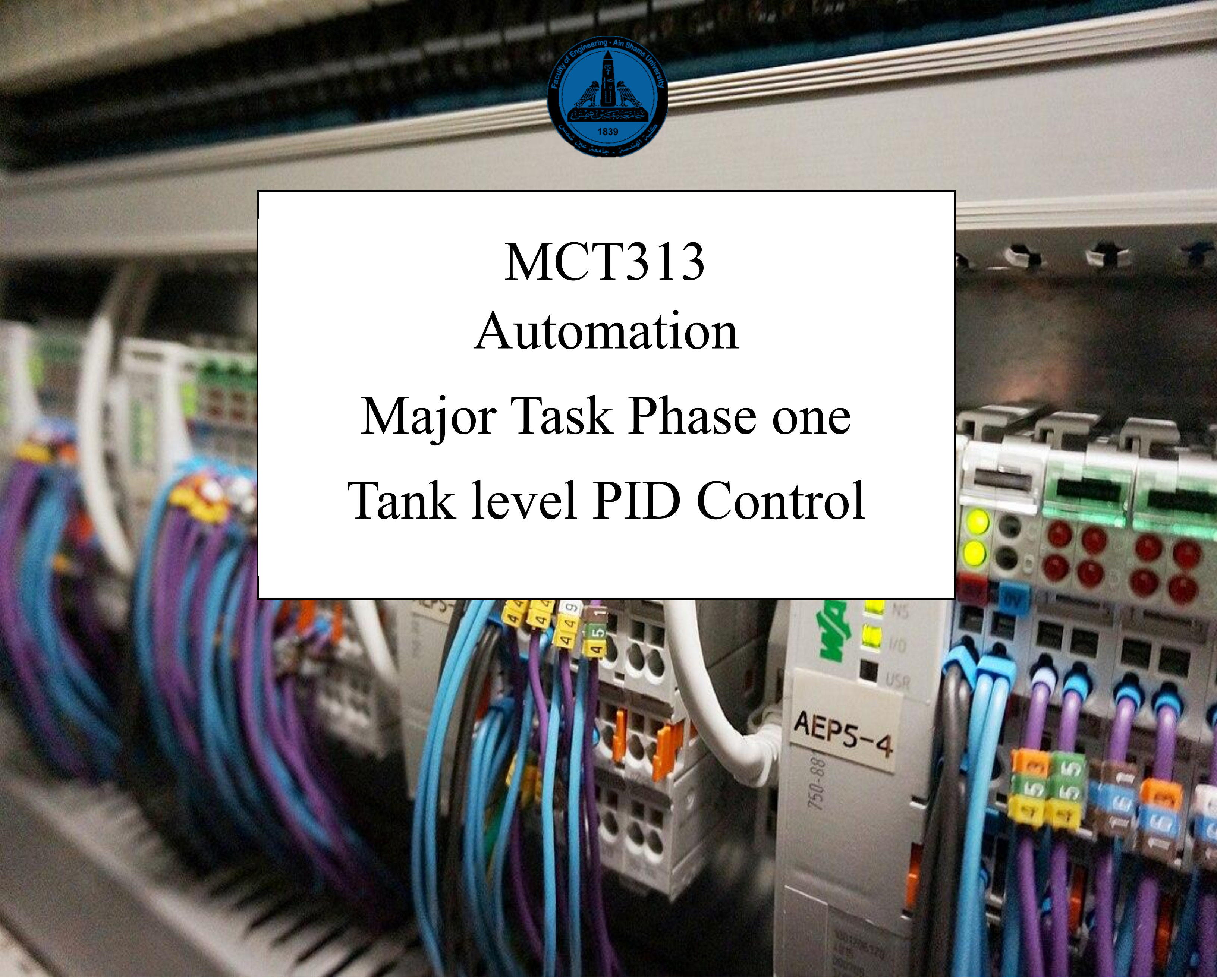

MCT313
Automation
Major Task Phase one
Tank level PID Control

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1.0 ABSTRACT

This project presents a PLC-based water tank level control system implemented using Siemens TIA Portal and simulated through Factory I/O. The system maintains the liquid level in a tank using the Compact PID control block available in TIA Portal, ensuring smooth and precise control. The PID parameters were auto tuned for optimal response. Additionally, a Human-Machine Interface (HMI) was designed to allow operators to monitor and control the system remotely. The HMI enables setpoint adjustment, manual override, and real-time level visualization. To enhance safety and awareness, an alarm system was integrated into the HMI to notify users of various tank conditions, such as high, low, and critical levels. This project demonstrates the effectiveness of PLCs in industrial process control and highlights the value of integrating PID, HMI, and alarm handling into a comprehensive control solution.

2.0 INTRODUCTION

Industrial process control plays a vital role in modern manufacturing and production systems, where automation ensures efficiency, accuracy, and safety. One common process in many industries is liquid level control, typically required in sectors such as chemical processing, water treatment, and food production. This project focuses on designing and simulating a tank level control system using a Siemens Programmable Logic Controller (PLC) with TIA Portal and Factory I/O.

The control strategy is implemented using the Compact PID block available in TIA Portal, providing automatic regulation of the water level within the tank. To enhance usability and operator interaction, a dedicated Human-Machine Interface (HMI) was developed. This interface allows users to monitor the system status, change setpoints, and manually control operations when necessary. Moreover, a multi-level alarm system was included in the HMI to indicate abnormal conditions such as overflow or underfill.

This project not only demonstrates the practical use of PID control in a simulated industrial environment but also emphasizes the importance of user interface and alarm management in real-time process control.

3.0 PROJECT OVERVIEW

3.1 System Description

The project involves the design and simulation of a water tank level control system using Siemens TIA Portal and Factory I/O. The system simulates an industrial environment where the water level within a storage tank must be continuously maintained at a specific setpoint. The tank receives water via an inlet controlled by a valve, and the level is monitored using an analog level sensor. Based on the feedback from the sensor, the Compact PID control block adjusts the valve position to regulate the inflow, ensuring the level remains within acceptable limits.

