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Study of PID Controller Mode at Biodiesel Pilot Plant at UTHM

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Abstract: Due to the loss of resources, the next generation of students will face difficulty to understand about the tuning process and Proportional Integral Derivative (PID) controller at Biodiesel Pilot Plant at UTHM. To manipulate and study processes, a variety of process controllers are used, but the PID controller is the simplest and often the most effective. The PID controller calculates the difference between the setpoint and the actual value and attempts to minimize it by adjusting the control input to achieve the desired output value. A PID controller regulates a process by utilizing three parameters: proportional (P), integral (I), and derivative (D). These parameters can be tuned to adjust their effect on the process. In order to determine the PID control parameters, the trial-and-error method involves observing the system's response curve through closed-loop operation and then testing the parameters repeatedly based on the three criteria for excellent control quality, which are stability, minimum deviation, minimum duration. According to the current simulation results, the appropriate parameters for PID in heating process for VE201 were proportional term with 2.0, integral with 20000ms, and derivatives 2500ms, while the appropriate parameters for PID in heating process for VE202 were P = 1.0, I = 20000ms, D = 5000ms, considering the combination of stability, overshoot, and settling time. Finally, it is a fact that achieving all of the process control objectives with PID tuning is impossible. In terms of efficiency, choosing the relative importance of these objectives and then focusing on achieving the most important at the expense of the least important should be considered.

Keywords: Control Quality, Trial-and-Error method (T-E method), PID Controller

1. Introduction

The Proportional Integral Derivative (PID) controller is the general form of feedback used in a control system. The PID controller is one of the most powerful but complex controller mode operations combines the proportional, integral, and derivative modes. This system can be used for virtually any

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process condition [1]. By tuning the 3 parameters in PID, the controller can provide specific control action designed for different needs such as in the field of metallurgy, chemical, food industry and oil refining.

In the period 1900-1940, the focus goes on invention: how the PID concept was formulated, the pneumatic feedback amplifier and the design of a practical PID controller. After 1940, the PID controller became a robust and reliable instrument. for everyday industrial use and how it has changed due to new technologies, and the digital computer. Conventional PID controller is widely used in the process control industry due to its simplicity in structure and ease of implementation. Although the control theory and method has made great progress, PID controllers are still common and well known. Statistics of metallurgical industry, chemical industry and food industry show that 97% of the controllers select PID structure [3].

All general control design methods can be applied to PID control. Several special methods adapted to PID control have also been developed. These methods are often referred to as tuning methods. Regardless of the method used, it is important to always consider key controls, load disturbances, sensor noise, process uncertainty, and reference signals [4].

The present paper aims to study and compare the performance of controller parameters in terms of rise time, settling time, percent of overshoot and its coefficient due to the presence of input constraint.

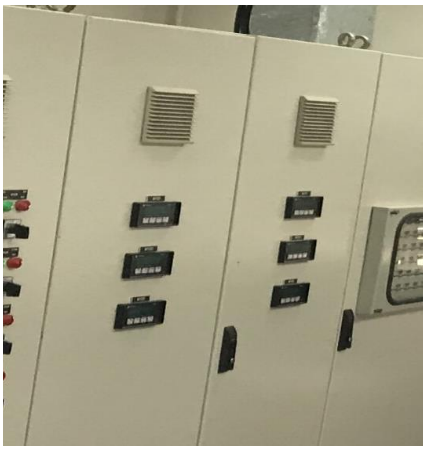
2. Equipment and Methods

2.1 Equipment

There are seven instrument types used to collect the data critical parameters of the control system as shown in Table below.

