Malikussaleh Journal of Mechanical Science and Technology

P-ISSN : 2337-6945
E-ISSN : 2828-2922
Vol.9 No.1 (2025) 299-304

Implementation of IOT in the Design of Arduino-Based Solar Panel Monitoring System

Karyadi[1*], Rizki Aulia Nanda[1], Tukino[2], Ade Suhara[3], Amalia[3], Dhea Intan Patya[1], Decut Della Oganda[3]

[1]Mechanical Engineering, Faculty of Engineering UBP Karawang, Karawang, Indonesia
[2] Informatics System, Faculty of Computer Science UBP Karawang, Karawang, Indonesia
[3] Industrial Engineering, Faculty of Engineering UBP Karawang, Karawang, Indonesia
[*]Corresponding Author: karyadi@ubpkarawang.ac.id, +6285714608897

Abstract – *In order to develop literature studies on this research, solar panel monitoring systems to track the efficiency of solar energy conversion processes into electrical energy have been developed. The aim of this study was to build an IOT monitoring system on a mini solar panel to examine the impact of storing data in a microcontroller or IOT manner on the Thingspeak website. However, in this study, the same research was conducted, the difference being the use of a mini solar panel with a voltage capacity of 5v and a current of 60mA with a series or parallel assembly to obtain a voltage in the process of charging a 12 V battery and a current of 5 Ah. When using circuit design techniques, creating connectivity testing tools, data comparison, data processing, and finally the test results, data is generated in the form of voltage, current, and power. The test results show that data storage using the microcontroller is faster than data storage using the IOT, which is due to the slow wifi signal speed. The error trend between the IOT and microcontroller from 10:00 to 11:00 o'clock decreased from the difference of 0.563 watts to 0.011 watts, indicating that the storage error between the IOT and the microcontroller is not too bad.*

Keywords: *IOT System, Microcontroller, Mini Solar Panel, Sensor INA219*

1 Introduction

The demand for and supply of alternative energy have increased, and solar panel technology has now advanced to the point where it can be used for daily needs like storing energy, the advancement of solar panel technology is ongoing in order to achieve the highest level of energy input and utilization efficiency [1]. However, the current issue is that using solar panels for energy storage rarely makes use of monitoring the power, current, and voltage generated, frequently leading to battery damage and overload[2], When solar panels are installed on the roof of a home, for example, it is very difficult for homeowners to climb onto the roof and check the energy supply, which is one of the reasons why monitoring is not done. The goal of this research is to develop an IOT system for remotely monitoring solar panels, which can be done at any time as long as they are connected to the internet. The monitoring results will allow solar panel owners to see the generated current, power, and voltage. Solar panel monitoring is required to determine how much energy is generated and how much energy is entering the energy storage system[3][4]. With the IOT system, monitoring the performance of solar panels can be known whether the solar panels have problems or not[5][6], Numerous IOT monitoring solar panel developments have been created and used in academic research.

2. Literature review

Several literature studies are cited to review previous related research, IoT-based solar panels are the latest trend for monitoring lighting levels against absorbed energy, this chapter will explain the concept of the literature studies cited related to the research being developed.

Manuscript received February 2025, revised February 2025, published April 2025
Copyright © 2025 Department of Mechanical Engineering, All right reserved.
DOI : 10.29103/mjmst.v9i1.21790

2.1 Solar Panel

A solar panel, also known as a photovoltaic (PV) panel, is a device that converts sunlight into electricity. It is made up of many solar cells, usually composed of silicon, which is a semiconductor material. When sunlight hits these cells, it excites the electrons in the silicon, creating an electric current. This process is called the photovoltaic effect. Solar panels are used as a clean and renewable energy source. They are commonly installed on rooftops of houses, buildings, and in large solar farms to generate electricity for homes, businesses, and even entire communities. Look at Figure 1 which shows the concept of a solar panel according to Priyadharsini's research[7].

