

Design and Build Hydroponic Installations and Applications Using IoT-Based Multisensors with Solar Panel Electrical Energy

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Abstrak

Penelitian ini merancang instalasi hidroponik berbasis IoT menggunakan mikrokontroler NodeMCU 8266 dilengkapi dengan multi-sensor seperti sensor suhu, kelembaban, tekanan udara, flow, pH, TDS (Total Dissolved Solid), dan EC (Electrical Conductivity) yang akan terhubung secara wireless dengan perangkat pengendali menggunakan software Arduino IDE, Firebase, dan MIT APP Converter serta menggunakan energi terbarukan berupa Panel Surya. Adapun hasil yang diharapkan adalah terciptanya sebuah inovasi dibidang teknologi pertanian khususnya pada teknik budidaya tanaman dengan hidroponik.. Dengan adanya alat ini, segala informasi mengenai keadaan lingkungan tumbuh tanaman dapat dipantau sepenuhnya oleh pengguna. Dari pengujian yang akan dilakukan nantinya, peneliti berharap dapat menghasilkan data pengujian pada setiap pembacaan sensor, pengaktifan motor pompa, dan respon pengiriman data dari aplikasi ke alat dan sebaliknya.

Kata kunci— Hidroponik, IoT, Mikrokontroler, Sensor, Aplikasi, Panel Surya

Abstract

This research designs an IoT-based hydroponic installation using a NodeMCU 8266 microcontroller equipped with multi-sensors such as temperature, humidity, air pressure, flow, pH, TDS (Total Dissolved Solid), and EC (Electrical Conductivity) sensors that will be wirelessly connected to controlling devices using Arduino IDE, Firebase, and MIT APP Converter software and using renewable energy in the form of Solar Panels. The expected result is the creation of innovation in the field of agricultural technology, especially in plant cultivation techniques with hydroponics. With this tool, the user can fully monitor all information about the state of the plant-growing environment. From the tests that will be carried out later, researchers hope to produce test data on every sensor reading, pump motor activation, and data delivery response from application from tool and otherwise.

Keywords— Hydroponics, IoT, Microcontrollers, Sensors, Applications, Solar Panel

1. INTRODUCTION

The practice of hydroponic plant cultivation has become increasingly prevalent in recent times, mainly due to limited space. The Deep Flow Technique (DFT) is a widely accepted hydroponic method that involves a continuous flow of nutrients, resulting in the inundation of the plant's roots. The application of IoT technology to hydroponic systems has enabled researchers to remotely monitor crucial parameters such as temperature, humidity, pH value, and water nutrient

levels using sensors. Moreover, researchers have developed a solar power generation system and control system to optimize water flow in the hydroponic installation, ensuring maximum efficiency in the field.

Hydroponic means Hydro = water, and phonic = workmanship. So in general it means an agricultural cultivation system without using soil but using water that contains nutrient solutions. Hydroponic cultivation is usually carried out in a greenhouse (greenhouse) to maintain optimal plant growth and is completely protected from the influence of external elements such as rain, pests, diseases, climate, and others. The advantages of some cultivation using hydroponic systems include the plant density per unit area can be doubled to save land use. [1]

Karim, Syaifei [2] In his journal titled "Monitoring System in Hydroponic Plants using Arduino UNO and NodeMCU," the author conducted research by applying the MQTT protocol to hydroponic IoT. Three sensors were used: the DHT-22 sensor to detect temperature and humidity, the pH sensor to detect the pH value, and the TDS sensor to detect water nutrients in plants. The sensor data was controlled by Arduino Uno, and the data was sent to the Thingsboard server using the MQTT protocol. The data was displayed in the form of charts and graphs. The sensor module testing showed that the sensor worked well based on time with a difference of one hour.

In their study titled "Application of IoT Technology in Hydroponic Plants using Arduino and Blynk Android," Ciptadi and Prahenusa Wahyu [3] utilized two sensors connected to a microcontroller for nutrient management: DHT11 for temperature and humidity and YF-S201 for nutrient intensity. The microcontroller used was an Arduino Uno. The application of IoT technology enables remote access to various environmental parameters in hydroponic systems, minimizing manual intervention and producing intelligent hydroponic systems through technology.

