Jurnal Elektronika dan Telekomunikasi (JET), Vol. 24, No. 1, August 2024, pp. 31-37
Accredited by RISTEKDIKTI, Decree No: **158/E/KPT/2021**
doi: 10.55981/jet.585

Nutrition, pH, Temperature, and Humidity Monitoring Hydroponics System based on Android

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Abstract

Agriculture plays a crucial role in the lives of Indonesian people. Technological advances and the increasing limitation of agricultural land have changed the patterns of matching crops in societies. Innovations have been implemented, including using technology such as hydroponic systems. Temperature and humidity are two of main factors influencing the success of hydroponic methods. The research aims to design and develop an autoLowc control system that uses Fuzzy Logic to regulate the temperature and moisture of hydroponic plants, and to design the control of the nutrition and pH supply of hydrogen plants. Hydroponics plant control systems are implemented using microcontrollers and DHT22, TDS sensors, and pH sensors. In addition, an Android-based interface has been developed to monitor and control the system remotely via an internet connection. In this study, the accuracy of the TDS sensor is 96.5%, the pH sensor was 98.19%, and the precision of the Fuzzy logic system at temperature and humidity is 100%.

Keywords: hydroponic system, NodeMCU ESP32, fuzzy Logic

I. INTRODUCTION

The combination of sensors in the Internet of Things (IoT) has produced significant trans-sensors in various aspects of human life in making work efficient. In the industrial sector, this transformation is often called the Industrial Revolution 4.0[1-3]. This collaboration has simplified work, increased efficiency in the industrial world, thereby increasing productivity [4-5]. The field of hydroponic cultivation is an example of a field that can benefit from collaboration between sensor technologies. Some have implemented simple timer-based sensor technology. Apart from that, it also develops intelligent and precise agricultural systems by utilizing collaboration between sensor technology in IoT [8-11].

There are still many research and development opportunities to improve the quality of hydroponic cultivation. Hydroponic plant cultivation without using soil media and prioritizing the provision of nutrients needed by plants [12-[13]. Hydroponic farming methods can optimize water use more efficiently than cultivation using soil. Therefore, this method is suitable for areas that have limited land and water supplies [14]. Nutrient Film Technique (NFT) is one of the most famous and popular hydroponic cultivation systems. The NFT hydroponic method offers several advantages such as easier maintenance, higher plant growth, more efficient fertilizer utilization, and less waste production. However, this method also has several disadvantages, including dependence on electricity supply, higher potential for disease spread, and higher initial costs associated with system installation [17]. Research [18] developed a nutritional control system for NFT hydroponic cultivation by applying the PID method [19] [20]. They entered the pH level data into the control system and controlled the air level with the ON/LOW method, as in previous research [21]. On the other hand, research [22] designed an NFT Hydroponic nutrient control system which also used the PID method. This system utilizes inputs that include water level and electrical conductivity [23] of the nutrient solution. Research [24] developed a nutritional control system for NFT-based hydroponic cultivation using the multiple linear regression method. This system automates the pH levels of hydroponic nutrients.

On the other hand, the study [25] designed a nutrient control system for cultivating celandine in the NFT hydroponic system using predictive values obtained through the DNN (Deep Neural Network) algorithm. The study [26-27] used 4000 nutrition control data as input for a DNN algorithm. Furthermore, the research [28] developed a nutrient control system in the hydrophone cultivation NFT based on demand predictions using the KNN algorithm [29] [30] [31]. The input variables include pH, TDS (Total Dissolved Solids), electrical conductivity, and temperature. The prediction results of this system include the ON/LOW state of the pH and the nutrient pump. The research described here [32] is a previous study that applied fuzzy methods to control nutrients in hydroponic cultivation. In this study, they performed Electrical Conductivity Control (EC) [33] [34] in hydroponic

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Received: September 26, 2023 ; Revised: March 8, 2024
Accepted: March 26, 2024 ; Published: August 31, 2024

nutrient solutions by considering the volume and EC error against a particular set point using a fuzzy controller. The result of this study is the active duration of the nutrient pump, which is controlled based on the fuzzy setting to the specified conditions. The study [35] conducted a control simulation on smart greenhouses using a fuzzy logic controller. The output of this control focused on the control of moisture in a greenhouse. Meanwhile, the study [36] controlled the electrical conductivity and pH levels in a hydroponic system using a logic method of fuzzy. This control result combined three output conditions (ON/LOW) with a fixed duration, which are used to maintain nutrient conditions in hydrophone cultivation.

