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Control and Monitoring System of Hydroponic Nutrients in Different Hydroponic Racks Based on IoT in Cibodas Village Lembang District

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***Abstract*— Hydroponics is a method of growing plants without soil, utilizing water to meet their nutritional needs. Nutrients and pH levels must be carefully managed externally, requiring special attention for each plant. In Cibodas village, farmers face challenges with daily manual control of nutrients and pH, especially as each hydroponic rack contains different types of plants, necessitating more attention. Previous research on nutrient control with IoT-based closed-loop methods focused on a single plant type per rack. This study broadens the scope by implementing IoT-based control and monitoring systems for various plants in different hydroponic racks. The system uses components like ESP32, a pH sensor (4502C), a TDS sensor (V1.0), relays, and peristaltic pumps, all within a closed-loop control framework. The interface employs an I2C LCD and a Kodular mobile application that connects to Firebase via the internet, enabling remote monitoring and control. Testing revealed high sensor accuracy: 99.16% for the pH sensor and 98.98% for the TDS sensor in one rack, and 98.91% for pH and 99.01% for TDS in another rack. This system successfully manages nutrient levels both manually and automatically across different hydroponic racks, even at a maximum tested distance of 62 km.**

***Index Terms*— Hydroponic, Cibodas, Internet of Things, mobile application, sensor, close loop, nutrient.**

I. INTRODUCTION

The growing world population will cause an increase in food needs. Food needs must be maintained in accordance with the world's sustainable development goals, or SDGs (Sustainable Development Goals) number two, namely "zero hunger," which means leaders in each country must maintain food security by innovating in utilizing agricultural land [1]. The area of agricultural land in Indonesia is decreasing due to the shifting function of agricultural land into urban areas, housing, industrial facilities, and other purposes. West Java is one of the regions that produces the highest horticultural crops in Indonesia [2]. Cibodas Village, Lembang Subdistrict, is a horticultural crop-producing area that applies organic and conventional crop cultivation, but several places in Cibodas Village have converted agricultural land into tourism land and turned their land into lodging or homestays because it is considered more profitable. This has caused agricultural land to narrow [2]. Therefore, it is necessary to make innovations to increase agricultural production in a sustainable manner. Hydroponics is an innovative method of cultivating plants without using soil and utilizing water by prioritizing the nutritional needs of plants [3]. The hydroponic method is an effective agricultural option in areas with limited land area. In general, hydroponic practices prioritize the use of water media, where aspects such as water supply, plant nutrients, oxygen levels, and pH levels are important factors that must be considered [4]. The content of hydroponic nutrients such as macro elements and micro elements must be given every day at the appropriate dose because it will affect plant growth [5], [6]. The problem of conventional farmers in Lembang Village in utilizing hydroponic plant cultivation technology is that controlling the concentration value of plant nutrients and pH levels is done manually and every day; therefore, each hydroponic rack that has different types of plants must be given more attention. Therefore, to support the productivity of farmers, the right technological innovation is needed—a tool to help farmers in the process of controlling the pH level and hydroponic nutrient levels on each different hydroponic rack with different types of plants in one hydroponic planting cycle. The Internet of Things is a technology to communicate data between interfaces (smartphones and laptops) and machines (automatic hydroponic media) so that farmers can monitor hydroponic plants remotely [7].

Previous research that has been published in journals was cited. The information that has been cited includes: According to [8], the research produced a close-loop control system for a wick hydroponic system. However, plant growth does not look optimal and may not be applicable to different types of plants. According to [9], the research produced a close-loop control system for NFT hydroponic systems that was able to calculate the water flow needed by plants. However, the only parameter for plants is pH, so the solubility value of nutrients cannot be controlled. According to [10], the study used the Multiple Linear Regression Method on hydroponic plants using the NFT method, producing a method for controlling pH. However, the results of the plants were not explained, and the sensor accuracy value was still small at 89.73%. According to [11], the research uses the fuzzy logic Mamdani method with the Wick method hydroponic system to produce plants that can grow optimally. However, it does not include sensor accuracy and success rate in fuzzy logic mamdani. According to [12], the study used the fuzzy logic method with the NFT hydroponic system to produce pakcoy plants that were not good enough. However, the error value of the EC sensor is 8.97%, and it only uses one type of plant in one planting cycle. Research in the form of developing a control system and monitoring hydroponic nutrition and pH levels automatically on each different hydroponic rack with different types of plants each cycle using microcontrollers with the Close-Loop method in the NFT hydroponic method needs to be implemented in order to increase farmer productivity and solve agricultural problems.

II. METHODS

The method to solve the problem in this study uses the VDI2206 method. This method is considered appropriate in solving problems in the automation of hydroponic cultivation with different plant species, different hydroponic nutrient levels, different pH levels in the same planting cycle.