Growing hydroponics using the NFT (Nutrient Film Technique) method requires a maintained flow of water, the goal is to drain nutrient water at the plant roots. In practice, PLN is used to turn on the water pump, but if the energy supply from PLN dies due to disruption or negligence, the supply of plant nutrients will also stop so a solution is needed. In this study, researchers made a design of a solar power generation system (solar panel) and a control system for water flow that will supply nutrients to the hydroponic plant. [4]

Based on the background and reference description of supporting journals that have been mentioned, researchers are interested in developing a hydroponic installation system equipped with monitoring plant growth elements such as water circulation, humidity, temperature, nutrients, and pH, in one integrated monitoring application to improve the quality of plant cultivation with hydroponic methods. To optimize the function of this hydroponic installation in the field, researchers also apply renewable sources of electrical energy using solar panels. Therefore, researchers took the theme "Design and Build Hydroponic Installations and Applications Using IoT-Based Multisensors with Solar Panel Electrical Energy" as the title of this research.

2. METHODS

2.1 Research Framework

For this research stage, a comprehensive diagram has been created as a framework. Block diagrams are crucial in determining the stages of the design process, ensuring that the resulting system functions optimally. This diagram will guide the entire research process and help produce a high-performing system.

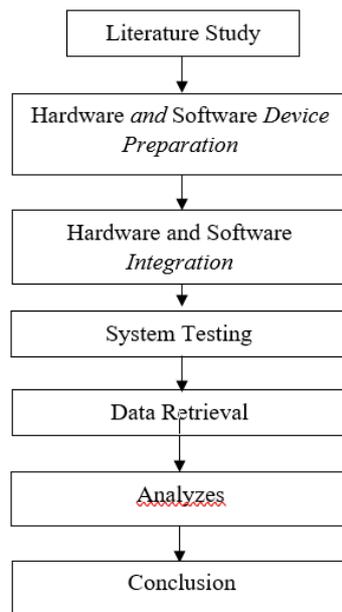


Figure 1 Research Framework Block Diagram

2.1.1 Literature Study

The first stage is to collect literature that discusses the research topic and related research variables. Collect various journals, search for e-books on the internet, and filter the literature used.

2.1.2 Hardware and Software Device Preparation

The preparation of hardware as a physical component that will run the system such as air pressure sensors, flowmeter sensors, temperature and humidity sensors, pH sensors, and electrical conductivity TDS sensors for nutrient readings. The preparation of software devices as software that runs hardware devices are: Arduino IDE, MIT Inventor, and Firebase.

2.1.3 Hardware and Software Integration

After the *hardware* and *software* have all been prepared. Then the device is connected and the *software* is installed.

2.1.4 System Testing

The system testing conducted in this study is:

1. Perform tests or measurements on individual sensors
2. Testing software systems and application access connections.

2.1.5 Data Retrieval

Data retrieval is of two types based on the stages of system testing:

1. Measurement data capture on each sensor used
2. Data retrieval on response and access information via built applications.

2.1.6 Analyzes

This stage is a long process to analyze how the design of the system we have built is by the objectives of writing. This stage also produces many new theories and observations to be written based on the data obtained during testing

2.1.7 Conclusion

This stage is the last stage is the process of concluding the results of research that has been done.