In addition to the automated PID-based control, the project includes a Human-Machine Interface (HMI) that provides full monitoring and operational capabilities. The HMI displays the current water level, allows setpoint modification, and offers manual control features for system override. The simulation was built in Factory I/O, where all sensors, actuators, and control components are visually represented, providing a realistic virtual environment for testing and validation.

3.2 Project Objectives

The primary objectives of this project are as follows:

- To implement closed-loop level control using the Compact PID block in Siemens TIA Portal.
- To auto-tune the PID parameters for optimized and stable system performance.
- To integrate a fully functional HMI that supports:
    - Real-time level visualization
    - Setpoint adjustment
    - Manual/automatic mode switching
    - Alarm notifications for abnormal tank conditions
- To simulate and validate the complete control system using Factory I/O.
- To demonstrate the practical application of PLCs, PID control, and HMIs in industrial automation.

4.0 SOFTWARE SETUP

4.1 Tia Portal (Totally integrated Automation Portal)

Tia portal is software used for PLC programming on Siemens' PLC devices accompanied with other software such as PLCSIM to connect with other software like factory IO and WINCC for viewing HMI Layout.

Figure 1 Tia Portal

The PLC logic was developed using LAD which is widely used in Industrial Automation.

The simulated **PLC model** used in the project was the Siemens S7-1500 series specifically the **1511-1 PN**. This virtual controller executed automation logic in real-time through **PLC Sim**, managing the behavior of all connected elements in the simulation. Analog signals from the level sensor and control commands to the valve were mapped to the PLC's I/O structure, simulating a real-world closed-loop control system.

A custom HMI panel, created using WinCC within the TIA Portal, provided the interface between the operator and the control system. The HMI displayed live tank level data, allowed users to modify the level setpoint, and included manual control options for the valve. Furthermore, an alarm management system was integrated to notify the operator of abnormal conditions such as high, low, or critically low tank levels.

4.2 Factory IO

Factory I/O was employed to simulate the physical process of the water tank system. The software allows for realistic 3D representation of industrial environments, including tanks, sensors, valves, and piping. Within this simulation, the tank's inlet valve and level sensor were modeled, enabling real-time interaction with the control logic developed in TIA Portal. This integration allows for thorough testing and validation of control algorithms before deploying them to physical hardware.

For this project, we used a preset scene for Tank level control.

Figure 2 Factory IO

5.0 SYSTEM CONFIGURATION

5.1 Network and Devices

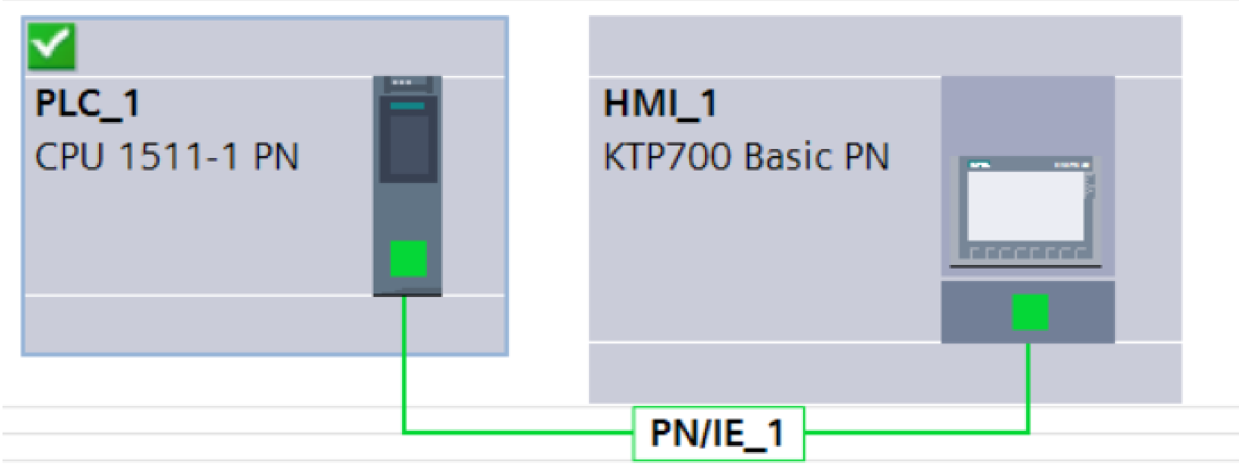
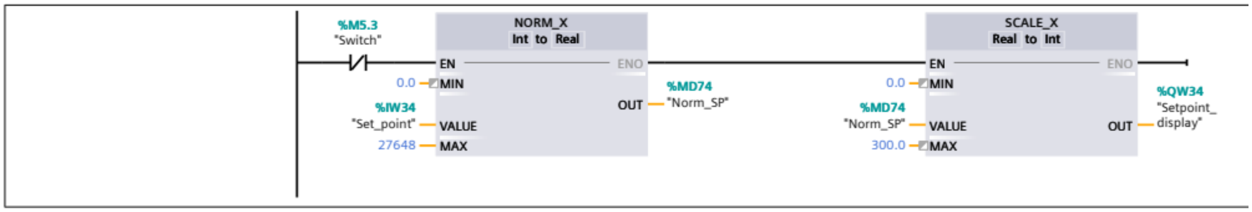