Success in cultivating plants depends heavily on temperature, humidity, pH, and nutrition. With the advancement of technology, Android-based smartphone devices no longer function only as a means of communication via telephone or SMS. Nowadays, they have evolved into a control tool that can regulate nutrition, acidity (pH), temperature, and humidity in various applications, including in crop cultivation [38]. One implementation of the smart hydroponics system is remote control via smartphones using an Android system connected to the internet, as well as an application that can control and monitor crops' growth and productivity. These four aspects, namely nutrition, acidity (pH), temperature, and humidity, are crucial in determining the success of crop cultivation.

In this research, an automatic system has been created to regulate nutrition, control pH levels, and regulate temperature and humidity using the Mamdani Fuzzy Logic method. This method is used to improve the efficiency and accuracy of plant growth environment control [39]. The ideal nutrition for hydroponic cultivation ranges from 1050 to 1200 ppm. (parts per million). The optimal temperature for hydroponic cultivation ranges from 24 ºC to 32 ºC, while the ideal humidity is between 40% and 60%. Sustainable control is the key to success in hydroponic cultivation. However, traditional controls can cause problems and difficulties for farmers as they require constant monitoring. Developing technologies that can carry out sustainable controls in hydroponic cultivation and facilitate crop management is necessary[40].

II. HYDROPONIC MONITORING SYSTEM

According to reference [41], the Internet of Things (IoT) is a concept that can help humans manage devices remotely by utilizing information from sensors and microcontrollers. The main goal of IoT is to simplify daily activities, including in the context of hydroponic cultivation.

A. TDS Sensor

TDS sensor are sensors that function for measuring nutritional values in plants. This sensor is used to determine the Electrical Conductivity (EC) scale of a nutrient solution. The ppm value is calculated from the EC solution. The EC is the electrical transmitter present in a liquid, it obtained from the measurement of the resistance between two probes (pin plug), when the plug is immersed in the liquid [42].

B. pH Sensor

A pH sensor is a sensor used to determine the degree of acidity. A pH meter is a device used to measure the acidity or acidity of a solution. The main principle of the pH meter's operation is to be located on a glass electrode sensor, which is measures the amount of H30+ ions in a solution [43]. In its use, the pH sensor needs to be calibrated periodically so that its accuracy can be awakened. Some manufacturers of pH sensors generally include instruments to perform manual calibration. The calibration results are then stored in the EEPROM so that they can be used for normal measurements.

C. Node MCU ESP32

Two main elements, namely hardware and software, were used in the research on the design monitoring of this IoT-based hydroponic system. This basic concept becomes the guideline for designing something, where the concept itself contains steps and clues that underpin the design. These inserts are sensors used to monitor indoor air quality. This sensor is connected to the ESP32 microcontroller using a jumper cable. After the ESP32 microcontrollers read the input data from the sensor, the data is sent to the IoT server/platform via the WiFi ESP32 module for processing. Then, the received data is displayed on the platform page so that the user can view the data [44].

D. Dimmer Module

The Dimmer module is a tool for regulating the voltage intensity. This module works by adjusting the electrical voltage that enters the lamp so that the intensity of the light generated can be adjusted according to the needs. The dimmer module can be used on a variety of types of lamps, such as flashlights, neon lights, and LED lights. The dimmer modules can be controlled manually or using an automatic control system such as Fuzzy Logic [45].

E. Fuzzy Logic Mamdani

Fuzzy Logic is a decision-making approach rooted in the principles of fuzzy logic itself. This technique facilitates modeling and solving problems with elements of uncertainty and complexity by introducing of the concept of partial membership in the assembly. Regarding temperature and humidity, Fuzzy Logic is useful for describing the relationship between the two and making decisions based on less accurate or ambiguous data. Fuzzy Logic overcomes doubts about these variables and frames them in linguistic form. In this study, the Fuzzy Logic Mamdani method was used. Fuzzy Mamdani is one of the most popular and simple types of fuzzy systems. This approach receives input in the form of a variable with a fuzzy value and produces output in a Fuzzy set with a clear and defined linguistic interpretation [46]. Fuzzy Logic has assemblies, variables, Fuzzy sets, and membership functions. A membership function is a curve showing the mapping of data input points into membership values with intervals between 0 and 1. One of the functions of the Fuzzy Logic pass system is the Representation of the Shoulder Curve. The shoulder curve is a combination of three curves; the first curve lies in the middle of a variable represented in the form of a triangular curve, and then on the right and left sides, there are linear up and down curves. The left arm moves from right to wrong, and the right shoulders move from wrong to right.

