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Memonitor Hidroponik Dengan Sistem Wick Berbasis Internet Of Things (IoT) Menggunakan Mikrokontroler Dengan Metode Fuzzy Logic

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Abstract

Hydroponics is one of the innovations in the food system that does not use soil but uses water elements and other mediums. The hydroponic farming system can help in farming activities, one of the hydroponic methods that is easy to apply is the wick system, but it requires attention and time to be able to carry out a hydroponic planting system. Along with the development of technology, innovations have emerged for hydroponic cultivators to carry out remote monitoring through the concept of the Internet of Things (IoT) with tools that will work automatically in measuring the pH of water and the water level of hydroponic plants of the wick system. The automated system uses the fuzzy logic method as data processing and ESP32 as the microcontroller. To avoid misreading the value of the pH sensor and water level sensor, the calculation of the average equation, comparison, and presentation of errors is used in the sensor data readings. The test results showed that the design tool in monitoring hydroponic plants of the wick system was able to maintain the normal value of water pH, maintain the stability of the water level and identify errors in the reading of the sensor data value. With this research, it is hoped that the application of IoT and the Fuzzy Logic method can become literature in the integration of the development of wick method hydroponic systems in order to maximize yields and reduce the risk of plant errors and failures.

Keywords: *Microcontroller, Hydroponic, Fuzzy Logic, Internet of Things (IoT).*

1. Introduction

Hydroponics has been recognized as a viable method of producing vegetables (tomatoes, lettuce, cucumbers and peppers) as well as ornamental plants such as spices, roses, freesia and foliage plants [1]. The farming system using hydroponics has begun to be widely looked at by some circles of the community because it can save space and the results of crop quality can be regulated. The wick system is one of the hydroponic techniques widely used by most humans because it is the simplest in its application. This technique uses the static solution principle by using water and a nutrient mixture that is flooded under the root of the plant which will later be absorbed by the plant for its growth [2].

The nutrients given to plants are closely related to the degree of acidity (pH) of water, where the pH of the water will affect the solubility of nutrients in plants which results in the quality of fertility of the growth and development of the plant. In fact, the pH value of nutrients in the tank is always changing due to various factors such as planting media, respiration photosynthesis process and bacteria, so a control system is needed that can regulate the values of vegetable needs factors automatically, as in the research of Puspasari et al which uses an integrated wick system with the help of sensors. There have been many studies that research on control methods in wick system hydroponic plants [3], one of which is to apply the use of the internet such as using IoT methods. Another study designed a wick system hydroponic controller utilizing IoT (Internet of Things) [4] and Fuzzy Logic methods to monitor and control manually or automatically remotely on one

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type or several planting objects with an intersecting range of nutrients that can be adjusted. [5]

Internet of Things (IoT) is a concept that refers to the use of connected intelligent devices and systems to utilize data collected by sensors and actuators in machines and other physical objects. IoT works by utilizing a programming argument with each command argument it produces an interaction between fellow machines that connects automatically without human intervention and within any distance [1][2][3]. Fuzzy is linguistically defined as vague or vague. In fuzzy logic has a degree of membership that has a range of values from 0 to 1. Fuzzy Logic is used to translate a quantity expressed using language (linguistics). Fuzzy Logic shows the extent to which a value is true and to what extent a value is false. Unlike classical logic, a value has only 2 possibilities i.e. is a member of the set or not [4][5][6]. Internet of Things-based technologies with the Fuzzy Logic method in hydroponics are already widely applied, but production costs and problems with tools when working automatically are still common.

Previous research has also been carried out on automatic water pH control in DFT hydroponic systems using the Internet of Things (IoT) based on the Fuzzy Logic Controller (FLC) which uses the SEN0161 SKU sensor to detect the pH value as an error value and its changes in the FLC input. The use of IoT and other Fuzzy Logic is also carried out in predicting excess or deficiency of nutrient content based on the results of routine monitoring and has the ability to analyze the prediction of parts per million (PPM) values to find the nutritional value of plant media using Electrical Conductivity (EC) and Hydrogen Potential (pH) in the hydroponic plant media of the NFT system through the application of the fuzzy logic of the Mamdani method to determine the prediction of PPM values in providing nutrition in plants to adjust nutrients in each plant and the Internet of Things (IoT) for remote sensing using smartphones as a representation of the measurement results on hydroponic systems [6] [7].

Based on the description above, the study aims to design and make a tool that can be applied to the hydroponics wick system automatically. The design uses the fuzzy logic method as data processing and ESP32 as a microcontroller in measuring water pH and water levels of hydroponic plants wick systems that can be monitored through the Internet of Things (IoT) concept. The tool designed is intended to be able to control the pH value of water by automatically activating the water pump to maintain the pH stability of the water in the hydroponic main bath and is able to identify errors in the sensor readings. The design tool made will make it easier to monitor the hydroponic activities of the wick system using software that has been designed and is able to make reports according to what is needed by users.

