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2017196

by Jack Rogers

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Module: SGEE5009 Control Engineering

Assignment: Process Control Systems

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University number: 2017196

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1. Executive Summary

PID systems are employed in these activities to regulate the process rig's temperature and level. These PID systems were developed and evaluated using the research-based information to show that they function effectively and efficiently. The gain and time constant of the various systems employed in the tasks were determined through experiments. The transfer functions required to build a mathematical model using Simulink will be made using these values. With the help of this model, a graphed response was created, gathering tuned values for P, I, and D. These fine-tuned parameters were then used to the software-generated control loops in the CE117 Process Trainer to generate graphs. The system's performance was then evaluated using these graphs. The three tasks—level control in the process tank, heater tank temperature, and process tank water temperature—were repeated using this procedure. A conclusion was formed at the end to assess the effectiveness of the tasks.

process tank temperature was not part of this assignment

what were your conclusions?

Paragraphs should be fully justified text as required in the brief

2. Work plan for Life-long Learning

1. Research: Investigate the basics of process control systems and familiarize the reader with the various components and terminology associated with them.
2. Structure: Outline the key points to be covered in the assignment and decide on the structure for the report.
3. Create diagrams: Develop diagrams that illustrate the components of a process control system and their interconnections.
4. Write introduction: Introduce the topic of process control systems, their importance and applications.
5. Describe components: Explain each of the components in detail, including their purpose and role in the system.
6. Analyse systems: Analyse the different types of process control systems, their advantages and disadvantages.
7. Describe applications: Describe some of the applications of process control systems and explain how they can be used to improve efficiency.
8. Discuss challenges: Discuss some of the challenges associated with process control systems and how they can be addressed.
9. Conclusion: Summarize the main points and provide a conclusion.
10. Editing: Edit and proofread the assignment for accuracy and clarity.

Sounds like a good plan

3. Research

(PID) stands for proportional integral derivative in a controller. It is used to regulate a variety of process variables, including flow, pressure, temperature, and others. PID works by combining proportional control with integral and derivative adjustments to assist the unit in compensating for various system changes and variables. The PID's function is to force feedback to correspond to a system setpoint. (Engineering, 2003) [Correctly cited](#)

As an illustration, a thermocouple in a heating system will compel the heating unit to turn on or off based on the system's predetermined temperature. PID systems work best in environments with frequent load changes and quick response times to changes. Here, the PID system will automatically adapt to changes in the amount of energy available, the setpoint, or the mass. The fundamental idea behind PID is the individual tuning or adjustment of the proportional, integral, and derivative. The difference between these values is then used to calculate a correction factor, which is then supplied into the input. The unit will be helped by these adjustments to make up for changes in the target value. (CORP, 2023) [Correctly cited](#)

Method 1: Ziegler-Nichols Method

One of the first and most popular techniques for fine-tuning PID loop settings is the Ziegler-Nichols method. It is based on a series of tests in which the PID loop's parameters were changed while the system reaction was tracked to identify the ideal parameter values. This approach is based on the finding that the most stable feedback control system may be achieved for a particular process by selecting the optimal proportional gain (K_p), integral time (T_i), and derivative time (T_d) ratios. The ultimate gain (K_u) and ultimate period (P_u) of the system are experimentally determined using the Ziegler-Nichols method, and the optimum values for the PID parameters are then calculated using these values. (Ellis, 2012) (Bennett, 2022) [Separate your citations](#)

Grouping citations together is confusing for your reader as they don't know which source was use for which information

Method 2: Cohen-Coon Method

For fine-tuning PID loop parameters, the Cohen-Coon method is an alternative to the Ziegler-Nichols method. It is based on the finding that combining proportional, integral, and derivative control can increase the stability of the system. The ultimate gain (K_u) and ultimate period (P_u) of the system are empirically determined using this method, and the optimal values for the PID parameters are then calculated using these values. Although the Cohen-Coon approach is more intricate and time-consuming to use than the Ziegler-Nichlos method, it is also more accurate. (Bennett, 2022) (tools, 2023) [Separate your citations](#)

Method 3: Tyreus-Luyben Method

The Ziegler-Nichols and Cohen-Coon methods are alternatives to the Tyreus-Luyben approach for adjusting PID loop settings. It is based on the finding that combining proportional, integral, and derivative control can increase the stability of the system. For this procedure, the ultimate gain (K_u), ultimate period (P_u), ultimate gain margin (GM), and ultimate phase margin must all be experimentally determined (PM). The best values for the PID parameters are then determined using these values. Compared to the Ziegler-Nichols and Cohen-Coon methods, the Tyreus-Luyben method is more accurate, but its application is also more difficult and time-consuming. (rip, 2013) [Correctly cited](#)

Method 4: IMC Tuning

An increasingly popular technique for fine-tuning PID loops is the Internal Model Control (IMC) method. It is based on the finding that combining proportional, integral, and derivative control can increase the stability of the system. For this procedure, the ultimate gain (K_u), ultimate period (P_u), ultimate gain margin (GM), and ultimate phase margin must all be experimentally determined (PM). The best values for the PID parameters are then determined using these values. Compared to the Ziegler-Nichols and Cohen-Coon procedures, the IMC method is more accurate, but its application is also more difficult and time-consuming. (Dataforth, 1995-2023) [Correctly cited](#)

Method 5: Relay Feedback Method

The Ziegler-Nichols, Cohen-Coon, and IMC methods for fine-tuning PID loop parameters can be replaced by the Relay Feedback Method. It is based on the finding that combining proportional, integral, and derivative control can increase the stability of the system. For this method, the ultimate gain (K_u), ultimate period (P_u), ultimate gain margin (GM), and ultimate phase margin must all be experimentally determined (PM). The best values for the PID parameters are then determined using these values. Compared to the Ziegler-Nichols, Cohen-Coon, and IMC methods, the Relay Feedback Method is more accurate. However, it is also more difficult and time-consuming to apply. (Jermila, 2013) [Correctly cited](#)

Which one is the best for this assignment and why?

