CHAPTER I
INTRODUCTION

1.1 Background

A chemical plant is an arrangement or series of various processing units that are integrated with each other in a systematic and rational manner. The overall purpose of operating a chemical plant is to convert raw materials into more valuable products. In operation, the plant will always experience problems such as regulation or control of various process variables and disturbances from the external environment. During operation, the plant is required to consider aspects of engineering, economics, and social conditions so that the processes occurring in the plant are not significantly affected by these external changes and a stable process is achieved.

In order for the process to always be stable, the installation of control devices is required. Control devices include controllers, sensors, actuators, alarm systems, remote controllers, and so on. These control devices are installed with the aim of maintaining occupational safety and security, meeting desired product specifications, keeping process equipment functioning as desired in the design, keeping plant operations economical, and meeting environmental requirements.

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

1.2 Problem Formulation

In the course of a production process in industry, it is necessary to maintain the quality and quantity of the process. The guard is a system called process control. Process control is carried out to suppress or reduce human error and increase efficiency in the accuracy of the reaction of a device that works automatically against a disturbance compared to a manually driven device. Therefore, it is necessary to understand the operation of the controller system and variations in terms of proportional (P), proportional integral (I), and proportional integral derivative (PID).

1.3 Purposes

1. Able to operate a process with a controller system.
2. Able to evaluate a process with a variety of feedback controller systems (Proportional (P), Proportional Integral (I), and Proportional Integral Deritatived (PID).
3. Able to examine the relationship graph between level and elapsed time against set point, interval data, PID, and oriface variation.

1.4 Benefits

1. Students are expected to be able to know the operation of a process with a control system.
2. Students are able to evaluate the process with a variety of feedback controller systems (Proportional (P), Proportional integral (I), and Proportional Integral Derivative (PID).
3. Students are expected to be able to examine the relationship graph between level and elapsed time against set point, interval data, PID, and oriface variation.

CHAPTER II
LITERATURE REVIEW

2.1 Process Control

The control system is an arrangement of physical components assembled in such a way that it functions to control the system itself or other systems related to a process either in an open loop or close loop state (Benner, 1993). In another sense, the control system is a process / control of one or several quantities so that they are at a certain price or range. Almost all processes in the industrial world require automatic equipment to control process parameters. Automation is not only necessary for smooth operations, safety, economy, and product quality, but is more of a basic necessity. In an industry it is impossible if it does not involve process control, for example control in an oil refinery 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 liquid level in a tank, and chemical concentration (Dong et al., 2024). In addition, there are several other parameters beyond the four above that are quite important and also need to be controlled due to the specific needs of the process, including: pH in the petrochemical industry, water cut (BS & W) in a crude oil field, product color in a gas liquefaction (NGL) facility and so on.

Knowledge of the process is one of the main keys to success in controlling the parameters that must be controlled. Automatic control plays an important role and provides convenience in obtaining performance in a dynamic system, increasing quality, reducing production costs, and increasing production rates, as well as eliminating routine work that must be done by humans. However, all manual operator roles are replaced by a device called a controller. The task of opening and closing the valve is no longer done by the operator but at the command of the controller. For the purposes of automatic control, the valve must be equipped with a device called an actuator so that the valve unit is now a unit called a control valve. All of this control equipment (controller and control valve) is referred to as process control instrumentation.

The controller is a system that is added to the plant to get the expected overall system characteristics. PID control is a control that is used to improve the system through improving the resulting system response. Improvement of system response using PID can reduce and eliminate the steady state error value and increase the response speed to reach the set point.

2.2 Proportional (P) Control

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

$$\Delta Q_{output} = K_{C\,error} \quad (2.1)$$

Based on this approach where Kc is the proportional gain that shows the responsiveness of the controller to the set up process. Proportional gain can be adjusted to make the controller output change with the required sensitivity to the deviation between the set point and the controlled variable.

Proportional controllers have 2 parameters viz: proportional band and proportional constant. The effective working area of the controller is reflected by the proportional band, while the proportional constant indicates the value of the gain factor to the error signal, KC. The relationship between proportional band (PB) and proportional constant (KC) is shown as follows:

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

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

Characteristics of proportional controllers:

1. If the KC value is small, the proportional controller is only able to make small error corrections so that it will produce a slow system response (increase the rise time).
2. If the value of KC is increased, the response of the system will reach its steady state faster (reducing the rise time)
3. However, if the value of KC is enlarged so that it reaches an excessive price, it will cause the system to work unstable or the system response will oscillate /overshoot.
4. The KC value can be set such that it reduces the steady state error, but does not eliminate it.

2.3 Proportional Integral (PI) Control

PI controller is a combined controller system between proportional and integral controllers. Integral controllers are 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 shape of the controller output depends on the integral of the signal error over all time, where:

$$\Delta Q_{output} = Ki \int i.\ dt \quad (2.3)$$

or

$$p(t) = \bar{p} + \frac{1}{\tau_i}\int_0^t e\ (t)dt \quad (2.4)$$

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

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 processes that take place quickly, contain a large element of disturbance and are dominated by the existence of deadtime properties in product transportation. Its effect on steady state error is relatively small. This control is commonly used to reduce the offset between set point and process variable.