Table 1: Control System Equipment

1	**Main switch** - To supply current source to the control box.	 (a) Main Switch

<table>
<tr><td>2</td><td>Ammeter and voltmeter panel
- Located emergency button and reset.</td><td>
(b) Ammeter and Voltmeter Panel</td></tr>
<tr><td>3</td><td>Button panel of pump
- To select manual or automatic.</td><td rowspan="2">
(c) Button Panel of Pump and Button Panel of Mixer and Valve</td></tr>
<tr><td>4</td><td>Button panel for mixer and valve
- To select manual or automatic.</td></tr>
<tr><td>5</td><td>Weight transmitter panel
- To check the readingtransmitter.</td><td>
(d) Weight transmitter panel</td></tr>
</table>

6	**Actuator valve panel switch** - To switch between automaticor manual actuator valve	 (e) Actuator valve panel switch
7	**Computer** - To control and display all the process.	 (f) Computer

2.2 Software Application

In this study, AutoCad Plant 3D 2023 was used to draw Piping and Instrumentation Diagram (P&ID), as it is critical as we are able to figure out the instrument control loops through the diagram. Control loop is the fundamental building block of control systems. It consists of all the physical components and control functions necessary to automatically adjust the value of a measured process variable (PV) to equal the value of a desired setpoint (SP). It includes the process sensor, the controller function, and the final control element (FCE) which are all required for automatic control. Figure 1 shown AutoCad Plant 3D 2023 that is used to illustrate the type of control loop.

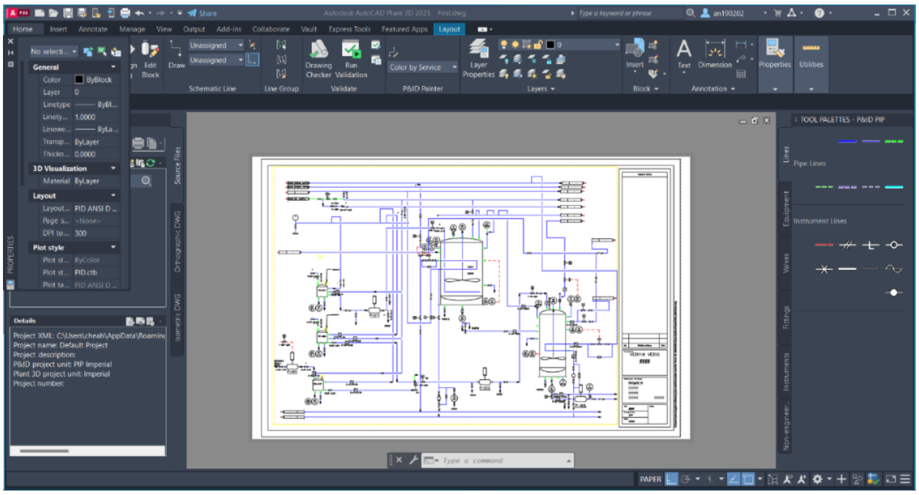
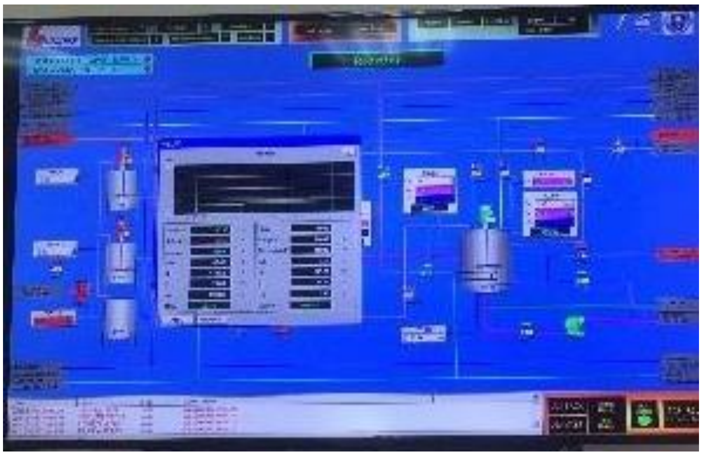


Figure 1: AutoCad Plant 3D 2023

. Also, software of Supervisory Control And Data Acquisition (SCADA) was used to control the heating processes in control room. Supervisory control and data acquisition (SCADA) is a control system architecture comprising computers, networked data communications and graphical user interfaces for high-level supervision of machines and processes. It also covers sensors and other devices, such as Programmable Logic Controllers (PLC), which interface with process plants or machinery. Figure 2 shows the SCADA system used at Biodiesel Pilot Plant in the control system.