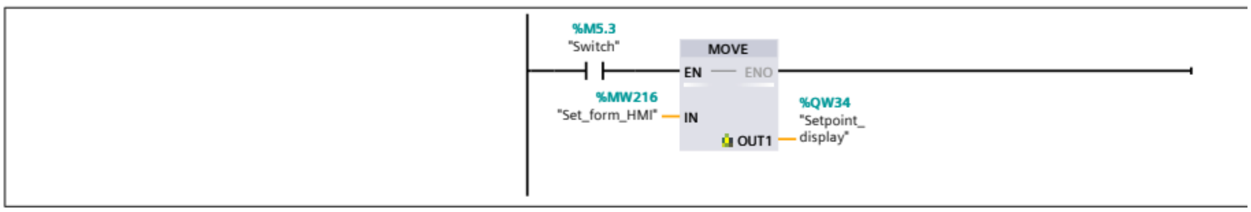
Figure 3 Devices and Network

5.2 PLC Networks

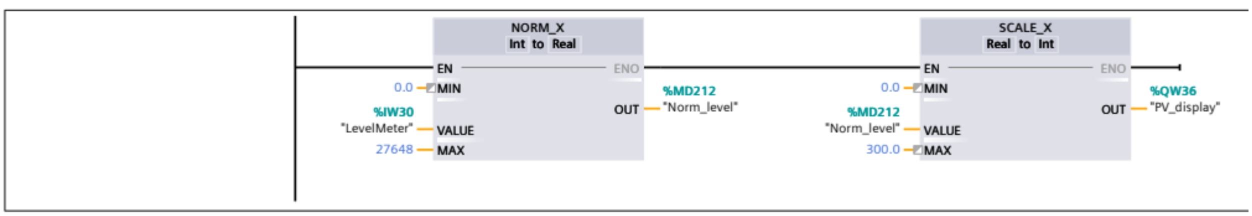
Network 1: Set point scale & display



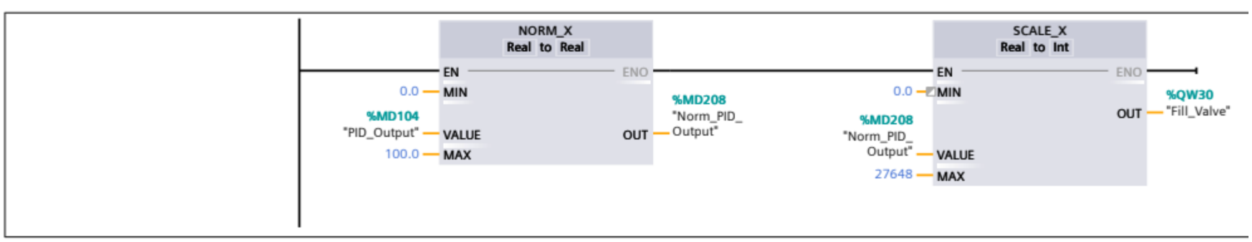
Network 2: Show HMI Setpoint on factory IO



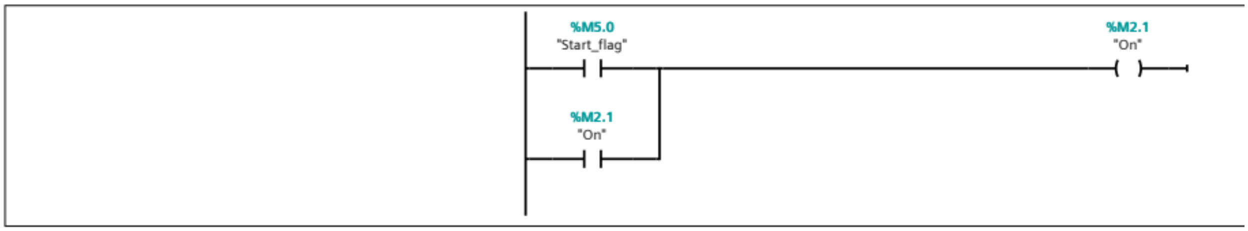
Network 3: Process value scale & display



