

PSDE 4005 - Assignment 3

by Jed Davies

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Control System Design



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colegsirgâr

Table of Contents

Table of Figures.....	1
System Description	3
Program Design and Explanation.....	7
Program Testing, Results and Evaluation	32
Safety, Maintenance, Reliability and Sustainable Development	39
Conclusion and Recommendations	41
Description of Team Working	41
Works Cited.....	42

Table of Figures

Figure 1 - System Overview (Davies, 2018).....	3
Figure 2 - Reciprocating Pump	4
Figure 3 - Turbine Flow Meter	4
Figure 4 - Float Switch.....	4
Figure 5 - Heating Element	5
Figure 6 - RTD.....	5
Figure 7 - Signal Converter	5
Figure 8 - Manual Control (Network 1).....	9
Figure 9 - Manual Control (Network 2).....	10
Figure 10 - Manual Control (Network 3).....	10
Figure 11 - Manual Control (Network 4).....	11
Figure 12 - Manual Control (Network 5).....	11
Figure 13 - Manual Control (Network 6).....	12
Figure 14 - Manual Control (Network 7).....	12
Figure 15 - Automatic Control (Network 1 & 2).....	13
Figure 16 - Flowrate Cyclic Interrupt	14
Figure 17 - Process Temperature Cyclic Interrupt	15
Figure 18 - Scaling Function Block.....	16
Figure 19 - Flowrate Scaling Data Block.....	16
Figure 20 - Example Scaling Data Block	17
Figure 21 - PID Control (Network 1 & 2)	18
Figure 22 - PID Control (Network 3 & 4)	19
Figure 23 - PID Control (Network 5 & 6)	20
Figure 24 - PID Control (Network 7 & 8)	21
Figure 25 - PID Control (Network 9).....	21
Figure 26 - PID Pump Control Data Block	22
Figure 27 - Main Sweep Cycle (Network 1 & 2)	23
Figure 28 - Main Sweep Cycle (Network 3 & 4)	24
Figure 29 - Main Sweep Cycle (Network 5 & 6)	25
Figure 30 - Main Sweep Cycle (Network 7 & 8)	26

Figure 31 - Main Sweep Cycle (Network 9).....	27
Figure 32 - Operator's HMI Screen	28
Figure 33 - Engineers 1 HMI Screen	29
Figure 34 - Engineers 2 HMI Screen	30
Figure 35 - Engineers 3 HMI Screen	31
Figure 36 - Test #1.....	33
Figure 37 - Test #2(a)	33
Figure 38 - Test #2(b)	34
Figure 39 - Test #3(a)	34
Figure 40 - Test #3(b)	35
Figure 41 - Test #3(c).....	35
Figure 42 - Test #3(d)	36
Figure 43 - Test #4.....	36
Figure 44 - Test #5(a)	37
Figure 45 - Test #5 (b)	37
Figure 46 - Risk Assessment	40

System Description

The focus of this task will be on the Bytronic Process Rig shown in Figure 1.

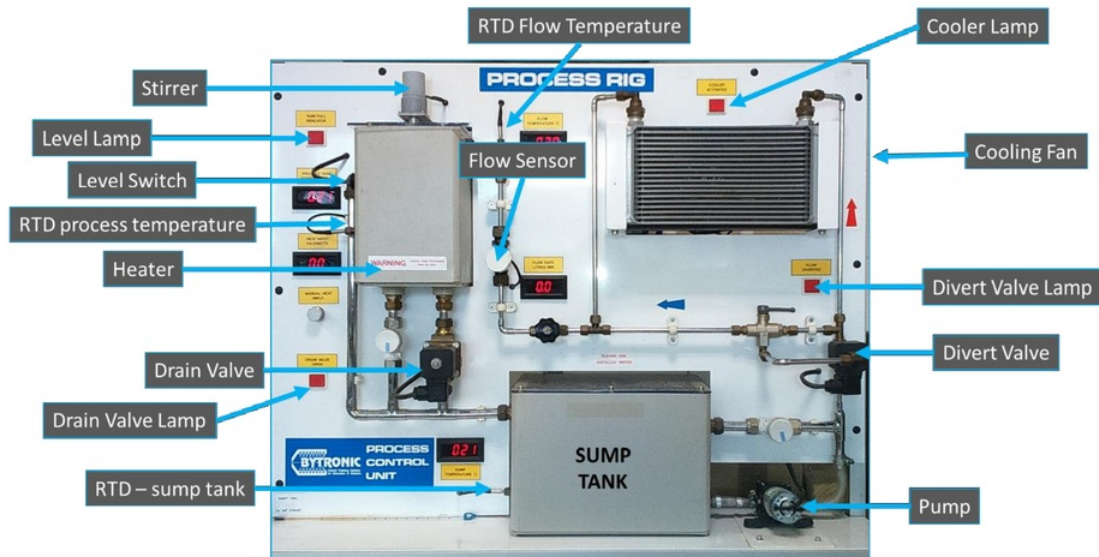


Figure 1 - System Overview (Davies, 2018)

There are four lamps mounted to the process rig which are digital outputs. These can be used to indicate whether an output is on or off.

There are two tanks, a process tank and a sump tank which are connected together by pipework. The water is pumped from the sump tank by a reciprocating pump. The water can then either go straight to the process tank or through the cooling fan depending on the state of the divert valve. Either way the flow then travels through the turbine flow meter. The water is held in the process tank by a manual valve and a solenoid valve. There is a level switch fitted within the process tank to indicate that the tank is full, and a stirrer used to circulate the water within the tank. To heat the water there is a heating element.

Reciprocating Pump

The pump used within the system is a reciprocating pump which requires a 12V supply and has the capability of producing a flow of up to 4.0 litres/minute. Shown in Figure 2



*image has not come out well,
however, printed copy was fine*

Figure 2 - Reciprocating Pump

Turbine Flow Meter

The flow meter has a 6-blade turbine within it which is turned by the flowing liquid. The optical sensor detects the speed that the turbine is turning at and outputs a pulse train. The frequency at which the pulse train is operating at can be converted to a voltage via a frequency to voltage (F/V) converter. It is calibrated so that 2 litres/min is equal to 5 Vdc.

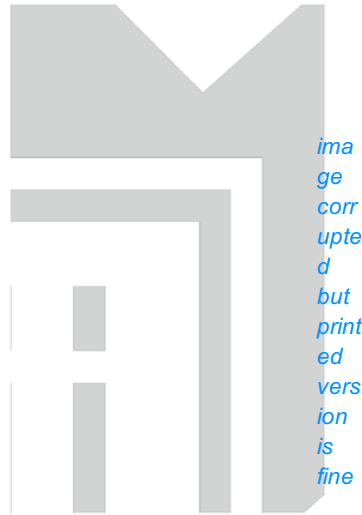


Figure 3 - Turbine Flow Meter

image
corrupted
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is
fine

Level Sensor

The level sensor is a normally open float switch, it is fixed to the tank at the position where the tank will be deemed to be full. When the water reaches the level of the sensor it will move one part of the switch to make an electrical connection providing an input signal to the PLC. shows an image of the float switch.

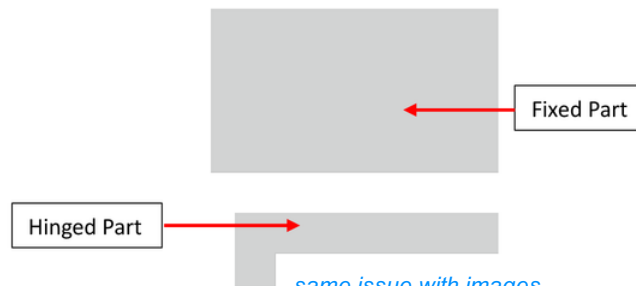


Figure 4 - Float Switch

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looks like this is a Turnit-
in problem

Heater

The heater is a 2.2Kw heating element similar to the heating element you would find in a kettle. An image of the heating element is shown in

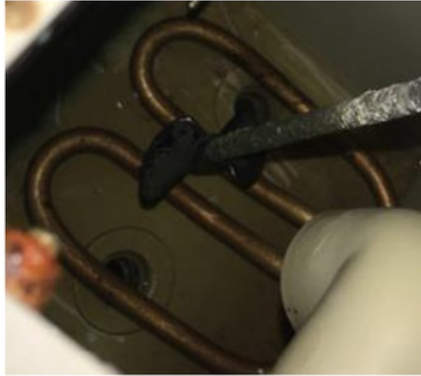


Figure 5 - Heating Element

Resistance Temperature Device (RTD)

All the temperature sensors within the system are RTDs, shown in Figure 6. They are made of a specific material which changes it's value of resistance when it changes temperature. The RTD outputs a resistance relative to is temperature which is then converted to a 4-20mA using a PT100 signal converter, shown in Figure 7.



Figure 6 - RTD



Figure 7 - Signal Converter

Input / Output List

After studying the system and its inputs and outputs a detailed input and output list

Input List	
Input	Address
Level Switch	I1.0
Flow Rate Sensor (Input Word)	IW66
RTD Process Tank Temp Sensor (Input Word)	IW96
RTD Sump Tank Temp Sensor (Input Word)	IW98
RTD Ambient Temp Sensor (Input Word)	IW100

was created.

Output List	
Output	Address
Cooling Fan	Q0.0
Stirrer	Q0.1
Drain Valve	Q0.2
Divert Valve	Q0.3
Cooler Lamp	Q0.4
Drain Valve Lamp	Q0.5
Divert Valve Lamp	Q0.6
Tank Full Lamp	Q0.7
Heater	Q1.0
Heater PWM (Output Word)	QW1002
Pump	Q1.1
Pump PWM (Output Word)	QW1000

a good list

Program Design and Explanation

Once the hardware had been analysed and an input output list established. A tag list could then be made which includes all the I/O and also any memory bits required to operate the program.

Tag List

Inputs

1		Level Switch	Tag table_1	Bool	%I1.0
2		Flow Rate Sensor	Tag table_1	Word	%IW66
3		Process Tank Temp Sensor (RTD)	Tag table_1	Word	%IW96
4		Sump Tank Temp Sensor (RTD)	Tag table_1	Word	%IW98
5		Ambient Temp Sensor (RTD)	Tag table_1	Word	%IW100

Outputs

6		Cooling Fan	Tag table_1	Bool	%Q0.0
7		Stirrer	Tag table_1	Bool	%Q0.1
8		Drain Valve	Tag table_1	Bool	%Q0.2
9		Divert Valve	Tag table_1	Bool	%Q0.3
10		Cooler Lamp	Tag table_1	Bool	%Q0.4
11		Drain Valve Lamp	Tag table_1	Bool	%Q0.5
12		Divert Valve Lamp	Tag table_1	Bool	%Q0.6
13		Tank Full Lamp	Tag table_1	Bool	%Q0.7
14		Heater	Tag table_1	Bool	%Q1.0
15		Pump	Tag table_1	 Bool 	%Q1.1 
16		Flow %CV PWM Duty Cycle	Tag table_1	UInt	%QW1000
17		Process Temperature %CV PWM...	Tag table_1	UInt	%QW1002

Memory Bits

18		Auto	Default tag table	Bool	%M1.0
19		Cooling Fan Request	Default tag table	Bool	%M1.1
20		Stirrer Request	Default tag table	Bool	%M1.2
21		Drain Valve Request	Default tag table	Bool	%M1.3
22		Divert Valve Request	Default tag table	Bool	%M1.4
23		Tank Full Lamp Request	Default tag table	Bool	%M1.5
24		Heater Request	Default tag table	Bool	%M1.6
25		Pump Request	Default tag table	Bool	%M1.7
26		Cooling Fan HMI	Default tag table	Bool	%M2.0
27		Stirrer HMI	Default tag table	Bool	%M2.1
28		Drain Valve HMI	Default tag table	Bool	%M2.2
29		Divert Valve HMI	Default tag table	Bool	%M2.3
30		Tank Full Lamp HMI	Default tag table	Bool	%M2.4
31		Heater HMI	Default tag table	Bool	%M2.5
32		Pump HMI	Default tag table	Bool	%M2.6
33		Test Lamp	Default tag table	Bool	%M10.0
34		Auto Start	Default tag table	Bool	%M50.0
35		Auto Run	Default tag table	Bool	%M50.2
36		Stop	Default tag table	Bool	%M50.1
37		Auto Flow	Default tag table	Bool	%M60.0
38		Auto Heater	Default tag table	Bool	%M70.0

Manual Control

The initial part of creating the program was to create a functioning manual operation which could be controlled from an HMI screen. Figure 8 shows the cooling fan rung, when the Auto/Manual switch is in manual and the 'Cooling Fan' switch is on, the cooling fan will come on. The function has also been included to allow the cooling fan to be used during the Automatic function using the cooling fan request (M1.1) contact.