Since you have actually used the model based method, you should have included it in your research.

4. Level Control of the Process Tank

The assignment is based on the CE117 Process Trainer that is depicted in Figure 1 of the appendix. The ideal P, I, and D values will be identified for the water flow in this work in order to regulate the level of the main water tank using PID control over water level.

Instrumentation and Control Actuators – CE117 Process Trainer

An examination of the instrumentation and control mechanisms used by the CE117 Process Trainer to regulate the level in the process tank in figure 1, the process tank is depicted as the clear tank. The process tank's P&ID diagram is shown in Figure 2 of the appendix. The level transmitter is seen in the P&ID figure and is located outside of the process tank. The level transmitter will provide feedback on the water level inside the tank. The manual drain valve is used to manually drain water from the process tank into the reservoir tank. It is located at the bottom of the tank. A second manual valve is located at the top of the tank and is kept open in the event that pressure builds inside the tank. The reservoir tank is where the backup water is kept for storage. Pump 2 is located at the lowest level of the reservoir tank for steady water and needs to be tuned. After the pump, there is a bypass valve that, when closed, directs the pumped water away from the process tank and back into the reservoir tank. A second "pump valve" permits the pumped water to pass through and into the process tank.

Figure 3 in the appendix depicts the block diagram for controlling the water level in 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 make "pump 2" work harder to increase the volume of water within the process tank, maintain the speed once the tank setpoint is satisfied, or reduce the rate of pumping at which "pump 2" is operating to decrease the volume of water within. The process tank's "drain valve" is purposefully left partially open to disrupt the control loop, forcing the pump to work continuously to maintain the desired water level. Depending on the nature of the disturbance, the drain valve may widen, causing the water to drain more quickly, or it may close, causing the water to drain more slowly. In order to compare the level transmitter's 0-10V value with the controller's set value, the controller will output either a positive or negative value. The PID controller will then alter the voltage it sends to "pump 2" in accordance with the amount of water in the tank.

A good explanation, well written

Paragraphs should be fully justified text as required in the brief

Calibration curve for the level transmitter

A group was established to control "pump 2," visually check the water level in the tank, and measure the voltage of the level transmitter at a given water level in order to determine a calibration curve for the level transmitter. The task's results are displayed in "Table 1." The information received from the level transmitter's manual calibration curve is displayed in "Table 1". The findings obtained are in line with expectations because the voltage range of the "LT" is 0-10V and the process tank's maximum water level is 180mm; as a result, the "LT" will read close to 0V when the tank is empty and close to 10V when it is full. The voltage reading is displayed in "Figure 4" of the appendix when the tank is empty. The graphical curve from the data collected in "table 1" is shown in "Figure 5," and the line is linear as expected because the level was rising in 10mm increments at each reading.

Better to put the table in the appendix and the graph in the report. Pictures are more interesting than numbers

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 Calibration – Level Control

Time constant and gain experiment for level control

A test was conducted to determine the time constant for the level of the process tank. The drain valve, air intake/outtake, and "bypass valve" were left open during the test, while the proportional valve was fully opened. The water level was then allowed to settle for a few minutes while the pump was left running at 5.3V. The level A for this specified voltage was noted. The same test was conducted once more using the identical steps for a fair test, but this time the voltage was raised to 5.8V and recorded 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.

Using the following equation, the time constant was calculated:

$$\text{Tank radius} = 7.5\text{cm}$$

$$= 0.075\text{m}$$

$$\text{Therefore Area} = \pi r^2$$

$$= 0.01767\text{m}^3$$

This calculation should be in the appendix with the answer in the report

$$h = B - A$$

$$= 0.149 - 0.115$$

$$= 0.031$$

$$q = B - A$$

$$= 73.5 \times 10^{-6} - 69.33 \times 10^{-6}$$

$$= 4.17 \times 10^{-6}$$

$$\text{Radius} = \frac{h}{q}$$

$$= \frac{0.031}{4.17 \times 10^{-6}}$$

$$= 7434.1$$

$$\tau = \text{Area} \times R$$

$$= 0.01767 \times 7434.1$$

$$= 131.361\text{Sec}$$

When the water is above the element located in the process tank, an appropriate experiment was carried out to determine the time constant and gain of the tank. The graph created after the experiment is shown in "Figure 6" in the appendix. The experiment involved filling the process tank to the level above the heating element because doing otherwise would result in a measurement error between the level transmitter and measuring guide for the actual water volume in the tank.

The location of the time constant is highlighted on the graph, and the value discovered is 131.15 seconds, which is shown in "figure 6". The volume that the heating element occupied during the measured test is the reason why the value is found to be different.

