Journal for Technology and Science
Homepage : https://journal.antispublisher.com/index.php/IPTEKS/index
Email : admin@antispublisher.com

e-ISSN : 3047-4337
JOTECH, Vol. 2, No. 3, July 2025
Page 30-40

Monitoring Voltage and Temperature Parameters at Smartphone Solar Charger Stations Using Google Spreadsheet

Muhamad Fakhrudin[1], Jamaaluddin[2]
[1,2]Muhammadiyah University of Sidoarjo, Indonesia

Check for updates OPEN ACCESS

DOI : https://doi.org/10.61796/ipteks.v2i2.423

Sections Info

Article history:
Submitted: September 17, 2025
Final Revised: October 20, 2025
Accepted: November 23, 2025
Published: December 16, 2025

Keywords:
Google spreadsheet
Monitoring
NodeMCU ESP8266
PZEM-004T
DHT 22

ABSTRACT

Objective: *Consumption of electronic devices, particularly smartphones, is on the rise, leading to a significant reliance on electrical energy by humans. However, the battery of your smartphone may deplete rapidly with daily usage from morning till night. To cater to individuals with high mobility and outdoor tendencies, a charging station has been developed.* ***Method:*** *This station utilizes two sensors, namely PZEM-004T and DHT 22, which are then processed by the NodeMCU ESP 8266. The NodeMCU ESP 8266 generates temperature, current, and voltage readings, which are displayed on a 20x4 LCD screen and transmitted via Google Spreadsheet.* ***Results:*** *The sensor data accuracy is impressive, with the DHT 22 sensor achieving 98.2% and the PZEM 004T sensor reaching 94.5%. Based on the test results, it can be concluded that this tool effectively facilitates monitoring during the operation of solar panels.* ***Novelty:*** *To cater to individuals with high mobility and outdoor tendencies, a charging station has been developed.*

INTRODUCTION

The rapid advancement of technology, especially in alternative energy sources, where energy is easily obtained from steam, water, wind, and geothermal power plants. Another often overlooked development in alternative energy sources is solar power. This technology is known as solar panels or solar cells. The advantage of solar energy over other forms of energy is that it does not produce pollution like steam energy from coal. By switching to solar energy, global warming can be reduced. because that energy has an unlimited and continuous supply.

The continuous increase in electricity consumption is due to the rapid development of science and technology (S&T), which makes people easily lazy and increasingly dependent on electronic devices, especially smartphones, which are communication tools [3]. Almost everyone has a smartphone for their daily activities, from morning until nite. However, smartphones require a battery to operate. For people with high mobility who are often outdoors, finding a power source is certainly difficult [4][5].

Public facilities provided by the state for the welfare of its citizens. For example, on sidewalks, many pedestrians run out of battery, but there aren't many places to put chargers at every location on the sidewalk [6]. This problem arises because there are few smartphone charging stations on the street for pedestrians, so smartphones often run out of battery [7].

Therefore, with the implementation of charging stations as a renewable and environmentally friendly energy source, it is suitable to develop the use of solar power to make it easier for pedestrians on the sidewalk to access the charging station. With this research, business owners can monitor the health conditions of the charging station, including voltage, current, and the battery on the solar panel [8][9]. Several previous studies have been conducted on charging station devices, such as the research by Ragil Putra Ardhiansyah (2022), where the researcher built a system to address the very vulnerable or unfavorable weather conditions for capturing sunlight, creating equipment to monitor the constraints on solar panels and the efficiency levels of temperature, humidity, and sunlight intensity using DHT 11 and LDR sensors to increase the effectiveness of the solar panel to 7.5% [10]. Then, research by Mochhamad Aji Prasetyo (2021) utilized a tracking system for solar panels, allowing sunlight to be captured comprehensively by following the sun's path from morning to evening. Using the INA 219, BHT 1750, and MPU6050 sensor devices, this system is connected to IoT and displayed on the thinger.io website [11].

