Design and implementation of training module for control liquid level on tank using PID method based PLC

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Abstract. Process control is widely used in various industries to maximize production, maintain desired quality levels, product safety and make the process more economical. Control that is generally used in industry is to control liquids, such as controlling the level, flow, pressure, and temperature of the liquid using the Proportional-Integral-Derivative (PID) method, the PID controller attempts to correct errors between the measured process variables and the desired set-point by calculation and then issue actions corrective which can be arranged according to the process. In the past, most PID controllers were based on microcontrollers, but now Programmable Logic Controller (PLC) can also operate PIDs with analog function control because PLC speeds and capabilities have increased. To meet the needs of student competence in process control following industry demands, especially the use of PLC with the PID Method, students need to be given knowledge and skills. One way is the availability of training modules that can grow their enthusiasm and skills when they learn. This paper presents the design and implementation of PLC Omron CP1H based process control training modules that can be used by students to study liquid level control in tanks with PLC-based PID methods. Based on the test results when the plant is disturbed, the system response obtained by the PID method is a 15 second settling time, 10.9% undershoot, and a steady-state value of 14.6 cm or ± 97.3% of the 15 cm setting value.

1. Introduction
Various studies on the control of liquid processes have been carried out by researchers to get the best method so that it meets the desired level of quality, product safety and makes the process more economical. Jaafar et al conducted a study on controlling fluid levels with a two-tank system model with the PID method as process control [1]. Based on the simulation results with Matlab software, the researchers concluded that the system performance can achieve good results but it is difficult to find the parameters. Almost the same research regarding the control of the liquid process by the PID method which is simulated with software is also done by researcher Fellani [2], Jondhale [3], Getu [4] and Şimşek et al [5]. The researchers controlled the liquid level process with Matlab simulation, PID implementation in this system minimized overshoot, improved settling time (transient response) and steady-state error. The PLC-based liquid level study was conducted by Alem and Vankdoth [6], the automation of the control of the filling of the water tank was achieved by using a pressure switch as a level sensor to regulate the low and high levels of water in the tank.

Research on temperature and water level monitoring based on PLC Siemens S7-200 was conducted by Hamzah et al [7]. In this study, LVDT sensors were used to measure levels, whereas RTD sensors
were used to measure water temperatures. These sensors are connected to the PLC via a transducer circuit. PLC is used to control motor work through a linear drive circuit and heating work is controlled through a Pulse Width Modulation (PWM) drive circuit. In contrast to the research of Hamzah et al [8] researched the level, temperature and flow control of Profibus-DP Fieldbus-based liquid from PLC, where PLC S7-300 as master control unit and PLC S7-224 slave control unit. The control device is equipped with a PC and touch screen so that it can monitor the process in real-time. Research on controlling the level, temperature and flow of liquid is also carried out by Rathore et al [9], which distinguishes from the X. Ding, Y et al PLC research that is used is the Mitsubishi Nexgenie 1000 NG14RL PLC and uses the PID method in its control. Based on the results of the average error testing of the PLC-based control system with this PID method, for a temperature of 7.92%, a level of 6.22% and for an error flow of 4.9%.

The process control method applied in the training set was examined by Kaplan et al [10], the parameters controlled were the level, flow, pressure, and temperature of the water in a tank using the PID method based on PLC Siemens S7-1200. The researcher did not explicitly publish the value of the test results for each parameter, in this paper that the researcher described, through testing with different control methods and the results were compared to determine the efficiency of the control of the system. The PI control method in this system according to the researchers gave the best results compared to the PID control method. Because the quality of the proportional valve is higher than the PID control. Liquids in tanks with PI controls create less turbulence.

This paper presents the design and implementation of PLC Omron CP1H-based process control training modules that can be used by students to study fluid level control in tanks with PLC-based PID methods. The input component is in the form of a level sensor, while the output part consists of a pump as actuators. PLC functions as a controller that regulates fluid levels. The Controller Unit uses the OMRON CP1H PLC with Cx-Programmer software. In the PLC embedded control program with the PID method that is connected MCCDAQ is used to observe the response that occurs in the plant during trials/observations.