The following equation was used in order to calculate the gain and transfer function:

$$\begin{aligned} (\text{Gain}) K &= \frac{LT(V)}{Pump(V)} \text{ incorrect, you should be using the change in the voltages not the voltages themselves} \\ &= \frac{8.4}{5.3} \\ &= 1.59 \end{aligned}$$

Your model in figure 7 has a gain of 2.77 which does not match up with your calculations here

$$\begin{aligned} \text{Transfer Function} &= \frac{K}{\tau s + 1} \\ &= \frac{1.59}{131.361s + 1} \\ &= 0.012 \end{aligned}$$

this is nonsense, the s has disappeared from the transfer function
leaving out the s from the equation has tempted you to calculate a value
what does 0.012 mean?

Simulation of the system from a mathematical

Simulink on the Matlab platform is used to create an online simulation. The findings from earlier tests on the level control system served as the foundation for the simulation. In order to achieve the best response and recovery time for level control over the process tank, the Simulink system is tuned when it is built. The response and accuracy can be altered after the values have been tuned for the best tuning outcomes. To find the best value outcome, the dials are moved back and forth using a trial-and-error methodology. The control loop simulation used to fine-tune the PID parameters for process tank level control is shown in "Figure 7". The response curve from the chosen PID settings is then displayed in "Figure 8," where the graph illustrates the overshoot of the water level and the recovery time required for the level to return to its set position.

The P, I, and D values that will be used on the process tank control loop in the event of a disturbance where the bypass valve is slightly opened are shown in "Figure 9." The setpoint was increased to 130mm, which is approximately 8V on the level transmitter, after the PID values were applied to the Process tank control loop. After the setpoint was reached with the PID values, a disturbance was added repeatedly to observe the recovery time and the overshoot on the actual Process rig. The results graph for the impact the PID values had on the level control and when the bypass valve was opened is shown in "Figure 10."

The distrubance graph should be in the main report

5. Temperature Control of the Heater Tank

Investigate the instrumentation and control actuators

The heater tank on the CE117 process trainer, which is seen in "figure 1" in the appendix, has a red tank with the label "Heater tank," which controls the temperature. The process tank is equipped with an electronic solenoid valve that must be activated in order for the heated water to pass through. Once the heated water has passed through the element in the process tank, it can be submerged in cooler water, allowing the water to cool down. The process tank also has a temperature transmitter that measures the water temperature inside the tank. Pump 1 is located underneath the tank and pumps the heated water throughout the tank. Another temperature transmitter, which measures the water's temperature after it has undergone cooling, is installed on the heater tank's inlet. The process loop will then assess whether the water has to be heated up or cooled down once more, which will influence the rate of operation of "pump 2" and the voltage delivered to the electric heating element located inside the heater tank.

The heating tank's control loop is depicted in "Figure 12". The temperature transmitter labelled "TT1" provides feedback on the temperature, which is compared to the setpoint temperature and corrected if necessary. The figure depicts the temperature set point incoming as the positive and the temperature PV as the negative. The calculated value will then be processed by the PID controller and fed to the heating element.

Time constant and Gain

For determining the heater tanks' time constant and gain, an experiment was conducted. When the water reached the ambient temperature, which was 27 degrees Celsius, the experiment was launched. The voltages of the temperature transmitter and the pump are displayed in "figure 13," and the gain may be determined using these values.

$$K = \frac{TT1}{Pump1}$$

The gain should be calculated from the changes in the voltages divided by each other not the voltages themselves

$$= \frac{3}{6}$$

$$= 0.5$$

Running the heating tank and gathering the graph data, which is presented in "figure 14" in the appendix, allowed for the measurement of the time constant. The calculated time constant was 579 seconds. This allows for the calculation of the transfer function.

Your model in figure 15 has a gain of 0.1516 which does not match up with your calculations here

$$\begin{aligned} \text{Transfer function} &= \frac{K}{\tau s + 1} \\ &= \frac{0.5}{579s + 1} \quad \text{0.5 is incorrect} \\ &= 0.00086 \end{aligned}$$

This is meaning less, you have dropped the s from the transfer function and performed a calculation which has no meaning

Simulation of the system from a mathematical model

Simulink on Matlab is used to build an online simulation. The simulation is based on the findings from earlier tests conducted on the heater tank. The system is fine-tuned once Simulink is constructed for the best PI values for the fastest response and recovery time for the heater tank's temperature regulation. The response and accuracy can be altered for the outcomes of fine-tuning when the values are adjusted. Figure 15 demonstrates how the heating tank PI values were adjusted using a control loop simulation. The response curve of the PI values is shown in "Figure 16" and "Figure 17," where the graph depicts the overshoot of the water temperature and the recovery time needed for the temperature to rise or fall to the setpoint. On "figure 18," the carefully calibrated PI values are displayed.

What were your tuned values of Kp, Ki, and Kd?

Implement the control method

By implementing the PI values that were simulated online from the heating tank's prior tests. The PI values utilised for the process trainer implementation are displayed in "Figure 18." The tank's setpoint temperature was set at 40 degrees Celsius, and before introducing a disturbance to the control loop, the tank was given time to reach that temperature. A disturbance was applied to the water temperature after the setpoint was reached, causing the temperature to overshoot before falling to once more reach the setpoint values.

