## REFERENCES

Das, R., Samanta, K., Dutta, S. & Sarkar, A., 2013. Automation of Tank Level Using PLC and Establishment of HMI. *IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)*, 7(2), pp. 61-67.

Electronics Tutorials, 2014. *Electronics Tutorials.* [Online]
Available at: https://www.electronics-tutorials.ws/systems/closed-loop-system.html
[Accessed December 2022].

Elroy, A., 2018. *Developing a PLC and HMI Based of Heat Treatment Control System*, s.l.: s.n.

Gupta, K. P. & Gupta, K. M., 2018. Smart Electric Control System Using PLC & HMI. *International Journal of Mechanical Engineering and Technology (IJMET)*, 9(4), p. 548–555.

Kelemen, M. & Sinčák, P. . J., 2020. PROGRAMMABLE LOGIC CONTROLLER TRAINING STANDS. *TECHNICAL SCIENCES AND TECHNOLOGIES*, 3(21), pp. 274-280.

Mahmood, Q. A. et al., 2018. PID Temperature Control of Demineralized Water Tank. *International Conference on Materials Engineering and Science*, pp. 1-8.

National Instruments, 2023. *The PID Controller & Theory Explained.* [Online]
Available at: https://www.ni.com/en-id/shop/labview/pid-theory-explained.html
[Accessed April 2023].

Ogata, K., 2010. *Modern Control Engineering.* 5 ed. s.l.:Prentice Hall.

SIEMENS, 2022. *Siemens S7-1200 Product Detail.* [Online]
Available at:
https://mall.industry.siemens.com/mall/en/ww/Catalog/Product/?mlfb=6ES7214-1AG40-0XB0
[Accessed December 2022].

Wikipedia, 2023. *Open Loop Controller*. [Online]
Available at: https://en.wikipedia.org/wiki/Open-loop_controller
[Accessed December 2022].

Yahya, S., Jadmiko, S. W., Wijayanto, K. & Tahtawi, A. R. A., 2020. Design and Implementation of Training Module for Control Liquid Level on Tank Using PID Method Based PLC. *IOP Conf. Series: Materials Science and Engineering*, Volume 830.

# APPENDICES

## APPENDIX 1 DATASHEET

Datasheet Analog Water Level Sensor

| | |
|---|---|
| Range | 0~50mm...3000mm optional |
| Output | 4~20mA,0~5V;Digital RS485 |
| Accuracy | 0.5%F.S 1.0%F.S |
| Probe Diameter | 12mm 16mm 18mm optional |
| Blind Zone | 10mm Standard,7mm customized |
| Stability | Standard: 0.1%F.S/3 years, Max: 0.2%F.S/3years |
| Medium working Temp | -30°C to 85°C Standard , -40°C~300°C by customized. |
| Materials of probe | 304/316 stainless steel with PTFE/brass |
| Power supply | 11VDC~33VDC |
| Pressure port | G1/2" ,M20*1.5 male,Flange by customized |
| With adjustable Zero and Span automatically | |
| Certificate | CE,ExiaII CT6 Ga ,ATEX,RoHS |
| Application | Truck,Bus , Fleet management,Water treatment |

**Order information**
Level range : 500m , Output : 0-5v , Power supply : 11~33VDC ,
1m directly cable : IP68



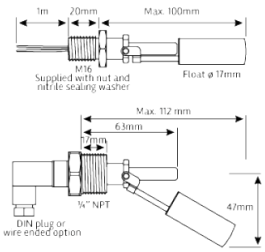
Datasheet RTD PT 100

**PT100 series RTD Temperature Sensor**

| Case Type | Model | Graduation | Measuring Range (℃) | Accuracy Class | Tolerance (Δ℃) | Output Mode | Thermowell Material |
|---|---|---|---|---|---|---|---|
|  | WZP | PT20 | -200～+500 | 1/3DIN | ±（0.10+0.0017\|t\|） | Two-wire /three wire | Stainless steel |
| | | | | A level | ±（0.15+0.0002\|t\|） | | |
| | | | | B level | ±（0.30+0.0005\|t\|） | | |
| | | | | 2B level | ±（0.60+0.0010\|t\|） | | |
|  | | PT100 | | 1/3DIN | ±（0.10+0.0017\|t\|） | | |
| | | | | A level | ±（0.15+0.002\|t\|） | | |
| | | | | B level | ±（0.30+0.005\|t\|） | | |
|  | | PT500 | | 2B level | ±（0.60+0.0010\|t\|） | | |
| | | | | 1/3DIN | ±（0.10+0.0017\|t\|） | | |
| | | | | A level | ±（0.15+0.002\|t\|） | | |
| | | | | B level | ±（0.30+0.005\|t\|） | | |
|  | | PT1000 | | 2B level | ±（0.60+0.0010\|t\|） | | |
| | | | | 1/3DIN | ±（0.10+0.0017\|t\|） | | |
| | | | | A level | ±（0.15+0.002\|t\|） | | |
| | | | | B level | ±（0.30+0.005\|t\|） | | |
| | | | | 2B level | ±（0.60+0.0010\|t\|） | | |

