

Assignment 3

by Christopher Milner

FILE	10826_CHRISTOPHER_MILNER_ASSIGNMENT_3_157791_94903709.DOC X		
TIME SUBMITTED	08-MAY-2018 07:19PM (UTC+0100)	WORD COUNT	14 17
SUBMISSION ID	88676279	CHARACTER COUNT	12599

Title:

Assignment 3

Course:

HNC Electrical and Electronic Engineering

Module:

PSDE4005 Programmable Logic Controllers

Date:

08/05/2018

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Word Count: 1417

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1. System Description

The Bytronic process rig (Figure 1) is an educational simulation of a basic control system using typical inputs and outputs found in industrial applications. It comprises of a sump tank containing water, a pump motor to move the water to a process tank via a direct pipe with a flow check valve or via a divert valve, through a heat exchanger. The process tank is fitted with a level switch, a heating element, temperature sensor and a motorised stirrer.

In operation, the pump will fill the tank at a set flow rate until the tank full switch is operated. At this point the pump should stop and the heating element should start heating the water. The stirrer is built into tank to help keep the temperature uniform throughout. The heating will continue until it reaches a set point at which the temperature will be held. Then if necessary the heater can be turned off and the drain valve opened, returning the water to the sump to repeat the process. Also if required the water can be pumped into the process tank via a heat exchanger if the temperature needs reducing.



Figure 1 Bytronic Process Control Rig

Control of the process rig is taken care of by a Siemens S7-1200 PLC with a SM1231 analogue input expansion module (Figure 2). Because the temperature sensors used are resistive and the PLC requires a 4-20mA analogue input, three PT100 temperature transmitters are used to convert the voltage input to a scaled current output that can then be read by the analogue module.

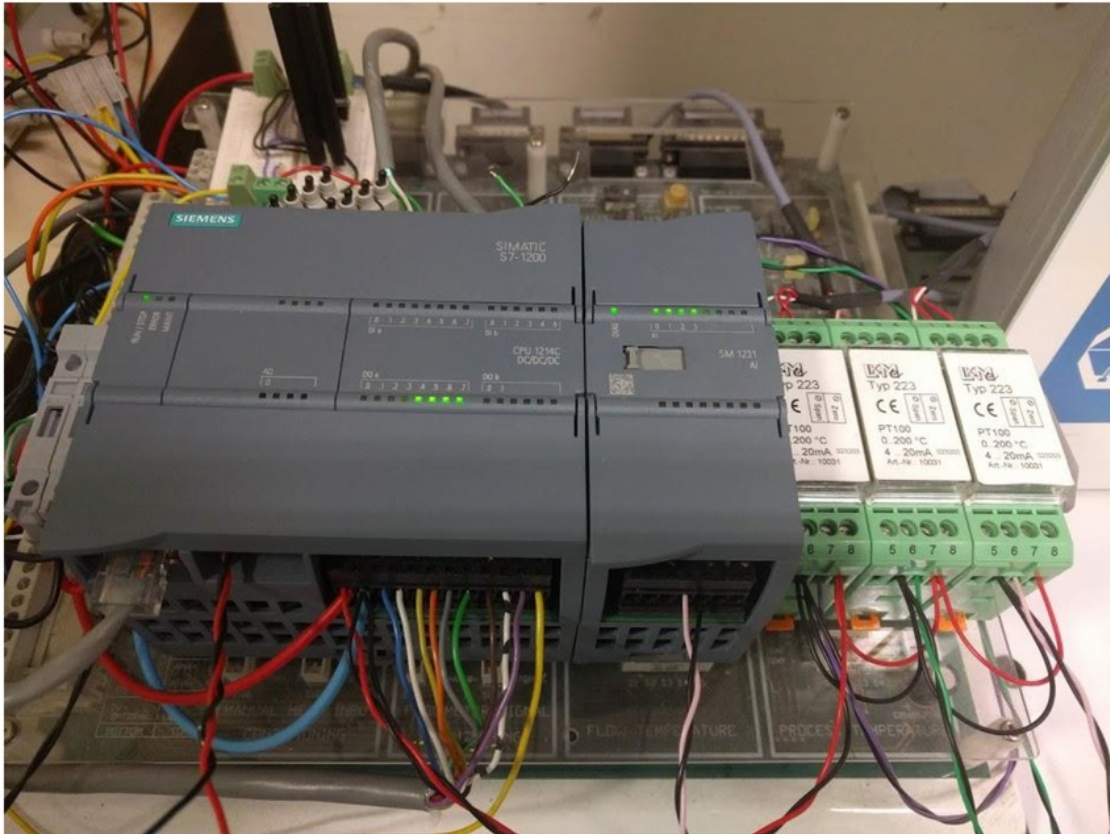


Figure 2 Seimens S7-1200 PLC, SM1231 Analogue Expansion and PT100 Temperature Transmitters

Figure 3 shows the I/O list for the system. All the components that have an address starting %I are inputs with the ones starting %IW being the analogue devices. The components with %Q addresses are outputs and the %QW addresses are pulse generators for the PWM control.

Name	Data Type	Logical Address
Level Switch	Bool	%I1.0
Flow Rate Sensor	Word	%IW66
RTD Process Tank Temp Sensor	Word	%IW96
RTD Sump Tank Temp Sensor	Word	%IW98
RTD Ambient Temp Sensor	Word	%IW100
Cooling Fan	Bool	%Q0.0
Stirrer	Bool	%Q0.1
Drain Valve	Bool	%Q0.2
Divert Valve	Bool	%Q0.3
Cooler Lamp	Bool	%Q0.4
Drain Valve Lamp	Bool	%Q0.5
Divert Valve Lamp	Bool	%Q0.6
Tank Full Lamp	Bool	%Q0.7
Heater	Bool	%Q1.0
Pump	Bool	%Q1.1
Flow %CV PWM duty cycle	UInt	%QW1000
Process Temperature %CV duty cycle	UInt	%QW1002

Figure 3 I/O List

2. Program Design and Explanation

PLC Program

Name	Data Type	Logical Address
Level Switch	Bool	%I1.0
Flow Rate Sensor	Word	%IW66
RTD Process Tank Temp Sensor	Word	%IW96
RTD Sump Tank Temp Sensor	Word	%IW98
RTD Ambient Temp Sensor	Word	%IW100
Cooling Fan	Bool	%Q0.0
Stirrer	Bool	%Q0.1
Drain Valve	Bool	%Q0.2
Divert Valve	Bool	%Q0.3
Cooler Lamp	Bool	%Q0.4
Drain Valve Lamp	Bool	%Q0.5
Divert Valve Lamp	Bool	%Q0.6
Tank Full Lamp	Bool	%Q0.7
Heater	Bool	%Q1.0
Pump	Bool	%Q1.1
Flow %CV PWM duty cycle	UInt	%QW1000
Process Temperature %CV duty cycle	UInt	%QW1002
FSP	Bool	%M50.0
HMIPump	Bool	%M50.1
HMI Heater	Bool	%M50.2
HMI Tank Full Lamp	Bool	%M50.3
HMI Divert Valve Lamp	Bool	%M50.4
HMI Drain Valve Lamp	Bool	%M50.5
HMI Cooler Lamp	Bool	%M50.6
HMI Divert Valve	Bool	%M50.7
HMI Drain Valve	Bool	%M51.0
HMI Stirrer	Bool	%M51.1
HMI Cooling Fan	Bool	%M51.2
Auto	Bool	%M51.3
Auto Heater	Bool	%M51.4
Auto Pump	Bool	%M51.5
Auto Divert Valve	Bool	%M51.6
Auto Drain Valve	Bool	%M51.7
Auto Stirrer	Bool	%M52.0
Auto Cooling Fan	Bool	%M52.1
Pump Start	Bool	%M52.2
Heater Start	Bool	%M52.3
HMI Start System	Bool	%M0.0
HMI Stop System	Bool	%M0.1
Auto Run	Bool	%M0.2