When the cooling fan is operating it also brings on the 'Cooling Fan' Lamp to indicate that it is on. In parallel with the contact to energise this lamp is a 'Test Lamp' (M10.0) contact, this is linked to a HMI pushbutton which allows all lamps to be tested.

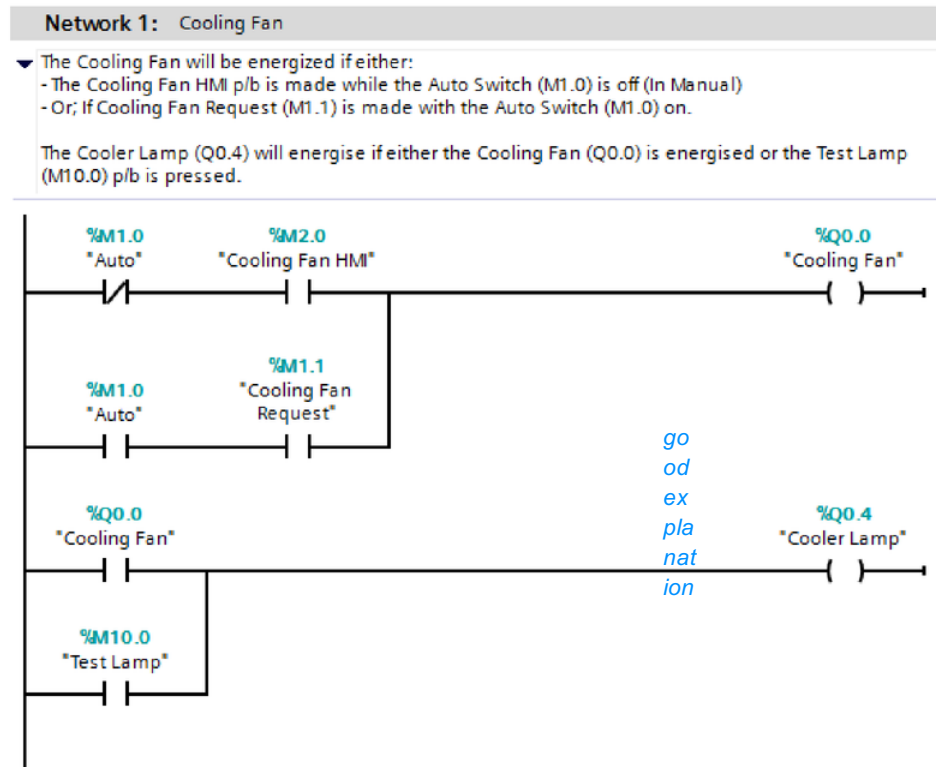


Figure 8 - Manual Control (Network 1)

Figure 9 shows the cooling fan rung, when the Auto/Manual switch is in manual and the 'Stirrer' switch is on, the stirrer will come on.

Also, if the automatic heater coil has been energised within the automatic function, the stirrer will energise.

Network 2: Stirrer

- ▼ The Stirrer (Q0.1) will energize if either the Stirrer HMI (M2.1) p/b has been pressed while the Auto Switch (M1.0) is off (In Manual), or the Auto Heater (M70.0) is energised.

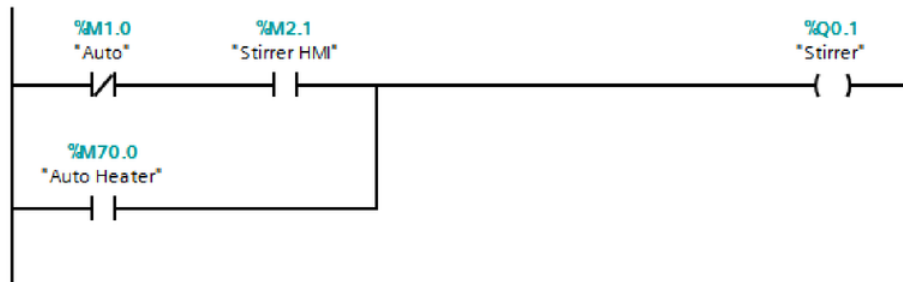


Figure 9 - Manual Control (Network 2)

Figure 10 shows the drain valve rung, when the Auto/Manual switch is in manual and the 'Drain Valve' switch is on, the drain valve will open. The function has also been included to allow the drain valve to be utilised during the Automatic function using the 'Drain Valve Request' request contact (M1.3).

When the drain valve is open it also brings on the 'Drain Valve' Lamp to indicate that it is open. Again, there is a 'Test Lamp' (M10.0) function.

Network 3: Drain Valve

- ▼ The Drain Valve will energize if the Drain Valve HMI p/b is made while the Auto Switch is off, or if the Drain Valve Request Contact is made with the Auto Switch on.

The Drain Valve Lamp will energise if either the Drain Valve Contact (Q0.2) or the Test Lamp Contact (M10.0) are energised.

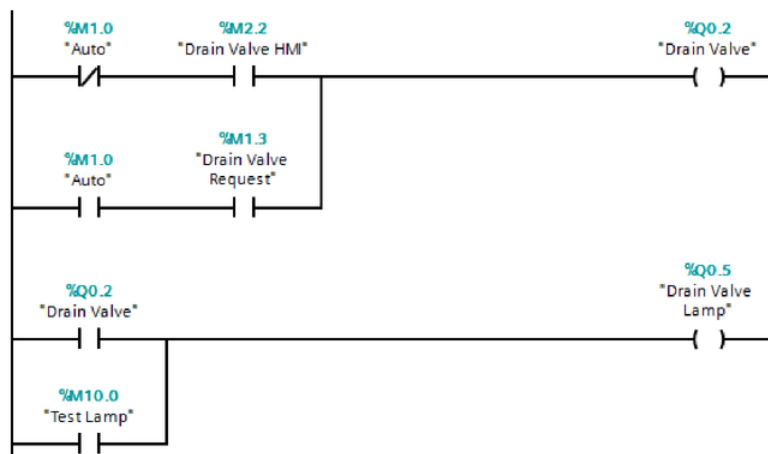


Figure 10 - Manual Control (Network 3)

Figure 11 shows the divert valve rung, when the Auto/Manual switch is in manual and the 'Divert Valve' switch is on, the divert valve will open. The function has also been included to allow the divert valve to be utilised during the Automatic function using the 'Divert Valve Request' request contact (M1.4).

When the divert valve is open it also brings on the 'Divert Valve' Lamp to indicate that it is open. Again, there is a 'Test Lamp' (M10.0) function.

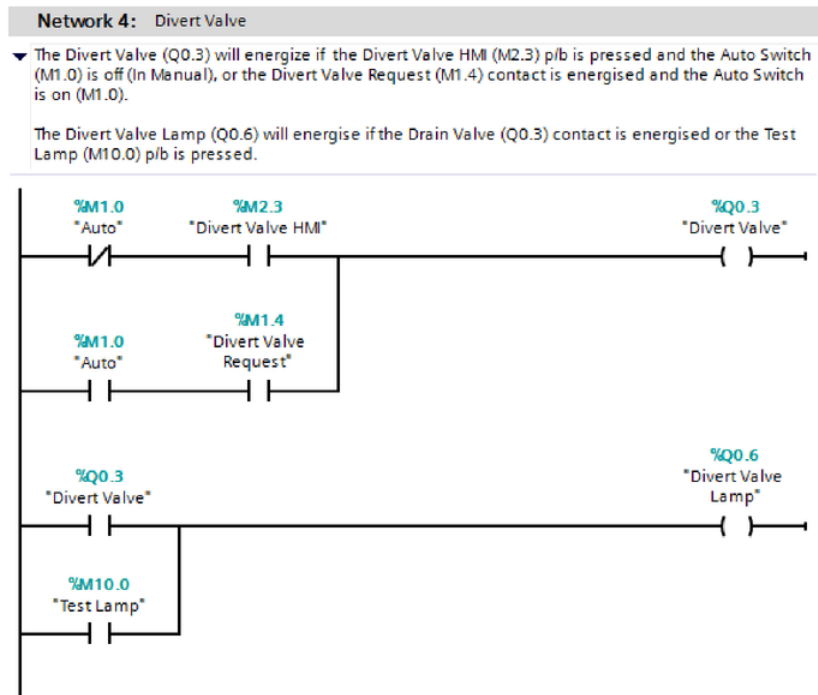


Figure 11 - Manual Control (Network 4)

The rung shown in Figure 12 operates the 'Tank Full' Lamp. When the level switch is made meaning that the tank is full it will energise the lamp. Again, there is a 'Test Lamp' (M10.0) function.

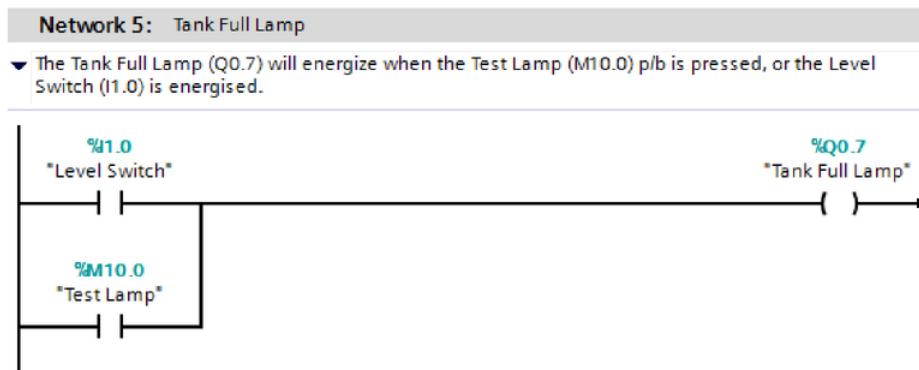


Figure 12 - Manual Control (Network 5)

Figure 13 shows the heater rung, when the Auto/Manual switch is in manual and the 'Heater' switch is on, the heater will come on providing the level switch is made. The level switch is included as an interlock to prevent the heater from being switched on with an empty tank as this will damage components. There is also a move function block which is moving a value of 100 to output word QW1002, this is to reset the PWM control to its maximum after it has been utilised in the automatic function.

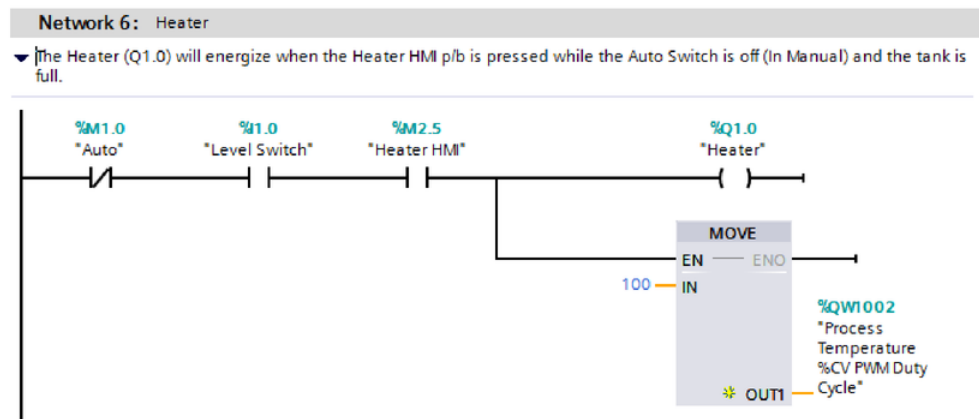


Figure 13 - Manual Control (Network 6)

Figure 14 shows the pump rung, when the Auto/Manual switch is in manual and the 'Pump' switch is on and the level switch has not been made, the pump will come on. There is also a move function block which is moving a value of 100 to output word QW1000, this is to reset the PWM control to its maximum after it has been utilised in the automatic function.

