NELSON MANDELA UNIVERSITY

Faculty of Engineering, the Built Environment & IT
Technology for tomorrow

Department of Mechatronics
Process Control and Instrumentation 4
ECIV401

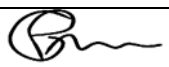
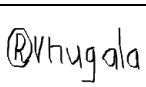
April 2024

Simulation and Visualization of Tank Level Control System

Laboratory 1

I hereby declare that

- I understand what plagiarism is and I know that it constitutes unacceptable academic behaviour.
- I declare that the proposal submitted with my application is my own work. In so far as I have made use of other people's work, it has been duly acknowledged and properly referenced in accordance with departmental guidelines and prescriptions.
- I declare that I was not assisted by a research supervisor/academic from another university in writing my proposal.
- I have not allowed, and will not allow, anyone to copy my work with the intention of passing it off as their own work.
- I understand that should plagiarism be detected in my proposal it may negatively impact the outcome of my application.

	Name	**Student No.**	**Signature**
1	Jason Saptoe	s224255800	
2	Michael Boreham	s224022008	
3	Gareth Pienaar	s220672326	
4	Vhugala Raphunga	s223236101	
5	Kyle Flanegan	s220324085	

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Aim

The aim of this laboratory assignment is to design and implement a control system using ladder logic for a simulated tank liquid level control system using a Siemens S7-1200 Programmable Logic Controller (PLC) and to integrate a Human Machine Interface (HMI) for visualization and operator control. The program will maintain the liquid level within the tank, ensuring it remains between 30% and 70% in automatic mode. Manual mode will leave the pump and valve actuation in the hands of the operator. The automatic and manual modes can be switched between in the HMI. Additionally, the project demonstrates the application of deadband control to maintain the system's stability and efficiency, while also providing an interactive HMI for real-time monitoring and control.

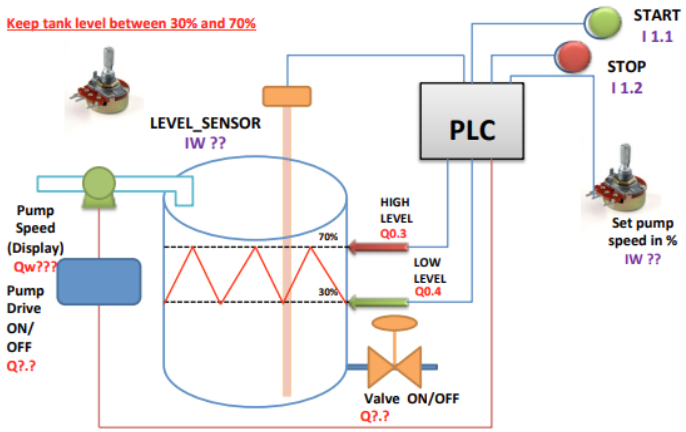

Figure 1: Visualization of Single Tank Control System. Found At: ECIV401 Lab 1 Assessment Rubric

Introduction

Process control plays a pivotal role in the automation industry by ensuring the safety and efficiency of industrial operations. This laboratory assignment details a tank liquid level control system that represents a fundamental example of how automated control can be applied to manage the levels of liquids within industrial tanks. This is a crucial task for industries, namely the pharmaceutical, food and beverage industries. A Siemens S7-1200 PLC is utilized to create a program capable of controlling the level of liquid within a tank by actuating a pump and valve, respectively, after receiving input from level sensors.

The system has two modes: manual and automatic. In manual mode, the pump and valve are controlled by the operator, whereas in automatic mode, the pump and valve are actuated according to signals from a level sensor. The goal is to maintain the level of liquid in the tank to be within a certain range to avoid wastage of materials and overflows. The creation of a human

machine interface allows real time monitoring of the system, allowing an operator to observe the system and intervene if necessary.

This laboratory assignment serves as an introduction to PLC ladder programming and automated process control, giving students hands on experience and a deeper understanding of the world of industrial process control.

Explanation of Ladder Code

Figures 1 to 4 show the code in network 1.

Figure 2 shows the starting latch. This latch is required to be set in order for the system to operate. If this latch is not set, the pump, valve, and the main LED indicators will not be able to function. The conditions required to be met before this latch can be set is that the E-stop latch must not be set (E-stop not pressed) and the start button must be pressed.
If the stop button, E-stop button, or the “Terminate and Reset System” button is pressed, the start latch will be reset and the system will be paused or reset in the case of the “Terminate and Reset System” button.

Figure 3 shows a latch which records if the start button has been pressed indicate that the system has been started. The reset condition for this latch is when the “Terminate and Reset System” button has been pressed, which will reset the system meaning that the start button has effectively not yet been pressed.
This figure also shows a latch which records when the stop button has been pressed which will cause the system to pause. The reset condition for this latch is obviously when the start button is pressed again.
Additionally, the figure shows the E-stop Latch, which is set when the E-stop button is pressed and it is only reset when the acknowledge button is pressed, before the start button can be pressed again.