Good observations

6. Conclusions and Recommendations

This is an unfinished sentence

Based on the information learned via the research, including the various tuning techniques and their effects on altering P, I, and D. This made it easier to develop the control loops and tune the PID models. By establishing the control loops, it was possible to have a deeper comprehension of how to use all the acquired knowledge in real-world situations. For instance, how to utilise the CE117 Process Trainer, how to construct P&ID and block diagrams, how to calibrate a level transmitter, and how the feedback from the sensing element enables the system to make performance modifications. A deeper comprehension of how to interpret graphs and come to a decision. Simulated and real experiments were conducted as part of these activities in order to compare them and make sure they were carried out correctly and that the study they conducted was supported by the results. The system's conclusion is that after the PID values have been correctly tuned, the reaction time is considerably more effective, demonstrating the significance of doing so correctly. A better and more accurate result will be provided if the calculations are done correctly, which places a strong premium on doing so. *Is this an admission?*

Paragraphs should be fully justified text as required in the brief

7. Team Working

The success of the experiments depended heavily on the team's ability to work collaboratively across a variety of responsibilities. To help everyone better grasp each component of the system, roles were switched with each work. For example, one team member would perform computations, and the following assignment would require him to build the control loop for the CE117 Process Trainer.

How did you treat each other?

8. Citation List

Correct method of listing.

A good range of sources

Bennett, J., 2022. *PID Tuning via Classical Methods*. [Online]

Available at:

[https://eng.libretexts.org/Bookshelves/Industrial and Systems Engineering/Book%3A Chemical Process Dynamics and Controls \(Woolf\)/09%3A Proportional-Integral-Derivative \(PID\) Control/9.03%3A PID Tuning via Classical Methods#:~:text=The%20Ziegler%2DNichols%](https://eng.libretexts.org/Bookshelves/Industrial_and_Systems_Engineering/Book%3A_Chemical_Process_Dynamics_and_Controls_(Woolf)/09%3A_Proportional-Integral-Derivative_(PID)_Control/9.03%3A_PID_Tuning_via_Classical_Methods#:~:text=The%20Ziegler%2DNichols%20method%20for%20tuning,of%20oscillation%20is%20f0.)

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tools, i., 2023. *inca tools*. [Online]

Available at: <https://www.incatools.com/pid-tuning/pid-tuning-methods/>

[Accessed 07 02 2023].

9. Appendix



Figure 1 – CE117 Process Trainer

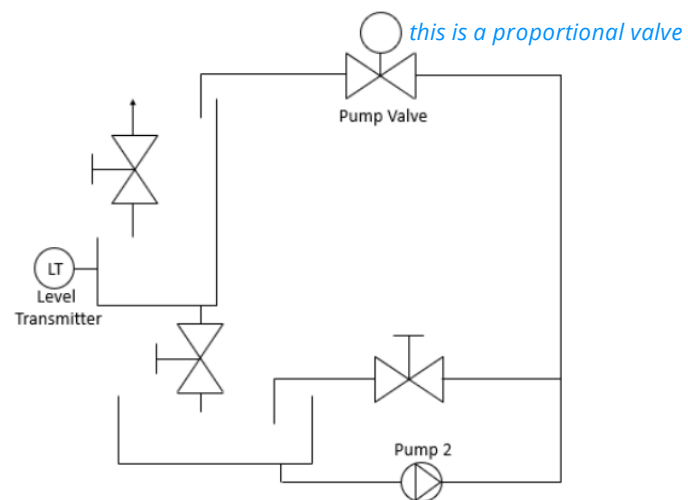


Figure 2 – P&ID diagram of the process tank.

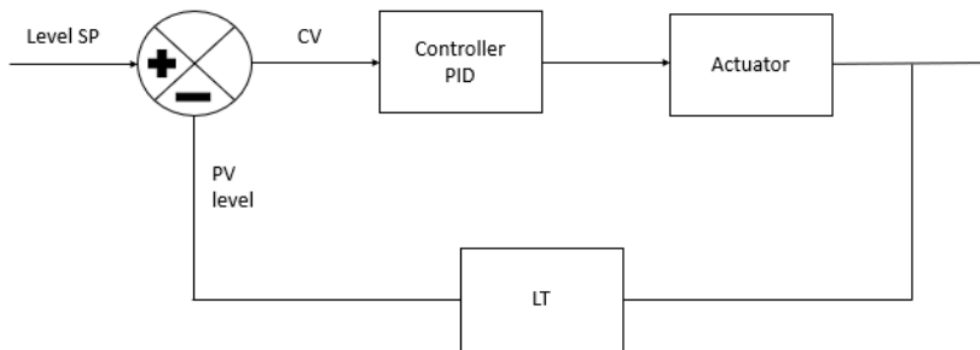


Figure 3 – Block diagram of level control for the process tank.

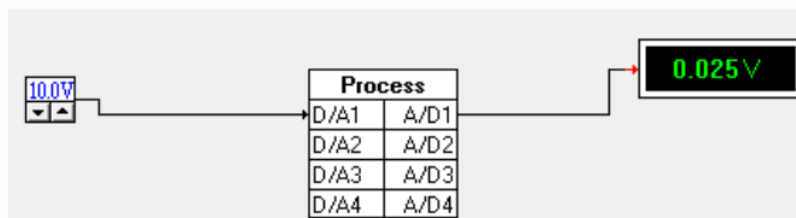


Figure 4 – Voltage reading of calibration curve when tank is empty.