2. Research Method

The manufacture of this controlling device goes through several stages. Before the design of the tool is carried out, preliminary library research is first carried out to collect various materials and literature studies related materials, both in the form of library materials from journals, supporting books and other information media. From these various literature studies, it further determines what fuzzy logic method is used in answering water pH problems and can read errors that occur in the hydropnics of the wick system. This is a stage in designing a controlling device by recognizing various parts that must be prepared and made. The next step is to design and manufacture electronic systems and control systems on research objects, such as creating programs and designing components to build systems. Then testing and data retrieval is carried out, namely conducting trials on the tool as a whole and retrieving the data contained in the system from what has been designed to minimize errors in the system. The test was carried out using the help of an appropriate MySQL database in evaluating how to store and manipulate large amounts of heterogeneous data obtained from IoT [8].

2.1. Hardware Design

In order to facilitate the understanding of the tool work system, a block diagram is made consisting of three main blocks, namely Input, Process and Output.

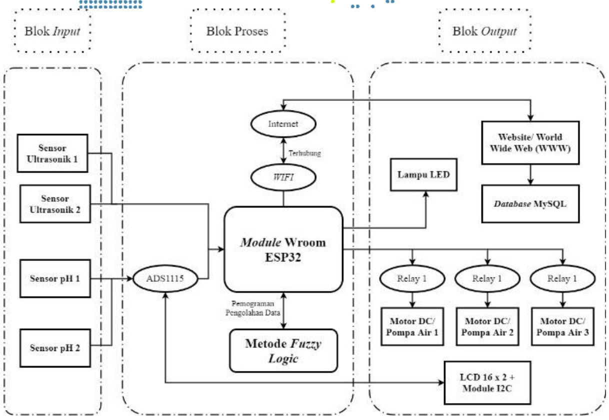

Figure 1. Tool Diagram

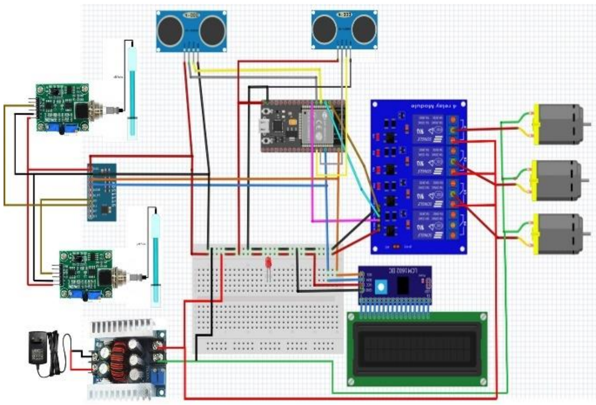

Figure 2. System Hardware Design

2.2. How the Tool Works

In the input block there are 2 types of sensors, the first is a pH sensor used to measure acidity and wet conditions in water used as nutrients in hydroponic plants and the second is a water level sensor functioning to measure the depth of water nutrients to the hydroponic wick system .

The process block consists of components that are used to control the overall components and process data connected to the process block and also as a transmission medium to transmit the data that has been processed. In the process block the ESP32 microcontroller can be directly connected to WIFI and has been entered into a data processing program using the Fuzzy Logic method.

In the output block consisting of 4 outputs, first a result of reading data from the process block will be sent via WIFI and then displayed on the local host website that has been designed. The second is an LCD that will display in real time the results of water level, water pH and display the conditions when ESP32 to WIFI is connected and not connected. The third is a controller output by turning on 3 relays, each relay is connected to a mini water pump continuously according to the designed program command. The fourth is that the LED will light up when there is a junction of more than 1.0 from the readings of the same two sensors. To obtain the results of the research empirically, a hydroponic prototype of the wick system is designed which will be applied to the tool that has been designed.