F. DHT22 Sensor

The DHT22 sensor uses a capacitor and a thermistor to measure the air around it and output the signal on the data pin. DHT22 claims to have good reading quality, as judged by its quick data acquisition process response and minimalist size, as well as its relatively low price compared to a thermohygrometer [48].

G. Android

In this era, the development of Android-based mobile applications has made significant progress, especially in the context of applications related to IoT data recording. System applications associated with IoT data recording are important in system monitoring management. Using a computer-based system will save time, reduce the effort required, and provide accuracy in data presentation. Moreover, when enriched with a database system as a means of storing data [49].

H. Firebase

Firebase is an Application Programming Interface (API) designed by Google for building mobile and web applications. Apart from that, Firebase also has the ability to build and access real-time databases, where these databases are stored in JSON file format [50].

III. RESULT AND ANALYSIS

A. Circuit Schematic

This time, the author used ESP32 as a microcontroller in the study, as shown in the system scheme in Figure 1. Figure 1 shows a design scheme of the tool to be used in this investigation. In the study of the Smart Hydroponics of this system, the authors used the ESP32 microcontroller, as well as sensors such as TDS, pH, and DHT22 as Input, pumps as outputs for nutrition and pH, and the blower and light as outputs on the temperature and humidity controllers that can be seen.

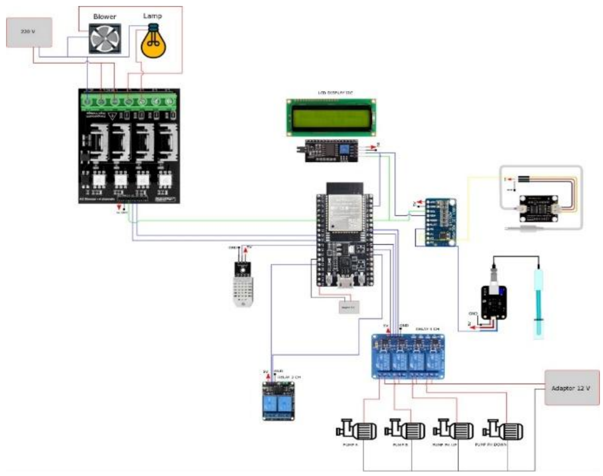

Figure 1. Circuit Schematic.

B. Fuzzy Logic

In the Fuzzy Logic system, the author uses the Mamdani method. In this study, a set of fuzzy variables and fuzzy sets can be seen in Table 1. There is a Fuzzy talk universe, which in this study uses two variables: temperature and humidity. In this study, the author uses triangular function values so that each assembly has 3 Fuzzy sets. After getting a fuzzy set on the temperature and moisture variables, the next step is to make a rule of the temperature control system and humidity, as seen in Table 2. Table 2 explains a Fuzzy Logic Rule, which in this study uses 9 Rules with 3 Temperature and 3 Humidity Assemblies.

B. Flowchart

The flowchart of how the system works in the research at this time can be seen in Figure 2. In Figure 2, there is a flowchart of the nutrition and pH system, which is divided into two ways of working: manual and automatic. The following flowchart of the temperature and humidity control system using Fuzzy Logic can be seen in Figure 3. Figure 3 shows the workflow of the temperature and humidity control system using fuzzy logic. In the workflow system, temperature and humidity have three fuzzy variables: "Cold, Normal, and Hot" for temperature and "Dry, Normal, and Wet" for humidity.

TABEL 1
FUZZY TALK UNIVERSE

Variable	Assembly	Fuzzy Set	Units
Temperature	Cold	0, 12.5, 25	C
	Normal	24, 26.5, 28	
	Hot	28, 40, 50	
Humidity	Dry	0, 32.5, 6	%
	Normal	65, 71.5, 78	
	Wet	78, 89, 100	
Blower	Low	0	%
	Medium	50	
	High	100	
Lamp	Low	[0]	%
	Medium	[50]	
	High	[100]	

TABEL 2
FUZZY RULE

Ru-le	if	Tempe-rature	&	Humi-dity	then	Blower	Lamp
R1		Cold		Dry		Low	High
R2		Cold		Normal		Low	Medium
R3		Cold		Wet		High	High
R4		Normal		Dry		Medium	Low
R5		Normal		Normal		Low	Medium
R6		Normal		Wet		Medium	High
R7		Hot		Dry		High	Low
R8		Hot		Normal		High	Low
R9		Hot		Normal		High	High