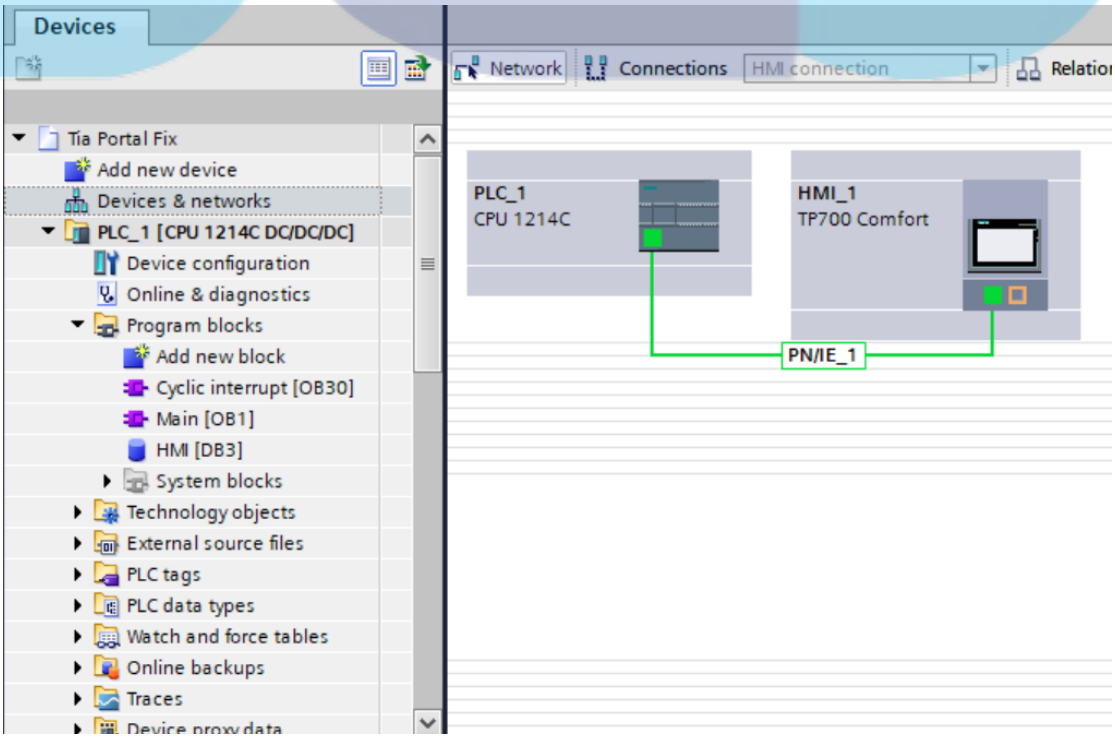
Datasheet Digital Water Level Sensor

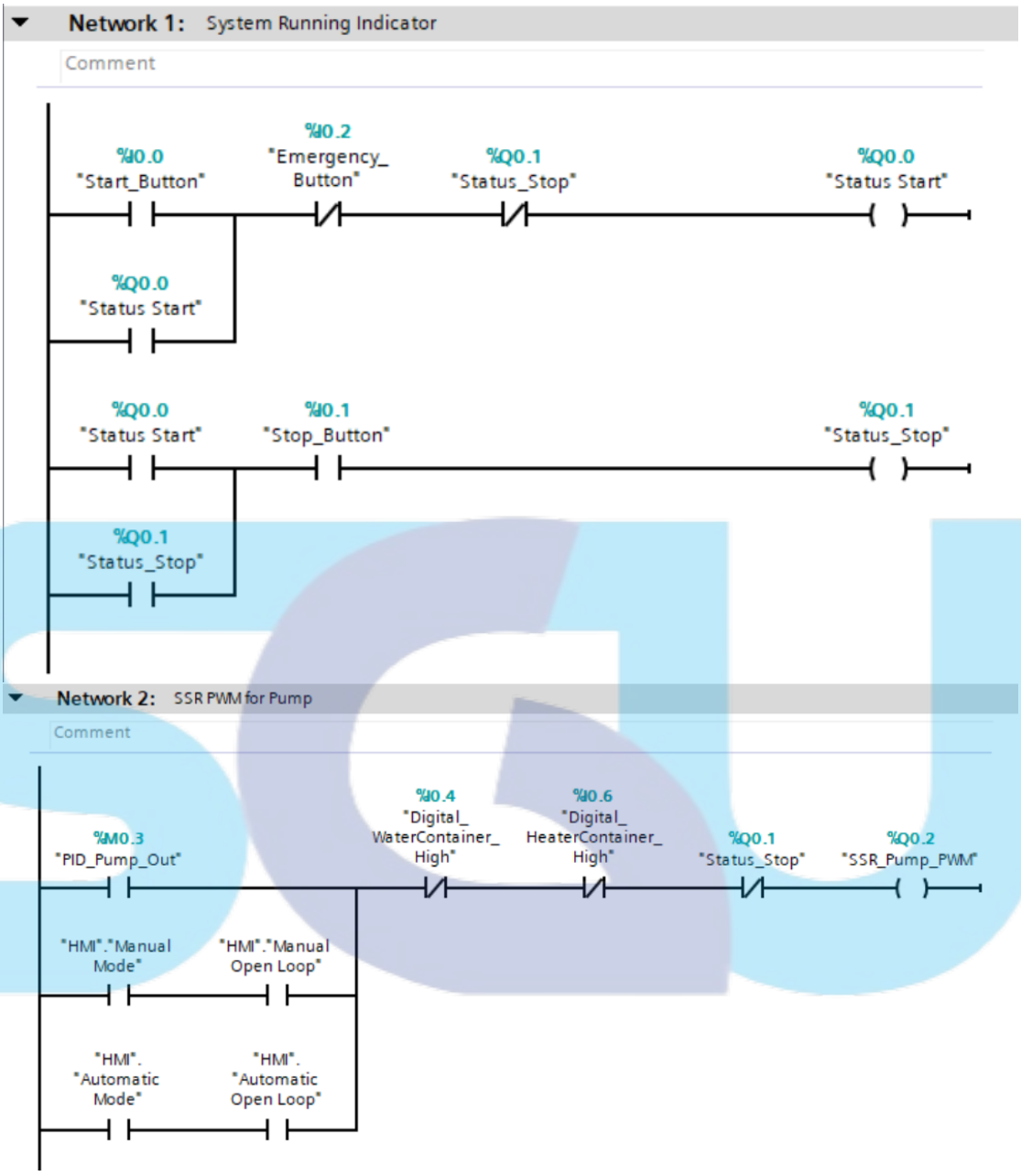
**Technical Data**

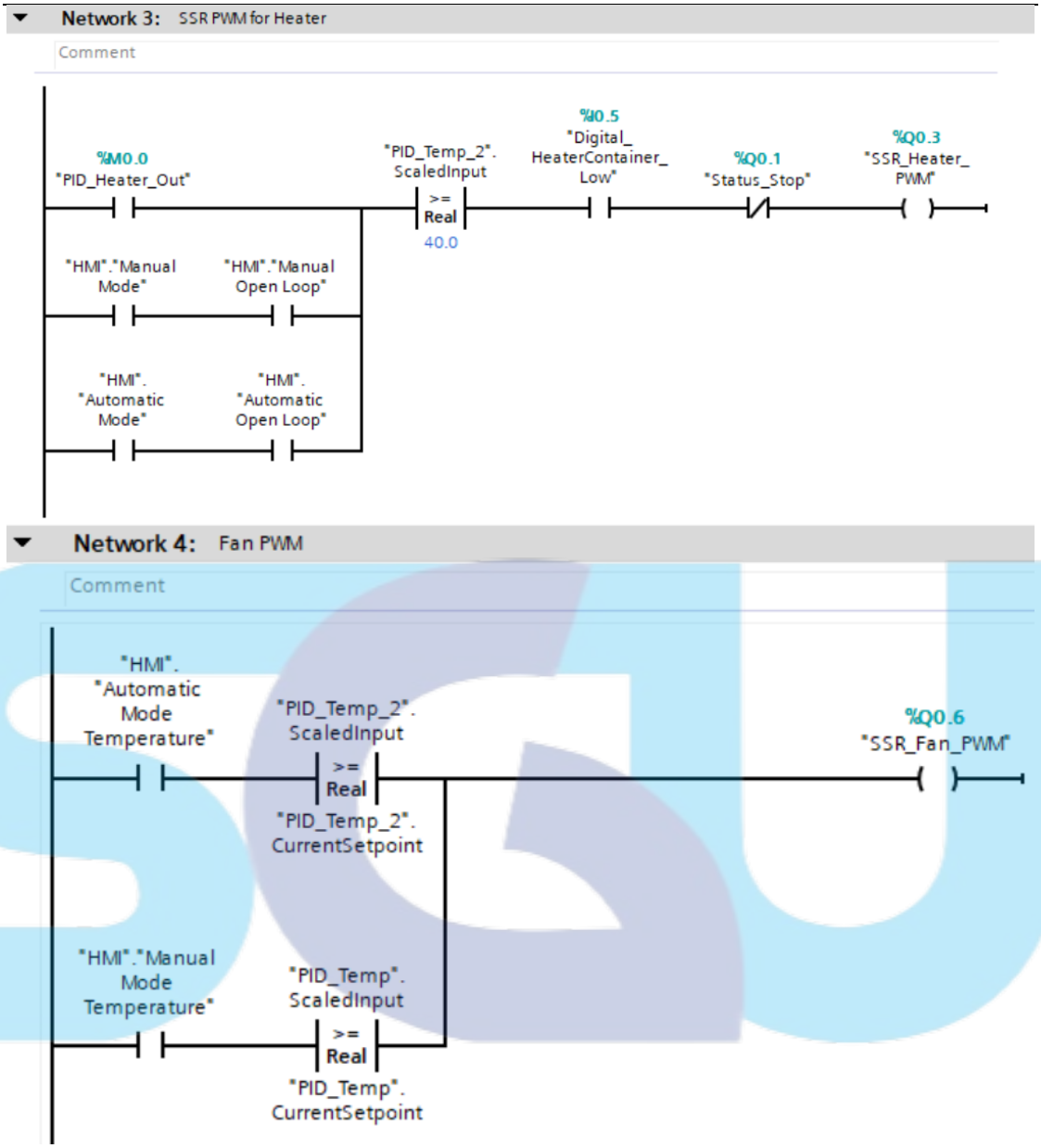


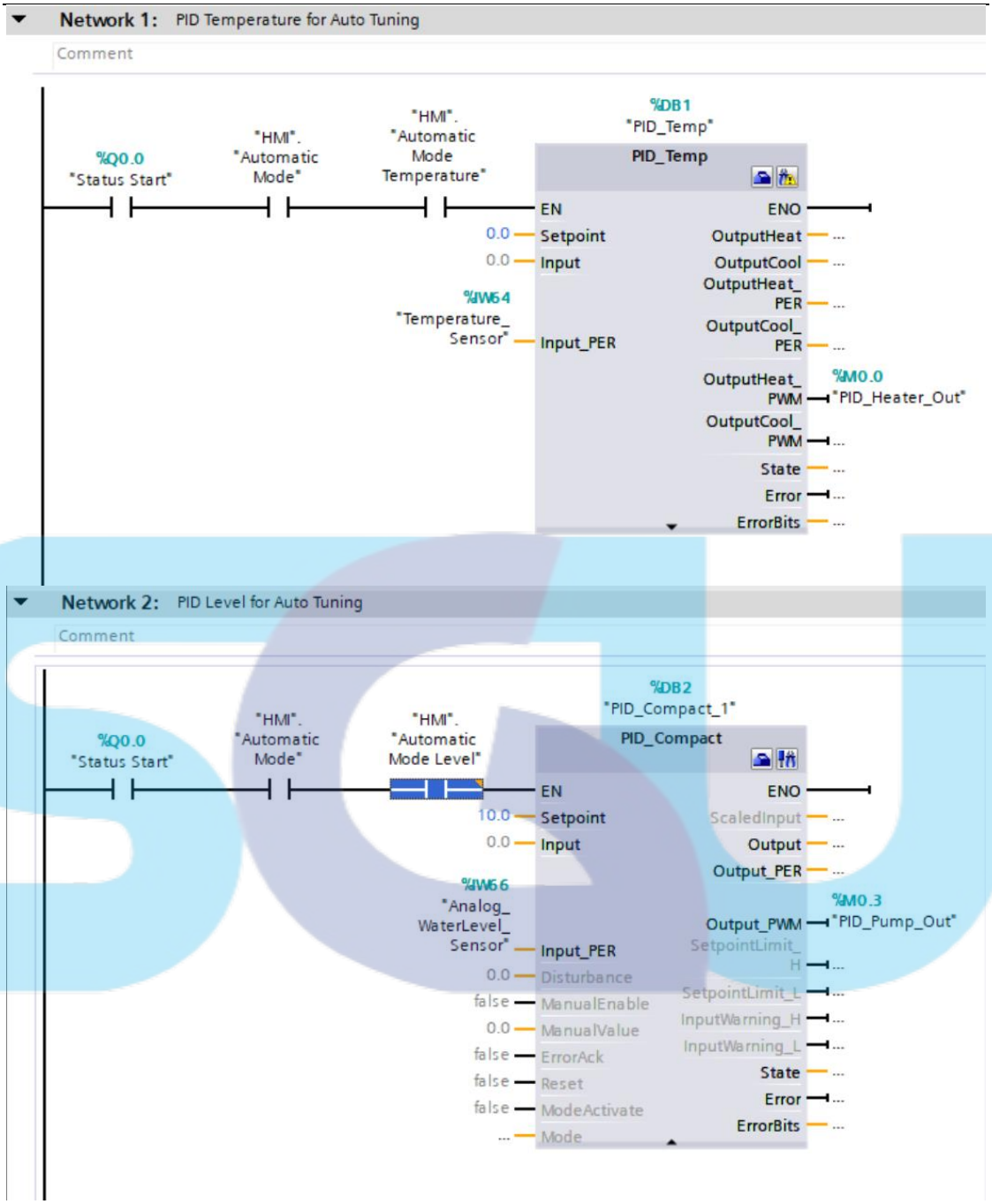

| | |
|---|---|
| **Switch contact rating (pure resistive load).** For other loads ie. capacitive, inductive or incandescent lamps please contact Deeter for advice. | 50 Watts max. Form A SPST Contacts 250vAC max. switching voltage 1.0 Amps max. switching current. 10 Watts max. Form C SPDT Contacts 60v DC max. switching voltage 200v DC breakdown voltage 1A max switching. |
| **Cable type** | Black P.T.F.E insulated 7/0.2mm rated to 200°C max |
| **Cable length** | 1 metre |
| **Operating Pressure** | 350 p.s.i (2400 kPa) |
| **Operating Temperature** | -20°C to +120°C (Standard version)<br>-20°C to +200°C (High Temperature version) |
| **Specific Gravity of float** | 0.9 |
| **Mounting Detail** | M16 or 3/4"NPT for external mount option |
| **Maximum Tank Wall thickness** | 8MM (internal mount only) |
| **Wetted Materials** | 316 Stainless Steel |
| **Weight** | 80g |