Research by Sulthan Shidqi (2021) designed this system using a 50wp off-grid solar panel system with an Arduino UNO microcontroller and an I2C display to show the current and voltage values generated by the solar panel, as well as a battery for power storage connected to a stepdown module so that current can flow out [12]. Recent research by Mochamad Adi Darmawan (2022) involved the creation of this device to monitor and measure the output parameters of solar panels, including voltage, current, and charging status on an LCD, using an Arduino UNO as the microcontroller and an ACD712 sensor module as the maximum current limit of 5A [13].

Current research is attempting to provide updates in the form of innovations to solar panels by utilizing Internet of Things technology obtained thru the application of the NodeMCU ESP8266 microcontroller, enabling faster message transmission so that disruptions can be addressed immediately [14].

Researchers used the PZEM-004T sensor module and DHT22 to read temperature, humidity, current, and voltage values, and then an I2C 20x4 LCD device was used as a display to view the measurement results on-site. Sensor reading data is sent to a Google Spreadsheet server so that it can be monitored in real-time by users via smartphone.

RESEARCH METHOD

The research utilizes a research and development method by testing the effectiveness of the tool thru various experiments, improvements, and finalization of the tool in order to overcome the problems faced and achieve the final goal where the product functions according to the research objectives [15]. The stages in the research and development method are problem identification (1); literature review (2); design (3); testing (4); improvement (5); and implementation (6).

A. Block diagram

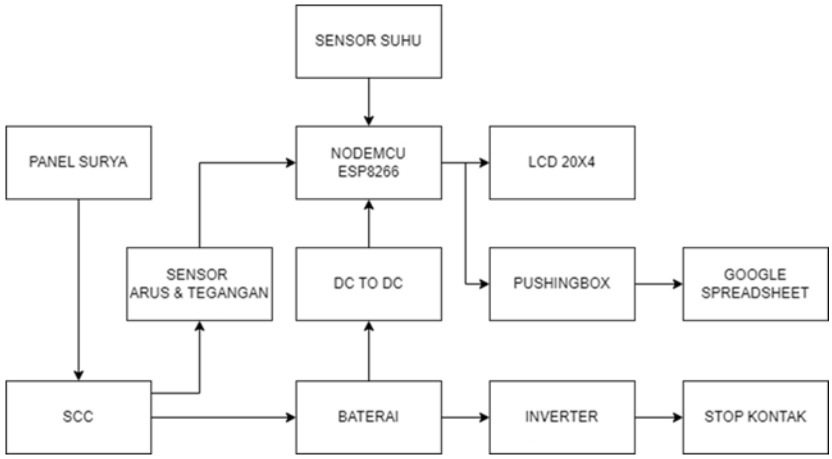


Figure 1. Block Diagram.

The research uses solar panels connected to an SCC (solar charger controller) to distribute power to a 12V battery. There are also sensor inputs, including two PZEM-004T sensors to detect current and voltage values, and a DHT 22 sensor for humidity and temperature readings in the room. The reading values from the three sensors are then processed by the NodeMCU ESP8266. The output components used in this study are a 20x4 I2C LCD as the main display and data is sent to Google Sheets as a real-time remote monitoring device on the tool.

B. Flowchart

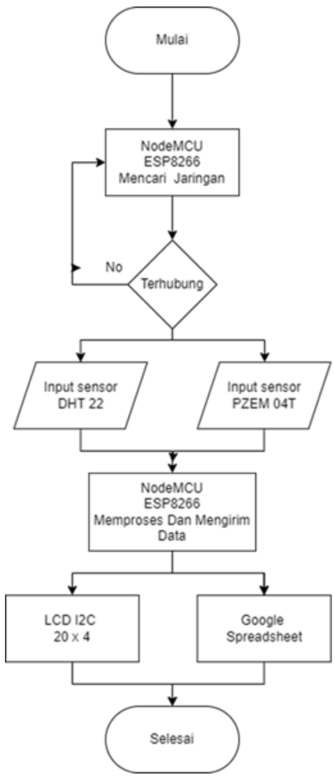


Figure 2. Flowchart.