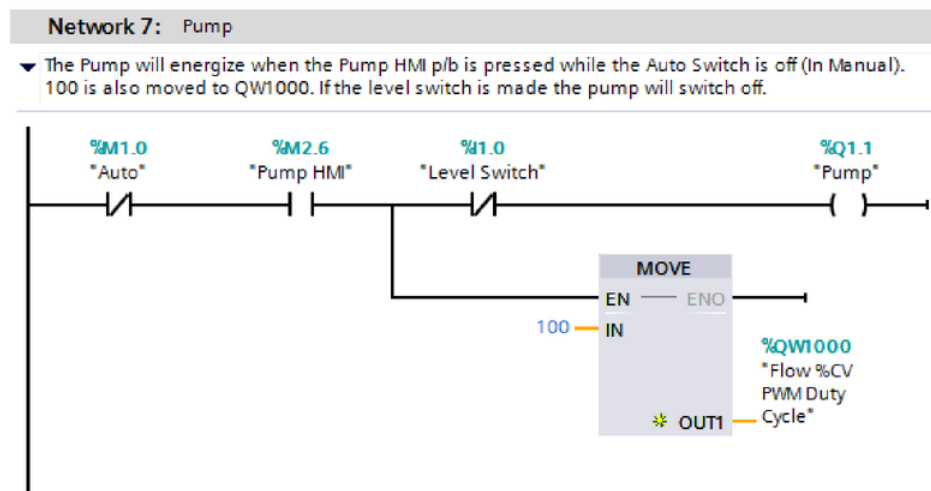


Figure 14 - Manual Control (Network 7)

Automatic Control

Once the manual control was functioning, the automatic sequence could then be created. Figure 15 shows both rungs created for the operation of the automatic sequence.

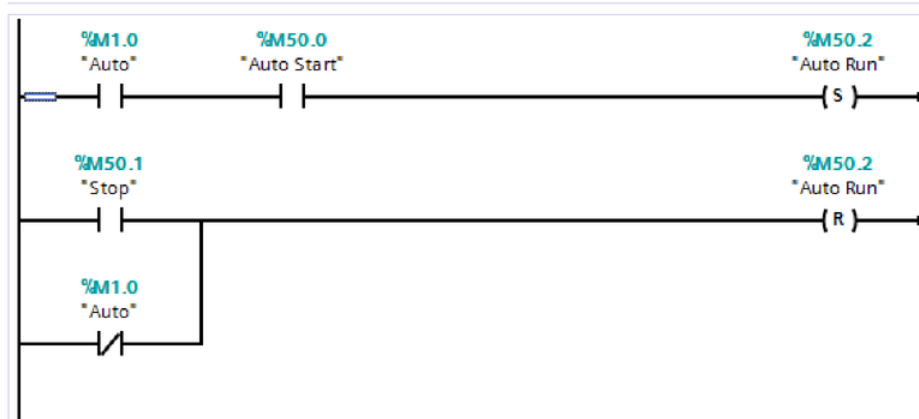
Network 1 sets automatic mode (M50.2) if the Auto/Manual switch is in Auto and the Automatic 'Start' pushbutton (M50.0) is pressed.

Network 2 decides if the pump needs to run to fill the tank or if the heater needs to be on to heat the water. Providing that the Auto Run bit is set, and the level switch is not made then the Auto Flow bit (M60.0) will energise.

Once the tank fills and the level switch makes the 'Auto Flow' bit will de-energise stopping the pump and then turning the heater on.

Network 1: Automatic Sequence Select

- ▼ 'Auto Run' (M50.2) will set when the 'Auto' selector switch (M1.0) is selected and the 'Start' pushbutton (M50.0) is pressed.
- 'Auto Run' (M50.2) will reset when the 'Stop' pushbutton (M50.1) is pressed or when the system is in manual mode.



Network 2: Automatic Pump/Heater selection

- ▼ When 'Auto Run' is energised and the level switch (I1.0) is NOT energised the 'Auto Flow' memory bit (M60.0) will energise.
- When the level switch (I1.0) is energised 'Auto Flow' (M60.0) will de-energise and 'Auto Heater' (M70.0) will energise.



Figure 15 - Automatic Control (Network 1 & 2)

Flow – Cyclic Interrupt

Figure 16 shows the cyclic interrupt for flow. The PLC will scan OB1 at its standard scan rate but will alternate and scan the cyclic interrupts at a given scan time. When creating this cyclic interrupt, it was selected that it will scan every 1 millisecond.

Included in this block is the Flowrate scaling block (Network 1) and the PID pump control (Network 2). These blocks are created separately (shown in Figure 18 &) and can be called where required.

The raw value is received from the flow rate sensor, however it outputs a value of 34 when the flow is at 0, therefore an offset of 34 is inserted to insure that when the flow is at zero the scaled value also shows 0. It is then multiplied by 100 as the desired value is a percentage. The value is finally divided by the maximum raw value, less the offset which is equal to 13,766.

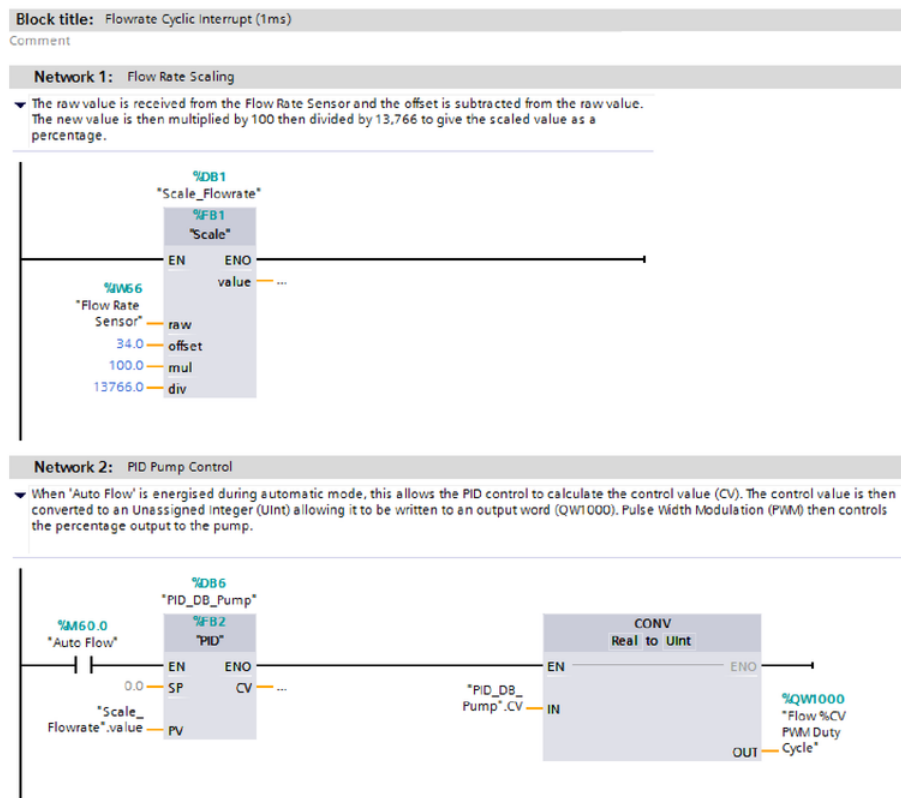


Figure 16 - Flowrate Cyclic Interrupt

The PID pump control will only operate if the automatic flow contact is energised. Similarly to the scaling block, the internals of the PID block are created separately and are then called where needed. This block for the pump control receives its process value (PV) from the scaled flowrate value and then outputs a control value (CV). However, the CV comes out as a real value therefore must be converted to an unassigned integer (UInt) in order to be used by the pulse width modulation (PWM) control.

Temperature – Cyclic Interrupt

Figure 17 shows the cyclic interrupt for temperature. When creating this cyclic interrupt, it was selected that it will scan every 100 milliseconds.

Included in this block is the Process Temperature scaling block (Network 1) and the PID heater control (Network 2).

The raw value is received from the process tank temperature sensor, however it outputs a value of 40 when the temperature is at 0, therefore an offset of 40 is inserted to insure that when the temperature is at zero the scaled value also shows 0. It is then multiplied by 100 as the desired value is a temperature of between 0 and 100 degrees. The value is finally divided by the maximum raw value, less the offset which is equal to 13,760.

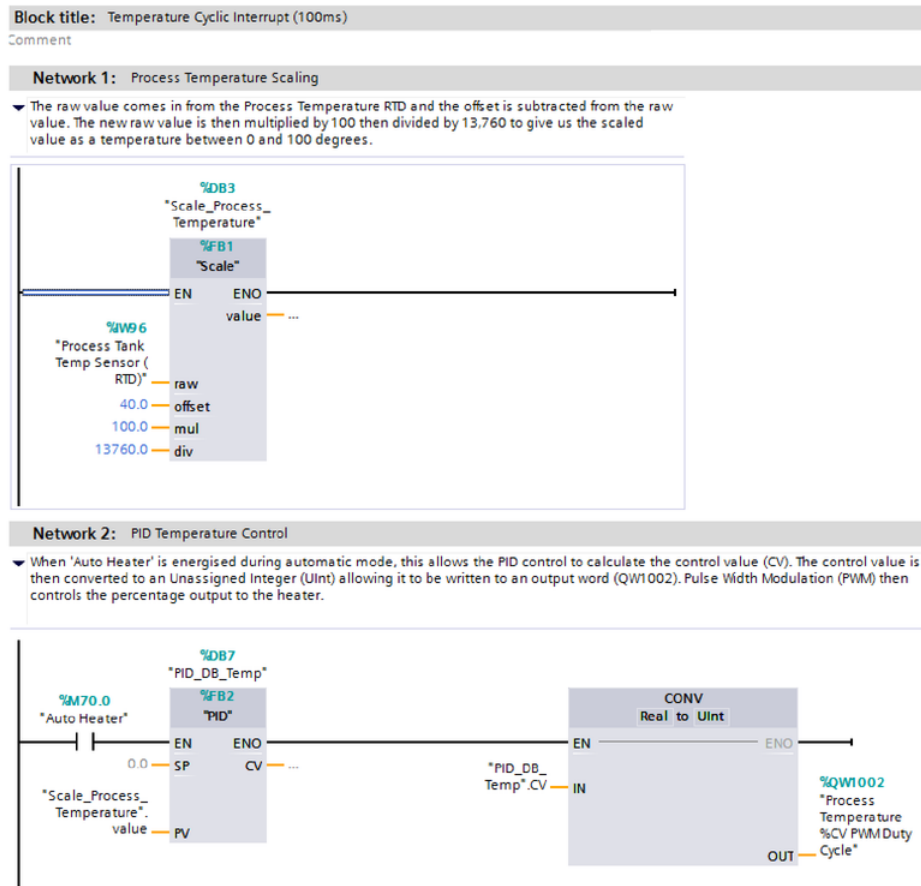


Figure 17 - Process Temperature Cyclic Interrupt

The PID heater control will only operate if the automatic heater contact is energised. This block for the heater control receives its process value (PV) from the scaled process temperature value and then outputs a control value (CV). However, like the pump control, the CV comes out as a real value therefore must be converted to an unassigned integer (UInt) in order to be used by the pulse width modulation (PWM) control.