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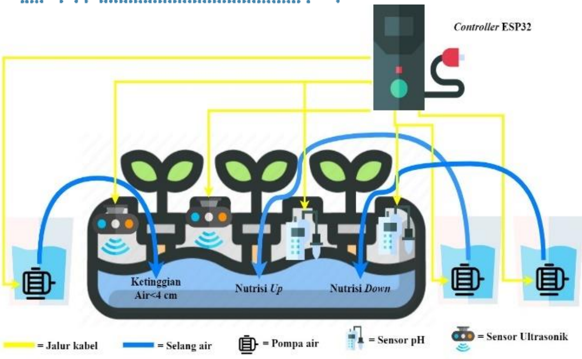

Figure 3. Hydroponic Prototype Design on Hardware Equipment

2.3. Sofware Design

Hydroponics does not cause a deterioration in soil quality, and does not produce harmful waste to the environment, the hydroponic method of its application is more efficient in areas that have limited green space. pH is important in hydroponics because pH has an influence on the plant's ability to bind nutrients passing around plant roots [7][8][9]. In this study, which used the Fuzzy method, not all types of sensors, this is because it looks at the way the sensor works and the resistance itself, therefore what uses the Fuzzy method is a pH sensor. The pH sensor was chosen because the sensor readings are very sensitive and the solution may change at any time. There are many things that can make the pH sensor readings change, for example when the water bath is exposed to rain, experiencing shocks so that the water in the tub is corrugated, the volume of water changes and when the main water bath receives the nutrient solution to be given according to the conditions of the main water bath needs. As for the water level sensor, the water level reading is quite stable in both sensors, therefore on the water level sensor, it is enough to use the method of calculating the difference between the sensor and the crossbar measuring instrument and find the average value of the two water level sensors.

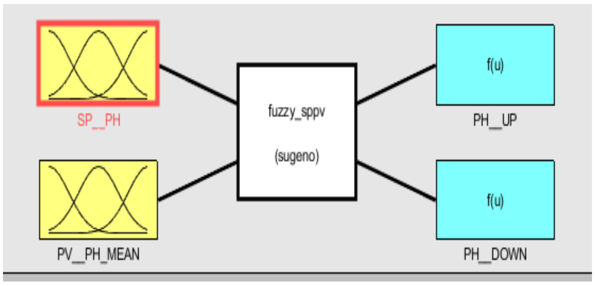

Figure 4. Ph Sensor Inputs and Outputs Using Fuzzy Logic Sugeno

For this study, the Fuzzy method used is the Fuzzy Sugeno method, because the Sugeno method has an output that has become a crisp number or constant so that it will make it easier to find the weight point [10][11][12]. The Fuzzy Logic Sugeno design has 2 inputs and 2 outputs where the first input is the Set Point pH (SP pH) which functions as a regulation of the desired pH condition, namely the normal pH in the range of 6.5 to 7.5. The second input is the result of readings when the two sensors are operating which is called Point Value pH (PV pH). While the designed output stage has 2 outputs, namely pH up nutrition and pH down nutrition.

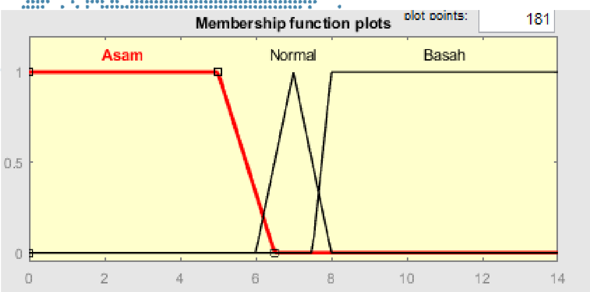

Figure 5. pH Set Point Design

The SP pH input design has 3 membership function plots (MFP), namely Acid (A), Neutral (N) and Wet (B). The data to be processed is data from the pH sensor which will later be regulated through a microcontroller so that the condition of the main water bath can become a normal pH. In order to understand the scale range of membership function plots on the designed pH SP, it can be seen in the table of the set of pH set points .

Table 1. Set Point pH Level Set

MF	Poimt 1	Point 2	Point 3	Point 4
A	0	0	5	6.5
N	6	7	8	-
B	7.5	8	14	14

In the PV pH input design, it has 5 membership function plots, namely Highly Acidic (SA), Acidic (A), Normal (N), Wet (B) and Very Wet (SA). The data that will be processed is data from the reading of the pH sensor while it is in process which will later be regulated through a microcontroller so that the condition of the main water bath can become a normal pH.

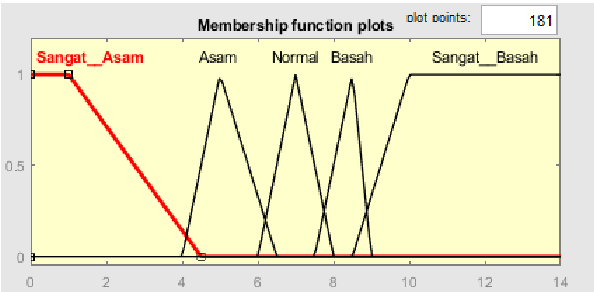

Figure 6. Draft Point Value pH.

To be able to understand the scale range of membership function plots on PV pH that has been designed, it can be seen in the table of the set of pH point value levels .

