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Smart Farm Agriculture Design by Applying a Solar Power Plant

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A B S T R A C T

Every year as the world's population increases, land is getting full and not enough to be used in agriculture. Various types of technological developments have been abused to grow crops. The purpose of this research is to design a *smart farm agriculture* system by planting without soil and utilizing technological advances in the city. *Smart farming* is a technology in agriculture with the *Internet of Things* (IoT) to help farmers public people get data easy from the garden. Hydroponics is soil-less farming that uses minerals or fertilizers dissolved in water. *Nutrient Film Technique* (NFT) is one of the hydroponic methods using a thin layer on the flow of nutrients through pipe installations. Pumps that require continuous electrical power can harness solar power plants as an energy source. *Off-grid* system on solar panel plan produce electrical energy according to the required power without being connected to state electricity network. The design applies a multi-sensor system that includes nutrient sensors and pH sensors, as well as automatic solution pumps, temperature PZEM-004T sensors, and a data logger that collects data and connected to internet server with visual on app Thinger.io as monitoring platform. The results, pH is ranging from 6.5 to 7.5. The TDS sensor testing resulted in a 0.313% pH sensor error with an accuracy of 99.69%, and the TDS sensor testing resulted in a 1.18% TDS sensor error with an accuracy of 98.82% also the agriculture farm system testing, the testing in 1 until 2 weeks showed an error percentage of 38% in the pH solution and 38.73% in the nutrient solution. In addition, the solar panels generated a total power output of 1700.56 W, while the total load demand was 1165.74 W. Based on the testing results, the *smart farming* system can monitor nutrient and PH solution levels, the automatic pump controls a stable solution, and the power sourced from PLTS can supply the pump properly

INTRODUCTION

The reduction of agricultural land will lead to a decrease in agricultural production capacity, necessitating the government to import agricultural products to fulfill domestic food needs [1]. Land scarcity and limited availability for agriculture pose challenges as agriculture plays a vital role in feeding the global population [2].

Smart farming, utilizing Internet of Things (IoT) technology, is employed in the field of agriculture to assist farmers in monitoring and obtaining information from their fields to improve the quality and quantity of their produce [3]. One of the most rapidly adjustable production methods in modern technology for the agricultural sector is hydroponics [4]. The Thinger.io platform can be used as an IoT monitoring tool to receive data from connected sensors and hardware devices towards the cloud [5].

Hydroponics is a soilless cultivation method that uses dissolved minerals or nutrients in water. It is considered an innovative approach as it no longer relies on soil as the growing medium and can be implemented in urban areas with limited space for large-scale farming [6]. The Nutrient Film Technique (NFT) involves circulating plant roots with a nutrient solution, requiring specific attention to parameters such as acidity (pH) and nutrient concentration (PPM) [7].

Hydroponic farmers currently check the nutrient solution density daily, which can be inefficient and less effective [8]. Technological advancements, such as the Internet of Things, enable remote operation, which can assist hydroponic farmers in automating the monitoring and maintenance of nutrient solutions in reservoirs [9]. Smart farming systems function to automatically control the pH and nutrient levels in hydroponic plants. Parameters that need adjustment are pH values and EC values that deviate from normal conditions [10].
The Nutrient Film Technique hydroponic cultivation method involves submerging plants in a nutrient-containing liquid that is continuously circulated for 24 hours [11]. The pump used to continuously flow the water as the growing medium requires electricity sourced from the power grid. The availability of solar energy can be utilized to implement renewable energy technologies, such as solar cells [12]. In photovoltaic effects, sunlight supplies energy to outer electrons, moving them from the valence band to the conduction band within materials, thus generating electricity [13]. Solar power plants, known as

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Photovoltaic Power Plants, utilize solar energy as their source. Off-grid or standalone systems can generate electricity according to the required power without being connected to the power grid, as solar energy is the main source for off-grid systems [14]. Utilizing photovoltaics as a power supply for water pumps can reduce dependence on electricity sourced from diesel, coal, and gas [15].

Based on the background issue mentioned above, this research aims to design a smart farming system for hydroponic plants using the Nutrient Film Technique method. The system will be controlled and monitored automatically by farmers, specifically focusing on pH and nutrient conditions when the solution is circulated using a pump connected to a solar power generator.