Scaling Function Block

Figure 18 shows the internal parts of the scaling block. All raw values are received as unassigned integers (UInt) but the values are needed as reals for the mathematics to be carried out. This 'real' value is then labelled as junk, then the offset is subtracted from it to give a new 'junk' value. The value is then multiplied by the maximum value of the desired range and finally divided by a given divisor which is generally the maximum possible raw value.

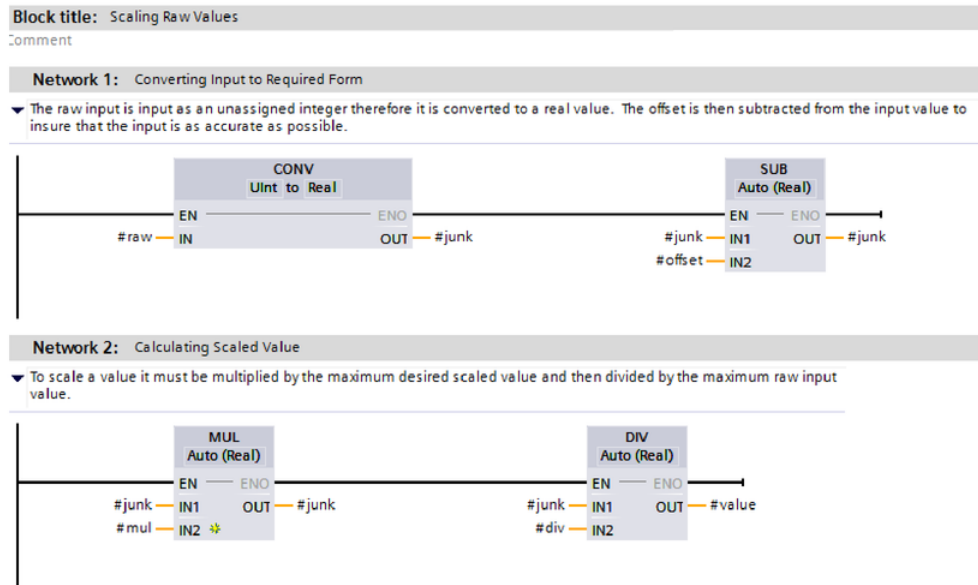


Figure 18 - Scaling Function Block

When the scaling block shown in Figure 18 is called anywhere within the program it creates a new data block. Figure 19 shows an example of the data block that is created when the scaling function block is called. When the block is called within the program a function block is created with the inputs and outputs created to insert the desired values, shown in Figure 20.

Scale_Flowrate			
	Name	Data type	Start value
1	▼ Input		
2	raw	UInt	0
3	offset	Real	0.0
4	mul	Real	0.0
5	div	Real	0.0
6	▼ Output		
7	value	Real	0.0
8	InOut		
9	▼ Static		

Figure 19 - Flowrate Scaling Data Block

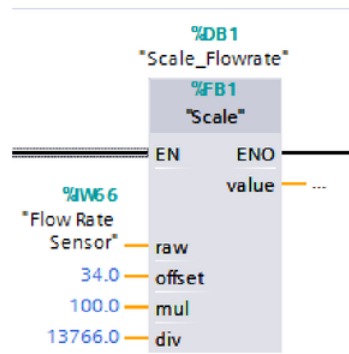


Figure 20 - Example Scaling Data Block

Proportional Integral Derivative (PID) Function Block

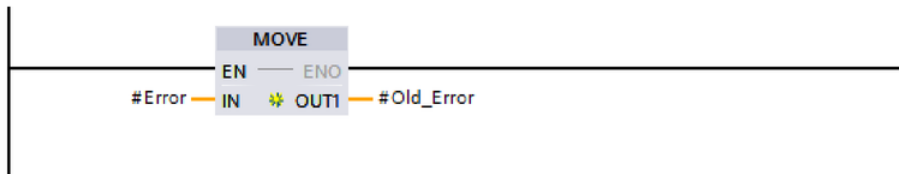
The following section shows the internal parts of the PID block. Figure 21 shows networks 1 and 2. Where network 1 is simply storing the old error by moving the error to old error. Network 2 calculates the new error which is done by a simple equation, subtracting the process value from the set point.

Block title: PID Control

Comment

Network 1: Storing Old Error

This rung moves the error value to old error.



Network 2: Calculating New Error

The new error is calculated by subtracting the process value (PV) from the setpoint (SP).

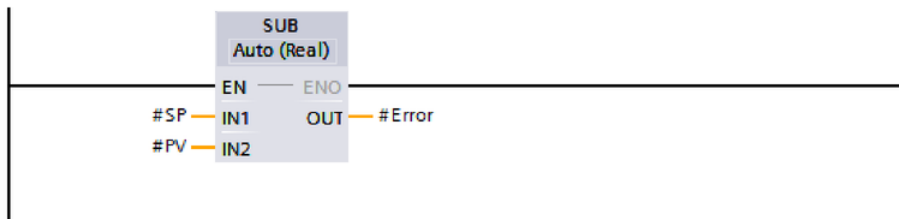


Figure 21 - PID Control (Network 1 & 2)

Figure 22 shows Network 3 & 4. Network 3 is calculating the 'P' part, this is calculated by multiplying the constant P by the error.

Network 4 is limiting the value of 'Ki' between 0.0001 and 100 this is to prevent unrealistic values being entered and the control damaging equipment. The maximum integral accumulator value is then calculated by dividing 100 by 'Ki'.

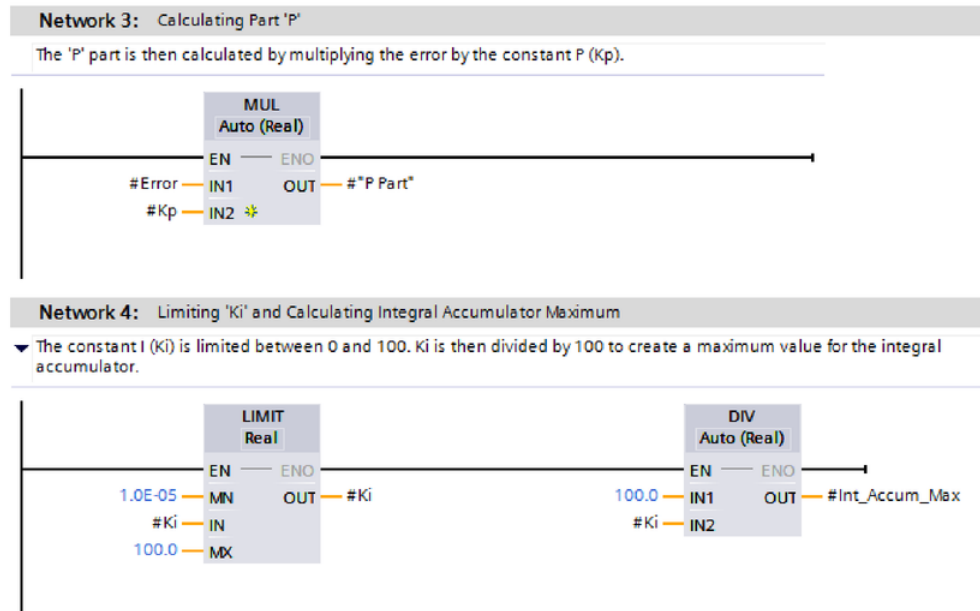


Figure 22 - PID Control (Network 3 & 4)

Below, Figure 23 contains networks 5 and 6 of the PID control. Network 5 updates the integral accumulator as the error changes by adding the new error to it. This is also limit between 0 and the maximum integral accumulator (calculated previously) for safety purposes.

Network 6 calculates the 'I' part by multiplying the integral accumulator and 'Ki'.

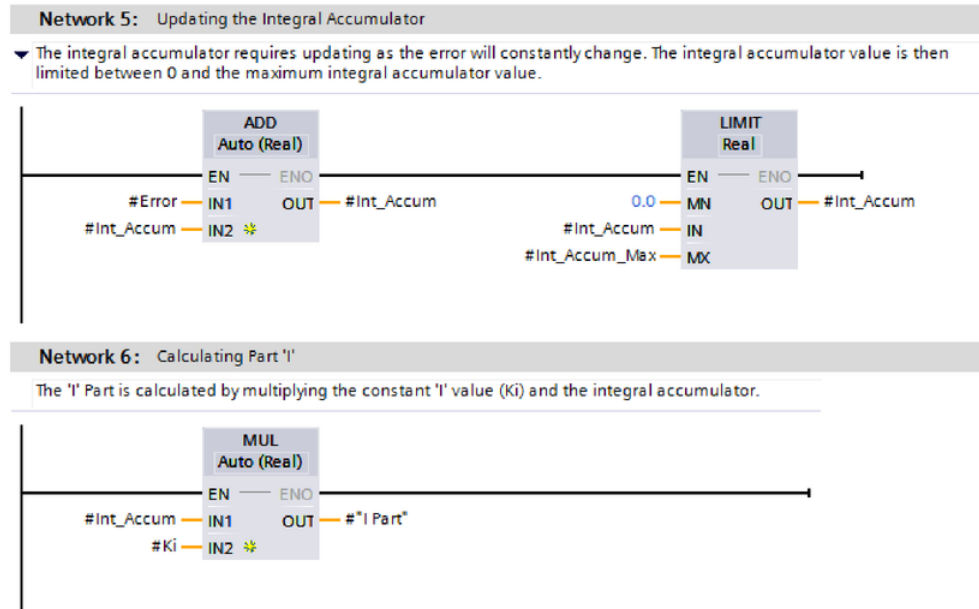


Figure 23 - PID Control (Network 5 & 6)

Figure 24 shows networks 7 & 8. Network 7 calculates the difference of the old and new error by subtracting the old error from the new error.

Network 8 calculates the 'D' part by multiplying the difference by 'Kd'.

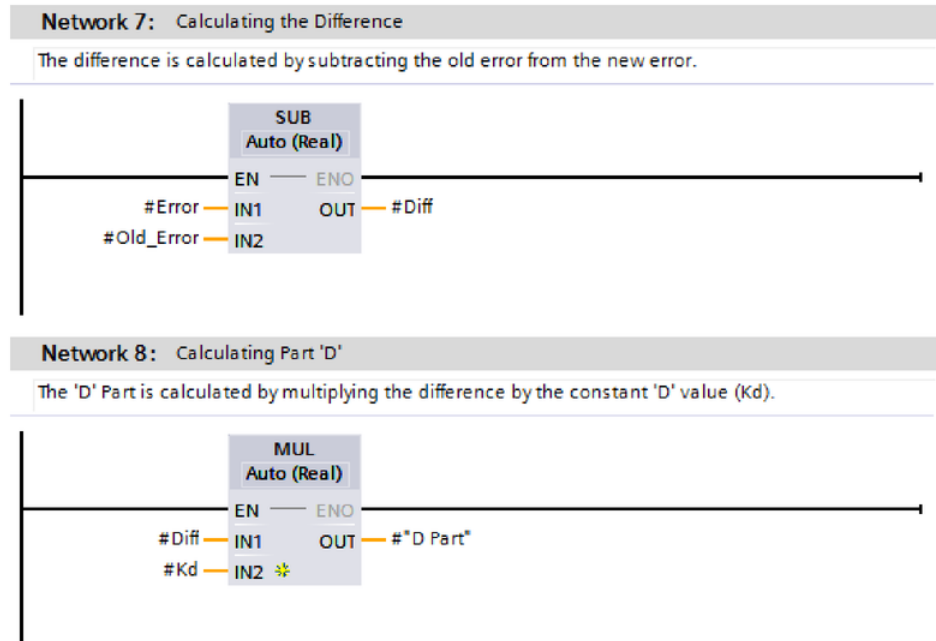


Figure 24 - PID Control (Network 7 & 8)

Network 9 calculates the control value by adding the P, I and D parts together, this is then limited as a percentage, between 0 and 100. This is shown in Figure 25.

