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Prototype Design of Clean Water Distribution Control System Based on Proportional Integral Derivative (PID) and Android

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Abstract

This research proposes the application of a Proportional Integral Derivative (PID) controller as a solution to overcome this problem. By controlling water flow in real-time, it is hoped that it can overcome the problem of unequal water distribution that often occurs, as well as increasing the efficiency of water use. In this system, data from the flow meter is then processed by the NodeMCU ESP8266 using the PID algorithm to determine the optimal position of the servo motor. The servo motor installed on the water tap functions to regulate the valve opening in the pipe according to the control signal produced by the PID. NodeMCU ESP8266 is also equipped with a Wi-Fi module to enable system monitoring and control via the Android application..

1 INTRODUCTION

The pump functions as a driver for water or gas fluid to be moved from one place to another (Yani, 2022). The way it works is by lowering the pressure in the suction channel so that liquid is sucked in and then released from the channel on the pressure side or outlet side with higher pressure. In addition, pumps have variations, which causes their characteristics to vary. This is done to meet community needs.

Water is essential for human survival, and without it there is no life on Earth. Therefore, because it is very important for human survival, it is natural that the clean water sector must be given top priority in handling because it is related to human life (Deriana, Kartini, & Herawati, 2022). The need for unequal and efficient distribution of water causes water shortages. In some distribution places, the challenge of water distribution itself is demand fluctuations that are difficult to predict. PID control is a common control method in industry because it has a high accuracy value, is easy to implement, and is reliable (Simanullang, et al, 2017). The advantages of this controller are the speed of response from transient conditions to steady conditions, small overshoot in transient conditions, small off-set during steady conditions and simple structure. Therefore, the author tries to apply the use of Proportional Integral Derivative (PID) to water distribution as a water flow regulator in the clean water distribution network (Sulistiyadi, Sugiarto, & Yuliani, 2020).

One of the factors influencing the popularity of PID as a process control component is its simple structure and ease of setting control parameters (Z.A, Roja, & Sylvia, 2018). The use of PID in clean water distribution offers innovative solutions to overcome various challenges and increase water efficiency and reliability.

Based on the background of the problem above, the author presents it in the form of a Final Project entitled "Design and Build a Prototype of Clean Water Distribution Control System Based on Proportional Integral Derivative (PID) and Android"

2 METHODOLOGY

Research Design

In research design using the tool development method or what is called Research and Development (R&D) *method* to Design and Build a Prototype Based Clean Water Distribution Control System *Proportional Integral Derivative* (Pid) And Android. Below is a flow diagram of the research stages we carried out:

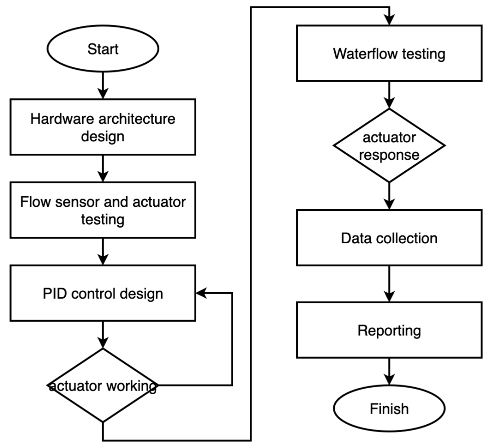

Figure 1. Research methodology

Tool Design

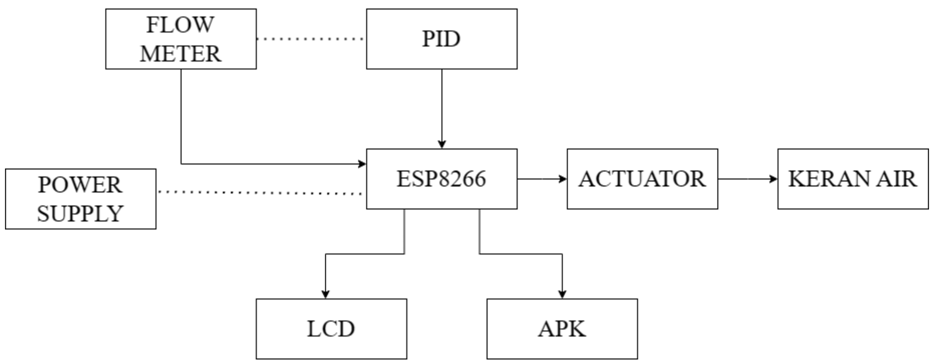

Figure 2 Tool Design

In the block diagram above it can be explained, the NodeMCU ESP8266 which controls the data process acts as a PID control and communicates with other components such as flow meters, Servo Motors and water taps. The NodeMCU ESP8266 as the main brain is equipped with Wi-Fi and I/O pins which can be used for various things which can work together to control water flow, a flow meter which continuously monitors water flow in real time and provides feedback on PID control. A servo motor regulated by PID is installed to regulate the output and opening to regulate water flow. This system works continuously by receiving feedback and. The data obtained is processed by the NodeMCU ESP8266 and then displayed on the LCD and also on the Android application that has been created.

Tool Components

1. Hardware

When making tools, the thing that needs to be prioritized is the component devices, including the following:

a. Buck Converter LM2596
   Buck Converter is a power electronics system that reduces DC input voltage to DC output voltage. This is a type of DC-DC converter that is used to convert the DC voltage from the input source into a voltage that suits the user's needs (Yunta, 2022).
b. DC Air Pump
   DC water pumps offer convenience and efficient solutions for moving liquids or water in a variety of applications. Unlike AC pumps, DC pumps utilize direct current with varying voltages ranging from low voltage (12V) to high

voltage (48V). This is useful because of its flexibility in using power sources such as solar panels, batteries and other DC power.

c. Power adaptor
The DS18B20 water temperature sensor is a sensor that measures water temperature. Water temperature sensors are usually equipped with a waterproof probe that can be immersed in water to measure the temperature. Commonly used water temperature sensors include thermistor sensors, RTD sensors, and LM35 sensors. Water temperature sensors measure changes in the resistance of the sensing element caused by changes in water temperature.

d. Flowsensor
A flow sensor, also known as a flowmeter, is an instrumental device used to measure the volumetric or mass flow velocity of a fluid, such as a liquid or gas, flowing through a pipe or pipeline.

e. NodeMCU ESP8266
The NodeMCU ESP8266 is a low-cost, highly integrated Wi-Fi microcontroller that has revolutionized Internet of Things (IoT) device development.

f. Motor Servo
Servos are *actuator* with rotary or linear types that offer precise control of angular position, speed and acceleration in a mechanical system.

g. LCD 16x2
Liquid crystal displays, also known as LCDs, are a type of display that is widely used in electronic devices such as cell phones, laptops, televisions, and calculators.

2. Software

a. Arduino IDE
Arduino IDE (Integrated Development Environment) is software that is very important in developing and programming Arduino microcontrollers. The Arduino IDE is made with the C/C++ programming language and is equipped with libraries that make input and output operations easier. This software is available for Windows, Mac OS to Linux and can be downloaded for free from the official Arduino website.

b. MIT App Inventor
MIT App Inventor is a web-based mobile application development platform that allows users to create Android applications easily, without the need to learn too complex programming languages with an intuitive drag and drop interface, users can add components such as buttons, images, or input. text to their app layouts easily.

Component Test Results

1. Flowmeter Test Results
Testing on *flowmeter* carried out to ascertain whether *flowmeter* can read the difference in flow on *system* PID. Testing is carried out by changing *setpoint* on the android application and observe the results *flowmeter* shown on the LCD with *setpoint* on the Android application.

Table 1. Test Results *flowmeter*

No	Flow meter reading	Manual measurement	Error
1.	1L/m	0.7	0.3
2.	1,5L/m	1.4	0.1
3.	2L/m	2	-
4.	2.5L/m	2.7	0.2
5.	3L/m	3	-
6.	3.5L/m	3.7	0.2
7.	4L/m	4	-
8.	4.5L/m	4.7	0.2
9.	5L/m	4.7	0.3

Based on the results of measurement data carried out by the author nine times with nine *setpoint* these differences, it is concluded that the flow meter can read water flow with an accuracy percentage of 99%

2. Actuator Test Results
Actuator testing is carried out to prove that the PID system can work to control water flow by moving the actuator. Testing was carried out using an Android application that had been created to set several new setpoints and see the response of the actuator in receiving signals from the application and adjusting to the setpoints.