METHOD

The research tool design provides an overview of the overall relationship between input and output components. The designed tool model consists of interconnected components. The structure of the research tool components can be seen in Figure 1.

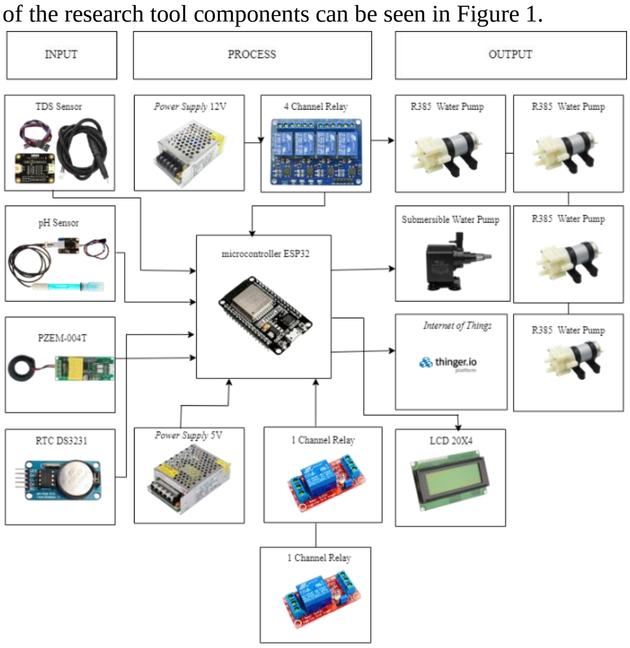

Figure 1. Tool Block Diagram

The design of the research tool system in Figure 1 goes through several stages to activate the designed components, from the input process to the output. The system starts with an off-grid solar power generator that produces electricity to supply the pump and microcontroller through a power supply, which functions to convert AC power into DC power. The tool design consists of several supporting sensors, including the TDS sensor, pH sensor, PZEM-004T, and RTC DS3231. The connected components are processed using the ESP32 microcontroller, which is uploaded with code for system reading, monitoring, and commands from the sensors. The ESP32 microcontroller processes the commands to activate the load output, which includes the submersible pump and the R385 pump. The generated data is displayed on a 20x4 LCD and can be monitored through the Thinger.io platform.
The design of the hardware and software working system can be seen in Figure 2.