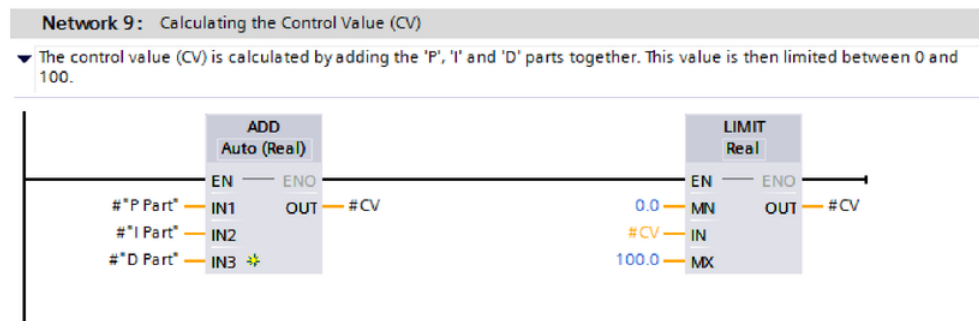


Figure 25 - PID Control (Network 9)

PID Data Blocks

When the scaling block is called anywhere within the program it creates a new data block. Figure 26 shows an example of the data block that is created when the PID function block is called. When the block is called within the program a function block is created with the inputs and outputs created to insert the desired values.

PID_DB_Pump			
	Name	Data type	Start value
1	▼ Input		
2	■ SP	Real	0.0
3	■ PV	Real	0.0
4	▼ Output		
5	■ CV	Real	0.0
6	InOut		
7	▼ Static		
8	■ Error	Real	0.0
9	■ Old_Error	Real	0.0
10	■ Int_Accum_Max	Real	0.0
11	■ Int_Accum	Real	0.0
12	■ Diff	Real	0.0
13	■ P Part	Real	0.0
14	■ I Part	Real	0.0
15	■ Kd	Real	0.0
16	■ Ki	Real	0.0
17	■ Kp	Real	0.0
18	■ D Part	Real	0.0

Figure 26 - PID Pump Control Data Block

Main

All function calls which are created must be included in the main programs sweep cycle to ensure they are scanned and function properly when downloaded to the PLC. It can also be used for something which does not necessarily fit into a function call but is needed for the programming to function correctly.

Figure 27 shows networks 1 & 2 of OB1. Network 1 is the manual output function call.

Network 2 contains the scaling block for the sump tank temperature. The raw value is received from the sump tank temperature sensor. However, it outputs a value of 40 when the temperature is at 0, therefore an offset of 40 is inserted to insure that when the temperature is at zero the scaled value also shows 0. It is then multiplied by 100 as the desired value is a temperature of between 0 and 100 degrees. The value is finally divided by the maximum raw value, less the offset which is equal to 13,760.

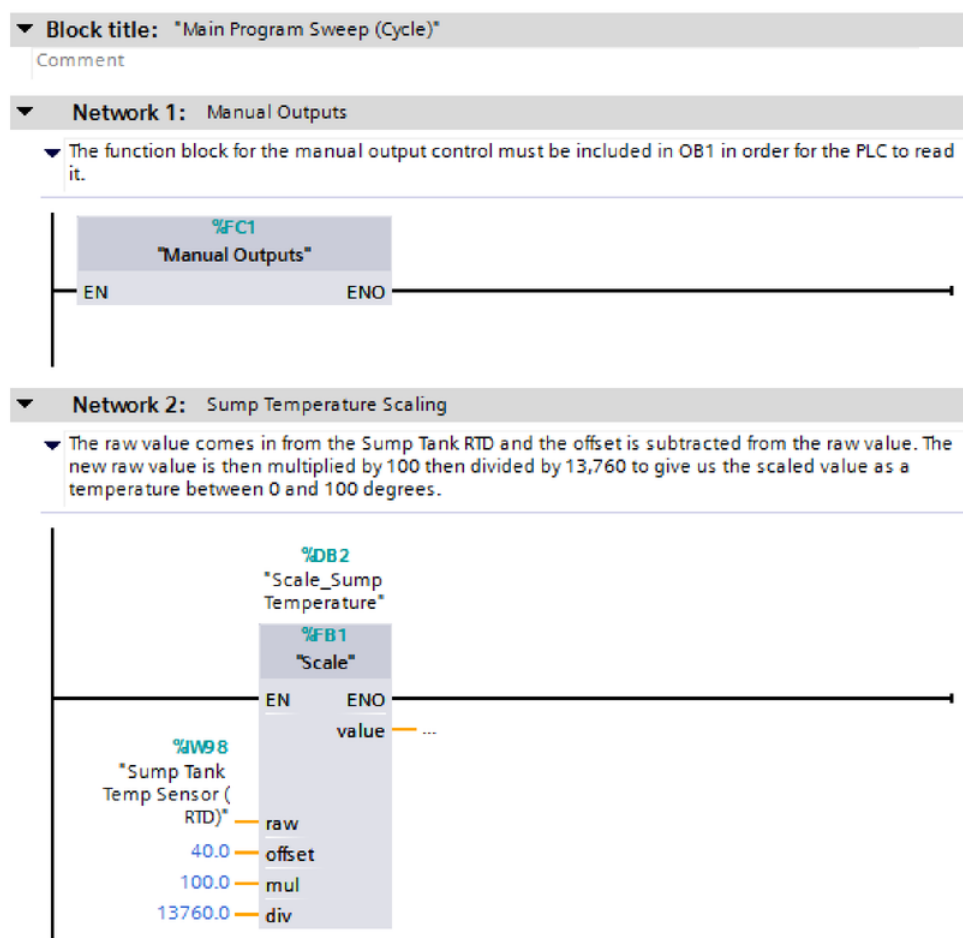


Figure 27 - Main Sweep Cycle (Network 1 & 2)

Network 3 contains the ambient temperature scaling block. The raw value is received from the sump tank temperature sensor. However, it outputs a value of 40 when the temperature is at 0, therefore an offset of 40 is inserted to insure that when the temperature is at zero the scaled value also shows 0. It is then multiplied by 100 as the desired value is a temperature of between 0 and 100 degrees. The value is finally divided by the maximum raw value, less the offset which is equal to 13,760.

Network 4 is the PWM control for the pump. This is only enabled when the automatic flow contact is energised. The data block is set up and the output word and output address must be manual set before the block is created. Both networks are displayed in Figure 28.

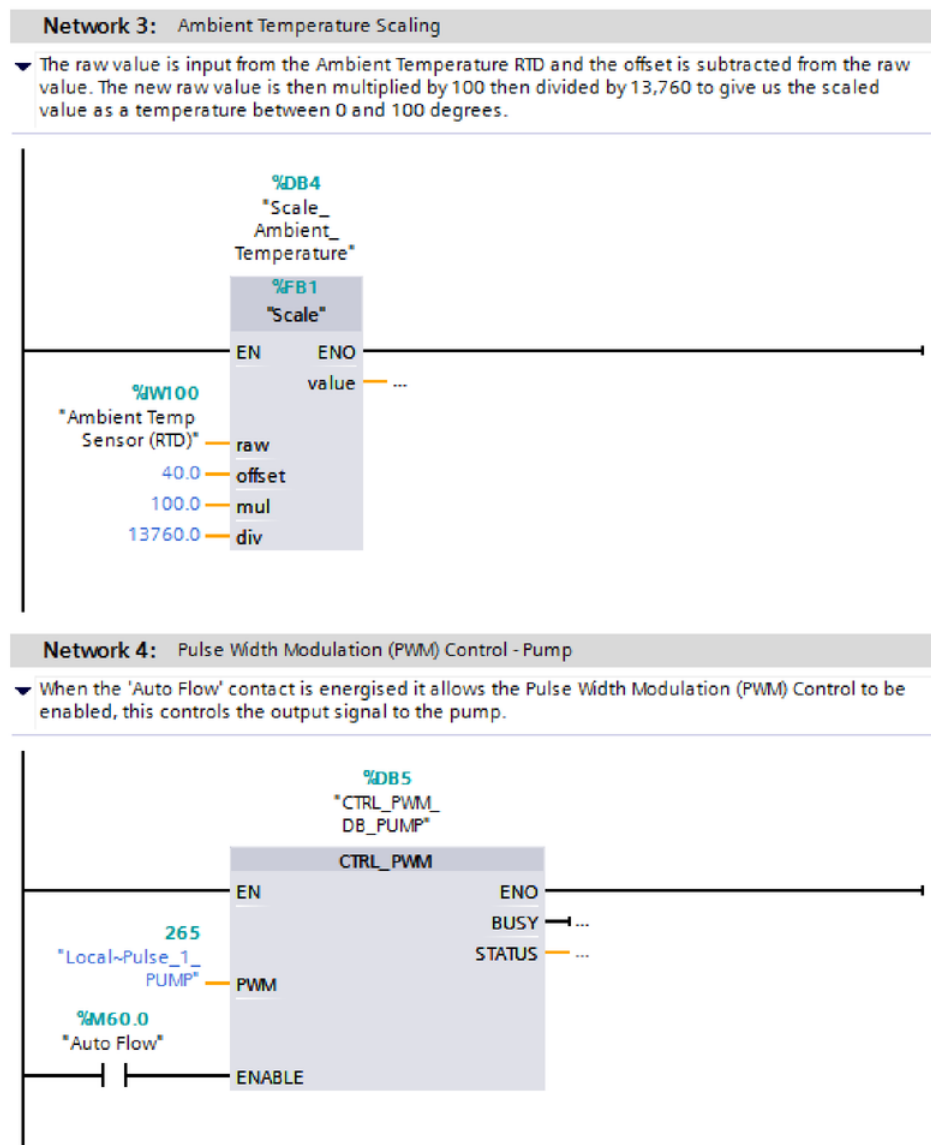


Figure 28 - Main Sweep Cycle (Network 3 & 4)

Figure 29 shows networks 5 and 6.

Network 5 is the PWM control for the heater. This is only enabled when the automatic heater contact is energised. The data block is set up and the output word and output address must be manual set before the block is created.

Network 6 contains the 'automatic control' function call.

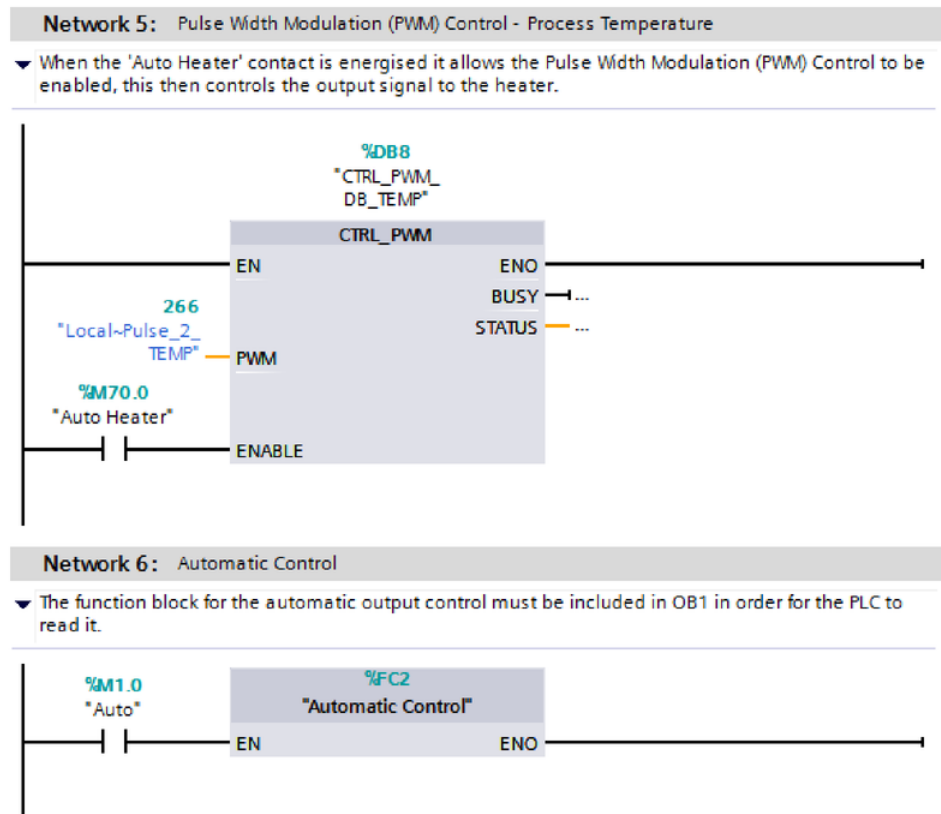


Figure 29 - Main Sweep Cycle (Network 5 & 6)

Figure 30 shows Networks 7 and 8. Network 7 shows 'First Scan Pulse' (FSP) (M80.0) energising when the initial call contact is made. Network 8 moves the desired constant values for flow PID control to their required destination on the first scan pulse. These can be altered while the program is running via the HMI screens.

