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2017194

by Hefin Williams

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1 Executive Summary:

Within this report, firstly research has been carried out on five different methods of PID loop parameters tuning. Where tuning is taken place for the best performance from each control loop regardless of the application, the five methods researched are as follows, Ziegler-Nichols, Cohen-Coon, Tyreus-Luyben, IMC, and relay feedback tuning. *Which was the best method?*

Secondly, level control over a process tank has been looked into where experiments and tuning has taken place. The tank has been practically tested and simulated online using Simulink on matlab, where the PID values were tested and tuned for the best response curve for any changes to the level control loop. *which method of tuning did you use?*

Thirdly, temperature control over the heat tank on the process trainer. The temperature of the water within the heat tank had many factors working against holding the heat where the water is pumped through an element within the process tank for cooling or various voltage on the heating element for less heat output, therefore water will take longer to get up to temperature.

Finally, ^aan conclusion is made up of each task, covering areas where valuable information was found, the teamworking is described in the report for the team work carried out for each of the tasks. *What were your conclusions?*

2 Work plan for Life-long Learning:

This assignment will be approached with in depth knowledge focussed into process control systems. Specific aspects of control engineering will be researched, and practical experiments will be carried out whilst doing aspects of the practical in groups.

In depth research will be carried out, researching Five various methods of tuning PID loop parameters for prime operation of control systems. From researching Five various methods one method will be preferred for a first order system, the choice will be justified within the report.

In completion of the research aspect, the report will then follow up with Two practical tasks which ^{will be} were carried out in G8 on the Graig campus. One of which will be level control on a process tank, and the other will be temperature control on a heater tank. The practical tasks will be carried out within a group where the analysis and calculations will be carried out individually.

The report will close with a detailed conclusion of all results gathered and research obtained throughout the report.

3 Research:

This task will research into five different methods of tuning PID, PID means Proportional Integral Derivative, which is used for controlling various control loops within industry whether you want to control gas flow, water flow, Pressure, conveyor speed control. The adjustments between P, I, and D are made very slightly for fine tuning and has tremendous effects on the outcome of the control system.

PID systems are most effectively used in systems fast reacting such as mechanical changes or flow rate changes as the object weather its gas liquid or solid can be forced to move fairly quickly different to a control system on a dosing plant or a temperature dependent control system. PID control systems rely heavily on very highly tuned and accurate instruments. The best quality measuring instruments will give the best control tuning. (phillips, 1998) Correctly cited

1 Ziegler-Nichols

Ziegler-Nichols is an ancient and vastly used method for tuning PID control loop parameters. Its works when the tests on each parameter of the PID loop is changed and the control system response will be monitored which then determines the best fine-tuned PID parameters. (phillips, 1998) Correctly cited

2 Cohen-Coon

Cohen-Coon is a dissimilar method to the Ziegler-Nichols process for fine tuning the PID loop parameters. It monitors how stable the system is and if an instability is found the PID values are changed for optimal Control loop parameters (phillips, 1998) Correctly cited

3 Relay Feedback

Relay feedback tests and confirms and compares the overall gain 'KU', overall period 'PU', and the overall gain margin 'GM', and overall phase margin 'PM'. The values are used to calculate the best values for PID loop parameters. (parr, 2004)

4 IMC Tuning

IMC tuning involves testing to determine the overall gain 'Ku' and the overall period 'PU', overall margin 'GM' overall phase margin 'PM'. The values used for calculating the finest tuned values for the PID parameters. (morris, 2000)

This is a very brief section

Which one did you choose for use in this assignment?

Since you actually used the model based approach with simulation, you should have research this method as one of your five.

5 Level Control of the Process Tank:

Within this task, PID control over water level will be set and the best P, I, and D values will be found for the water flow for level control over the main water tank. The task is based on a CE117 Process Trainer which is shown on figure 1 in the appendix.

A)

Investigation into the instrumentation and control actuators which belong to the CE117 Process Trainer for the control over the level in the process tank. The process tank is shown as the clear tank on figure 1. Figure 2 in the appendix shows the P&ID diagram of the process tank. The P&ID diagram shows the level transmitter, which is situated outside of the process tank, the level transmitter will give feedback of the water level within the tank. The manual drain valve situated at the bottom of the tank for draining the water from the process tank into the reservoir tank. Another manual valve situated at the top of the tank which is kept open in case of a pressure built up within the tank. The reservoir tank where the reserve water is held for storage. 'Pump 2' which is the pump that needs tuning is situated at the minimum level of the reservoir tank for constant water. A bypass valve which is kept closed which is located after the pump which will bypass the process tank and redirect the pumped water back into the reservoir tank. Another 'pump valve' which allows the pumped water through and into the process tank.