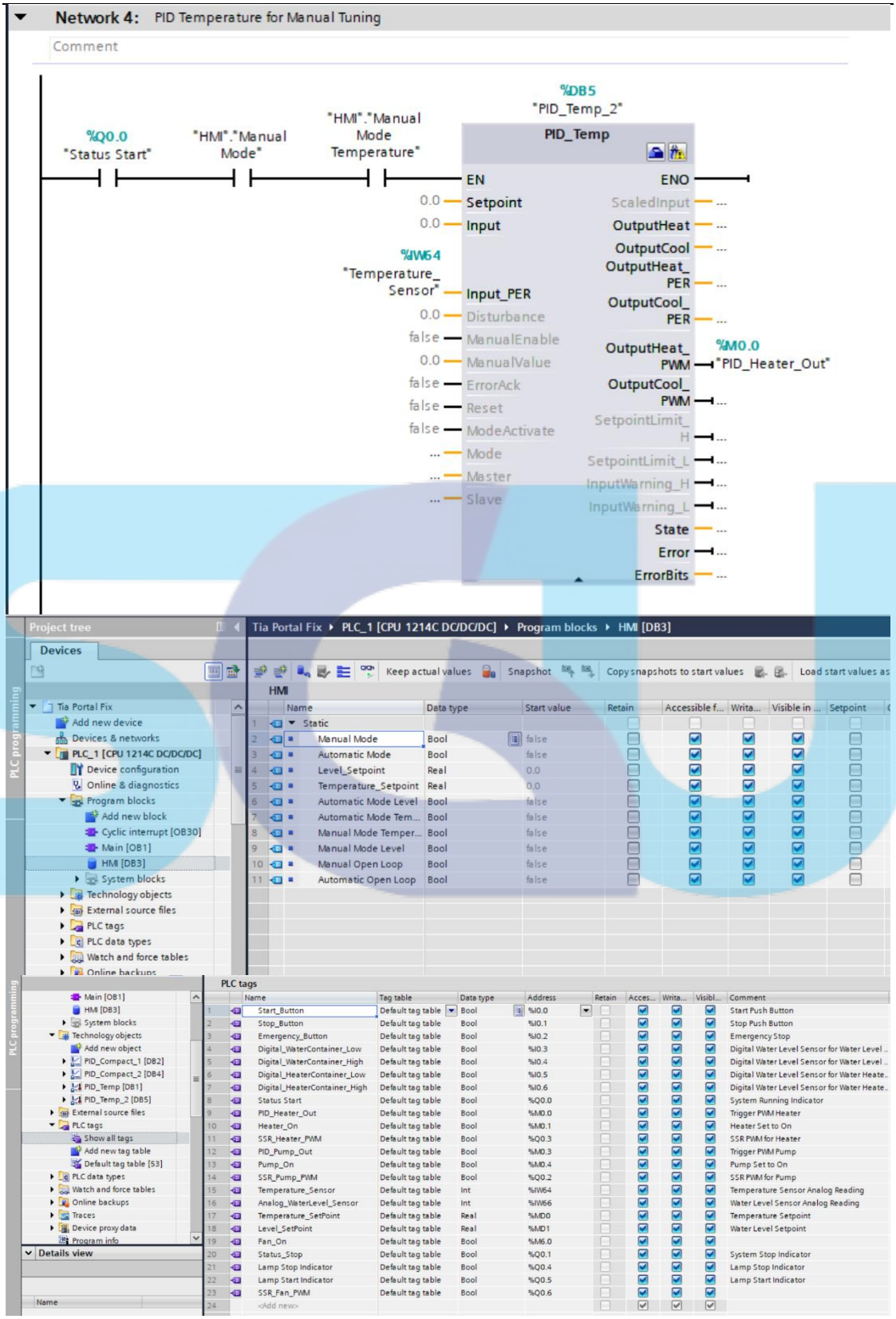
# APPENDIX 2 TIA PORTAL PROGRAM



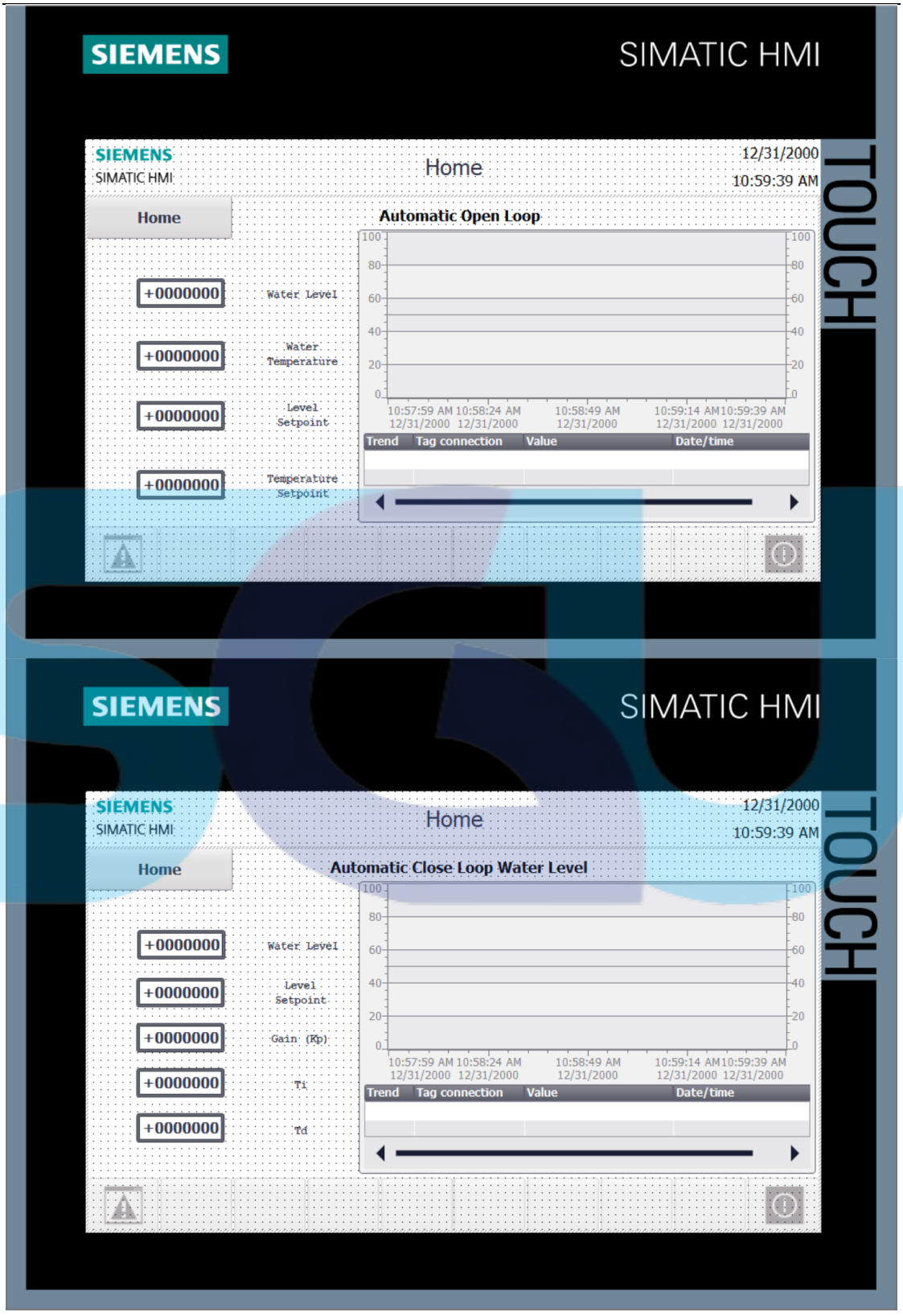

Network 1: System Running Indicator
Comment
%I0.0
"Start_Button"
%I0.2
"Emergency_
Button"
%Q0.1
"Status_Stop"
%Q0.0
"Status Start"
%Q0.0
"Status Start"
%Q0.0
"Status Start"
%I0.1
"Stop_Button"
%Q0.1
"Status_Stop"
%Q0.1
"Status_Stop"
Network 2: SSR PWM for Pump
Comment
%M0.3
"PID_Pump_Out"
%I0.4
"Digital_
WaterContainer_
High"
%I0.6
"Digital_
HeaterContainer_
High"
%Q0.1
"Status_Stop"
%Q0.2
"SSR_Pump_PWM"
"HMI"."Manual
Mode"
"HMI"."Manual
Open Loop"
"HMI".
"Automatic
Mode"
"HMI".
"Automatic
Open Loop"

