

PSDE4005 Assingment 3

by Jonathon Williams

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HNC Electrical & Electronic Engineering
PSDE4005 Programmable Logic Controllers

2017-2018

Process Control System Design

Assignment No. 3

Jonathon Williams

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System Description

The Bytronic Process Rig, is controlled with a Siemens Simatic S7-1200 PLC with an additional analogue output module and a SM 1231 module added. Figure 1 shows an overview of the system.



Figure 1: Overview of the Bytronic Process Rig

Table 1 below contains a description of the hardware for the system.

Table 1: Hardware Description

Hardware	Description	Figure
Flow Rate Sensor	Flow rate sensor is used to measure the flow of a substance in a given area, i.e. in a pipe. This flow rate sensor has 6 blades which when it turns creates a pulse, the rate of this pulse then goes into a and produces a signal between 0 – 5v which is connected to the PLC input. This value can then be scaled to produce a flow rate.	Figure 2
Indicator Lamps	Lamps are used to indicate that a particular piece of equipment is switch on.	Figure 3
Temperature Sensor RTD (Resistance Temperature Detector)	The temperature sensor is used to measure the temperature in the two tanks and the ambient temperature of the room. They work by measuring the resistance. As the temperature changes, the resistance in the sensor changes. This then goes through a ___ and is imputed into the PLC. This is then scaled to give you a temperature in °C	Figure 5
HMI	Human machine interface, can be used to send inputs or display outputs	
PLC	Programmable Logic Controller, sores the PLC program and	
Solid State relay	Used so that the low control voltage can be used to turn on the heater which has a higher voltage requirement.	
DC pump	DC pump used to pump water from the sump tank to the process tank.	Figure 6

what type of pump was it?

Divert Valve	A valve that is operated via a solenoid that will divert which way the water goes around the system.	Figure 4
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Figure 2: Flow rate sensor



Figure 3: Indicator Lamps

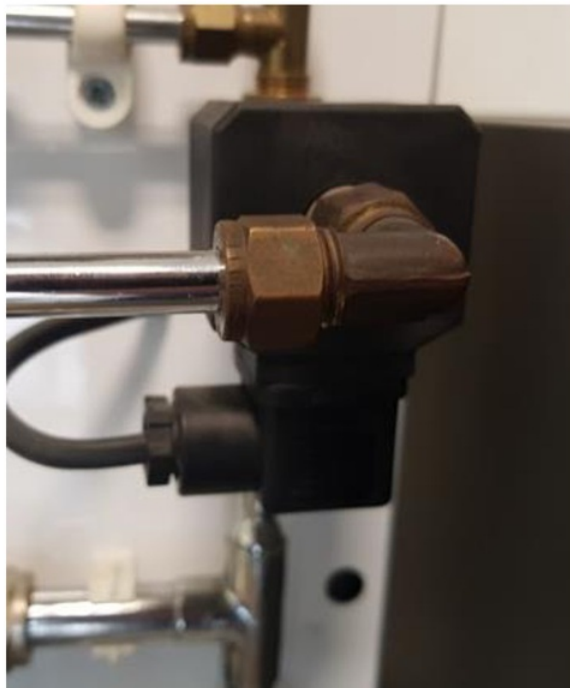


Figure 4: Divert Valve



Figure 5: Level Switch & RTD Temperature Sensor



Figure 6: DC Motor

Program Design and Explanation

Table 2 below is the I/O list for the system.

Table 2: I/O List

this table belongs in
section 1

Input		Output	
Address	Tag Name	Address	Tag Name
I1.0	Level Switch	Q0.0	Cooling Fan
IW66	Flow Rate Sensor	Q0.1	Stirrer
IW96	RTD Process Tank Temperature Sensor	Q0.2	Drain Valve
IW98	RTD Sump Tank Temperature Sensor	Q0.3	Divert Valve
IW100	RTD Ambient Temperature Sensor	Q0.4	Cooler Lamp
		Q0.5	Drain Valve Lamp
		Q0.6	Divert Valve Lamp
		Q0.7	Tank Full Lamp
		Q1.0	Heater
		Q1.1	Pump
		QW1000	Flow%CV PWM Duty Cycle
		QW1002	Process Temperature %CV PWM Duty Cycle

Figure 7 displays the PLC Tag list.

1		LEVEL SWITCH	Default tag table	Bool	%I1.0
2		FLOW RATE SENSOR	Default tag table	Word	%IW66
3		RTD PROCESS TANK TEMP SENS...	Default tag table	Word	%IW96
4		RTD SUMP TANK TEMP SESNOR	Default tag table	Word	%IW98
5		RTD AMBIENT TEMP SENSOR	Default tag table	Word	%IW100
6		COOLING FAN	Default tag table	Bool	%Q0.0
7		STIRRER	Default tag table	Bool	%Q0.1
8		DRAIN VALVE	Default tag table	Bool	%Q0.2
9		DIVERT VALVE	Default tag table	Bool	%Q0.3
10		COOLER LAMP	Default tag table	Bool	%Q0.4
11		DRAIN VALVE LAMP	Default tag table	Bool	%Q0.5
12		DIVERT VALVE LAMP	Default tag table	Bool	%Q0.6
13		TANK FULL LAMP	Default tag table	Bool	%Q0.7
14		HEATER	Default tag table	Bool	%Q1.0
15		PUMP	Default tag table	Bool	%Q1.1
16		FLOW %CV PWM DUTY CYCLE	Default tag table	UInt	%QW1000
17		PROCESS TEMPERATURE %CV P...	Default tag table	UInt	%QW1002
18		HMI COOLER	Default tag table	Bool	%M0.1
19		HMI STIRRER	Default tag table	Bool	%M0.2
20		HMI DRAIN VALVE	Default tag table	Bool	%M0.3
21		HMI DIVERT VALVE	Default tag table	Bool	%M0.4
22		LAMP TEST	Default tag table	Bool	%M0.5
23		AUTO	Default tag table	Bool	%M0.0
24		HMI HEATER	Default tag table	Bool	%M0.6
25		HMI PUMP	Default tag table	Bool	%M0.7
26		Auto Start	Default tag table	Bool	%M1.0
27		Auto Flow	Default tag table	Bool	%M1.1
28		Auto Heater	Default tag table	Bool	%M1.2
29		HMI Auto Start	Default tag table	Bool	%M1.3
30		HMI Auto Stop	Default tag table	Bool	%M1.4
31		Auto Run	Default tag table	Bool	%M1.5

Figure 7: PLC Tag list

The 'Main' block contained all the manual controls as well as the triggers for the automatic sequences.

Figure 8 shows the ladder for setting and resetting the auto run memory bit which is used to control the automatic sequence.