2.2 Comparison of Previous Research

Table 1 Comparison of Previous Research

Number	Reference Title	Researcher Name and / Year	Superiority	Deficiency
1.	Monitoring System on Hydroponic Plants Using Arduino UNO and NodeMCU	S. Karim, I. M. Khamidah, and Yulianto / 2021	The sensor data is controlled by Arduino Uno and the data is sent to the Thingsboard server using the MQTT protocol whose data is displayed in the form of charts and graphs.	The number of sensors used is only two: humidity temperature and pH. In the MQTT protocol used, this tool only uses one-way communication, namely from the sensor node to the cloud server.
2.	Application of IoT Technology in Hydroponic Plants using Arduino and Blynk Android,	P. W. Ciptadi and R. H. Hardyanto / 2018	using an Arduino Uno microcontroller equipped with a DHT11 (humidity temperature) sensor module and a YF-S201 (intensity) sensor connected to the <i>Blynk</i> android application, which can be known by <i>smartphones</i> connected to the <i>Blynk cloud</i> .	This study uses pH meters and TDS / EC meters that are not connected to microcontrollers so monitoring pH and plant nutrients must be done manually.
3.	Solar Power Generation System for Hydroponic Plants	D. Setiawan, H. Eteruddin, and L. Siswati / 2020	The installation of hydroponic plants in this study uses solar panels as power plants which are renewable energy or substitutes for PLN.	There is no automation system for monitoring pH, nutrients, temperature and humidity, and others, so plant care must be done directly / manually.

From the table above, researchers take three references, where in the final results the researcher will combine all methods in the three studies above and meet the shortcomings that exist in the three previous studies.

2.3 Device Design

This report presents a comprehensive overview of the design process for a system, which has been divided into two distinct components: hardware and software design. To initiate the hardware design process, a detailed block diagram of the entire system is generated, providing a clear understanding of the circuit's workflow as an integrated whole. By creating a complete block diagram of the circuit, a fully functional system can be developed.

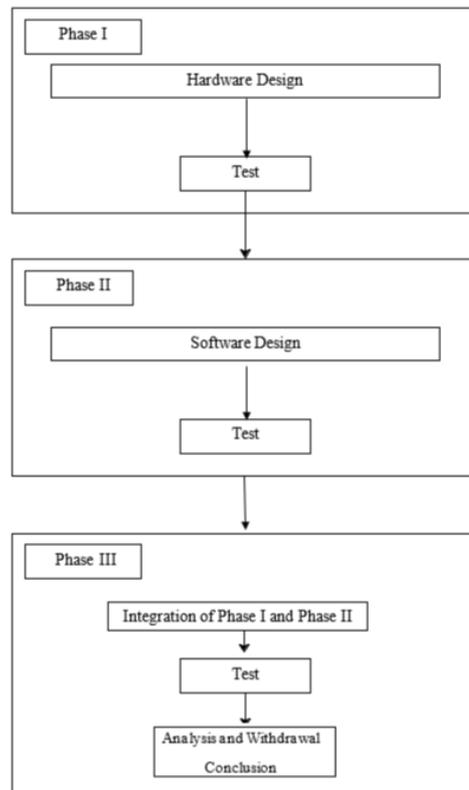


Figure 2 Stages of Research as a Whole

2.4 Hardware Design

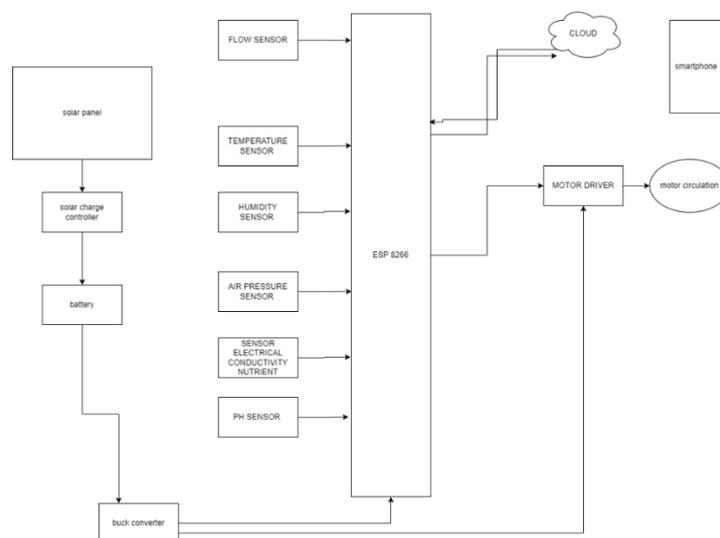


Figure 3 Hardware System Block Diagram

In Figure 3.3 it can be seen that the power supply used comes from an electrical energy source using solar panels. The results of energy conversion through solar panels are then forwarded to the battery as an energy storage medium through a series of solar charge controllers. The distribution of electrical energy to the entire circuit is then carried out by a series of buck converters to adjust the needs of the voltage value in each part of the tool.