Figure 4 PLC Tag list

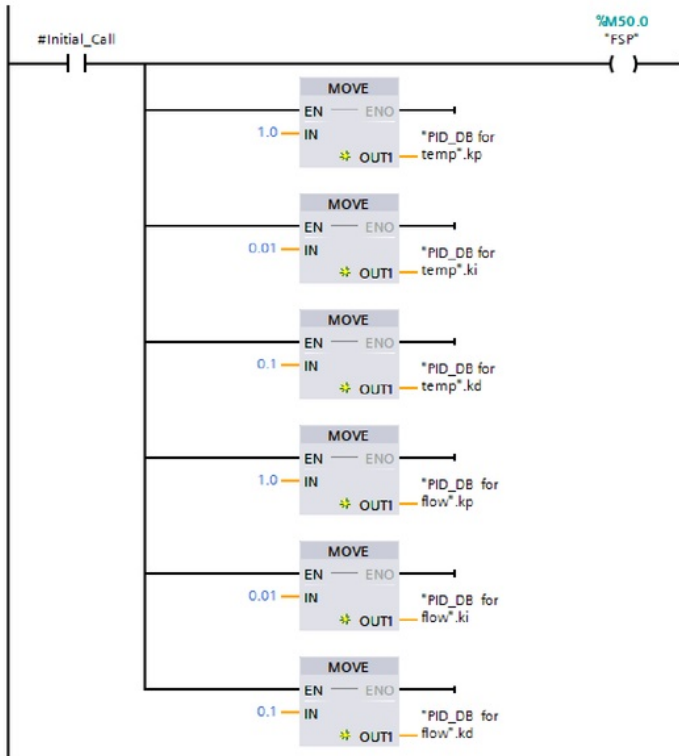
- Cyclic interrupt 1m...
- Cyclic interrupt 100...
- Main [OB1]
- Input Scaling [FC3]
- Outputs [FC2]
- PID [FB1]
- Analogue [DB5]
- PID_DB for flow [D...
- PID_DB for temp [D...

Figure 5 Program and Data blocks

Main

Network 1:

Enables first scan pulse and pre loads PID values.



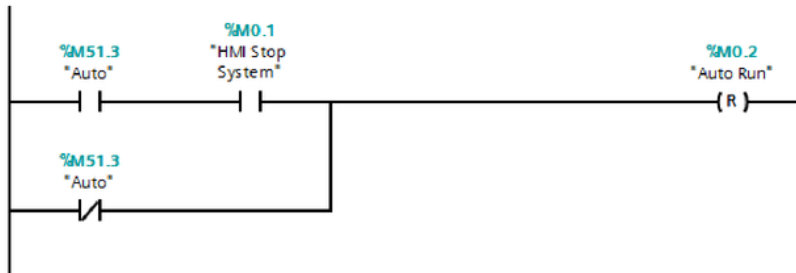
Network 2: Automatic run set bit

Sets the automatic run memory bit.



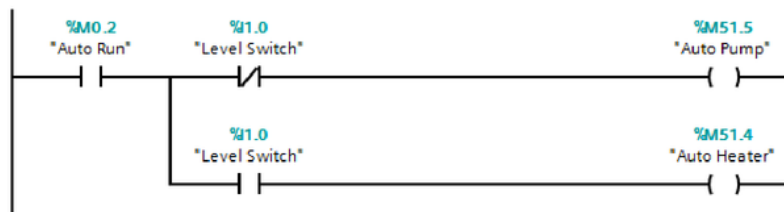
Network 3: Automatic run reset bit

Resets the automatic run memory bit.



Network 4:

Uses the Level switch as an interlock



Network 5:

Adds the Input scaling function call into the main program

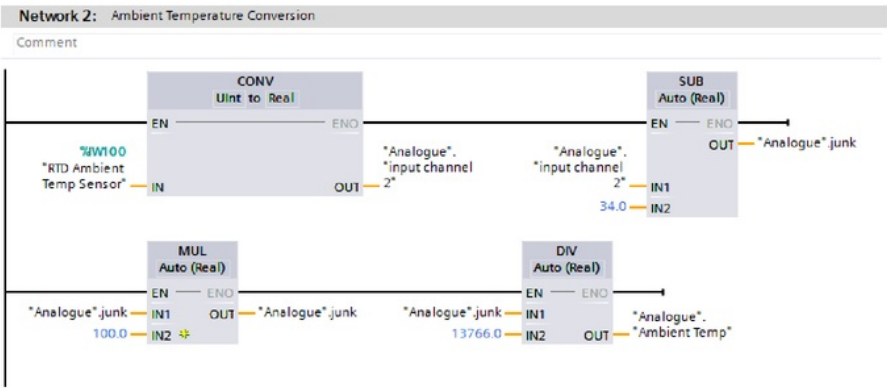
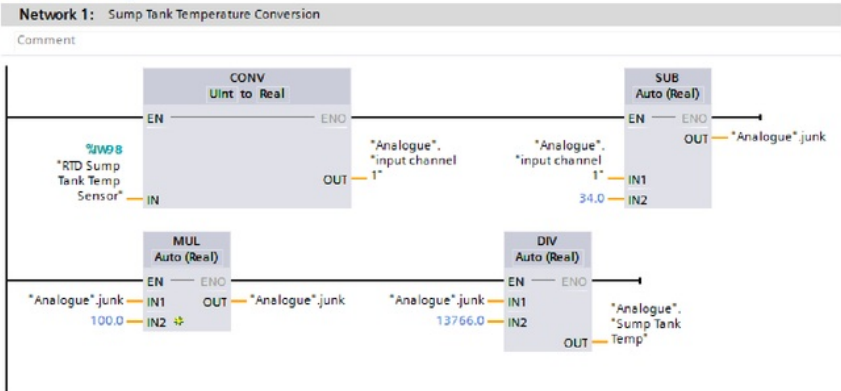


Network 6:

Adds the outputs function call to the main program



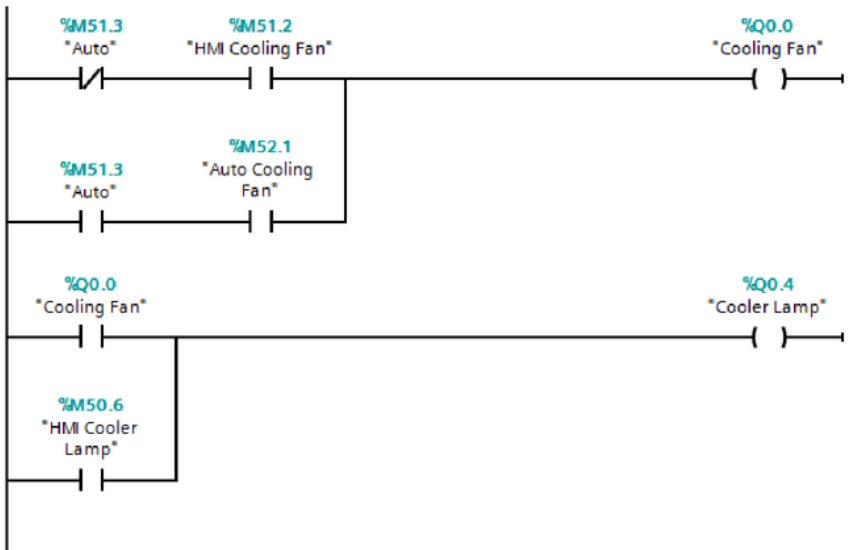
Input Scaling



Outputs

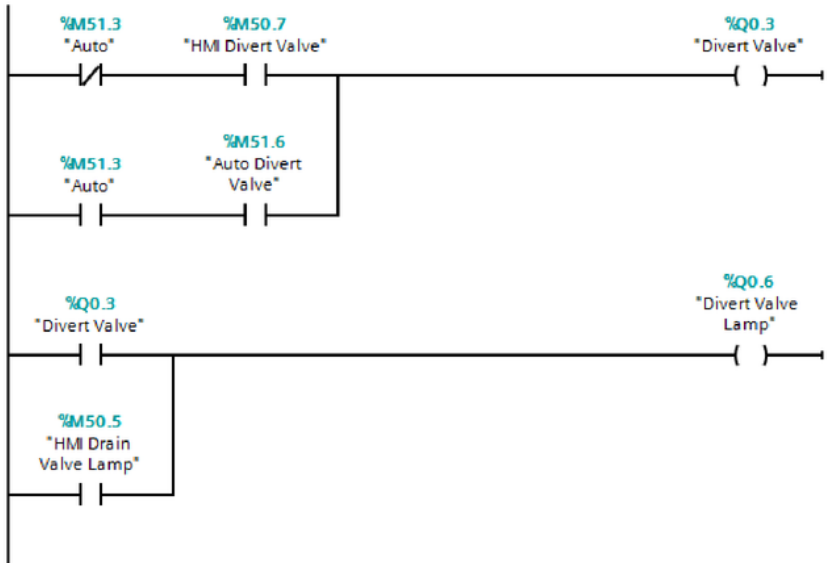
Network 1:

Auto and manual control of the cooling fan and indicator lamp



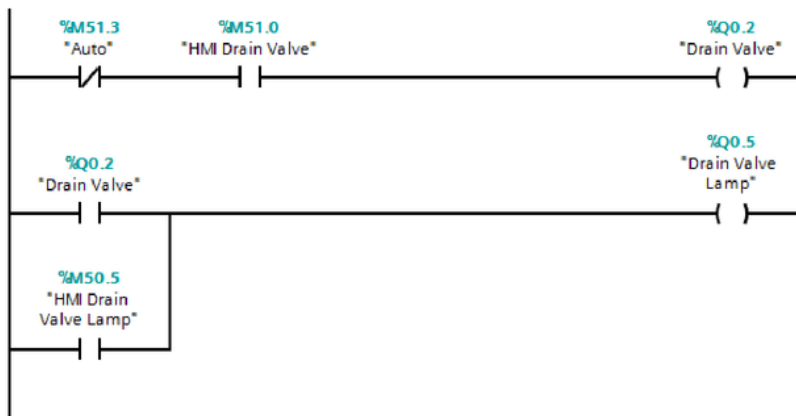
Network 2:

Auto and manual control of the divert valve and indicator lamp



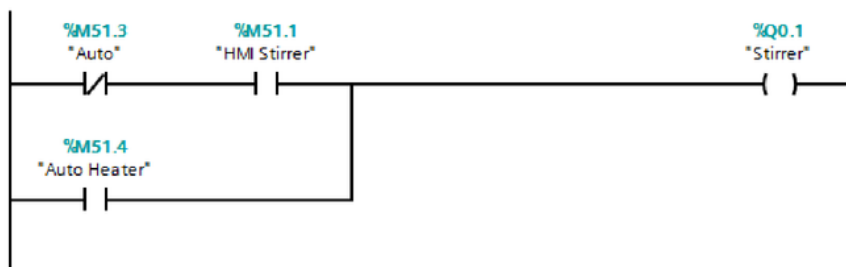
Network 3:

Auto and manual control of the drain valve and indicator lamp



Network 4:

Control of the stirrer motor



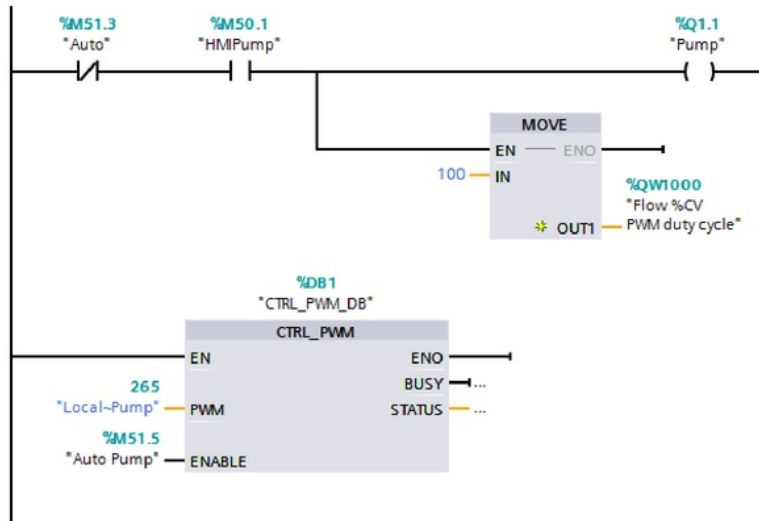
Network 5:

Control of the tank full indicator lamp



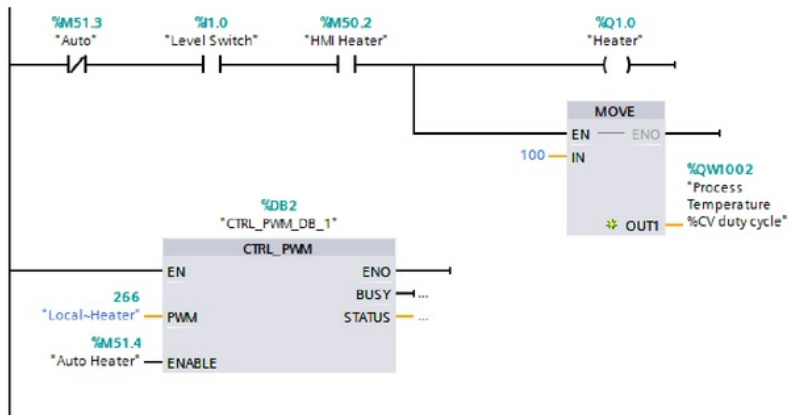
Network 6:

PWM control of the pump motor speed



Network 7:

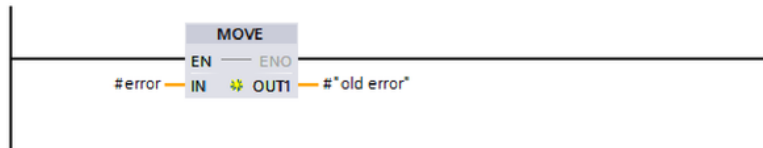
PWM control of the process heater.



PID Function block

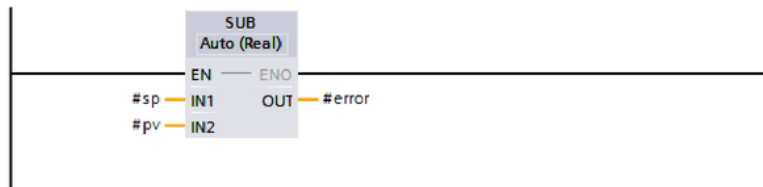
Network 1:

Moves the current error into the old error memory



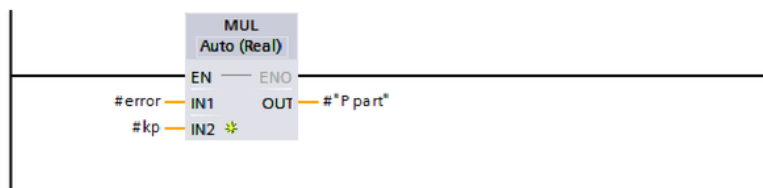
Network 2:

Subtracts the process variable from the set point to calculate the error



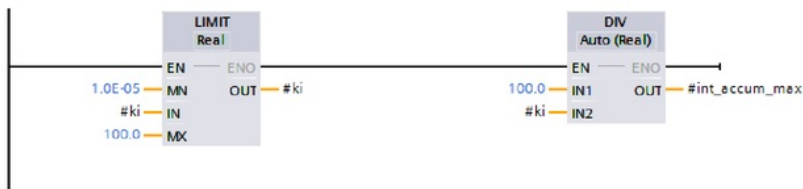
Network 3:

Multiplies the error by the proportional gain



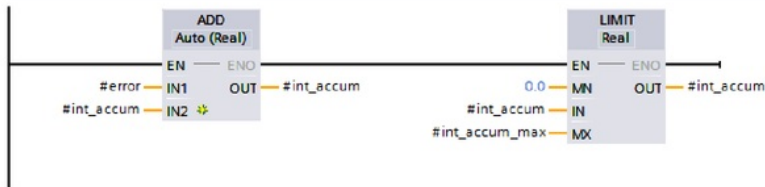
Network 4:

Sets limits for the value of ki then divides 100 by ki to calculate the accumulator



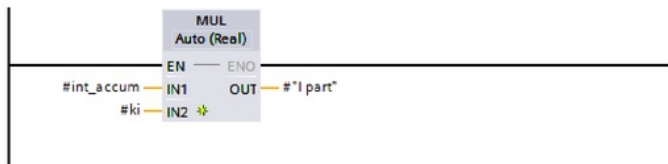
Network 5:

Adds the error to the accumulator and sets the limit



Network 6:

Multiplies the accumulator by ki



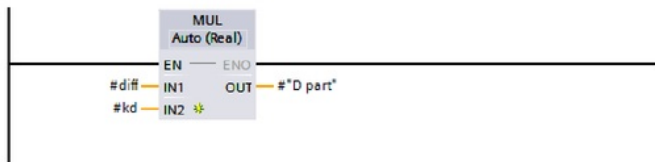
Network 7:

Subtracts the old error from the current error to calculate the difference



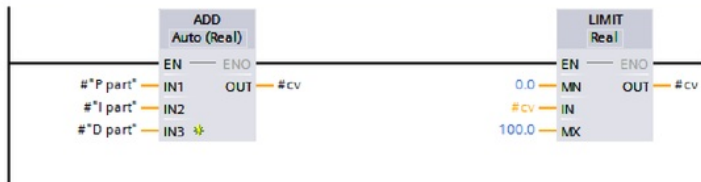
Network 8:

Multiplies the difference by kd

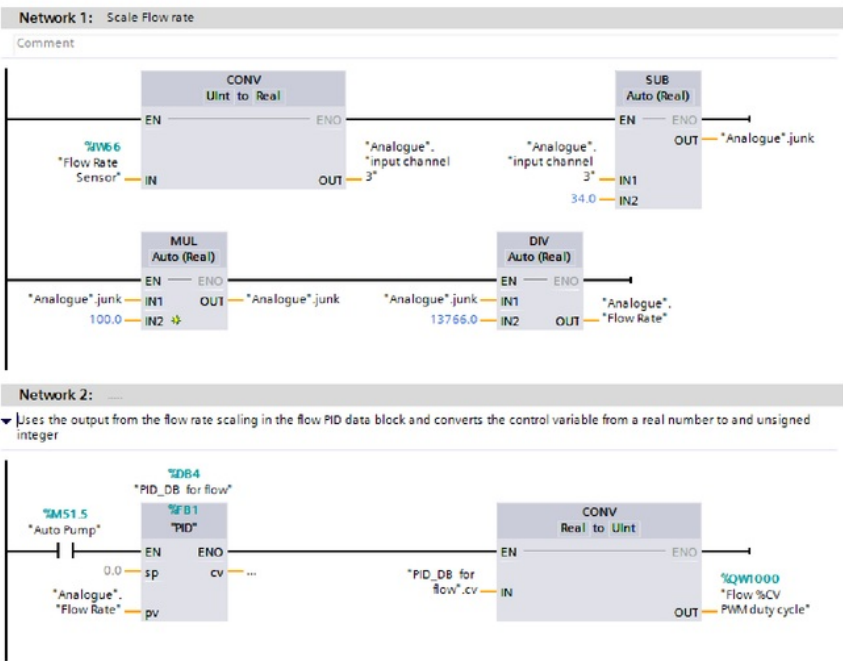


Network 9:

Adds the proportional, integral and differentiation value together and limits the control variable output to 100



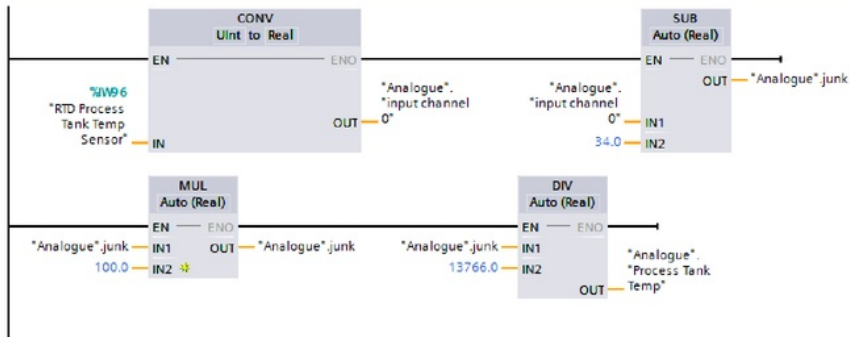
1ms Cyclic Interrupt



100ms Cyclic Interrupt

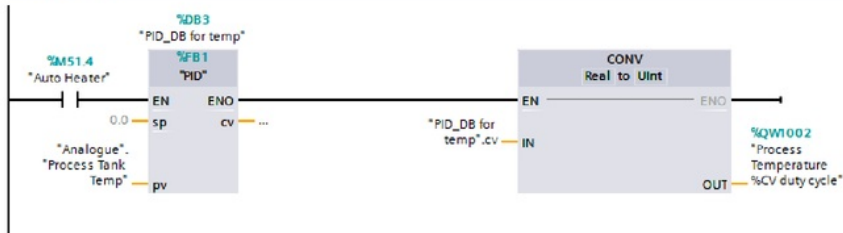
Network 1: Process Tank Temperature Conversion

Comment



Network 2:

Uses the output from the tank temperature scaling in the temp PID data block and converts the control variable from a real number to an unsigned integer



Analogue Data Block

Analogue	
Name	Data type
Static	
input channel 0	Real
input channel 1	Real
input channel 2	Real
input channel 3	Real
junk	Real
Process Tank Temp	Real
Sump Tank Temp	Real
Ambient Temp	Real
Flow Rate	Real

Flow PID Data Block

PID_DB for flow	
Name	Data type
▼ Input	
▪ sp	Real
▪ pv	Real
▼ Output	
▪ cv	Real
InOut	
▼ Static	
▪ error	Real
▪ old error	Real
▪ kp	Real
▪ ki	Real
▪ kd	Real
▪ int_accum	Real
▪ int_accum_max	Real
▪ diff	Real
▪ P part	Real
▪ I part	Real
▪ D part	Real