Figure 2: SCADA system used at Biodiesel Pilot Plant in the control system



2.3 Methods

The flowchart is very important as a diagram that shows how a workflow or process works. PSM 1 is the beginning of a study where to determine what studies will be done. While at PSM 2, experiments are conducted in the control room. The data results are analyzed and included in the project report. Figure 3 shows the process flow of drawing and analysis, while Figure 4 shows the Process flow of tuning as below.

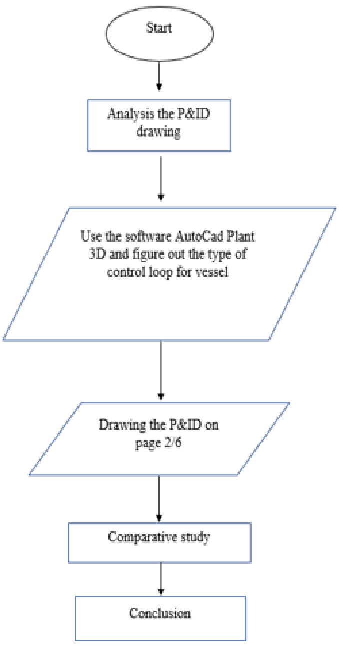


Figure 3: Process flow of drawing and analysis

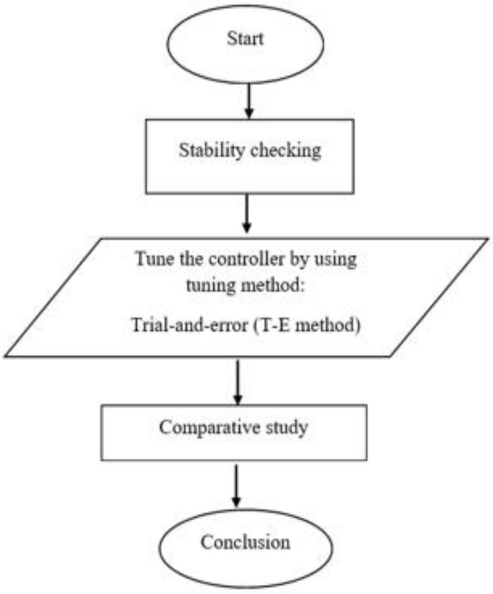


Figure 4: Process flow of tuning

2.4 Trial-and-Error Method (T-E method)

The trial-and-error method entails observing the system's response curve via closed-loop operation and then repeatedly testing the parameters based on the influence of each parameter on the system until a satisfactory response occurs. During the trial run, we can refer to the influence trend of the above parameters on the system control process and adjust the parameters in proportion, integral, and differential steps until it meets three conditions: system stability, minimum deviation, and minimum duration.

2.5 Stimulation

Several parameters for the simulation will be tested to analyze the difference among P, I, D value to determine the most suitable value for each of the vessel to achieve optimum performance. Table 2 shows the parameter use in stimulation analysis for VE201 and VE202.

Table 2: parameter use in stimulation analysis for VE201 and VE202

VE201			
Adjustment / Parameter	Proportional Term, K_p	Integral Term, T_I (ms)	Derivative Term, T_D (ms)
Original	2.0	20000	10000
Proportional	0	20000	10000
	0.5	20000	10000
Integral	2.0	5000	10000
Derivative	2.0	20000	2500
VE202			
Adjustment / Parameter	Proportional Term, K_p	Integral Term, T_I (ms)	Derivative Term, T_D (ms)
Original	1.0	20000	10000
Proportional	0.5	20000	10000
Integral	1.0	10000	10000
	1.0	5000	10000
Derivative	1.0	20000	5000
	1.0	20000	2500

3. Results and Discussion

The present chapter critically discussed the findings results of this study related to the Proportional (P), Integral (I), Derivative (D) controller method for heating process on VE201, VE202.

3.1 Comparison between the proportional adjustments and the default setting for VE201

To compare the data between the proportional adjustments and the VE201 default setting, all the setpoint values were adjusted to the same level, so that the process value could be compared within a narrow range of values. In this comparison, 34.5℃ was set as reference setpoint and other process value was lowered down respectively. Figure 5 shows the result of comparison between the proportional adjustments and the default setting.