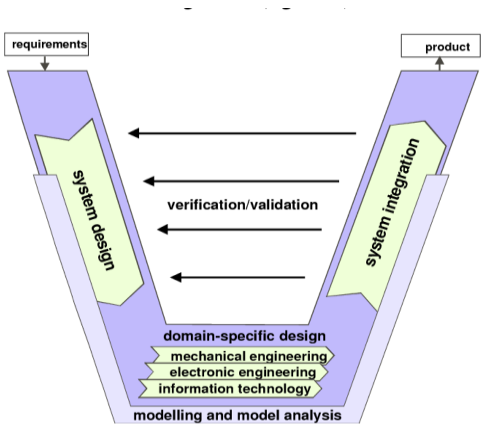

Fig. 1. VDI Model

The VDI 2206 model is used in the mechatronics-based design framework. The stages that will be carried out include:

A. Requirements

The problem-solving stages are designed within the parameters of the requirements, as in the following table:

TABLE I. REQUIREMENT PRODUCT

Domain	requirements
Mechanical System	Hydroponic media for planting process, sensor sensing and data communication.
Electrical System	One microcontroller controls two different hydroponic media with different parameters in the same growing cycle.
Informatics System	Create manual and automatic programs for hydroponic media control and monitoring.
Control System	Closed loop control

B. System Design

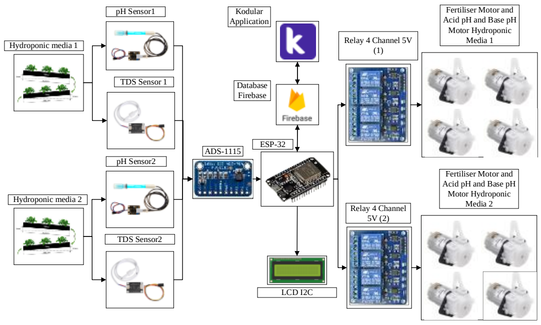

Fig. 2. System Design

The system overview generally explains the description of the pH and TDS control systems in hydroponic nutrition. The manufacture of this tool consists of a controller in the form of an ESP32 microcontroller as a data processor and data communication via wifi internet, input in the form of two TDS sensors for measuring water solubility with ppm units and two pH sensors for measuring the acid-base level of a solution, and output in the form of a peristaltic pump as an actuator to activate liquid pH up, pH down, and nutrients. On the peristaltic pump, an electric switch is added as a safety measure in the form of a relay. LCD I2C serves as a monitor of sensor value data. The way the system works starts with input data from the sensor value that enters the microcontroller, which is processed by the microcontroller. The data is then sent serially to the serial monitor, and the data is sent to the to the IoT via Firebase. Furthermore, the microcontroller will update the sending data according to the response from the sensor. Then, the microcontroller will respond to data changes. If the TDS level has not reached the target, the nutrient pump will be activated. Likewise with pH, if the pH is less than the target, the pH enhancer solution pump will be active. If the pH exceeds the target, the pH-lowering solution pump will be active. In addition, the data on the pH and TDS sensors is not only displayed on the Kodular interface but also on the I2C LCD on the panel.

C. Domain Specific Design

There are four domains designed in this research, including the mechanical domain, the electrical domain, the informatics domain, and the following domain-specific design details:

TABLE II. SYSTEMS DEMAND

Device	Demands
ESP32 30 Pin (Mikrokotroler)	Able to control the system and communicate data between the microcontroller and the interface via a wifi internet connection.
pH Sensor	Able to read pH.
TDS Sensor	Able to read nutrient values in water.
Peristaltic Pump	Able to adjust nutrient and pH values.
LCD I2C 16x2	Able to display pH sensor and TDS sensor value data.
Kodular (Interface	Able to perform system monitoring and control.

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D. Domain Mechanic

The mechanical design adopted from several journals and modified the hydroponic media mechanics according to the needs that will be used in this study.

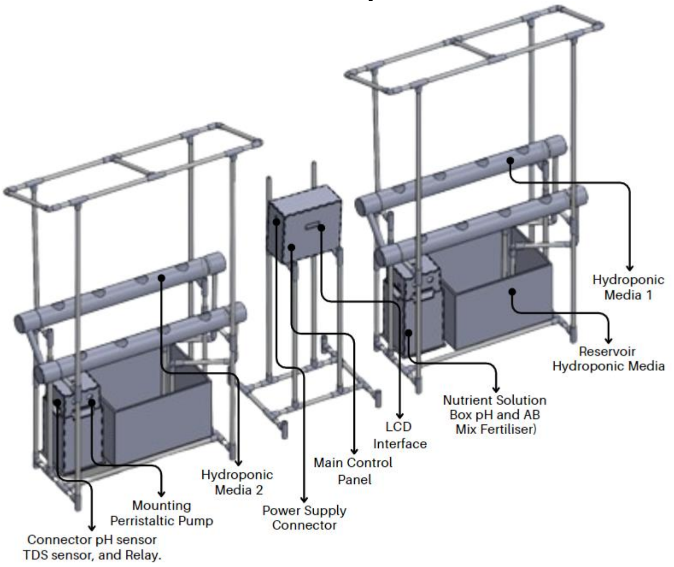

Fig. 3. Hydroponic Media

In the previous journal [22], the slope was not so concerned; based on the book [20], the slope of hydroponic media in the NFT planting method has an influence on the accumulation of fertilizer. Therefore, this research uses PVC pipes as hydroponic media with a slope of 10 mm.