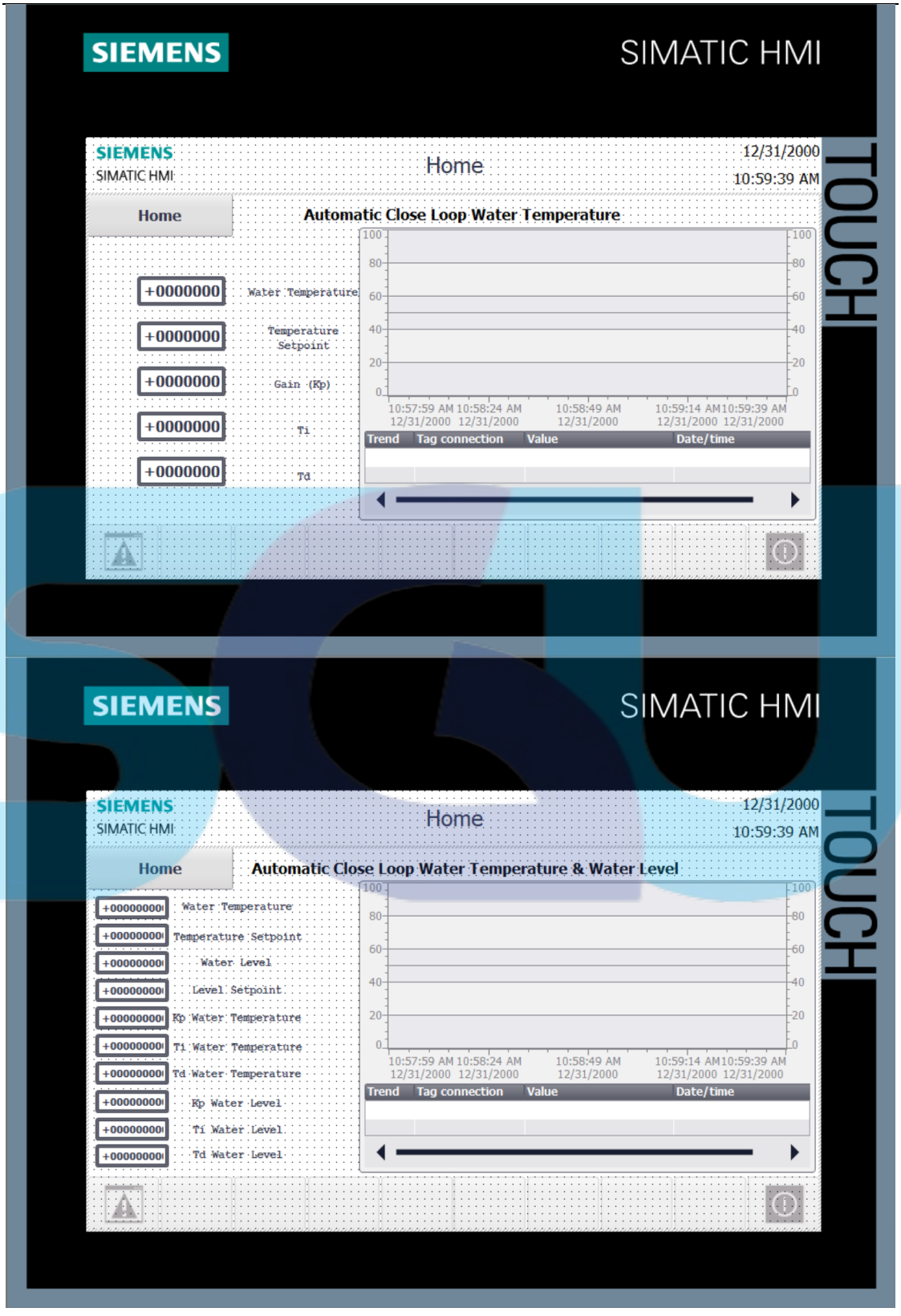

Network 3: SSR PWM for Heater
Comment
%M0.0
"PID_Heater_Out"
"PID_Temp_2".
ScaledInput
>=
Real
40.0
%I0.5
"Digital_
HeaterContainer_
Low"
%Q0.1
"Status_Stop"
%Q0.3
"SSR_Heater_
PWM"
"HMI"."Manual
Mode"
"HMI"."Manual
Open Loop"
"HMI".
"Automatic
Mode"
"HMI".
"Automatic
Open Loop"
Network 4: Fan PWM
Comment
"HMI".
"Automatic
Mode
Temperature"
"PID_Temp_2".
ScaledInput
>=
Real
"PID_Temp_2".
CurrentSetpoint
%Q0.6
"SSR_Fan_PWM"
"HMI"."Manual
Mode
Temperature"
"PID_Temp".
ScaledInput
>=
Real
"PID_Temp".
CurrentSetpoint

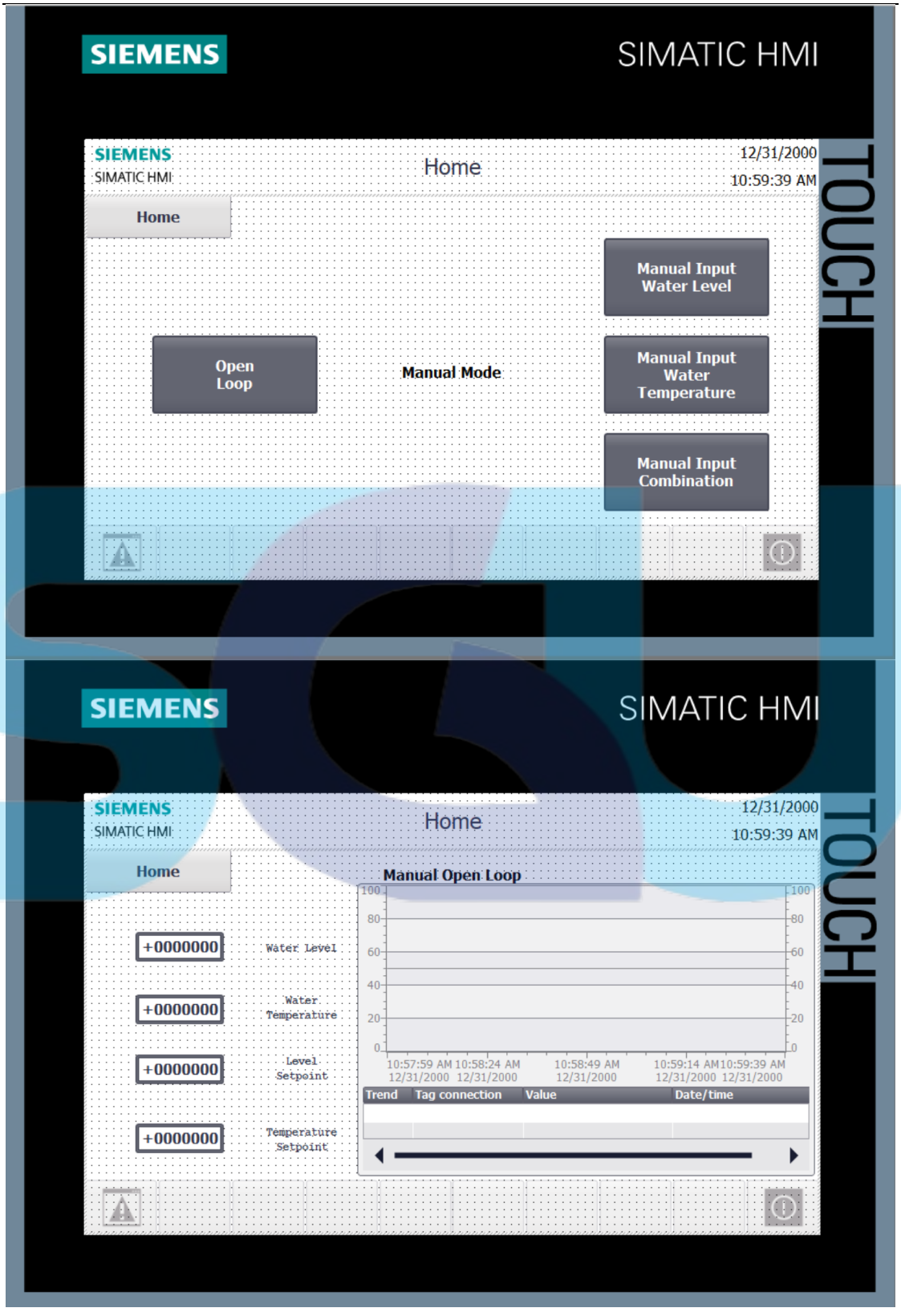

Network 1: PID Temperature for Auto Tuning
Comment
%Q0.0
"Status Start"
"HMI".
"Automatic
Mode"
"HMI".
"Automatic
Mode
Temperature"
%DB1
"PID_Temp"
PID_Temp
EN
ENO
0.0
Setpoint
OutputHeat
0.0
Input
OutputCool
%IW64
"Temperature_
Sensor"
Input_PER
OutputHeat_
PER
OutputCool_
PER
OutputHeat_
PWM
%M0.0
"PID_Heater_Out"
OutputCool_
PWM
State
Error
ErrorBits
Network 2: PID Level for Auto Tuning
Comment
%Q0.0
"Status Start"
"HMI".
"Automatic
Mode"
"HMI".
"Automatic
Mode Level"
%DB2
"PID_Compact_1"
PID_Compact
EN
ENO
10.0
Setpoint
ScaledInput
0.0
Input
Output
Output_PER
%IW66
"Analog_
WaterLevel_
Sensor"
%M0.3
"PID_Pump_Out"
Output_PWM
Input_PER
SetpointLimit_
H
0.0
Disturbance
SetpointLimit_L
false
ManualEnable
InputWarning_H
0.0
ManualValue
InputWarning_L
false
ErrorAck
State
false
Reset
Error
false
ModeActivate
ErrorBits
...
Mode