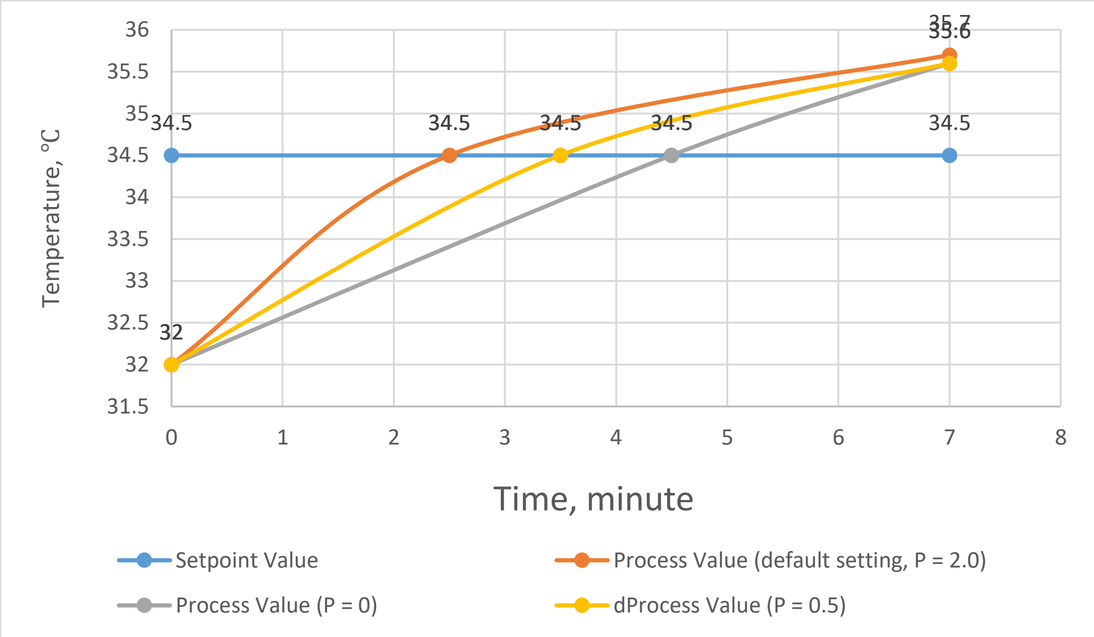


Figure 5: Result of comparison between the proportional adjustments and the default setting

Based on the figure 5, Process Value from default setting (P = 2.0) was the first to achieve the setpoint, while the second was process value with P = 0.5, and the last was Process Value with P = 0.5, hence it shows that as the larger P term typically faster response since the larger error, the larger the proportional term compensation. In terms of deviation from the default setting, Process Value (P = 2.0) was slightly higher than others, but not significantly so, so it could be considered as acceptable. The most suitable parameter among them was P = 2.0.

3.2 Comparison between the Integral adjustment and the default setting for VE201

To compare the data between the integral adjustment and the VE201 default setting, all the setpoint values were adjusted to the same level, so that the process value could be compared within a narrow range of values. In this comparison, 34.5℃ was set as reference setpoint and other process value was lowered down respectively.

