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Design And Construction Of Automatic Ph And Water Level Control In Tilapia Fish Farming Ponds

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Abstract

This This study aims to design and build an automatic control system to control pH and water level in tilapia fish farming ponds. This system consists of a pH sensor and an ultrasonic sensor (HC-SR04) integrated with an ESP32 microcontroller. Data obtained from the sensor is processed to control the pH solution pH up and down solenoid valve and the inlet and outlet water solenoid valve. The test results show that the system is able to respond well to changes in pH and water level. The fastest system response to control water pH in the second test showed a settling time (ts) of 1950 seconds with a steady-state error (ess) of 0.93%. The response of the water level system showed that the water addition process was faster in the second test based on the settling time (ts) of 7570 seconds and had no steady-state error (ess). For the water drainage process, the second test also showed a faster time based on the settling time (ts) of 2965 seconds and a steady-state error of 0.04%. The designed system successfully carried out automatic control of pH and water level in tilapia fish farming ponds.

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1. Introduction

Indonesia is an archipelagic maritime country that stretches 3,977 miles between the Indian Ocean and the Pacific Ocean. Indonesia's territory consists of 75% ocean and 25% land[1]. With these geographical conditions, the fisheries sector is one of the great potentials in supporting the Indonesian economy[2]. Indonesia has various species of fish, one of which is favored for consumption is tilapia[3]. Tilapia is widely cultivated because it is easy to adapt to less favorable environments and is easy to spawn[4]. Tilapia is also a type of freshwater fish that is economical, has a distinctive meat taste and is quite high in protein[5].

In fish farming activities, several water quality parameters must be considered in an effort to improve the quality of fish production[6]. Water quality is one factor in the success of tilapia cultivation[7]. Several water quality parameters that affect the survival of fish are physical and chemical parameters. Physical parameters are color, temperature and brightness. For chemical parameters that can be seen are pH, dissolved oxygen (DO), hardness, carbon dioxide (CO2), and ammonia[8]. Fish farming requires regular maintenance and monitoring for fish health. Among the factors that affect water quality are pH and water temperature. Based on SNI 6141:2009 data, the pH level in tilapia ponds ranges from 6.5 - 8.5 and the water temperature is between (25-30)[9]. If the pH level of the water is higher or lower than the standard pH, it will make the fish uncomfortable, stressed and can cause the fish to die[10].

However, fish farmers still measure the pH level and water level manually, by taking water using litmus paper and comparing the color results with the specified scale or using a pH[10], [11]. With these problems, a tool is needed that can facilitate controlling pH and water level in order to save more energy and time.

Several previous studies have discussed the control system in fish farming ponds, including by Azizah et al. in 2022, they have succeeded in designing an automatic pH control system[12]. Research conducted by Mege et al. in 2024 has succeeded in designing an automatic pH control system in tilapia farming ponds to maintain pH stability by controlling pumps and solenoid valves for water changes[13]. Based on previous research, developments were carried out in the research that will be carried out in order to be able to control pH and water level automatically according to the set point.

2. Methods

This research began with a comprehensive literature review on feasibility studies and planning processes to gain insights from prior research in the relevant field. The methodology is outlined as follows, with sufficient detail provided to ensure the reproducibility of the work. Where methods have been previously published, appropriate references are cited; only relevant modifications to these methods are described.

2.1. Architectural design

Electronic design in the design of automatic control of pH, temperature and water level in ponds for tilapia cultivation was carried out in stages by testing all the sensors used.