The interaction that occurs between the user and the hydroponic installation system designed is in the form of accessing reading information for each sensor used so that users can find out the condition of the needs of cultivated hydroponic plants. The readings include readings of pH value, nutrients, air pressure, nutrient flow, nutrient levels, temperature, and air humidity in the plant environment. On the output side of the system, there is an activation of the pump motor which functions to circulate the flow of nutrients in hydroponic installations. The following is the design of the system to be built in the form of a designed mechanical design.

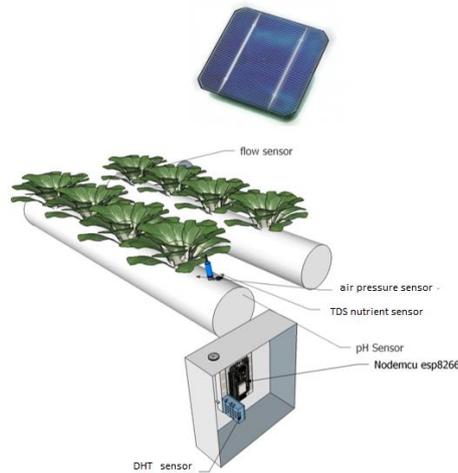


Figure 4 Device Design

2.5 Software Design

Software design can be described in the following flowchart description.

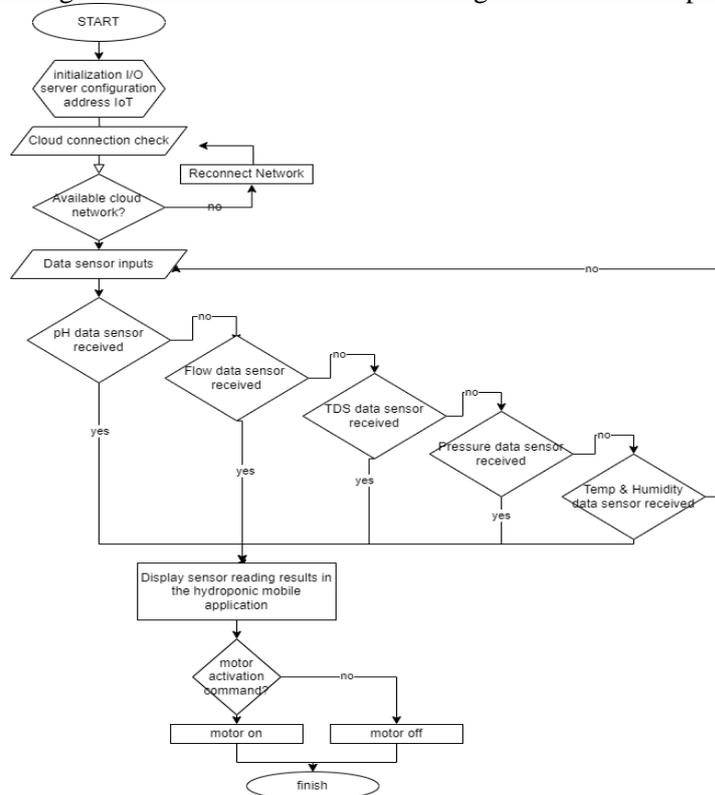


Figure 5 Software Flowchart

The collected data will be processed to analyze the results from the monitoring response in designing the hydroponic tools. Further analysis of the data will be carried out to combine the research findings with other data results.

2.5 Development of Methodology

By writing this Research, we aim to bring innovation to the agricultural technology industry, specifically in plant cultivation with hydroponics. Our tool, equipped with multi-sensors, will function optimally by conveying sensor readings to a mobile application. This will allow users to monitor temperature, humidity, air pressure, flowmeter, pH, and nutrient levels in ppm. With our tool, users can fully monitor the state of their plant-growing environment. Through the tests that we will conduct, we aim to produce test data on every sensor reading, pump motor activation, and data delivery response from the application to the tool and vice versa.