Figure 1. Solar Panel

2.2 Monitoring System IOT Solar Panel

The Internet of Things (IoT) enables remote monitoring systems by connecting sensors and devices to the internet, allowing real-time data collection, transmission, and analysis from distant locations. This technology allows users to monitor equipment or environments without being physically present, providing instant alerts, remote control, and automated responses based on specific conditions. IoT enhances efficiency, improves decision-making, and supports predictive maintenance by identifying potential issues early, making it valuable in various fields such as energy management, agriculture, healthcare, and industrial operations.

In the study, Shapsough and associates describe how a control system and an IOT system can cooperate to track sunlight intensity[8]. Ashwin and friends' research on the use of IOT solar panels to power automatic trash cans integrated into the IOT system to facilitate monitoring of waste levels also makes use of solar power[9]. González and friends' research explains how to quickly and accurately monitor solar panel systems that are accurate remotely by integrating all power data on solar panels into an IOT system that operates in real time[10]. The real time monitoring work system can be seen in Figure 2.

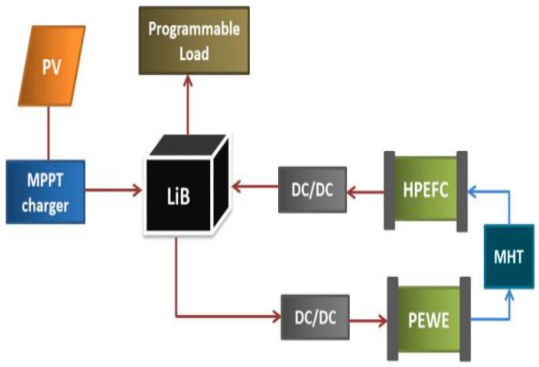

Figure 2. System tracking real time[7]

According to research by Balakrishna and Rajesh, tracking solar panels are urgently needed for some areas, so a system design was made to track and track well-lit areas using an IOT-based robotic car[11]. From the literature study that has been explained in previous research, what is related and updated in this research is tracking IOT-based solar panels with components, Mini solar panels 5 V and a current of 60mA arranged in series and parallel to produce a voltage of 10.56 V and a current of 120 mA is connected to the solar controller and stored in a battery with a capacity of 12 V 5 Ah, each circuit is paired with an INA219 current sensor for the Arduino system as a Microcontroller-based reading and ESP32 for IOT-based reading. The current system that is read on Arduino will be displayed on the 16x2 LCD and on the ESP32 it will be displayed on the Thingspeak application, the resulting data is in the form of current, voltage and generated power. The method used is; system design methods, testing methods and data collection methods.

3 Research Methods

The first method to be developed is the system design and manufacture method, in Figure 3 is a flowchart of research on system design and manufacture methods.

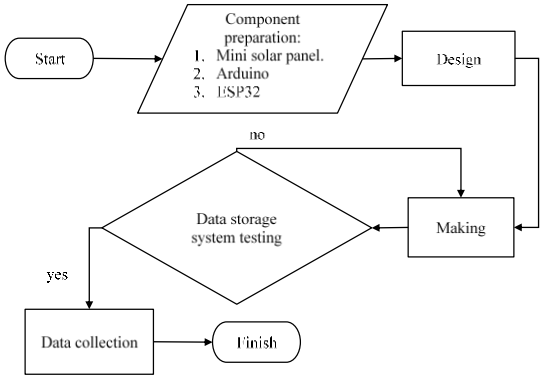

Figure 3. The flow of system design and manufacture

From Figure 3 it can be explained that the components used are in the form of a system that can

track solar panels by IOT. The components used can be seen in Table 1.

Table 1. Specifications adopted for the simulated inverter

No.	component
1	Mini Solar Panel
2	Solar Charger kontroler
3	Baterry 12v 5Ah
4	Arduino Uno
5	ESP32 Wifi
6	Sensor INA219
7	LCD 16x2

In Table 1. Are the components that will be used in developing this research, these components are available in the design design system which can be seen in Figure 4 and Figure 5. The first design is a solar panel design for battery energy storage, this design uses the fritzing application which can be seen in Figure 3.