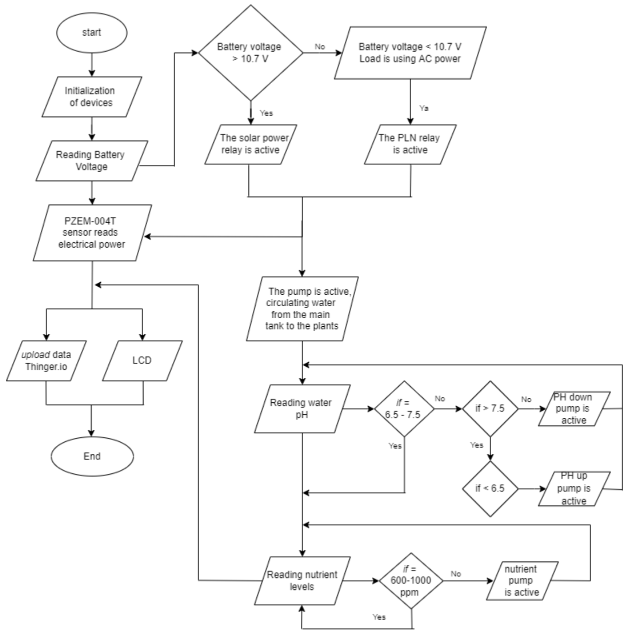

Figure 2. System Device Design Flowchart

Figure 2 represents the program system in the research designed using Arduino IDE software and supported by the Internet of Things (IoT). The first step is to initialize the ESP32 microcontroller and establish an internet connection to connect to the Thinger.io platform for monitoring and Network Time Protocol (NTP) time synchronization. The second step is for the system to read the voltage value of the battery. The program code will command the relay based on the battery voltage parameters. If the voltage value read by the sensor is above 10.7 V or if the remaining battery capacity is above 30%, the relay will activate the power sourced from the Solar Panels. If the voltage is less than 10.7 V, the relay will activate the load using AC power sourced from the utility grid (PLN). The backup power source is designed to replace the solar panels power, ensuring that the device continues to operate when rainy weather conditions result in the battery not being fully charged by the solar module. Furthermore, all sensors connected to the microcontroller perform readings based on the parameters uploaded to the ESP32 via the Arduino IDE software and send commands to activate the R385 pump. The sensor readings are displayed on the LCD and the Thinger.io platform with an internet connection to ensure proper monitoring and data recording. The hardware design can be seen in Figure 3.

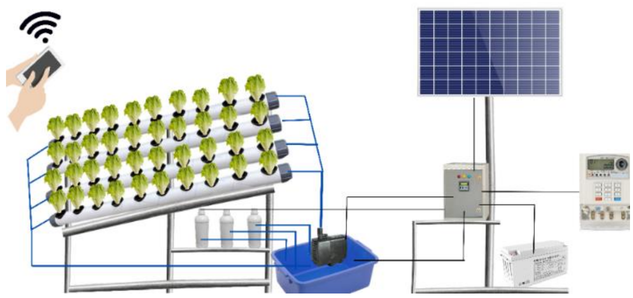

Figure 3. Hardware Installation

Figure 3 shows the design of the placement of the solar panel system using a ground-mounted installation system, which involves placing the Solar Panels on the ground using lightweight steel support racks. This ground-mounted solar module system was chosen based on the requirements that facilitate the installation of various numbers and sizes of Solar Panels.

The installation can be positioned in an open area exposed to direct sunlight to avoid shading that can affect the performance of the Solar Panels. The placement is determined based on factors that influence the performance of the Solar Panels, such as solar intensity. Each region has different solar radiation, and the higher the received solar intensity, the better the performance of the Solar Panels in generating electricity. System will work optimally when positioned based on the equatorial line. In this study, it is designed to face north as it is located in Java Island. The installation location of the solar panels in this research is based on normal environmental temperature, around 25°C, as it affects the performance of the Solar Panels. Higher temperatures can cause a decrease in the performance of the Solar Panels.

The design of the solar panels involves several stages, including analyzing the installation location to ensure that the ground area can support the capacity of the solar panel system. Next, shadow analysis is conducted to determine that the sunlight captured by the Solar Panels is not obstructed by objects in the surrounding area. Analyzing the frame structure is another step, aiming to ensure that the frame construction is strong enough to support the Solar Panels. The next step is analyzing the effective area of the Solar Panels, which is calculated during the solar panels system design phase. Accurate area analysis is necessary because if certain areas are shaded or occupied by utility equipment, such as outdoor AC units, the potential area for solar panel placement will be smaller than the total available area.

RESULTS AND DISCUSSION

The testing aims to determine whether the device's performance meets the specifications of the system according to the desired parameters. The testing is conducted by calibrating the sensors and running the program to obtain the success percentage or detect any errors in the device. This serves as the basis for drawing conclusions and identifying shortcomings in the research.

The testing of the PZEM-004T sensor was conducted to determine the accuracy of the sensor when reading values compared to a measuring instrument. The PZEM-004T sensor is used to read current, voltage, and frequency values in the Alternating Current (AC) electrical system connected to the smart farm device. This testing was performed 10 times to generate more varied measured data. The results of the PZEM-004T sensor testing for voltage readings can be seen in Figure 4.

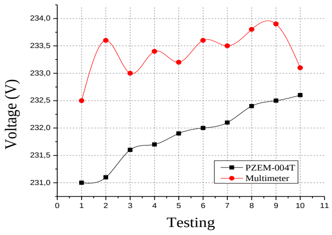

Figure 4. Results of Voltage Testing for PZEM-004T Sensor

Figure 4 shows the results of the testing of the PZEM-004T sensor compared to a multimeter. The average voltage testing value on the PZEM-004T sensor resulted in a percentage error of 0.54% with an accuracy of 99.46%.