Figure 3 within the appendix shows the block diagram in order to control the water level within the process tank, the block diagram uses the 'LT' feedback value which is then compared to the set value, where the PID controller will either, force the 'pump 2' to work harder to increase the volume of water within the process tank, maintain the speed as the tank setpoint is satisfied or decrease the rate of which 'pump 2' is pumping at to decrease the volume of water within the process tank. In order to disturb the control loop of the process tank the 'drain valve' is left slightly opened where the pump will have to constantly work to maintain the set water level, the disturbance can change where the drain valve will open wider causing the water to drain faster or the drain valve will close causing the water to drain at a slower rate. Therefore, the level transmitter will give a 0-10V value into the controller where the set value will be compared, from the positive or negative value output of the controller the PID controller will give a varying voltage to 'pump 2' dependent on the water volume within the tank.

B)

To find a calibration curve for the level transmitter a group was formed where one would control the 'pump 2', one would visually inspect the tank water level, and one would take the voltage of the level transmitter at the specific water level. 'Table 1' shows the results gathered from the task.

Level (mm)	LT (Voltage)
0	0.025
10	0.6
20	1.3
30	2.38
40	3.22
50	3.95
60	4.39
70	4.84
80	5.49
90	6.08
100	6.59
110	7.03
120	7.54
130	7.98
140	8.54
150	8.9
160	9.3
170	9.66
180	10

Table 1 – Level Transmitter voltage table of results.

'Table 1' shows the results gathered from the manual calibration curve of the level transmitter. The results gathered are of what was expected as the voltage range of the 'LT' is 0-10V and the maximum water level of the process tank is 180mm therefore the 'LT' will give a reading of next to 0V when process tank is empty and a value of next to 10V when the tank is full. 'Figure 4' in the appendix shows the voltage reading when the tank is empty. 'Figure 5' shows the graphical curve from the results gathered in 'table 1', where the line is linear which is what was expected as the level was increasing in increments of 10mm at each reading.

Tables should be in the appendix and the graphs in the main report

C)

To calculate the time constant for the level of the process tank, a test was carried out. For the test to be carried out the drain valve and the air intake/out-take was kept open, the 'bypass valve' as closed, and the proportional valve was open fully. The pump was then set to pump at 5.3V where it was left for a few minutes in order for the water level to settle. This set voltage was noted as level A. The same test was run again with the same procedure for a fair test where the voltage was increased to 5.8V and the voltage was noted as level B.

Level	VP	VL	VF	h Level (m)	q Flowrate m^3/sec
A	5.3	7.525	4.16	0.118	69.33×10 ⁻⁶
B	5.8	8.91	4.41	0.149	73.5×10 ⁻⁶

Table 2 – Time constant.

To measure the time constant the following equation was used:

$$\text{Tank radius} = 7.5\text{cm} = 0.075\text{m therefore Area} = \pi r^2 = 0.01767\text{m}^3$$

$$h = B - A = 0.149 - 0.115 = 0.031$$

$$q = B - A = 73.5 \times 10^{-6} - 69.33 \times 10^{-6} = 4.17 \times 10^{-6}$$

$$\text{Radius} = \frac{h}{q} = \frac{0.031}{4.17 \times 10^{-6}} = 7434.1$$

$$\tau = \text{Area} \times R = 0.01767 \times 7434.1 = 131.361\text{Sec}$$

D)

A suitable experiment was executed in order to find the time constant and gain of the process tank when the water is above the element situated in the tank. 'Figure 6' in the appendix shows the graph drawn after the experiment was taken place. The experiment was to fill the process tank above the heating element as that would take up a lot of the volume which would make the measuring guide and the level transmitter have a error for actual water volume within the tank. On the graph its highlighted where the time constant is found, and the value found is 131.15 seconds shown on 'figure 6'. The value is found to be different, and this is because of the volume of which the heating element has taken up within the measured test.

Calculating the gain. *Incorrect value of gain, should be calculated as the change in output divided by the change in the input*

$$K = \frac{LT(V)}{Pump(V)} = \frac{8.4}{5.3} = 1.59$$

Transfer function.

This transfer function does not match the one you have implemented in the task

$$\frac{K}{\tau s + 1} = \frac{1.59}{131.15s + 1} = 0.012$$

You cannot calculate the answer like this as you have left out the s variable from your transfer function - you have treated it as a numerical fraction.

E)

An online simulation is created using Simulink on matlab. The simulation is built upon the results found in the previous tests carried out on the level control system. When the Simulink is built the system is tuned for the best PID values gathered for the best response and recovery time for level control over the process tank. When the values are tuned the response and accuracy can be changed for the best tuning results. The method used is trial and error when sliding the dials back and fourth for finding the best outcome of values. 'Figure 7' shows the control loop simulation that was used for tuning the process tank level control PID parameters. 'Figure 8' and 'figure 11' then shows the response curve from the decided PID values, where the graph shows the overshoot of the water level and the recovery it takes for the level to meet its set point.