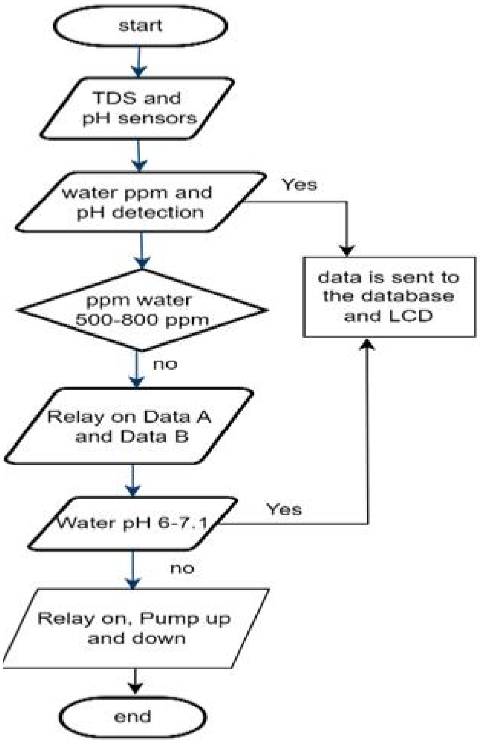

Figure 2. pH and Nutrition Flowchart

Figure 2, shows a flowchart of the nutrition and pH system, which is divided into two working modes: manual and automatic. The following Flowchart of the temperature and humidity control system using Fuzzy Logic can be seen in Figure 3.

Figure 3 shows the temperature and humidity control system workflow using fuzzy logic. In the workflow system above, temperature and humidity have three fuzzy variables: "Cold, Normal, and Hot" for temperature and "Dry, Normal, and Wet" for humidity.

C. Implementation

In this implementation, the entire system is combined in a panel box (Figure 4), and monitored with an Android application.

Figure 4, we can see a set of implemented tools, with the brain of this system being ESP 32. TDS sensors and pH sensors, as inputs for ppm and pH values, are united on the ADS1115 module. The relay functions as ON/OFF for the feeding pump and pH automatically or manually. The DHT22 sensor, as the input for temperature and humidity, is then used as the output of the flow supply to the Blower and Lamp.

In Figure 5, the Android app displayed a Nutrition and pH graph per hour, a monitoring display on temperature and humidity and a control on Nutrition and pH.

