CHAPTER I
INTRODUCTION

1.1 Background

A chemical plant is a systematic and rational arrangement or series of integrated processing units. The overall objective of operating a chemical plant is to convert raw materials into products with greater utility. During operation, the plant will always encounter problems such as regulations or control of various process variables and disturbances from the external environment. During operation, the plant must consider technical, economic, and social aspects so that the processes occurring within the plant are not significantly affected by these external changes and a stable process is achieved.

In order for the process to remain stable, control equipment must be installed. These control devices include controllers, sensors, actuators, alarm systems, remote controllers, and so on. These control devices are installed for the purpose of maintaining work safety and security. In addition, they can function to meet the desired product specifications, ensure that the process equipment functions as intended in the design, keep factory operations economical, and meet environmental requirements.

To meet the above requirements, continuous monitoring of chemical plant operations and external intervention are necessary to achieve operational objectives. This can be accomplished through a series of equipment (measuring instruments, controllers, and computers) and human intervention (plant managers and plant operators) that together form a control system. In plant operation, various prerequisites and specific operating conditions are required, thus necessitating efforts to monitor plant operating conditions and control processes so that operating conditions remain stable (Liu et al., 2023).

1.2 Problem Formulation

In the course of a production process in industry, it is necessary to monitor the quality and quantity of that process. This monitoring is a system known as process control. Process control is implemented to minimize or reduce human error and enhance efficiency in the accuracy of an automated device's response to disturbances compared to a manually operated device. Therefore, an understanding of the operation of control systems and their variations in terms of proportional (P), proportional integral (I), and proportional integral derivative (PID) is essential.

1.3 Objectives

1. Able to operate a process with a control system.
2. Able to evaluate processes with variations in feedback control systems (Proportional (P), Proportional Integral (I), and Proportional Integral Derivative (PID)).
3. Able to examine graphs showing the relationship between level and elapsed time against set points, data intervals, PID, and orifice variations.

1.4 Benefits

1. Students are expected to be able to understand the operation of a process with a control system.
2. Students should be able to evaluate processes with various feedback control systems (Proportional (P), Proportional Integral (I), and Proportional Integral Derivative (PID)).
3. Students are expected to be able to examine graphs showing the relationship between level and elapsed time against set points, data intervals, PID, and orifice variations.

CHAPTER II
LITERATURE REVIEW

2.1 Process Control

A control system is a set of physical components designed to control a system or other systems related to a process in an open loop or closed loop (Benner, 1993). In general, process control is the control of one or more variables so that they remain at a certain value or range. For example, the fluid level in a reactor must be maintained at a certain level, so a control valve is needed to regulate the flow rate into the reactor. It is impossible to achieve precise results manually, so automatic equipment is needed to solve the problem. Almost all processes in the industrial world require automated equipment to control process parameters. Automation is not only necessary for smooth operation, safety, economy, and product quality, but is also a basic requirement. It is impossible for an industry not to involve process control, for example, control in an oil refining process.

There are many parameters that must be controlled in a process. Among the most common are pressure in a vessel or pipe and reactor, flow in a pipe, temperature in a process unit such as a heat exchanger, or the surface of a liquid (level) in a tank, and chemical concentration (Dong et al., 2024). In addition, there are several other parameters outside of the four above that are quite important and also need to be controlled due to specific process requirements, including: pH in the petrochemical industry, water cut (BS & W) in crude oil fields, product color in a gas liquefaction facility (NGL), and so on.

Understanding the process is one of the main factors in the successful control of the parameters that must be controlled. In practice, automatic control systems play an important role because they can improve dynamic system performance, improve product quality, reduce production costs, increase production speed, and reduce routine work that was previously done by humans. The role of manual operators has now been largely replaced by a device called a controller. For example, the task of opening and closing valves is no longer done manually, but is controlled by a controller. For this control to run automatically, the valve needs to be equipped with a device called an actuator, so that the valve changes function to become a control valve. All equipment used in this control process, such as controllers and control valves, are known as part of the process control instrumentation system.