Table 2. Test Results *Actuator*

Setpoint	Tap water discharge 1 (LCD)	Tap water discharge 2 (LCD)	Condition
1L/m	0.8 L/m	1.2 L/m	Normal
2L/m	2 L/m	2 L/m	Normal
3L/m	2.7 L/m	3.3 L/m	Normal
4L/m	4 L/m	4 L/m	Normal
5L/m	4.7 L/m	4.7 L/m	Normal

Based on testing *actuator* can work as the author specifies *setpoint* up to 5L/m then *actuator* open according to *setpoint* set. Looking at the test results that the author has carried out shows that the components *actuator* works well.

3. Trial and error test results on PID parameters
   PID parameters have several components, namely Kp, Ki, and Kd, which are entered manually and tested to be able to find and find out good parameters, along with the results of trial error experiments to find out which PID parameters will be used. Testing is carried out by determining the setpoint and seeing the response of the PID controller in reaching the setpoint. The most important thing in determining a PID controller is finding the constant parameter values of Kp, Ki, and Kd. This process is also called "tuning". In the "tuning" process, overshoot is required as long as the process is in another part of the setpoint, larger or smaller than the setpoint. In almost every case, the accumulated error value can exceed the setpoint, which means that the tuning process definitely requires an overshoot of the setpoint so that the error sum can be adjusted. repeat in the opposite direction. In this test the author used the Ziegler-Nichols tuning method which is the most well-known way of experimenting in determining PID controller parameters.