3. RESULTS AND DISCUSSION

3.1 Software Results

The first stage in making the application is to configure IoT coding on NodeMCU ESP8266, Internet of Things (IoT) is a concept/scenario where an object can transfer data over a network without requiring human-to-human or human-to-computer interaction. The basic concept of IoT is the existence of node devices in the form of embedded intelligent systems that will sensor and control various physical objects around humans. These nodes are connected through the internet network so that they can interact with each other and work together to achieve common goals. [5]

The second stage is to create a database, here researchers use Firebase as a data storage center. Firebase is a service from Google that is used to make it easier for application developers to develop applications. With Firebase, app developers can focus on developing apps without having to put in a lot of effort. Two interesting features of Firebase are Firebase Remote Config and Firebase Realtime Database. In addition, there is a supporting feature for applications that require notifications, namely Firebase Notifications. [6]

The third stage is to link from the database to MIT App Inventor, with App Inventor, users can do computer programming to create software applications with an Android-based operating system. This app inventor is based on visual block programming because it allows users to use, view, arrange, and drag and drop blocks which are command symbols and event handler functions to create an application that can run on the Android system. [7]

This is what the finished app looks like after completion. Screen 1 on the home display features two buttons: "START" and "About." Pressing "START" will take you to Screen 2, labeled "MONITORING TANAMAN," while pressing "About" will take you to Screen 3, labeled "Smartfarming Hidroponik." On Screen 2, there are four buttons: "TANAMAN" takes you back to the "MONITORING TANAMAN" screen, "INSTALASI" takes you to the "MONITORING INSTALASI" screen, and the other two buttons, "About Hydroponic" and "About Project," will take you to their respective screens as listed below.



Figure 6 App Design

3.2 Installation Results

Here is the final result of the installation series in the form of an image.

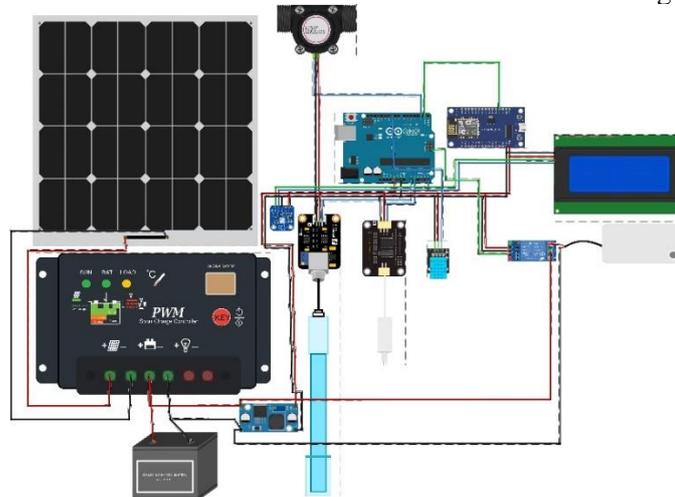


Figure 7 Fritzing Installation Design

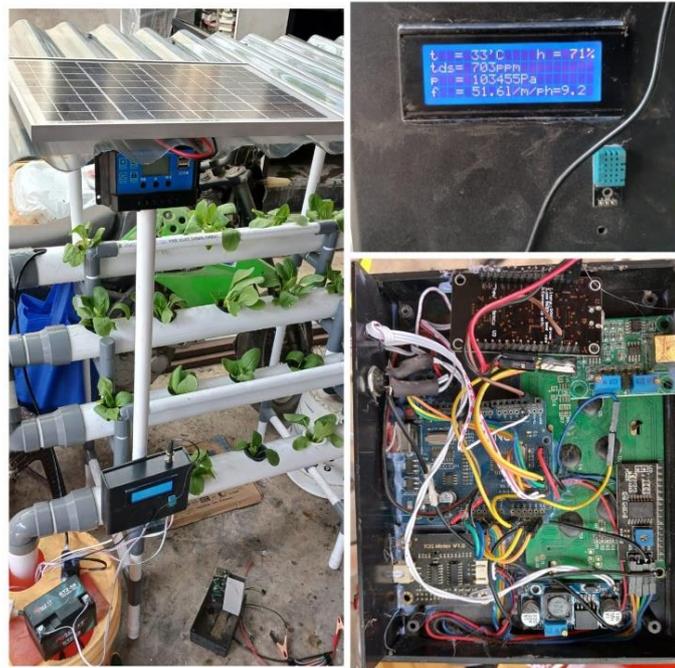


Figure 8 Whole Installation (Left), LCD Display (Top Right), Board (Bottom Right)