Network 4: PID Temperature for Manual Tuning
Comment
%Q0.0
"Status Start"
"HMI"."Manual Mode"
"HMI"."Manual Mode Temperature"
%DB5
"PID_Temp_2"
PID_Temp
EN
ENO
0.0 Setpoint
0.0 Input
%IW64
"Temperature_Sensor"
Input_PER
0.0 Disturbance
false ManualEnable
0.0 ManualValue
false ErrorAck
false Reset
false ModeActivate
... Mode
... Master
... Slave
ScaledInput
OutputHeat
OutputCool
OutputHeat_PER
OutputCool_PER
OutputHeat_PWM
%M0.0
"PID_Heater_Out"
OutputCool_PWM
SetpointLimit_H
SetpointLimit_L
InputWarning_H
InputWarning_L
State
Error
ErrorBits
Project tree
Devices
Tia Portal Fix
Add new device
Devices & networks
PLC_1 [CPU 1214C DC/DC/DC]
Device configuration
Online & diagnostics
Program blocks
Add new block
Cyclic interrupt [OB30]
Main [OB1]
HMI [DB3]
System blocks
Technology objects
External source files
PLC tags
PLC data types
Watch and force tables
Online backups
Traces
Device proxy data
Program info
Details view
Tia Portal Fix ▸ PLC_1 [CPU 1214C DC/DC/DC] ▸ Program blocks ▸ HMI [DB3]
Keep actual values
Snapshot
Copy snapshots to start values
Load start values as
HMI
Name | Data type | Start value | Retain | Accessible f... | Writa... | Visible in ... | Setpoint
Static
Manual Mode | Bool | false
Automatic Mode | Bool | false
Level_Setpoint | Real | 0.0
Temperature_Setpoint | Real | 0.0
Automatic Mode Level | Bool | false
Automatic Mode Tem... | Bool | false
Manual Mode Temper... | Bool | false
Manual Mode Level | Bool | false
Manual Open Loop | Bool | false
Automatic Open Loop | Bool | false
PLC tags
Name | Tag table | Data type | Address | Retain | Acces... | Writa... | Visibl... | Comment
Start_Button | Default tag table | Bool | %I0.0 | Start Push Button
Stop_Button | Default tag table | Bool | %I0.1 | Stop Push Button
Emergency_Button | Default tag table | Bool | %I0.2 | Emergency Stop
Digital_WaterContainer_Low | Default tag table | Bool | %I0.3 | Digital Water Level Sensor for Water Level ..
Digital_WaterContainer_High | Default tag table | Bool | %I0.4 | Digital Water Level Sensor for Water Level ..
Digital_HeaterContainer_Low | Default tag table | Bool | %I0.5 | Digital Water Level Sensor for Water Heate..
Digital_HeaterContainer_High | Default tag table | Bool | %I0.6 | Digital Water Level Sensor for Water Heate..
Status Start | Default tag table | Bool | %Q0.0 | System Running Indicator
PID_Heater_Out | Default tag table | Bool | %M0.0 | Trigger PWM Heater
Heater_On | Default tag table | Bool | %M0.1 | Heater Set to On
SSR_Heater_PWM | Default tag table | Bool | %Q0.3 | SSR PWM for Heater
PID_Pump_Out | Default tag table | Bool | %M0.3 | Trigger PWM Pump
Pump_On | Default tag table | Bool | %M0.4 | Pump Set to On
SSR_Pump_PWM | Default tag table | Bool | %Q0.2 | SSR PWM for Pump
Temperature_Sensor | Default tag table | Int | %IW64 | Temperature Sensor Analog Reading
Analog_WaterLevel_Sensor | Default tag table | Int | %IW66 | Water Level Sensor Analog Reading
Temperature_SetPoint | Default tag table | Real | %MD0 | Temperature Setpoint
Level_SetPoint | Default tag table | Real | %MD1 | Water Level Setpoint
Fan_On | Default tag table | Bool | %M6.0
Status_Stop | Default tag table | Bool | %Q0.1 | System Stop Indicator
Lamp Stop Indicator | Default tag table | Bool | %Q0.4 | Lamp Stop Indicator
Lamp Start Indicator | Default tag table | Bool | %Q0.5 | Lamp Start Indicator
SSR_Fan_PWM | Default tag table | Bool | %Q0.6

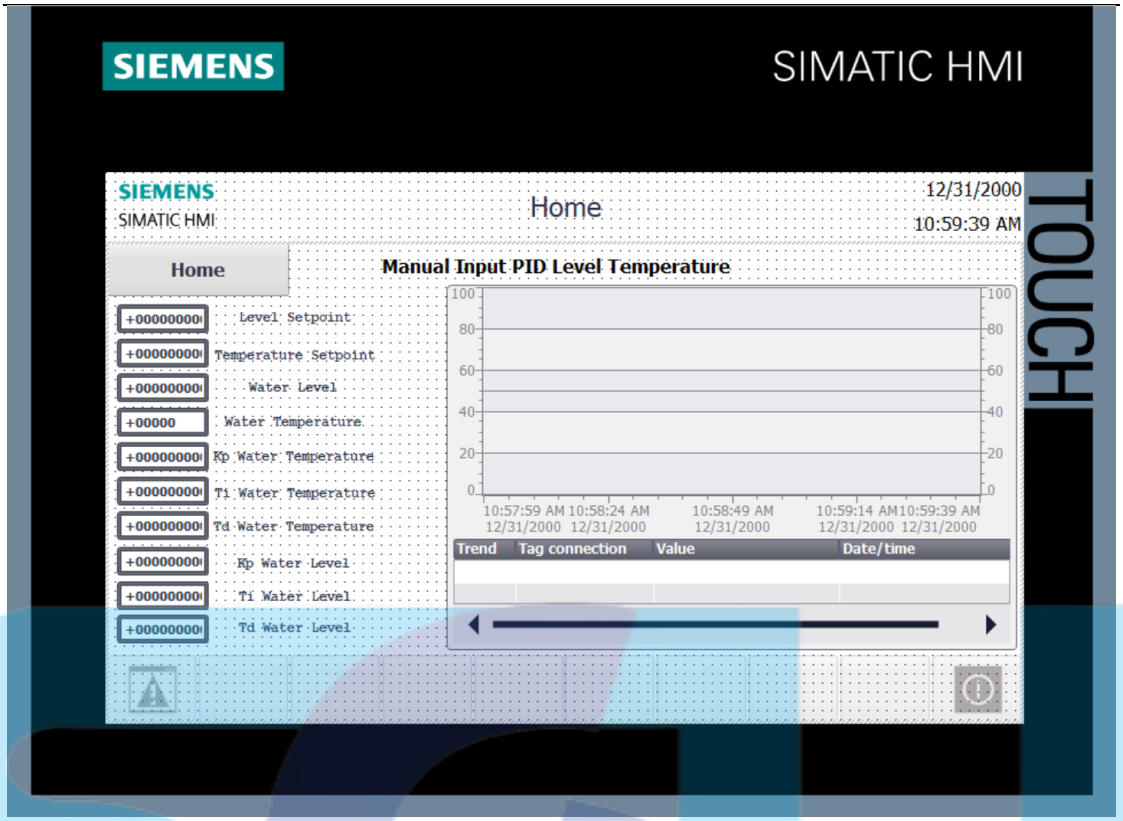
# APPENDIX 3 HMI TIA PORTAL WINCC


SIEMENS
SIMATIC HMI
SIEMENS
SIMATIC HMI
Home
12/31/2000
10:59:39 AM
Home
Automatic Open Loop
+0000000
Water Level
+0000000
Water Temperature
+0000000
Level Setpoint
+0000000
Temperature Setpoint
100
80
60
40
20
0
10:57:59 AM 12/31/2000
10:58:24 AM 12/31/2000
10:58:49 AM 12/31/2000
10:59:14 AM 12/31/2000
10:59:39 AM 12/31/2000
Trend
Tag connection
Value
Date/time
TOUCH
SIEMENS
SIMATIC HMI
SIEMENS
SIMATIC HMI
Home
12/31/2000
10:59:39 AM
Home
Automatic Close Loop Water Level
+0000000
Water Level
+0000000
Level Setpoint
+0000000
Gain (Kp)
+0000000
Ti
+0000000
Td
100
80
60
40
20
0
10:57:59 AM 12/31/2000
10:58:24 AM 12/31/2000
10:58:49 AM 12/31/2000
10:59:14 AM 12/31/2000
10:59:39 AM 12/31/2000
Trend
Tag connection
Value
Date/time
TOUCH


SIEMENS
SIMATIC HMI
SIEMENS
SIMATIC HMI
Home
12/31/2000
10:59:39 AM
Home
Automatic Close Loop Water Temperature
+0000000
Water Temperature
+0000000
Temperature Setpoint
+0000000
Gain (Kp)
+0000000
Ti
+0000000
Td
100
80
60
40
20
0
10:57:59 AM 12/31/2000
10:58:24 AM 12/31/2000
10:58:49 AM 12/31/2000
10:59:14 AM 12/31/2000
10:59:39 AM 12/31/2000
Trend
Tag connection
Value
Date/time
TOUCH
SIEMENS
SIMATIC HMI
SIEMENS
SIMATIC HMI
Home
12/31/2000
10:59:39 AM
Home
Automatic Close Loop Water Temperature & Water Level
+00000000
Water Temperature
+00000000
Temperature Setpoint
+00000000
Water Level
+00000000
Level Setpoint
+00000000
Kp Water Temperature
+00000000
Ti Water Temperature
+00000000
Td Water Temperature
+00000000
Kp Water Level
+00000000
Ti Water Level
+00000000
Td Water Level
100
80
60
40
20
0
10:57:59 AM 12/31/2000
10:58:24 AM 12/31/2000
10:58:49 AM 12/31/2000
10:59:14 AM 12/31/2000
10:59:39 AM 12/31/2000
Trend
Tag connection
Value
Date/time
TOUCH


SIEMENS
SIMATIC HMI
SIEMENS
SIMATIC HMI
Home
12/31/2000
10:59:39 AM
Home
Manual Input
Water Level
Open
Loop
Manual Mode
Manual Input
Water
Temperature
Manual Input
Combination
TOUCH
SIEMENS
SIMATIC HMI
SIEMENS
SIMATIC HMI
Home
12/31/2000
10:59:39 AM
Home
Manual Open Loop
+0000000
Water Level
+0000000
Water
Temperature
+0000000
Level
Setpoint
+0000000
Temperature
Setpoint
100
80
60
40
20
0
10:57:59 AM 12/31/2000
10:58:24 AM 12/31/2000
10:58:49 AM 12/31/2000
10:59:14 AM 12/31/2000
10:59:39 AM 12/31/2000
Trend
Tag connection
Value
Date/time
TOUCH