A controller is a system added to a plant to obtain the overall system performance characteristics as expected. One commonly used control method is PID (Proportional-Integral-Derivative) control. PID control serves to improve system performance by increasing the response to changing conditions. With the application of PID control, the system can reduce or even eliminate steady-state errors and increase the response speed in reaching the desired set point value.

2.2 Proportional Control (P)

Proportional control is a controller whose output signal (p(t)) is proportional to the error (e(t)), which is the difference between the set point and the measurement result, which can be expressed mathematically as follows:

$$p(t) = \bar{p} + K_{\mathbf{c}} \times \text{eror}(t) \quad (2.1)$$

Based on this approach, where Kc is the proportional gain that indicates the responsiveness of the controller to the setup or correction process provided to achieve the set point. The proportional gain is adjusted to regulate how responsive the system is to differences between the set point and the process variable.

The proportional controller has two parameters, namely: proportional band and proportional constant. The effective working range of the controller is reflected by the proportional band, while the proportional constant indicates the amplification factor value for the error signal, KC. The relationship between the proportional band (PB) and the proportional constant (KC) is shown as follows:

$$PB = \left(\frac{1}{K_C}\right) \text{x } 100\% \quad (2.2)$$

This control system is a very simple form of process control system with a very fast response to set points and disturbances in the process, but it has a large steady state error characteristic.

Characteristics of proportional controllers:

1. When the KC value is small, proportional controllers are only capable of making small error corrections, resulting in a slow system response (increasing rise time).
2. When the KC value is increased, the system response will reach a steady state more quickly (reducing rise time).
3. However, if the KC value is increased to an excessive level, it will cause the system to become unstable or the system response will oscillate/overshoot.
4. The KC value can be adjusted to reduce steady state error, but not eliminate

it.

2.3 Integral Control (I)

Integral control serves to eliminate errors as a whole, especially steady-state errors. The main purpose of the integral component is to ensure that the error between the set point and the system output becomes zero. It works by continuously calculating errors over time, then summing them (integration) to produce a control signal.

$$p(t) = \bar{p} + \frac{1}{\tau_i}\int_0^t \mathrm{eror}(t_i)\, dt_i \qquad (2.3)$$

By integrating errors, the system output value can be corrected cumulatively, especially when errors occur over a long period of time. However, integral control is rarely used alone because it has several disadvantages. One common problem that arises is reset windup, which is a condition where the accumulation of errors causes the control signal to exceed the control valve's capacity (control valve) which is already in a saturated state (fully open), so that the system no longer responds to control commands. This can cause overshoot or even cause the controller to lose its function as a controller. To overcome this, additional methods such as anti-reset windup are usually used to keep the system response stable, responsive, and controlled.

2.4 Derivative Control (D)

Derivative control serves to anticipate error signals that will occur by observing the rate of change and predicting changes so that the system reacts more quickly and intelligently to changes. Derivative controllers are known for their speed of action, pre-action, or anticipatory control. Their function is to anticipate error signals that will occur by observing the speed of change and predicting changes. Derivative controllers can accelerate system response, thereby reducing overshoot (signals exceeding the set point).

$$p(t) = \bar{p} + \tau_i \frac{d\, \mathrm{eror}(t)}{dt} \qquad (2.4)$$

Derivative controllers help the system respond more quickly at the beginning and prevent signals from exceeding the desired value (set point). It works by observing how quickly the error changes. If the error increases rapidly, the controller will react immediately before the error becomes too large. Conversely, if the error decreases rapidly, the controller will reduce its reaction so that it does not decrease excessively. This makes the system more stable, less likely to exceed limits, and quicker to reach a stable condition.