Table 2. Set of pH Point Value Levels

MF	Point 1	Point 2	Point 3	Point 4
HIS	0	0	1	4.5
A	4	5	6.5	-
N	6	7	8	-
B	7.5	8	5	9
SB	8.5	10	14	14

As for the design in both outputs, it has the same membership function plots design, where there are 5 MFPs, namely Very Many (SB), Many (B), Normal (N), Few (S) and

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Empty (K). To be able to understand it, it can be seen in the drawing of the pH up and pH down output designs.

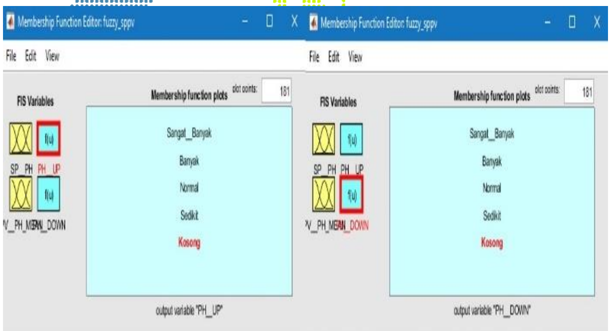

Figure 7. Output Design pH Up and pH Down

The pH up and pH down water nutrition pumps will work with the calculation of millimeters (ml) of water according to the commands executed. The results of Fuzzy Logic data processing at the output can be seen with the scale range in the output table of the pH up water pump and the pH down water pump.

Table 3. Output of pH up Water Pump and pH Down Water Pump

MF	Water Pump (ml)	
	pH *up*	pH *down*
SB	200	200
B	150	150
N	100	100
S	50	50
K	0	0

After compiling inputs and outputs in accordance with the purpose of the next research is to display the rule-base used in Fuzzy Logic. To make it easier to understand the rule base, you can see table 4. rule-base Fuzzy Logic sugeno method.

Table 4. Rule-Base Fuzzy Logic Metode Sugeno

Input		*Output*	
Set Point pH	Point Value pH Mean	pH *Up*	pH *Down*
Sour	Highly acidic	Sedikit	Blank
Sour	Sour	Blank	Blank
Sour	Normal	Blank	Sedikit
Sour	Wet	Blank	Normal
Sour	Very Wet	Blank	Many
Normal	Highly acidic	Very Much	Blank
Normal	Sour	Many	Blank
Normal	Very Wet	Blank	Very Much
Normal	Wet	Blank	Normal
Normal	Normal	Blank	Blank
Wet	Highly acidic	Very Much	Blank
Wet	Sour	Normal	Blank
Wet	Very Wet	Blank	Sedikit
Wet	Wet	Blank	Blank
Wet	Normal	Sedikit	Blank

Internet of Things refers to the Internet to be able to connect with humans, things through the Internet and data storage is done in could for analysis. The advent of IoT allowed farmers to automate hydroponic culture. Monitoring of water level, pH, temperature, flow, and light intensity can be carried out, and can be regulated with the use of IoT. Therefore, quite a lot of research is carried out by utilizing IoT to monitor and control hydroponic systems [13][14][15]. The concept of the Internet of Things includes 3 main elements, namely physical or real objects that have been integrated into sensor modules, internet connections, and data centers on servers to store data or information from applications. The use of objects connected to the internet will collect data which is then collected into 'big data' to be processed, analyzed both by government agencies, related companies, and other agencies then utilized for their respective interests [16][17][18]. The stages of the work process of the design tool as a whole can be seen in the flowchart below.