Temperature PID Data Block

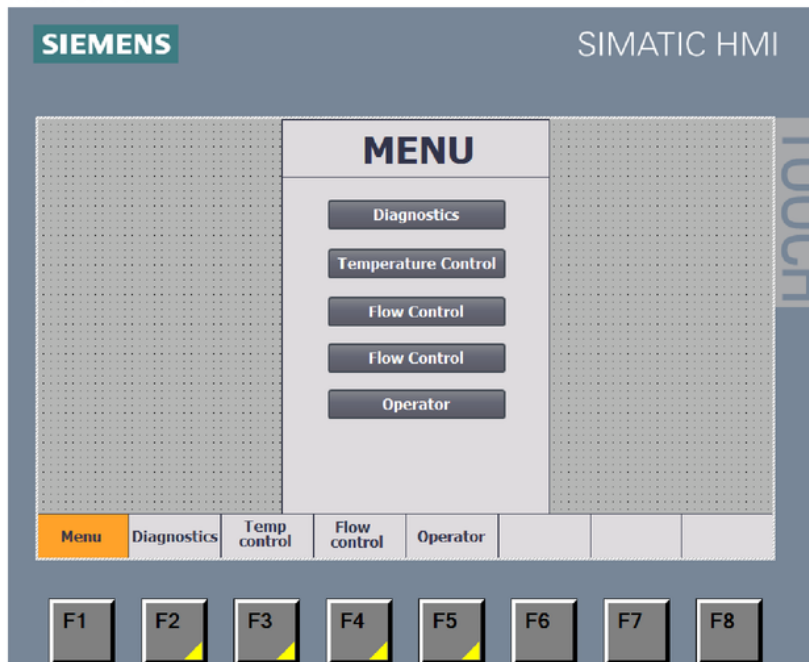
PID_DB for temp	
Name	Data type
▼ Input	
▪ sp	Real
▪ pv	Real
▼ Output	
▪ cv	Real
InOut	
▼ Static	
▪ error	Real
▪ old error	Real
▪ kp	Real
▪ ki	Real
▪ kd	Real
▪ int_accum	Real
▪ int_accum_max	Real
▪ diff	Real
▪ P part	Real
▪ I part	Real
▪ D part	Real

HMI Screens

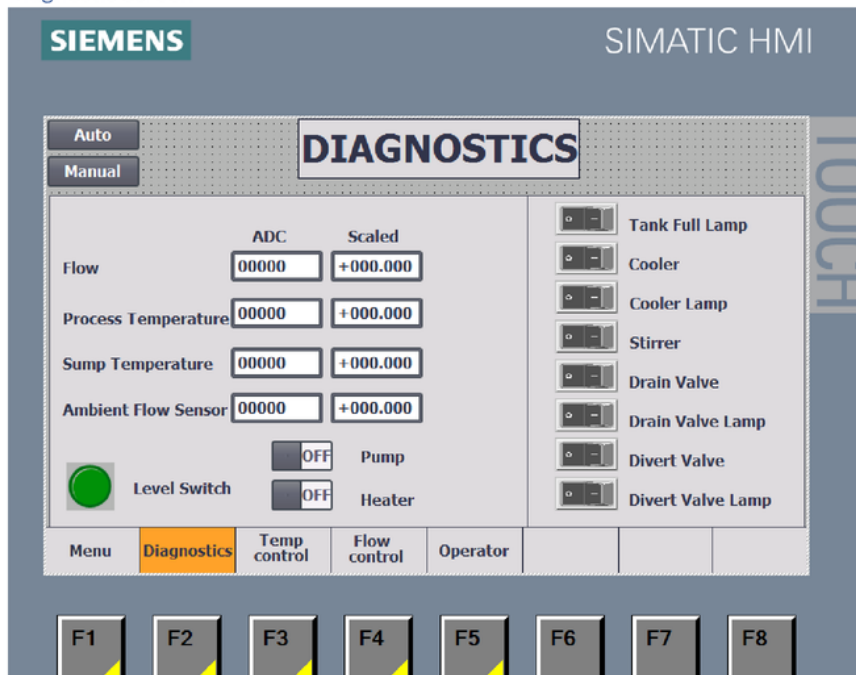
Name	PLC tag	Data Type	Length	Coding
Level Switch	"Level Switch"	Bool	1	Binary
HMI Cooler Lamp	"HMI Cooler Lamp"	Bool	1	Binary
HMI Drain Valve Lamp	"HMI Drain Valve Lamp"	Bool	1	Binary
HMI Divert Valve Lamp	"HMI Divert Valve Lamp"	Bool	1	Binary
HMI Tank Full Lamp	"HMI Tank Full Lamp"	Bool	1	Binary
RTD Sump Tank Temp Sensor	"RTD Sump Tank Temp Sensor"	Word	2	Binary
Flow Rate Sensor	"Flow Rate Sensor"	Word	2	Binary
RTD Ambient Temp Sensor	"RTD Ambient Temp Sensor"	Word	2	Binary
Analogue_Sump Tank Temp	Analogue."Sump Tank Temp"	Real	4	IEEE754
Analogue_Process Tank Temp	Analogue."Process Tank Temp"	Real	4	IEEE754
Analogue_Flow Rate	Analogue."Flow Rate"	Real	4	IEEE754
Tag_ScreenNumber	<No Value>	UInt	2	Binary
Analogue_Ambient Temp	Analogue."Ambient Temp"	Real	4	IEEE754
Process Temperature %CV duty cycle	"Process Temperature %CV duty cycle"	UInt	2	Binary
Flow %CV PWM duty cycle	"Flow %CV PWM duty cycle"	UInt	2	Binary
RTD Process Tank Temp Sensor	"RTD Process Tank Temp Sensor"	Word	2	Binary
Auto	Auto	Bool	1	Binary
HMI Divert Valve	"HMI Divert Valve"	Bool	1	Binary
HMI Drain Valve	"HMI Drain Valve"	Bool	1	Binary
HMI Stirrer	"HMI Stirrer"	Bool	1	Binary
Stirrer	Stirrer	Bool	1	Binary
HMI Cooling Fan	"HMI Cooling Fan"	Bool	1	Binary
PID_DB_1_pv	"PID_DB for flow".pv	Real	4	IEEE754
PID_DB_1_error	"PID_DB for flow".error	Real	4	IEEE754
PID_DB_1_kp	"PID_DB for flow".kp	Real	4	IEEE754
PID_DB_1_P part	"PID_DB for flow"."P part"	Real	4	IEEE754
PID_DB_1_ki	"PID_DB for flow".ki	Real	4	IEEE754
PID_DB_1_I part	"PID_DB for flow"."I part"	Real	4	IEEE754
PID_DB_1_kd	"PID_DB for flow".kd	Real	4	IEEE754
PID_DB_1_diff	"PID_DB for flow".diff	Real	4	IEEE754
PID_DB_1_D part	"PID_DB for flow"."D part"	Real	4	IEEE754
PID_DB_1_cv	"PID_DB for flow".cv	Real	4	IEEE754
PID_DB_1_int_accum	"PID_DB for flow".int_accum	Real	4	IEEE754
PID_DB_sp	"PID_DB for temp".sp	Real	4	IEEE754
PID_DB_pv	"PID_DB for temp".pv	Real	4	IEEE754
PID_DB_error	"PID_DB for temp".error	Real	4	IEEE754
PID_DB_kp	"PID_DB for temp".kp	Real	4	IEEE754
PID_DB_P part	"PID_DB for temp"."P part"	Real	4	IEEE754
PID_DB_ki	"PID_DB for temp".ki	Real	4	IEEE754
PID_DB_int_accum	"PID_DB for temp".int_accum	Real	4	IEEE754
PID_DB_I part	"PID_DB for temp"."I part"	Real	4	IEEE754
PID_DB_kd	"PID_DB for temp".kd	Real	4	IEEE754
PID_DB_diff	"PID_DB for temp".diff	Real	4	IEEE754
PID_DB_D part	"PID_DB for temp"."D part"	Real	4	IEEE754
PID_DB_cv	"PID_DB for temp".cv	Real	4	IEEE754
HMIPump	HMIPump	Bool	1	Binary
HMI Heater	"HMI Heater"	Bool	1	Binary
PID_DB_1_sp	"PID_DB for flow".sp	Real	4	IEEE754
Pump Start	"Pump Start"	Bool	1	Binary
Heater Start	"Heater Start"	Bool	1	Binary
HMI Start System	"HMI Start System"	Bool	1	Binary
HMI Stop System	"HMI Stop System"	Bool	1	Binary
Auto Run	"Auto Run"	Bool	1	Binary