SIEMENS
SIMATIC HMI
SIEMENS
SIMATIC HMI
Home
12/31/2000
10:59:39 AM
Home
Manual Input PID Level
+0000000
Water Level
+0000000
Level Setpoint
+0000000
Gain (Kp)
+0000000
Ti
+0000000
Td
100
80
60
40
20
0
10:57:59 AM 12/31/2000
10:58:24 AM 12/31/2000
10:58:49 AM 12/31/2000
10:59:14 AM 12/31/2000
10:59:39 AM 12/31/2000
Trend
Tag connection
Value
Date/time
TOUCH
SIEMENS
SIMATIC HMI
SIEMENS
SIMATIC HMI
Home
12/31/2000
10:59:39 AM
Home
Manual Input PID Temperature
+0000000
Water Temperature
+0000000
Temperature Setpoint
+0000000
Gain (Kp)
+0000000
Ti
+0000000
Td
100
80
60
40
20
0
10:57:59 AM 12/31/2000
10:58:24 AM 12/31/2000
10:58:49 AM 12/31/2000
10:59:14 AM 12/31/2000
10:59:39 AM 12/31/2000
Trend
Tag connection
Value
Date/time
TOUCH


SIEMENS
SIMATIC HMI
SIEMENS
SIMATIC HMI
Home
12/31/2000
10:59:39 AM
Home
Manual Input PID Level Temperature
+00000000
Level Setpoint
+00000000
Temperature Setpoint
+00000000
Water Level
+00000
Water Temperature
+00000000
Kp Water Temperature
+00000000
Ti Water Temperature
+00000000
Td Water Temperature
+00000000
Kp Water Level
+00000000
Ti Water Level
+00000000
Td Water Level
100
80
60
40
20
0
10:57:59 AM 12/31/2000
10:58:24 AM 12/31/2000
10:58:49 AM 12/31/2000
10:59:14 AM 12/31/2000
10:59:39 AM 12/31/2000
Trend
Tag connection
Value
Date/time
TOUCH

# PLC AND HMI EXPERIMENT MODULE

Mechatronics Department

FEIT

SWISS GERMAN UNIVERSITY

The Prominence Tower

Jalan Jalur Sutera Barat No. 15, Alam Sutera

Tangerang, Banten 15143 - Indonesia

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# 1. Introductions

The primary objective of a training module, also referred to as a training kit, is to enhance students' comprehension levels by providing them with a comprehensive set of tools or devices that aid in explaining and illustrating the functioning of various concepts. Numerous studies have demonstrated that incorporating visualization techniques or demonstrations during educational activities can significantly enhance the overall quality of the learning experience. The training module served as an instrumentation device to demonstrate how a PLC-controlled closed loop control system (using PID) operated. The general idea of the training module was to control the water temperature and water level using PID. Four digital water level sensors, one analog water level sensor, and a thermocouple is used to measure water level and temperature respectively. These sensors were utilized as a feedback system to ensure that the closed loop system functioned smoothly.

## 1.1 Components Used

### 1.1.1 PLC SIMATIC S7-1200

PLC stands for Programmable Logic Controller. There are multiple manufacturers that are well-known for their PLCs product. Siemens's PLC is one of the most well-known products among others. SIMATIC S7-1200 stands out as one of the most feasible in terms of price along with the numbers of input and output in this thesis. The Simatic S7-1200 CPU 1214C DC/DC/DC or 6ES7 214-1AG40-0XB0 is a programmable logic controller (PLC) that operates on a 24VDC power supply. This means that the PLC itself requires a 24VDC power source to function properly. Additionally, the digital output ports of the PLC also provide a 24VDC voltage level. The PLC offers digital input, digital output, and analog input ports for connecting external devices and sensors. The digital input ports are used to receive signals from devices such as switches or sensors. The digital output ports, on the other hand, can provide a 24VDC signal to control or activate external devices like solenoids or relays. (SIEMENS, 2022)


**Figure 51 SIMATIC S7-1200**

### 1.1.2 Water Level Sensor

The level of water in the tank was detected using inductive proximity sensors. These sensors are able to pick up on the magnetic loss that occurs when an external magnetic field causes eddy currents in a conductive surface. Through the application of an alternating current magnetic field to the detection coil, eddy currents can be detected when the object's impedance changes. The switch is activated when an object passes through the electromagnetic field (Das, et al., 2013). There are 2 different types of water level sensor that are going to be used in this thesis, analog and digital. Both are going to be used to detect the water level and give feedback to the PLC.

### 1.1.3 PT 100 RTD Thermocouple

RTD stands for resistance temperature detector. The one that is going to be used in this thesis is PT 100. It is a thermocouple, used to detect temperature inside the water temperature container. It will be able to detect temperature from 0 degree Celsius up to 100 degrees Celsius.

**Figure 52 PT 100 RTD Thermocouple**

### 1.1.4 HMI

HMI stands for Human Machine Interface, there are multiple manufacturers that are well-known for their HMIs product. Siemens's SIMATIC HMI is one of the most popular products among others. Siemens's 6AV2 124-0GC01-0AX0 is going to be used in the module. 6AV2 is Siemen's product code for its HMI. This HMI type is TP700 Comfort, meaning that the HMI's monitor is 7 inches big.


**Figure 53 6AV2 124-0GC01-0AX0 HMI TP 700 Comfort**

### 1.1.5 Transmitter

A relevant transmitter is often used to make it easier to measure and send temperature data from an RTD PT 100 to S7-1200 PLC. This transmitter is made to connect to the PT 100 sensor and turn its temperature readings, which are based on resistance, into a suitable output signal, usually a standard electrical signal like 4-20 mA or 0-10 V. The

transmitter makes sure that the PT 100 sends accurate and reliable temperature data to tracking or control systems.


**Figure 54 Transmitter**

## 1.2. Theories Used

Implemented theories in this module included a closed loop feedback system and a PID control method. These theories were essential for implementing the module's methodology. In addition, they were included in the control technique learning procedures.

### 1.2.1 Open-Loop System

An open loop system functions without taking outside influences or input feedback into account. An open loop system operates irrespective to external factors or feedback gained from the input (Wikipedia, 2023). While easier and cheaper to create, open loop systems can't adapt the system behaviours to new circumstances. They can be used in situations where accuracy and precision aren't as important, and the surroundings is fairly stable and predictable.

### 1.2.2 Closed-Loop Feedback System

A closed loop feedback system is a system that uses feedback elements. The PLC will then read the feedback signal and compare it to the input in order to minimize the error until it reaches the desired setpoint based on the input (Electronics Tutorials, 2014).

Typically, the feedback elements are sensors; in this module, the feedback elements are a digital and analog water level sensor and an RTD thermocouple.

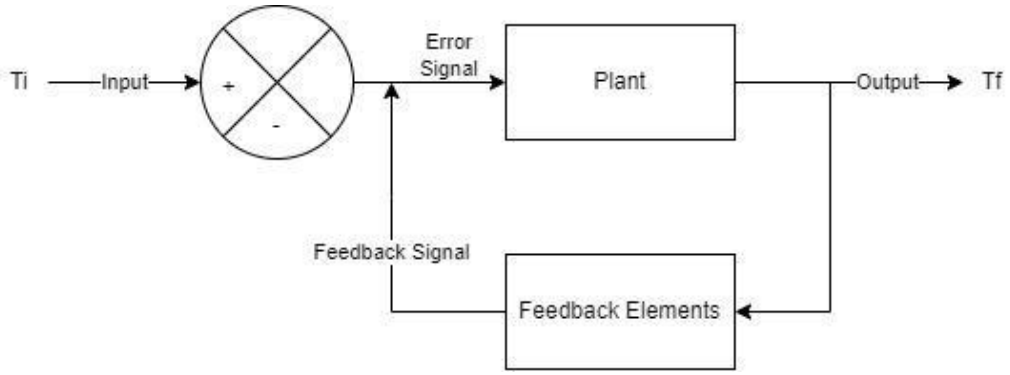


**Figure 55 Close Loop Feedback Control System**

### 1.2.3 PID Control Method

PID is a type of controller that can reduce the time required to reach setpoint, minimize or eliminate error, and reduce overshoot and undershoot, as well as reduce the time required for the system to settle. Proportional, Integral, and Derivative is the abbreviation for PID. Proportional control is used to amplify the signal to the system to improve/minimize the rising time. Whilst integral control can eliminate steady-state error and derivative control can improve or minimize overshoot and settling times (National Instruments, 2023).

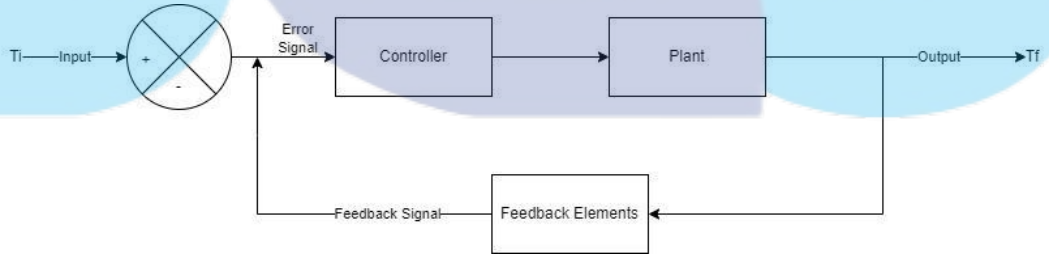


**Figure 56 PID Control Feedback System**

## Precautions

1. Before turning on the devices, always check the cable connections to ensure that no cables are unplugged or loose. Verify that all connections are secure and properly seated to prevent electrical hazards or equipment malfunctions.
2. Avoid touching the water heating element and cables located around the solid-state relays. These components can become hot during operation and may cause burns or electrical shocks. Maintain a safe distance and use appropriate tools or personal protective equipment when necessary.
3. When plugging banana jacks or any other connectors, ensure that the cables are not wet. Wet cables can increase the risk of electrical shock or short circuits. Inspect all cables for moisture or damage before connecting them to any devices or power sources.
4. During the initial setup or initialization process, carefully inspect the water container to ensure there are no leaks or drips. Leaking containers can cause damage to the equipment or create slippery surfaces, posing a safety hazard. Address any leaks before proceeding with the training activities.
5. Verify the proper functioning of the emergency button before commencing the training. The emergency button should be easily accessible and responsive in case of an urgent situation. Test the button periodically to confirm that it activates the appropriate safety protocols and stops the equipment as intended.