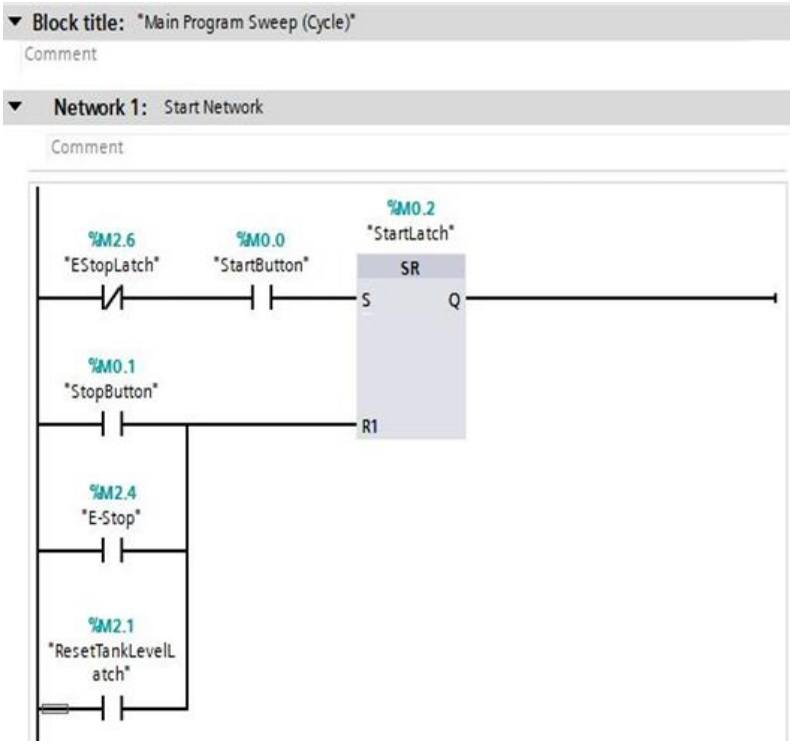

Figure 2: Network 1 – Start Latch

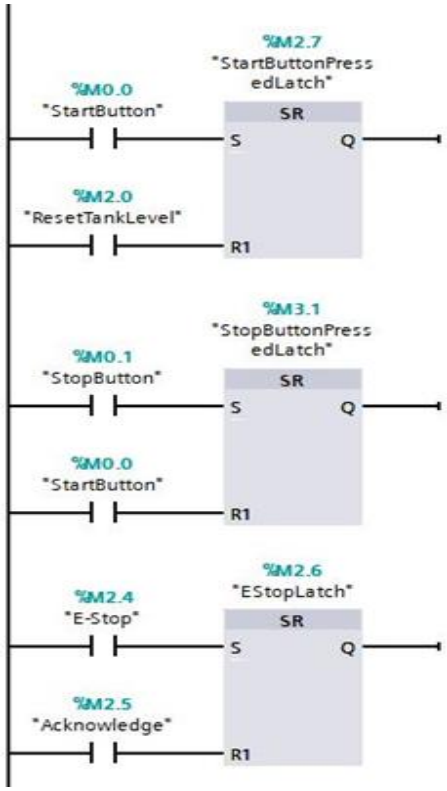

Figure 3: Network 1 – Start, Stop and E-Stop Latch

Figure 4 shows the Reset Tank Level Latch which is set when the "Terminate and Reset System" button is pressed. The reset conditions for this latch are obviously when the "Terminate and Reset System" button is not pressed and the start latch is set (meaning the start button has been pressed again) or when the start button pressed latch is set. It seems redundant but it is a necessary condition.
Additionally, when the Reset Tank Level Latch is set, it sets the stop button because the system needs to stop when it is terminated and reset.

Figure 5 shows the latch which switches the system between the automatic and manual modes. The system is in manual mode by default and can only be switched to automatic mode once the start latch has been set and once the switch has been changed to automatic mode.
Additionally, this figure shows a latch which is used to determine the colour of the start button in the HMI. The aim is to have the HMI prompt the operator as to which buttons can be pressed. So, when the start button is pressed or the E-stop latch is set, this latch will be reset meaning that the start button will appear grey in the HMI. On the other hand, if the start button has not yet been pressed at all, or if the acknowledge button is pressed after the E-stop button, or if the stop button has been pressed, the start button will appear a bright green in the HMI, prompting the operator to press it.

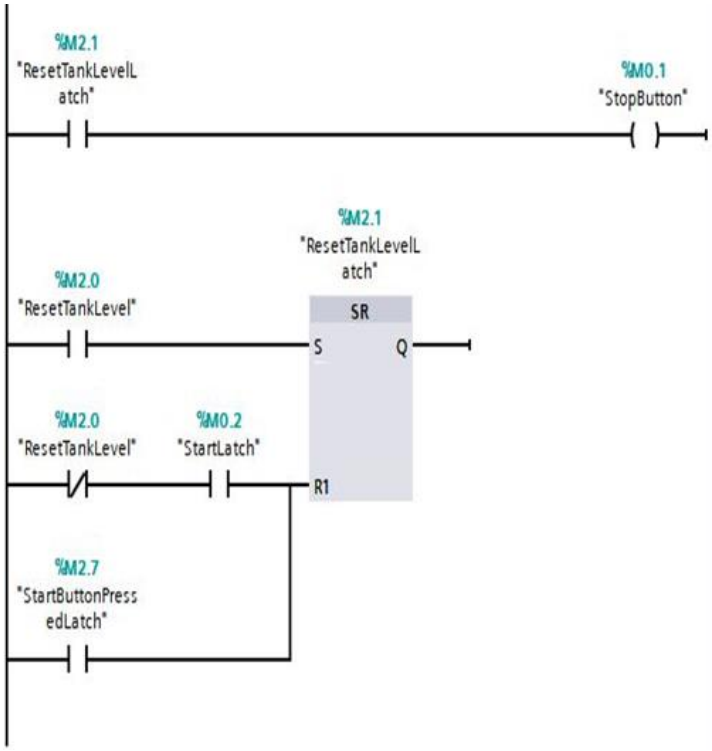

Figure 4: Network 1 – Reset Tank Level Latch

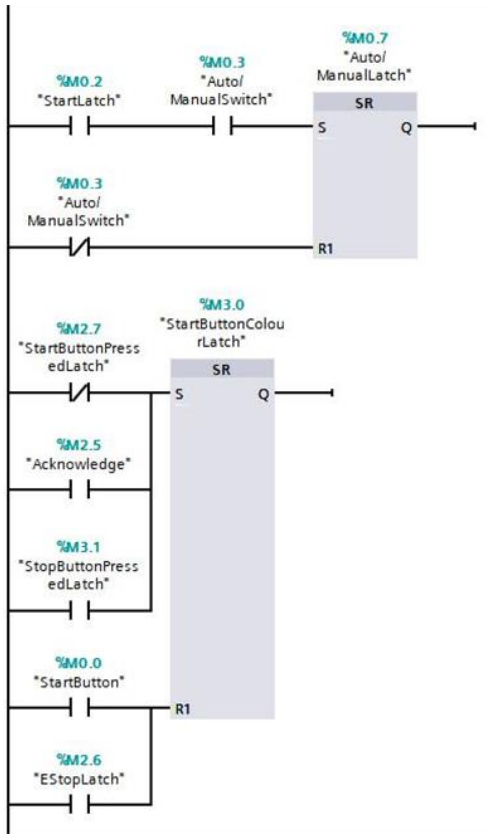

Figure 5: Network 1 – Auto/Manual and StartButtonColour Latches

Figures 6 and 7 show the code for network 2.

Figure 6 shows the code for the “Alert Latch” and the red and green LEDs.
The alert latch is used to determine when the liquid level of the tank is outside the optimal range (above 70% or below 30%). This latch is set when the tank level is above 70% (When the low-level and high-level sensors are set) or when it is below 30% (When neither the high-level nor the low-level is set). The reset condition for this latch is when the liquid level in the tank is between 30% and 70% (When low-level is set and when high-level is reset).
Then, if the start button has been pressed and the alert latch is set, the red LED will flicker at 0.5Hz using the clock memory byte.
Additionally, if the start button has been pressed and the liquid level is between 30% and 70% (low-level set and high-level reset), then the green LED will burn and the red LED won’t burn.