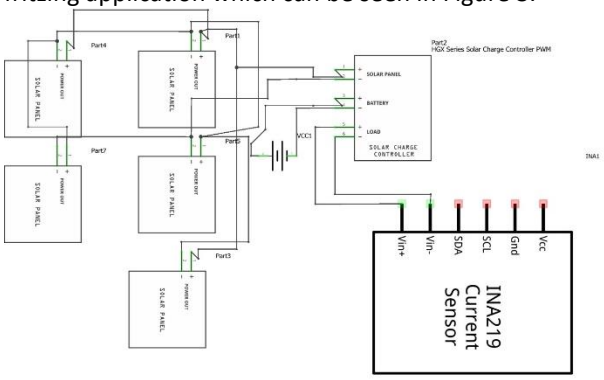

Figure 4. Solar panel system design

This system design uses a parallel circuit where the voltage is only 5 V and the current increases to 180 mA so that from this design a series circuit is installed so that the voltage is 10.58 v and the current is 180 mA. The system has a 12 v DC battery and current sensor installed. In Figure 4, is a series of IOT systems and microcontrollers.

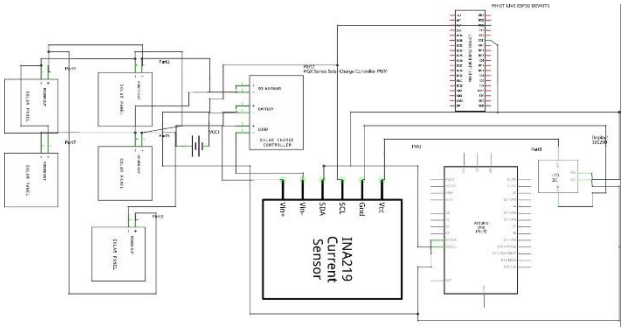

Figure 5. IOT system design

The design in Figure 5 is the overall plan. The results of the system assembly can be seen in Figure 6.

Figure 6. The result of assembling the solar panel system

The results of the assembly in Figure 5 carried out a test, the test refers to the solar panel energy absorption system for stored battery power, the microcontroller system has a good role to store and display data and the IOT system to send data to the IOT[12][13]. The testing process that can be seen in Figure 7 is the testing method.

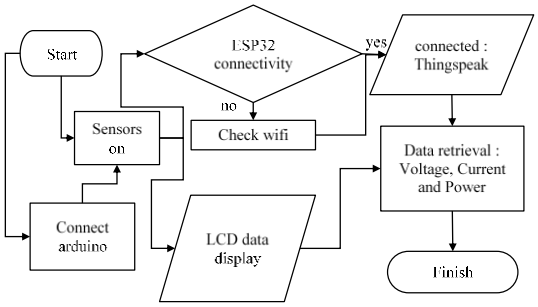

Figure 7. Test flow chart

The testing process in Figure 7 if all the system circuits are connected and can turn on properly then it starts by connecting the sensors and those connected to the ESP32 and Arduino systems, if the ESP32 system is connected then the next step is to connect to the graphical website, namely Thingspeak and if the data is entered then testing this was successful, then reviewed on the Arduino system if the 16x2 LCD system displays a voltage and current data then this test tool is successful then data retrieval is carried out by IOT and data by microcontroller. This system is called a data comparison system which is carried out to see differences in IOT data and Microcontroller data. Next is the data collection method which can be seen in Figure 8.