F)

What were your values of Kp, Ki and Kd?

Implementing the results gathered from the PID values tuned off the online simulation. 'Figure 9' shows the P, I, and D values which will be implemented on the process tank control loop when there is a disturbance where the bypass valve is slightly opened. After implementing the PID values onto the Process tank control loop the setpoint was raised to 130mm which is around 8V on the level transmitter, after the setpoint was reached with the PID values a disturbance was added multiple times to see the recovery time and the overshoot on the actual process rig. 'Figure 10' shows the results graph of the effect the PID values had on the level control and when the bypass valve was opened.

5 Temperature Control of the Heater Tank:

Within this task, PI control over water level will be set and the best P, and I values will be found for the temperature control over the heater tank. The task is based on a CE117 Process Trainer which is shown on 'figure 1' in the appendix.

A)

The temperature control of the heater tank on the CE117 process trainer shown on 'figure 1' within the appendix, is a red tank labelled 'Heater tank'. The tank has a temperature transmitter for reading the water temperature within the tank, where 'pump 1' is located underneath the tank which will pump the heated water throughout the process tank, before the heated water can travel through the element in the process tank a electronic solenoid valve has to be energised to be open, then the water will be able to travel through the element in the process tank to cool down as it can be submerged in cooler water, the water is then pumped back out the element and back into the heater tank. There is another temperature transmitter situated on the incoming of the heater tank which will measure the water temperature after going through its cooling stage. The process loop will then calculate if the water needs heating up or cooling down again and this will determine at what rate the 'pump 2' will work at and what voltage will be fed to the electric heating element situated within the heater tank.

'Figure 12' shows the control loop for the heater tank. The figure shows the temperature set point incoming as the positive and the temperature PV as the negative where the calculated value will then be processed by the PID controller, where the output values will be fed to the heating element, where if the temperature is not met feedback from the temperature transmitter labelled 'TT1' will be compared to the setpoint temperature and will then be corrected.

B)

An experiment was carried out for the findings of the heater tanks time constant and gain. The experiment was begun when the water temperature was at ambient temperature which was 27 degrees Celsius. From 'figure 13' the voltages of the temperature transmitter and the pump is shown, from this the gain can be calculated.

$$K = \frac{TT1(V)}{Pump1(V)} = \frac{3}{6} = 0.5$$

Incorrect value of gain, should be calculated as the change in output divided by the change in the input

The time constant was measured from running the heater tank and gathering the graph information which is shown on 'figure 14' in the appendix. The time constant calculated was 579 seconds.

From this the transfer function can be calculated.

This transfer function does not match the one you have implemented in the task

$$\frac{K}{\tau s + 1} = \frac{0.5}{579s + 1} = 0.00086$$

You cannot calculate the answer like this as you have left out the s variable from your transfer function - you have treated it as a numerical fraction.

C)

An online simulation is created using Simulink on matlab. The simulation is built upon the results found in the previous experiments carried out for the heater tank. After building the Simulink the system is fine tuned for the best PI values for the finest response and recovery time for temperature control of the heater tank. When the values are fine-tuned the response and accuracy can be changed for the fine-tuning results. 'Figure 15' shows the control loop simulation was used for fine-tuning of the heater tank PI values. 'Figure 16' and 'figure 17' shows the response curve of the PI values, where the graph shows the overshoot of the water temperature and the recovery it takes for the temperature to increase or decrease to satisfy the setpoint. The PI values which were finely tuned are shown on 'figure 18'.

D)

What were your values of K_p , K_i and K_d ?

Implementing the PI values simulated online from the previous tests on the heater tank. 'Figure 18' shows the PI values used for the process trainer implementation. The setpoint of the tank was set to 40 degrees Celsius, the tank was left to meet the setpoint temperature before an disturbance was implemented on the control loop. After the setpoint was met a disturbance was added to the water temperature where the temperature would overshoot and then drop down to yet again meet the setpoint values.

6 Conclusions and Recommendations:

From carrying out the research task many of PID tuning loops parameters were researched into, where information was found how critical each P, I, and D parameter have got to be fine-tuned for an optimal result. After the research the theoretical information was used in order to complete tasks 3 and four which were the PID tuning of level control and PI control of the heater tank. The information gathered implemented and used in these tasks have been very in depth and accurate. Graph analysing skills came into play where each tuned response had a graph showing the overshoot and the time response curve, where the graph would have to be read and adapted for the best PID or PI values.

7 Team Working:

Team working within this report was a vital aspect where each of the practical tasks were completed in teams, where each individual would have a roll to play whether they would be reading results to jotting them town in tables. The teamwork was essential in completing the tasks.

How did you treat each other?