Figure 7 shows the code for the pump and valve actuation. (Note that when the pump/valve LEDs are set, it means that the pump is on or the valve is open)
As a group, the instructions were interpreted to say that, in automatic mode, if the system starts with the liquid below 30%, then the pump is turned on until the level reaches 70% where the pump is turned off and the valve is opened until the level reaches 30% again, where the cycle repeats. Additionally, if the liquid level starts above 70%, then the valve will open until the level reaches 30% where the same cycle of filling up to 70% and draining to 30% is repeated.
In automatic mode (when the auto/manual latch is set), the pump LED will be set when the “Below30” latch (to be explained) is set, meaning that the liquid level in the tank is below 30% and the pump needs to turn on. Another condition to set the pump LED is when the liquid level has come from 30% or below and is in the optimal zone filling up (when the SafeZone_FillingUpLatch is set). Also, in manual mode (when the auto/manual latch is reset) the pump LED will be set when the pump button is pressed. Additionally, in order for the pump LED to be set, the start latch must be set and the tank must not be full. The reason for the tank not being full being one of the conditions to set the pump is a safety feature to automatically prevent overflow in either automatic or manual mode.
In automatic mode (when the auto/manual latch is set), the valve LED will be set either when the “Above70Latch” is set, meaning that the level in the tank is above 70% and needs to be drained meaning that the valve needs to open. Also, when the liquid is coming from 70% or above (when the SafeZone_DrainingLatch is set), the valve needs to remain open until the level in the tank reaches 30%. In manual mode (when the auto/manual latch is reset), the valve LED will be set when the valve button is pressed. Additionally, in order for the valve LED to be set, the start latch must be set and the tank must not be empty. The reason for the tank not being empty being one of the conditions to set the valve is simply because it does not make sense to have the valve open when the tank is empty.

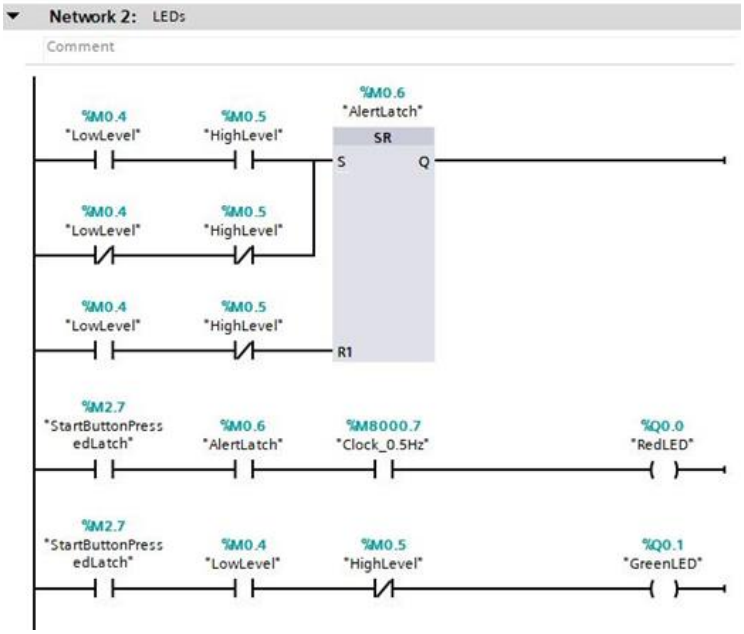

Figure 6: Network 2 – Alert Latch and Red and Green LEDs

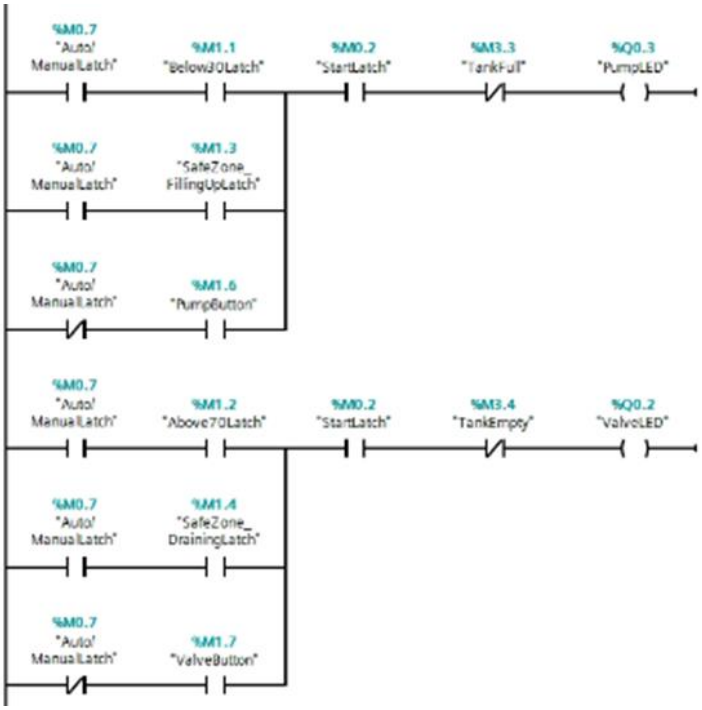

Figure 7: Network 2 – Pump and Valve LEDs

Figures 8 and 9 show the code for network 3.
This network is used for the automatic mode to set various latches to determine where the liquid level is in the system and which direction it should be going according to the aforementioned logic.

Figure 8 shows the “Below30Latch” and the “SafeZone_FillingUpLatch”.

The “Below30Latch” is set when the system is in automatic mode and the low- and high-level sensors are reset, meaning the liquid level is below 30%. The reset condition for this latch is when the low-level sensor is set, meaning that the liquid level is at or above 30%.
The “SafeZone_FillingUpLatch” is set in automatic mode when the low-level sensor has been set (meaning at or above 30%) and when the high-level and draining latch are reset, meaning that the liquid is in the safe zone, filling up. The reset condition for this is when the liquid level passes 70% and the “Above70Latch” is set.

Figure 9 shows the code for the “Above70Latch”, the “DrainingLatch” and the “SafeZone_DrainingLatch”.
The Above70Latch is set in automatic mode when the low- and high-level sensors are set. This latch being set will also be the condition to set the DrainingLatch because, once the liquid level reaches 70%, the system needs to automatically start draining. The reset condition for the Above70Latch is when the high-level sensor is reset, meaning that the liquid is in the safe zone (not above 70% anymore).
The reset condition for the DrainingLatch is when the low-level sensor is reset, meaning that the liquid level has reached 30% and the system need to automatically start filling again.
The conditions to set the SafeZone_DrainingLatch in automatic mode are when the low-level is set, the high-level is not set and the DrainingLatch is set, meaning that the level is between 30% and 70% and it is draining. The reset condition for this latch is when the low-level is reset, meaning that the system needs to start filling again,