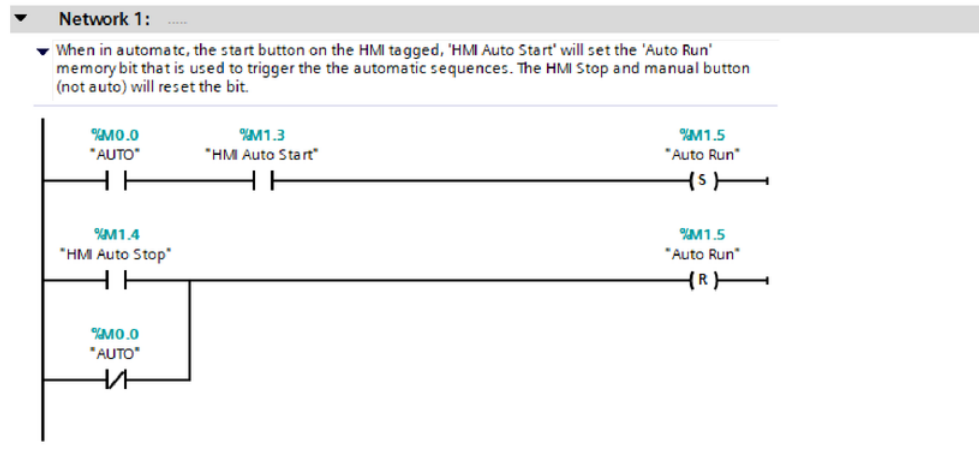


Figure 8: Network 1 - Auto Run

Figure 9 shows which part of the automatic sequence is selected depending on the conditions specified in the program.

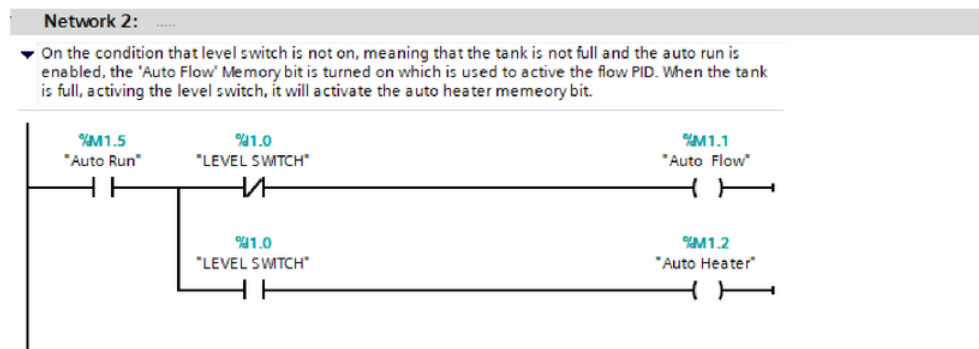


Figure 9: Network 2 - Selecting Auto Flow / Heat

Figure 10 shows the ladder rung which controls the stirrer in both manual and automatic mode.

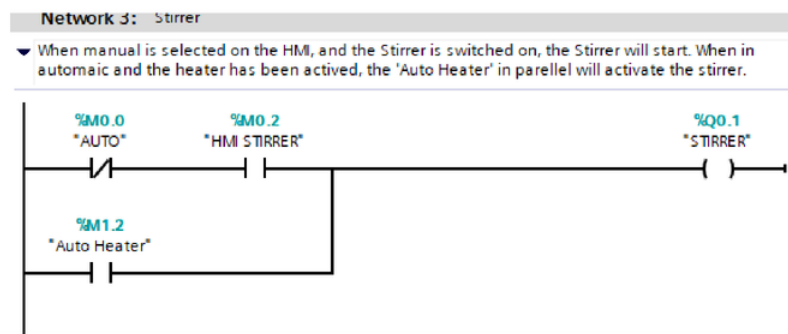


Figure 10: Network 3 - Stirrer controls

Figure 11 shows the software for the drain valves. It also had a lamp test feature. The lamp test input is in parallel with all conditions that would need the lamp turned on. This gives the engineer the ability to check that all the lamps are working.

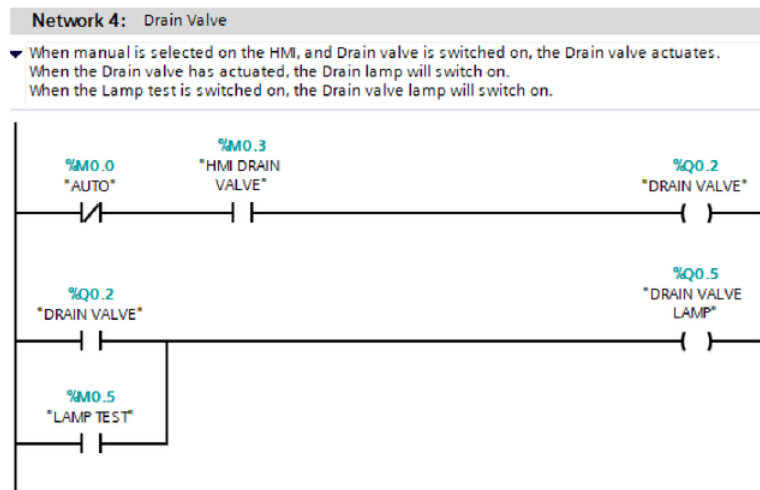


Figure 11: Network 4 - Drain Valve

Figure 12 shows the rungs for the cooler

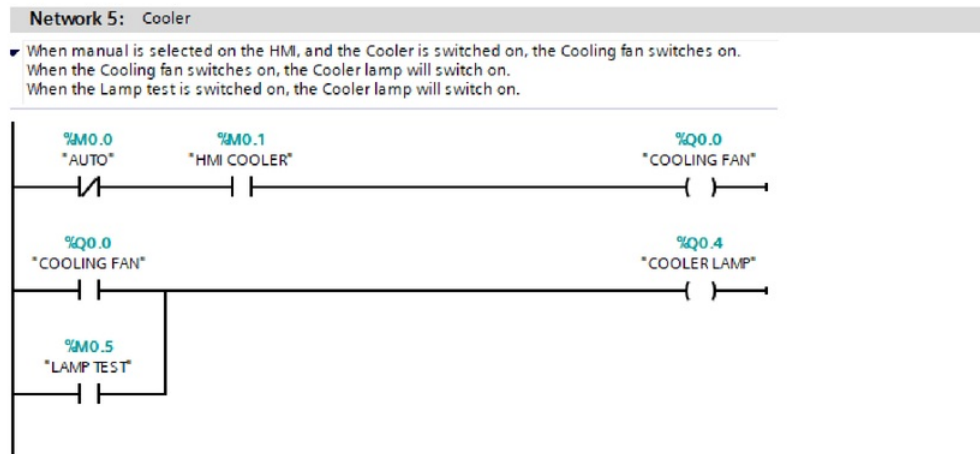


Figure 12: Network 5 – Cooler

Figure 13 shows the rungs for the divert valve.