Description of circuit schematic based on Figure 7 and Figure 8:

1. Solar Cell, A solar cell is a device consisting of solar cells that convert light into electricity. They are called solar or solar or "sol" because the sun is the strongest source of light that can be harnessed. Solar panels are often called photovoltaic cells, photovoltaic can be interpreted as "electric light". Solar cells rely on the photovoltaic effect to absorb energy.[8] In this circuit, the solar cell is connected to the SSC (Solar Charge Controller) unit.
2. SSC (Solar Charge Controller), In the use of solar panels with off-grid systems, there is an important tool to note. The tool is a SCC (Solar Charge Controller), installed between the solar panel and the battery. SCC is an electronic device that is useful for regulating the electric current entering the battery. [9] serves to regulate the charging current in the battery derived from the solar cell. This tool will adjust the charging current rate according to battery needs and will stop charging when the battery is full to prevent damage due to overcharging.
3. Buck Converter, is a DC-DC Converter type of voltage lowering or step down. A Buck Converter can produce an output voltage value equal to or lower than its input voltage This buck converter is composed of MOSFETs (active switches) and diodes (passive switches). The passive switch can be replaced with an active when the working voltage is low, to reduce the power loss that occurs Basically, the working principle of buck Converter uses a switch that works with two modes, namely the ON switch and the OFF switch. [10] lowering the voltage level from 12V to 5V according to the needs of the logic circuit and sensors in the circuit.
4. The BMP180 sensor, The BMP180 is a very high-performance digital barometric pressure sensor from Bosch Sensortec that can be applied to a wide range of mobile devices, and connected to the system via VCC pin 5V SDA data pin on pin A4 and SCL on pin A5 which communicates with Arduino using I2C data communication format. With units of Pa reading results (Pascal)
5. pH sensor A pH sensor is a sensor used to determine the degree of acidity (c). A pH meter is a device used to measure the acidity or alkalinity of a solution read acid-base

- in nutrient water to regulate pH suitability for hydroponic plants. [12] This sensor uses a 5V VCC and connects to the Arduino via analog pin A0.
6. TDS sensor (Total Dissolved Solid), In hydroponics, this sensor is used to measure the concentration of solution or concentration of hydroponic nutrients. In hydroponics, hydroponic nutrient measurement is necessary because if the nutrient solution is not measured then the plant may be deficient in nutrients or excess nutrients resulting in being toxic to the plant itself. [13] serves to measure the levels of nutrients dissolved in liquids in installations. This sensor uses a 5V VCC and is connected via the A1 pin with readings in units of Ppm (Parts per Million).
 7. The DHT11 sensor, is a sensor module that functions to sense temperature and humidity objects that have analog voltage outputs that can be further processed using a microcontroller. [14] The sensor is used in reading temperature values in units of degrees Celsius (C) and air humidity in units of a percent (%), this system communicates with Arduino using a one-wired protocol and connects to Arduino via pin 10. This sensor uses a VCC of 5V.
 8. Sensor Flow Meter, this sensor works by measuring the flow rate of water and produces readings in units of L/m (Liters per Minute). This sensor communicates with the Arduino via the interrupt pin on pin 2 and uses a 5V DC voltage source
 9. Arduino, as the main data processing center functions to process the data readings of all sensors which are then forwarded to the data viewer in the form of a 20x4 LCD and also forwarded to the Firebase Cloud Database using the NodeMCU8266 intermediary.
 10. LCD, serves to display the reading data of all sensors so that users can observe data readings through the display on the device.
 11. DC Motor Pump, works to drain nutrient water in hydroponic installations. The energy used by this pump motor is taken from the battery by the working range of the pump motor of 12V.
 12. NodeMCU ESP8266, in general, refers to the firmware used rather than the NodeMCU development kit hardware and can be analogous to the Arduino board ESP8266. [15] This tool is connected to Arduino through RX pin which functions to forward sensor reading data that has been brought by Arduino so that it can be uploaded to the cloud so that it can be accessed by users through the application.