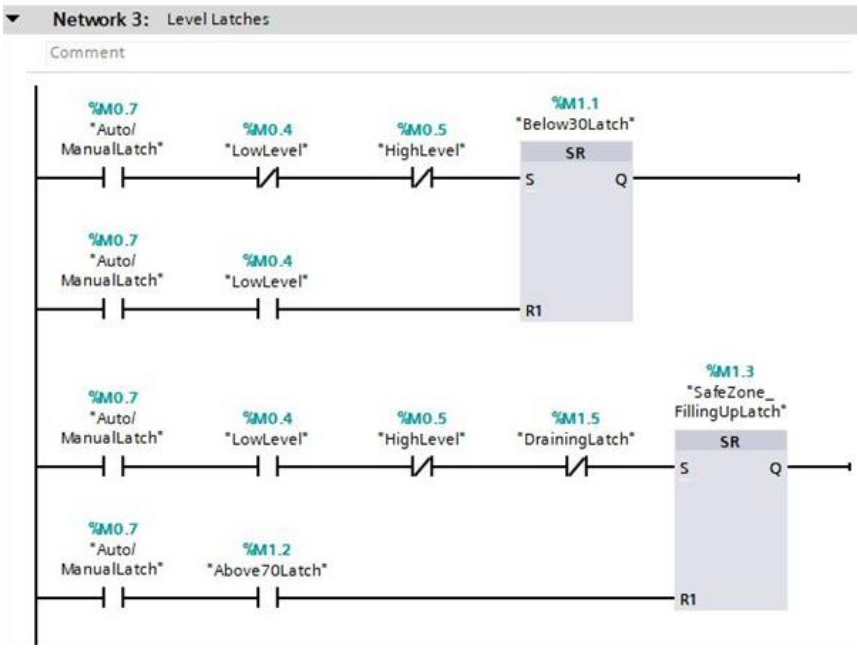

Figure 8: Network 3 – Below30Latch and SafeZone_FillingUpLatch

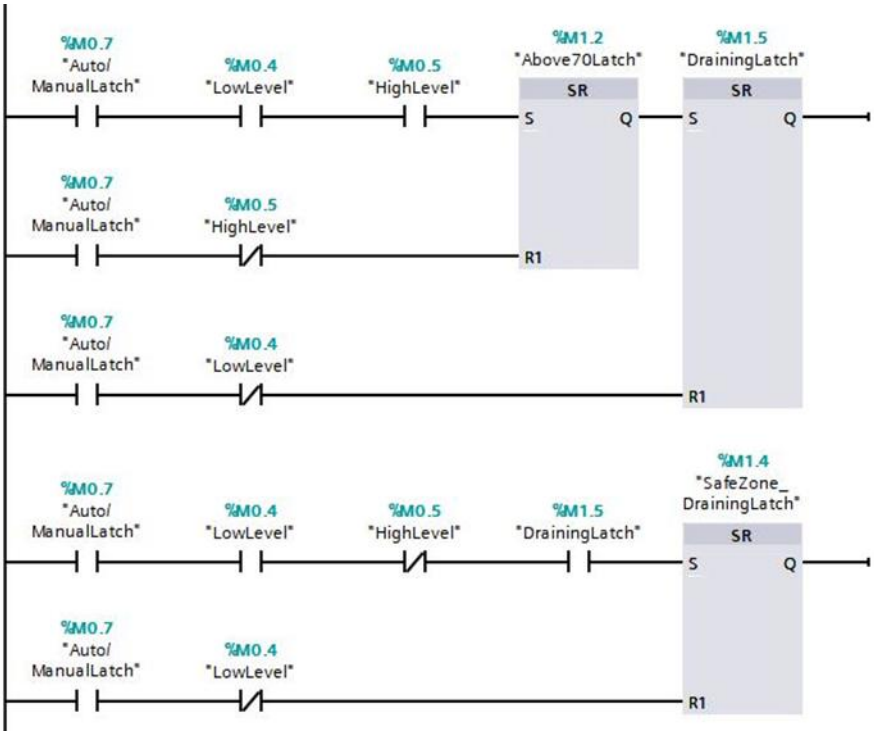

Figure 9: Network 3 – Above70Latch, DrainingLatch and SafeZone_DrainingLatch

Figure 10 shows the code for network 4, which is used for level setting.
When the tank level is at 30% or above, the low-level sensor is set.
When the tank level is at 70% or above, the high-level sensor is set.
When the tank level is at 100%, “TankFull” is set because the tank is full.
When the tank level is at 0%, the code ensures this by multiplying the TankLevel by zero and then setting “TankEmpty” because the tank is empty.

Figure 11 shows the code for network 5, which is used to scale the input from the simulated potentiometer (slider).
The output value from the slider is one between 0 and 100. Network 5 simply scales this to be between a value of 0 and 10 and this output is called “LevelRateOfChange”.
The reason for this is because, as a group, it was decided that at 100% pump speed, the tank will fill by 10%/sec. Meaning that at 50% pump speed, the tank will fill by 5%/sec.