The tool's flowchart begins by ensuring the NodeMCU ESP8266's connection to the internet via Wi-Fi is working correctly. This is followed by reading the temperature, humidity, current, and voltage data values from two PZEM-004T and DHT 22 sensors. If the sensor readings are successful, the 20x4 I2C LCD will display the temperature, humidity, current, and voltage data values to the user and Google Sheets in real-time.

C. Wiring Diagram

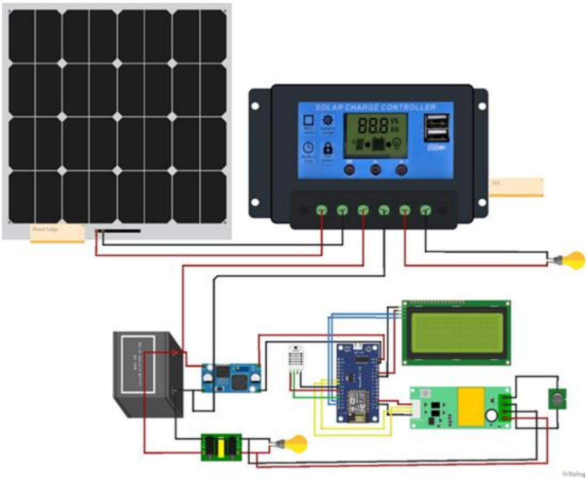


Figure 3. Wiring Diagram.

The wiring diagram for this device is as follows: LCD I2C 20 x 4 pins, SDA is connected to pin D2, and SCL is connected to pin D1 of the NodeMCU ESP8266. Then, pin 2 of the DHT 22 temperature sensor is connected to pin D3, and pin 2 of the PZEM 04T current and voltage sensor is connected to pin D5. Pin 3 is connected to pin D6 of the NodeMCU ESP8266. The outputs of these sensors, pins 1 and 2, are connected to the load, and pins 3 and 4 are connected to the current transformer (CT). The solar panel VCC and GND are connected to the Solar Charger Controller (SCC) at pins 1 and 2. The output from pins 3 (VCC) and 4 (GND) is then connected to a 12V battery, stepped down to 5V, and connected to the VCC of the NodeMCU ESP8266.

RESULTS AND DISCUSSION

A. Solar panel charging test

The solar panel testing was conducted to determine the magnitude of the charging value regulated using a solar charge controller (SCC) and then transmitted to the 12V battery.

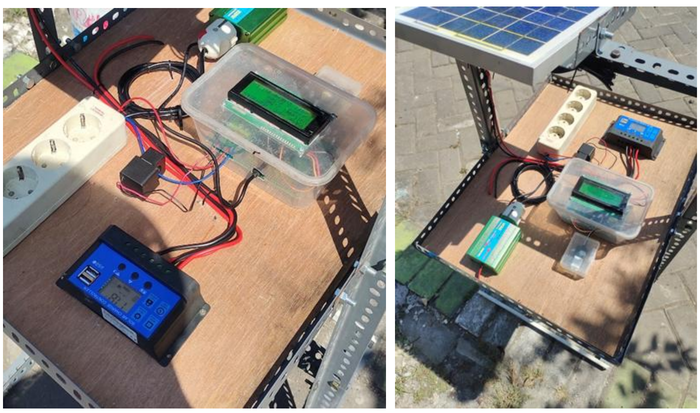


Figure 4. Charging Process on Solar Panels.

In this research, different conditions were observed where the weather was sunny and cloudy, in order to determine the difference in voltage charging under those conditions. The results of the test can be summarized in the following table.

Table 1. Battery Charging Test.