8 Citation List:

Bibliography

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Available at: <https://www.incatools.com/pid-tuning/pid-tuning-methods/>
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phillips, C. L., 1998. *digital control systems analysis and design*. essex: phillips nagle
chakraborty fourth edition.

This list is far too short at this level, it does not show a wide range of reading

9 Appendix:



Figure 1 – CE117 Process Trainer

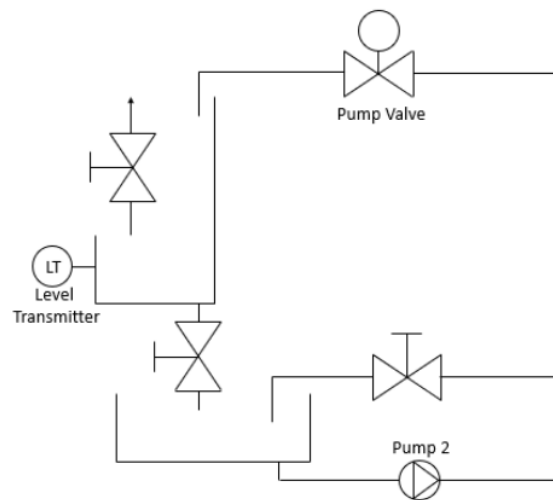


Figure 2 – P&ID diagram of the process tank.

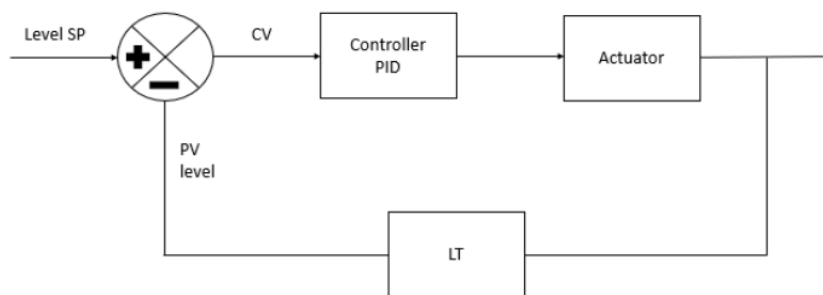


Figure 3 – Block diagram of level control for the process tank.

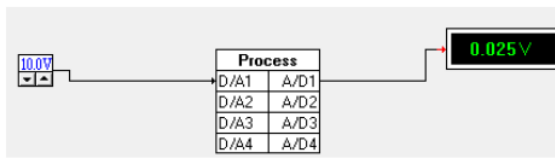


Figure 4 – Voltage reading of calibration curve when tank is empty.

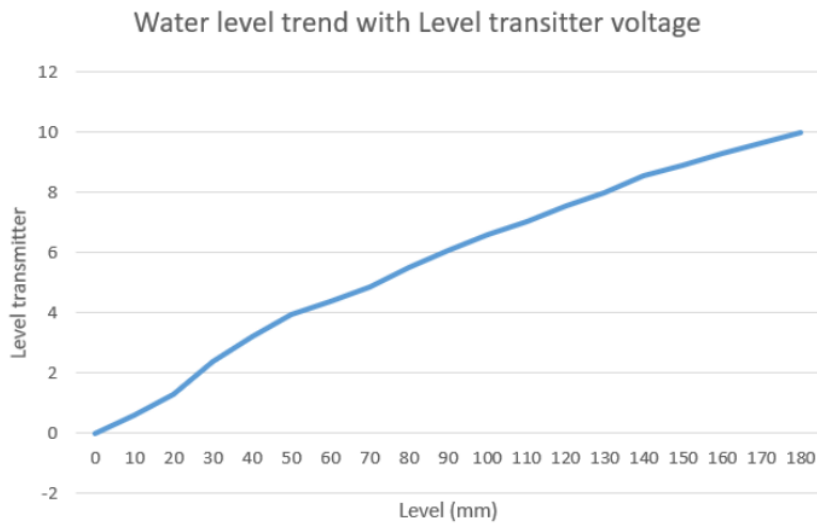


Figure 5 – Calibration curve of the level transmitter.