3.3 Sensor Testing

Table 2 Sensor Testing Table

Number	Time	Temperature (°C)	Humidity (%)	pH	TDS (ppm)	Air Pressure (Pa)	Flowmeter (Lpm)
1	08.00	27	98	6.6	703	101200	4.2
2	09.00	27.5	97	6.8	705	101000	4.5
3	10.00	27.8	95	6.7	702	101200	4.3
4	11.00	28	96	6.5	706	101100	4.1
5	12.00	28.2	92	6.3	705	101300	4.2
6	13.00	28.6	95	6.6	703	101200	3.9
7	14.00	28.8	95	6.7	707	101000	4
8	15.00	28.1	93	6.4	710	101200	4.3
9	16.00	27.4	96	6.7	706	101100	4.2
10	17.00	27.2	98	6.8	705	101200	4.1

We experimented by collecting sensor data from the installation between 8:00 AM to 5:00 PM. The table above shows the results of our test samples.

3.4 Testing Data Delivery

Sensor data is effectively transmitted to the Arduino device through an established setup. The data is subsequently forwarded to the Firebase cloud server through the intermediary, which is identified as ESP8266. The data is then presented to the user on their application interface. In the following table, we have documented experiments conducted to measure the delay between the sensor and the user's device, demonstrating the efficacy of the system.

Table 3 Data Delivery Testing Table

Number	Data Sent	Data Received	Interval (Second)
1	12.10.35	12.10.38	3
2	12.10.46	12.10.50	4
3	12.11.15	12.11.17	2
4	12.12.20	12.12.22	2
5	12.12.35	12.12.38	3
6	12.12.45	12.12.49	3
7	12.13.05	12.13.09	4
8	12.13.15	12.13.17	2
9	12.13.30	12.13.35	5
10	12.13.46	12.13.49	3

Based on our ongoing data analysis conducted for approximately three minutes, we have identified a delay in the time between the incoming and received data. Our findings show that the shortest delay observed was 2 seconds, whereas the longest delay recorded was 5 seconds. These results suggest that some underlying issues may be causing this delay, and we will continue to monitor the situation closely to provide further insight into the matter.

4. CONCLUSIONS

Based on the test results that we have obtained, we can determine the range of sensor readings for hydroponic installations on any given day. Specifically, the temperature sensor readings range from 27°C to 28°C, while the humidity sensor readings range from 92% to 98%. In addition, the pH sensor readings range from 6.3 to 6.8, the TDS sensor readings range from 702Ppm to 710Ppm, the air pressure sensor readings range from 101000Pa to 101300Pa, and the flowmeter sensor readings range from 3.9Lpm to 4.5Lpm. Notably, all of these readings fall within the ideal range for hydroponic plants.

The application that we have developed is designed to display real-time sensor test results, and there is a slight delay of anywhere from 2 to 5 seconds for data transmission from the sensor to the user's device. It is also worth mentioning that the device is powered by solar panels, which are closely monitored using a solar charge controller. Furthermore, the energy conversion from 12V to 5V is accomplished using a voltage buck converter. We are proud to report that the device has undergone three stages of rigorous testing, and has performed exceptionally well every time.

REFERENCES

- [1] I. S. Roidah, "Menggunakan Sistem Hidroponik s," vol. 1, no. 2, pp. 43–50, 2014.
- [2] S. Karim, I. M. Khamidah, and Yulianto, "Sistem Monitoring Pada Tanaman Hidroponik Menggunakan Arduino UNO dan NodeMCU," *Bul. Poltanesa*, vol. 22, no. 1, Jun. 2021, doi: 10.51967/tanesa.v22i1.331.