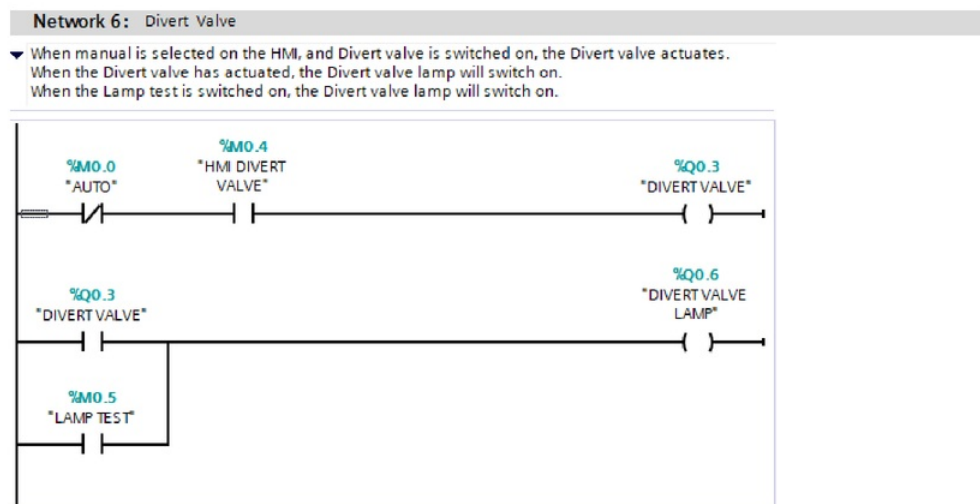


Figure 13: Network 6 - Divert Valve

Figure 14 shows the ladder rung that controls the heater in manual.

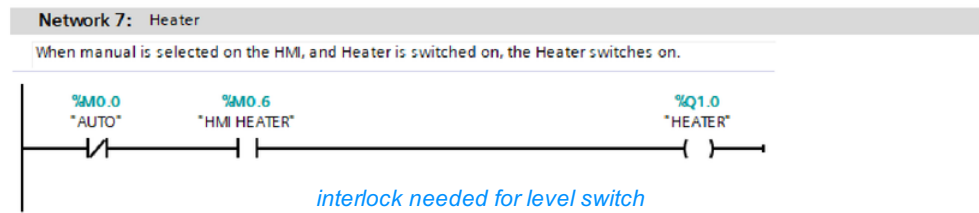


Figure 14: Network 7 – Heater

Figure 15 shows the controls for the pump.

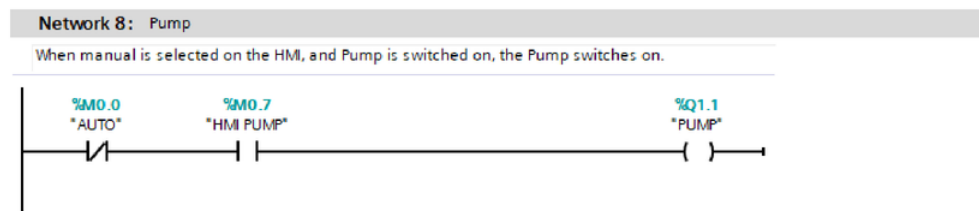


Figure 15: Network 8 – Pump

Figure 16 shows the rung that control the tank full lamp. When the level switch is made, it will turn on the tank full indicator lamp. The lamp test is in parallel so you can ensure the lamp is working.

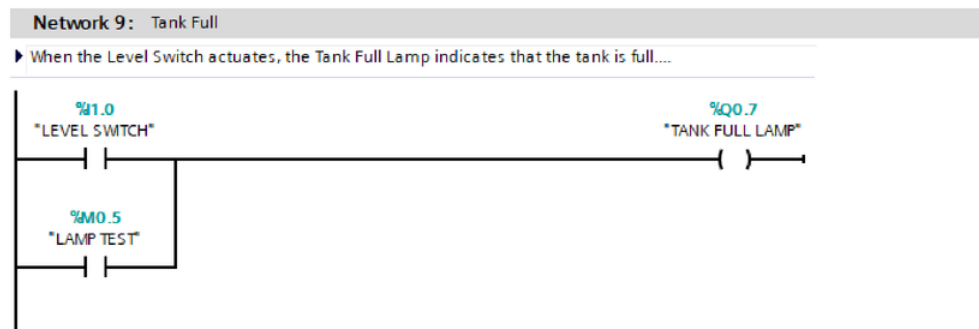


Figure 16: Network 9 - Tank Full

Figure 17 shows the rung where the scaling function block is used.

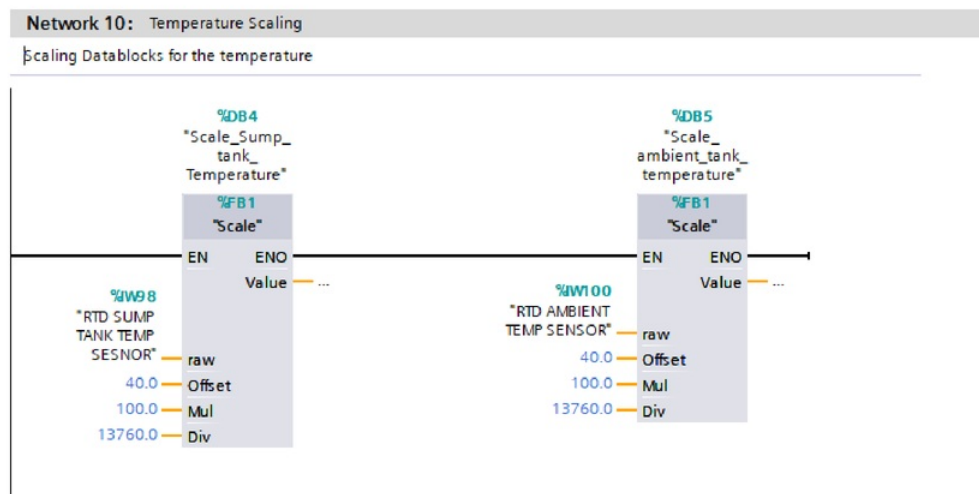


Figure 17: Network 10 - Temperature scaling

Figure 18 shows the PWM control for the flow and what enables it which is the auto flow memory bit which is controlled by a rung earlier in the cycle.

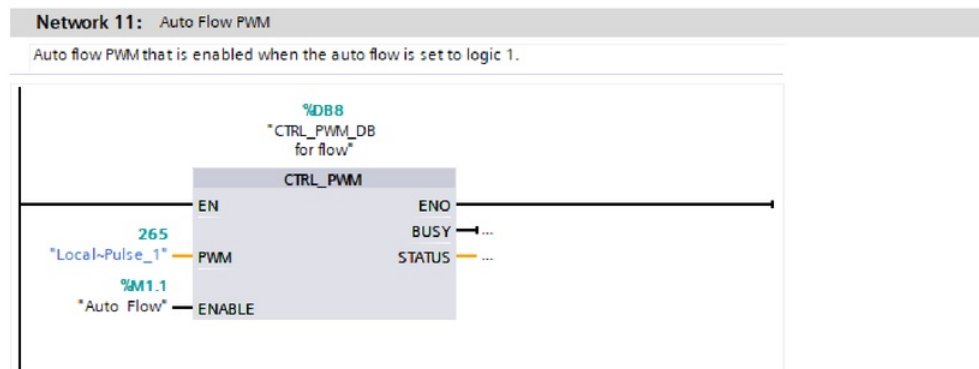


Figure 18: Network 11 - Auto Flow PWM

Figure 19 shows the PWM control for the temperature and what enables it which is the auto heater memory bit which is controlled by a rung earlier in the cycle.