**Pre-steps**

1. Prior to initiating any actions, carefully review the provided precautions page and diligently follow all the specified steps. This page outlines crucial safety measures to ensure a secure training environment.

2. Fill the water bucket with water up to the marked heights. Ensure that the bucket is placed on a flat, level surface to prevent accidental spills or instability. Position the water hose inside the bucket, making sure it is fully submerged in water to avoid air entering the pump and causing damage. Regularly monitor the water level in the bucket to ensure it is adequate for the training activities. Refill as necessary. Prioritize safety by keeping the water bucket away from electrical components or other potential hazards to minimize the risk of accidents or damage. Refer to Figure 8 to see which water hose is supposed to be submerged into the water bucket.

**3.** Connect the AC cable, which comprises live and neutral wires of the power supply to the wall plug. Ensure a secure connection. Once connected, activate the power supply by turning on the switch. Please refer to Figure __ as a reference to identify which switch should be turned on.

4. Connect the AC cable, which comprises live and neutral wires, to the appropriate plug on the power supply. Ensure a secure connection. Once connected, activate the power supply by turning on the switch.

5. Proceed by activating the DC water pump. Locate the switch designated for the pump and turn it on. This action will set the pump in motion, allowing the controlled flow of water for the intended training activities. Please refer to Figure __ as a reference to identify which switch should be turned on.

6. Verify whether the Human Machine Interface (HMI) displays the home screen of the training module. Please refer to Figure __ as a reference for the home screen of the training module.

7. Inspect the Programmable Logic Controller (PLC) indicator for any error indications. Carefully examine the indicator lights or display on the PLC to determine if any error codes or messages are present. Promptly address any identified errors or abnormalities before proceeding with the training activities.

8. Once all the pre-steps have been completed, press the start button to initiate the training module. Ensure that all necessary preparations and safety checks have been carried out before pressing the start button to begin the training session.

## Steps: Introduction

The training module offers two modes: automatic and manual, each with four different options to choose from. This means there are a total of eight possible scenarios that can be explored with the training module. In the automatic mode, all the values, including the PID (Proportional-Integral-Derivative) and setpoint, are pre-determined. This means the module operates based on predefined values without user intervention. On the other hand, in the manual mode, users have the ability to manually enter the values for the PID and setpoint. This allows for more customization and flexibility in the training process.

Within both modes, there are four different options available:

Open Loop: This option allows users to observe the system's behavior without any control mechanism in place. While the usage of sensors in here are only to prevent damages.

Closed Loop Water Temperature: This option focuses on controlling the system's temperature using the PID and setpoint values. Users can observe how the system reacts and adjusts to maintain a specific water temperature.

Closed Loop Water Level: This option concentrates on controlling the system's water level, utilizing the PID and setpoint values. Users can observe how the system responds to maintain a desired water level.

Closed Loop Combinations: This option involves combining multiple control aspects, such as temperature and water level, using the PID and setpoint values. Users can explore how different control variables interact and affect the system's behavior.

By selecting different modes and options, users can experiment with various scenarios, gaining a better understanding of how the system operates and responds under different conditions.

## Steps: Manual Mode

To select the manual mode, follow these steps:

1. On the home screen of the training module, click or tap on the manual mode option to activate it. This action will switch the training module to manual mode.
2. By clicking or tapping on the manual mode option on the home screen, you will enable the ability to manually enter values for the PID and setpoint, allowing for more control and customization in the training process.

3. After selecting the manual mode, four options will become available to choose from. These options could include manual open loop, manual closed loop temperature, manual closed loop water level, and manual closed loop combinations. Select the desired option by clicking or pressing on the corresponding option displayed on the screen.

4. On each page within the selected option, you will find a home button located at the top left corner. This button can be used to reset the system and return to the home screen, allowing you to restart the training module or switch to a different mode or option if needed.

## Manual Mode Open Loop Precautions

In the manual mode open loop, it is important to maintain the system using the sensors. Here are additional details regarding the usage of sensors in the open loop mode:

1. Digital Water Level Sensor (Top Sensor): This sensor, located at the top of the containers, serves as a maximum water level limit indicator. It helps ensure that the water inside the container does not exceed a specified threshold. It provides a digital signal when the water level reaches the predetermined maximum limit.

2. Digital Water Level Sensor (Bottom Sensor): This sensor, positioned at the bottom of the water temperature container, plays a crucial role in controlling the water heating element. It must be energized, indicating the presence of sufficient water, before the water heating element is turned on. The bottom sensor provides a digital signal to activate the heating element once the water level reaches the desired level.

By incorporating these sensor-driven safeguards, the open loop mode provides a controlled environment for monitoring and adjusting the system manually, offering valuable insights into the system's behavior and responses.

**Steps: Manual Mode Open Loop**

After selecting the manual mode, follow these steps to proceed with the open loop option:

1. On the HMI screen, select the open loop option from the available choices. This will set the system to operate in open loop mode.
2. Press the start button to start the system.
3. Before observing the system's behavior, ensure that the banana jacks for the water pump, water heating element, and fan are properly connected. Check that the cables are securely plugged into the corresponding jacks to ensure proper functioning and prevent any potential disruptions. Please refer to Figure __ as a reference for how to connect the banana jack of the training module.
4. Set the desired setpoint of the water level and water temperature using the HMI.
5. Once the connections are confirmed, closely observe the behavior of the system. Monitor the water pump's operation, the response of the water heating element, and the behavior of the fan. Pay attention to any changes, patterns, or anomalies that occur as the system operates in open loop mode.
6. After finished with the observations, press the stop button and press the home screen at the top left of the HMI.

*****TABLE 1*****

**Misalkan: manual input desired setpoint sekian, bakal met the value atau nggak?**

**Seperti apa behaviour dari system?**

**Apakah hanya dengan menggunakan open loop, desired setpoint dapat dicapai?**

**Steps: Manual Mode Water Temperature Controller**

After selecting the manual mode, follow these steps to proceed with the water temperature option:

1. On the HMI screen, select the water temperature option from the available choices. This will set the system to operate in closed loop mode.
2. Press the start button to start the system.
3. Before observing the system's behavior, ensure that the banana jacks for the water pump, water heating element, and fan are properly connected. Check that the cables are securely plugged into the corresponding jacks to ensure proper functioning and prevent any potential disruptions. Please refer to Figure __ as a reference for how to connect the banana jack of the training module.
4. Set the desired setpoint of the water temperature and PID values using the HMI.
5. Once the connections are confirmed, closely observe the behavior of the system. Monitor the water pump's operation, the response of the water heating element, and the behavior of the fan. Pay attention to any changes, patterns, or anomalies that occur as the system operates in closed loop mode.
6. After finished with the observations, press the stop button, and press the home screen at the top left of the HMI.

*****TABLE 2*****

**Gunakan value Kp sekian, Ki sekian, Kd sekian pada setpoint sekian**

**Misalkan: manual input desired setpoint sekian, bakal met the value atau nggak?**

**Seperti apa behaviour dari system?**

**Bagaimana perbandingan dari behaviour system saat open loop vs close loop?**

**Steps: Manual Mode Water Level Controller**

After selecting the manual mode, follow these steps to proceed with the water level option:

1. On the HMI screen, select the water level option from the available choices. This will set the system to operate in closed loop mode.
2. Press the start button to start the system.
3. Before observing the system's behavior, ensure that the banana jacks for the water pump is properly connected. Check that the cables are securely plugged into the corresponding jacks to ensure proper functioning and prevent any potential disruptions. Please refer to Figure __ as a reference for how to connect the banana jack of the training module.
4. Set the desired setpoint of the water level and PID values using the HMI.
5. Once the connections are confirmed, closely observe the behavior of the system. Monitor the water pump's operation, the response of the water heating element, and the behavior of the fan. Pay attention to any changes, patterns, or anomalies that occur as the system operates in closed loop mode.
6. After finished with the observations, press the stop button, and press the home screen at the top left of the HMI.

*****TABLE 3*****

**Gunakan value Kp sekian, Ki sekian, Kd sekian pada setpoint sekian**

**Misalkan: manual input desired setpoint sekian, bakal met the value atau nggak?**

**Seperti apa behaviour dari system?**

**Bagaimana perbandingan dari behaviour system saat open loop vs close loop?**

**Steps: Manual Mode Combinations**

After selecting the manual mode, follow these steps to proceed with the combination mode option:

1. On the HMI screen, select the water combination option from the available choices. This will set the system to operate in closed loop mode.
2. Press the start button to start the system.
3. Before observing the system's behavior, ensure that the banana jacks for the water pump, water heating element, and fan are properly connected. Check that the cables are securely plugged into the corresponding jacks to ensure proper functioning and prevent any potential disruptions. Please refer to Figure __ as a reference for how to connect the banana jack of the training module.
4. Set the desired setpoint of the water temperature, water level, and PID values using the HMI.
5. Once the connections are confirmed, closely observe the behavior of the system. Monitor the water pump's operation, the response of the water heating element, and the behavior of the fan. Pay attention to any changes, patterns, or anomalies that occur as the system operates in closed loop mode.
6. After finished with the observations, press the stop button, and press the home screen at the top left of the HMI.