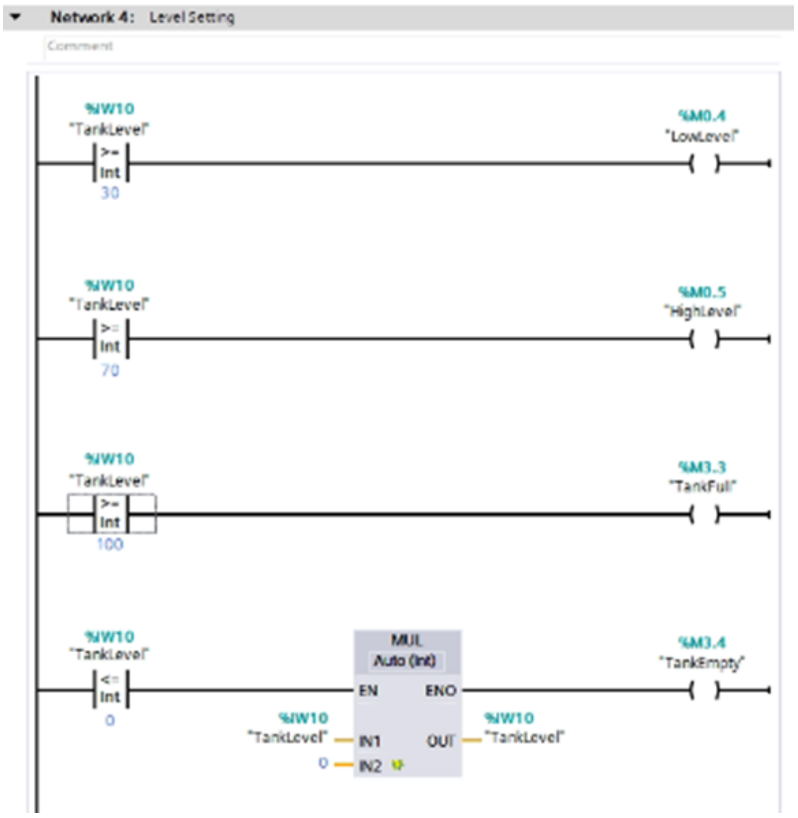

Figure 10: Network 4 - Level Setting

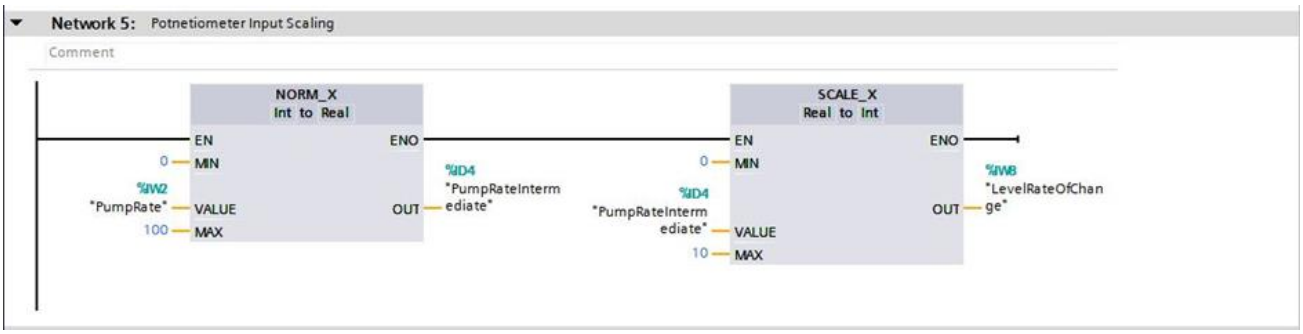

Figure 11: Potentiometer Input Scaling

Figure 12 shows the code for network 6, which is mainly used to control the simulated tank level changes due to the pump.

As can be seen in figure 11, when the start latch and the pump LED are set, a 1Hz clock triggers a pulse trigger which sends a single pulse to the ADD block every second. Therefore, this ADD block will add “LevelRateOfChange” to the tank level every second provided that the aforementioned conditions have been met. (Therefore, the tank level increases by LevelRateOfChange/sec)

Additionally, in this network, there is a multiplication block which resets the tank level to zero after the ResetTankLevelLatch has been set.

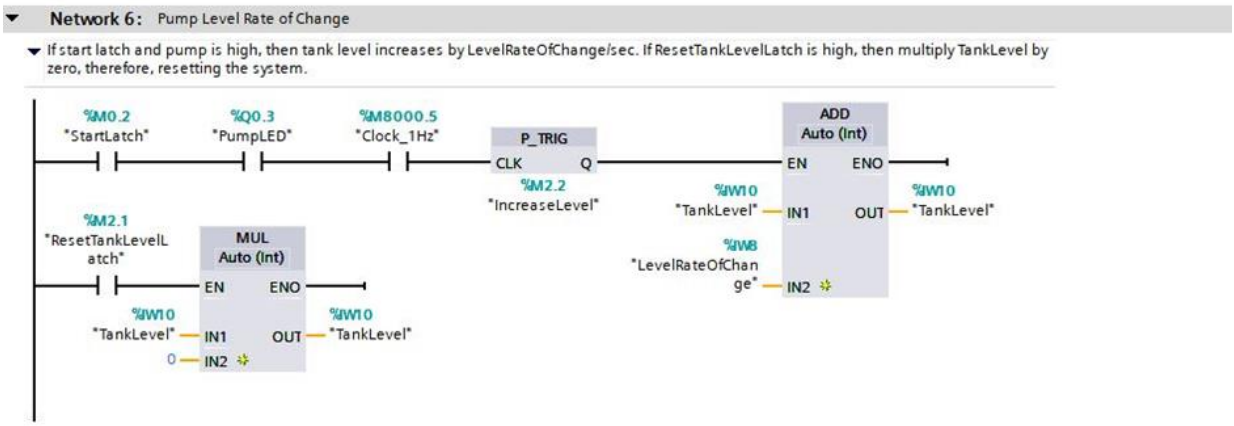

Figure 12: Network 6 - Level Rate of Change Due to Pump and Reset Tank Level

Figure 13 shows the code for network 7, which controls the simulated tank level changes due to the valve.

As can be seen in figure 12, when the start latch and valve LED have been set, the same pulse trigger as in network 6 is triggered which sends a single pulse to a SUB block every second. This means that, every second, the tank level will decrease by a constant rate of 5%/sec, which is what the group agreed upon in terms of the draining rate of the valve.

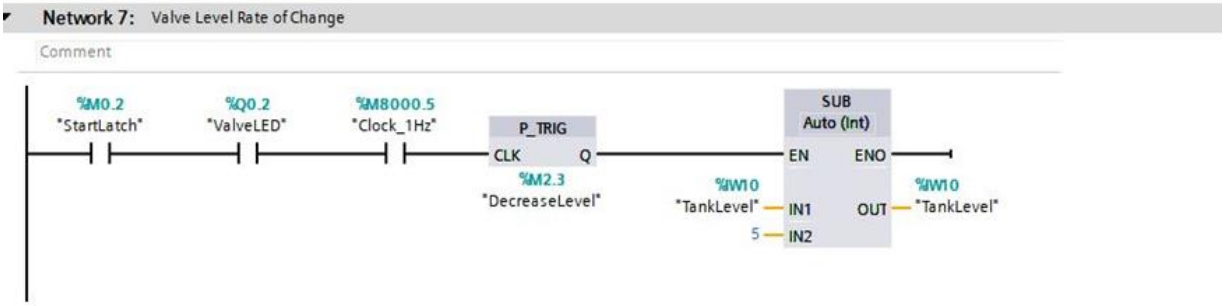

Figure 13: Network 7 - Level Rate of Change Due to Valve

Figures 14 shows the HMI tag table and figures 15 to18 show the PLC tag tables.