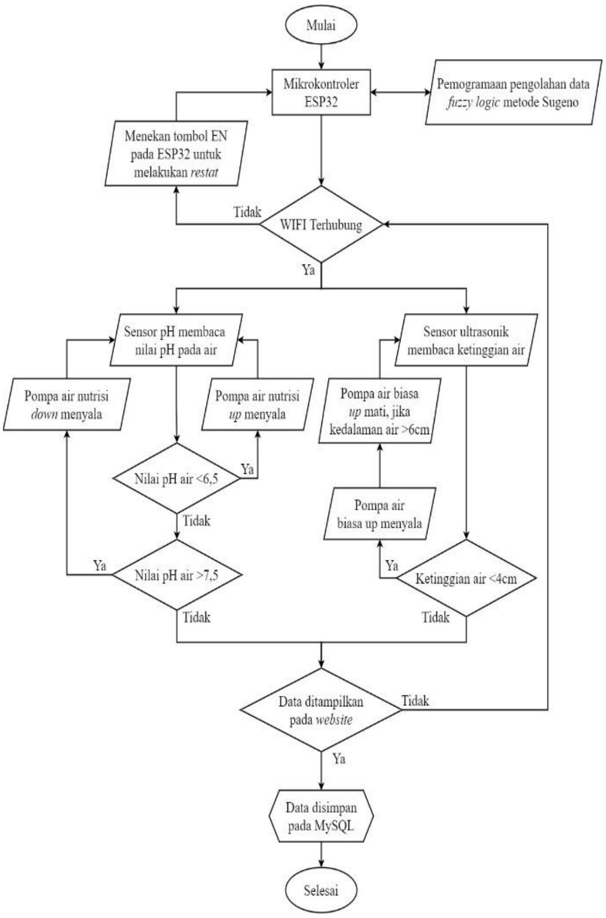

Figure 8. Main Program Flowchart

The results of the pH sensor readings will be processed using the Fuzzy Logic method where in the data processing process data readings will be reddened. The results of data processing will be stored, so that in the process of data redundancy do not use data storage which will later be used for data testing on the tool as a whole.

When the pH value of the nutrient bath water is less than 6.5, the microcontroller will provide instructions on the mini water pump machine that regulates nutrients up to ignite filling the main hydroponic tub, while when the pH sensor reads that the pH value in the hydroponic water bath is more than 7.5, the water pump that regulates nutrient down will turn on according to the instructions of the program that has been made and controlled through ESP32. For the reading of the water level sensor, it is tasked with knowing the depth or water level in the hydroponic bath so that the plant will always be supplied with the water that has been provided, when the hydroponic water level is less than 4 cm (centimeters) then the microcontroller will instruct the water pump to be on and off when the water level reaches 6 cm. The results of the readings of all sensors will be displayed on the website that has been designed and uses a local host as the network, while a laptop or computer is used as a server and interface to monitor the hydroponics of the wick system according to the design that has been made. If the sensor readings cannot be displayed on the website, a reset will be performed on the ESP32 microcontroller.

3. Results and Discussion

3.1. Testing

In this section, we will discuss the test and analysis results of the design of a tool to monitor water pH and water level in an Internet of Think (IoT) -based hydroponic wick system with Fuzzy Logic as data processing. To be able to find out the percentage of success or error value in the design tool, the first stage is carried out by calculating the average value of the same two types of sensors. After getting the average value of the two types of sensors, the next step is to calculate the percentage of the error value.

3.1.1. pH Sensor Testing

Testing on the pH sensor is carried out by simulating methods of various conditions, if the results of the reading of the pH 1 sensor data and the pH 2 sensor are different or more than 1.0, the LED light will automatically turn on to notify that there has been a deviation from the pH sensor data reading. Some of the conditions created are as many as 10 test sheets of pH sensor data readings, so that output data from pH 1 sensors and pH 2 sensors are obtained which are shown in Table 5.

Table 5. Simulated Test Results on pH Sensors

Number of Tests	pH Sensor Testing 1	pH Sensor Testing 2	Difference Difference	LED Lights
1	3,22	3,05	0,17	Die
2	4,45	5,20	0,75	Die
3	3,82	5,55	1,73	Live
4	5,30	5,15	0,15	Die
5	6,11	7,12	1,01	Live
6	7,77	6,77	0,99	Die
7	6,98	9,23	2,25	Live
8	8,15	7,45	0,70	Die
9	8,85	9,76	0,91	Die
10	4,32	8,96	4,64	Live
Average Difference			13,31%	

From Table 5. shows that the test results of the two pH sensors designed are able to correct data values if some are not linear or have a difference in values of more than 1.0. The test is carried out using various types of aqueous solutions that are arranged in composition so that the pH sensor test tool gets the maximum value, so as to reduce the error value in data reading or the difference in the difference in data values from the two pH sensors used.

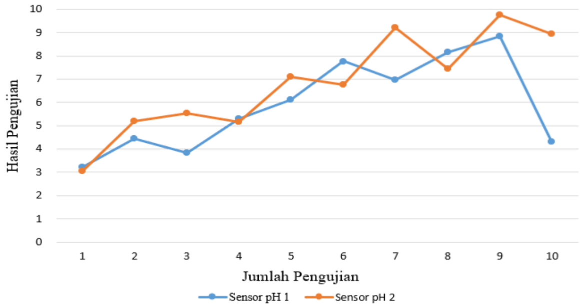

Figure 9. pH Sensor Type Simulation Test Graph

After successfully testing the ability of the design tool to correct the deviation of data readings from the two pH sensors, then conducting equation testing with a pH measuring instrument using 10 different pH splinters of water. Before testing on a pH sensor with a pH meter, the results of data readings from the two pH sensors will first be calculated to get the average value. The data of the two pH sensors were averaged using the Arduino IDE programming language as follows "mean_PH=(phValue1+phValue2)/2; ". After successfully averaged, the test is carried out with measuring instruments which can be seen through Table 6. which shows the error rate in the reading of the pH sensor with a pH meter measuring instrument.