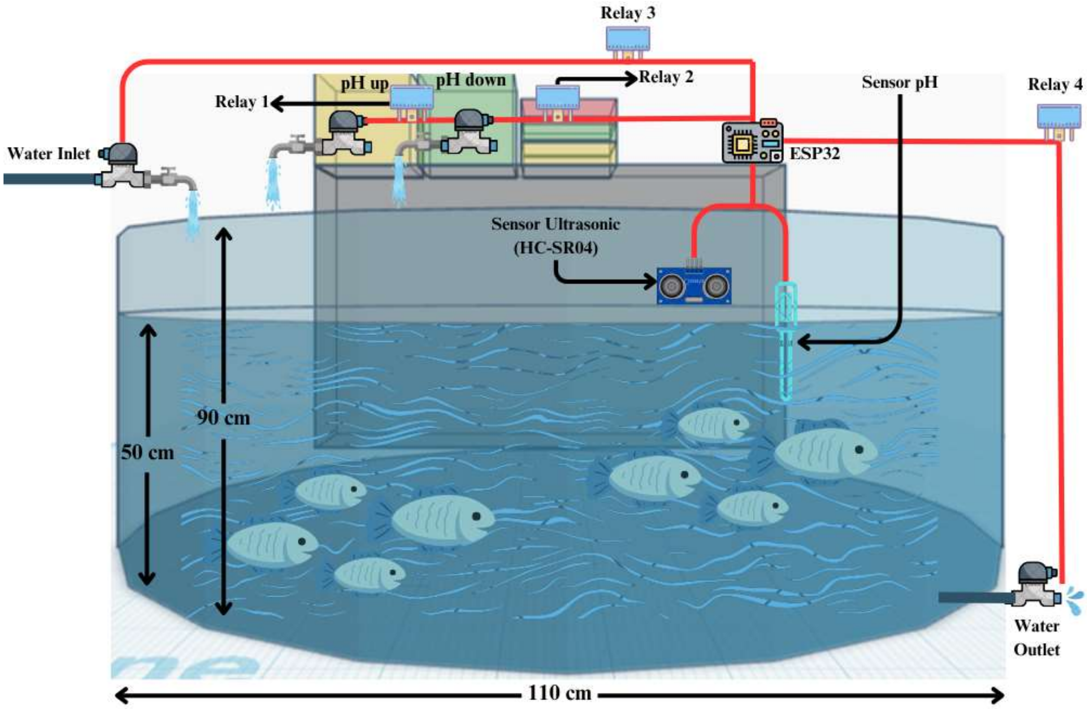

Figure 1. Tilapia fish pond architectural design

In Figure 1, is the architectural design of a tilapia fish farming pond and four separate containers, namely the pH up solution container and pH down solution container. The fish farming pond is designed in the form of a tube with a diameter of 110 cm, a height of 90 cm and a water height of 50 cm. There are two sensors used, namely the pH sensor and the ultrasonic sensor (HC-SR04). To regulate the pH of the water, pH up and pH down solutions are used. Meanwhile, to maintain the water at a height of 50 cm, a solenoid valve is used to add and drain pond water.

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2.2 Electronics design

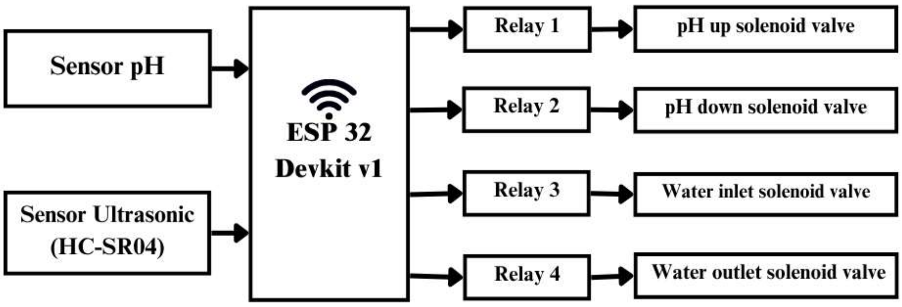

Figure 2. System workflow

Figure 2, is the workflow of the system. At the input, using pH sensor and ultrasonic sensor (HC-SR04). Data obtained from sensor readings are processed by the ESP32 Devkit V1 microcontroller as a control center to control the system. At this stage, input data is processed to make decisions based on the results of data processing. Furthermore, the decisions taken will be executed to run the system as output from the process. The output of this system is in the form of real-time readings of pH values, temperature and water levels on control of the pH solution solenoid valve up/down and inlet/outlet water solenoid valve.