E. Domain Electric

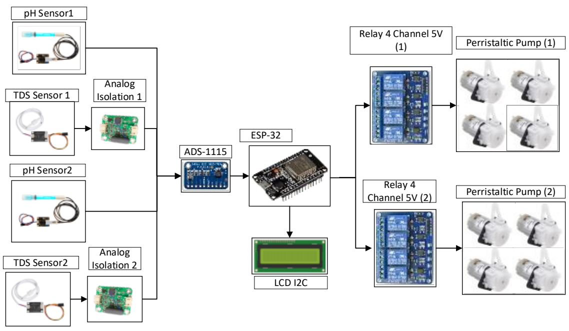

Fig. 4. Diagram Electric

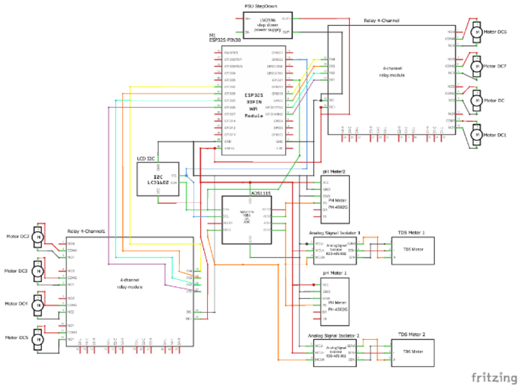

Fig. 5. General flowchart

Figure 5. contains an electrical circuit consisting of a controller, an input circuit, and an output circuit. The controller in this study uses an ESP32-30P. The input circuit consists of a pH sensor and a TDS sensor. The pH sensor serves to obtain the pH value of water [13], and the TDS (Total Dissolve Solution) sensor serves to obtain the concentration value or solubility of nutrients in water [14]. Both sensors are stored for hydroponic media 1 and hydroponic media 2. Before heading to the TDS sensor, there is an analog isolator that serves to isolate the analog signal from two sensors that have a conductivity value in a liquid [15], because without using an analog signal isolator, the pH sensor and TDS sensor readings will affect each other. Sensor The output circuit consists of a peristaltic pump connected to a safety switch in the form of a 4-channel 5V relay. The pH sensor and TDS sensor values are displayed through an interface using an I2C LCD.

F. Domain Information

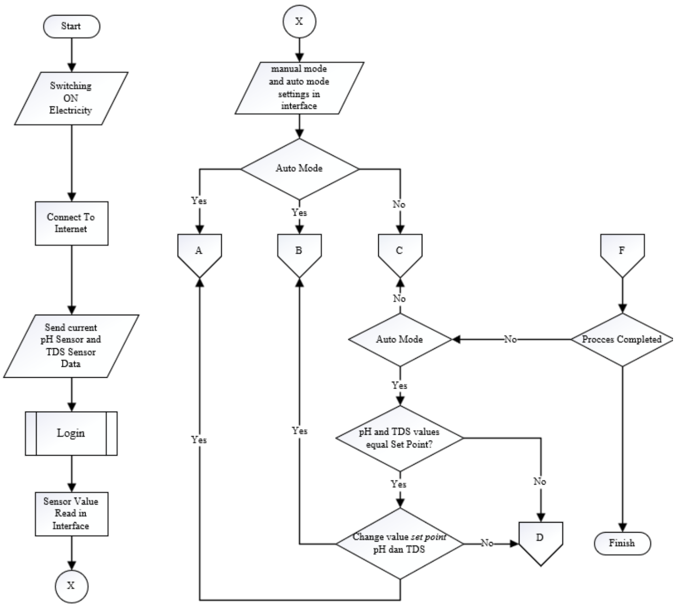

Fig. 6. General flowchart

The system starts by activating the electrical contact on the panel, then the current sensor data will be read by the LCD, the ESP32 will be connected to the internet, and the mobile phone interface reads the current sensor data. Then there are control options, namely automatic or manual mode control. Section A is the auto mode of hydroponic growing media 1, Section B is the auto mode of hydroponic growing media 2, and Section C is the manual mode. Then E is the final part of the two controls. If the control result is not in accordance with the result desired by the user through the set point, the system performs the process again. If the nutrition is not in accordance with the set point, the pH level will be mixed automatically. Then, if no set point change is made, the system will stop after reaching the predetermined set point. Then, if the system has finished using it, it can be deactivated by turning off the source.

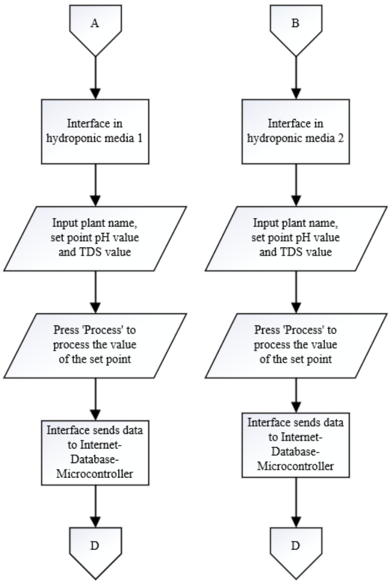

Fig. 7. Automotic mode flowchart

Section A and Section B are flowcharts in auto mode, which begins with selecting hydroponic media 1 or hydroponic media 2 and determining the desired set point value. Set points can be entered through a text box feature that can enter plant names, pH values, and TDS values. Set-point data will be sent to ESP32 by the interface via the internet. Then in Section D, there is a flowchart of pH and TDS parameter control.

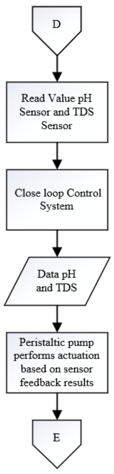

Fig. 8. Automotic mode flowchart

The flowchart starts by reading the pH value and TDS value. The data enters the control system, which then compares the set point value with the latest pH and TDS values accordingly. The peristaltic pump will then actuate based on sensor feedback. If the adjustment of the pH value and TDS value is the same, then the next process is in Section E, which is a flowchart for sending data to the interface.