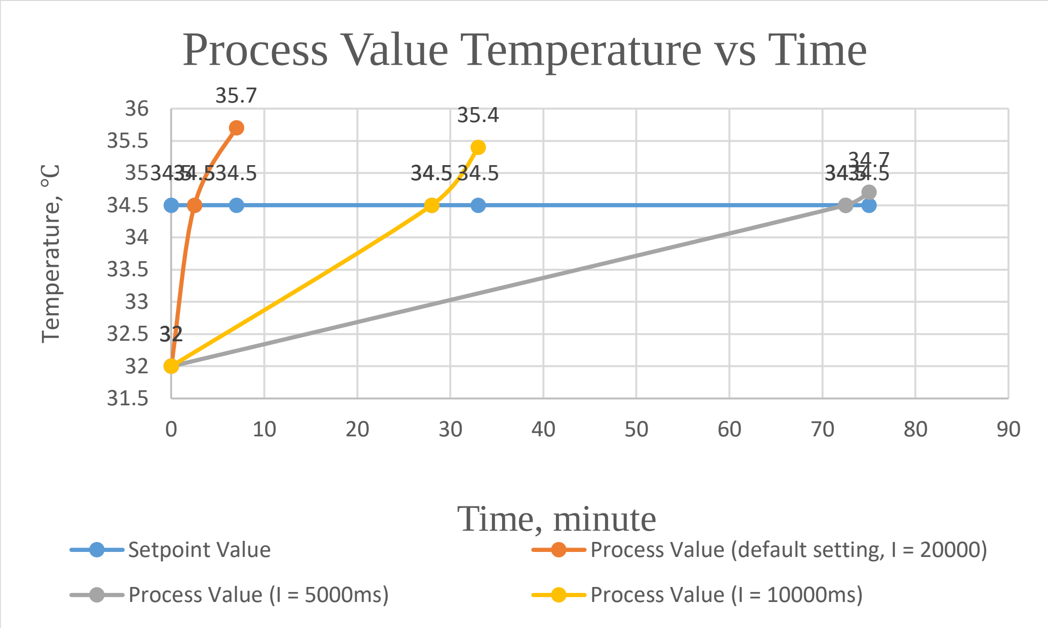


Figure 6 show the result of comparison between the Integral adjustment and the default setting

Figure 6 above shows the result of comparison between the Integral adjustment and the default setting. Based on the figure 6, Value from default setting (I = 20000ms) was much faster than Process Value (I =5000ms) and Process Value (I = 10000ms) to achieve the setpoint, hence it shows that as the larger I term, the faster the response to eliminate steady state error, but the larger the overshoot, where the overshoot value for I = 20000 was 1.20℃ which was the highest among of these parameters, I = 10000ms with 0.90℃ overshoot and I = 5000ms with 0.20℃ overshoot. It showed the characteristics of Integral term, larger integral term, K_I implies that steady-state errors are eliminated more quickly. The trade-off is greater overshoot because negative error integrated during transient response must be offset by positive error before reaching steady state. With the comparison of these results, the default setting value (I = 20000ms), it still be considered as the most suitable value for Integral term, as it provided the fastest response to the control system to achieve the predetermined setpoint, but it highly depends on the process, different processes require different conditions to be achieved of, so choosing the relative importance of these objectives and sacrificing some of the least important objectives should be considered in terms of efficiency.

3.3 Comparison between the Derivative adjustment and the default setting for VE201

To compare the data between the Derivative adjustment and the VE201 default setting, all the setpoint values were adjusted to the same level, so that the process value could be compared within a narrow range of values. In this comparison, 34.5℃ was set as reference setpoint and other process value was increased respectively.