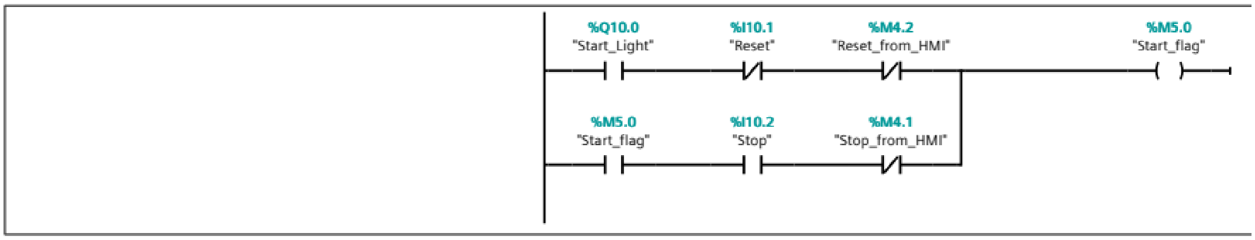
Network 4: Fill Valve output



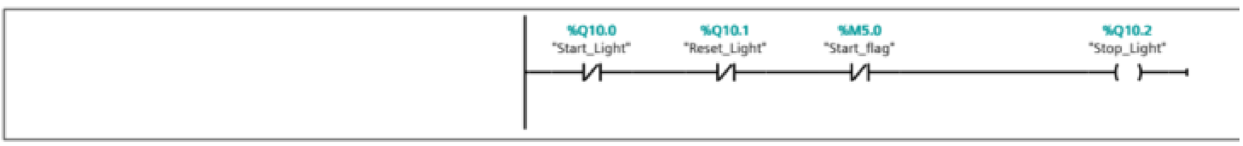
Network 5: PID Continuous



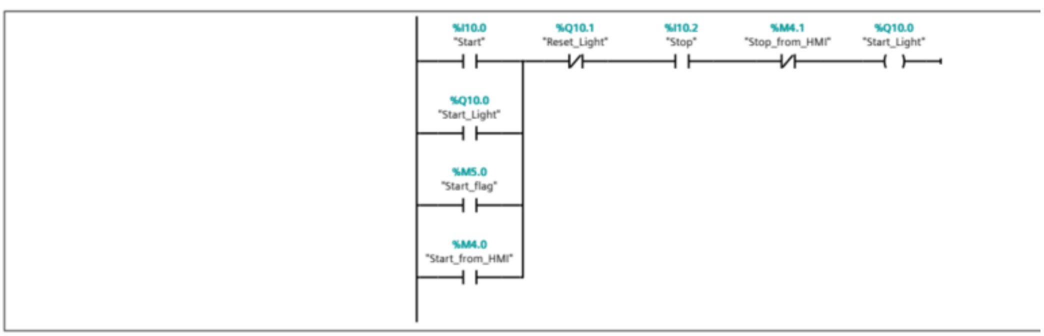
Network 6: Start Flag



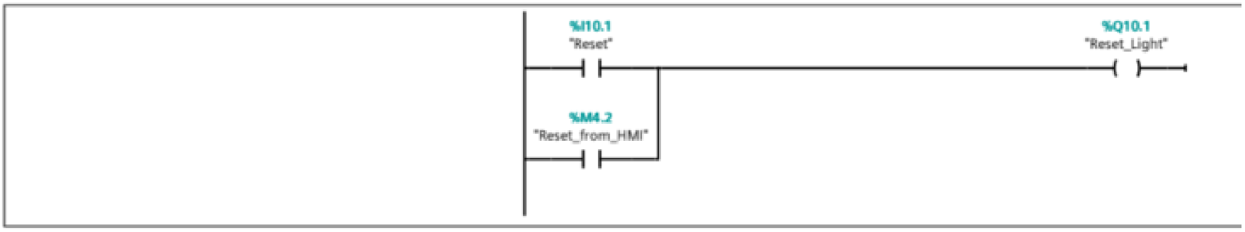
Network 7: Stop Light



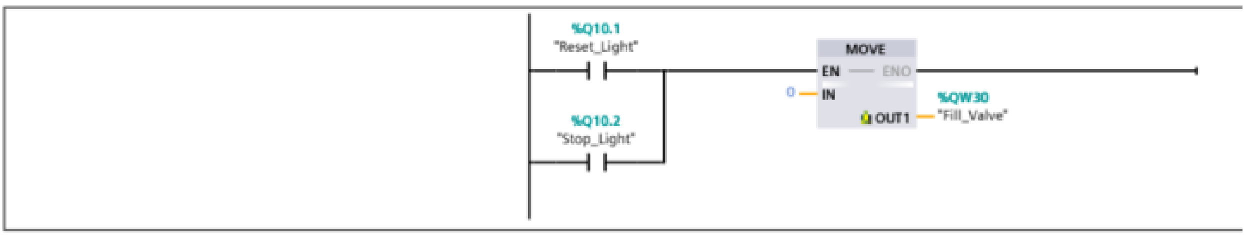
Network 8: Start Light



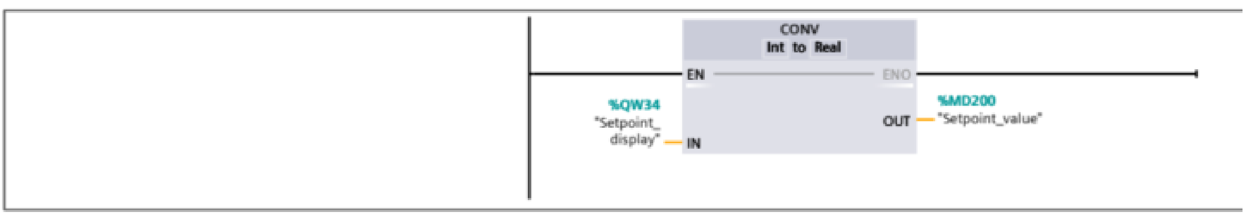
Network 9: Reset Light



Network 10: Fill Valve Stop

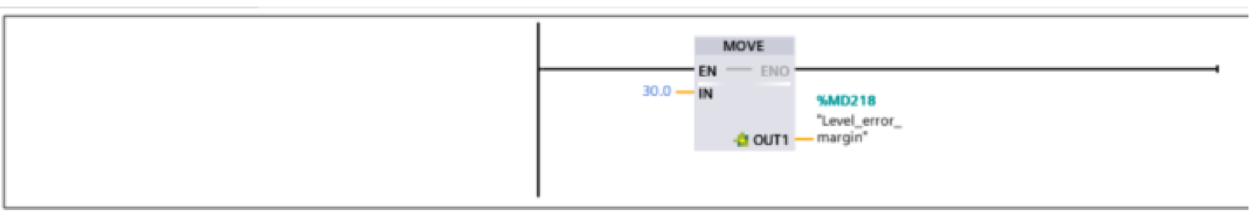


Network 11: Convert Setpoint to Real for PID

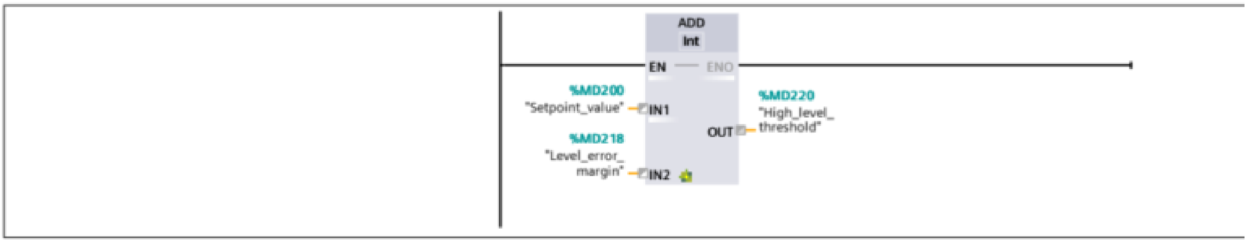


Network 12: Convert PV to Real for PID

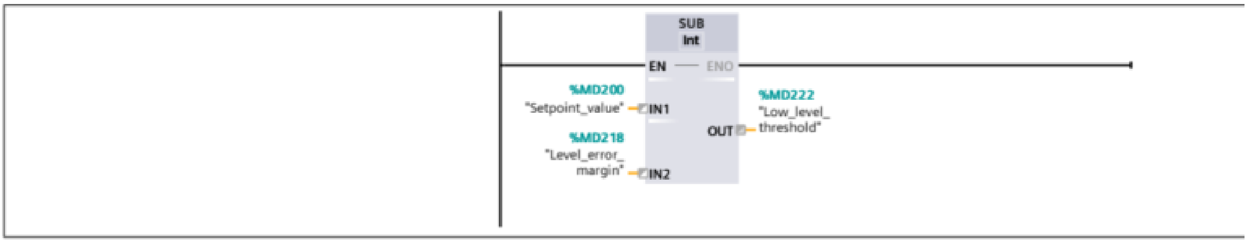
Network 13: Store error margin value



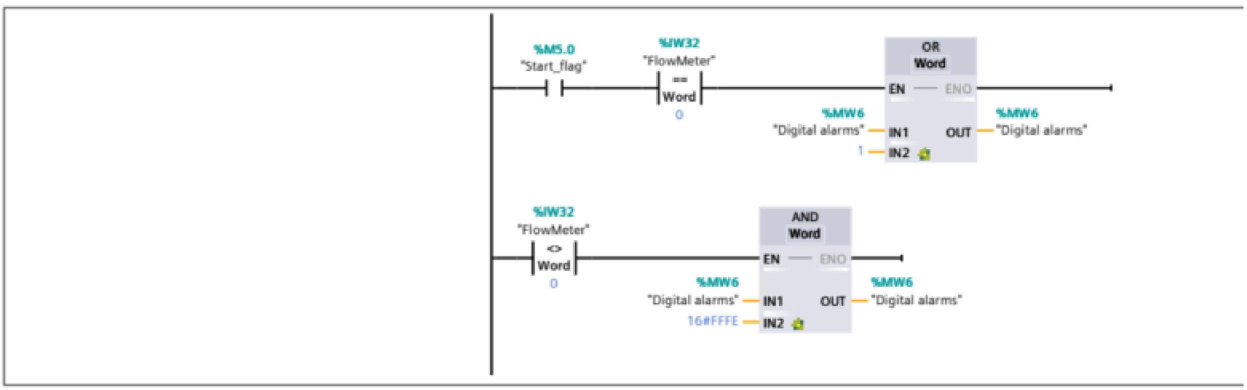
Network 14: High Level Alarm Network



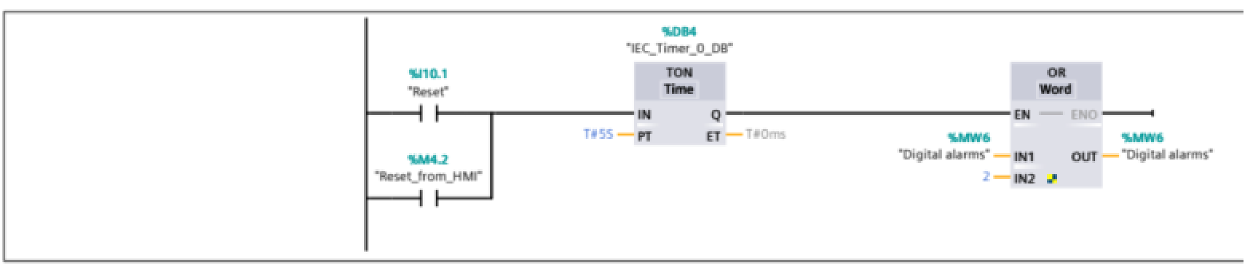
Network 15: Low Level Alarm Network



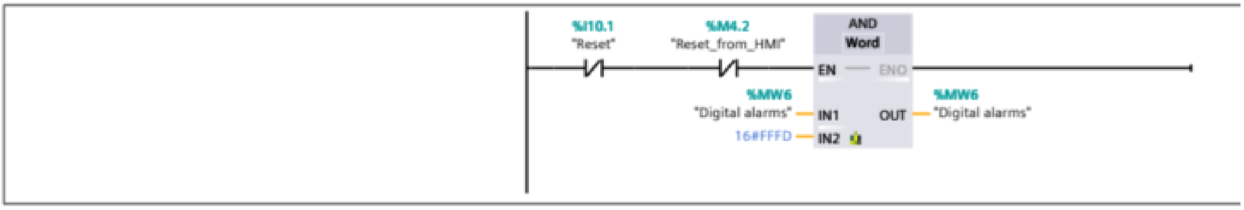