3. Results and Discussion

3.1 Research result

Based on the architectural design of the tilapia pond in Figure 1, this study has succeeded in designing a control system for pH and water level in a tilapia fish farming pond. Figure 3, is the application of the system to the pond. The tool designed uses a cylindrical pond with a diameter of 110 cm, a height of 90 cm and a water height of 50 cm.

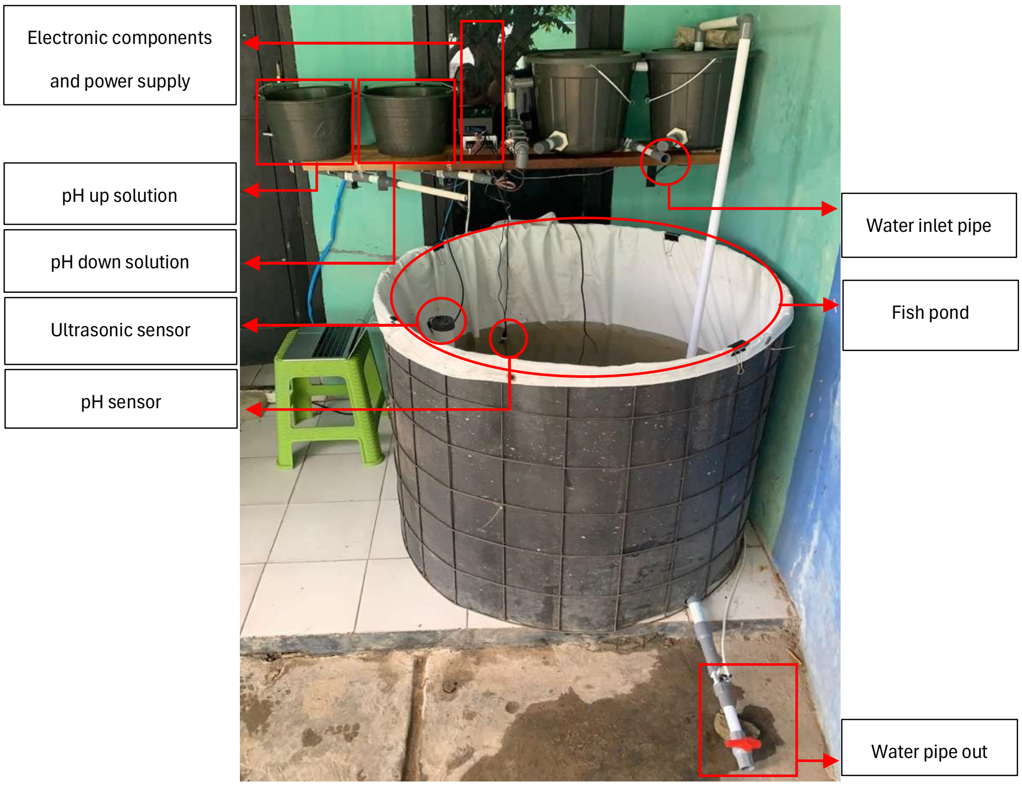

Figure 3. Application of the system in the pool

Figure 3, is a tilapia pond designed with a supporting frame and covered with a waterproof tarpaulin as a container equipped with pipes for the water intake and discharge process. At the back of

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the pond there are two buckets, the leftmost bucket contains a pH up solution, while the bucket next to it contains a pH down solution, which is used to regulate the pH balance of the water. Between the two filtration buckets, there is an inlet water pipe that flows clean water connected to a hose from the tap to the pond. Then at the end of the pipe is equipped with a solenoid valve to automatically regulate the water flow. In addition, at the bottom right of the pond is installed an outlet water pipe and at the end of the pipe is also equipped with a solenoid valve which is used to remove excess water or for the circulation process. Sensors are strategically placed on the edge of the pond to obtain accurate reading data.