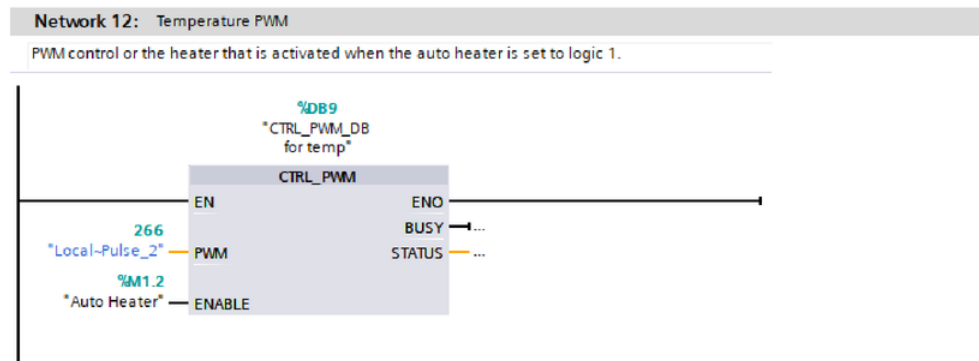
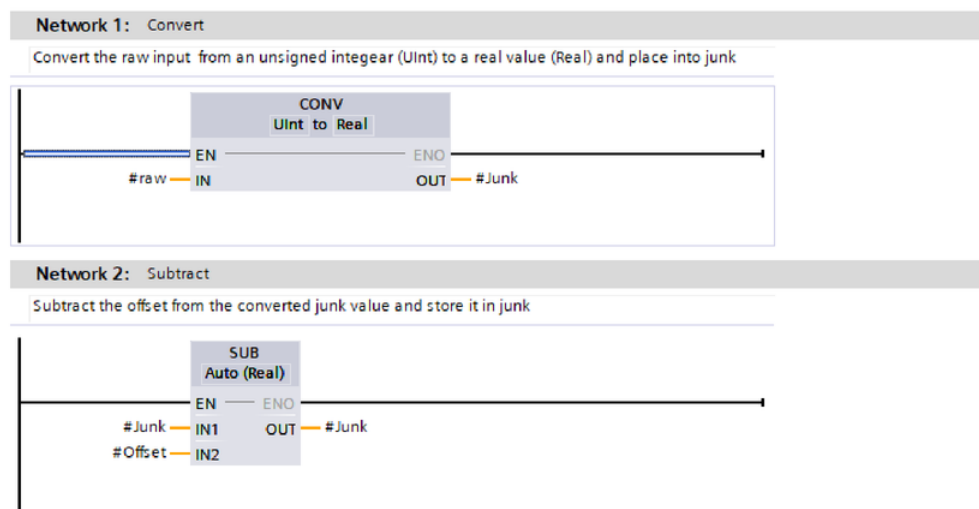


Figure 19: Network 12 - Temperature PWM

The Scaling to get the results is shown in Figure 20.



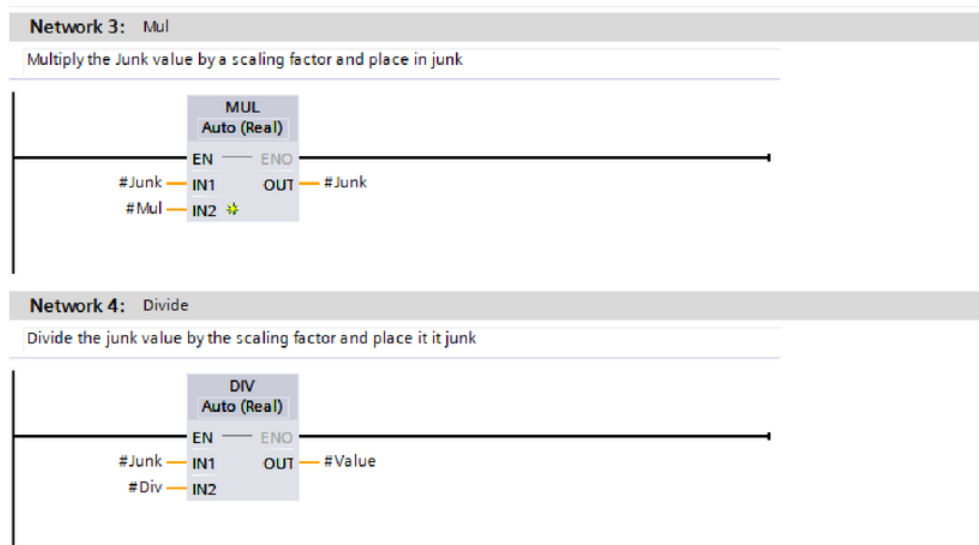
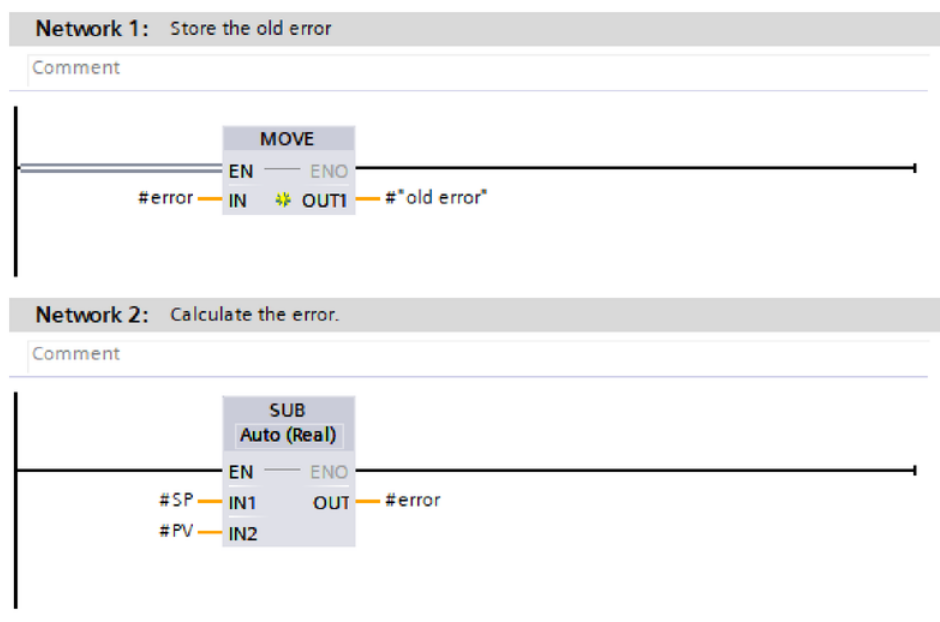


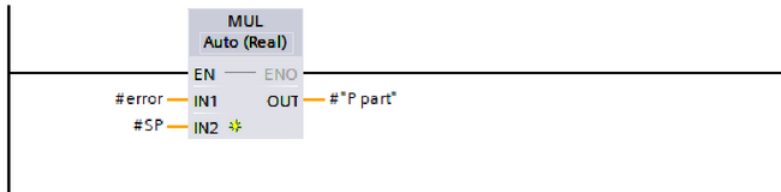
Figure 20: Scaling Function block

Figure 21 shows the Function Block for the PID control. This function block was then used twice, one for flow and one for temperature.