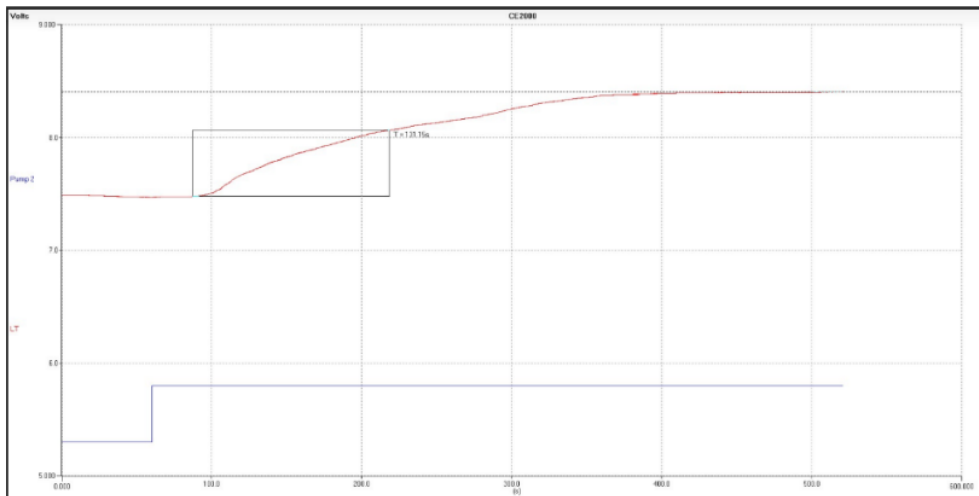


Figure 6 – Level measured time constant.

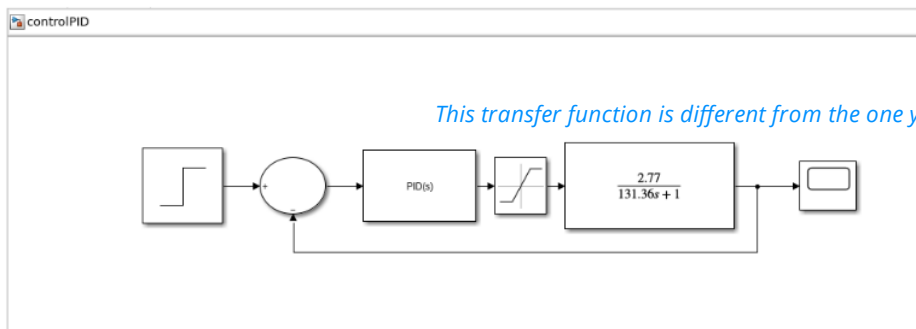


Figure 7 – Online simulation of Level control PID loop.

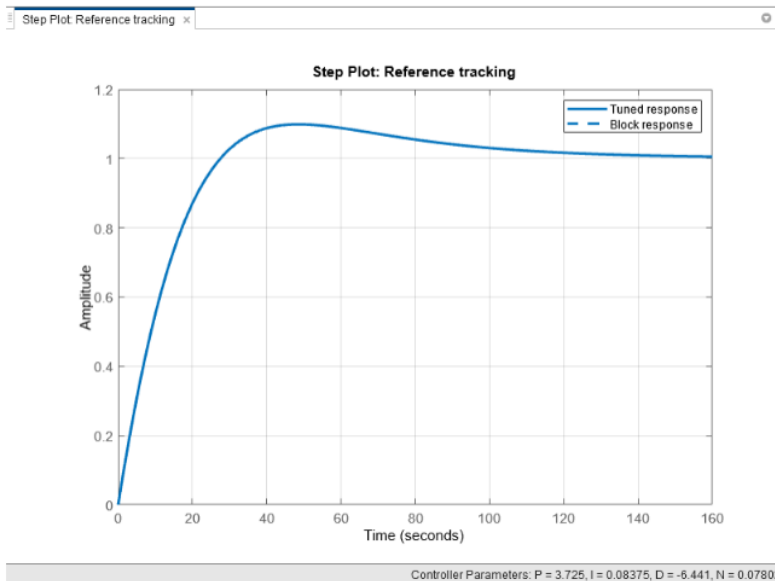


Figure 8 – Response curve of level control simulation.

Source: internal

Proportional (P): 5.53918599887614

Integral (I): 0.180643793060317 0.0085629 ☐ Use I*Ts (optimal for codegen)

Derivative (D): 10.6852634627152

Figure 9 – Tuned PID values for Process tank.

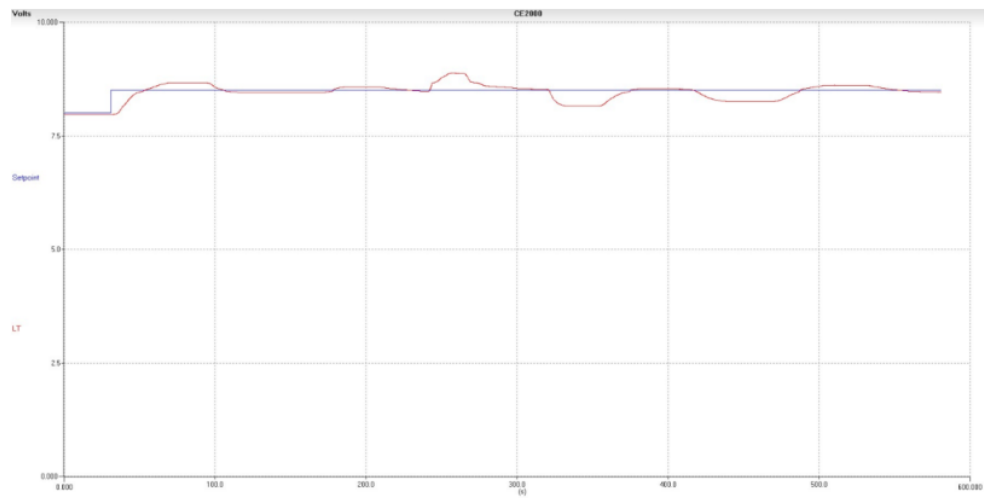


Figure 10 – PID values implemented.