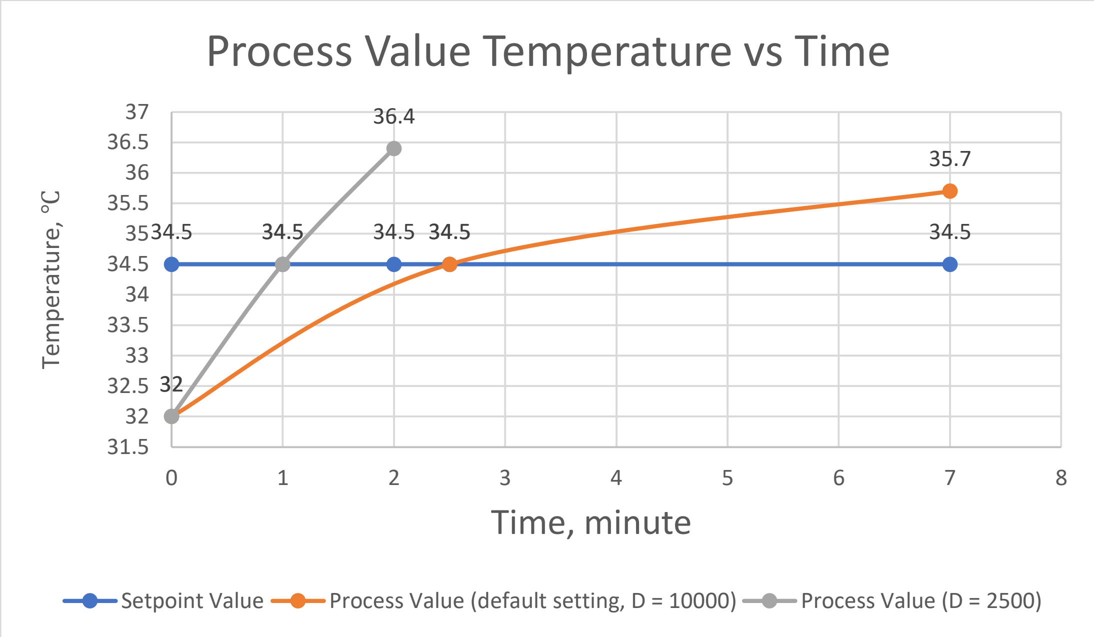


Figure 7: Result of comparison between the Derivative adjustment and the default setting

Figure 7 show the result of comparison between the Derivative adjustment and the default setting. Based on the figure 7, Process Value with D = 2500 was the first to achieve the setpoint, while the second was process value from default setting (D = 10000). In terms of deviation from the default setting, Process Value (D = 10000) with overshoot value is 1.20℃ was significantly lower than Process Value with D = 2500 (Overshoot value = 1.90℃), hence it showed larger K_d decreases overshoot. In this case, the derivative term, D = 2500 is more suitable for this control system, as it provided the faster response to achieve the setpoint, and 1.90℃ overshoot value is considerably acceptable for the heating process.

3.4 Comparison between the Proportional adjustments and the default setting for VE202

To compare the data between the Proportional adjustments and the VE202 default setting, all the setpoint values were adjusted to the same level, so that the process value could be compared within a narrow range of values. In this comparison, 39.5℃ was set as reference setpoint and other process value was lowered down respectively.

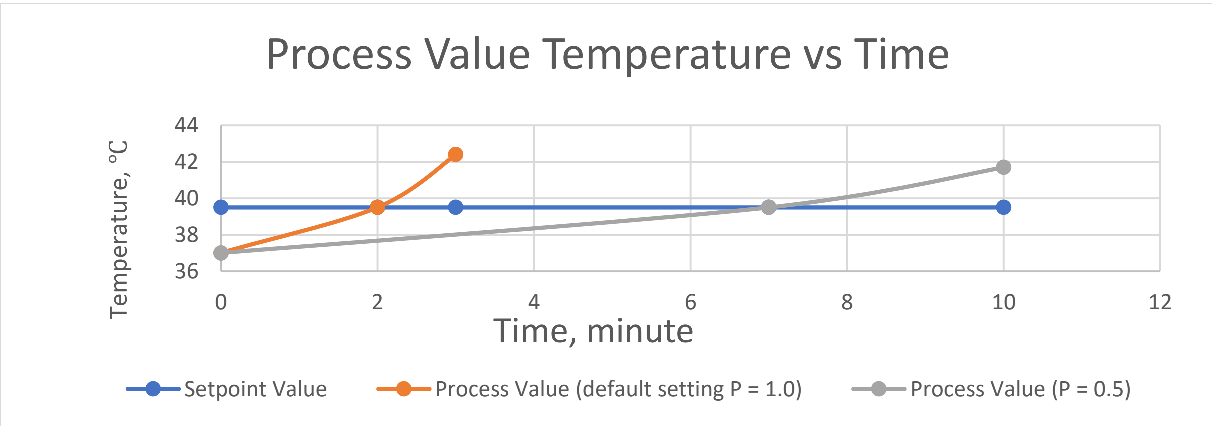


Figure 8: Result of comparison between the Proportional adjustment and the default setting

Figure 8 above shows the result of comparison between the Proportional adjustment and the default setting. Based on the figure 8, Process Value from default setting (P = 1.0) was the first to achieve the setpoint, while the process value with P = 0.5 was the last, it shows the characteristics of proportional term, whereas the larger P term, the faster response since the larger error, the larger the proportional term compensation. In terms of deviation from the default setting, Process Value from default setting (P = 1.0) was slightly higher than process value with P = 0.5, but not significantly so, so it could be considered as acceptable. The most suitable parameter among them was P = 1.0 for this heating process.