2.4 Proportional Integral Derivative (PID) Control

Proportional Integral Derivative (PID) control is a type of system control that combines three different control elements, namely proportional, integral, and derivative. Derivative controllers are known as speed action, pre-act, or anticipatory controllers. Its function is to anticipate the behavior of fault signals that will occur by paying attention to the speed of change and predicting changes. Derivative controllers can speed up the initial response of the system and reduce overshoot (signal exceeds set point). This PID control is used to determine the values of K_p, T_i, dan T_d. Derivative control is commonly known as "rate". The value of this parameter basically means how far in the future you want to predict the rate of change. The equation model used is:

$$\Delta Q_{output} = Kd\frac{de}{dt} \quad (2.5)$$

$$p(t) \quad = \bar{p} + \tau_D\frac{de}{dt} \quad (2.6)$$

Kd = *time constant*

τ_D = *derivative time*

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

2.5 Ziegler-Nichols Method

The Ziegler-Nichols tuning method is a method used to tune the value of PID parameters to produce a stable system (whose transfer function is unknown) with a maximum overshoot of 25%. This method is designed to determine the optimal parameters of the PID controller so that the system can operate efficiently and stably. With an empirical approach that relies on observing the system's response to changes in input, the Ziegler-Nichols method allows for quick and effective adjustments, making it very useful in a variety of industrial applications, ranging from process control to automation systems.

The Ziegler-Nichols method for PID controller tuning starts by setting the PID controller with integral (K_i) and differential (K_d) lues equal to zero, only the proportional gain (K_p) is active. Then, gradually increase the value of K_p until the system begins to exhibit unstable oscillatory (fluctuating) behavior. The value of K_p at the point when the system is oscillating is called K_{MAX} (the maximum value at which the system can still operate but has started to oscillate). During oscillation, the frequency is called f0. After reaching K_{MAX}, lower the Kp value to a lower level, which is usually set at about 50-75% of K_{MAX}. Finally, use the value of f0 to set the integral (T_i) and differential (T_d) gain berdasarkan rumus yang ditentukan oleh Ziegler-Nichols. gain values based on the formula defined by Ziegler-Nichols. Generally, the formula for setting PID parameters is as follows:

$$K_p = 0{,}6 \times K_{MAX} \tag{2.7}$$

$$T_i = \frac{1}{2 \times f_0} \tag{2.8}$$

$$T_d = \frac{1}{8 \times f_0} \tag{2.9}$$

(Ellis, 2012)

2.6 PCT 50 *Level Control*

Gambar 2.1 PCT 50 *level control*

The PCT 50 is a level control process that uses water as the working fluid for safety and user convenience. Water stored in the lower holding tank is transferred to the upper process vessel via a submerged variable speed centrifugal pump. A quick release connector allows the flexible pump outlet tube to be removed to assist pump priming after filling the lower tank with water. The vertical inlet arrangement in the process vessel allows visualization of the water entering the vessel, regardless of the water level and an integral non-valve (check valve) prevents back flow into the containment vessel when the pump speed is reduced or stopped. An inline ball valve (CV1) above the quick release connector allows the water flow entering the process vessel to be varied, independent of pump speed, to suit specific demonstrations.

The water level inside the process vessel is measured using an electronic pressure sensor mounted 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. This sensor therefore measures the water level inside the process vessel. The level is also indicated on a scale on the side of the process vessel. Water flows from the process vessel back to the lower holding tank through two outlets at the base of the process vessel. Flow through the main outlet is continuous. Flow through the second outlet can be started and stopped by a remote controlled solenoid valve (SOL). 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 at a predetermined size. The orifice size is changed by removing the plastic cap containing the orifice and replacing it with the required alternative. Installation utilizes an 'O' ring seal and only requires tightening by hand. The alternate orifice size is stored in a threaded hole in the front of the base plate when not in use.

Overflow in the process vessel serves to return water to the holding tank so that overfilling of the process vessel during use is prevented. The pressure sensors that measure level, the centrifugal pump, and the selenoid valves are connected to an electrical interface that incorporates the necessary signal conditioning, so that the process can be operated directly from a PC using a single USB port. The computer software supplied with the PCT50 allows control of the level process and recording of response data using a PC. Alternatively, the software allows data logging only when remotely operating the process using a PID controller. When filled with water, the standalone PCT50 requires only a mains power supply to an in-line DC converter and connection to a PC via a USB port. The unit is drained using a water drain located at the rear.