3.2 calibrated sensor

1. PH sensor calibration

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Calibration of the pH sensor was carried out using a pH meter as a calibrator. The number of pH variations used was 6 variations and the number of repetitions was 10 times for each sample. The calibration data was made in the form of a graph to obtain a linear equation that describes the relationship between the pH meter and the pH sensor. The results of the calibration graph can be seen in Figure 4. Based on the graph, the trendline obtained between the pH sensor and the pH meter can be presented by the equation y = 21.540 - 0.006491x with a coefficient of determination R2 of 0.9880.

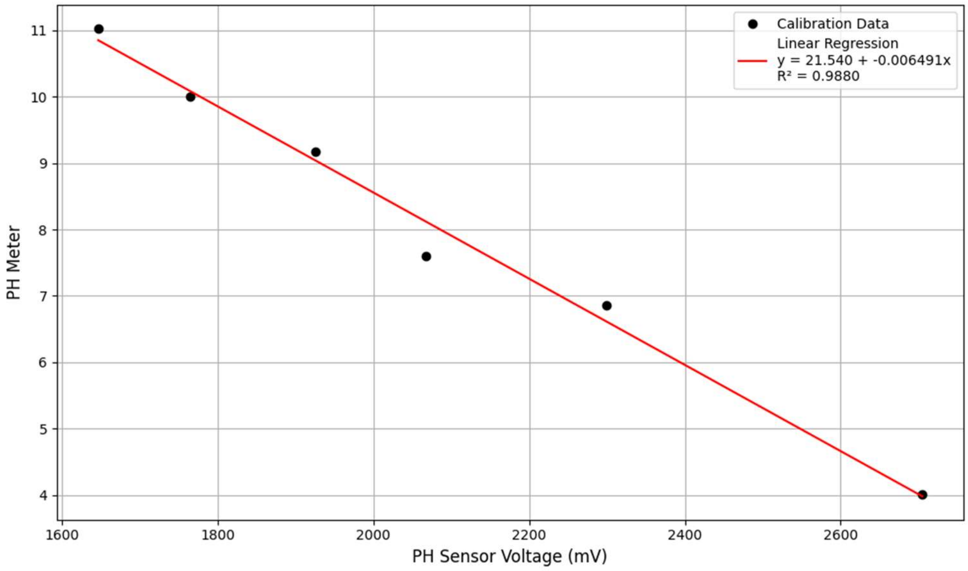

Figure 4. PH sensor calibration

Calibration of the ultrasonic sensor was carried out using a ruler as a calibrator. The number of pH variations used was 10 variations and the number of repetitions was 10 times for each sample. The calibration data was made in the form of a graph to obtain a linear equation that describes the relationship between the ruler and the ultrasonic sensor. The results of the calibration graph can be seen in Figure 5. Based on the graph, the trendline obtained between the ultrasonic sensor and the ruler can be presented by the equation y = 0.207 + 0.9777x with a coefficient of determination R2 of 0.9995.

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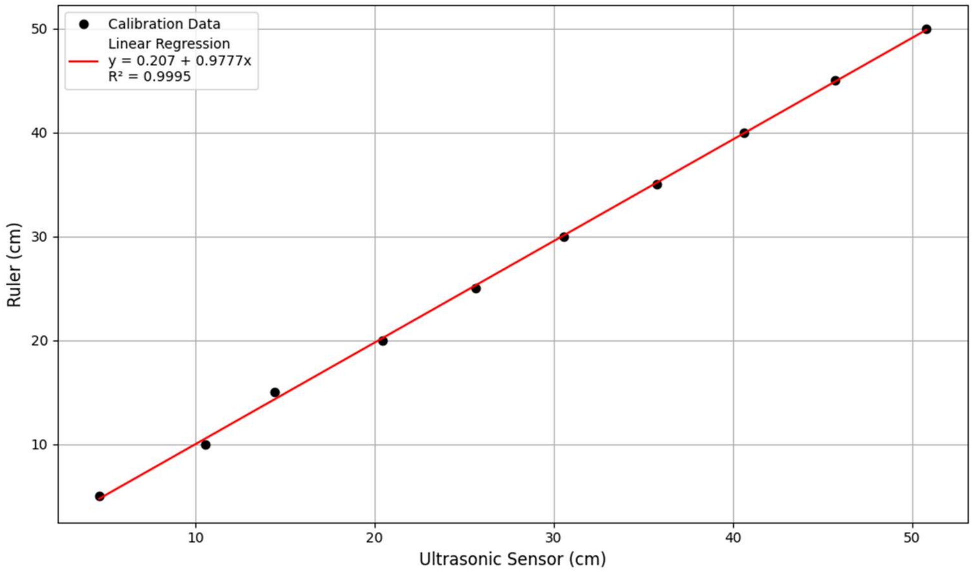