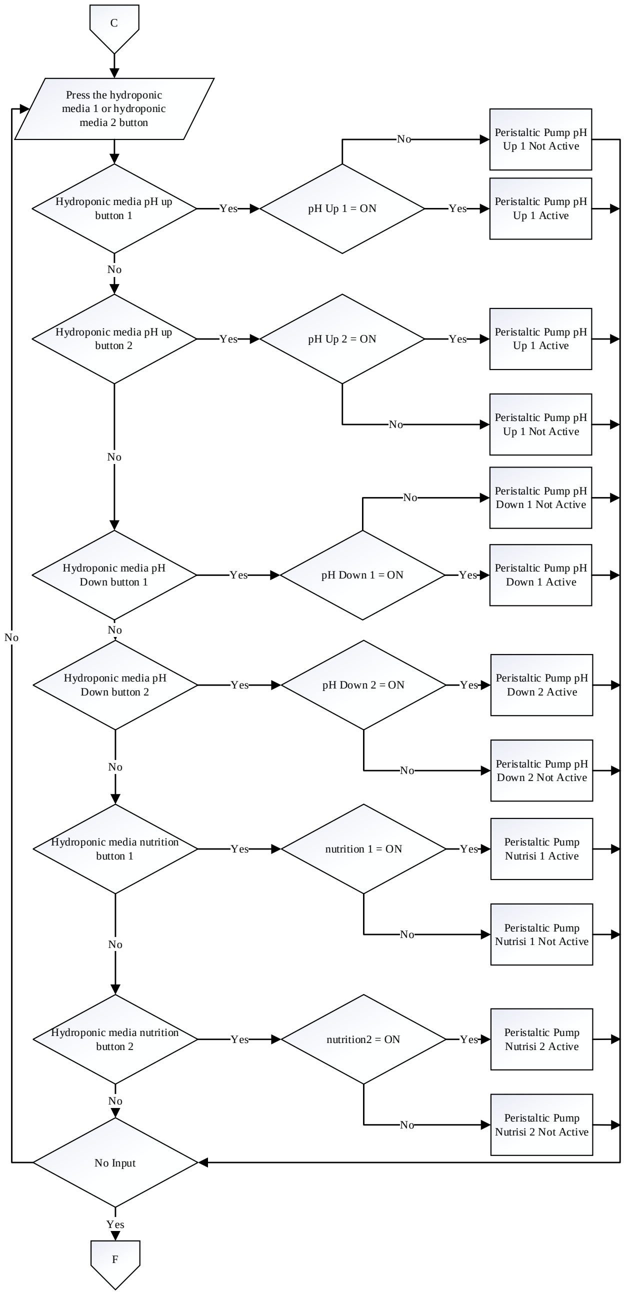

Fig. 9. Manual mode flowchart

Manual mode provides options to enable and disable peristaltic pumps. pH up on hydroponic media 1 and on hydroponic media 2, peristaltic pump pH down on hydroponic media 1 and on hydroponic media 2, peristaltic pump nutrient A and nutrient B on hydroponic media 1 and on hydroponic media 2 nutrient AB mix. There are motor on and motor off indicators on the interface, as well as values from the pH sensor and TDS sensor. If the pH sensor reading exceeds the set point, the user can press the pH down push button on the ON status in the manual setting. If the pH sensor reading is less than the set point, the user can

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press the pH up push button on the ON status in the manual setting. For nutrition, if the TDS sensor reading is less than the set point, the user can press the TDS up push button (AB mix nutrition) on the ON status in the manual setting. The push button can be pressed again at OFF status when the pH and TDS values have reached the appropriate value.

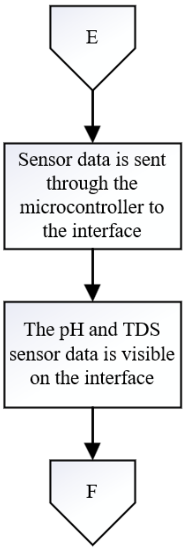

Fig. 10. Data Communication sensor to interface

Sensor data that has been sent to the microcontroller, then sent to the interface via the internet. The pH and TDS sensor data can be read on the interface. The process ends in Section F.

G. System Integration

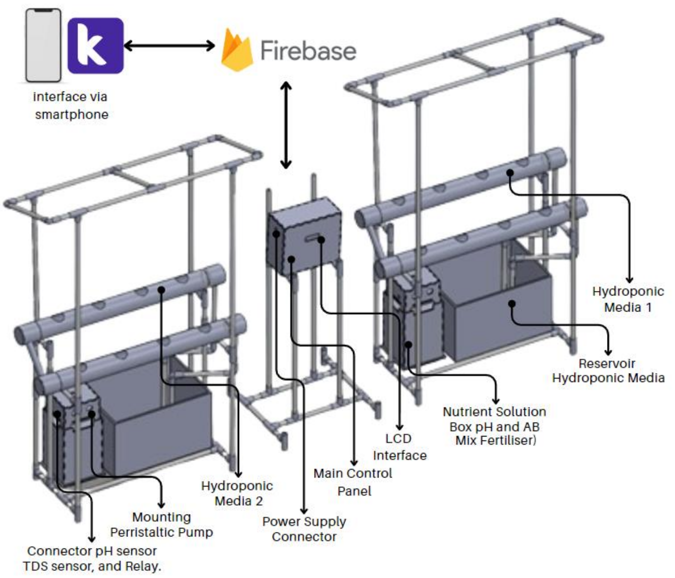

Fig. 11. System integration

Based on Figure 11, System integration can be explained by the fact by the fact that there are two hydroponic media. With each hydroponic media, there are fertilizer boxes and sensor and actuator boxes. Each fertilizer box contains AB Mix Hydroponic Nutrition liquid fertilizer, pH Up liquid, and pH Down liquid. In each sensor and actuator box, there is a pH sensor, TDS sensor, relay, and four peristaltic pumps. Each sensor and actuator box is connected serially via cable to the main control panel, which will be connected to the ESP32 microcontroller. The ESP32 main control panel performs data processing and data communication with the database in the form of Firebase via the internet, or IoT. Firebase becomes a data communication channel between the mobile Android and the ESP32. Mobile Android with the Kodular application will communicate to control data and monitor the hydroponic media plant.