3.5 Comparison between the Integral adjustments and the default setting for VE202

To compare the data between the Integral adjustments and the VE202 default setting, all the setpoint values were adjusted to the same level, so that the process value could be compared within a narrow range of values. In this comparison, 39.5℃ was set as reference setpoint and other process value was reduced respectively.

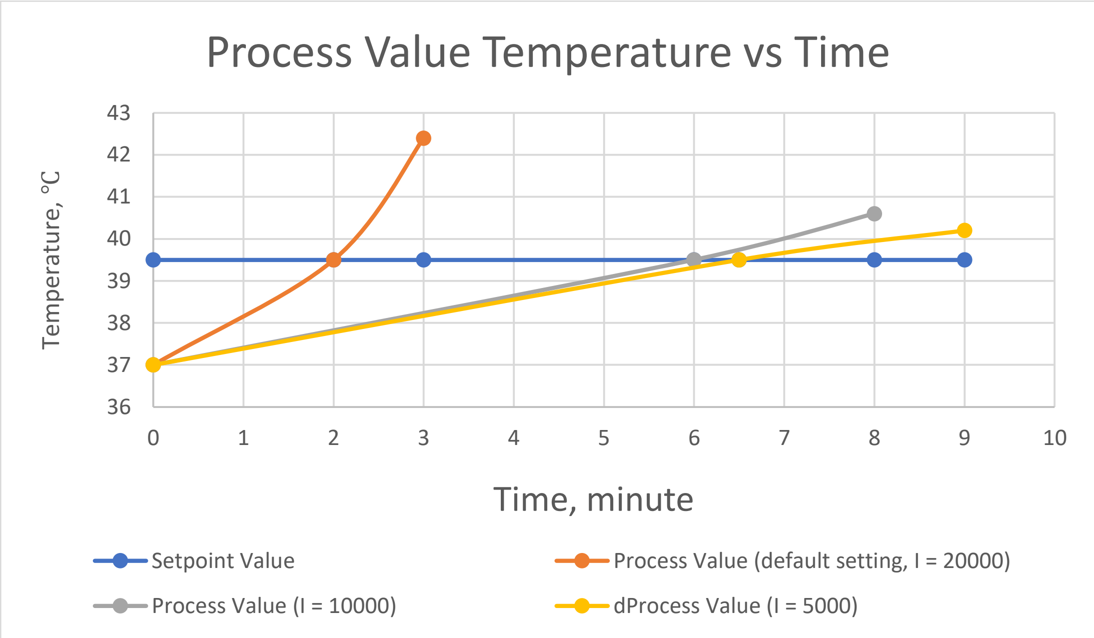


Figure 9: Result of comparison between the Integral adjustments and the default setting

Figure 9 shows the result of comparison between the Integral adjustments and the default setting. Based on the figure 9, Process Value from default setting (I = 20000) was much faster than Process Value (I =5000) and Process Value (I = 10000) to achieve the setpoint, hence it shows that as the larger I term, the faster the response to eliminate steady state error, but the larger the overshoot, where the overshoot value for I = 20000 was 2.20℃ which was the highest among of these parameters, I = 10000ms with 1.10℃ overshoot and I = 5000ms with 0.70℃ overshoot. It showed the characteristics of Integral term, larger integral term, K_I implies that steady-state errors are eliminated more quickly. The trade-off is greater overshoot because negative error integrated during transient response must be offset by positive error before reaching steady state. With the comparison of these results, the default setting value (I = 20000), it was the most suitable value for Integral term, as it provided the fastest response to the control system to achieve the predetermined setpoint with the acceptable range of overshoot value, hence the suitable value of integral term is 20000 in this heating process.

3.6 Comparison between the Derivative adjustments and the default setting for VE202

To compare the data between the Derivative adjustments and the VE202 default setting, all the setpoint values were adjusted to the same level, so that the process value could be compared within a narrow range of values. In this comparison, 39.5℃ was set as reference setpoint and other process value was reduced respectively.