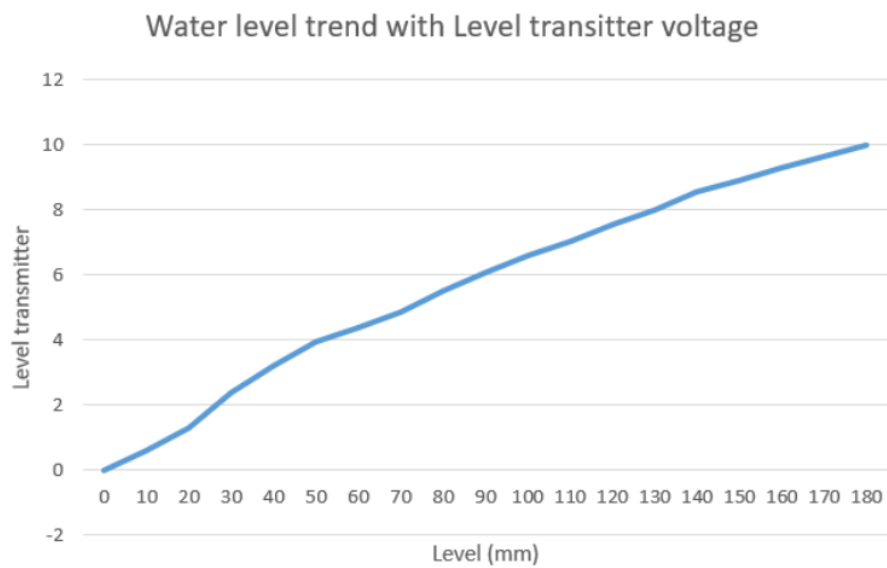


Figure 5 – Calibration curve of the level transmitter.

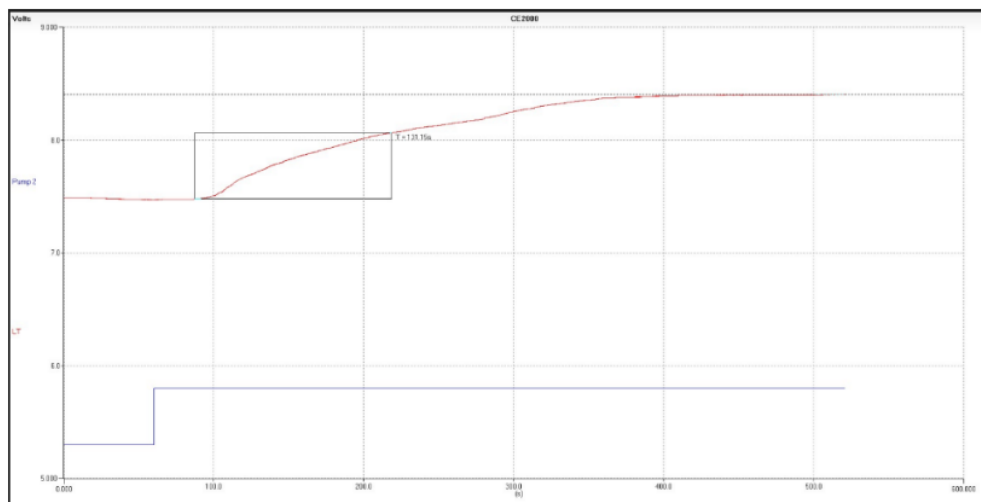


Figure 6 – Level measured time constant.

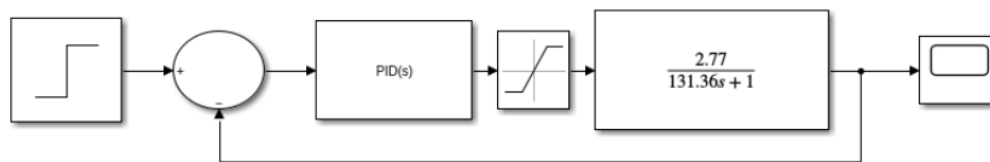


Figure 7 – Online simulation of Level control PID loop.

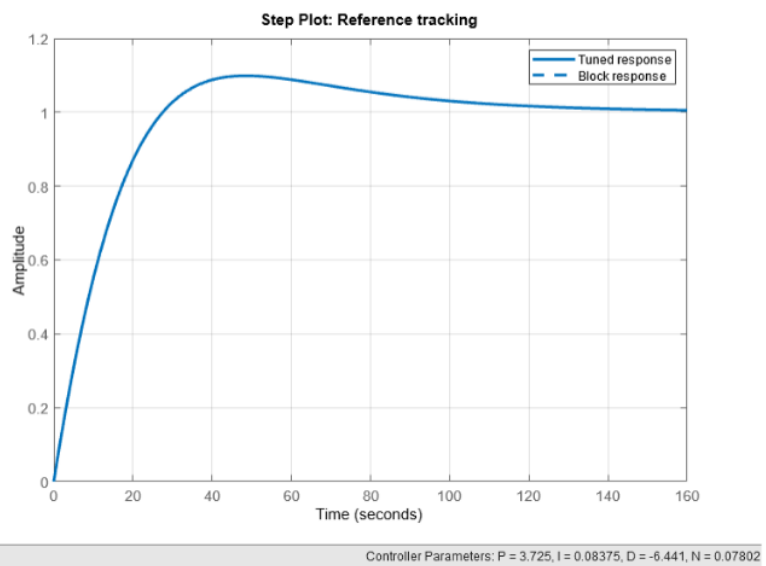


Figure 8 – Response curve of level control simulation.

Source:

Proportional (P):

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

Derivative (D):

Figure 9 – Tuned PID values for Process tank.