Network 16: Discharge Valve error



Network 17: Reset Abuse error



Network 18: Reset Abuse error reset



5.3 PLC Tags

Name	Data Type	Logical Address
LevelMeter	Word	%IW30
FlowMeter	Word	%IW32
Set_point	Word	%IW34
Norm_SP	Real	%MD74
PID_Output	Real	%MD104
Start	Bool	%I10.0
Fill_Valve	Word	%QW30
Start_Light	Bool	%Q10.0
Reset	Bool	%I10.1
Reset_Light	Bool	%Q10.1
On	Bool	%M2.1
Stop	Bool	%I10.2
Stop_Light	Bool	%Q10.2
PV_display	Word	%QW36
Setpoint_display	Word	%QW34
Setpoint_value	Real	%MD200
Process_value	Real	%MD204
Norm_PID_Output	Real	%MD208
Start_from_HMI	Bool	%M4.0
Stop_from_HMI	Bool	%M4.1
Reset_from_HMI	Bool	%M4.2
Start_flag	Bool	%M5.0
Reset_flag	Bool	%M5.1
Stop_flag	Bool	%M5.2
Switch	Bool	%M5.3
Set_form_HMI	Word	%MW216
Norm_level	Real	%MD212
Level_error_margin	Real	%MD218
High_level_threshold	Real	%MD220
Low_level_threshold	Real	%MD222
Digital alarms	Word	%MW6
Discharge valve	Word	%QW32