CHAPTER III
PRACTICUM METHOD

3.1 Practicum Design

3.1.1 Practicum Design

Figure 3.1 Practical design

3.1.2 Variable Determination

3.2 Materials and Tools Used

3.2.1 Materials

Aquadest 8 Liter

3.2.2 Tools

PCT 50 *Level Control*

3.3 Tool Picture

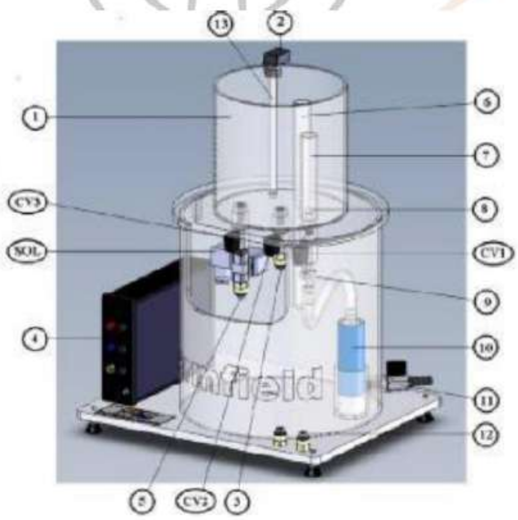


Figure 3.2 PCT 50 level control tool and its parts

(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 Trial Procedure

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 Practical Implementation

a. Find the maximum level

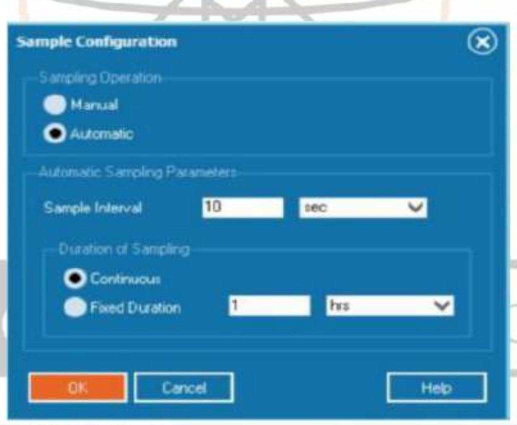
1. Plug the power cord of the appliance into the power source;
2. Calibrate the tool with the following procedure:
    1) Close the CV2 output valve at the bottom of the process vessel, then pour about 10 mm of distilled water into the process vessel.
    2) Open the CV2 outlet valve and allow the distilled water to drain from the process vessel into the sump until the process vessel is empty.
    3) Ensure that the drain valve at the rear of the sump tank is securely closed, then fill the bottom of the sump tank with clean aquadest to approximately 30 mm below the opening at the front of the tank.
    4) Ensure that flow control valve CV1 is fully open at the inlet of the process vessel so that distilled water can flow into the vessel while the pump is running.
    5) Ensure output valve CV2 is fully open at the base of the process vessel to allow the aquadest to return to the sump tank as the process vessel fills with aquadest.
    6) Ensure output valve CV2 is fully open at the base of the process vessel to allow aquadest to return to the sump tank when the process vessel is filled with aquadest.

    7) Ensure valve CV3 is fully open above the SOL solenoid valve to drain the aquadest back to the sump tank when the solenoid valve is open and the process vessel is filled with aquadest.
    8) Open the drain valve to remove any water in the sump tank.
3. Open valve CV2 and close the drain valve;
4. Fill the tank with 8 liters of distilled water;
5. Turn on the computer/laptop that has the PCT-50 software installed;
6. Set the sample interval and fixed duration on the sample configuration menu according to the predetermined variables.
7. 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.
8. Operate the tool according to the specified variables by clicking power on and go to record the data obtained;
9. 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);
10. If the time has reached the desired, decrease the pump speed to return the water to the tank.
11. Perform steps 7-9 with different variables (operating modes).

b. Find the value of PID

1. Ensure that the process vessel tank is empty.
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 obtained in the graph menu. If it is stable, check the data to get the PC value.
6. The PC value is entered and calculated into excel calculations.
7. Input the calculation results in excel to the PID menu.
8. Operate the device and observe the graph, take and save the practical data according to the data listed in the PCT-50 application (excel).

9. 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.
10. After cleaning and draining, the equipment can be turned off gradually.



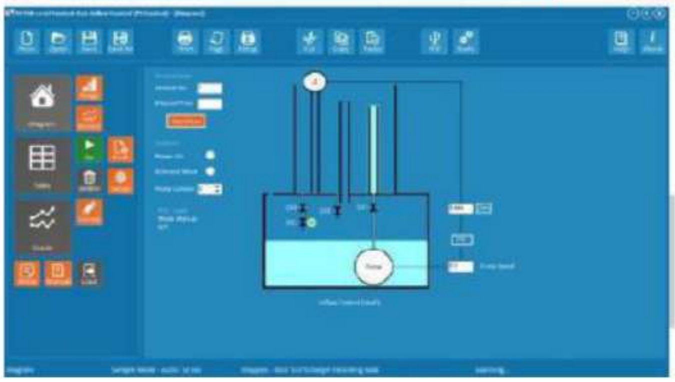


Figure 3.3 Steps to use Armfield PCT 50 software

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