H. Verification/validation

The tools that have been integrated are then verified and validated in terms of their functionality; this aims to ensure the tools have achieved their planned objectives.

TABLE III. REQUIRE SYSTEMS

Device	Demands	Requirements
ESP32 30 Pin (Mikrokotroler)	Able to control the system and communicate data between the microcontroller and the interface via a wifi internet connection.	Accomplished
pH Sensor	Able to read pH.	Accomplished
TDS Sensor	Able to read nutrient values in water.	Accomplished
Peristaltic Pump	Able to adjust nutrient and pH values.	Accomplished
LCD I2C 16x2	Able to display pH sensor and TDS sensor value data.	Accomplished
Kodular (Interface	Able to perform system monitoring and control.	Accomplished

I. Modelling and model analysis

System modeling is designed in accordance with the VDI 2206 method, namely the modeling and model analysis stages. The modeling stage of the system includes a system block diagram model.

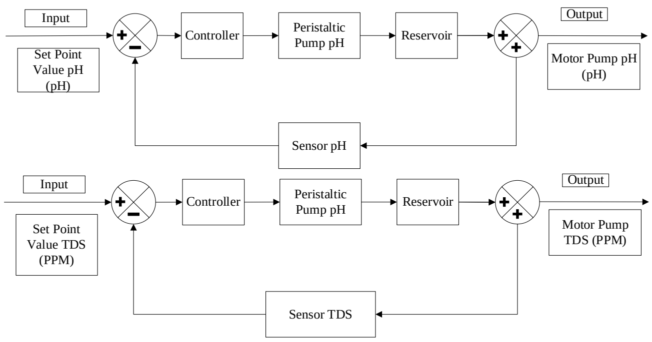

Fig. 12. Block Diagram System

The block diagram uses a close loop system. System inputs are pH values and TDS values, which are used as control system inputs. The actuators used are peristaltic pumps pH and TDS, which will be activated based on sensor value reading data using close loop control. The peristaltic pump will be active within a few seconds or minutes according to the input response given, so that the motor is in accordance with the output of the set point that has been set.

J. pH sensor reading

In the calibration of the pH sensor using a test solution in the form of pH buffer 4.01 and pH buffer 6.86, calibration is done by comparing the sensor output voltage value with pH buffer 4.01 and pH buffer 6.86. Measurement of the pH sensor with pH buffer 4.01 produces an output voltage value of 3.60 V, measurement of the pH sensor with pH buffer 6.86 produces an output voltage value of 3.40 V. of the two sensor output voltage values are stored in the variables pH4 and pH 6.86, these variables will be used for the slope value (m) in the linear equation that has been written in mathematical modeling. The modeling of the pH equation is written as follows:

Linear equation:

$$y = mx + b \quad (1)$$

Linear Regression Formula Based on Measurements with pH Meter

$$y = 8.2088x - 7.5227 \quad (2)$$

(1)

Conclusion of pH sensor formula

$$\therefore y = m(output\ voltage\ sensor) + b$$

$$\therefore y = m(output\ voltage\ sensor) + b \quad (3)$$

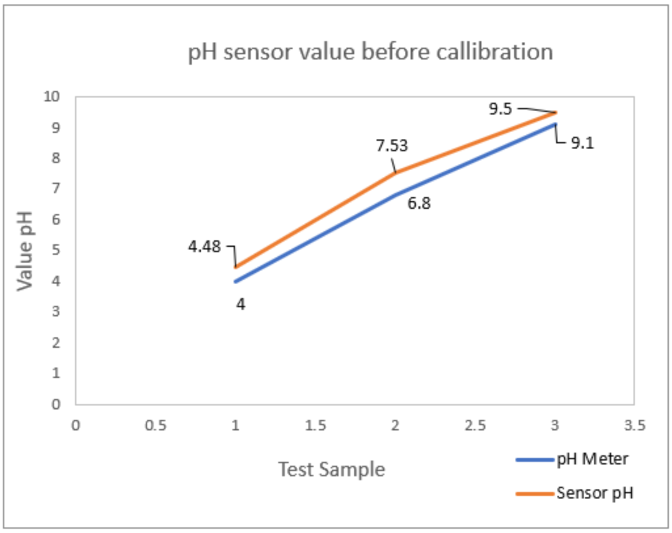

Fig. 13. pH sensor value before calibration

Sensor data before calibration shows that the average error value is 9.04%, and the graph shows that the data and lines between the pH meter value and the pH sensor have different points, so it can be concluded that the pH sensor is not accurate.

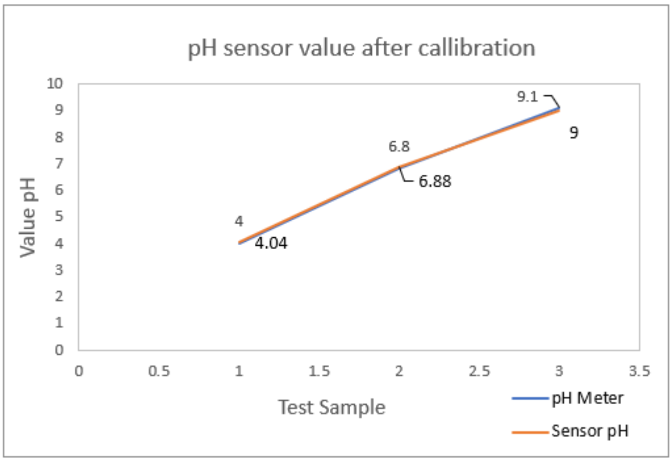

Fig. 14. *pH sensor value after calibration*

Based on the pH sensor calibration data shows that the average error value is 1.09% and the graph shows that the data and the line between the pH meter value and the pH sensor value are close, so it can be concluded that the pH sensor is accurate.