Table 6. Testing equations with pH meters

Number of Tests	pH Meter	Average pH Sensor	*Error*%	LED Lights
1	3,1	3,12	0,64%	Die
2	4,7	4,75	1,06%	Die
3	5,5	5,32	3,27%	Die
4	6,7	6,64	0,89%	Die
5	6,9	7,11	3,04%	Die
6	7,2	7,21	0,13%	Die
7	8,3	8,14	1,92%	Die
8	9,5	9,36	1,47%	Die
9	9,8	9,93	1,32%	Die
10	10,1	9,77	3,26%	Die
Average *error*			1,70%	

From Table 6. it was found that the sensor alignment rate of 1.70% until the accuracy level calculation was carried out using the calculation of 100% - 1.70% = 98.3% is the level of accuracy of the pH sensor that has been obtained. In Figure 10. is a graph of the test results from Table 6. on pH meters and average pH sensors.

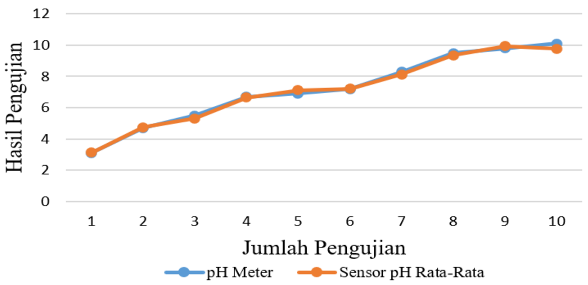

Figure 10. Graph of Average pH Sensor And pH Meter Drawing Results

Thus it can be concluded that the pH sensor can work very well which is able to correct tool errors if the sensor readings have a difference of more than the value of 1.0. In the test results on the pH sensor and pH meter, it can be seen that the pH sensor has a very good value in reading acidity and base in a solution. This is in line with the success of the tool built by Muhtar and Huda where the system can monitor and be controlled remotely for pH measurement of hydroponic nutrient solutions based on Fuzzy Logic. The system can measure pH 5 - 7 with a characteristic delay of 240 seconds, an up time of 429 seconds, a steady state of 452 seconds and an overshoot of 1.4%. Controlling pH dropped from 9 to 7 ppm with characteristics of delay time of 239 seconds, time up 459 seconds, steady state 479seconds and overshoot 1.4%[9].

3.1.2. Water Level Sensor Testing

The test is carried out in two stages where in the first stage is a non-linear simulation in the readings of the two sensors with the aim of being able to correct errors if there is an intersection of data readings from the two water level sensors with a difference in values greater than or equal to 1 cm, if there is a reading from one of the sensors with a difference in values greater than or equal to 1 cm, the LED light will light up to confirm an error in the sensor readings water level.

Table 7. Simulation Test Results on Water Level Sensors

Number of Tests.	Water level sensor 1 (cm)	Water level sensor 2 (cm)	Difference difference	LED Lights
1.	4	4	0	Die
2.	5	5	0	Die
3.	6	4	2	Live
4.	5	4	1	Live
5.	5	5	0	Die
6.	6	7	1	Live
7.	7	4	3	Live
8.	9	7	2	Live
9.	8	8	0	Die
10.	4	8	4	Live
Average Difference			1,3%	

With the test results in the table above, it can be seen that the design of the tool is able to correct errors in data readings on the water level sensor if there is a difference in the difference in values of more than or equal to 1 centimeter. To be able to make it easier to understand from the test results the tool's ability to correct errors in the reading of values on the water level sensor, it can be seen through Figure 11. is a graph of the results of non-linear simulation tests on the HC-SR04 sensor type or water level sensor.

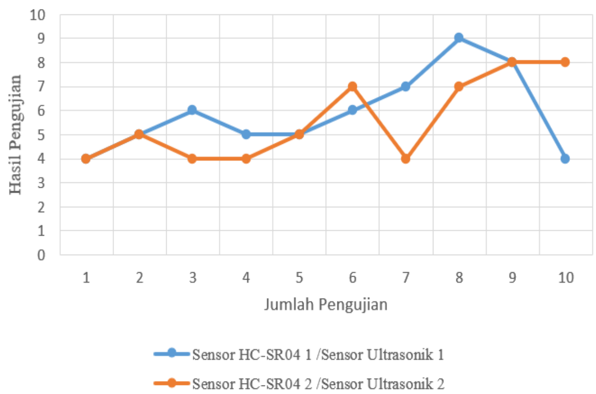

Figure 11. HC-SR04 Sensor Type Simulation Test Graph

In the second stage, the test was carried out on the HC-SR04 sensor with a measuring device with the aim of being able to find out the reading error on the water level sensor with a distance of 13 to 4 cm. The distance range used to measure the distance of the water level sensor is measured using a ruler crossbar measuring instrument with an accuracy level of 1 (one) millimeter. The test value used on the water level sensor is the result of calculating the value that has been averaged using the Arduino IDE programming language as follows "mean_ketinggianair = (altitudeValue1+ altitudeairValue2)/2; ".