Figure 5. Ultrasonic sensor calibration

3.3 System testing

Table 1 shows the testing of the pH up and pH down solution solenoid valves carried out to ensure that the solenoid valve can be Open or Closed using relays 1 and 2 based on the pH sensor readings. This test is carried out by varying the acidity and alkalinity of the air. The condition of the solenoid valve is regulated based on logic where when the pH sensor reading is below 6.0 then the solenoid valve is in the Open or Closed state and when the pH Sensor reading is above 8.0 then the solenoid valve is in the Open or Closed state.

Table 1. Solenoid valve test results pH up and pH down

No	pH sensor	Solenoid Valve pH up condition	Solenoid Valve pH down condition	Information
1	9.67	Closed	Open	Correspond
2	9.45	Closed	Open	Correspond
3	9.12	Closed	Open	Correspond
4	8.34	Closed	Open	Correspond
5	8.27	Closed	Open	Correspond
6	8.13	Closed	Open	Correspond
7	4.27	Open	Closed	Correspond
8	4.18	Open	Closed	Correspond
9	3.78	Open	Closed	Correspond
10	3.49	Open	Closed	Correspond

Table 2, shows the testing of the inlet and outlet solenoid valves to ensure that the solenoid valves can be opened or closed using relay 3 and relay 4 based on the ultrasonic sensor readings. This testing is done by varying the pool water level. The condition of the inlet and outlet solenoid valves is set based on logic where when the ultrasonic sensor reading is below 45 cm then the solenoid valve is

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open or closed and when the ultrasonic sensor reading is above 55 cm then the solenoid valve is open or closed.

Tabel 2. Results of testing the inlet and outlet solenoid valves

No	Ultrasonic sensor	Solenoid Valve water in condition	Solenoid Valve water out condition	Information
1	71.12 cm	Closed	Open	Correspond
2	67.35 cm	Closed	Open	Correspond
3	63.21 cm	Closed	Open	Correspond
4	62.40 cm	Closed	Open	Correspond
5	58.44 cm	Closed	Open	Correspond
6	44.26 cm	Open	Closed	Correspond
7	43.81 cm	Open	Closed	Correspond
8	41.20 cm	Open	Closed	Correspond
9	40.16 cm	Open	Closed	Correspond
10	38.88 cm	Open	Closed	Correspond

3.4 System Response

1.Water pH

Figure 6 and Figure 7, shows a graph of the water pH system response over time as it decreases toward the set point of 8.00.