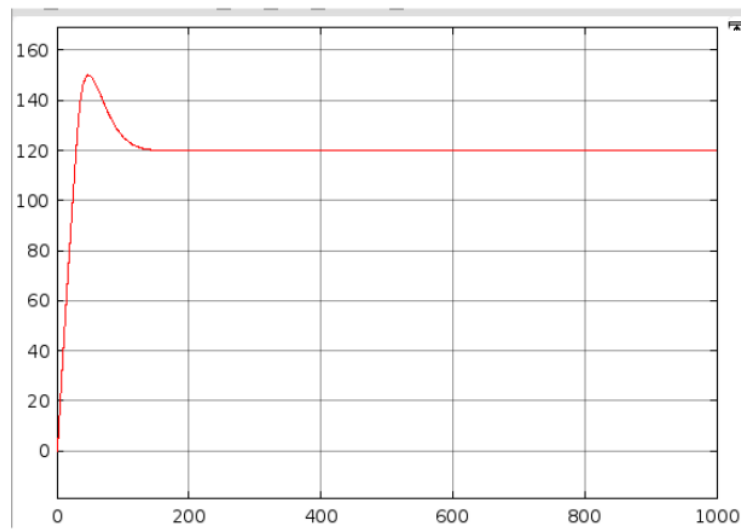


Figure 11 – Level PID graph

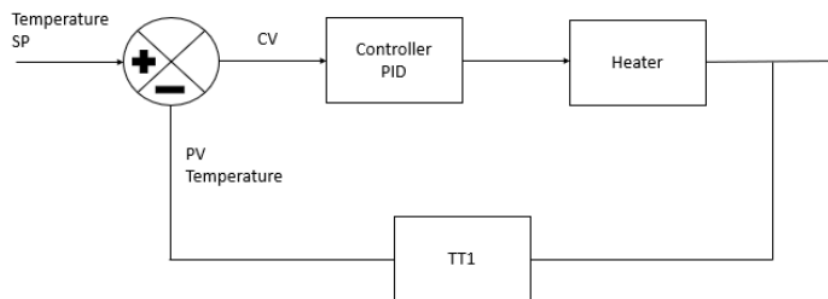


Figure 12– Temperature control loop of the heater tank.

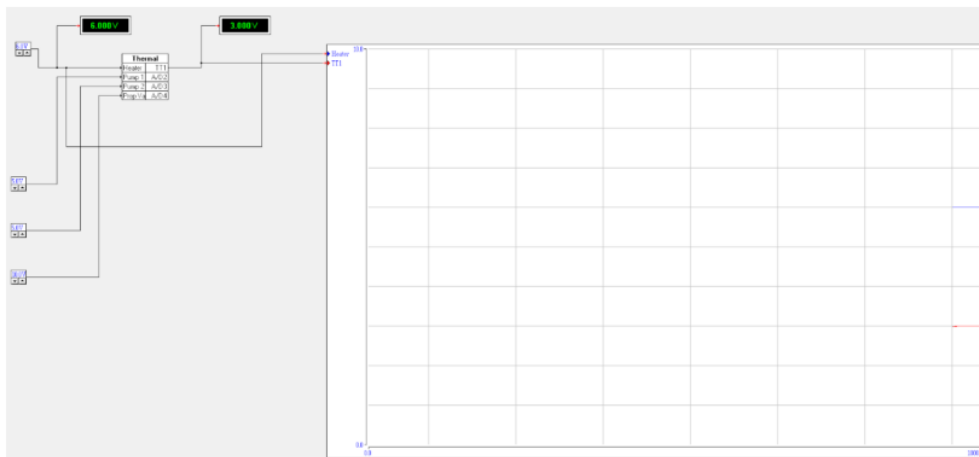


Figure 13 – Heat run for the Heater tank.