After successfully obtaining the average data values from the two water level sensors using a predetermined formula, the test data is obtained as shown in table 8. which is the result of testing the water level sensor and ruler crossbar in the error reading of the distance value.

Table 8. Testing of Water Level Sensors and Ruler Stars

Number of Tests	Crossbar Panggaris	Average water level sensor	*Error*%	LED Lights
1	13.1 cm	13 cm	0,76%	Die
2	12.4 cm	12 cm	3,23%	Die
3	11.5 cm	11 cm	4,35%	Die
4	10.1 cm	10 cm	0,99%	Die
5	9.3 cm	9 cm	3,23%	Die
6	8.2 cm	8 cm	2,44%	Die
7	7.1 cm	7cm	1,41%	Die
8	6.3 cm	6 cm	4,76%	Die
9	5.2 cm	5 cm	3,85%	Die
10	4.1 cm	4 cm	2,44%	Die
Average *Error*			2,74%	

The results of the water level sensor distance reading were obtained by the difference in readings on the ruler crossbar with an average reading error of 2.74%. The water level sensor readings are rounded up so that the distance displayed is an integer. While the distance measured using the ruler crossbar is obtained decimal number because the accuracy level of the ruler is 1 millimeter. In figure 12. is a graph of the test results from table 8. on the water level sensor and ruler crossbar.

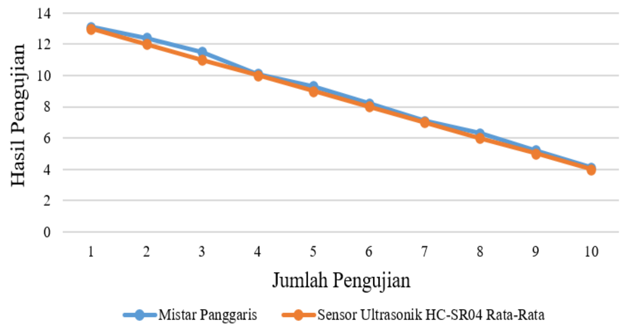

Figure 12. Graph of Test Results on HC-SR04 Sensor and Ruler Crossbar

3.2. Overall Tool Test Results

Overall testing is carried out to show that the tool that has been designed can run without interruption and in accordance with its function. The test was carried out within a period of 5 days for 3 hours, where each day was divided into 3 time periods. Period 1 is determined at 16.25-18.25, then period 2 at 06.30-10.00 and finally period 3 at 12.30-15.30. then the value of each test sensor data is taken at the first 1 hour in each period such as in period 1 at 16.25, period 2 at 06.30, and period 3 at 12.30 WIB. In table 9. is the result of observations in a predetermined period.

Table 9. Overall Tool Observation Results

pH measurement		Water level measurement		Relay Conditions		
Sensor pH	pH Meter	Sensor (cm)	Metre (cm)	pH *Up*	pH *Down*	Water Pump
4,80	4,7	6	6,2	Live	Die	Die
7,50	7,1	8	8,3	Die	Live	Die
6,72	6,5	7	7,4	Die	Die	Die
6,51	6,3	6	6,1	Die	Die	Die

pH measurement		**Water level measurement**		**Relay Conditions**		
Sensor pH	**pH Meter**	**Sensor (cm)**	**Metre (cm)**	**pH *Up***	**pH *Down***	**Water Pump**
6,45	6,2	6	6,2	Die	Die	Die
6,39	6,2	5	5,4	Die	Die	Die
6,69	6,6	3	3,8	Die	Die	Live
7,59	7,6	7	7,3	Die	Live	Die
6,61	6,8	6	6,1	Die	Die	Die
5,83	5,3	3	3,5	Live	Die	Live
8,15	8,1	7	7,4	Die	Live	Die
6,67	6,5	5	5,7	Die	Die	Die
3,42	3,4	4	4,2	Live	Die	Die
6,98	7,1	2	2,5	Die	Die	Live
7,41	7,3	7	7,3	Die	Die	Die
6,44 %		5,64 %		Average Error%		

After the results of observations that have been made, the error value in the sensor readings was obtained with an average value of 6.44 + 5.64 = 12.08%. So to find out the accuracy level of the sensor is 100 – 12.08 = 87.92% so that the hardware tools that have been designed can work very well. In figure 13. is a graph of the overall test results of the tool.