Network 3: Calculate the P Part

Comment



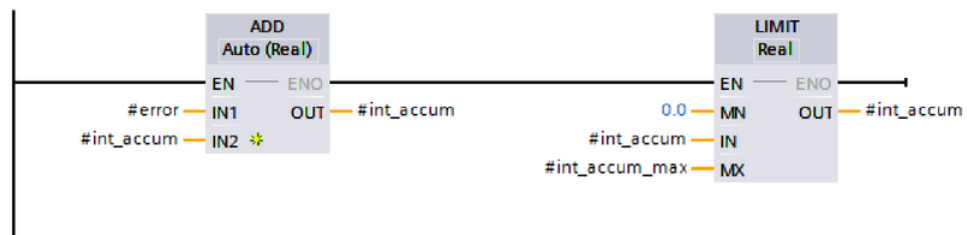
Network 4: Reject erroneous values of the ki and calculate integral accumulator max value

Comment



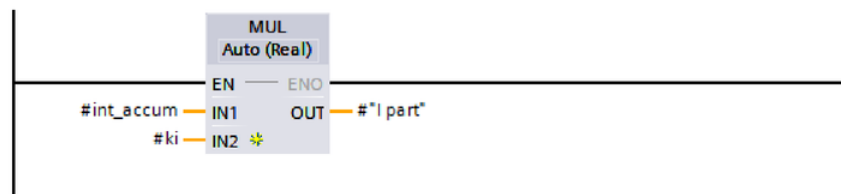
Network 5: Update the integral accumulator

Comment



Network 6: Calculate the i part

Comment



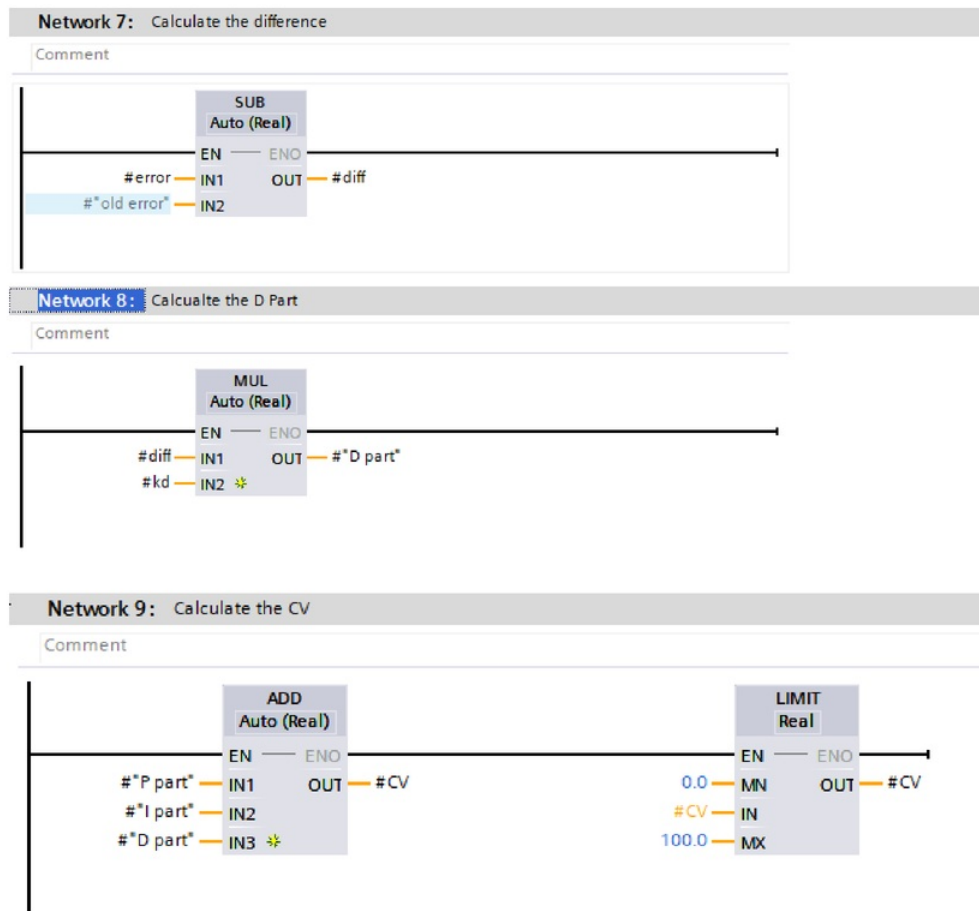


Figure 21: PID Function Block

Figure 22 & Figure 23 show the cyclic interrupts for the PID control including the mathematical values needed.

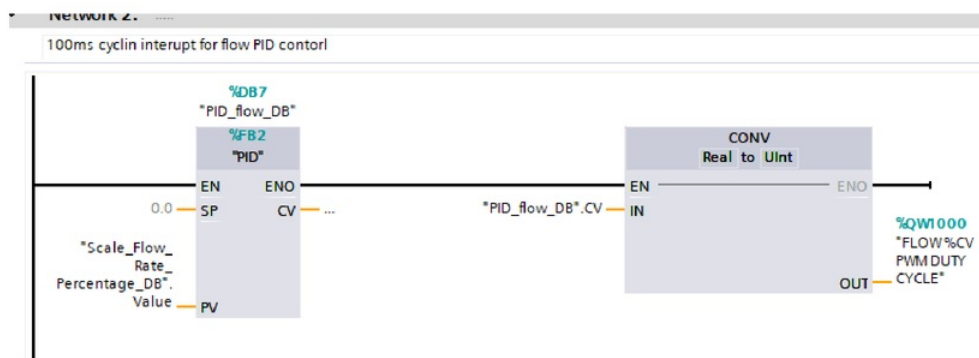


Figure 22: Flow cyclic interrupt

where is network 1?

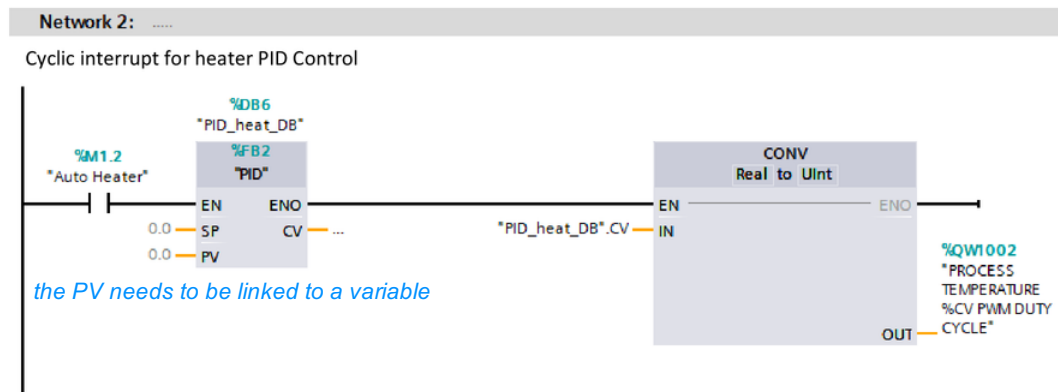


Figure 23: Cyclic interrupt for heat

Figure 24 to Figure 26 show the HMI design for the Engineers screen. The engineer's screen has the ability to control each output individually as well as displaying the raw and scaled values for the flow rate and temperature. It also displays the PID control for temperature and flow. Figure 27 shows the HMI design for the operator who only needs to start and stop the sequence, see when the tank is full and control the set points for the flow and heater. It also displays the current value.