2.5 Proportional Integral Control (PI)

A PI controller is a combined control system consisting of a proportional and integral controller. An integral controller is used to eliminate errors by integrating the error over a certain period until the error is "zero" or there is no error at all. The output form of the controller depends on the integral of the signal error over the entire time, where:

$$\Delta Q_{output} = Ki \int i.\ dt \quad (2.5)$$

or

$$p(t) = \bar{p} + K_c(eror(t) + \frac{1}{\tau_i}\int_0^t eror(t_i)\ dt_i) \quad (2.6)$$

Ki = integral gain or "reset rate" (repeat/minute)

Kc = amount of correction given

τ_i = integral time or reset time

Integral control is also known as "reset," which has a relatively slow response but is quite effective for controlling fast processes that contain large disturbances and are dominated by the dead time of product transport. Its effect on steady-state error is relatively small. This control is commonly used to reduce the offset between the set point and the process variable.

2.6 Proportional Integral Derivative Control (PID)

Proportional Integral Derivative (PID) control is a type of system control that combines three different control elements, namely proportional, integral, and derivative. PID control is used to determine the values of K_p, T_i, and T_d. The derivative of this control is commonly known as the "rate." The value of this parameter basically means how far into the future you want to predict the rate of change. The equation model used is:

$$\Delta Q_{output} = Kd\frac{d\ eror(t)}{dt} \quad (2.7)$$

or

$$p(t) = \bar{p} + K_c(eror(t) + \frac{1}{\tau_i}\int_0^t eror(t_i)\ dt_i + \tau_D\frac{d\ eror(t)}{dt}) \quad (2.8)$$

Kd= time constant

τ_D = derivative time

The derivative model never stands alone but is always accompanied by proportional or proportional-integral because derivative control only changes when there is an error change, so when the error is static (fixed), this control will not react. In PID control, there are three parameters that can be set, namely Kc, τ_i and τ_D. In PID control itself, it is necessary to avoid derivative kick (large disturbances) by adjusting the existing parameters.

2.7 Ziegler-Nichols Method

Tuning is the process of adjusting parameter values in a controller, such as PID (Proportional, Integral, Derivative), so that the system can work properly as desired. In control systems, tuning is very important because it determines how quickly, stably, and accurately the system responds to changes or disturbances. If tuning is done correctly, the system will respond quickly without excessive oscillation, will not be too slow, and will be able to reach the target or set point efficiently. The tuning process is usually done by trial and error with parameter values, using mathematical methods, or experimental approaches, depending on the type of system and the information available.

One tuning method used is the Ziegler-Nichols method. The Ziegler-Nichols method is a practical way to tune a PID controller so that the system can work quickly and stably, without needing to know the formula or mathematical model of the system. This method is done by observing how the system responds when we change the input, then from that observation we determine the appropriate PID parameter values. The goal is for the system to respond quickly but remain stable, usually with an overshoot of around 25%. Because it is easy and does not require complicated calculations, this method is very useful in various industrial fields, such as temperature, pressure, flow, or other automatic systems that require a fast and efficient response.

The Ziegler-Nichols method for tuning PID controllers begins by setting the PID controller with integral (Ki) and differential (Kd) values equal to zero, with only the proportional gain (Kp) active. Then, gradually increase the Kp value until the system begins to exhibit unstable oscillatory (fluctuating) behavior. The Kp value at the point when the system oscillates is called KMAX (the maximum value at which the system can still operate but has started to oscillate). During oscillation, the frequency formed is called f0. After reaching KMAX, lower the Kp value to a lower level, which is usually set at around 50-75% of KMAX. Finally, use the f0 value to set the integral (Ti) and differential (Td) gain values based on the formula specified by Ziegler-Nichols. Generally, the formula for setting PID parameters is as follows:

$$K_p = 0{,}6 \times K_{MAX} \quad (2.9)$$

$$T_i = \frac{1}{2 \times f_0} \quad (2.10)$$

$$T_d = \frac{1}{8 \times f_0} \quad (2.11)$$

(Ellis, 2012)