Test No.	Voltage (Sunny Weather)	Voltage (Cloudy Weather)
1	13.50 V	12.00 V
2	13.54 V	12.04 V
3	13.60 V	12.10 V
4	13.69 V	12.12 V
5	13.90 V	12.15 V
Average	13.709 V	12.024 V
SD	0.12	0.02

Therefore, it can be concluded from the table above that there are differences in values under clear weather conditions, with better voltage reaching 13VDC, while under cloudy weather conditions, the voltage produced is less favorable.

B. Battery Endurance Testing

Battery endurance testing can be calculated and performed using a 12V car battery. The battery voltage read was 13.90V, which means the 12V battery is considered low voltage. If the battery voltage is known to be 13.90V with a battery capacity of 2 x 3.5Ah, what is the battery endurance value?

Battery capacity = 13.90 x 2 x 3.5 = 97.3 Wh (watt per hour) Control circuit power = 12.4V x 2A = 24.8 Watts Battery endurance = 97.3 Watts / 24.8 Watts = 4 Hours Therefore, based on the calculations, the battery can support the control circuit for a duration of 4 hours when fully charged. However, to keep the condition from deteriorating quickly, it is limited to 50% capacity to prevent the battery from degrading rapidly.

Table 2. Battery Life Testing.

Test No.	Battery Capacity	Battery Endurance	Measured
1	100%	4 hours	13.90
2	75%	2 hours	13.05
3	50%	1 hour	12.09
4	25%	0 hours	11.0

The battery can last for 4 hours on a full charge at 13.90 Volts, and its power will gradually decrease until it reaches 11.0 Volts.

C. DHT 22 Sensor Testing

The DHT 22 sensor was tested to determine the accuracy of its readings in detecting temperature and humidity at room temperature. The DHT 22 sensor was tested five times. The sensor was tested by connecting it to the NodeMCU ESP8266. A good error value level is below 10%. To obtain the % error value, it is calculated using the equation:

%error = (|sensor reading value - measuring instrument reading value|)/(measuring instrument reading value) x 100%

Figure 5. DHT 22 Sensor Testing Process.

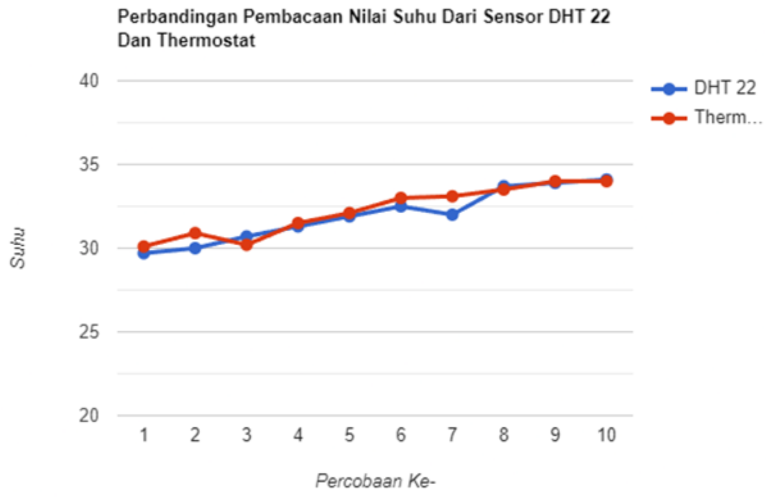
Table 3. DHT 22 Temperature Value Measurement Testing.

Test No.	DHT 22 Sensor	Thermostat	Difference	Measurement Error (%)
		DHT 22		
1	29.7	30.1	0.4	0.17
2	30.0	30.9	0.9	0.40
3	30.7	30.2	0.5	0.19
4	31.3	31.5	0.2	0.08
5	31.9	32.1	0.2	0.08

Table 4. DHT 22 Humidity Value Measurement Testing.