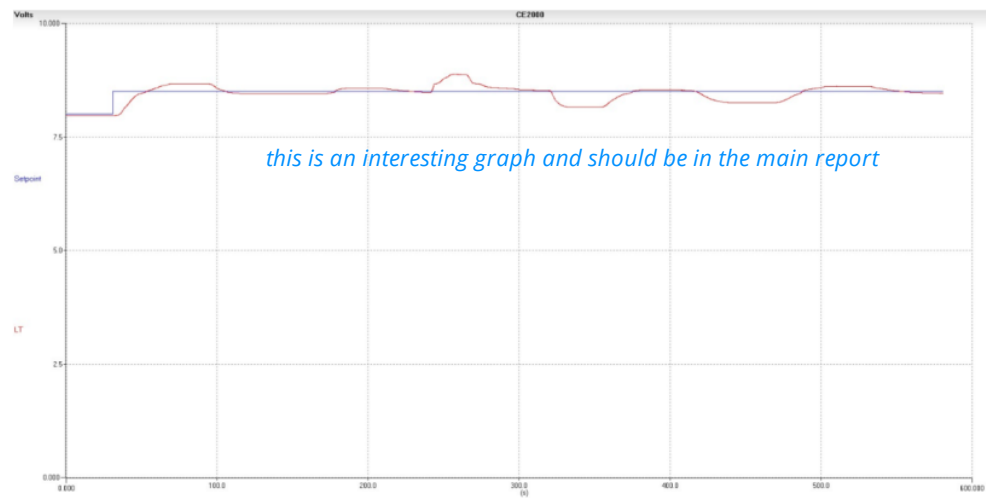


Figure 10 – PID values implemented.

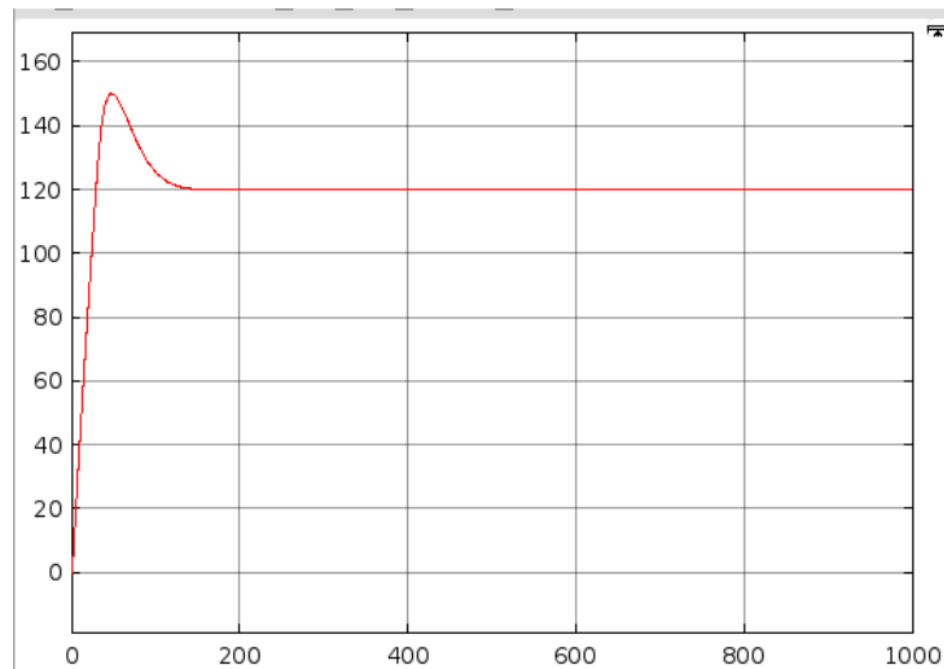


Figure 11 – Level PID graph

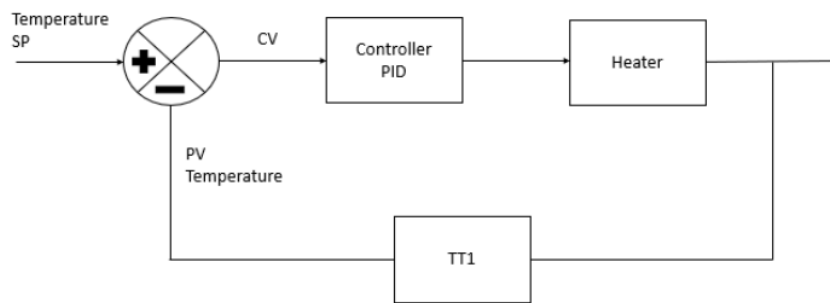


Figure 12 – Temperature control loop of the heater tank.

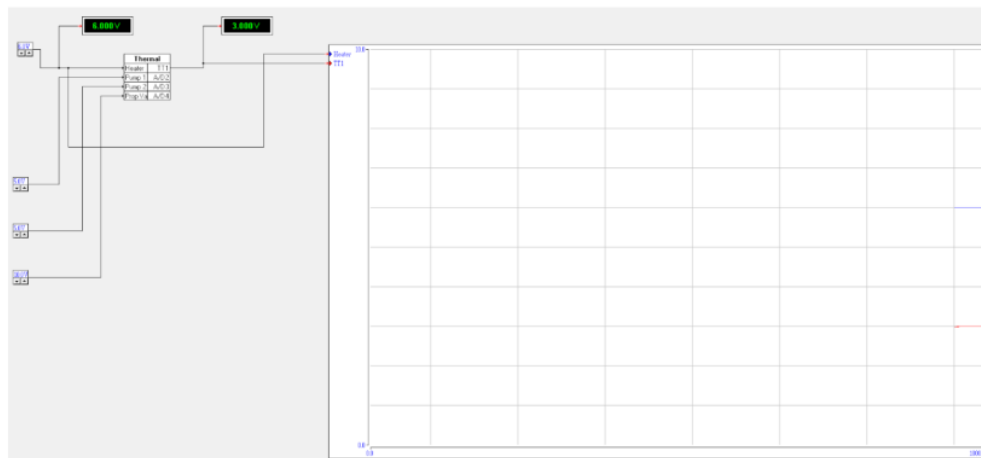


Figure 13 – Heat run for the Heater tank.