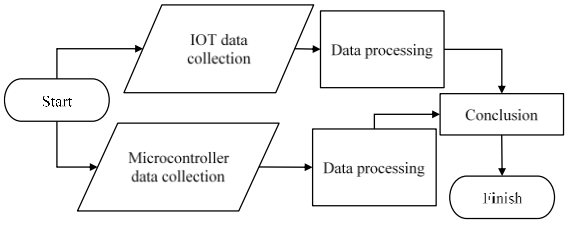

Figure 8. Data retrieval flowchart

In data processing from the diagram in Figure 7, where the equations needed are current, voltage, power and efficiency equations[14].

1. Power Equation

$$\mathrm{P} = \mathrm{VOLTAGE} \times \mathrm{AMP} \quad (1)$$

P = Power (Watt)
Voltage = Voltage (V)
Amp = Current (A)

2. Voltage Equation

$$\mathrm{VOLTAGE} = \frac{\mathrm{P}}{\mathrm{AMP}} \quad (2)$$

3. Current Equation

$$\mathrm{AMP} = \frac{\mathrm{P}}{\mathrm{VOLTAGE}} \quad (3)$$

After knowing the current, power and voltage equations in the solar panel system, efficiency calculations are also needed.

$$\mathrm{E}\% = \frac{P_{In}}{P_{Out}} \quad (4)$$

After processing data both by IOT or on the microcontroller system, a conclusion can be drawn on energy efficiency that is received, data retrieval by IOT can be seen in the Thingspeak application.

4 Results and Discussion

The test was carried out in the Buana Perjuangan University campus area, Karawang. The test was carried out for 1 hour from 10.00-11.00 to test the IOT system on solar panels in receiving data. The testing process can be seen in Figure 9.

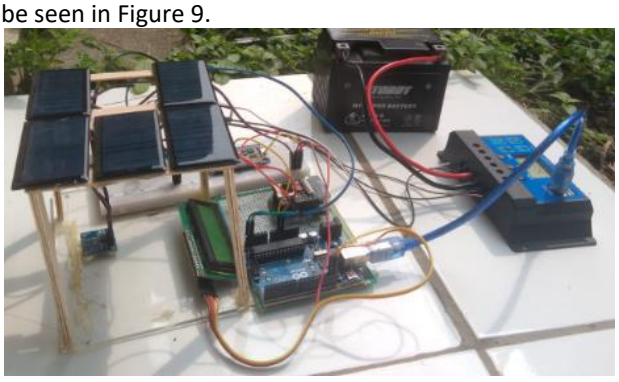

Figure 9. Testing process

In this test, the data obtained for one hour and taken every 20 seconds can be seen in Figure 10.

Figure 10. Graphic data on Arduino

From this test, it is obtained that the graphic form is displayed in a graph and can be changed in the form of numbers. Next in Figure 11 is the IOT graph data on the Thingspeak website.

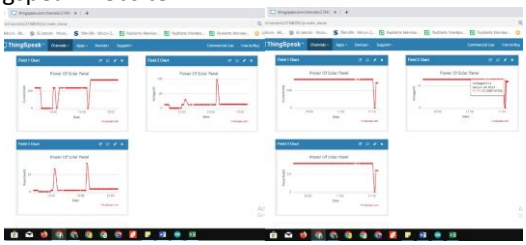

Figure 11. Graphic data on IOT

The data in Figure 11 can be downloaded in excel form and can be calculated in a comparison chart. The average test results can be seen in Table 2. Additionally, data on microcontroller and IOT data are gathered, all data collection is for 20 seconds, the average is calculated every 5 minutes, and a comparison of the data differences between microcontroller and IOT is conducted.