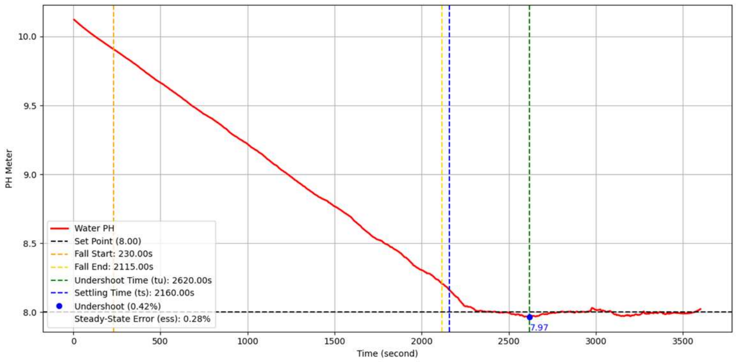

Figure 6. First test result of system response

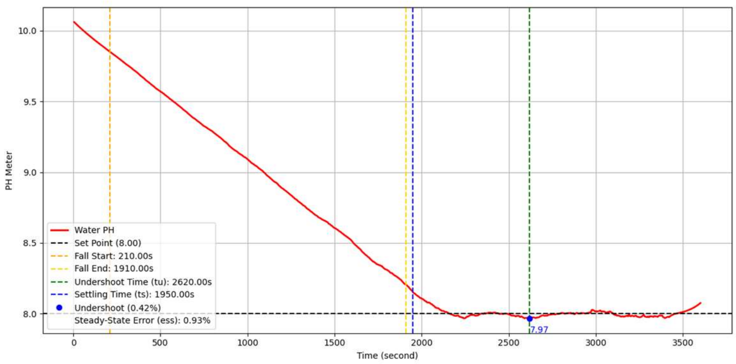

Figure 7. Second test result of system response

Figure 6 and Figure 7, show the response of the water pH reduction system to time due to the addition of pH down solution using a solenoid valve from an initial pH of around 10.00 to a pH setpoint of 8.00 based on pH sensor readings. In the first test graph, the decrease time starts at 230 seconds and ends at 2115 seconds. The second test graph has a decrease time starting at 210 seconds and ending at 1910 seconds.

In terms of time to steady state with settling time (ts), the second test graph also shows the best performance with settling time achieved at 1950 seconds faster than the first test graph with settling time at 2160 seconds, indicating that the system is within the tolerance limit of ±2% of the setpoint.

When viewed from the undershoot value, the results of the first and second tests show the same value, namely 0.42%. Meanwhile, for steady-state error (ess), the second test graph also shows the highest steady-state error of 0.93%, compared to the first test graph of 0.28%. Thus, although the second test graph reaches stability the quickest, it has the worst final stability compared to the first test graph based on steady-state error.

2. Water level

Figure 8 and Figure 9, shows the system response graph to the addition of water into the tank, with a water level set point of 50.00 cm.

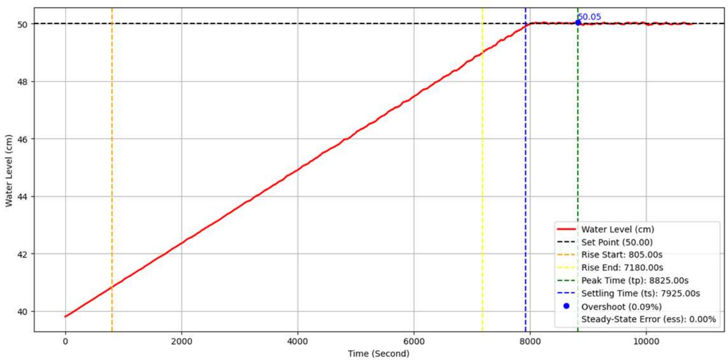

Figure 8. First test result of system response

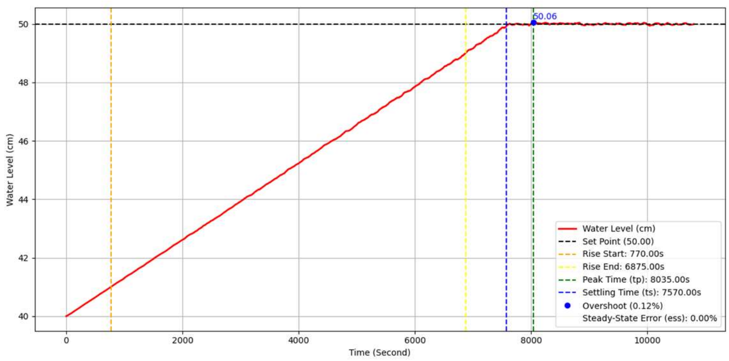

Figure 9. Second test result of system response

Figure 8 and Figure 9 show the response graph of the water level system to the time of adding water from an initial height of around 40 cm to a setpoint of 50 cm based on ultrasonic sensor readings. The first test graph shows the rise time starting at 805 seconds and the rise time ending at 7180 seconds, the second test graph starts at 770 seconds and ends at 6875 seconds.