Test No.	DHT 22 Sensor	Thermostat	Difference	Measurement Error (%)
		DHT 22		
1	79.7	80.1	0.4	0.17
2	75.9	76.3	0.4	0.17
3	73.2	73.7	0.5	0.19
4	72.0	73.6	0.6	0.25
5	70.3	71.5	0.2	0.08

Tables 3 and 4 show a comparison of temperature readings from the DHT 22 temperature sensor against standard thermostat readings. The results showed that the PZEM-004T sensor had an average error of 0.20%, 0.28%, and 0.16% for temperature. The implication of these test results is that the PZEM-004T sensor is considered reliable for measuring temperature values around the room.



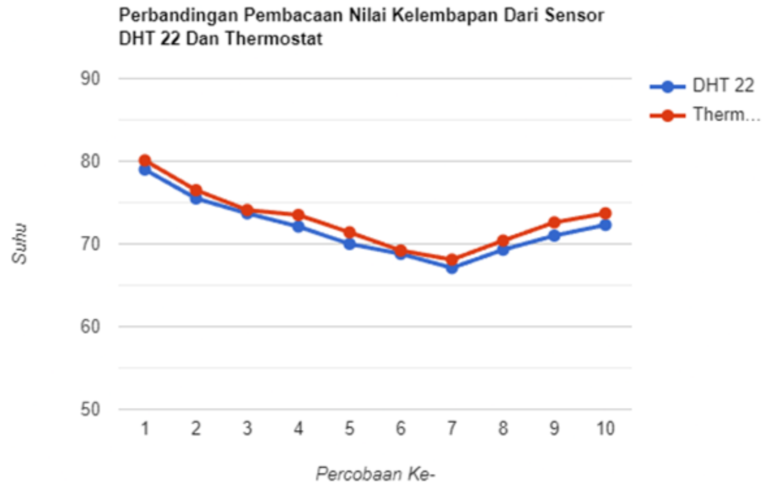


Figure 6. Comparison Graph of Temperature and Humidity Readings from DHT 22 Sensor vs. Thermostat.

The graph above illustrates a comparison of readings between the DHT 22 sensor and a standard thermostat, showing almost identical results.

D. Testing the readings from the PZEM-004T sensor

The PZEM-004T sensor was tested to determine the accuracy of the sensor's readings in detecting current values at the power outlet. The standard current measurement tool used as a comparator is the Dekko multimeter. The testing was conducted five times for each of the three PZEM-004T sensors.

Table 5. Voltage Value Measurement Testing of the PZEM-004T Sensor Table 6. PZEM-004T Voltage Value Measurement Testing.

Test No.	PZEM-004T Sensor (V)	Multimeter Value (V)	Difference (V)	Measurement Error (%)
		PZEM-004T		
1	234.7	234.3	0.4	0.17
2	230.9	231.4	0.5	0.17

3	229.5	229.7	0.2	0.08
4	228.6	229.0	0.4	0.17
5	225.3	225.9	0.6	0.25

Table 6. Testing the Voltage Value Measurement of the PZEM-004.

Test No.	PZEM-004T Sensor (A)	Multimeter Value (A)	Difference (A)	Measurement Error (%)
		PZEM-004T		
1	0.6	0.7	0.1	11.1
2	0.8	0.8	0	0
3	0.9	1.0	0.1	9.09
4	1.0	1.1	0.1	11.1
5	1.0	1.2	0.2	16.6

Tables 5 and 6 show a comparison of current reading values from the PZEM-004T sensor and a standard multimeter. The results indicate that the PZEM-004T shows an average error of 7.56%, 9.37%, and 9.97% for each PZEM-004T installed on the load in the outlet. The implication of these test results is that the PZEM-004T sensor is considered reliable for measuring current and voltage values on a load.

Figure 6. Comparison Graph of PZEM-004T Sensor Current Readings with Multimeter.

The graph above illustrates a comparison of readings between the PZEM-004T sensor and a standard multimeter, showing fairly close results.