Table 2. IOT and Microcontroller test data

Time	Data Microcontroller			Data IOT		
	W	V	mA	W	V	mA
10.05	4,03	12,25	328,79	4,14	12,22	338,79
10.10	4,03	12,26	328,79	4,28	12,26	348,79
10.15	4,03	12,27	328,79	4,41	12,29	358,79
10.20	4,16	12,28	338,79	4,42	12,35	357,79
10.25	4,16	12,29	338,79	4,56	12,36	368,79
10.30	4,51	13,30	338,79	4,95	13,42	368,79
10.35	4,51	13,31	338,79	4,96	13,45	368,79
10.40	4,51	13,32	338,79	4,97	13,48	368,79
10.45	4,58	13,52	338,79	5,14	13,58	378,79
10.50	5,28	13,58	388,79	5,30	13,62	388,79
10.55	5,28	13,59	388,80	5,30	13,64	388,80
11.00	5,30	13,62	388,80	5,31	13,65	388,80

Table 2 shows the results of data collection by IOT and microcontroller, which was done on average once every five minutes and recorded for 20 seconds. Figure 12

shows the graph that was created from the data to show the results.

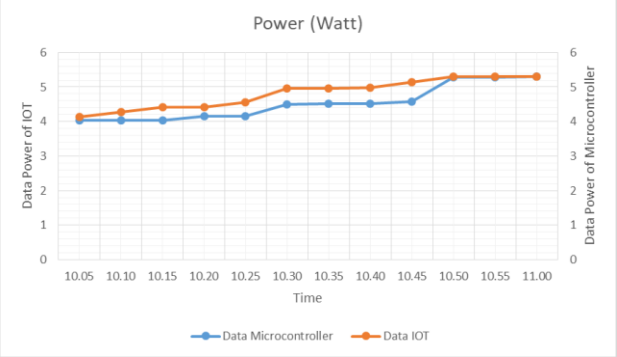

Figure 12. Graphic data Power(watt)

The power data in Figure 12 can be explained by the fact that the tests were carried out between 10:00 and 11:00 WIB, with the lowest data being 4.02 Watts for the microcontroller and 4.13 Watts for IOT storage, and the highest being 5.2 Watts for the microcontroller and 5.3 Watts for the IOT system. However, the testing from 10:00 to 10.45 shows the highest difference, with an average difference of 0.462 Watts.

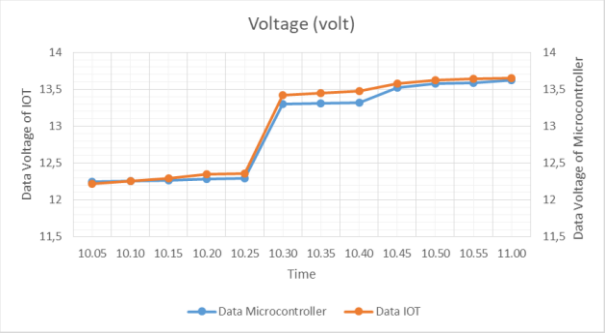

Figure 13. Graphic data Voltage(V)

The difference in error data is very small when testing the electric voltage between 10 and 11, but in this test, the lowest voltage is at 12.25 V for microcontroller data and 12.22 V for IOT data. The microcontroller and IOT data have the highest data voltages at 13.62 V and 13.65 V, respectively. the highest difference, with an average difference of 0.02 V, occurred between 10.35 and 10.40 WIB.

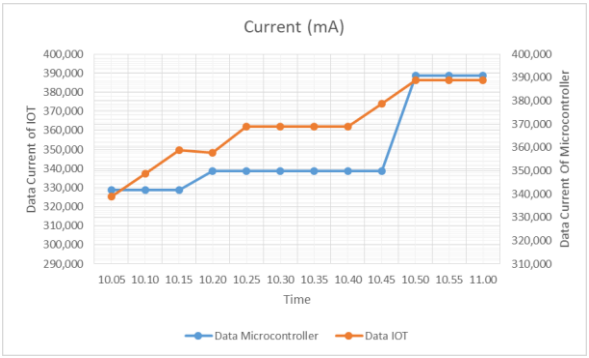

Figure 14. Graphic data Current(mA)

The current test at 10.05 was 328.785 mA on the microcontroller data and 338.785 mA on the IOT data, which is the lowest data. The highest data was 388.796 A on the microcontroller and 388.796 A on the IOT data, according to the graph in Figure 14. This means that the average difference is 2.502 mA. The difference error that occurs between 10.30 and 10.45 WIB is very high. Figure 15 shows the linear error data between IOT and Microcontroller.