When viewed from the settling time (ts), the second test graph is superior because it reaches a settling time at 7570 seconds compared to the first test with a settling time at 7925 seconds, which indicates that the system is within the tolerance limit of ±2% of the setpoint.

Regarding the maximum overshoot (Mp), the second test with the highest value of 0.12%, compared to the first test of 0.09%. However, the first and second tests show the same steady-state error (ess), which is 0.00%.

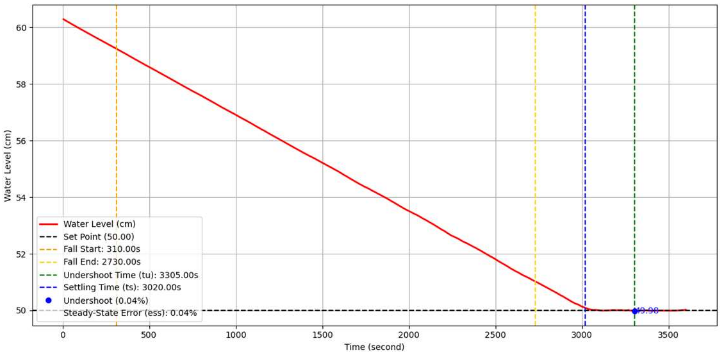

Figure 10. Firts test result of system response

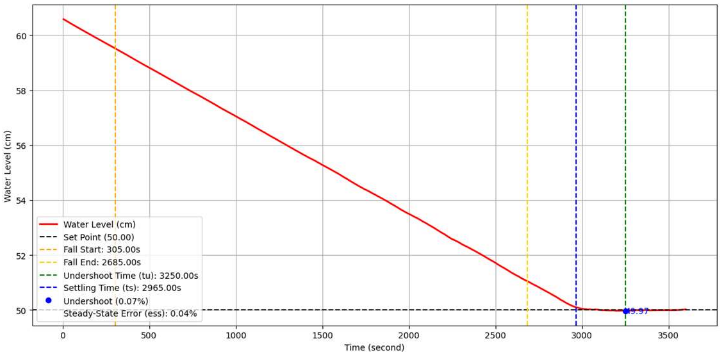

Figure 11. Second test result of system response

Figure 10 and Figure 11 show the response graph of the water level system to the water draining time from an initial height of around 60 cm to a setpoint of 50 cm based on ultrasonic sensor readings. The first test graph shows the descent time starting at 310 seconds and the descent time ending at 2730 seconds, the second test graph starts at 305 seconds and ends at 2685 seconds.

When viewed from the settling time (ts), the second test graph is superior because it reaches a settling time at ts compared to the first test with a settling time at 2965 seconds, which indicates that the system is within the tolerance limit of ±2% of the setpoint.

Regarding undershoot, the second test has the highest value of 0.07%, compared to the first test of 0.04%. However, the first and second tests show the same steady-state error (ess), which is 0.04%.

4. Conclusions

This study successfully developed an automatic system to control pH and air level in tilapia fish farming ponds. The system worked according to the specified parameters, with the fastest settling time (ts) for pH control in the second test at 1950 seconds and a stable-state error (ess) of 0.93%. The height control system showed a faster response to air addition in the second test with a settling time (ts) of 7570 with no stable-state error (ess). For the fastest air removal process in the second test with a settling time (ts) of 2965 seconds and a stable-state error of 0.04%. This study was able to improve the effectiveness of aquaculture management through automation and real-time control of pH and air level.

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