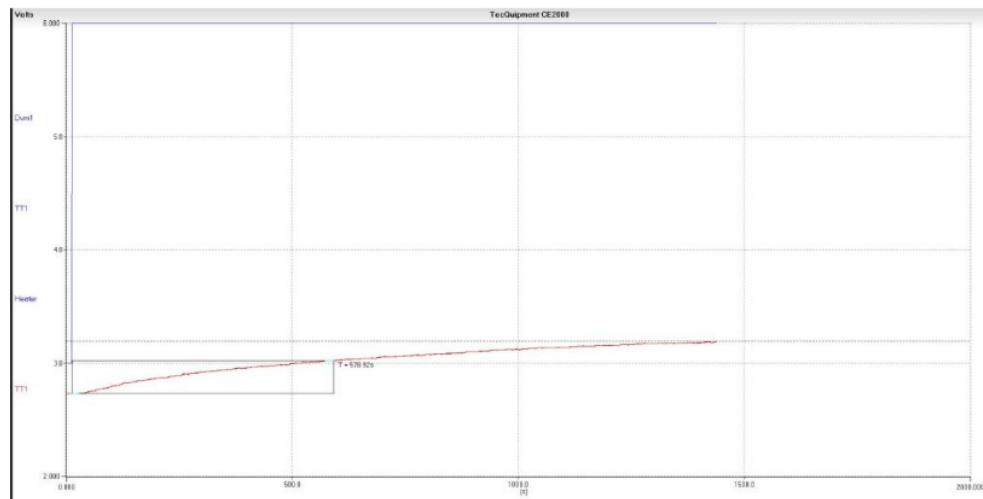


Figure 14 – Heater tank time constant.

This transfer function is different from the one you calculated

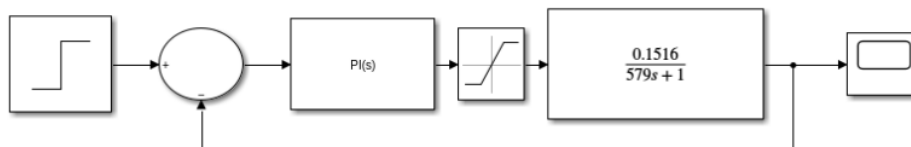


Figure 15 – Temperature control loop.

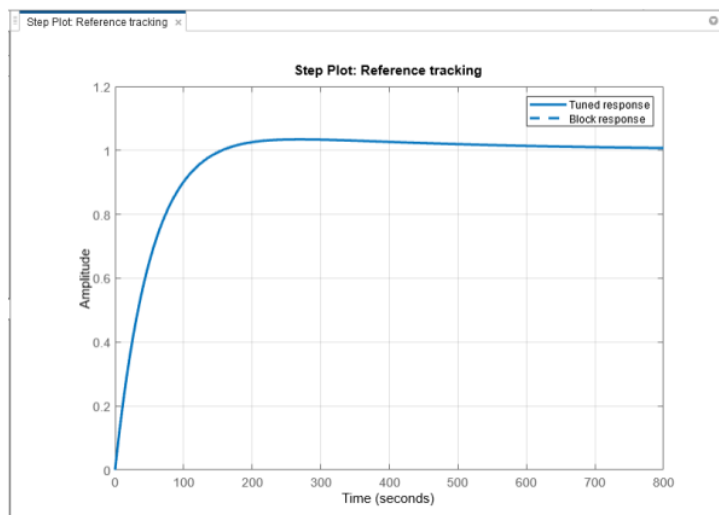


Figure 16 – Response curve of temperature tuning results.

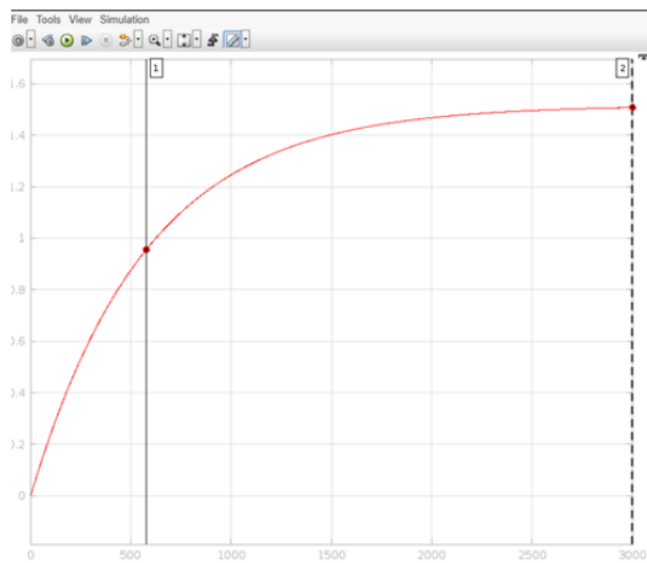


Figure 17 – Response curve of temperature tuning results.

Source:	internal
Proportional (P):	108.9704
Integral (I):	0.80791

Figure 18 – Fine tuned PI values for temperature control loop.