2.8 PCT 50 Level Control

Figure 2.1 PCT50 *level control*

PCT 50 is a level control process device that uses water as the working fluid for safety and user comfort. Water stored in the lower storage tank is transferred to the upper process vessel via a submerged variable speed centrifugal pump. A quick release connector allows the pump outlet pipe to be easily removed, facilitating the pump priming process after the lower tank is filled with water. The vertical inlet arrangement in the process vessel allows the water entering the vessel to remain visible regardless of the water level, and a non-valve (check valve) integral with the vessel prevents back flow into the storage tank when the pump speed is reduced or stopped. The in-line ball valve (CV1) above the quick release connector allows the flow of water entering the process vessel to be varied, regardless of the pump speed, to suit specific demonstrations.

The water level in the process vessel is measured using an electronic pressure sensor installed on the edge of the vessel. One side of the pressure sensor is connected inside the process vessel and the other side is open to the atmosphere, allowing the pressure inside the process vessel to be measured relative to the atmosphere. Therefore, this sensor measures the water level in the process vessel. The height level is also indicated on a scale on the side of the process vessel. Water flows from the process vessel back to the lower storage tank through two outlets at the bottom of the process vessel. The flow through the main outlet is continuous. The flow through the second outlet can be started and stopped by a solenoid valve (SOL) with remote control. Both outlets are equipped with manually operated ball valves (CV2 and CV3) that allow the water flow to be continuously varied to suit specific demonstrations. Both outlets are also equipped with changeable orifices (3 and 5) that allow the flow to be set to a predetermined size. The size of the orifice is changed by removing the plastic cap containing the orifice and replacing it with another one of the required size. Installation uses 'O' ring seals and only requires hand tightening. Alternative orifice sizes are stored in threaded holes in the front of the base plate when not in use.

Overflow in the process vessel returns water to the storage tank, preventing overfilling of the process vessel during use. The pressure sensor that measures the level, centrifugal pump, and solenoid valve are connected to an electrical interface that combines the necessary signal conditioning, allowing the process to be operated directly from a PC using a single USB port. The computer software included with the PCT 50 allows for level process control and response data logging using a PC. Alternatively, the software allows data logging only when operating the process remotely using a PID controller. When filled with water, the PCT 50 is self-contained and requires only a main power supply to the in-line DC converter and a connection to a PC via the USB port. The unit is drained using a drain located at the rear.

CHAPTER III
PRACTICUM METHOD

3.1 Practicum Design

3.1.1 Practicum Design

Figure 3.1 Practicum design

3.1.2 Variable Determination

3.2 Material and Tools Used

3.2.1 Materials

Aquadest 8 liter

3.2.2 Tools

PCT 50 *Level Control*

3.3 Tool Picture

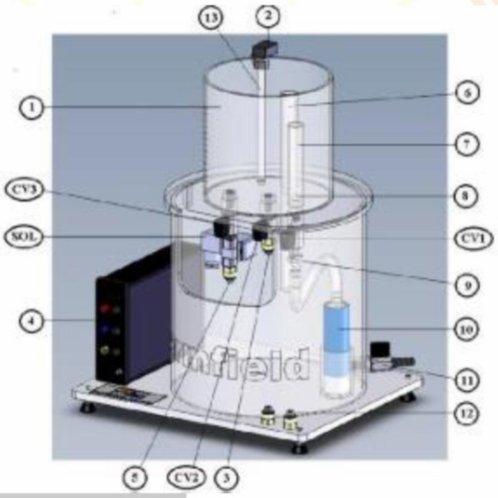

Figure 3.2 PCT 50 level control tool and its parts

(1) Upper Process Vessel
(2) Level Sensor
(3) Manual Discharge Port
(4) Electrical interface
(5) Solenoid Discharge Port
(6) Overflow
(7) Inlet
(8) Integral non-return valve
(9) Quick Release Conenector
(10) Centrifugal Pump
(11) Water Discharge
(12) Alternative sizes of orifice
(CV1) Control Valve 1
(CV2) Control Valve 2
(CV3) Control Valve 3
(SOL) Solenoid Drain Valve