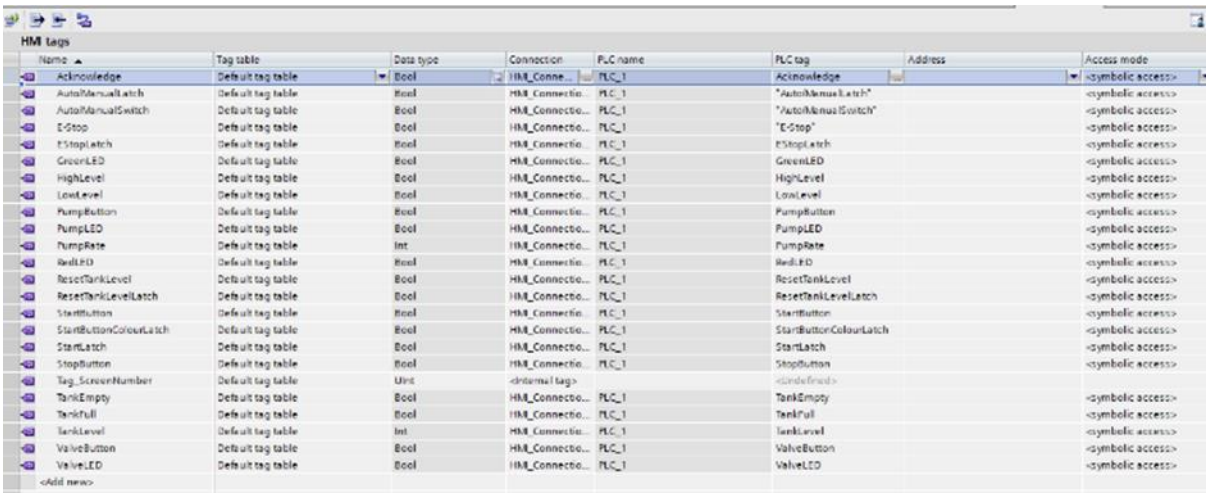

Figure 14: HMI Tag Table

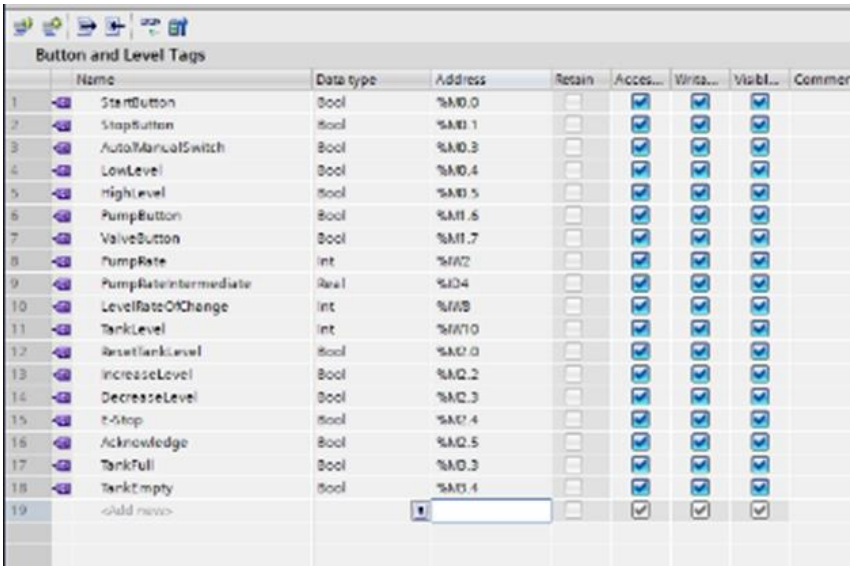

Figure 15: PLC Button and Level Tags

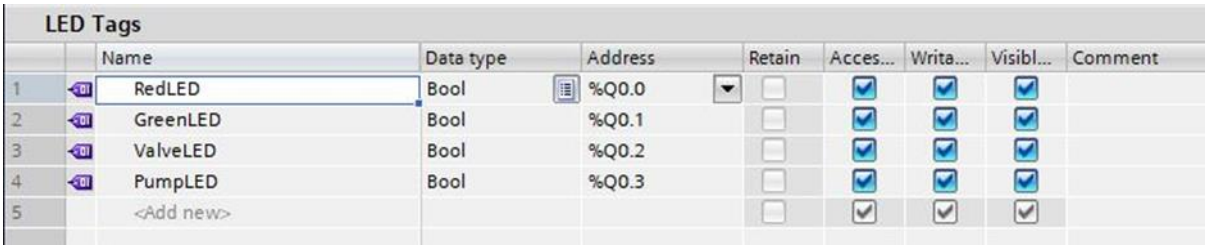

Figure 16: PLC LED Tags

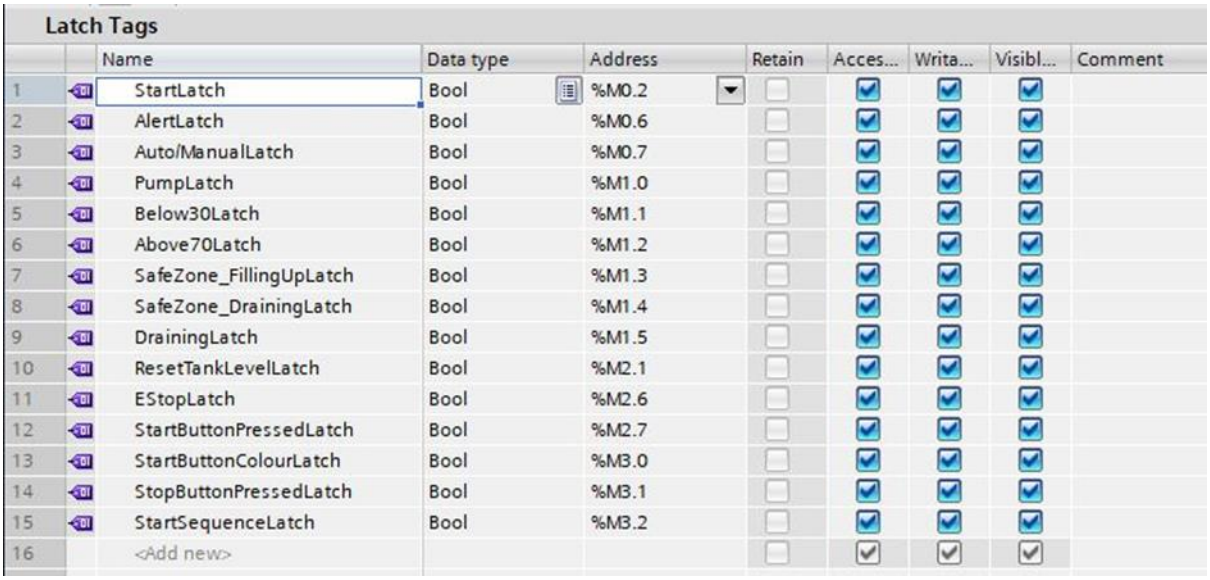

Figure 17: PLC Latch Tags

ClockTags

	Name	Data type	Address	Retain	Acces...	Writa...	Visibl...	Comment
1	Clock_Byte	Byte	%MB8000		☑	☑	☑	
2	Clock_10Hz	Bool	%M8000.0		☑	☑	☑	
3	Clock_5Hz	Bool	%M8000.1		☑	☑	☑	
4	Clock_2.5Hz	Bool	%M8000.2		☑	☑	☑	
5	Clock_2Hz	Bool	%M8000.3		☑	☑	☑	
6	Clock_1.25Hz	Bool	%M8000.4		☑	☑	☑	
7	Clock_1Hz	Bool	%M8000.5		☑	☑	☑	
8	Clock_0.625Hz	Bool	%M8000.6		☑	☑	☑	
9	Clock_0.5Hz	Bool	%M8000.7		☑	☑	☑	
10	<Add new>				☑	☑	☑	

Figure 18: PLC Clock Tags

Figures 19 to 22 show various instances of the HMI developed for the system.