5.4 HMI Tags

Name	PLC tag	DataType
Tag_ScreenNumber	<No Value>	UInt
Start_from_HMI	Start_from_HMI	Bool
Stop_from_HMI	Stop_from_HMI	Bool
Reset_from_HMI	Reset_from_HMI	Bool
Start_Light	Start_Light	Bool
Stop_Light	Stop_Light	Bool
Reset_Light	Reset_Light	Bool
PV_display	PV_display	Word
Setpoint_display	Setpoint_display	Word
Set_point	Set_point	Word
Switch	Switch	Bool
Set_form_HMI	Set_form_HMI	Word
Process_value	Process_value	Real
Setpoint_value	Setpoint_value	Real
High_level_threshold	High_level_threshold	Real
Low_level_threshold	Low_level_threshold	Real
Level_error_margin	Level_error_margin	Real
Digital alarms	"Digital alarms"	Word

6.0 CONTROL

The core objective of the control strategy is to maintain the water level in the tank at a desired setpoint despite process disturbances, such as inflow variation or demand changes. This is achieved through a closed-loop control system implemented using the Compact PID block available in Siemens TIA Portal. The PID controller continuously monitors the actual tank level using analog feedback from the level sensor and compares it to the user-defined setpoint.

When a deviation between the setpoint and the actual level is detected, the PID controller computes a control output to adjust the inlet valve opening accordingly. This output signal modulates the flow rate of water into the tank, reducing the error over time. The Compact PID block provides internal processing of the Proportional, Integral, and Derivative components, allowing for smooth and stable regulation of the process variable.

6.1 Inputs and Outputs

We use the scaled value of the Setpoint coming from Factory IO or the HMI as an input to the Pid along with the Process Value (Feedback) from the sensor in Factory IO. The PID out is then normalized and scaled to a value from 0:27648 as analog value to the Factory IO fill valve.

The PID block is also reset using the reset button either from the HMI or the Factory.

6.2 PID Control (compact PID)

For PID parameters we used the Compact PID's auto tune feature which accelerated the tuning process greatly with extra manual tuning intuitively to achieve peak performance.