K. TDS sensor reading

The TDS sensor is modeled with mathematical equations in the form of polynomial equations, this is based on the official website and the TDS sensor v1.0 library. The following is the equation used:

Polynomial formulas based on the datasheet:

$$TDS = (133.42V^3 - 255.86V^2 + 857.39V)0.5$$

$$TDS = (133.42V^3 - 255.86V^2 + 857.39V)0.5 \quad (4)$$

Linear regression formula with polynomial equation based on TDS meter and TDS sensor readings with a correlation coefficient of 0.998 or.

$$TDS\ Reg = 0.0081V^2 + 0.0021V + 149.21$$

$$TDS\ Reg = 0.0081V^2 + 0.0021V + 149.21 \quad (5)$$

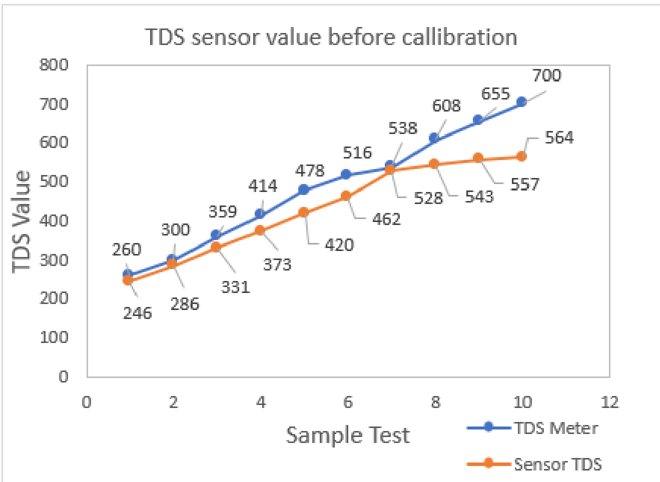

Fig. 15. TDS sensor value before calibration

Sensor data before calibration shows that the average error value is 9.73%, and the graph shows that the data and lines between the TDS meter value and the TDS sensor have differences at several points, so it can be concluded that the TDS sensor is not accurate.

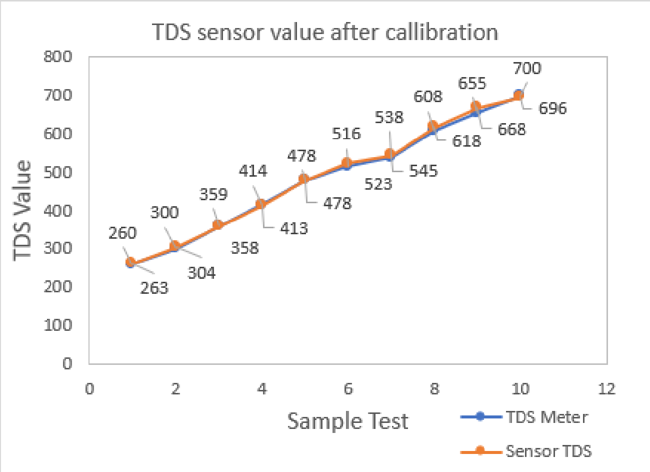

Fig. 16. pH sensor value after calibration

Based on the TDS sensor calibration data, it shows that the average error value is 0.98%, and the graph shows that the data and the line between the TDS meter value and the TDS sensor value are at the same point at several points, so it can be concluded that the pH sensor is accurate.

L. Product

The system has been designed from requirements, system design, domain specific design, domain mechanics, domain electric, domain information, modeling and model analysis, system integration, verification/validation, and product. The product stage is the final stage, which means the tool can be realized. The following is a picture of the system that has been realized.

III. Results and Discussions

A. Interface Testing

Interface testing is intended to see the features that have been made in this study. This test is carried out by looking at the input value and output value displayed on the interface. Testing to find out the button and input/output value runs according to its function.

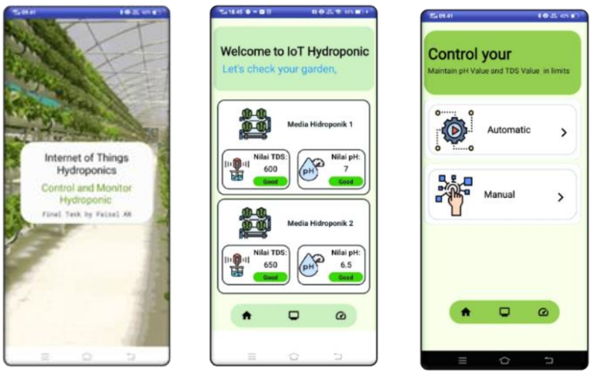

Fig. SEQ Fig._ * ARABIC 17. *Landing page, monitor*

The landing page is the initial page when the application is opened. On the landing page, there is a cardview button to go to the next screen, the monitoring screen. The Sensor Monitoring page contains a display of the pH sensor value monitoring system and the TDS sensor value, this monitoring page contains sensor values for hydroponic media one and hydroponic media two. The control method selection page has two control selections, namely the manual control method and automatic control.