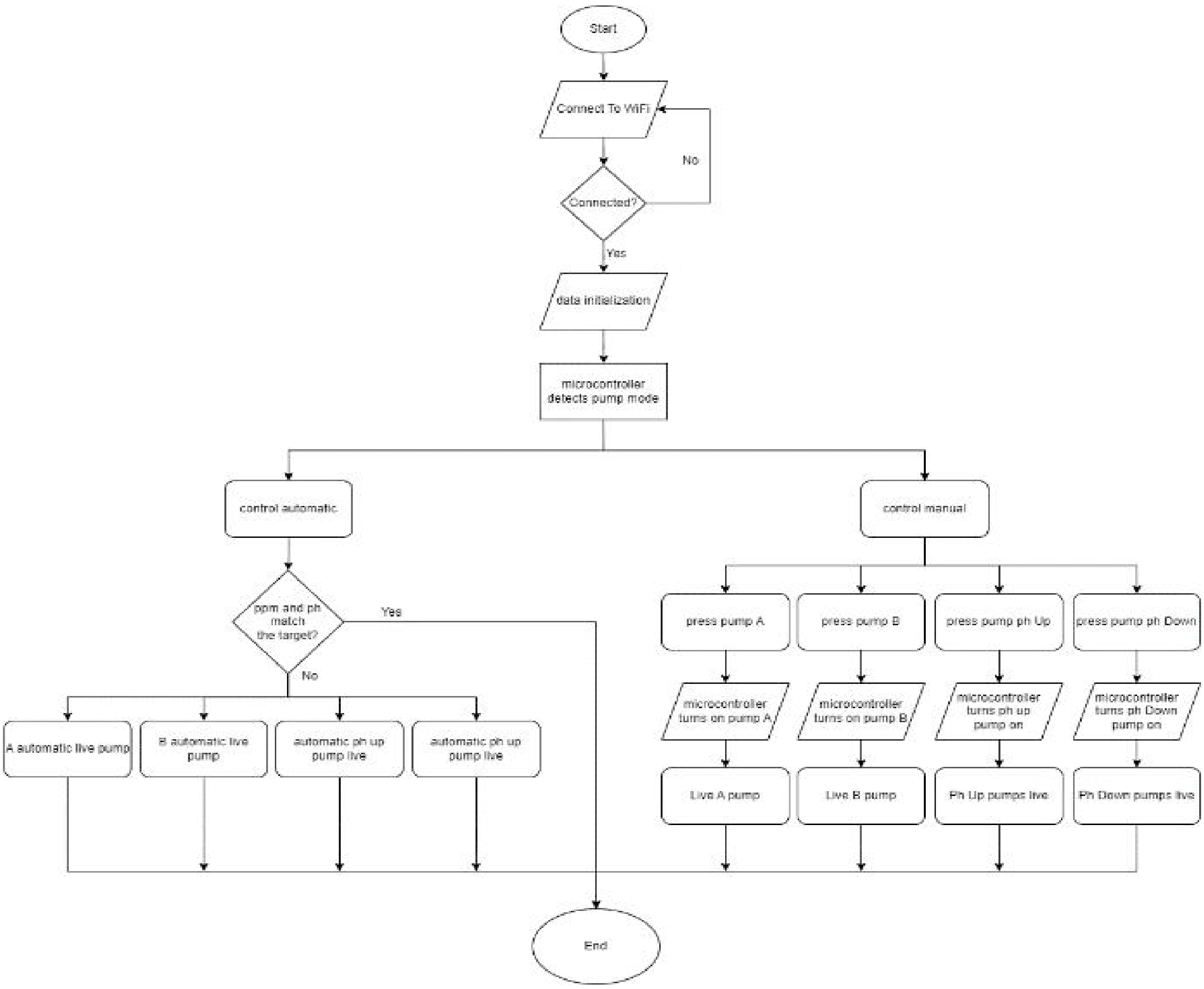

Figure 3. Hydroponic Monitoring System Flowchart

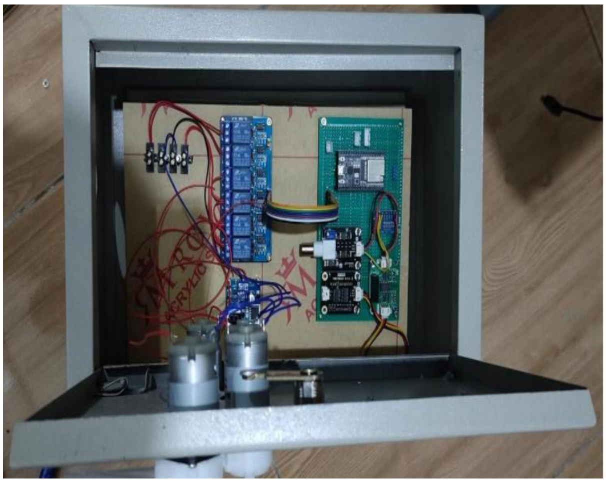

Figure 4. System Implementation

Figure 5. Graphical data for TDS and pH

D. Test Results

This test is performed to measure the hardware and software performance in this system. The authors attach the test to the accuracy of the TDS sensor in Table 3.As we can see in Table 3, where the values of TDS sensor and TDS meter differences were obtained during the experiment 10 times; with the calculations performed, the value of the differences was divided by the largest ppm value, and all errors were added, then summed and divided over the entire experiment. And on TDS sensors can read nutrients up to 1300ppm average. To measure errors of the sensor can use the MAPE formula:

$$MAPE = \sum_{n} (\frac{|actaul-forecast|}{actual} * 100 \quad (1)$$

where n is number of input samples, a sensor error on of 3.35% can be said to indicate that the plant's nutritious system is running well. The test of the pH sensor that can be seen in Table 4.

TABEL 3
TDS SENSOR TESTING

No	Tds Sensor	Tds Meter	Discre-pancy	Presentation
1	57 ppm	57 ppm	0	0 %
2	1277 ppm	1281 ppm	4	0,31%
3	435 ppm	920 ppm	3	0,68%
4	965 ppm	958 ppm	7	0,73%
5	321 ppm	497 ppm	1	0,3%
6	272 ppm	543 ppm	0,1	0,03%
7	303 ppm	630 ppm	1	0,3%
9	1277 ppm	1281 ppm	4	0,31%
10	347 ppm	795 ppm	0,3	0,09%
Total				3.35%