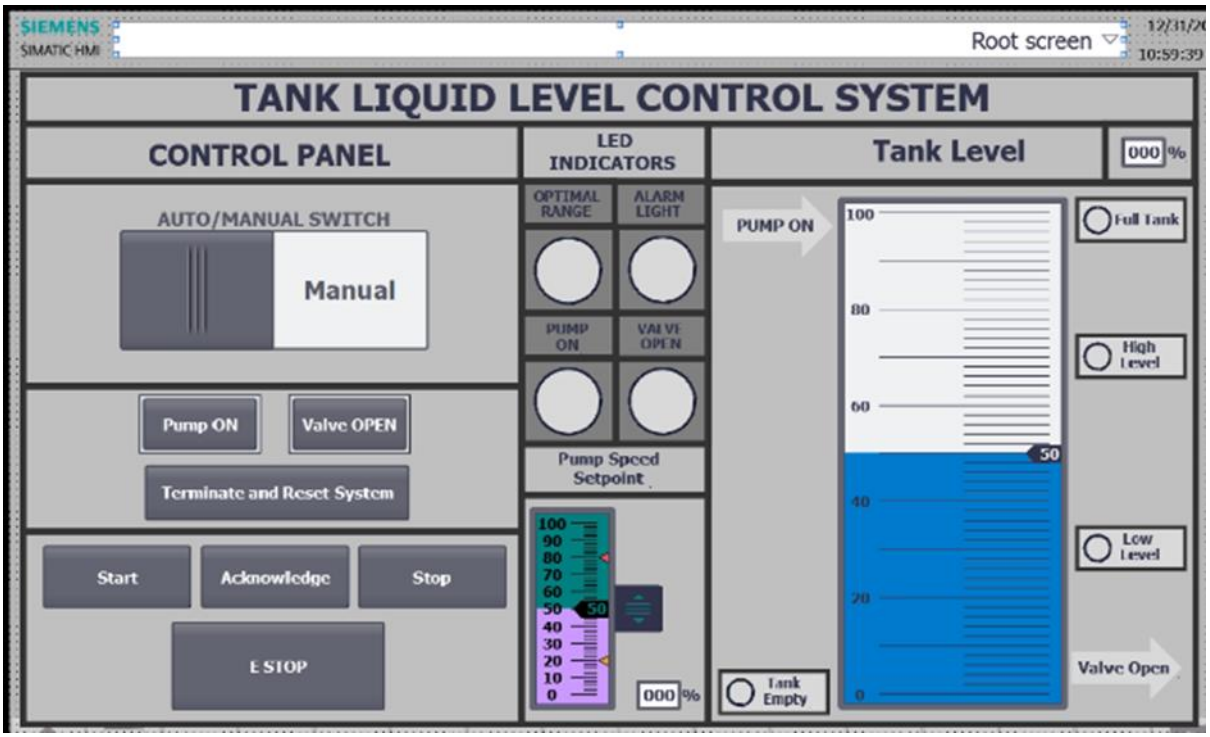

Figure 19: HMI Development Screen

Figure 20: HMI Start-Up Screen

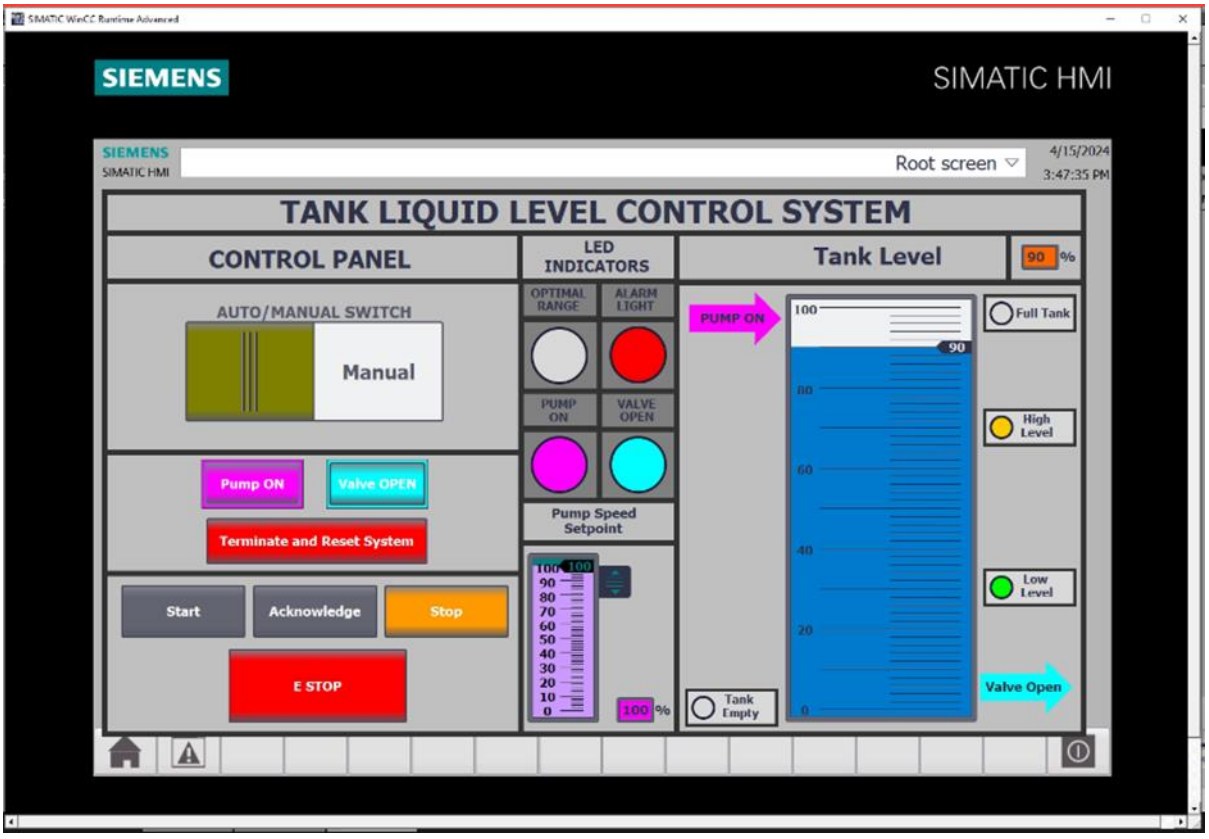

Figure 21: HMI in Manual Mode with Pump on and Valve Open with Tank Level in Critical Zone