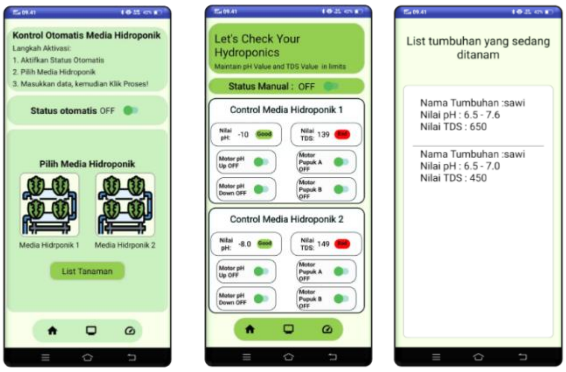

Fig. SEQ Fig._ * ARABIC 18. Pages Automatic

On the automatic control page, there are steps for operating the automatic mode, and there is an automatic status for activating the automatic mode control mode for hydroponic media one and hydroponic media two. On the manual control page, there is a description of manual mode operation, and there is a manual status for activating the manual control mode of hydroponic media one and manual mode control of hydroponic media two. On the plant list page, there is a description of the list of plants being grown. There is a list of plant names, pH values, and TDS values for hydroponic media one; and there is a list of plant names, pH values, and TDS values for hydroponic media two.

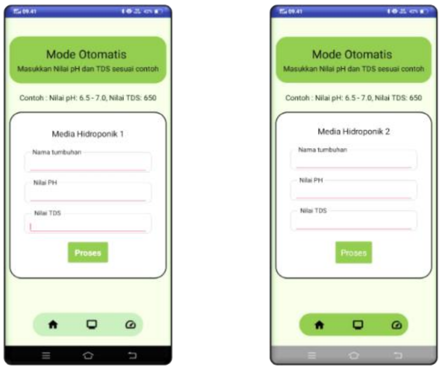

Fig. SEQ Fig. * ARABIC 19. *Set point value automatic control*

On the automatic mode set point value input control page, there is a description of the automatic mode, how to input the pH value, and how to input the TDS value. There is also a process button to process the set point input.

B. TDS sensor testing

Nutrient sensor testing is done by comparing the TDS sensor reading with the TDS meter. The treatment is given with the addition of AB Mix solution. AB Mix solution used is a separate powder solution; fertilizer powder A is a fertilizer powder containing macronutrients, and fertilizer powder B is a fertilizer powder containing micronutrients. Between powder A and powder B, the bottles are separated, then each bottle is filled with fertilizer powder A and fertilizer powder B, then dissolved in 1 L. The TDS sensor test solution is made by preparing a glass cup that has been filled with 500 mL of water, then adding a few drops of AB fertilizer liquid that has been dissolved. The solution can be made with the value of the TDS range as needed.

TABLE IV TDS Sensor testing for Hydroponic media 1

TDS Meter [PPM]	TDS Sensor [PPM]	ADC	Voltage	Deviation [PPM]	Error [%]	Accuracy [%]
260	265	4010	0.75	5	1.92	98.08
300	304	4679	0.88	4	1.33	98.67
359	354	5408	1.01	5	1.39	98.61
414	405	6039	1.13	9	2.17	97.83
478	480	6818	1.28	2	0.42	99.58
516	520	7169	1.34	4	0.78	99.22
538	538	7323	1.37	0	0.00	100.00
608	615	7903	1.48	7	1.15	98.85
655	660	8202	1.54	5	0.76	99.24
700	698	8411	1.58	2	0.29	99.71
Average					1.02	98.98

Table 4: is a comparison of TDS sensor accuracy data with the TDS Meter. Data collection experiments were carried out ten times, thus it can be concluded that the average error value of the TDS sensor is 1.02% and has a sensor accuracy of 98.98%.

TABLE V. TDS Sensor testing for Hydroponic media 2

TDS Meter [PPM]	TDS Sensor [PPM]	ADC	Voltage	Deviation [PPM]	Error [%]	Accuracy [%]
260	263	4029	0.76	3	1.15	98.85
300	304	4720	0.88	4	1.33	98.67
359	358	5480	1.03	1	0.28	99.72
414	413	6131	1.15	1	0.24	99.76
478	478	6767	1.27	0	0.00	100.00
516	523	7155	1.34	7	1.36	98.64
538	545	7333	1.37	7	1.30	98.70
608	618	7849	1.47	10	1.64	98.36
655	668	8166	1.53	13	1.98	98.02
700	696	8332	1.56	4	0.57	99.43
Average					0.99	99.01

Table 5: is a comparison of TDS sensor accuracy data with TDS Meter, Data collection experiments were carried out ten times. Thus, it can be concluded that the average error value of the TDS sensor is 0.98% and that it has a sensor accuracy of 99.01%.

Based on table 5: and Table 6: it can be concluded that the analog value is directly proportional to the voltage and is also directly proportional to the resulting TDS value. The voltage value and the analog value generated from the TDS value of 260 PPM towards the TDS value of 700 PPM are getting bigger. This can be a validation between the mathematical equations that have been modeled with the output value that has been converted from voltage to TDS value with the appropriate value.

C. pH sensor testing

Testing the pH sensor is done by comparing the pH sensor reading with the pH meter. The treatment is given by adding pH Up and pH Down solutions, The pH Up solution used is a basic solution (KOH 10%), which functions to increase the pH value, and the pH Down solution used is an acidic solution (HNO3 10%), which functions to decrease the pH value. Adding a few mL of pH Up or pH Down solution to 500 mL of water can increase or decrease pH levels. The mixed solution can be made with varied pH values according to testing needs.