Figure 6 HMI Tag List

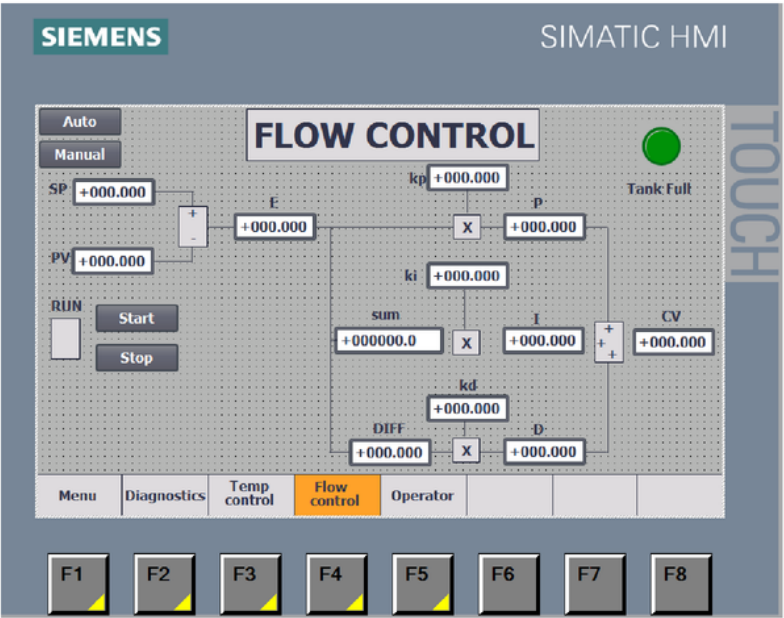
Menu Screen



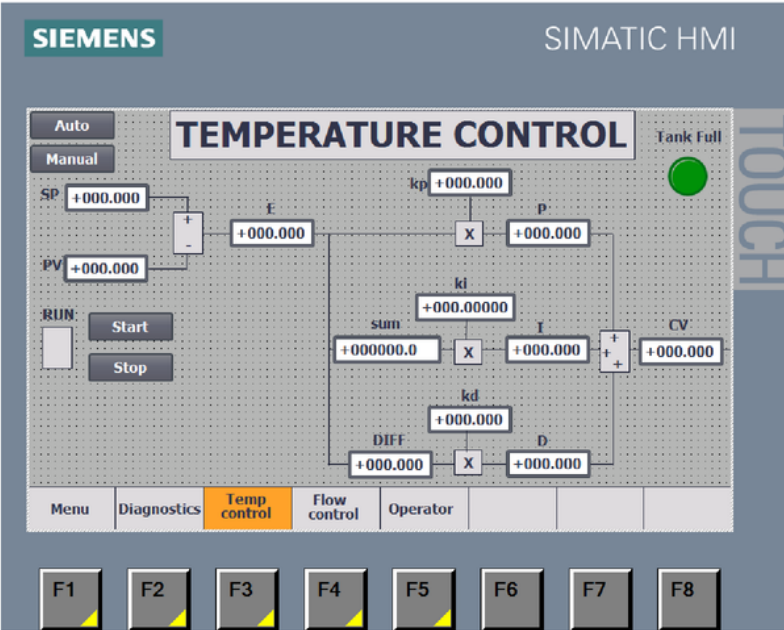
Diagnostic Screen



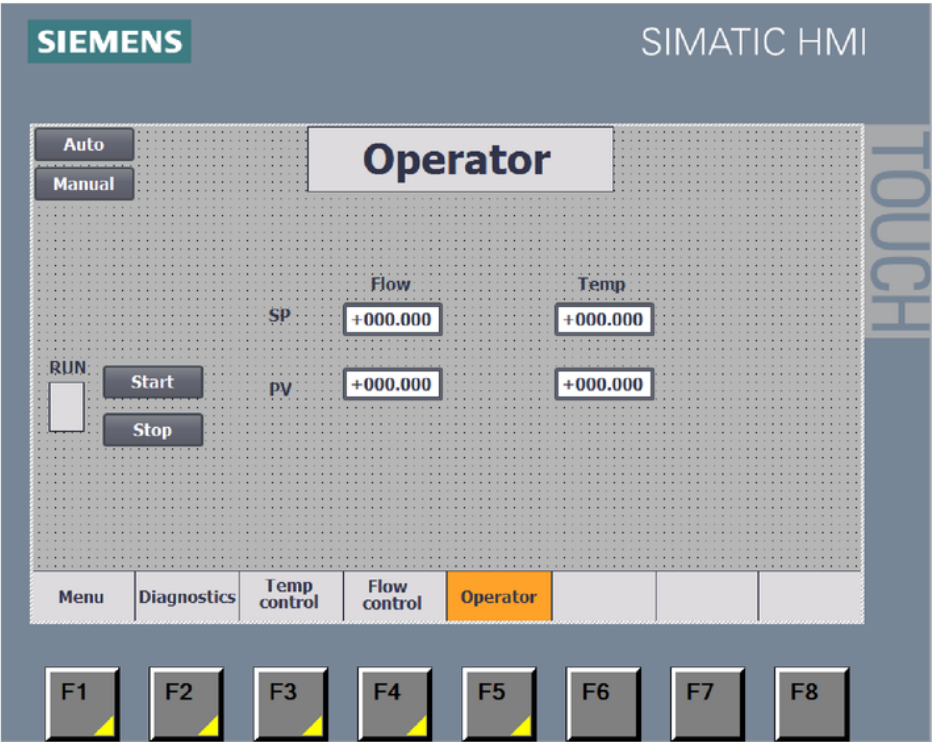
Flow Control Screen



Temperature Control Screen



Operator Screen



3. Program Testing, Results and Evaluation

Manual control testing

Action	Expected Result	Actual Result
Indicator Lamp Test	When the lamp test switches on the HMI are activated, all the indicator lamps on the rig should illuminate.	Pass
Check Temperature Scaling	On the diagnostic HMI screen the raw ADC values can be seen alongside the scaled values. These values should match the fixed temperature displays on the rig.	Pass
Check Flow Rate Scaling	With the pump motor running compare the scaled value from the flow rate sensor with the display on the rig.	Pass
Manual Pump Test	Using the diagnostic screen in manual mode activate the pump motor using the HMI.	Pass
Process Tank Level Interlock Test	Before the process tank is full an attempt to turn the heating element on should be made. It should not turn on.	Pass
Manual Heater and stirrer Test	Using the diagnostic screen, turn the heating element on and observe the temperature of the water in the process tank. The Stirrer should be active when the heating element is on.	Pass

you could have described what actually happened and figures could have been linked to each test as evidence.