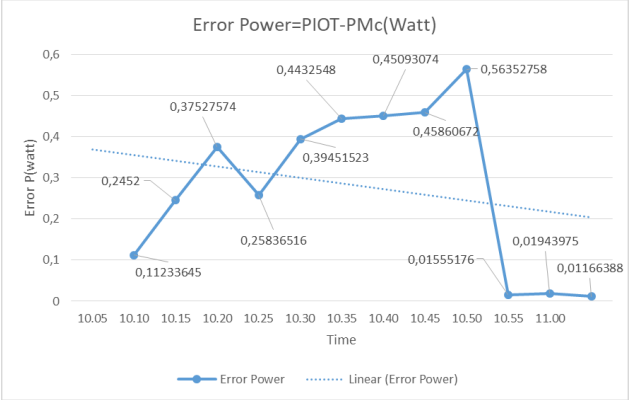

Figure 15. Graphic data of Error IOT and Microcontroller (watt)

The difference in trend errors that occur in the outcomes of data retrieval performed manually or using the Website thing speak system is observed in this test by comparing the error value between P(IOT) and P(Mc). According to the data in Figure 13, the lowest error, 0.011 W, occurred in the 11.00 hit test, and the highest error difference, 0.563 watts, were found. Based on this test, we can infer that from 10 to 11.00, the trend of errors that occur is decreasing, indicating that the testing of this tool is successful and close to what actually occurs. Here, we can see that the difference arises from differences in the incoming data between the microcontroller and the IOT method rather than from the influence of the sensor or the data reading system. The microcontroller can read incoming data more quickly than an IoT system. It can be said that the test IOT and Arduino Uno-based solar panel current is successful because of the influence of the Wifi network, which needs to be improved, and the impact of data transmission delays to the website, but the difference in errors that occur is not too high and the error trend is decreasing. Successful measurements have been made, and tracking can be done to observe how a charged power system affects a 12 V battery. The research by Liang and colleagues, whose title is "Real-time monitoring implementation of PV/ T façade system based on IoT," explains that data can be read in real time despite there being a difference between manual and IOT reading data. This test is almost identical to that research.

5 Conclusion

To create a solar panel system that can be remotely monitored at any time by displaying current, voltage, and power generated data is in line with the research's title and goal. With a capacity of 5 v 60 mA and a power supply voltage coupled with the INA219 sensor, which can read data in real time using a microcontroller system, this research creates a mini solar panel monitoring system product. The INA219 sensor is also attached to the ESP32, which is the same as the jumper process. The data was collected once every 20 seconds during the test, but on average, the data was collected once every 5 minutes. The research method only examines the microcontroller and IOT data on the thingspeak website. The objective methodology and the findings indicate that there is some degree of error between the microcontroller data and the data from the Internet of Things. The largest error is 0.011 watts, and the largest error difference is 0.563 watts. However, because the power monitoring device on the solar panel used manual measurements on the microcontroller, the results of the trend error comparison test showed that it could function properly and could be validated. Further research suggests that a good programming algorithm can be used to assess the effectiveness of the solar panel system.

Acknowledgements

We would like to thank LPPM for providing funding for this research, and thank the team of lecturers from the Mechanical Engineering, Industrial Engineering, and Information Systems departments.

References

[1] A. R. Al-Ali, A. Al Nabulsi, S. Mukhopadhyay, M. S. Awal, S. Fernandes, and K. Ailabouni, “IoT-solar energy powered smart farm irrigation system,” *J. Electron. Sci. Technol.*, vol. 17, no. 4, pp. 332–347, 2019, doi: 10.1016/J.JNLEST.2020.100017.