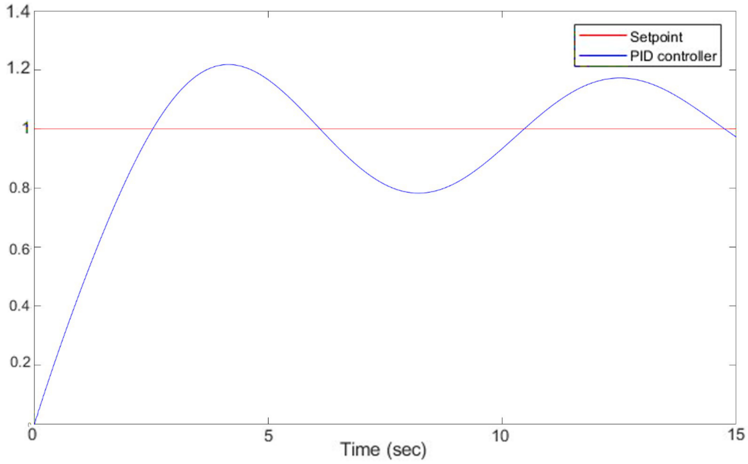

Figure 4 Experiment 1 tuning PID controller

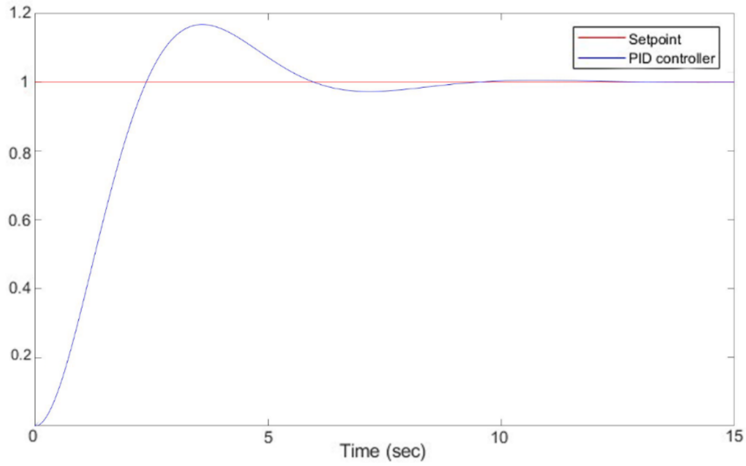

Figure 5 Experiment 2 PID controller tuning

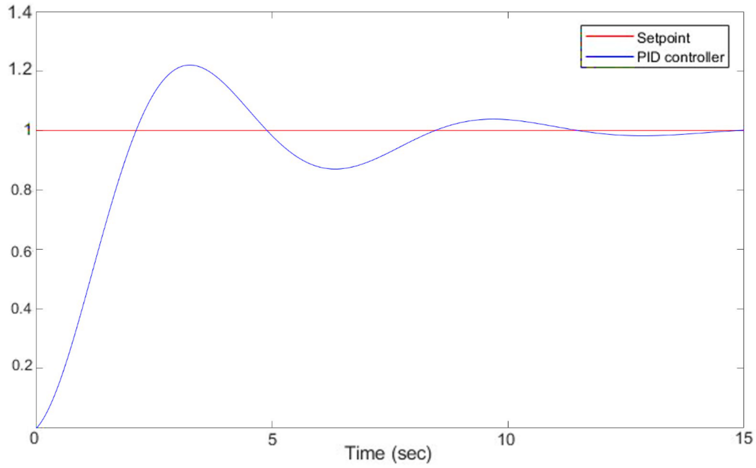

Figure 6 Experiment 3 PID controller tuning

Based on the test that the author carried out above, the author used the Ziegler-Nichols tuning method, namely by turning off the integral and derivative parameters of the controller and only using proportional then slowly increasing it until a constant wave or oscillate appears, then a minor adjustment is needed on the PID controller to get a PID response What is desired here is that the author gets the parameter value Kp=0.005, Ki value=0.001, and Kd value=0.001.

4. Overall Test Results of the Tool

After testing each hardware component or hardware and software, the author then tests the entire tool. This PID-based clean water distribution system test aims to prove the system response to varying setpoints using a PID controller. The author will try several scenarios to test the tool. distribution of clean water. The first is to be given a disturbance and see how the PID controller can respond to the changes that occur. Second, change the setpoint alternately and monitor how quickly the PID response commands the actuator to adjust to the change in setpoint.

a. First mode

In this testing mode the author will test how quickly and accurately the PID controller regulates the water flow based on changes in the initial setpoint to the final setpoint. The following is the data from the test:

Table 3. Test results of the first mode of the tool.

No	*Setpoint*		Time (second)
	early	End	
1.	0L/m	5L/m	8.53 seconds
2.	5L/m	1L/m	8.75 seconds
3.	1L/m	4L/m	5.15 seconds
4.	4L/m	3L/m	4.40 seconds
5.	3L/m	2L/m	5.12 seconds
6.	2L/m	1L/m	7.36 seconds
7.	1L/m	0L/m	5.14 seconds

In the first mode test results, namely by looking at the PID response to setpoint changes attached in table 4.6 above, after testing and collecting data, the author found that the average PID response to setpoint changes was 6.35 seconds with the longest setpoint change being 0L/ m to 5L/m, which is 8.53 seconds and the fastest is 4.40 seconds from the initial setpoint of 4L/m to 3L/m.

b. The second mode

In this testing mode the author will test the tool by giving interference to the first tap and seeing the response to the second tap and vice versa. The following is the test results data.

Table 4. Test results of the second mode of the tool.

No	Tap 1	Tap 2	Time (seconds)	Condition
1	Normal	Has been disturbed	7.42 seconds	Normal
2	Has been disturbed	Normal	9.24 seconds	Normal
3	Normal	Has been disturbed	10.02 seconds	Normal
4	Has been disturbed	Normal	9.42 seconds	Normal

5	Normal	Disturbed	8.64 seconds	Normal
6	Has been disturbed	Normal	11, 22 seconds	Normal

In this second mode of testing, the author carried out a test by providing interference to the first tap and seeing how the second tap responded to the changes that occurred. After testing, data was obtained that the two taps were able to adjust each other to the flow of water that came out even though they were disturbed and required an average of time. an average of 9.32 seconds to adjust to changes in water flow.

3 CONCLUSIONS AND RECOMMENDATIONS

Conclusion

From all the testing stages of the author's research with the title "Prototype Design of a Clean Water Distribution Control System Based on Proportional Integral Derivative (PID) and Android", and based on the discussion, a conclusion can be drawn that the PID controller can control the water flow at both taps, but not yet. able to produce water output that is consistent and in accordance with expectations where there is a difference in the actual and predetermined output values and the results of this test provide a good understanding of the application of PID control in water control systems. It is hoped that this research can become valuable information as a basis for conducting further research with developments in hardware and software.

Suggestion

After completing all stages of writing and testing the tool, the author can provide feedback or suggestions for conducting additional analysis to achieve better results. The following are some suggestions that can be given to get optimal and precise design results, the author can then adjust the PID parameters more optimally so that the results obtained are more accurate and stable, the next researcher can add the number of taps, use a bigger water pump, use sensors which is more accurate, and actuators with different types such as solenoid valves as water flow regulators for faster response and higher precision to maximize the work of the PID controller.

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