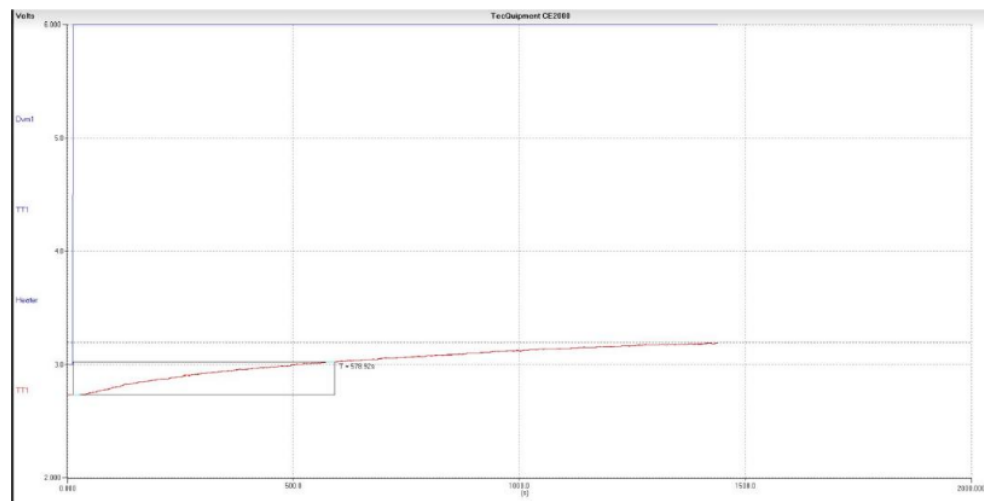


Figure 14 – Heater tank time constant.

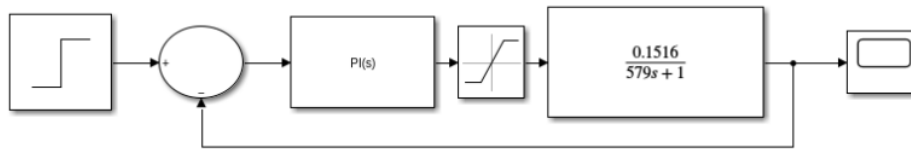


Figure 15 – Temperature control loop.

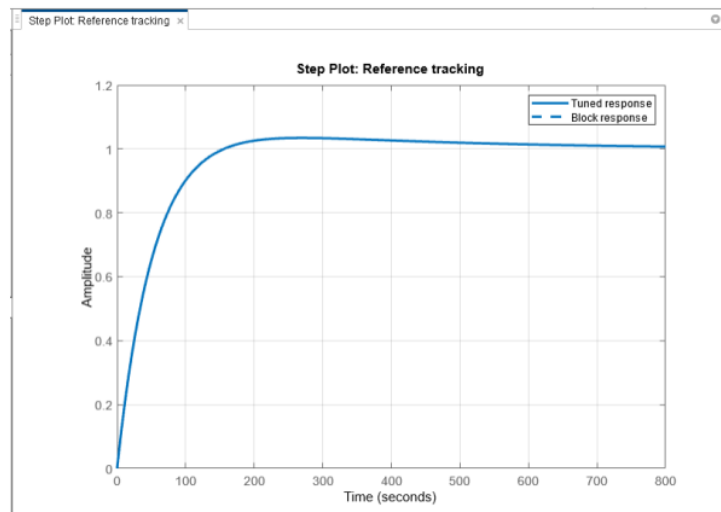


Figure 16 – Response curve of temperature tuning results.

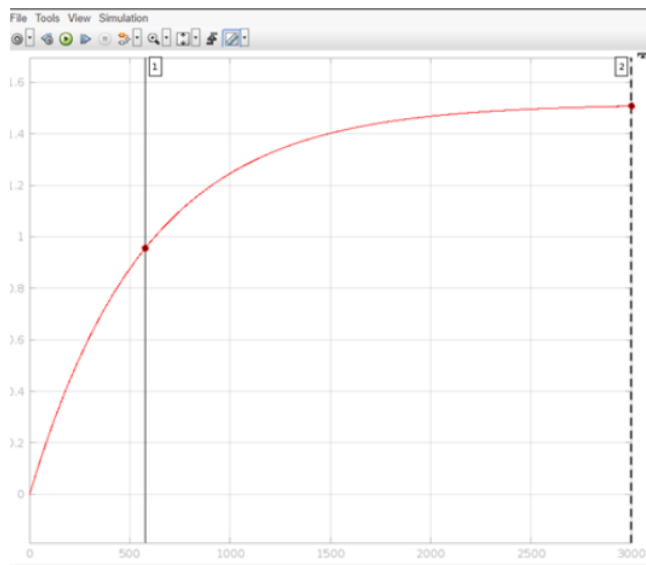


Figure 17 – Response curve of temperature tuning results.