The TDS sensor testing was conducted to determine the concentration of dissolved AB mix in the water used as hydroponic plant nutrient solution. The results of the testing can be seen in Figure 5.

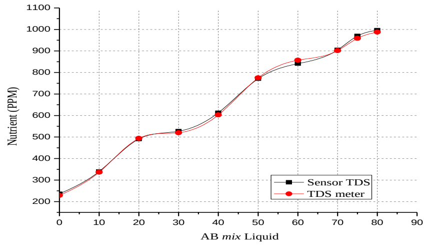

Figure 5. Results of TDS Sensor Testing

Figure 5 shows the results of the TDS sensor testing compared to a conventional device, the TDS meter. In this study, the DFRobot V1.0 SEN0244 sensor was used, which provides readings in Parts Per Million (PPM) unit. The average percentage error of the testing was found to be 1.18%, with a testing accuracy of 98.82%.

The pH sensor testing was conducted to determine the acidity level of the solution in the container used for hydroponic plants. The results of the testing can be seen in Figure 6.

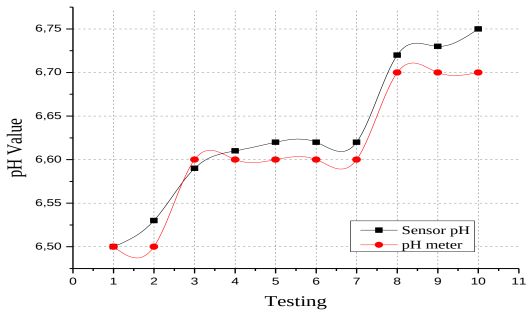

Figure 6. Example on How to Put Caption for a Figure

Figure 6 shows the results of the pH sensor testing compared to a conventional device, the pH meter. In this study, the DFRobot V1.1 SEN0161 sensor was used, which resulted in an average percentage error of 0.313% and a testing accuracy of 87.69%.

The testing of the solar panel system involved evaluating the power generated by the Solar Panels, which was stored in the battery and used as a power source to activate the load for 24 hours. The testing included monitoring the voltage, current, and power of the battery using a data logger system. The graph of the battery voltage can be seen in figure 7.

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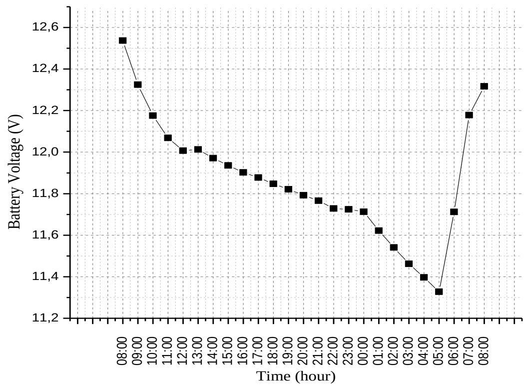

Figure 7. The Usage of Battery Voltage

Figure 7 represents the average battery voltage usage obtained from the solar module, which is used to activate the smart farm system. From the graph in Figure 7, it can be observed that the battery supplies power to the load for 24 hours, with the highest voltage value recorded as 12.5 V and the lowest voltage value recorded as 11.3 V. The setpoint is set to limit the maximum battery charging voltage at 13.7 V, which is intended to prevent the battery from exceeding its capacity or experiencing overvoltage.

The next testing is conducted to determine the acidity and alkalinity levels of water, which affect the solution in the container for the smart farm system. The graph of the pH testing can be seen in Figure 8.

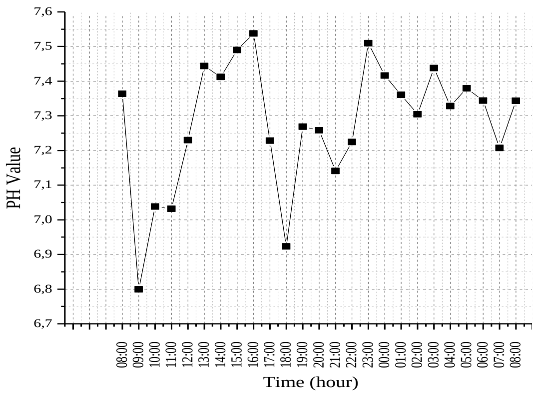

Figure 8. The Average pH Value During Research Study

Figure 8 shows the graph displaying the average values resulting from the testing of the smart farm system. The setpoint value remains consistent throughout the second week, ranging from 6.5 to 7.5. The lowest pH value was recorded at 09:00, measuring 6.79, while the highest pH value was observed at 16:00, measuring 7.53. Based on the graph of the testing results, the pH values of the solution in the container are in line with the setpoint established. However, there are significant variations in the values due to changes in weather conditions and the growth stage of the plants, which affect the pH levels in the main solution container.