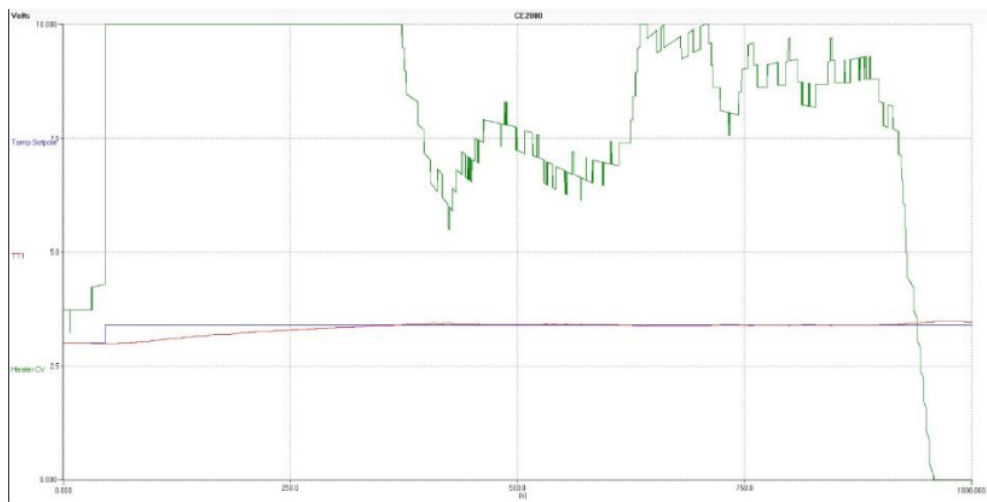


Figure 19 – PI values results when implemented on the process trainer.

FINAL GRADE

GENERAL COMMENTS

Instructor

50/100

PAGE 1

PAGE 2

PAGE 3

Text Comment. should on a new page

Text Comment. Which was the best method?

Text Comment. which method of tuning did you use?

Text Comment. a

Text Comment. What were your conclusions?

PAGE 4

Text Comment. will be

PAGE 5



Write in the third person

Don't refer to your self as I, me, my or others as you etc. Avoid personal references. If absolutely necessary, refer to self as "the author".



Correctly cited

Citation method conforms to Harvard standard, well done.



Correctly cited

Citation method conforms to Harvard standard, well done.



Correctly cited

Citation method conforms to Harvard standard, well done.

Text Comment. This is a very brief section

Text Comment. Which one did you choose for use in this assignment?

Text Comment. Since you actually used the model based approach with simulation, you should have research this method as one of your five.

PAGE 6

PAGE 7

Text Comment. Tables should be in the appendix and the graphs in the main report

PAGE 8

Text Comment. Incorrect value of gain, should be calculated as the change in output divided by the change in the input

Text Comment. This transfer function does not match the one you have implemented in the task

Text Comment. You cannot calculate the answer like this as you have left out the s variable from your transfer function - you have treated it as a numerical fraction.

Text Comment. What were your values of K_p , K_i and K_d ?

PAGE 9

Text Comment. Incorrect value of gain, should be calculated as the change in output divided by the change in the input

Text Comment. This transfer function does not match the one you have implemented in the task

Text Comment. You cannot calculate the answer like this as you have left out the s variable from your transfer function - you have treated it as a numerical fraction.

PAGE 10

Text Comment. What were your values of K_p , K_i and K_d ?

Text Comment. How did you treat each other?

PAGE 11

Text Comment. This list is far too short at this level, it does not show a wide range of reading

PAGE 12

PAGE 13

PAGE 14

Text Comment. This transfer function is different from the one you calculated

PAGE 15

PAGE 16

Text Comment. This transfer function is different from the one you calculated

PAGE 17

PAGE 18

GRADING FORM: NEW CSG-RUBRIC

HEFIN WILLIAMS

50

1. ENGAGEMENT WITH LITERATURE



Little evidence of reading from a very small range of sources cited correctly and listed correctly using the Harvard method. You have not research the method use in the assignment. 7/20

7

2. KNOWLEDGE AND UNDERSTANDING



Some evidence of understanding in your report overall and particularly in your explanation of your Level Control of the Process Tank and Temperature Control of the Heater Tank experiments. 10/20

10

3. COGNITIVE AND INTELLECTUAL



Adequate analysis of results in your Level Control of the Process Tank and Temperature Control of the Heater Tank experiments with some conclusions presented. 12/20

12

4. PRACTICAL APPLICATION



Good use of equipment and presentation of results in your Level Control of the Process Tank and Temperature Control of the Heater Tank experiments. 11/20

11

5. TRANSFERABLE SKILLS



Satisfactory report style, presentation, use of grammar, spelling and punctuation. Brief executive

10

summary, good work plan and explanation of team working. Word count not exceeded. 10/20