TABLE VI pH Sensor testing for Hydroponic media 2

pH Meter [pH]	pH Sensor [pH]	ADC	Voltage	Deviation [pH]	Error [%]	Accuracy [%]
4.01	4.02	19244	3.61	0.01	0.25	99.75
5.5	5.45	18455	3.46	0.05	0.91	99.09
6	6.09	18057	3.39	0.09	1.5	98.5
6.4	6.46	17897	3.36	0.06	0.9375	99.06
6.86	6.91	17647	3.31	0.05	0.73	99.27
7	7.1	17546	3.29	0.1	1.43	98.57
7.5	7.43	17361	3.26	0.07	0.93	99.07
8	8.08	17007	3.19	0.08	1	99
9	8.96	16522	3.1	0.04	0.44	99.56
10	9.97	15965	2.99	0.03	0.3	99.7
Average					0.84	99.16

TABLE I. pH Sensor testing for Hydroponic media 2

pH Meter [pH]	pH Sensor [pH]	ADC	Voltage	Deviation [pH]	Error [%]	Accuracy [%]
4.01	4.06	19271	3.61	0.05	1.25	98.75
5.5	5.55	18366	3.44	0.05	0.91	99.09
6	5.94	18136	3.4	0.06	1	99
6.4	6.31	17909	3.36	0.09	1.41	98.59
6.86	6.83	17594	3.3	0.03	0.44	99.56
7	6.97	17514	3.28	0.03	0.43	99.57
7.5	7.46	17215	3.23	0.04	0.53	99.47
8	7.97	16904	3.17	0.03	0.38	99.63
9	8.83	16385	3.07	0.17	1.89	98.11
10	9.73	15841	2.97	0.27	2.7	97.3
Average					1.09	98.91

Table 6: is the pH sensor data on hydroponic media. The data is taken by comparing the pH sensor accuracy value with the pH Meter value. The data collection experiment was carried out ten times. Based on the results and accuracy of the sensor, it can be concluded that the average error value of the pH sensor is 0.84% and has a sensor accuracy of 99.16% table 7 is the pH sensor data on hydroponic media. The data is taken by comparing the pH sensor accuracy value with the pH meter value. The data collection experiment was carried out ten times. Based on the results and sensor accuracy, it can be concluded that the average error value of the pH sensor is 1.09% and has a sensor accuracy of 98.91% based on table 6 and table 7 it can be concluded that the analog value is directly proportional to the voltage and inversely proportional to the resulting pH value. The voltage value and the resulting analog value from pH 4.01 to pH 10 become smaller and smaller; this can be a validation between the mathematical equation that has been modeled and the output value that has been converted from voltage to pH with the appropriate value.

D. Monitoring and controlling distance testing

Testing the farthest distance of monitoring and control is done by comparing the sensor monitoring value listed on the Firebase real-time database with the sensor monitoring value listed on the mobile application. This test is used to test the durability of the tool. Based on the test results in table 7: it can be concluded that the tool has good durability for monitoring and control, with the farthest test distance of 62 KM.

TABLE II. Longest distance testing control and monitoring

Distance [KM]	Monitoring	Controlling
1	√	√
2	√	√
5	√	√
10	√	√
15	√	√
20	√	√
30	√	√
40	√	√
50	√	√
62	√	√

E. Plant Growth Results

Plant growth in this study from both hydroponic media with hydroponic media one is lettuce and hydroponic media two is caisim mustard plant planting starts from the seedling phase, rejuvenation, to maturity in hydroponic media. Here are some photos on the transition from rejuvenation to maturation.

In week 3 or the transition phase from rejuvenation to maturation with 400 PPM AB Mix fertiliser on two pieces of hydroponic media and pH values set at a distance of 6.0 - 7.0 for lettuce plants and pH values set at a distance of 6.5 - 7.0 for caisim mustard plants. The growth results are in the form of mustard caisim plants with a total of 6 leaves with a height of 15 cm and in lettuce plants there are 3 leaves with a height of 10 cm.

In week 4 or the maturation phase with AB Mix fertiliser 400 PPM for lettuce plants and 450 for mustard caisim plants and pH values set at a distance of 6.0 - 7.0 for lettuce plants and pH values set at a distance of 6.5 - 7.0 for mustard caisim plants. The growth results are in the form of mustard caisim plants with a total of 7 leaves with a height of 26 cm and in lettuce plants there are 5 leaves with a height of 14 cm.

1. In week 5 or the maturation phase with 600 PPM AB Mix fertiliser for lettuce plants and 650 PPM AB Mix for mustard greens hydroponic media fruit and pH values set at a distance of 6.0 - 7.0 for lettuce plants and pH values set at a distance of 6.5 - 7.0 for mustard greens plants. The results of growth in the form of mustard greens with a total of 9 leaves with a height of 30 cm and in lettuce plants there are 6 leaves with a height of 17 cm.

IV. CONCLUSIONS

A control and monitoring system of hydroponic nutrition in different hydroponic racks, different types of plants, pH values, and different TDS values using one microcontroller can be implemented. Hydroponic media has been integrated with the Internet of Things system and LCD. Automatic control mode and manual mode can be implemented on two hydroponic media with the farthest distance of control and monitoring of 62 KM. Sensor testing is done by comparing sensors with measuring instruments. Testing the pH sensor on hydroponic media 1 gives an accuracy value of 99.16%. The TDS sensor on hydroponic media has an accuracy value of 98.98%. Testing the pH sensor on hydroponic media 2 gives an accuracy value of 98.91%. The TDS sensor on hydroponic media has an accuracy value of 99.01%.

Based on the research that has been done and the limitations of the problem that have been determined, there are several developments that can be applied to the system. The following are suggestions for system development that can be done with further research. For further research, it can create a wireless network sensor (WSN) system for sensing pH sensors and TDS sensors so that sensing can be done remotely.

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