*****TABLE 4*****

**Gunakan value Kp sekian, Ki sekian, Kd sekian pada setpoint sekian**

**Misalkan: manual input desired setpoint sekian, bakal met the value atau nggak?**

**Seperti apa behaviour dari system?**

**Bagaimana perbandingan dari behaviour system saat open loop vs close loop?**

**Steps: Automatic Mode**

To select the automatic mode, follow these steps:

1. On the home screen of the training module, click or tap on the automatic mode option to activate it. This action will switch the training module to automatic mode mode.
2. By clicking or tapping on the automatic mode option on the home screen, you will disable the ability to manually enter values for the PID and setpoint. Therefore, the module shows the behavior of the system through the pre-tuning and fine tuning from the TIA Portal.
3. After selecting the automatic mode, four options will become available to choose from. These options could include automatic open loop, automatic closed loop temperature, automatic closed loop water level, and automatic closed loop combinations. Select the desired option by clicking or pressing on the corresponding option displayed on the screen.
4. On each page within the selected option, you will find a home button located at the top left corner. This button can be used to reset the system and return to the home screen, allowing you to restart the training module or switch to a different mode or option if needed.

**Automatic Mode Open Loop Precautions**

In the automatic mode open loop, it is important to maintain the system using the sensors. Here are additional details regarding the usage of sensors in the open loop mode:

1. Digital Water Level Sensor (Top Sensor): This sensor, located at the top of the containers, serves as a maximum water level limit indicator. It helps ensure that the water inside the container does not exceed a specified threshold. It provides a digital signal when the water level reaches the predetermined maximum limit.

2. Digital Water Level Sensor (Bottom Sensor): This sensor, positioned at the bottom of the water temperature container, plays a crucial role in controlling the water heating element. It must be energized, indicating the presence of sufficient water, before the water heating element is turned on. The bottom sensor provides a digital signal to activate the heating element once the water level reaches the desired level.

By incorporating these sensor-driven safeguards, the open loop mode provides a controlled environment for monitoring.

**Steps: Automatic Mode Open Loop**

After selecting the automatic mode, follow these steps to proceed with the open loop option:

1. On the HMI screen, select the open loop option from the available choices. This will set the system to operate in open loop mode.
2. Press the start button to start the system.
3. Before observing the system's behavior, ensure that the banana jacks for the water pump, water heating element, and fan are properly connected. Check that the cables are securely plugged into the corresponding jacks to ensure proper functioning and prevent any potential disruptions. Please refer to Figure __ as a reference for how to connect the banana jack of the training module.
4. Set the desired setpoint of the water level and water temperature using the HMI.
5. Once the connections are confirmed, closely observe the behavior of the system. Monitor the water pump's operation, the response of the water heating element, and the behavior of the fan. Pay attention to any changes, patterns, or anomalies that occur as the system operates in open loop mode.
6. After finished with the observations, press the stop button and press the home screen at the top left of the HMI.

*****TABLE 5*****

**Desired setpoint sekian, bakal met the value atau nggak?**

**Seperti apa behaviour dari system?**

**Apakah hanya dengan menggunakan open loop, desired setpoint dapat dicapai?**

**Apakah ada perbedaan antara automatic mode open loop dengan manual mode open loop?**

**Steps: Automatic Mode Water Temperature Controller**

After selecting the automatic mode, follow these steps to proceed with the water temperature option:

1. On the HMI screen, select the water temperature option from the available choices. This will set the system to operate in closed loop mode.
2. Press the start button to start the system.
3. Before observing the system's behavior, ensure that the banana jacks for the water pump, water heating element, and fan are properly connected. Check that the cables are securely plugged into the corresponding jacks to ensure proper functioning and prevent any potential disruptions. Please refer to Figure __ as a reference for how to connect the banana jack of the training module.
4. Once the connections are confirmed, closely observe the behavior of the system. Monitor the water pump's operation, the response of the water heating element, and the behavior of the fan. Pay attention to any changes, patterns, or anomalies that occur as the system operates in closed loop mode.
5. After finished with the observations, press the stop button, and press the home screen at the top left of the HMI.

*****TABLE 6*****

**Seperti apa behaviour dari system?**

**Bagaimana perbandingan dari behaviour system saat open loop vs close loop?**

**Bagaimana perbandingan data saat menggunakan PID di manual mode vs automatic mode?**

**Steps: Automatic Mode Water Level Controller**

After selecting the automatic mode, follow these steps to proceed with the water level option:

1. On the HMI screen, select the water level option from the available choices. This will set the system to operate in closed loop mode.
2. Press the start button to start the system.
3. Before observing the system's behavior, ensure that the banana jacks for the water pump is properly connected. Check that the cables are securely plugged into the corresponding jacks to ensure proper functioning and prevent any potential disruptions. Please refer to Figure __ as a reference for how to connect the banana jack of the training module.
4. Set the desired setpoint of the water level and PID values using the HMI.
5. Once the connections are confirmed, closely observe the behavior of the system. Monitor the water pump's operation, the response of the water heating element, and the behavior of the fan. Pay attention to any changes, patterns, or anomalies that occur as the system operates in closed loop mode.
6. After finished with the observations, press the stop button, and press the home screen at the top left of the HMI.

***TABLE 7***

**Seperti apa behaviour dari system?**

**Bagaimana perbandingan dari behaviour system saat open loop vs close loop?**

**Bagaimana perbandingan data saat menggunakan PID di manual mode vs automatic mode?**

**Steps: Automatic Mode Combinations**

After selecting the automatic mode, follow these steps to proceed with the combination mode option:

1. On the HMI screen, select the water combination option from the available choices. This will set the system to operate in closed loop mode.
2. Press the start button to start the system.
3. Before observing the system's behavior, ensure that the banana jacks for the water pump, water heating element, and fan are properly connected. Check that the cables are securely plugged into the corresponding jacks to ensure proper functioning and prevent any potential disruptions. Please refer to Figure __ as a reference for how to connect the banana jack of the training module.
4. Once the connections are confirmed, closely observe the behavior of the system. Monitor the water pump's operation, the response of the water heating element, and the behavior of the fan. Pay attention to any changes, patterns, or anomalies that occur as the system operates in close loop mode.
5. After finished with the observations, press the stop button, and press the home screen at the top left of the HMI.

*****TABLE 8*****

**Seperti apa behaviour dari system?**

**Bagaimana perbandingan dari behaviour system saat open loop vs close loop?**

**Bagaimana perbandingan data saat menggunakan PID di manual mode vs automatic mode?**

**Post-steps**

1. Record and document important details from the training session, including observations, findings, and any adjustments made. Keep thorough notes for future reference or review purposes.
2. Safely power down and shut off all equipment used during the training. Follow proper procedures for shutting down each device, ensuring that all switches are turned off, and cables are disconnected.
3. Prioritize safety and prevent potential water damage by ensuring all water inside the water containers and water buckets is completely drained.
4. Conduct safety checks to ensure that all equipment, tools, and training areas are left in a safe condition. Inspect for any potential hazards or safety issues that may have arisen during the training. Address and rectify any identified concerns promptly.
5. Ensure that cables and components used for the training are stored in a safe and organized manner. Please refer to Figure __ as a reference to store the components.

# Curriculum Vitae

## Personal Data

| | |
|---|---|
| Name | :Raden Nur Muhammad Ihsan Luhur Jatmiko Wijoyojati |
| Place of Birth | :Balikpapan |
| Birthdate | :12. Januar 1999 |
| Address | :Apartment Springwood Residence Nr. 2619, Jalan MH. Thamrin, RT 002/RW 001, Pinang, Kota Tangerang 15143, Indonesia |
| Telephone Number | :+62 813 5762 4274 |
| E-Mail | :raden.wijoyojati@student.sgu.ac.id |

## Studium

From 2019 — Mechatronics – Mechanical Engineering Swiss German University

## Internship's Experience

Juni 2021 – July 2021 — Intern at PT Mitra Teknologi Persada (as a junior robot engineer)

Activities:

- Coding for Epson SCARA Robot
- Creating electrical schematic using SkyCad
- Making a training module using SCARA Robot collaborating with Kawan Lama Studio
- Training Workshop with Yaskawa

March 2022 – August 2022 — Intern at Siemens AG Schaltanlagenwerk Frankfurt (as a mechanical and electrical engineer intern)

Activities:

- Assembly and disassembly Switchgear
- Installing electrical components such as Circuit Breaker, Fuse, Protection Relay, PLC, etc.
- Quality control, packaging, and operating electric pallet jack lifter
- Training Electric Pallet Jack Lifter
- Training Workshop with Siemens AG Frankfurt

## School Education

| | |
|---|---|
| 2013 – 2016 | SMA Pribadi Bilingual Boarding School Bandung |
| 2010 – 2013 | SMP Nasional KPS Balikpapan |
| 2004 – 2010 | SD Nasional KPS Balikpapan |

**Organizational Experiences**

| | |
|---|---|
| 2021 – 2022 | Member of Mechatronics Student Association Academic Department |
| 2020 – 2021 | Member of Marketing Department in Mechatronics Day |
| 2019 – 2020 | Member of Marketing Department in Mechatronics Day |

**Linguistic Proficiency**

| | |
|---|---|
| Indonesian | Mother tounge |
| English | Able to speak, listen, write, and read fluently |
| Deutsch/German | Grundkenntnisse A2.1 / Level A2.1 |

**Computer Knowledge**

| | |
|---|---|
| MS Office | Word, Excel, PowerPoint |
| Arduino | Programming for microcontroller |
| Fluidsim | Creating a simple pneumatic design |
| Scilab | Creating a simple open-loop and closed-loop design |
| Skycad | Creating a simple electrical design |
| Codesys (Hitachi) | Creating a simple ladder diagram |
| SPEL Language | Creating a simple SCARA robot program for Epson Robot |
| Tia Portal | Creating a simple ladder diagram |

**Hobby and Interests**

Playing any kind of sport and video games. Interested in robotics and automation.

**Tangerang, 19 Juni 2023**

**(Raden Nur Muhammad Ihsan Luhur Jatmiko Wijoyojati)**