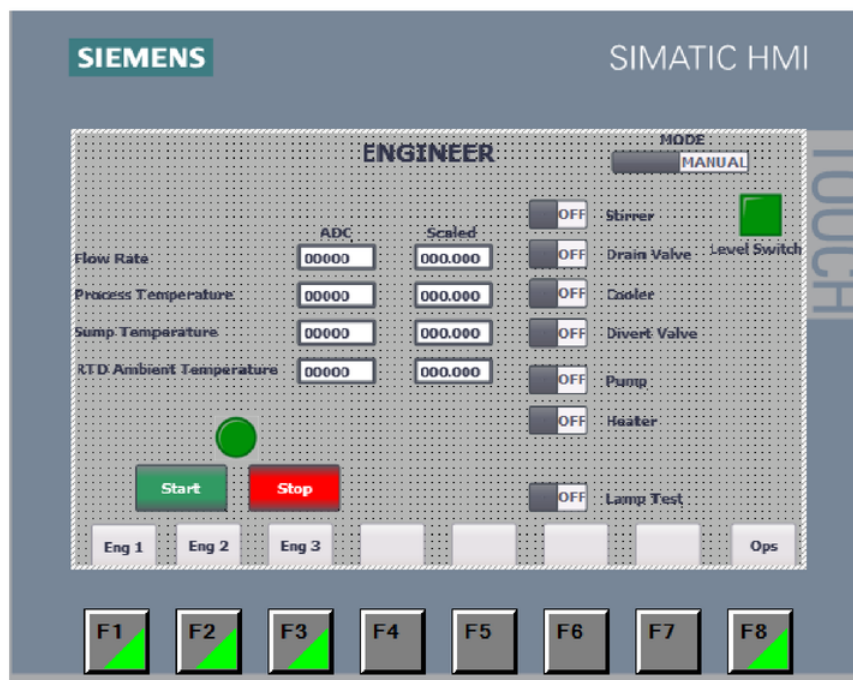


Figure 24:Engineer's screen 1 HMI design

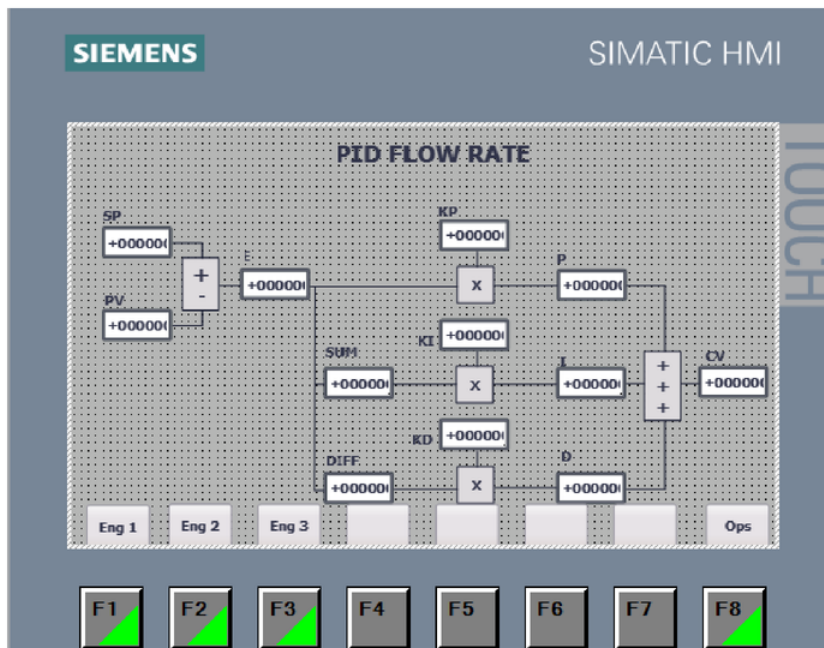


Figure 25: Engineer's screen 2 HMI design

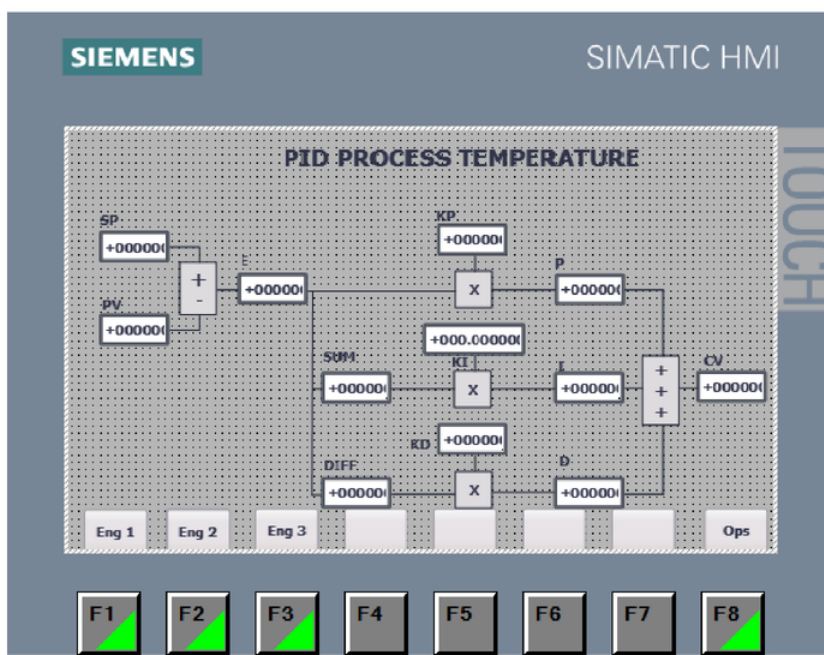


Figure 26: Engineer's screen 3 HMI design

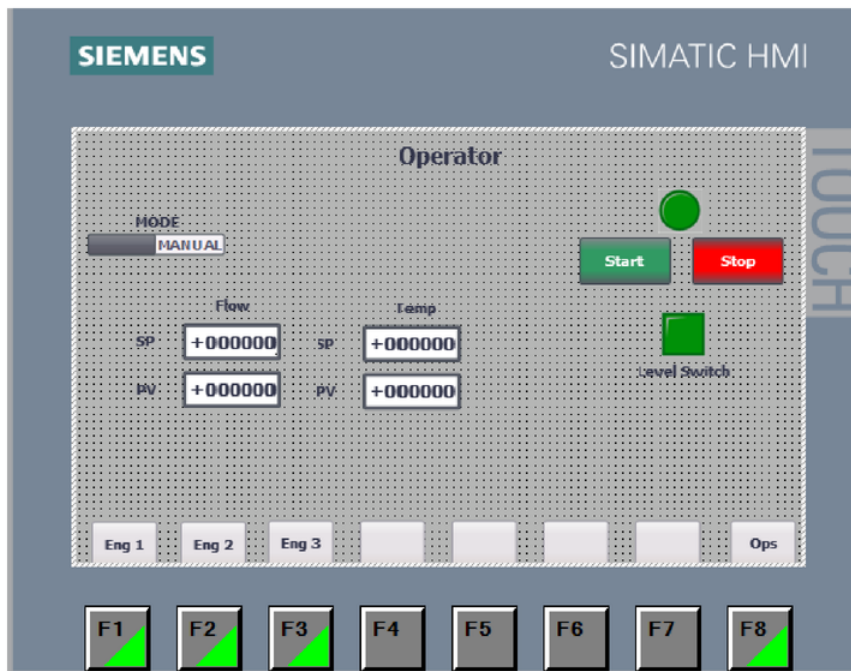


Figure 27: Operators Screen HMI design.