Source:

Proportional (P):

Integral (I):

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

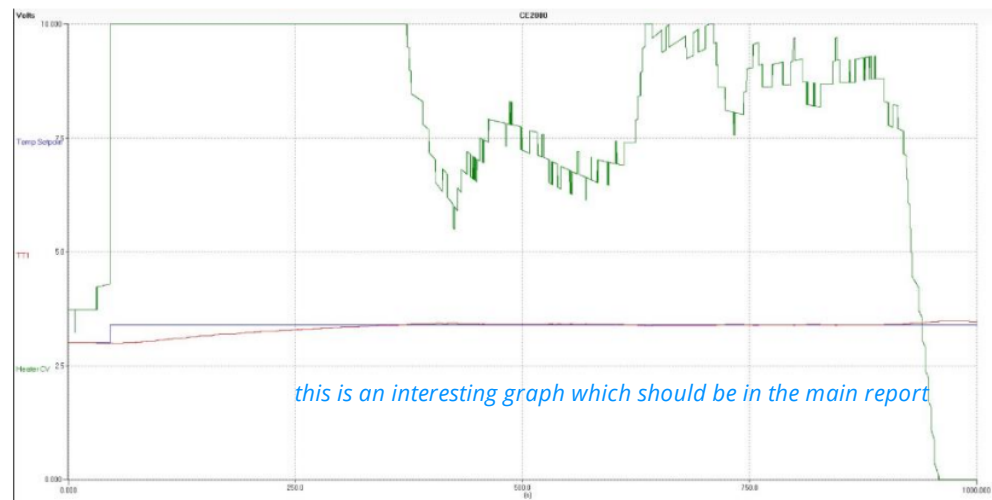


Figure 19 – PI values results when implemented on the process trainer.

FINAL GRADE

GENERAL COMMENTS

Instructor

54/100

PAGE 1

Text Comment. word count exceeded

PAGE 2

PAGE 3

Text Comment. process tank temperature was not part of this assignment

Text Comment. what were your conclusions?

QM

Paragraphs should be fully justified text as required in the brief

PAGE 4

Text Comment. Sounds like a good plan

PAGE 5

QM

Paragraphs should be fully justified text as required in the brief

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

QM

Separate your citations

Cite your source next to the information being used. Don't combine citations as your reader will not know which information is from which source.

Text Comment. Grouping citations together is confusing for your reader as they don't know which source was use for which information

QM

Separate your citations

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PAGE 6

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

Text Comment. Which one is the best for this assignment and why?

Text Comment. Since you have actually used the model based method, you should have included it in your research.

PAGE 7

Text Comment. didn't know there was grease in it!

Text Comment. open further

Text Comment. A good explanation, well written

QM

Paragraphs should be fully justified text as required in the brief

PAGE 8

Text Comment. Better to put the table in the appendix and the graph in the report. Pictures are more interesting than numbers

Text Comment. This calculation should be in the appendix with the answer in the report

Text Comment. incorrect, you should be using the change in the voltages not the voltages themselves

Text Comment. Your model in figure 7 has a gain of 2.77 which does not match up with your calculations here

Text Comment. this is nonsense, the s has disappeared from the transfer function

Text Comment. leaving out the s from the equation has tempted you to calculate a value

Text Comment. what does 0.012 mean?

Text Comment. what were your tuned values of Kp, Ki, Kd?

Text Comment. The disturbance graph should be in the main report

Text Comment. The gain should be calculated from the changes in the voltages divided by each other not the voltages themselves

Text Comment. Your model in figure 15 has a gain of 0.1516 which does not match up with your calculations here

Text Comment. 0.5 is incorrect

Text Comment. ^

Text Comment. s

Text Comment. This is meaning less, you have dropped the s from the transfer function and performed a calculation which has no meaning

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

Text Comment. Good observations

PAGE 14

Text Comment. This is an unfinished sentence

Text Comment. Is this an admission?

QM

Paragraphs should be fully justified text as required in the brief

Text Comment. How did you treat each other?

PAGE 15

QM

Correct method of listing.

You have listed your sources correctly according to the Harvard method.

Text Comment. A good range of sources

PAGE 16

Text Comment. this is a proportional valve

PAGE 17

PAGE 18

PAGE 19

Text Comment. this is an interesting graph and should be in the main report

PAGE 20

PAGE 21

PAGE 22

Text Comment. this is an interesting graph which should be in the main report

1. ENGAGEMENT WITH LITERATURE



Report section 3 and 8 Good evidence of reading from a range of sources cited correctly and listed correctly using the Harvard method. However, the method used to tune the loops in this assignment was not researched 10/20

10

2. KNOWLEDGE AND UNDERSTANDING



All report sections and particularly sections 3, 4 and 5 Some evidence of understanding in your report overall and particularly in your Research and your explanation of your Level Control of the Process Tank and Temperature Control of the Heater Tank experiments. 11/20

11

3. COGNITIVE AND INTELLECTUAL



Report sections 4, 5 and 6 Good analysis of results in your Level Control of the Process Tank and Temperature Control of the Heater Tank experiments with clear conclusions and recommendations presented 12/20

12

4. PRACTICAL APPLICATION



Report sections 4 and 5 Good use of equipment and presentation of results in your Level Control of the Process Tank and Temperature Control of the Heater Tank experiments. However, there is a mismatch with calculated gain and gain used in experiments. 11/20

11

5. TRANSFERABLE SKILLS



All report sections, but particularly sections 1, 2, 7 and word count penalty. Good report style, presentation, use of grammar, spelling and punctuation. Good executive summary, excellent work plan and explanation of team working (though you could have said how you treated each other. Word count exceeded. 10/20

10