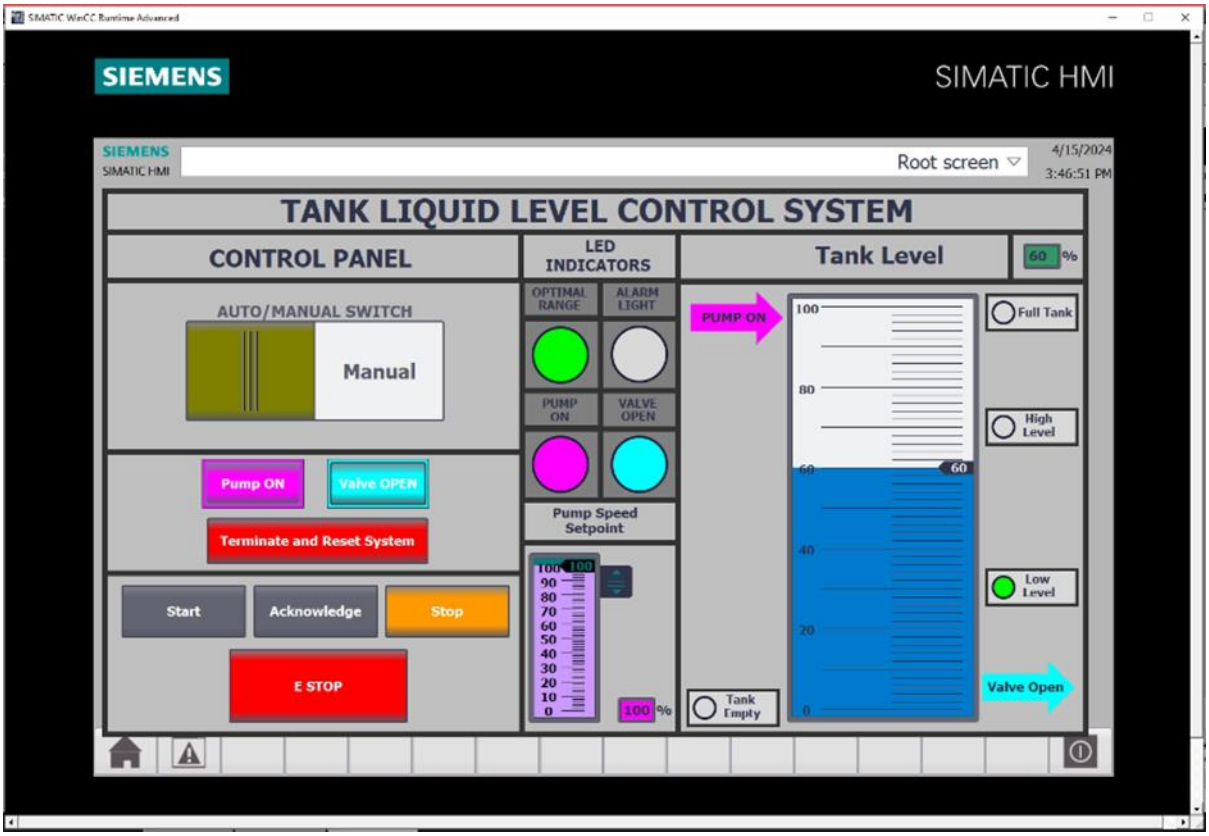

Figure 22: HMI in Manual Mode with Pump on and Valve Open with Tank Level in Optimal Zone

Please note that the figures of the HMI do not exhibit all of its features. All the features can be observed in the video explained in great detail.

References

PLC & Automation With Liam Bee - Learn Siemens TIA Portal, Allen Bradley, Schneider, Node-Red and More! (2023). PLC Basics – Latches - PLC & Automation With Liam Bee. [online] Available at: https://liambee.me/siemens/plc-basics-latches/ [Accessed 30 March 2024].

Solisplc.com. (2024). How to Create HMI Animations and Events in Siemens TIA Portal. [online] Available at: https://www.solisplc.com/tutorials/hmi-animations-and-events-in-siemens-tia-portal [Accessed 1 April 2024].

Assessment Rubric

PROCESS CONTROL & INSTRUMENTATION 4
Laboratory 01: Totally Integrated Automation Implementation and Integration of Dead-Band Tank Level Control System

Functionality of PLC Programme	YES	NO	%	Comment
Automatic and manual mode			5	
Start / stop process			5	
Pump on-off and speed display			5	
Initialization and manual to auto logic			5	
Red panel light flashing and green light			5	
Valve operation in combination with pump (indicate level direction).			5	
Pump operation (Above 70% and Below 30%)			5	
Special features and Safety (Own Initiative)			5	
Evaluation of logic innovations & functions (video)			5	
HMI Visualization and Control				
Tank system and component layout visualization.			5	
The tank level indicates the level sensor value			5	
Motor and valve status is displayed			5	
Start/Stop control and Indicate			5	
Selector switch control and Indicate			5	
Level indicators			5	
Motor speed			5	
Evaluation of HMI innovations (video)			5	
Safety and Restart (video)			5	
Subtotal (100)				
MULTIPLICATION FACTOR, BASED ON:				
Report: Layout and neatness, Structure and Comments of PLC Program, Variable – Tag Table, Realistic HMI Process, ProcessReferences.			10	
Mark				
Team Member Contribution Rating				**0.0-1.0**
Final Mark (Mark * Team Rating)				

Lab Assistant Name:_____

Moderator :_____ Assesment Date:_____

Comments:_____

Addendum

Time Slots Booked to Complete Lab 1

Week 27 March – 3 April

day	Slot #	Time			PC 2	PC 4	PC 3	PC 5
Thurs	1	10:00	-	11:30				
	2	11:30	-	13:00			Group 12	
	3	13:00	-	14:30	Group 2		Group 4	
	4	14:30	-	16:00		Group 5	Group 11	
Fri	1	10:00	-	11:30				
	2	11:30	-	13:00				
	3	13:00	-	14:30				Group 2
	4	14:30	-	16:00				
Sat	1	10:00	-	11:30				Group 2
	2	11:30	-	13:00				
	3	13:00	-	14:30				Group 10
	4	14:30	-	16:00				
		19:30		21:00				Group 2
Mon	1	10:00	-	11:30				
	2	11:30	-	13:00				
	3	13:00	-	14:30	Group 2			
	4	14:30	-	16:00				
Tue	1	10:00	-	11:30				
	2	11:30	-	13:00			Group 12	Group 2
	3	13:00	-	14:30			Group 4	Group 3
	4	14:30	-	16:00				

Week 4 – 10 April

Date	Slot #	Time		PC			PC	
				2		4	3	5
Thurs	1	10:00	-	11:30	Group 7	Group 5	group 11	Group 2
	2	11:30	-	13:00		Group 8	Group 1	Group 10
	3	13:00	-	14:30	Group 7	Group 12	Group 4	
	4	14:30	-	16:00		Group 10		Group 2
Fri	1	10:00	-	11:30	Group 7	group 8		Group 3
	2	11:30	-	13:00		Group 5		Group 2
	3	13:00	-	14:30	Group 7	Group 12	Group 4	Group 6
	4	14:30	-	16:00		Group 10		
Mon	1	10:00	-	11:30		Group 12		group 10
	2	11:30	-	13:00				Group 2
	3	13:00		14:30	Group 7	Group 3		group 10
	4	14:30	-	16:00		group 10	Group 1	Group 2