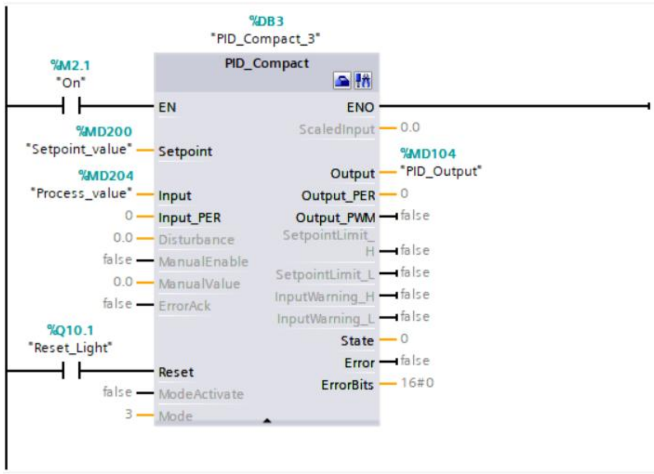


Figure 4 PID Block

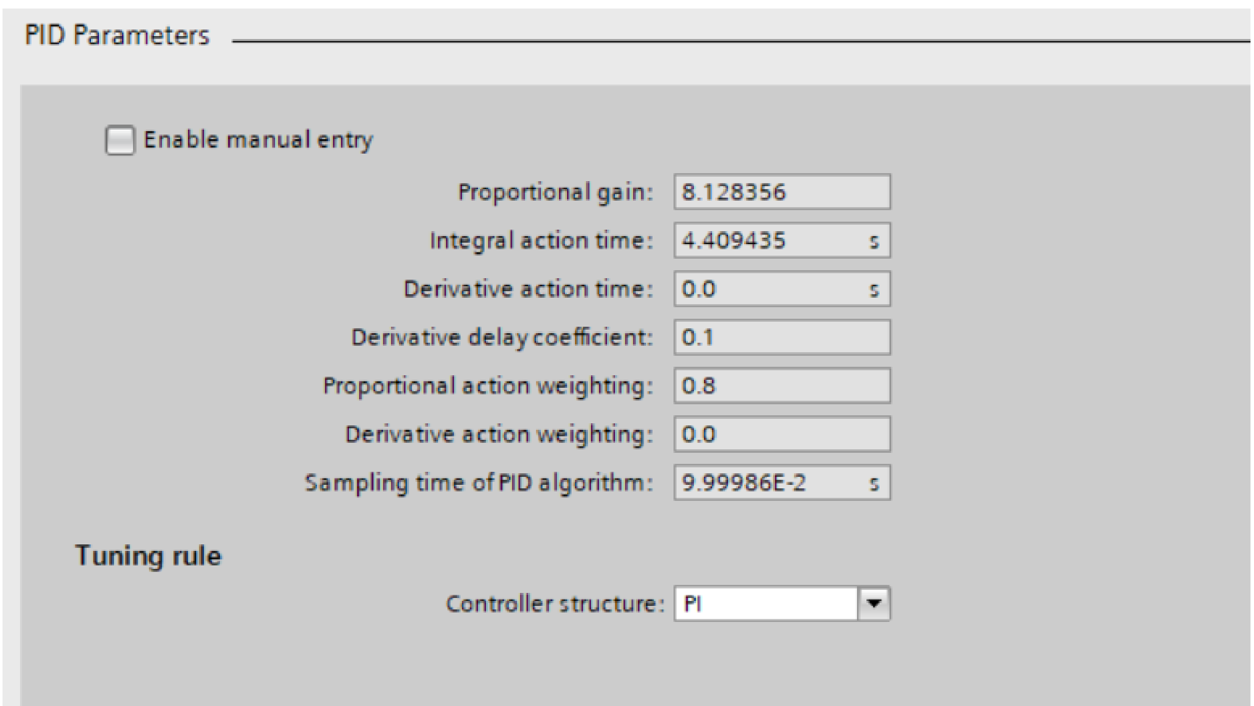


Figure 5 PID Parameters

7.0 HMI (Human – Machine Interface)

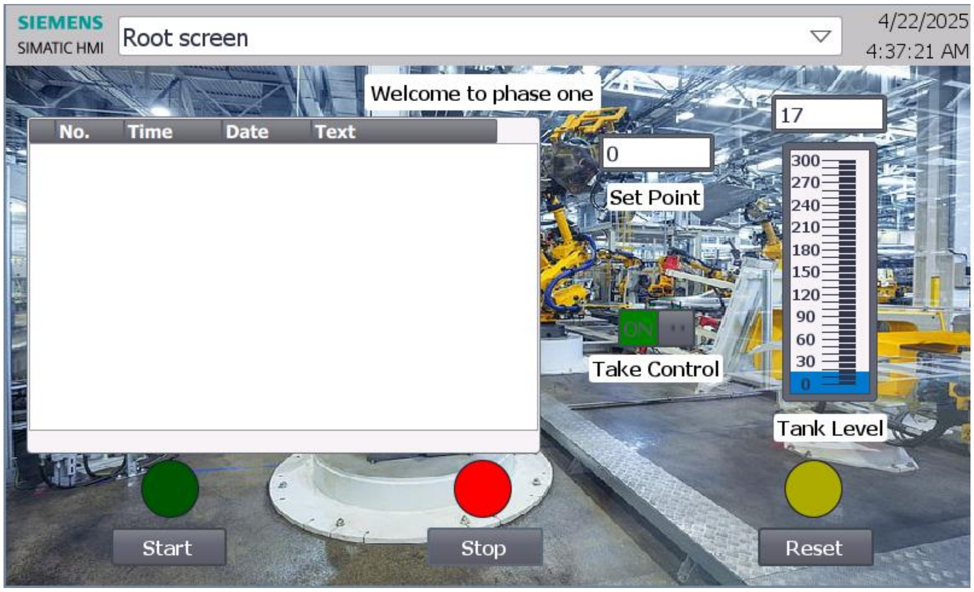


Figure 6 HMI Root Screen

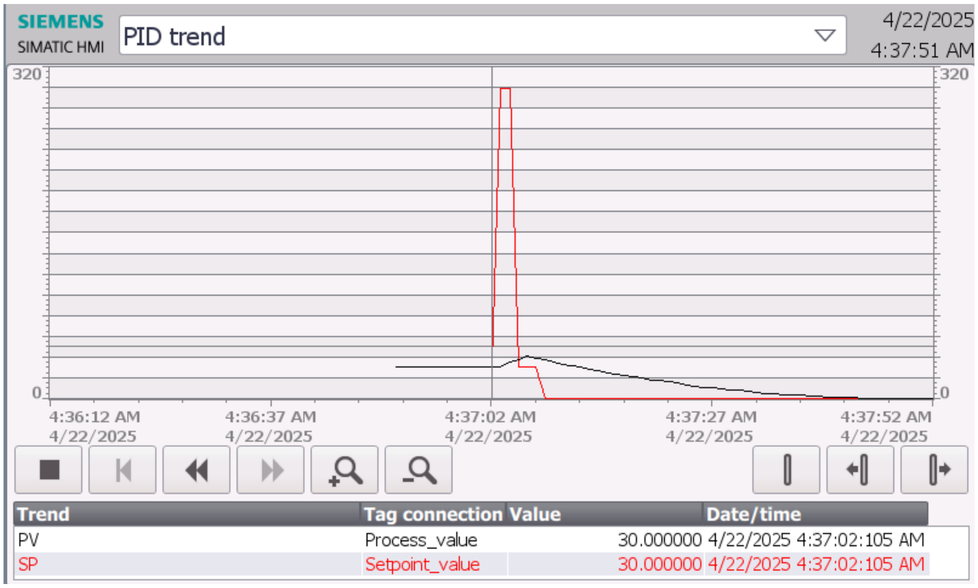


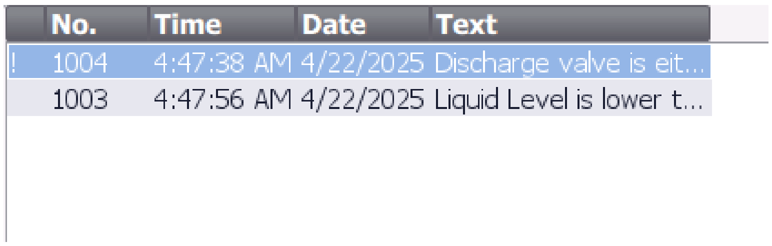
Figure 7 PID Trend

7.1 HMI Features

The HMI Produced using Tia Portal has three main buttons that control the station's state with unique lighting for each. Also, it can view the Tank liquid level with a cool bar like widget and a digital data viewer and the HMI user can take control of the control setpoint over the control panel analog potentiometer. Accompanied by an alarm logging window. The second screen views the PID trend and system's response for debugging and system installation phase.

7.2 Alarm System

The Alarm System consists of level alarms and system fault alarms. The level alarms are divided into four different types, critical High, High, Low and critical Low. The critical alarms are considered errors and cannot be ignored unless fixed, and the other two are considered warnings which can be acknowledged.



	No.	Time	Date	Text
!	1004	4:47:38 AM	4/22/2025	Discharge valve is eit...
	1003	4:47:56 AM	4/22/2025	Liquid Level is lower t...

Figure 8 Alarm Window

8.0 SIMULATION AND RESULTS

To evaluate the performance of the tank level control system, a series of simulations were conducted using varying setpoints. The main objective of this test was to observe how accurately and efficiently the Compact PID controller responds to changes in the desired water level, and how well the system maintains stability under dynamic conditions.