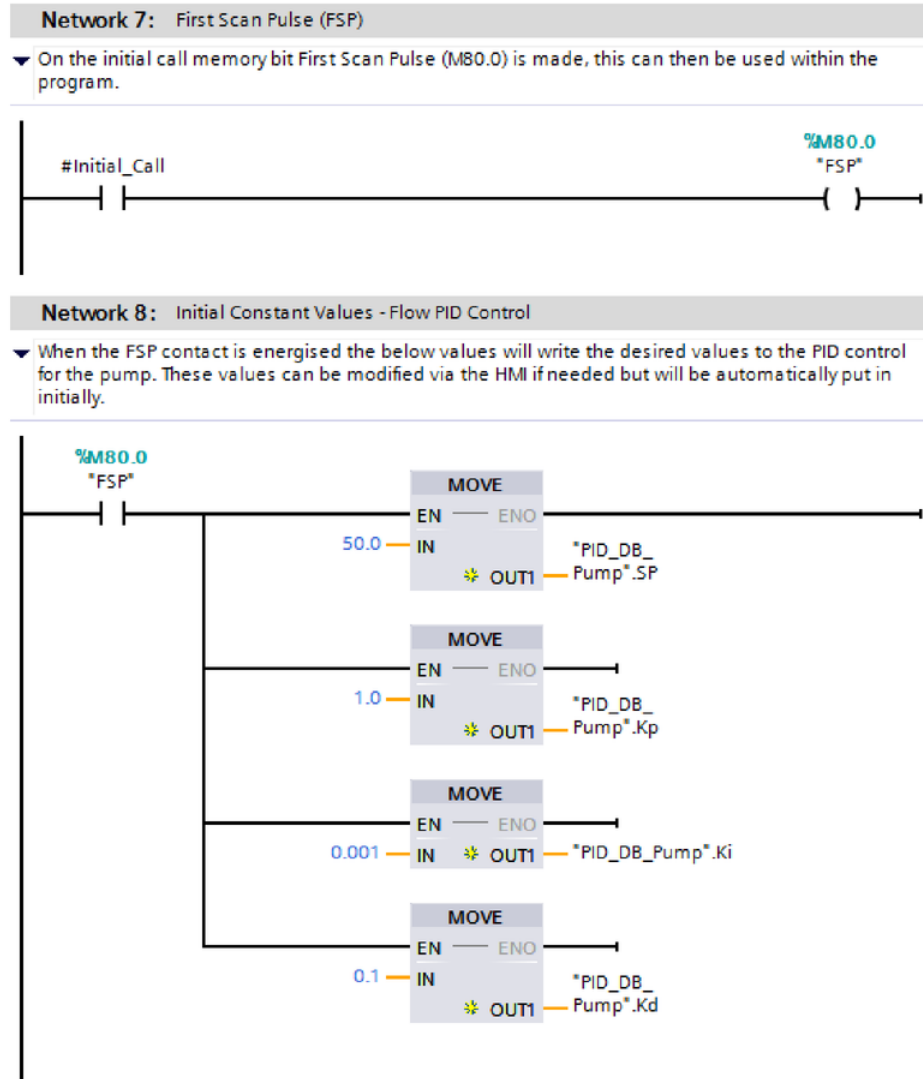


Figure 30 - Main Sweep Cycle (Network 7 & 8)

Figure 31 shows Networks 9 moves the desired constant values for temperature PID control to their required destination on the first scan pulse. These can be altered while the program is running via the HMI screens.

Network 9: Initial Constant Values - Temperature PID Control

- ▼ When the FSP contact is energised the below values will write the desired values to the PID control for the heater. These values can be modified via the HMI if needed but will be automatically put in initially.

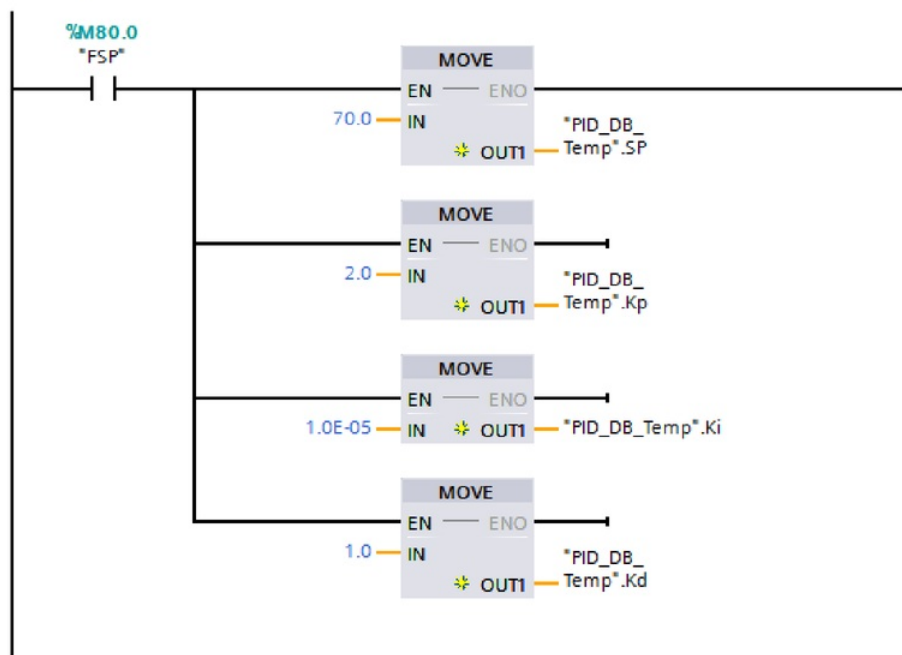


Figure 31 - Main Sweep Cycle (Network 9)

HMI Screens

Figure 32 shows the HMI screen designed for the operator of the system. It contains an auto / manual switch, a 'Start' and 'Stop' button for the automatic sequence as well as an indication lamp to show when the automatic sequence is running and also a decimal display for the setpoints and process values for both flow and temperature. The 'F' keys are used to alternate between the available screens.

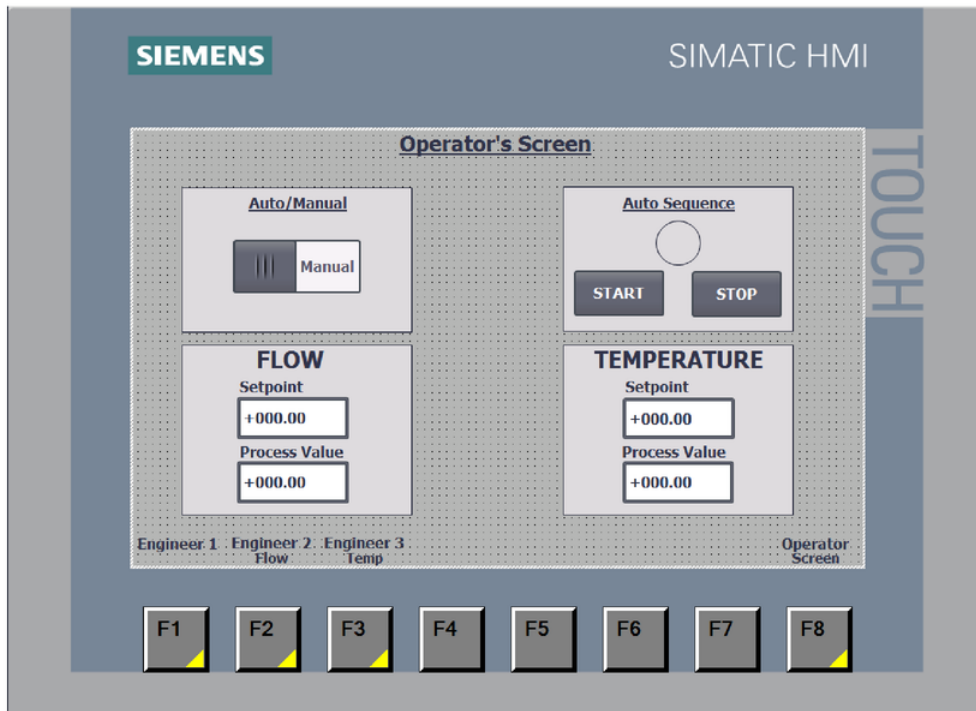


Figure 32 - Operator's HMI Screen

Figure 33 shows HMI screen 1/3 designed for the engineer or maintenance team of the system. It contains an auto / manual switch and a 'Start' and 'Stop' button for the automatic sequence with an indication lamp to show when the automatic sequence is running.

The 'Indicators' section has 4 indicators which are linked to the lamps on the system along with a 'Test' pushbutton, this can be used to function test the lamps.

The 'Outputs' section contains each output with a manual On / Off switch and an indicator which comes on when the outputs are energised within the program.

The 'Analogue Inputs' section shows the raw values received from the sensors on the system and also the scaled values calculated by the program.

The 'F' keys are used to alternate between the available screens.

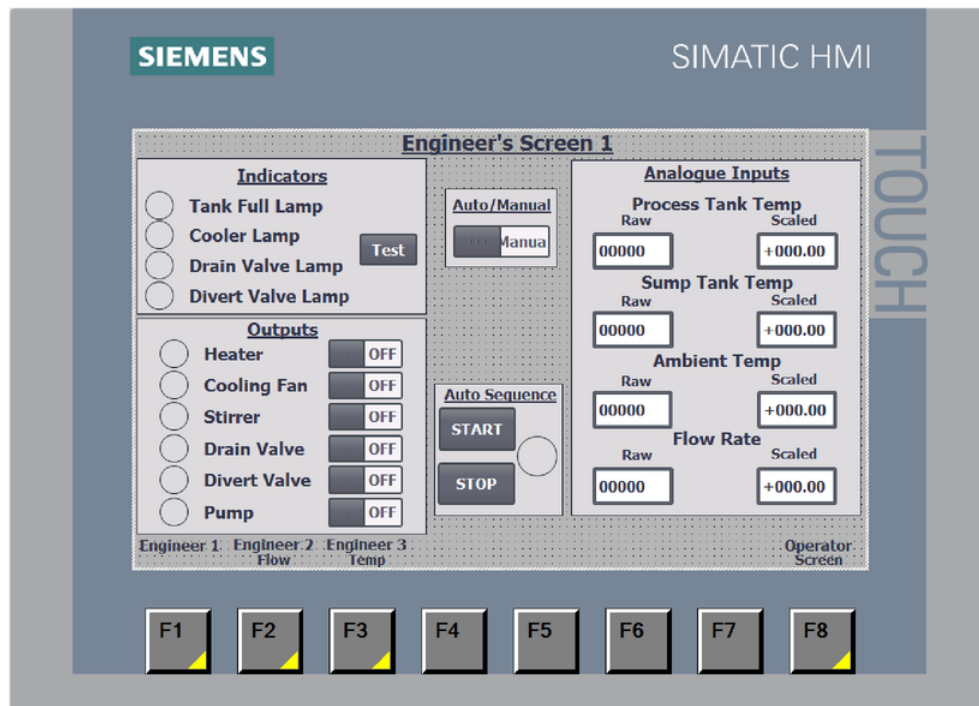


Figure 33 - Engineers 1 HMI Screen

well designed screens

Figure 34 shows HMI screen 2/3 designed for the engineer or maintenance team of the system. This is the PID control tuning for flow. It contains a 'Start' and 'Stop' button for the automatic sequence with an indication lamp to show when the automatic sequence is running. All decimal displays are connected to the PID data block for flow except for the process value (PV). The process value is received from the flow rate scaling block.