E. Testing the 20x4 I2C LCD

Testing the 20x4 I2C LCD was conducted to ensure that the data from the PZEM-004T and DHT 22 sensor readings could be displayed correctly and read clearly by the user. The test results showed that the 20x4 I2C LCD could display 4 lines of text and numerical data. All reading numbers were displayed in decimal form.

Figure 7. I2C 20x4 LCD Display.

F. Testing Data Transmission to Google Sheets

Testing the transmission of instrument reading data to Google Sheets is intended to determine the delay between reading time and transmission.

Table 7. Data Delivery Testing to Google Spreadsheet.

Test No.	Data Condition	Waiting Time (s)	Response Speed
1	Sent	1.5	FAST
2	Sent	1.4	FAST
3	Sent	1.8	MEDIUM
4	Sent	1.9	MEDIUM
5	Sent	2.0	MEDIUM
6	Sent	1.4	FAST
7	Sent	1.3	FAST
8	Sent	1.4	FAST
9	Sent	1.8	MEDIUM
10	Sent	1.9	MEDIUM
Average delay		1.67	

Table 7 shows the average delay between the instrument reading displayed on the 20x4 I2C LCD and the data reception from Google Spreadsheet is 1.67 seconds, which is considered fast, making it easy for users to obtain real-time data with sufficient accuracy.

CONCLUSION

Fundamental Finding : The solar panel system at the outdoor charging station aims to allow more users to charge their smartphones without having to go to a cafe or similar establishment. The solar panel charging indicates that the battery can last for 4 hours to run the DHT 22 temperature sensor and the PZEM 004T sensor for as long as possible. **Implication :** The solar panel system at the outdoor charging station aims to allow more users to charge their smartphones without having to go to a cafe or similar establishment. This provides an alternative for individuals who require outdoor charging solutions and could improve access to energy in outdoor or public spaces, enhancing user convenience and independence from traditional charging stations. **Limitation :** Although the system operates optimally according to the research objectives, there are still small values of 9.94% for current and 0.27% for voltage, indicating a need for more accurate sensor usage to match field readings. **Future Research :** Future research may focus on improving the accuracy of the sensors used in this system. Exploring more precise sensors and testing them under different environmental conditions could further enhance the reliability of the system in providing accurate data, especially in outdoor settings where sensor calibration can be challenging.

ACKNOWLEDGEMENTS

The author is very grateful to their classmates and lecturers from the Electrical Engineering Department of Muhammadiyah University of Sidoarjo for their guidance throughout the research process and report writing, which allowed the project to be completed successfully.

REFERENCES

[1] M. A. Prasetyo and H. K. Wardana, “Rancang Bangun Monitoring Solar Tracking System Menggunakan Arduino dan Nodemcu Esp 8266 Berbasis IoT,” Resist. Elektron. Kendali Telekomun. Tenaga List. Komput., vol. 4, no. 2, p. 163, Nov. 2021, doi: 10.24853/resistor.4.2.163-168.

[2] R. S. Poliyama, F. E. P. Surusa, and R. K. Abdullah, “Rancang Bangun Alat Sistem Monitor Lampu Jalan Umum Tenaga Surya Berbasis Teknologi Lo - Ra,” Jambura J. Electr. Electron. Eng., vol. 3, no. 2, pp. 34–40, Jul. 2021, doi: 10.37905/jjeee.v3i2.10202.

[3] M. A. D. Adi, A. Lomi, and I. Budi Sulistiawati, “Penggunaan Arduino pada Pengendali Pengisian Baterai Panel Surya,” Pros. SENIATI, vol. 6, no. 3, pp. 608–618, Jul. 2022, doi: 10.36040/seniati.v6i3.4844.