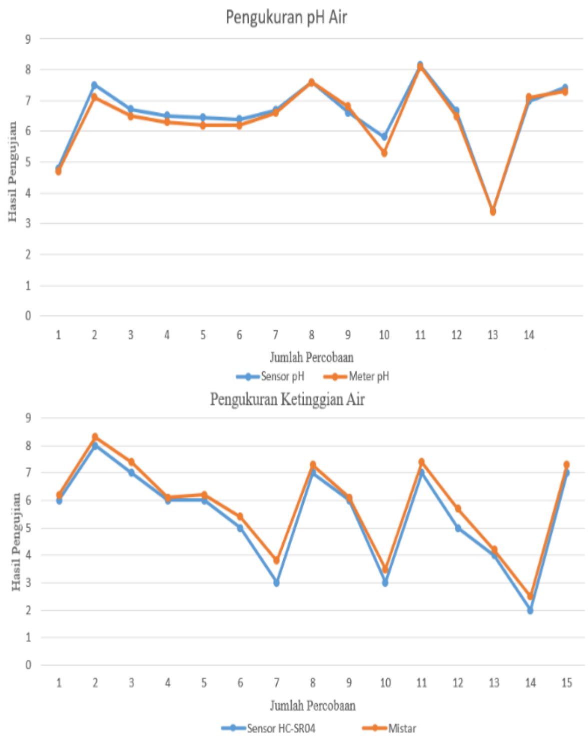

Figure 13. Graph of Overall Tool Test Results

Meanwhile, the test that will be carried out using software that has been designed is to show the test results automatically in the form of graphs displayed on the local host website and display part of the report creation on the design website. Testing that can be done on a MySQL database by creating a data report when the entire tool that has been designed is working automatically. The test is carried out when the condition of the computer as monitor is connected by WIFI as a server and then connected to a hardware device that has been designed, can be seen in figure 14. is the result of software testing.

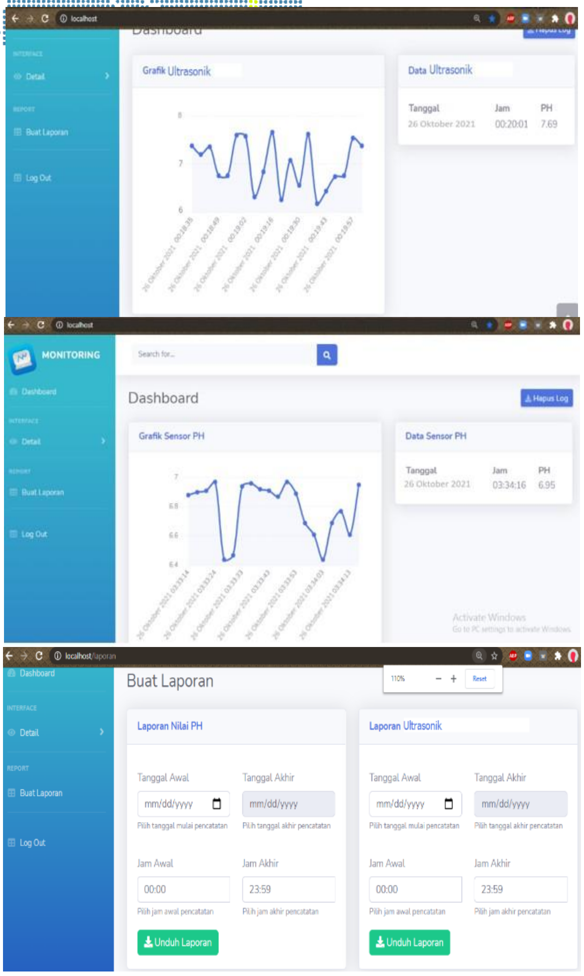

Figure 14. Software Test Results

With the results that have been obtained, the overall design of the hardware and software tools can work quite well as desired in the research.

4. Conclusion

The conclusion that can be drawn from this study is that the overall technical design of the tool and the performance of the tool can work automatically in controlling acidity and wet conditions in water conditions. In the designed data processing process, it can work well enough so that it can reduce data errors and can provide fairly stable output results when testing design tools with predetermined measuring instruments. Monitoring using a local host website cannot be determined in real-time transmission response time, because there is still dependence on public telecommunications network managers (providers). From the results of tests conducted when the WIFI conditions used had problems, ESP32 as the sending server could not connect or had to restart until the WIFI condition returned to normal.

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