TABEL 4
PH SENSOR TESTING

No	Analog Sensor PH	PH Digital	Discrepancy	Presentation
1	5.4	5.4	0	0%
2	5.5	5.5	0	0%
3	5.6	5.5	0.1	1.81%
4	5.7	5.7	0	0%
5	5.9	5.9	0	0%
6	6.0	6.0	0	0%
7	6.1	6.1	0	0%
8	6.2	6.2	0	0%
9	5.9	5.9	0	0%
Total				1.81%

It can be seen in table 4, where the values of the pH sensor and the pH meter differential values obtained during the experiment 10 times, with the calculations performed the difference values divided by the largest ppm values, then all the errors are added then summed and divided over the entire experiment. And on the pH sensor to measure the error of the sensor can use the MAPE formula. Error on the sensor is 1.81% can be said the pH system on the plant is running well.

Next is the Fuzzy Logic test, this test sees whether the fuzzy logic can run well under conditions of variable temperature and humidity can be seen in table 5. In Table 5, there are tests on fuzzy logic systems already running smoothly under variable temperature and humidity conditions, such as in the case above. When the temperature is 33°C (heat) and the humidity is 76.2 (normal), the output for the Blower and the pump is 100% and the Light is 0%. Then, all the blower and light tests are done using the fuzzy logic rule, which has an accuracy of 100%. The data accurateness and delay testing on the Android app in real time can be seen in Table 6.

TABEL 5
FUZZY LOGIC TESTING

No	Temperature (°C)	Humidity (%)	Output Blower (%)	Output Lamp (%)
1	29	91.4	100	100.
2	31.5	84.9	100	100
3	31.8	80.2	100	100
4	32.8	76.7	100	0
5	33.2	73.4	100	0
6	33	76.2	100	0
7	26.5	100	50	100
8	26.4	100	50	100
9	26.4	100	50	100

TABEL 6
DELAY TEST ON ANDROID APPS

No	Real-time test scenario		Delay
	Application	Monitor	
1	780 ppm	780 ppm	0
	6.2 pH	6.2 pH	0
	81 %	81 %	0
	30 °C	30 °C	0
	12 cm	12 cm	0
2	792 ppm	792ppm	0
	6.4 pH	6.4 pH	0
	79.0 %	79%	0
	29 °C	29 °C	0
	13 cm	13 cm	0
3	809 ppm	809ppm	0
	6.6 pH	6.6 pH	0
	78.0 %	78%	0
	30 °C	30 °C	0
	13 cm	13 cm	0
4	800 ppm	800ppm	0
	6.8 pH	6.8 pH	0
	75 %	77%	0
	30 °C	30 °C	0
	800 ppm	800ppm	0
5	820 ppm	816ppm	1 Minute
	7.0 pH	7.2 pH	1 Minute
	80 %	79%	1 Minute
	28 °C	29 °C	1 Minute
	820 ppm	816ppm	1 Minute

Table 5 is a real-time data test of data displayed on the monitor layer in the panel with data in the application; this test uses six smartphones at different times. In the fifth tes, there was a one-minute delay in the data from the application to the data on the screen due to a delay in the application's data update with the system caused by a poor smartphone network.

IV. CONCLUSION

The Smart Hydroponics system was designed to make it easier for hydroponic managers to avoid having to check the hydroponic lab directly regularly. The smart hydroponic system has three sensors, namely TDS, pH, and DHT22 sensors, as input and argillic pump, blower, lamp, andNozzle pump as output. In this study, the accuracy of the TDS sensor is 96.5%, the pH sensor was 98.19%, the precision of the Fuzzy logic system at temperature and humidity is 100%, and the accurate delay on the application has a delay of only 1 minute where the whole system has been running very well.

This study suggests adding a Scheduling Feature that covers the time range from early planting to crop harvesting in a hydroponic system and implementation in larger spaces and diverse environments to measure performance and reliability further.

Conflict of Interest

The authors have declared that no competing interests exist.

CRediT Authorship Contribution

Muda Wali Samudra Pasai, Mustofa, Royhan: Methodology, Software, Validation, Investigation, Data Curation, Writing-Original Draft; Prihatin Oktivasari: Conceptualization, Methodology, Formal Analysis, Resources, Writing-Review & Editing, Supervision and Funding Acquisition; Asep Kurniawan: Methodology, Sofware, Data Curation, Project Administration.

Funding

Research reported in this publication was supported by Politeknik Negeri Jakarta and Embedded System Laboratory.

Acknowledgment

This work was supported by Politeknik Negeri Jakarta on hydroponic laboratory facilities.

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