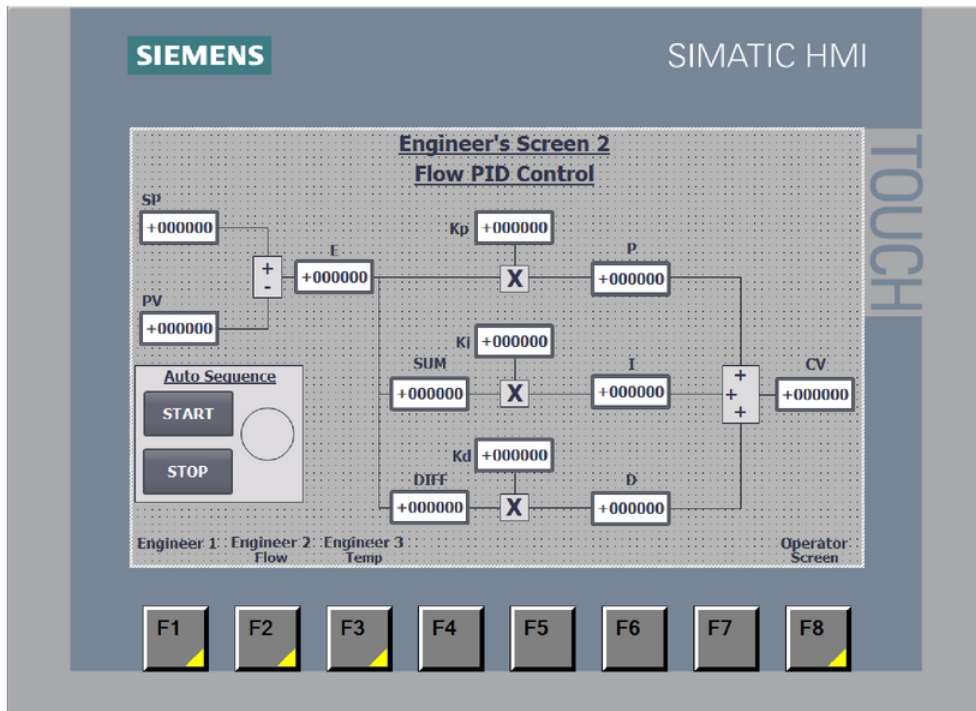


Figure 34 - Engineers 2 HMI Screen

Figure 35 shows HMI screen 3/3 designed for the engineer or maintenance team of the system. This is the PID control tuning for the process tank temperature control. It contains a 'Start' and Stop' button for the automatic sequence with an indication lamp to show when the automatic sequence is running. All decimal displays are connected to the PID data block for process temperature except for the process value (PV). The process value is received from the process temperature scaling block.

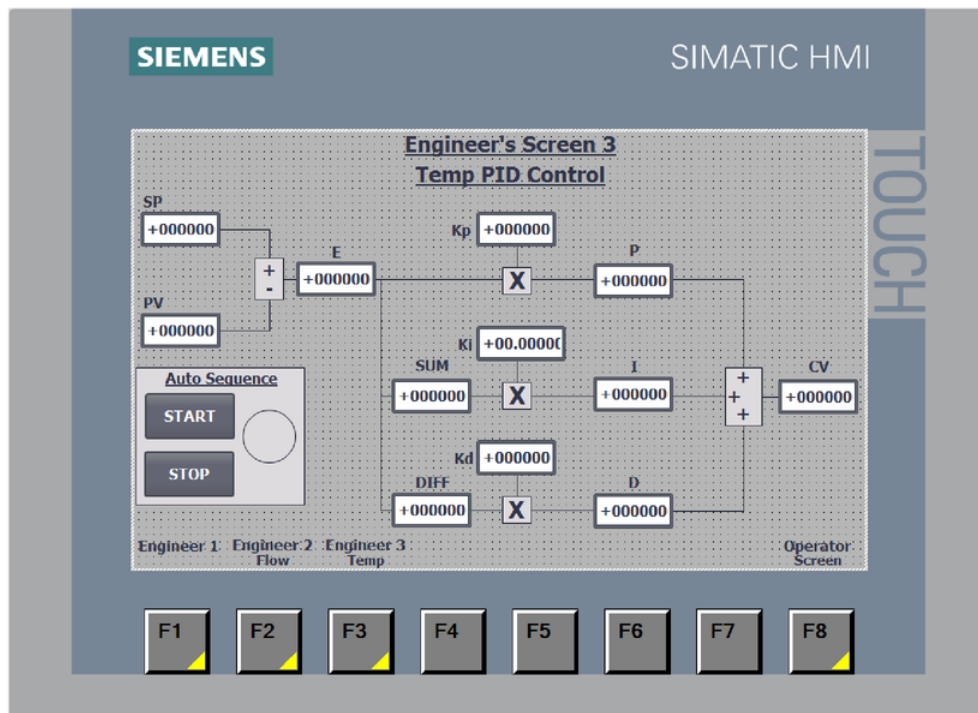


Figure 35 - Engineers 3 HMI Screen

Program Testing, Results and Evaluation

Below shows the testing table created and used to test the program. The actual results are linked with photographs of the system during the testing period.

Test No.	Test Description	Expected Result	Result
#1	Power up the system	On start up all outputs should be off, analogue inputs should be received and displayed and relevant scaled values also displayed.	As shown in Figure 36 the raw and scaled values are displayed on the HMI and no outputs are on.
#2	In manual, test all lamps using the lamp test push button.	When the test button is pressed all lamps on the rig should illuminate.	When the 'Test' push button was pressed (Figure 37) all lamps on the system illuminated (Figure 38).
#3	In manual, test all outputs.	With an empty tank, all outputs should come on and the indicators on the HMI should also be lit, except the tank full lamp and the heater. With a full tank and the drain valve turned off, all other outputs should turn on and their indicators lit.	With an empty process tank all outputs came on except the heater. The tank full lamp was also off. This is shown in Figure 39 & Figure 40. With the process tank full all outputs functioned as expected, shown in Figure 41 & Figure 42.
#4	Put auto / manual switch in automatic and test flow control PID.	With a desired set point entered the pump should run. The process value (PV) should match the set point (SP) relatively quickly.	As expected the PV and SP were almost equal very quickly, shown in Figure 43.
#5	Once tank is full test temperature control PID.	With a desired set point entered the heater should run and the stirrer should also come on. Initially there will be a gap between the process value and the set point (SP), with a high Control Value (CV). Eventually these values should be virtually equal. It will take a considerable amount longer for the temperature PV to reach the set point than the flow PV.	As expected initially there was a large gap between the PV and SP and a high CV, shown in Figure 44. They were then virtually equal, and the control value had dropped to zero. This is shown in Figure 45.

detailed testing with supporting evidence

Test #1

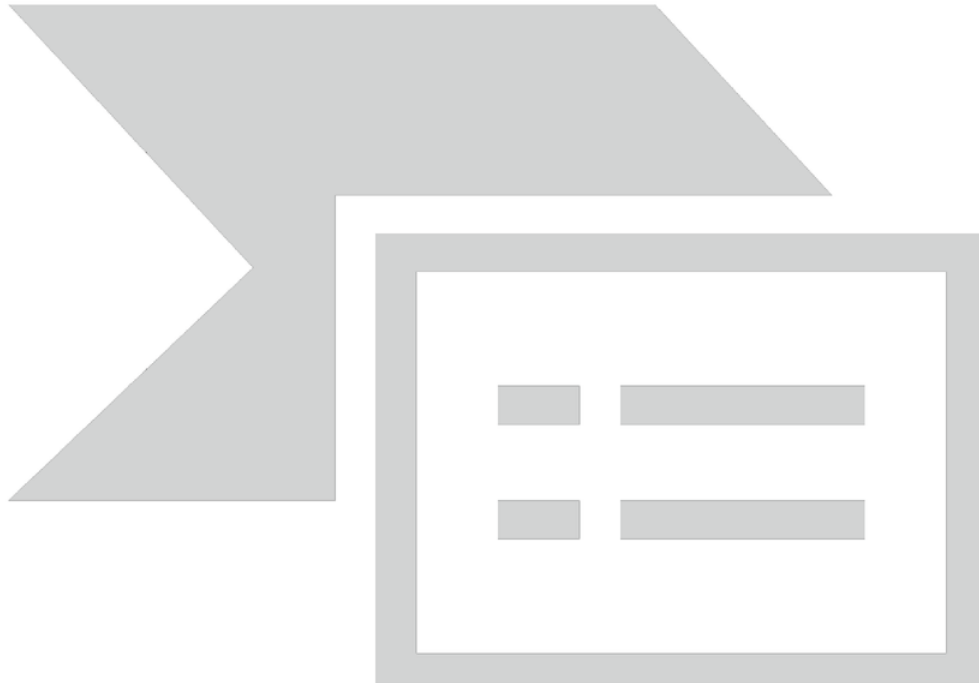


Figure 36 - Test #1

Test #2



Figure 37 - Test #2(a)



Figure 38 - Test #2(b)

Test #3



Figure 39 - Test #3(a)

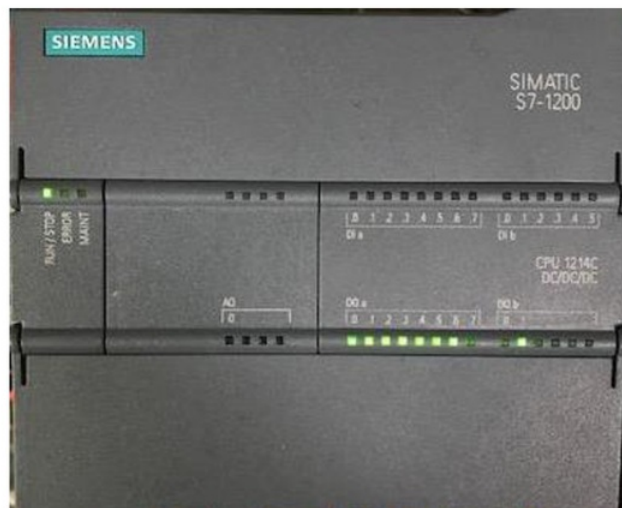


Figure 40 - Test #3(b)