The testing of nutrient concentration in the smart farm system aims to determine the dissolved nutrient condition in the main reservoir with a specified ppm value. The TDS testing involves measuring the nutrient levels, automating the R385 pump for dispensing the AB mix solution, and monitoring data on the Thinger.io platform. The results of the testing for the first week can be seen in Figure 9.

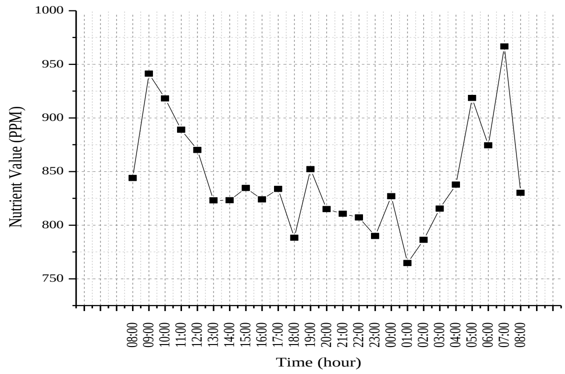

Figure 9. The Average Nutrient Value During Research Study

Figure 9 displays the graph of the average nutrient values in the main reservoir for the third week of testing, with a setpoint ranging from 750 ppm to 1000 ppm. This increase in nutrient concentration is due to the mature stage of the plants, which require higher nutrient levels. The graph in Figure 4.21 indicates the lowest value of 764 ppm at 01:00 and the highest value of 966 ppm at 07:00. The results remain within the specified setpoint range, as the smart farm system accurately reads the nutrient solution, and the automated nutrient pump system ensures stability. However, the study reveals fluctuating values due to the mature stage of the plants approaching the harvest period, with an increase in leaf count, taller plants, heavier root systems, and heterogeneous growth patterns. Additionally, there were days during the testing period with rain and overcast conditions, resulting in environmental moisture that influenced the fluctuating values in the main reservoir.

The testing of power source utilization and load power consumption involves gathering data to assess the overall performance of the power source as a generator and the power consumption for activating the AC electrical load in the smart farm system. This testing was conducted over a period of 3 weeks by reading the power source parameters using a data logger connected to the solar panels system. The PZEM-004T sensor was utilized to monitor the power consumption of the AC electrical load continuously for 24 hours, and the data was displayed on the Thinger.io platform every hour. The results of the power source utilization and load power consumption testing can be seen in Figure 10.

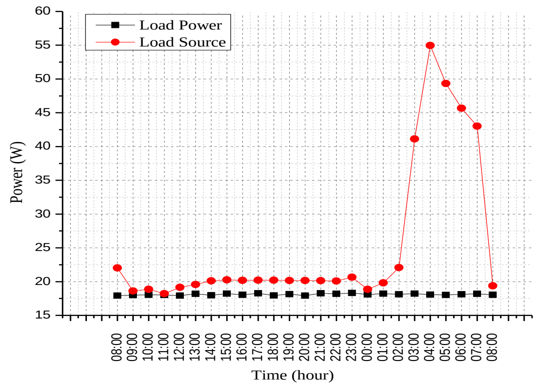

Figure 10. Power Source and Load Power Comparison

Figure 10 shows the results of the average power source and load power testing displayed in a graphical format. In this testing, the data logger and the temp PZEM-004T sensor performed, capturing parameters over a 24-hour period. The power source readings recorded the lowest value of 18.2 W at 11:00 and the highest value of 54.9 W at 04:00. On the other hand, the load power readings had the lowest value of 17.91 W at 12:00 and the highest value of 18.3 W at 23:00. Based on this testing, it can be concluded that the power source successfully supplies power to the load, as evidenced by the total power source value of 632.87 W, which is greater than the load power value of 452.58 W. This indicates that the battery is capable of activating the pump for 24 hours. The electricity consumption of the smart farm device during the research can be seen in Figure 11.