Program Testing, Results and Evaluation

Table 3 is the testing table used for the program.

Table 3: Test table

pass/fail ?

Test Number	Test	Expected Result	Actual Result
1	Navigate the four HMI screens by pressing the 'Function' keys which should take you to the different pages. Screens are assigned to F1,F2,F3,F8	The function keys navigate through the different screens. F1 – Eng 1 F2 – Eng 2 F3 – Eng 3 F8 – Operator	<i>evidence needed and linked to photos</i> Function buttons allow you to navigate through the different screens with no problems and load up the correct screen.
2	Turn on pump manually	Pump should run in manual mode	Pump ran in manual
3	Heater runs in manual <i>interlock should be tested</i>	Heater should run in manual mode	Heater ran in manual
4	Select to manually operate divert valve on HMI and check lamp illuminates.	Divert valve should operate when selected and the lamp should illuminate	Divert valve operated correctly and indicator light illuminates.
5	Select to manually operate cooler fan on HMI and check indicator lamp illuminates.	Cooler fan should operate when selected and the lamp should illuminate	Cooler fan operated correctly and indicator light illuminates.
6	Stirrer works in manual when selected on the HMI	Stirrer should run when selected	Stirrer ran when selected.
7	Select to manually operate the drain valve on HMI and check lamp illuminates.	Drain valve should operate when selected and the lamp should illuminate	Drain valve operated correctly and indicator light illuminates.
8	Run the pump so that the tank fills, Level switch operators when tank is full (HMI pilot light illuminates) and indicator light illuminates	When the tank is full, the level switch should activate and the HMI pilot light turns on and the 'Tank Full' indicator light should illuminate.	When the tank is full, the level switch pilot light on the HMI turns on and the indicator light illuminates.

9	Run the pump in manual, when the tank is full, the pump should turn off	When pump is running in manual, pump turns off when tank is full and indicator light should illuminate.	Pump switches off when tank is full and corresponding indicator lights illuminate.
10	Select lamp test on HMI.	All indicator lights should illuminate.	All indicator lights illuminated.
11	Select auto run and the pump should run automatically, powered by the PID control.	Pump runs automatically when auto start is pressed. As the tank gets filled more, the program slows down the pump not to overfill.	Pump runs when start is selected. PID works and slows down the pump not to overfill the tank
12	Once tank is full, auto heat and stirrer are active	Auto heat and stirrer activate when tank is full	Auto heat and stirrer activated when tank is full
13	When the program is in automatic mode, start is selected and the tank is full	Heater runs automatically when auto start is pressed. As the tank gets close to temperate, the program slows down the heater so that the tank does not get over heated The stirrer should run throughout. .	heater runs when start as selected and tank is full. PID works and slows down the heater not to overheat the water. Stirrer runs throughout

Figure 28 below shows the test lamps working.



Figure 28: Test lamps working



Figure 29: Operators HMI screen

Figure 30 shows the engineers screen when the tank is full, meaning the heater is running. The tank is full is indicated by the level switch pilot light in the top corner.

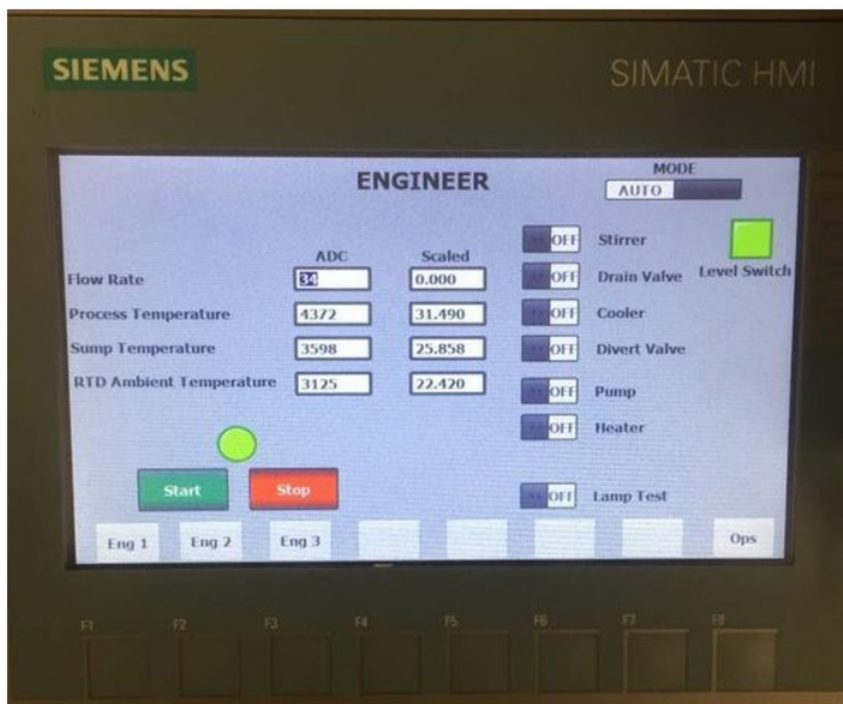


Figure 30: Engineers Screen 1

Figure 31 shows the PID control for flow functioning.

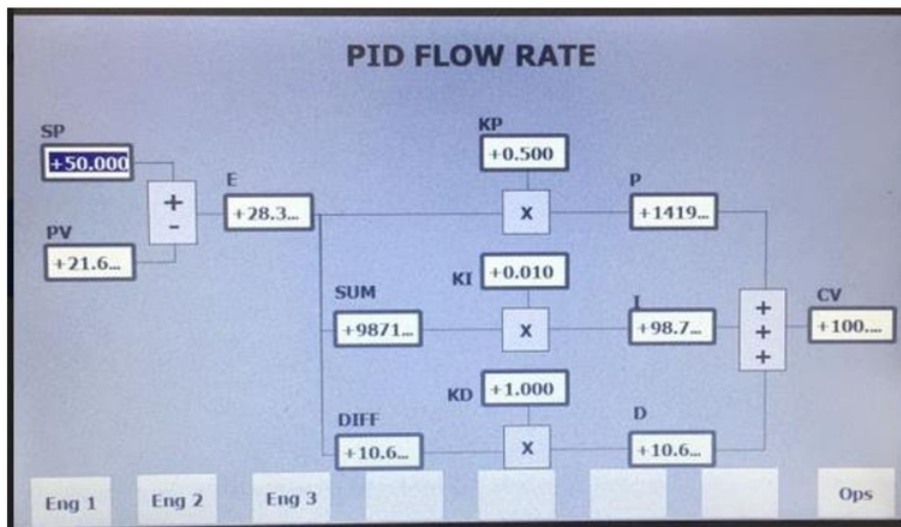


Figure 31: PID Flow rate functioning

Figure 32 shows the PID control for temperature working.