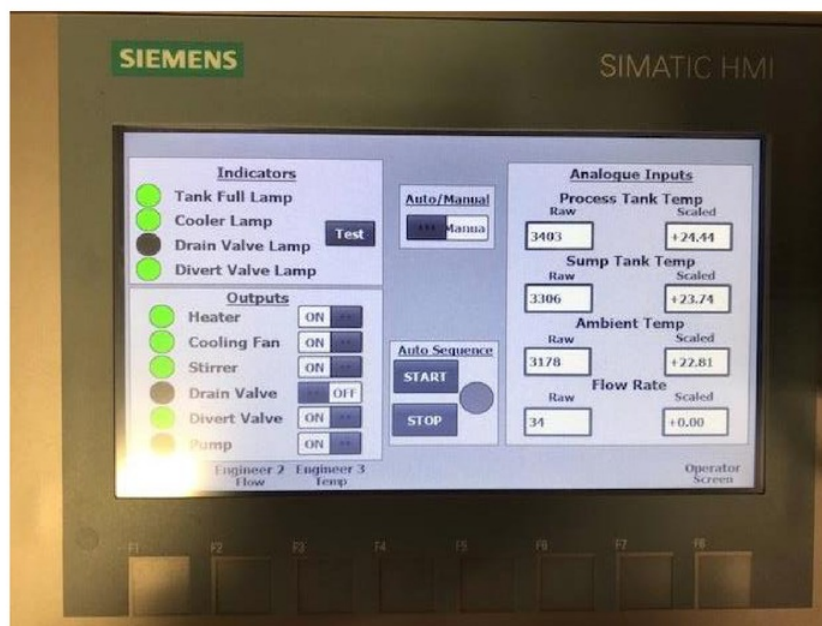


Figure 41 - Test #3(c)



Figure 42 - Test #3(d)

Test #4



Figure 43 - Test #4

Test #5

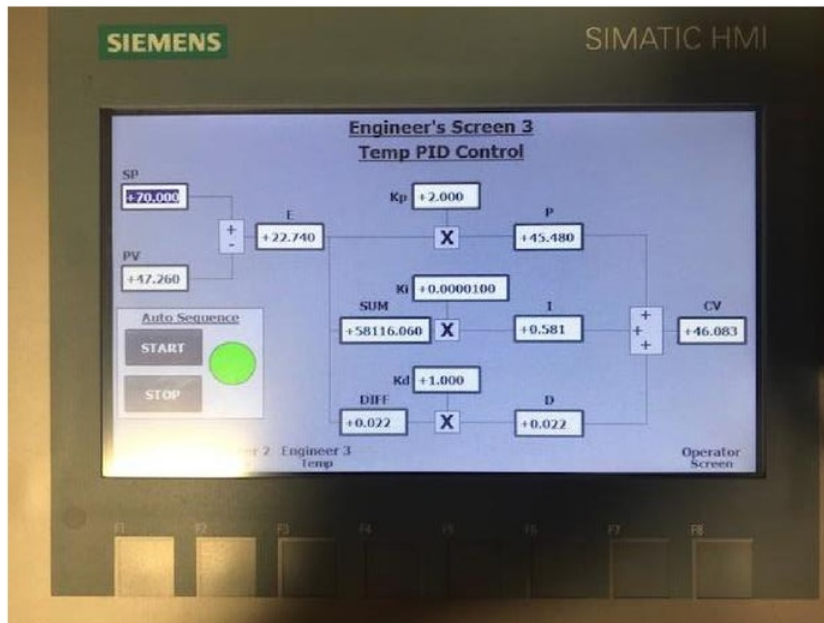


Figure 44 - Test #5(a)

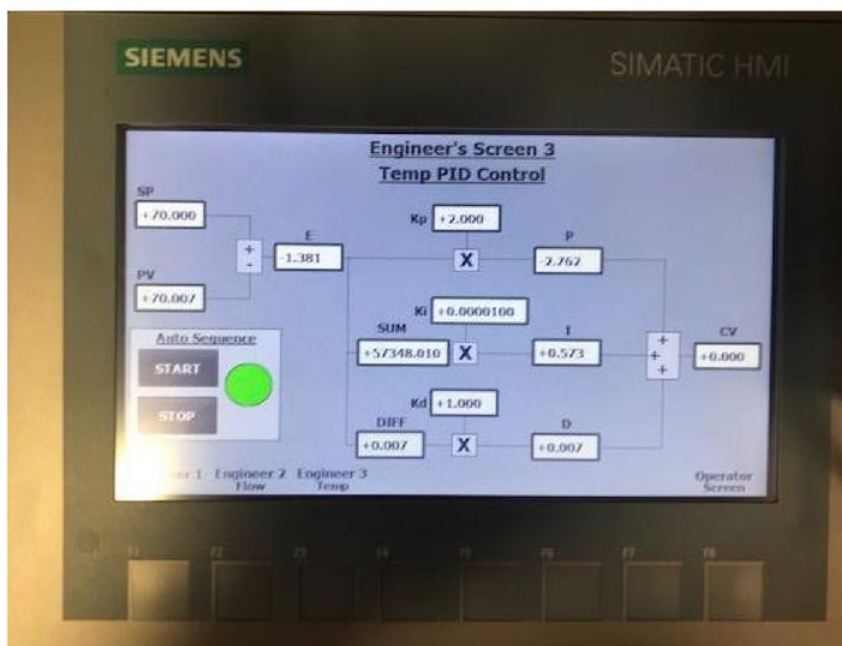


Figure 45 - Test #5 (b)

'Kp' is the proportional band, this value determines within which range of the set point the power supplied will be reduced. For example, the 'Kp' for flow was eventually selected at 1, with a set point of 50% this means that the proportional band is 49.5% and 50.5%, anywhere outside of this value the power will be at its maximum.

'Ki' is used to allow the actuator to respond to any disturbances or large setpoint alterations. If there are any disturbances the integral part keeps adding the error to ensure the actuator can overcome the disturbances.

'Kd' is used to dampen any overshoot, therefore stabilising the output.

(Elds, 2018)

Safety, Maintenance, Reliability and Sustainable Development

As a group a risk assessment was carried out on the system before any work was carried out. Included in the risk assessment are recommendations for improvements to the health and safety of the equipment shown in Figure 46.

The maintenance and fault finding of this system has been aided by the inclusion of the manual operation, with indicator lamps linked to the outputs. However, it is important that the sensors within the system such as the RTD's are calibrated as recommended by the manufacturer to ensure reliable and accurate feedback. The system has been thoroughly tested three or more times and has functioned correctly and accurately each time.

The use of Pulse Width Modulation (PWM) is certainly an efficient way of running the system. The reason for this being that the components only consume the energy that they require by varying their speed. If the duty cycle which in this case is the set point of the PWM control is set to 50.0 the power is on for 50% of the time, therefore saving energy.

The pumps PWM is controlled using a MOSFET and the heater using a solid-state relay (SSR). A solid-state relay is extremely efficient because it does not energise a coil or open and close any contacts physically.

This system also promotes sustainability as it is a simulation of re-using water within industry. Water is often used for cooling, then gets very warm before being recycled.

Risk assessment

Company name:

Date of risk assessment: 30/04/

What are the hazards?	Who might be harmed and how?	What are you already doing?	Do you need to do anything else to control this risk?	Action by who?	Action by when?	Done
Slips	Operators, Maintenance staff or visitors.	All water is contained in sealed tanks and pipe work.	Place system in a tray with raised edges to prevent any leaks going onto the floor.	Lab Technician	As soon as practicably possible	
Burns	Operators, Maintenance staff or visitors.	Plastic lid fixed over tanks to prevent access to hot liquid.	Interlocked guarding to prevent direct contact with hot tanks.	Lab Technician	As soon as practicably possible	
Electric Shock	Operators, Maintenance staff or visitors.	Only adequately trained persons have access to the room.	Put all electrical connections into a panel, allowing only authorised persons access with a key.	Lab Technician	As soon as practicably possible	
Contact with moving parts	Operators, Maintenance staff or visitors.	Majority of stirrer is covered within tank.	Interlocked guarding around the remainder of the moving machinery.	Lab Technician	As soon as practicably possible	

Figure 46 - Risk Assessment

Risk Assessment Template (HSE, 2018)

Conclusion and Recommendations

The program created has certainly met the specification of the brief however with more time some extra functions and features could certainly have been added.

The majority of the hardware was only utilised in the manual operation and could have been linked in to the program's automatic feature. This was considered when creating the program and within some of the manual rungs, the necessary additions were included to allow them to be used in automatic in future.

Some suggestions for future development would be to use the drain valve to automatically empty the process tank when the water reached a certain temperature. If the water within the sump tank was too hot the divert valve could have been used to divert the water through the cooling fan.

There were also a number of safety recommendations which are highlighted within the risk assessment in Figure 46 which for full effectiveness would require interlocks brought into the program. Such as all guards having limit switches which prevent the program from operating if guards are not in place.

For maintenance purposes a reminder could be included on the HMI screen to ensure the maintenance team calibrate all sensors within the system.

Unfortunately, although it was desired, it was not found how to password protect the engineers HMI screens as the 'F' keys were used to alternate the screens. With more time and research it would perhaps be possible and is certainly a recommendation to improve the security of the system.

Description of Team Working

For this assignment we worked as a pair on the Bytronic Process Rig to achieve the specification given in the brief.

Myself and Ethan firstly analysed the safety aspects of the system, carrying out a risk assessment on the system discussing the possible hazards and suggestions for improvement, although we carried out the assessment together the document was then completed individually with our own interpretation.

We then looked in to the hardware of the system, creating a list of the inputs and outputs., before documenting a description of the system's hardware individually. This allowed us to design and create the program.

In order to use the time given efficiently, after creating the document on TIA Portal we shared it with each other in order to carry out different tasks at the same time.

For us both to be able to gain experience, it was decided that we would create 2 HMI's each and both create parts of the program. When sections had been completed we brought both versions of the program together for testing.

Once the program was completed the testing process was carried out as a team, operating the system and monitoring the program when required. Our test results were then documented individually.

Works Cited

Davies, R. (2018, April 28). 15 Bytronic Rig Hardware. Llanelli.

Elds, G. (2018, May 01). Measurement Methods and Control Engineering. Digital Automation Training.

HSE. (2018, May 07). *Risk Management - Sources*. Retrieved from Health and Safety Executive : <http://www.hse.gov.uk/risk/resources.htm>

PSDE 4005 - Assignment 3

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

79/100

PAGE 1

PAGE 2

PAGE 3

PAGE 4

Text Comment. image has not come out well, however, printed copy was fine

PAGE 5

Text Comment. image corrupted but printed version is fine

Text Comment. same issue with images, looks like this is a Turnit-in problem

PAGE 6

PAGE 7

Text Comment. a good list

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PAGE 9

PAGE 10

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PAGE 11

PAGE 12

PAGE 13

PAGE 14

PAGE 15

PAGE 16

PAGE 17

PAGE 18

PAGE 19

PAGE 20

PAGE 21

PAGE 22

PAGE 23

PAGE 24

PAGE 25

PAGE 26

PAGE 27

PAGE 28

PAGE 29

PAGE 30

Text Comment. well designed screens

PAGE 31

PAGE 32

PAGE 33

Text Comment. detailed testing with supporting evidence

PAGE 34

PAGE 35

PAGE 36

PAGE 37

PAGE 38

PAGE 39

GRADING FORM: CSG-RUBIC

JED DAVIES**79****RESEARCH-INFORMED LITERATURE**

n/a

KNOWLEDGE AND UNDERSTANDING

Section 1: System description - Good description of the system with supporting photos. Good I/O list but you could have distinguished between analogue and digital devices. (13/15) Section 2: Program explanation - All networks have titles and comments (some very detailed). Networks and screens are explained well. (14/15)

27**ANALYSIS**

Section 3: Testing - A number of tests covered in the table. More detail was expected for each manual operation. (7/10) Section 3: Results and evaluation - Photographic evidence supplied to support tabulated results. Overall evaluation needed. (7/10)

20

Section 4: Conclusions and recommendations -
Good. (6/10)

PRACTICAL APPLICATION AND DEP.



Section 2: Program design - Excellent designs.
(10/10) Section 4: Safety, maintenance, reliability
and sustainable development - Risk assessment
included with some consideration given to the other
issues. (9/15)

19

SKILLS FOR PROFESSIONAL PRAC.



All sections – Good structure, well presented.
Figures numbered and listed correctly. However,
sections should be numbered according to the brief.
(8/10) Section 6: Team working – Good description
given. (5/5)

13