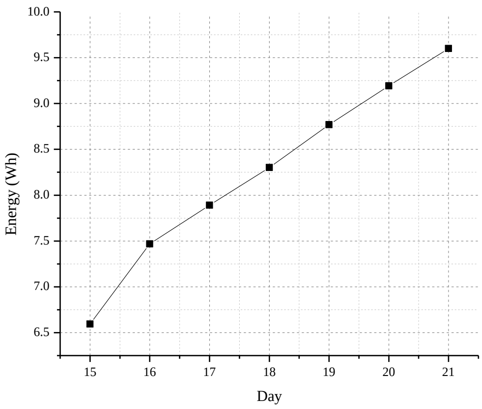

Figure 11. Electricity Consumption

Figure 11 displays the electricity consumption for activating the load. In the graph shown in Figure 11, the data is generated from the average values obtained from the readings of temperature sensor, starting from day 15, with an average energy value of 6.59 Wh. Based on the results of this testing, the device system can showed parameters and sending data to data logger with visual in the Thinger.io platform. The average energy value from week 1 to week 3 results in a total energy consumption of 9.6 Wh on day 21 when the testing is completed. The increasing energy value is due to various factors, one of which is the continuous usage of the load every day for 24 hours, resulting in an increasing daily electricity consumption.

CONCLUSIONS

This research discusses the design of a smart farming system using the nutrient film technique and a solar-powered water pump. The results of the study, which include the design and implementation carried out, can be summarized as follows.

1. The smart farming system using the nutrient film technique has been successfully developed, and the testing of the system compared to conventional methods showed only a small difference. The TDS sensor testing resulted in a 0.313% pH sensor error with an accuracy of 99.69%, and the TDS sensor testing resulted in a 1.18% TDS sensor error with an accuracy of 98.82%. The testing demonstrated that the smart farming system provides fairly accurate parameter data. This system offers the latest innovation to facilitate hydroponic farmers in their cultivation practices.

2. Based on the monitoring system testing, the Internet of Things (IoT) connected devices successfully transmitted and stored the data read by the sensors on the Thinger.io platform. This testing can assist farmers in remotely checking and monitoring the solution on a daily basis without physically inspecting the hydroponic garden.

3. Based on the agriculture farm system testing, the testing in weeks 1 (4.9.1) and 2 (4.9.2) showed an error percentage of 38% in the pH solution and 38.73% in the nutrient solution. This was because the R385 pump was not used to automatically supply pH up, pH down, TDS up, and TDS down solutions from the solution bottles to the main reservoir. After successfully implementing and operating the automated solution pump, this system facilitated farmers in managing the nutrient solution and pH values for hydroponic plant fertilization, which significantly accelerated the lettuce growth process.

4. The testing of power usage and load demand indicated that the solar power system could supply the load. For average, the solar panels generated a total power output of 1700.56 W, while the total load demand was 1165.74 W. Based on the testing results, it can be concluded that the power supply adequately meets the load requirements, allowing the pump to operate continuously for 24 hours.

REFERENCES

[1] Herman, N. Surantha, "Intelligent Monitoring and Controlling System for Hydroponics Precision Agriculture," *International Conference on Information and Communication Technology*, pp. 1–6, Jul. 2019, doi: 10.1109/ICoICT.2019.8835377.

[2] Nandwani, D., *Urban Horticulture*, Chapter 1, pp. 3-10, New York: Springer Cham, Jul. 2018, ISBN: 978-3-319-67016-4.

[3] Kadaba, A. M., K. Rajendra, "A Smart Farming System Using Arduino Based Technology," *International Journal of Advance Research, Ideas and Innovations in Technology*, vol. 4, no. 4, pp. 850–856, 2018, ISSN: 2454-132X.