Automatic Control Testing

Action	Expected Result	Actual result
Putting values in the set points	Entering values in the set point fields on the operator screen which should the appear in the sp fields of the control pages	Pass
Setting the rig into auto mode	Toggling the auto button on the operator screen should do the same on all screens	Pass
Pressing the start button	When the start button is pressed and the process tank is empty, the pump motor should start and quickly settle to the pre-set flow rate.	Pass
The tank full indicator illuminates	When the tank full indicator illuminates, the pump motor should stop and the heating element and the stirrer should turn on.	Pass
Observe the PID control whilst heating	When the heating element is turned on, the PID control should set the output at 100% duty cycle.	Pass
Observe the PID control when nearing set point	As the temperature of the water nears the set point the duty cycle should reduce and the temperature should reach the set point with little or no overshoot.	Pass



Figure 7 Lamp illumination test

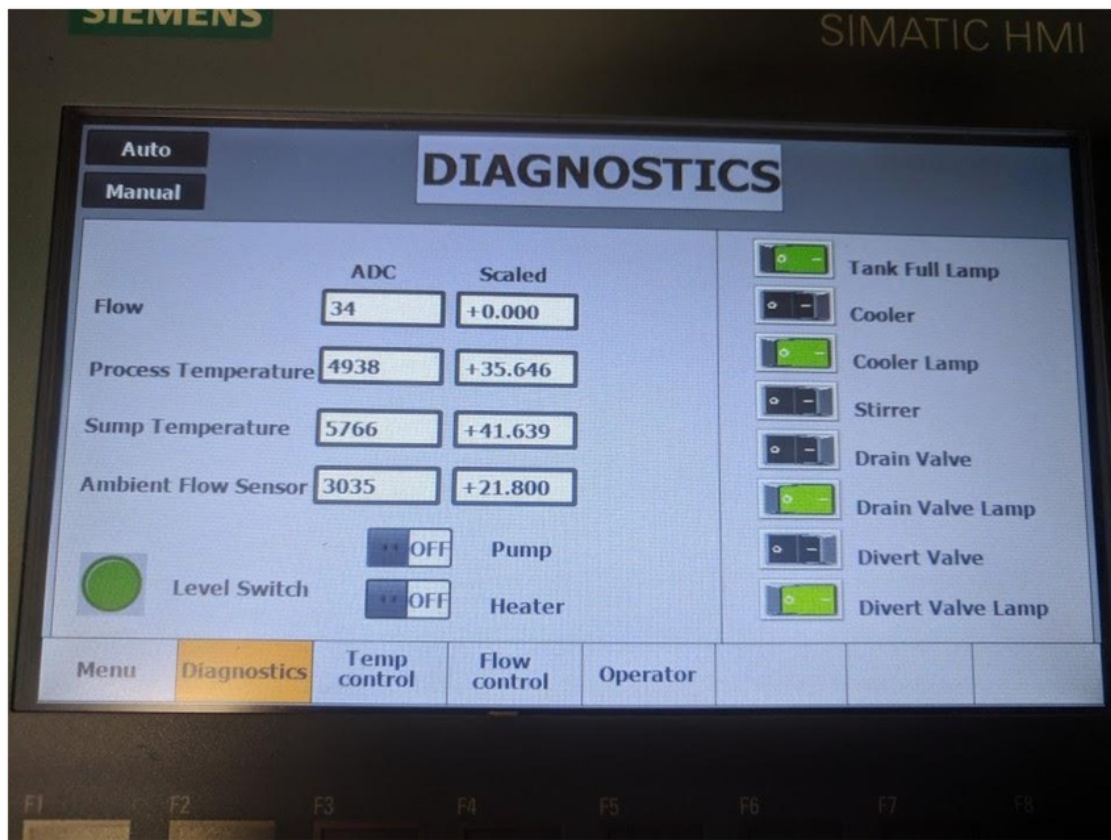


Figure 8 Diagnostic Screen



Figure 9 Operator Screen with set points

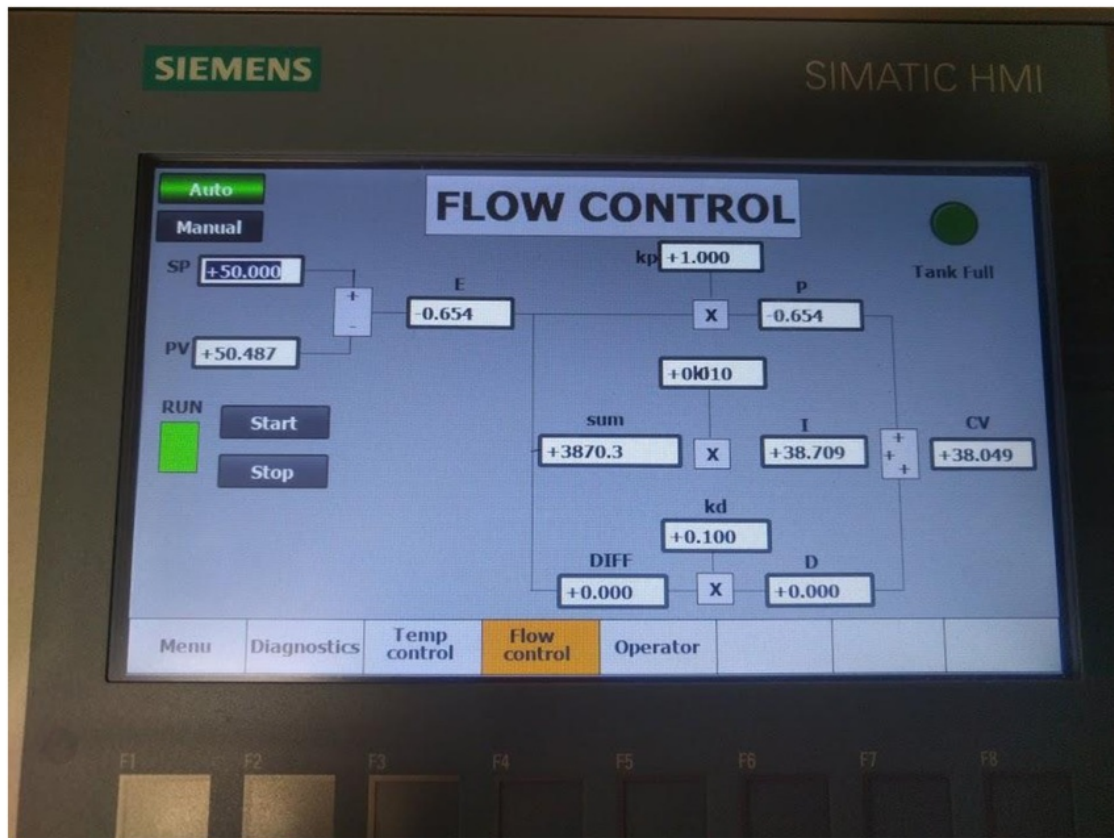


Figure 10 Flow Control Screen whilst pumping

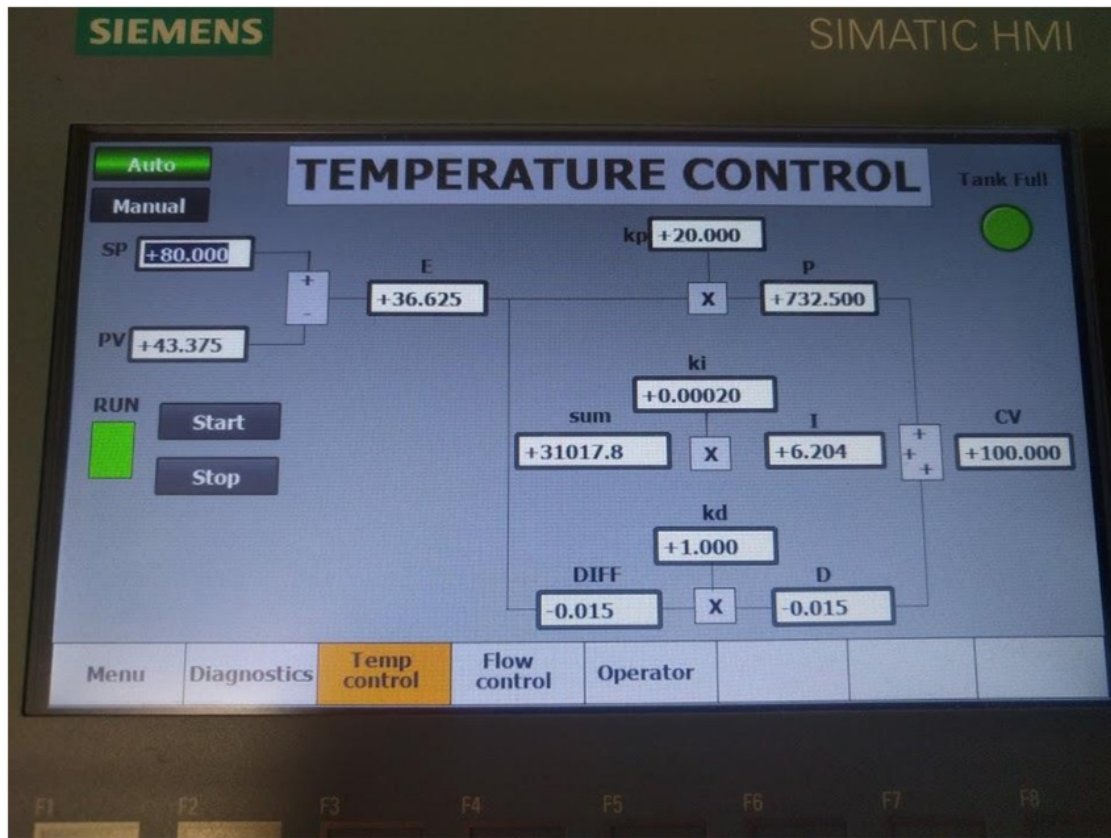


Figure 11 Temperature control screen whilst heating at full duty cycle

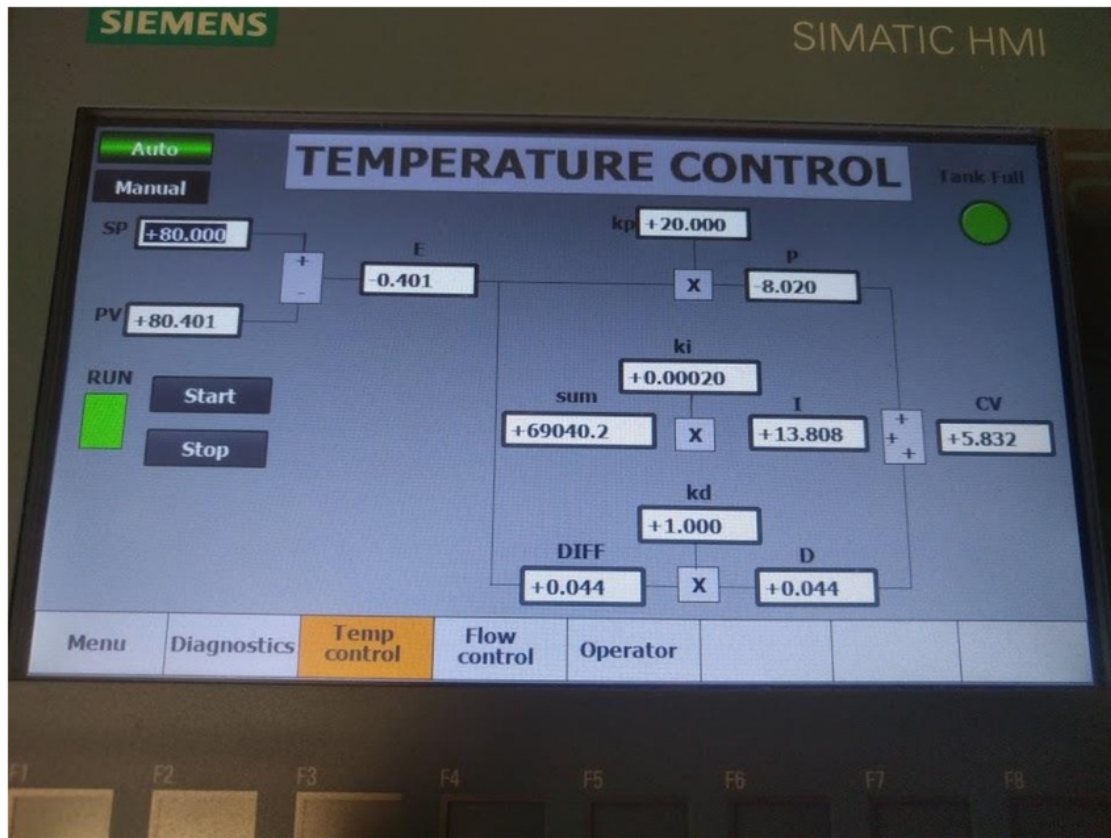


Figure 12 Temperature Control screen whilst maintaining set temperature

4. Safety, Maintenance, Reliability and Sustainable Development

The main safety consideration to take into account when using the process rig is the presence of hot liquids with the heater capable of raising the water temperature to over 100 degrees. The system is closed loop and there are covers over both tanks so the main concern would be with leaks from joints in the pipework. Signs are present warning of danger from hot surfaces. There is also the added danger of water near electrics, however the system runs on 24V so the risk is low but is present nonetheless.

Improvements in this area could include insulation on the pipework and tank surfaces so the risk of burns from touching is removed. The rig could be placed on a bunded stand so that in the event of a leak, the hot water runs safely away into a sump. Also the electrical and electronic control systems could be mounted in an IP rated enclosure where they would be safe from water ingress.

When carrying out maintenance operations on the rig it is important to let the whole thing cool down from being used before and work starts. Also draining the water from the system would be prudent in case of accidental operation or leak creation.

The reliability of the system should be good with only the pump motor and the heating element being placed under any stress. However in the event of either of these components failing, the down time could be significant.