[2] V. Sharma and A. K. Tripathi, “A systematic review of meta-heuristic algorithms in IoT based application,” *Array*, vol. 14, no. February, p. 100164, 2022, doi: 10.1016/j.array.2022.100164.

[3] R. Nagaraju, J. T. Pentang, S. Abdufattokhov, R. F. CosioBorda, N. Mageswari, and G. Uganya, “Attack prevention in IoT through hybrid optimization mechanism and deep learning framework,” *Meas. Sensors*, vol. 24, no. June, p. 100431, 2022, doi: 10.1016/j.measen.2022.100431.

[4] R. M. Ramli and W. A. Jabbar, “Design and implementation of solar-powered with IoT-Enabled portable irrigation system,” *Internet Things Cyber-Physical Syst.*, vol. 2, no. August, pp. 212–225, 2022, doi: 10.1016/j.iotcps.2022.12.002.

[5] M. Gopal, T. Chandra Prakash, N. Venkata Ramakrishna, and B. P. Yadav, “IoT Based Solar Power Monitoring System,” *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 981, no. 3, 2020, doi: 10.1088/1757-899X/981/3/032037.

[6] R. A. Nanda, A. Arhami, and R. Kurniawan, “Perancangan Dan Pengujian Model Mobil Robot Penanam Bibit Kangkung,” *Rona Tek. Pertan.*, vol. 13, no. 2, pp. 14–28, 2020, doi: 10.17969/rtp.v13i2.16982.

[7] K. Priyadharsini, J. R. Dinesh Kumar, C. Ganesh Babu, A. Srikanth, V. Sounddar, and M. Senthamilselvan, “Elegant method to improve the efficiency of remotely located solar panels using IoT,” *Mater. Today Proc.*, vol. 45, no. xxxx, pp. 8094–8104, 2021, doi: 10.1016/j.matpr.2021.01.572.

[8] S. Shapsough, M. Takrouri, R. Dhaouadi, and I. Zualkernan, “An IoT-based remote IV tracing system for analysis of city-wide solar power facilities,” *Sustain. Cities Soc.*, vol. 57, p. 102041, 2020, doi: 10.1016/j.scs.2020.102041.

[9] J. S. Botero-Valencia, J. Valencia-Aguirre, D. Gonzalez-Montoya, and C. A. Ramos-Paja, “A low-cost system for real-time measuring of the sunlight incident angle using IoT,” *HardwareX*, vol. 11, p. e00272, 2022, doi: 10.1016/j.ohx.2022.e00272.

[10] I. González, A. J. Calderón, and F. J. Folgado, “IoT real time system for monitoring lithium-ion battery long-term operation in microgrids,” *J. Energy Storage*, vol. 51, no. March, 2022, doi: 10.1016/j.est.2022.104596.

[11] B. K and R. N, “Design of remote monitored solar powered grasscutter robot with obstacle avoidance using IoT,” *Glob. Transitions Proc.*, vol. 3, no. 1, pp. 109–113, 2022, doi: 10.1016/j.gltp.2022.04.023.

[12] A. Ahrary, M. Inada, and Y. Yamashita, “Solar power monitoring system ‘SunMieru,’” *Smart Innov. Syst. Technol.*, vol. 73, no. Ina 219, pp. 216–224, 2018, doi: 10.1007/978-3-319-59424-8_20.

[13] R. Rizki Aulia Nanda, Jati and L. A. Kurniawan, “PERANCANGAN DAN PERAKITAN ELEKTRONIKA MIKROKONTROLER BERBASIS IOT UNTUK STUDI PENGUKURAN SISTEM HVAC,” *Buana Ilmu*, vol. 7, no. 1, pp. 43–55, 2022.

[14] M. E. Yuksel and H. Fidan, “Energy-aware system design for batteryless LPWAN devices in IoT applications,” *Ad Hoc Networks*, vol. 122, no. November 2020, p. 102625, 2021, doi: 10.1016/j.adhoc.2021.102625.