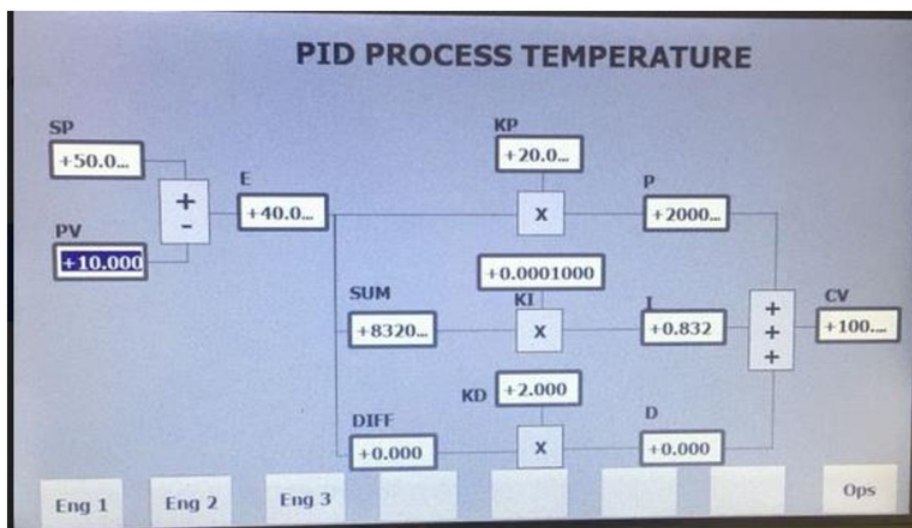


Figure 32: PID Temperature functioning

Safety, Maintenance, Reliability and Sustainable Development

Table 4 contains a risk assessment for the process rig

Table 4: Process Rig Risk Assessment

What are the Hazards?	Who might be harmed	Current Level of Risk	Control measure(s)	Remaining level of risk	Recommendations
Entrapment from moving parts	Operator	High	Guarding over the top of the tank, reducing chance of getting caught in the stirrer	Medium	The top end of the stirrer before it enters the tank is still exposed, this could be guarded to reduce risk. Interlock the lid so that if it is removed, the stirrer cannot run.
Burns & Scolds	Operator	Medium	Lid on top of the tanks which would contain hot liquids restricts access to hot fluids.	Low	Interlock tank lid so that if it is removed the heater cannot start.
		Medium	Warning label on tank warning people that tank and pipes maybe hot	Low	Insulate the pipes
Electrocution	Operator	Low	All wiring is run away from water and all components have a suitable IP rating.	Low	
Unauthorised use	All		Engineers manual controls are on a separate screen to the operators.	Medium	Password protect the engineers screen.

By using PID and PWM control, it is helping towards sustainable development. For example, when using the PID control for the heater, the heater puts less heat into the water as the temperature gets to temperature. If this features did not exist, the water would over heat meaning it would then have

needed to be drained, sent through the cooling system and then pumped back into the process tank using more energy and resulting in a higher production cost.

For effective maintenance of the system, engineer's screen was created on the HMI. The engineer's screens are shown in Figure 24 to Figure 26. The screens have the ability to manually operate each component as well as a lamp test option to test that indicator lights are working. This is useful for if an operator told you something was not working because the indicator was not on, it could just be because the lamp has blown rather than a deeper issue.

Conclusion & Recommendations

This report explains the PLC system design concepts for an industrial process rig. An investigation of the hardware used on the process rig shows that it comprises a divert valve, flow sensor, Resistance Temperature Detector pump and a solid state relay. An input-output list (I/O list) was created and from the I/O list a tag list was devised which would assist with the programming.

The system was fully tested and when the actual results were compared with the theoretical expectations, it showed that the PLC system design and implementation process did achieve the actual outputs that were expected. This demonstrated that the system was operating correctly. To ensure its effective maintenance and reliability, four HMI screens were created-one for the operator and three for the engineer. The engineer's screen is used for maintenance control to test individual components, whereas the operator's screen is used for operational control. This demonstrated that a system could be developed which includes built in maintenance checks and reliability checking.

To further improve the system there are improvements that I would make which are also suggested in the risk assessment. The main change I would make, would be to add a password to the engineer's HMI screens. By doing this, it will prevent unauthorised access to the screen meaning that the use of manual controls is restricted to authorised personnel.

Description of Team Work

During this project, I worked with a fellow student. Some of the work was shared out where we had our own specific tasks and other parts were worked on collectively. The program hardware configuration and the creation of the PLC 'Tag List' was done together to ensure that we both had to the same versions and that we used the same IO. When writing the manual controls, I wrote the ladder controls whereas my partner designed and created the HMI. The test table was created by us both thinking of test criteria. The reason we both devised the test table was to ensure that we did not miss any of the tests.

The automatic control was written together to ensure that the PID control was written correctly. The risk assessment was also done collectively to ensure that no hazards were missed and that the best recommendations were thought of.

At the end of each session when we were working on the software. We ensured that both of us had an up-to-date version of the software saved onto a USB and/or onto our hard drive. Once the software had been completed and tested, we all individually imputed our own comments on to the networks in the program. The work that was shared was the program design as stated, however, all drawings, figures and tables were unique to both individuals.

PSDE4005 Assingment 3

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

60/100

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

Text Comment. what type of pump was it?

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10

Text Comment. this table belongs in section 1

PAGE 11

PAGE 12

PAGE 13

PAGE 14

PAGE 15

Text Comment. interlock needed for level switch

PAGE 16

PAGE 17

PAGE 18

PAGE 19

PAGE 20

PAGE 21

Text Comment. where is network 1?

Text Comment. the PV needs to be linked to a variable

PAGE 22

PAGE 23

PAGE 24

Text Comment. pass/fail ?

Text Comment. evidence needed and linked to photos

Text Comment. interlock should be tested

PAGE 25

PAGE 26

PAGE 27

PAGE 28

PAGE 29

GRADING FORM: CSG-RUBIC

JONATHON WILLIAMS

60

RESEARCH-INFORMED LITERATURE

n/a



KNOWLEDGE AND UNDERSTANDING



Section 1: System description - Good description given in table form with supporting photos and a good I/O list. (8/15) Section 2: Program explanation - Many networks contain detailed comments and most have titles. Some explanations given. (8/15)

16

ANALYSIS



Section 3: Testing – Table contains many tests for manual and auto modes. (8/10) Section 3: Results and Evaluation – Evidence provided but should be linked to the table tests, evaluation should state pass or fail for each test. More evidence needed. (5/10) Section 4: Conclusions and Recommendations – Some given with 1 recommendation. (5/10)

18

PRACTICAL APPLICATION AND DEP.



Section 2: Program design – Generally a well designed program with good screens. Network 1 of each cyclic interrupt is missing. Heater should be interlocked with level switch. (6/10) Section 4: Safety, Maintenance, Reliability and Sustainable development – Some consideration given and risk assessment. (9/15)

15

SKILLS FOR PROFESSIONAL PRAC.



All sections – Good report structure but sections

should be numbered as stated in the brief. Pages are numbered and figures and numbered and listed correctly. However, you must not write in the first person except in the team working section. (7/10)
Section 6: Team working – Good explanation given but your team needs to be named. (4/5)