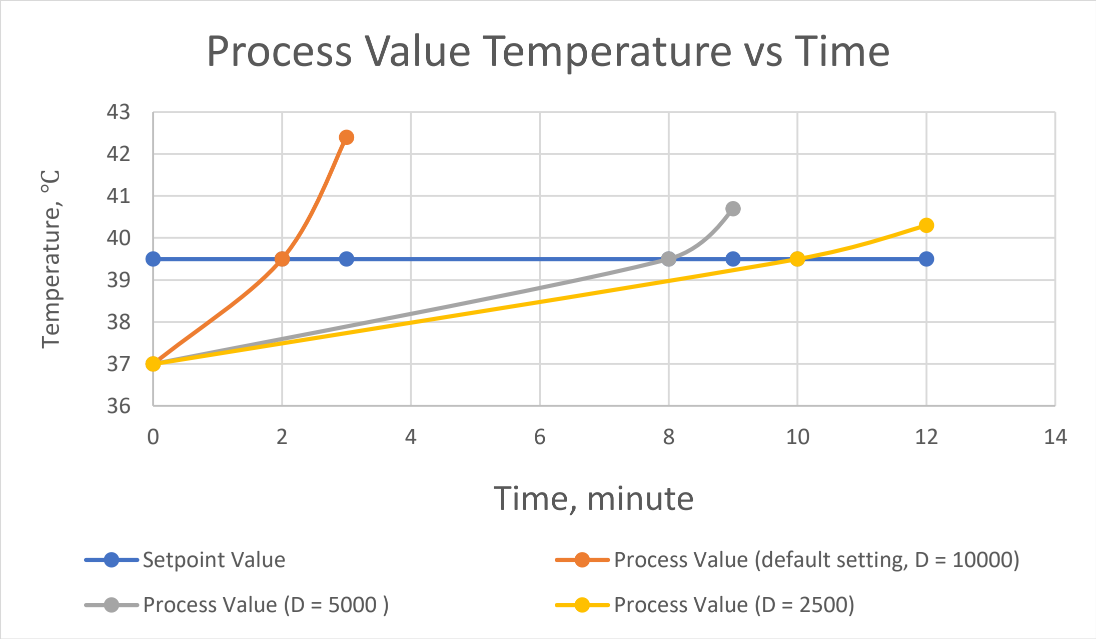


Figure 10: Result of comparison between the Integral adjustments and the default setting

Figure 10 shows the result of comparison between the Integral adjustments and the default setting. Based on the figure 10, Process Value with D = 10000 was the first to achieve the setpoint, while the second was process value from default setting (D = 5000) followed by the process value of D = 2500. In terms of deviation from the default setting, Process Value (D = 10000) with overshoot value is 2.20℃ was significantly higher than Process Value with D = 5000 (Overshoot value = 1.20℃) and Process Value with D = 5000 (Overshoot value = 0.80℃), hence it showed larger Kd decreases overshoot and speed up transient response. In this case, the derivative term, D = 5000 is relatively suitable for this control system, as it provided the moderate response to achieve the setpoint, with not so much overshoot value for the heating process.

4. Conclusion

From this study, the objective to understand and draft the piping and instrumentation (P&ID) of vessel 201 & vessel 202 has been implemented as it was drawn by using AutoCad Plant 3D 2023. The loop control in this research that involved Vessel 201 and Vessel 202 was determined, where both of the Vessels were close loop as we can refer to the P&ID Additionally, PID controller mode with heating process of Vessel 201, and Vessel 202 were performed to evaluate the overall effectiveness with each of the PID parameters. Overall, the most suitable value of PID was found, where the suitable parameters for PID in heating process for VE201 were proportional term with 2.0, integral with 20000ms and derivatives 2500ms, while the suitable parameters of PID in heating process for VE202 were P = 1.0, I = 20000ms, D = 5000ms in term of rise time and overshoot as compared to the others combination parameters. It is likely that achieving all of the process control objectives with PID tuning is impossible. In terms of efficiency, choosing the relative importance of these objectives and then focusing on achieving the most important at the expense of the least important should be considered.

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