3.4 Procedure Practicum

3.4.1 Installing Software Armfield Level Control

1. Install the driver first by going to this PC, right click then select properties then select device manager.
2. Insert the USB into the laptop, after which COM 5 will appear with an exclamation mark. Make sure the PCT-50 has turned on with the green light indicator on.
3. Remove the exclamation mark by updating the driver. Find the PCT-50 folder then select the second order icon from the top then select install by following the steps on the driver. The laptop will automatically restart after the installation process is complete.
4. Make sure the USB is connected perfectly so that the connection between the PCT-50 tool and the laptop is not cut off suddenly. Also make sure that when you want to use it, it is not in a scanning state.

3.4.2 Pelaksanaan Praktikum

a. Calibration of the PCT-50

1. Ensure that the drain valve at the rear of the tank is tightly closed, then fill the lower part of the tank with 8 L of distilled water.
2. Ensure that the sensor is empty before conducting each experiment. If there is water trapped inside the sensor, use a glass brush to ensure that the sensor is empty.
3. Ensure that the CV1 flow control valve is fully open at the process vessel inlet so that distilled water can flow into the vessel while the pump is running.
4. Ensure that the CV2 outlet valve is fully open at the bottom of the process vessel to allow distilled water to return to the tank when the process vessel is filled with distilled water.
5. Ensure that the CV3 valve is fully open above the SOL solenoid valve to allow aquadest to flow back to the storage tank when the solenoid valve is open and the process vessel is filled with aquadest.
6. Turn on the pump and ensure that the distilled water can flow into the process tank. If it does not flow, disconnect the pump hose connection filled with distilled water by submerging it into the distilled water in the storage tank.

7. Once the distilled water can be pumped smoothly into the storage tank, empty the process tank and conduct the test according to the variables.

b. **Find the maximum level**

1. Ensure that the process tank is empty.
2. Set the sample interval and fixed duration on the sample configuration menu according to the predetermined variables.
3. Set the variables (pump speed, set point, proportional band, integral time, derivative time, and mode of operation) that have been determined in the PID menu.
4. Operate the tool according to the specified variables by clicking power on and go to record the data obtained.
5. Observe the graph obtained in the graph menu, take and save the practicum data according to the data listed in the PCT-50 application (excel).
6. If the time has reached the desired, decrease the pump speed to return the water to the tank.
7. Perform steps 2-6 with different variables (operating modes).

c. **Find the value of PID**

1. Ensure that the process tank is emty.
2. Set the variables (set point and proportional band) that have been determined in the PID menu.
3. Operating mode is done in automatic mode.
4. Operate the tool according to the specified variables by clicking power on and go to record the data obtained.
5. Observe the graph, take and save the practical data according to the data listed in the PCT-50 application (excel).
6. After all is done, clean the equipment by opening the drain valve so that the water in the tank drains out, make sure the water in the tank and process vessel is completely gone.

7. After cleaning and draining, the equipment can be turned off gradually.

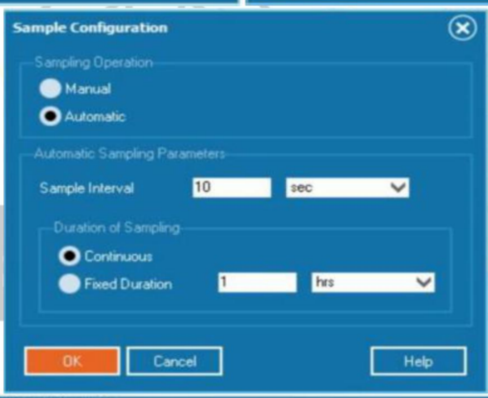

Figure 3.3 Steps to use Armfield PCT 50 software

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