[4] Alipio, M. I., A. E. M. D. Cruz, J. D. A. Doria, R. M. S. Fruto, "On The Design of Nutrient Film Technique Hydroponics Farm for Smart Agriculture," *Journal Engineering in Agriculture, Environment and Food*, vol. 12, no. 3, pp. 315–324, 2019, doi: 10.1016/j.eaef.2019.02.008.

[5] Drajat, M. K. R., M. N. Afif, I. Sudradjat, "Sistem Pemonitor Tinggi Air Bendungan Menggunakan Modul Wireless," *Prosiding Seminar Nasional Teknik Elektro*, vol. 4, pp. 382–387, 2019, ISSN: 2580-1988.

[6] Puno, J. C. V., J. J. I. Haban, J. D. Alejandrino, A. A. Bandala, E. P. Dadios, "Design of A Nutrient Film Technique Hydroponics System with Fuzzy Logic Control," *IEEE REGION 10 CONFERENCE*, pp. 403–408, Nov. 2020, doi: 10.1109/TENCON50793.2020.9293749.

[7] Adiimah, R. S. N., K. I. Fikri, L. Safiyah, F. Hanan, Suzanna, "Front-End Development of Nutrient Film Technique for Hydroponic Plant with IoT Monitoring

https://doi.org/10.25077/jnte.v12n2.1085.2023

System," *International Journal of Advanced Trends in Computer Science and Engineering*, vol. 9, no. 1.3, pp. 9–14, 2020, doi: 10.30534/ijatcse/2020/0291.32020.

[8] Crisnapati, P. N., I. N. K. Wardana, I. K. A. A. Aryanto, A. Hermawan, "Hommons: Hydroponic Management and Monitoring System for an IOT Based NFT Farm Using Web Technology," *International Conference on Cyber and IT Service Management*, pp. 1–6, Aug. 2017, doi: 10.1109/CITSM.2017.8089268

[9] Yakub, E. N., B. Irawan, R. E. Saputra, "System Design and Implementation Automation System of Expert System on Hydroponics Nutrients Control Using Forward Chaining Method ," *IEEE Asia Pacific Conference on Wireless and Mobile (APWiMob)*, pp. 41–46, Feb. 2017, doi: 10.1109/APWiMob.2017.8284002.

[10] Fuangthong, M., P. Pramokchon, "Automatic Control of Electrical Conductivity and PH Using Fuzzy Logic for Hydroponics System," *International Conference on Digital Arts, Media and Technology (ICDAMT)*, pp. 65–70, 2018, doi: 10.1109/ICDAMT.2018.8376497.

[11] Mufllih, M. T., G. I. Hapsari, M. I. Sari, "Sistem Otomasi Hidroponik NFT (Nutrient Film Technique) Menggunakan Sumber Energi Alternatif," *Karya Ilmiah, Universitas Telkom*, 2020.

[12] Samsurizal, M. T. Aji, K. T. Mauriraya, "Pemanfaatan Tenaga Surya Pada Photovoltaic Jenis Polycristaline Untuk Catu Daya Tanaman Hidroponik," *Energi dan Kelistrikan Jurnal Ilmiah*, vol. 13, no. 1, pp. 58–66, 2021, doi: 10.33322/energi.v13i1.984.

[13] Sampaio, P. G. V., M. O. A. Gonzalez, "Photovoltaic Solar Energy: Conceptual Framework," *Journal Renewable and Sustainable Energy Reviews*, vol. 74, pp. 590–601, 2017, doi: 10.1016/j.rser.2017.02.081.

[14] Santosa, A. N. T., S. Hani, G. Santoso, "Perancangan Sistem SOLAR PANELS Off-Grid Kapasitas 100 Wp Sebagai Sumber Energi Alternatif Charging 220 V di Daerah Terdampak Bencana Semeru," *Prosiding Seminar Nasional Aplikasi Sains & Teknologi*, pp. A35-A43, Nov. 2022, doi: 10.34151/prosidingsnast.v8i1.4102.

[15] Usman, A. Sunding, A. N. Parawangsa, "Analisis Kinerja dan Ekonomi Sistem Pompa Air Tenaga Surya Skala Laboratorium," *Jurnal Teknologi Terapan*, vol. 4, no. 1, pp. 12–18, Mar. 2018, P-ISSN: 2477-3506.