8.1 Factory IO scene

The Factory I/O scene used in this project simulates a realistic industrial setup designed for water tank level control. At the heart of the scene is a large, industrial-grade tank equipped with a fill valve to control the inflow of liquid and a discharge valve to release water from the tank. A level meter continuously monitors the tank's water level, providing real-time feedback to the PLC, while a discharge flow meter measures the outflow rate, enhancing the accuracy of the process simulation.

Figure 9 Factory IO scene

The setup also includes a control panel located near the tank, offering local manual control capabilities. This panel features a setpoint dial for adjusting the desired tank level, along with Start, Stop, and Reset push buttons. Each button is accompanied by an indicator light that visually confirms the activation state of the respective function, improving operator awareness. In addition, the panel includes two digital displays — one showing the current setpoint value and the other displaying the live tank level reading — ensuring that operators have full visibility of the control process.

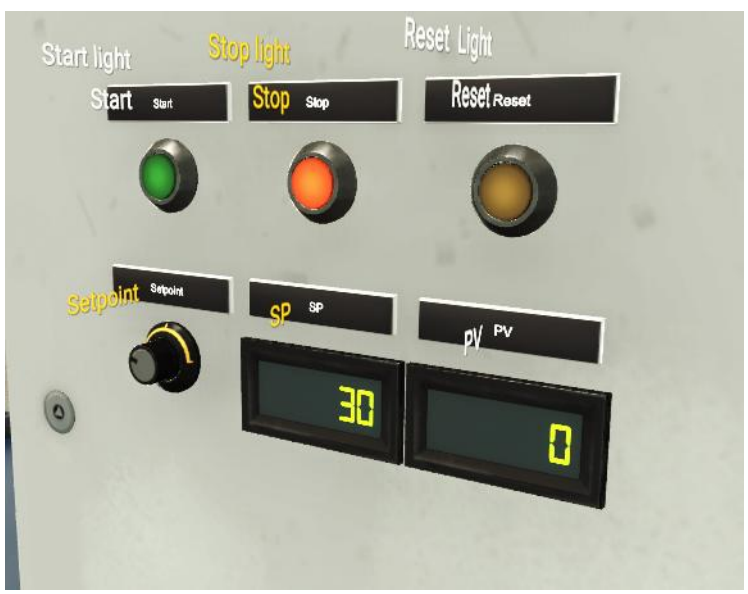


Figure 10 Control panel

8.2 PID testing and results

The system was tested with setpoints of 80, 160, 220, and 115. In each case, the Compact PID controller responded effectively, maintaining stable control with minimal overshoot. The level rose smoothly with each increase in setpoint and settled efficiently, even during the larger transition to 220. When the setpoint was reduced to 115, the system gradually lowered the level through controlled discharge, again stabilizing without oscillations. Throughout the test, the HMI provided accurate real-time feedback and triggered alarms appropriately as the level crossed defined thresholds.

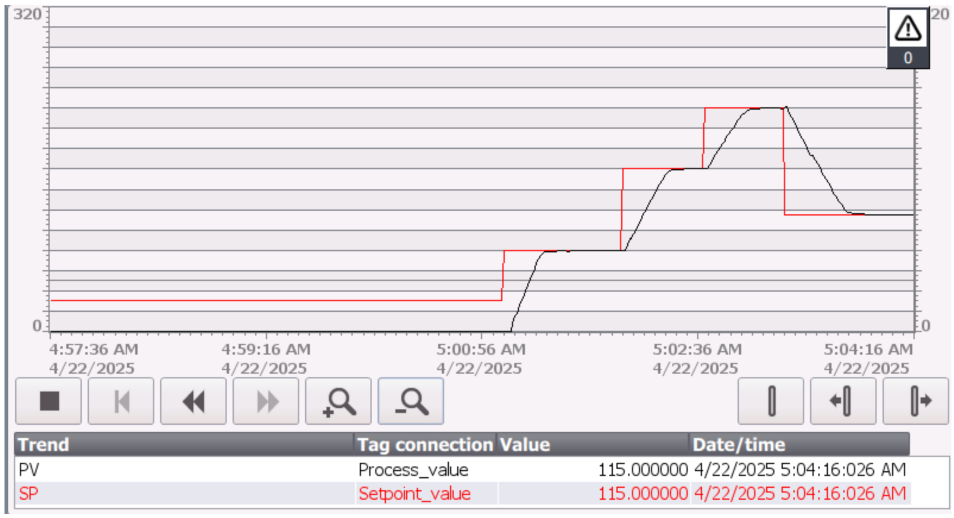


Figure 11 PID Response

Figure 12 Factory IO Results

The test results confirmed that the system is both responsive and reliable under different operating conditions. The use of simulation enabled full verification of the PID control strategy and HMI interface, ensuring the project meets industrial control standards in a risk-free virtual environment.

9.0 CONCLUSION

This project successfully demonstrated the design, implementation, and simulation of a water tank level control system using Siemens TIA Portal and Factory I/O. By integrating the Compact PID controller, precise and automated regulation of the tank level was achieved, with minimal overshoot and stable performance. The use of auto-tuning simplified the tuning process and ensured optimal controller response without the need for manual parameter adjustment.

The addition of a custom HMI panel greatly enhanced system usability, offering real-time monitoring, setpoint adjustment, manual override options, and alarm notifications. This user interface allowed for intuitive interaction with the control system and ensured that operators could quickly respond to abnormal conditions.

Overall, the project highlights the effectiveness of PLCs in process automation and illustrates how simulation tools like Factory I/O can be used to validate control strategies in a realistic industrial environment. The integration of PID control, HMI design, and alarm management provides a comprehensive solution that mirrors real-world industrial applications, making this project a valuable learning experience in both automation theory and practical implementation.