2. Methods
The design of the process control training module consists of the Plant and Controller Unit. Figure 1 shows a P&ID diagram of a process control training module with input components in the form of level sensors and output components in the form of pumps as actuators. The PLC will function as a controller that will adjust the level in the tank according to the set-point value. Figure 2 shows a realization of process control plants.

\[ \text{Figure 1. P & ID diagram of the process control.} \]

\[ \text{Figure 2. Realization of process control plants} \]
Figure 3 shows a block diagram of a tank liquid level control system. The block diagram consists of four main devices, namely PLC as a control device, a microcontroller as a data acquisition device, a plant in the form of a tank for liquid storage, and a liquid level sensor. PLC is used as a controller where the PID control system is embedded. PLC will produce a control signal in the form of analog data which is then forwarded to the Arduino Uno microcontroller to be converted into PWM data. Furthermore, the PWM data serves to regulate the voltage input of the pump through the MOSFET driver. At the plant there is an ultrasonic sensor that serves to detect the level of the liquid, this sensor works by emitting an ultrasonic signal that is triggered by a signal on the Trigger pin, then receives the reflection of the ultrasonic signal and is forwarded to the Echo pin. This process is then calculated by the microcontroller and produces distance data. For feedback needs, the distance data is converted into analog data through the DAC module and forwarded to the PLC. This process works continuously until the set-point value is reached.

![Block diagram of a tank fluid level control system.](image1)

**Figure 3.** Block diagram of a tank fluid level control system.

![Schematic diagram.](image2)

**Figure 4.** Schematic diagram.
Figure 5. Microcontroller program flow chart.

Figure 4 shows the schematic diagram of the fluid level control system, while Figure 5 is the Arduino Uno microcontroller program flow chart as a data acquisition device that reads fluid level data from an ultrasonic sensor. Before converting to an analog signal, the Kalman Filter program is used to filter the noise sensor. Figure 6 is a flow diagram and algorithm for the implementation of the PID program on the Omron CP1H PLC using Cx-Programmer software.

![Diagram](image_url)

**Figure 6.** Flowchart and PID algorithm PLC.
3. Results and discussion

3.1. Plant response without control

Figure 7 shows the plant response when without control, the level of water in the tank drops dramatically from 15 cm to 5 cm in 45 seconds.

![Figure 7. Plant response without control.](image)

3.2. Plant response with control

The liquid level control test in the tank is carried out with a P, PI, and PID controller. In the initial conditions the liquid in the tank is set at the 15 cm level and then disturbed by opening the tank output valve at 75% of normal conditions.

Figure 8 shows the response of controlling the liquid level with the P controller, where when given a disturbance the liquid level decreases to 13 cm and then the level oscillates with an amplitude of ± 2.5 cm from the steady-state value.

![Figure 8. Response with P controller.](image)

Figure 9 shows the control of the liquid level with a PI controller, which when given a disturbance the liquid level decreases to 14 cm approaching the initial position and then the liquid level oscillates with an amplitude of ± 2.5 cm from the steady state value.

![Figure 9. Response control with PI controller.](image)

Figure 10 shows the response of controlling liquid level with PID controller, where when given a disturbance the liquid level decreases to 14.6 cm near the starting position and oscillates with an amplitude of 0.5 cm.

![Figure 10. Response control with PID controller.](image)
Table 1. Response of liquid level control systems.

| Type of controller | Disturbance Performance parameters |  |
|--------------------|-----------------------------------|---|
|                     | Settling Time (s) | Undershoot (%) | Steady State Value (cm) |
| Proportional (P), Kp = 8,6 | 25 | 3,8 | 13,0 |
| PI, Kp= 8,1 ti = 15,3 sec | 20 | 10,7 | 14,0 |
| PID, Kp= 10,3 ti= 10,2 sec td= 2,5 sec | 15 | 10,9 | 14,6 |

4. Conclusion
The design of the training module for fluid level control in tanks using the PLC-based Omron CP1H PID method can be realized. Based on the test results when the plant was disturbance by opening the tank output valve 75% of normal conditions, the PID method system response with parameter values Kp = 10.3, ti = 10.2 sec, and td = 2.5 sec obtained the system settling time performance 15 seconds, undershoot 10.9%, and steady-state value of 14.6 cm or ± 97.3% of the setting value of 15 cm.

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