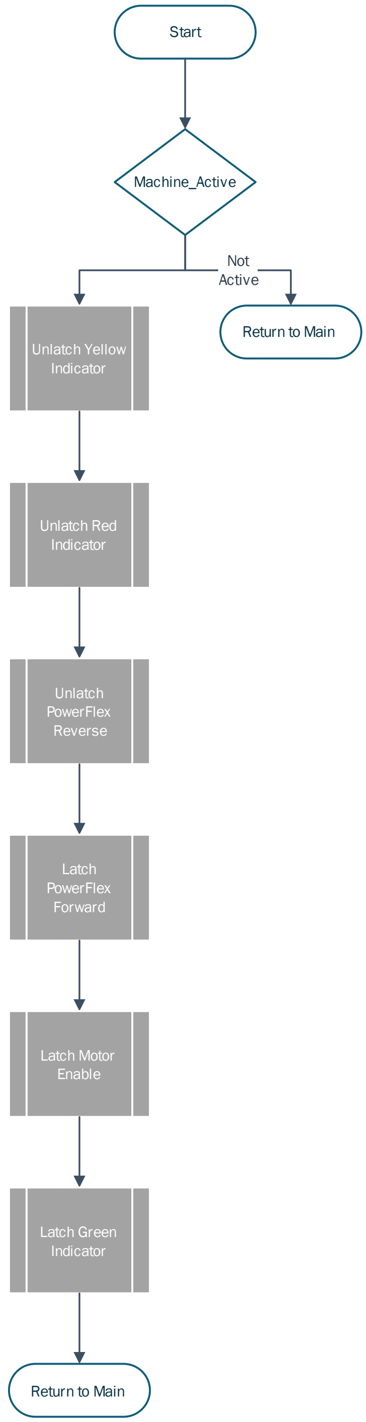
Shutdown Task:

This routine provides a consistent, safe shutdown of the motor and the VFD by resetting all parameters to idle, zero speed and updating the indicators to reflect a stop condition.



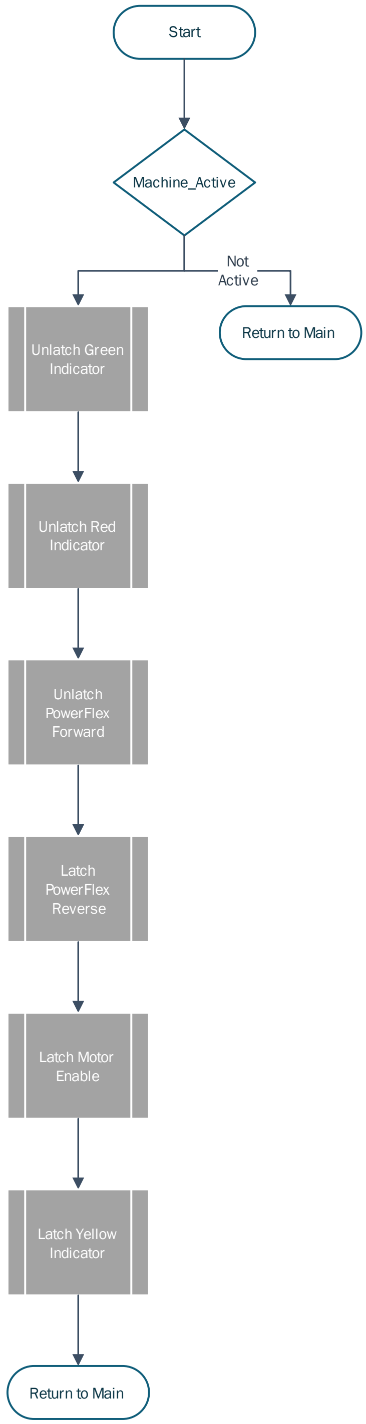
Forward Task:

This task handles configuration changes necessary to run the motor in the native forward direction. It also updates all indicators to reflect the new forward state.



Reverse Task:

This task handles VFD configuration changes necessary to run the motor in the reverse direction. It also updates all indicators to reflect the new reverse state.



Note:

This lab has no additional requirements for students enrolled in ETSC 522.

For Submission:

- **PDF copy of the program for MainRoutine, Forward Task, Reverse Task, and Shutdown Task. Each routine should be well-documented.**
- **Review the rubric on the next page for guidance.**

Grading Rubric						
	0	1	2	3	4	5
Functionality	No work attempted or Lab Document not submitted	Lab is non-functional either as a result of workmanship or implementation of lab requirements	Functionality is limited either as a result of workmanship or implementation of lab requirements	The Lab is functional but minimally satisfies the requirements of the lab document or workmanship impacts functionality.	The Lab is functional but only partially satisfies the requirements specified in the lab document or minimally impacted by workmanship.	The Lab is functional and fully satisfies the requirements specified in the lab document. Workmanship must be of professional quality.
Documentation		Minimal or unrelated documentation included in lab	Limited relevant documentation included in lab	Documentation is provided that supports the lab, but is incomplete	Documentation complete but with poorly structured responses	Documentation complete and well stated
Analysis		Minimal or unrelated Analysis included in lab	Limited relevant Analysis included in lab. May include significant errors in calculations	Analysis is provided that supports the lab, but is incomplete or contains significant errors	Analysis complete but with minor errors that have limited or no impact on results	Analysis complete and accurate
Workmanship		Implementation of hardware or software solution is of unacceptable quality and is unsafe	Implementation of hardware or software solution is deemed to be safe, but is of unacceptable quality	Implementation of hardware or software solution is of the lowest acceptable level of quality.	Implementation of hardware or software solution is acceptable with noted areas of improvement	Implementation of hardware or software solutions is of professional quality