[4] R. Kango, H. Hadiyanto, S. Suhaedi, and I. Ihsan, “Pemanfaatan Solar Cell Sebagai Sumber Energi Alternatif Untuk Fasilitas Bangku Taman Ruang Terbuka Hijau,” Literasi J. Pengabdi. Masy. Dan Inov., vol. 1, no. 1, pp. 50–55, Feb. 2021, doi: 10.58466/literasi.v1i1.18.

[5] M. A. Darmawan, “Rancang Bangun Mppt Charger Controller Untuk Implementasi Solar Cell Berbasis Arduino,” Undergraduate Thesis, Institut Teknologi Nasional Malang, Malang, 2022.

[6] F. I. Pasaribu and M. Reza, “Rancang Bangun Charging Station Berbasis Arduino Menggunakan Solar Cell 50 WP,” J. Tek. Elektro, vol. 3, no. 2, 2021.

[7] R. Firanda and M. Yuhendri, “Monitoring State Of Charge Accumulator Berbasis Graphical User Interface Menggunakan Arduino,” JTEIN J. Tek. Elektro Indones., vol. 2, no. 1, pp. 11–16, Jan. 2021, doi: 10.24036/jtein.v2i1.95.

[8] S. Wahyu, M. Syafaat, and A. Yuliana, “Rancang Bangun Sistem Monitoring Pertumbuhan Tanaman Cabai Menggunakan Arduino Bertenaga Surya Terintegrasi Internet of Things (IoT),” J. Teknol., vol. 8, no. 1, pp. 22–23, Dec. 2020, doi: 10.31479/jtek.v1i8.63.
[9] D. Kartikasari, R. Gazali, and M. S. Fatah, “Rancang Bangun Alat Pakan Ikan Otomatis Berbasis Catuan Panel Surya,” J. Elektro Inform., vol. 03, no. 01, 2023.
[10] R. P. Ardhiansyah and N. Kholis, “Rancang Bangun Alat Monitoring Gangguan Pada Panel Surya Menggunakan NodeMCU Berbasis Website,” Indones. J. Eng. Technol. INAJET, vol. 5, no. 1, 2022.
[11] S. Shidq, “Desain Sistem Charging Station Untuk Smartphone Sebagai Fasilitas Publik Menggunakan Panel Surya Off-grid,” E-Proceeding Eng., vol. 8, no. 5, 2021.
[12] D. Samodrawati and L. I. Santoso, “Rancang Bangun Stasiun Pengisian Daya Bateai Samrtphone Berbasis Panel Surya,” in TREnD - Technology of Renewable Energy and Development, 2022.
[13] S. D. Ayuni, S. Syahrorini, and J. Jamaaluddin, “Sosialisasi Aplikasi Monitoring Keamanan Tanggul Lapindo via Smartphone di Desa Gempolsari,” Jurnal Abdimas PHB : Jurnal Pengabdian Masyarakat Progresif Humanis Brainstorming, vol. 5, no. 1, pp. 154–161, Jan. 2022, doi: 10.30591/japhb.v5i1.2717.
[14] S. Haji, A. Ahfas, S. Syahrorini, and S. D. Ayuni, “Leakage Warning System and Monitoring Lapindo Sidoarjo Mud Embankment Based on Internet of Things,” Indonesian Journal of Artificial Intelligence and Data Mining, vol. 7, no. 1, pp. 57–63, Nov. 2023, doi: 10.24014/ijaidm.v7i1.25269.
[15] J. Pramana, D. H. R. Saputra, and S. Syahrorini, “Design of Speed Limiter Display For Uwin Fly Electric Bike Based on Internet of Things:,” Procedia of Engineering and Life Science, vol. 4, Jul. 2023, doi: 10.21070/pels.v4i0.1415.

Muhamad Fakhrudin
Muhammadiyah University of Sidoarjo, Indonesia

***Jamaaluddin (Corresponding Author)**
Muhammadiyah University of Sidoarjo, Indonesia
Email: jamaaluddin@umsida.ac.id