Developing the rig to improve its sustainability can be achieved by increasing its efficiency. As previously mentioned, the insulation of the pipes and tanks can work not just as a safety improvement but efficiency too, leading to the water heating up faster and requiring less energy to maintain a temperature. The type of motor could be changed from a brushed DC type to a brushless type as they are more powerful and efficient.

5. Conclusions and Recommendations

The program design was deemed a success as it met all of the requirements of the testing plan. Only very fine tuning was required of the PID values to improve settling time and stability. Once this was completed the operation of the pump motor and heating element by PID controlled PWM worked satisfactorily in that the pumps speed was adjusted to keep the flow at a constant rate in a stable fashion and also the heating element maintained the set temperature of the water accurately.

The program could be improved by introducing automatic control of the heat exchanger bypass valve and the drain valve. This could then allow the automatic cooling of the water using the heat exchanger and fan as the water circulates through the system.

6. Description of Team Working

Assignment 3

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

58/100

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Text Comment. you could have described what actually happened and figures could have been linked to each test as evidence.

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GRADING FORM: CSG-RUBIC

CHRISTOPHER MILNER

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RESEARCH-INFORMED LITERATURE



n/a

KNOWLEDGE AND UNDERSTANDING



Section 1: System description – Briefly given with supporting photos, I/O list and system requirements. (8/15) Section 2: Program explanation – Some network rungs have comments and some have titles only. Tag list provided, screens are included. However, no explanation given for program or screens. (9/15)

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ANALYSIS



Section 3: Testing – A good testing table covering most aspects including heater interlock. (6/10) Section 3: Results and Evaluation – Evidence provided but could be linked with the testing table and evaluation. (6/10) Section 4: Conclusions and Recommendations – Some conclusions offered and recommendation given. (5/10)

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PRACTICAL APPLICATION AND DEP.



Section 2: Program design – Very well designed and also the screens. (10/10) Section 4: Safety, Maintenance, Reliability and Sustainable development – Risk assessment included in written form but could be in table format. Some consideration given to maintenance and reliability and sustainable development. (9/15)

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SKILLS FOR PROFESSIONAL PRAC.



All sections – Report is well structured, pages and figures have been numbered, one blank page noted. Little description given. (5/10) Section 6: Team working – Not mentioned(0/5)

5