- [3] P. W. Ciptadi and R. H. Hardyanto, "Penerapan Teknologi IoT pada Tanaman Hidroponik menggunakan Arduino dan Blynk Android," *J. Din. Inform.*, vol. 7, no. 2, 2018.
- [4] D. Setiawan, H. Eteruddin, and L. Siswati, "Sistem Pembangkit Listrik Tenaga Surya untuk Tanaman Hidroponik," *J. Tek.*, vol. 14, no. 2, pp. 208–215, 2020, doi: 10.31849/teknik.v14i2.5377.
- [5] "Mari Mengenal Apa itu Internet of Thing (IoT) | IDCloudHost." [Online]. Available: <https://idcloudhost.com/mari-mengenal-apa-itu-internet-thing-iot/> [6] D. B. Widyantara, R. Sumiharto, and S. B. Wibowo, "Prototype of Fixed Wing Unmanned Aircraft Stability Control System Using Robust PID," *IJEIS (Indonesian J. Electron. Instrum. Syst.*, vol. 6, no. 2, p. 139, Oct. 2016 [Online]. Available: <https://jurnal.ugm.ac.id/ijeis/article/view/15260>.
- [6] R. Juliarto, "Apa itu Firebase? Pengertian, Jenis-Jenis, dan Fungsi Kegunaannya - Dicoding Blog," *Dicoding Indonesia*. 2020. [Online]. Available: <https://www.dicoding.com/blog/apa-itu-firebase-pengertian-jenis-jenis-dan-fungsi-kegunaannya/>
- [7] Universitas 'Aisyiyah Yogyakarta, "Apa Itu MIT App Inventor, Berikut Penjelasannya – Program Studi Teknologi Informasi," *Unisayogya.Ac.Id*. 2020. [Online]. Available: <https://psti.unisayogya.ac.id/2020/01/06/apa-itu-mit-app-inventor-berikut-penjelasannya/>
- [8] Erlita, "Pengaplikasian Solar Cell Pada Rumah," *Journal*, pp. 4–21, 2014, [Online]. Available: [http://eprints.polsri.ac.id/1109/3/BAB II.pdf](http://eprints.polsri.ac.id/1109/3/BAB%20II.pdf)
- [9] Cakrawala96, "Solar Charge Controller: Pengertian, Fungsi, dan Jenisnya." 2021.
- [10] F. W. Azhari and A. Aswardi, "Sistem Pengendalian Motor DC Menggunakan Buck Konverter Berbasis Mikrokontroler ATmega 328," *JTEV (Jurnal Tek. Elektro dan Vokasional)*, vol. 6, no. 1, p. 352, 2020, doi: 10.24036/jtev.v6i1.108020.
- [11] K. Fatihin, J. Dedy Irawan, and R. Primaswara Prasetya, "Rancang Bangun Sistem Monitoring Pengukur Cuaca Menggunakan Minimum System Arduino," *JATI (Jurnal Mhs. Tek. Inform.*, vol. 4, no. 1, pp. 303–310, 2020, doi: 10.36040/jati.v4i1.2355.
- [12] E. Mufida, R. S. Anwar, R. A. Khodir, and I. P. Rosmawati, "Perancangan Alat Pengontrol pH Air Untuk Tanaman Hidroponik Berbasis Arduino Uno," *INSANtek*, vol. 1, no. 1, pp. 13–19, 2020, [Online]. Available: <http://ejournal.bsi.ac.id/ejournal/index.php/insantek%0Ahttps://ejournal.bsi.ac.id/ejournal/index.php/insantek>
- [13] Pratama, "Implementasi Sensor TDS (Total Dissolved Solids) Untuk Kontrol Air Secara Otomatis Pada Tanaman Hidroponik" *STIKOM Surabaya*, 2017.
- [14] H. A. Nugroho, "Monitoring Alat Penetas Telur Dengan Android Berbasis Iot," Thesis (Diploma), p. *STMIK AKAKOM YOGYAKARTA*, 2019.
- [15] A. Deris, "Sistem Informasi Darurat Pada Mini Market Menggunakan Mikrokontroler Esp8266 Berbasis Internet of Things," *Komputasi J. Ilm. Ilmu Komput. dan Mat.*, vol. 16, no. 2, pp. 283–288, 2019, doi: 10.33751/komputasi.v16i2.1622.