Techno.Com, Vol. 24 No. 3, August 2025: 999 – 1011

Internet of Things Based Solar Battery Monitoring System

Annisa Tyas Muzazanah[1], Freddy Artadima Silaban*[2]
[1,2]Department of Electrical Engineering, Universitas Mercu Buana, Jakarta, Indonesia
E-mail : [2]freddy.artadima@mercubuana.ac.id
**Corresponding author*
Received 4 July 2025; Revised 31 July 2025; Accepted 8 August 2025

Abstract - There are two factors in the solar panel system that affect battery life, namely the battery discharge factor and the environmental factor temperature which the battery is placed in. The battery is damaged quickly if it is empty for a long time. The application of solar cells is widely used in street lighting and office buildings. However, in several research, it was observed there were deficiencies, namely both current and voltage measurements were still carried out manually using a multimeter so that the data taken had not been recorded continuously. The purpose of this research is to design the Solar Panel System Battery Telemetry to be a solution and to solve the problem of knowing the battery condition is monitored regularly. This system uses ESP32 as an IoT-based microcontroller that is connected to the internet. The website is used to display data from the output of a solar panel battery. Based on the results of the analysis and testing that has been carried out, the design system can run according to the initial concept and can record the current, voltage, and temperature in real-time resulting from the performance of the solar panel system. The results of measurements on 10 wp solar panel with an average power of 7.32 watts with a maximum current of 0.6 A and presentation of a solar panel efficiency of 0.82%. The use of solar panel system batteries with a power requirement of 9 Watt 12V (lamp load) does not experience losses during the charging process.

Keywords - Battery, Solar Panel, Internet of Things, Real Time, Website

1. INTRODUCTION

The utilization of solar energy as a source of electrical energy can be generated using photovoltaic panels or concentrating solar rays. With the limited availability of fossil energy sources as a producer of electrical energy, it has encouraged research and development towards the use of alternative energy sources, one of which is solar energy sources. Many electronic devices use solar panel energy sources which are stored in batteries[1]. Solar cells are very effective for use in equatorial areas, which are areas with high sources of sunlight[2][3].

Solar cells are widely used in everyday life including main street lighting, office buildings, and housing[4]. However, the energy system that uses solar cells has a drawback, namely the use of a limited battery[5][6]. The problem with battery life is usually due to unmonitored battery usage so that with continuous use the battery will empty without being noticed[7-10]. Additionally, temperature and humidity can affect battery life. If the battery is damaged, the solar system does not work[11-13], where the battery functions to store electrical energy generated from the solar cell[14][15]. Therefore it is necessary to monitor [16] the use of batteries in solar power plants so that the use of power and current in solar cells can be monitored periodically[17][18]. If a problem occurs in the system it can be detected from a damaged battery, as usual, the use of current and power in the battery can be observed via the internet from a long distance because direct monitoring at the generator site is less efficient[19-21]. One of the concepts that can support remote monitoring is the Internet of Things (IoT)[22-26].

This research builds upon previous implementations of solar power systems by integrating a real-time IoT-based monitoring platform for solar batteries, which addresses the

e-ISSN : 2356-2579 | p-ISSN : 1412-2693, DOI :10.62411/tc.v24i3.13499

limitation in previous systems that still rely on manual measurements without continuous data recording [1][4][7][10][13]. Based on our literature review of over 20 relevant studies, there is a clear research gap in integrating low-cost, real-time telemetry systems using ESP32 and dual INA219 sensors for simultaneous current-voltage monitoring at both the solar panel and battery ends. This study contributes by providing a complete telemetry architecture (hardware, software, and web-based dashboard), with performance evaluation over multiple days and weather conditions. The novelty lies in its holistic approach using open-source tools, real-time monitoring, web interface, and autonomous battery status management (relay control) to improve battery efficiency and reliability.

2. RESEARCH METHOD

2.1. System Specifications

System planning in the form of block diagrams is required before making a system that includes hardware and software.

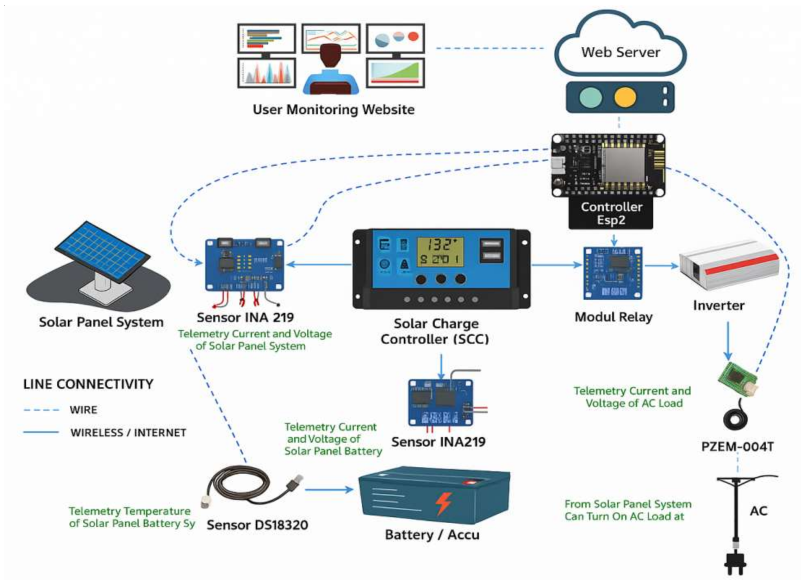


Figure 1. Architecture of solar panel system telemattery batteries

The voltage and current data collection use the INA219 sensor. The INA219 sensor is a sensor for measuring voltage, current, and power that are easily available on the market. Also, the INA219 sensor is a sensor compatible for use on the ESP32. In addition to the INA219 sensor, another sensor used is the PZEM-004T sensor which has more or less the same function, only this sensor is used for AC loads. Meanwhile, the temperature data collection uses the DS18b20 sensor. From the system that has been designed, Esp32 functions as a microcontroller equipped with a Wifi module that will receive data from the sensor, after the data is obtained, the data is sent to the server. On the server part, coding has been made so that the program code sent by Esp 32 can be read and stored in the database, then after being stored it is immediately displayed on a web page so that it can be accessed by users via a web browser.

2.2. Electrical Design

The choice of the Offgrid type Solar Panel System is because this type of Solar Panel System is best suited to a system that is made of either a monitoring system. There are 3 sensors used to determine the condition of the Solar Panel System, namely INA219 which functions as a measure of the output value of the battery, both voltage and current values because the INA219

e-ISSN : 2356-2579 | p-ISSN : 1412-2693, DOI :10.62411/tc.v24i3.13499

sensor is a sensor that is specialized for measuring the voltage and current of DC electricity, DS18B20 which functions as a gauge temperature conditions of the battery environment and the PZEM-004T Sensor to measure the voltage and current in AC loads. The design of the Solar Panel System is shown in Figure 2.

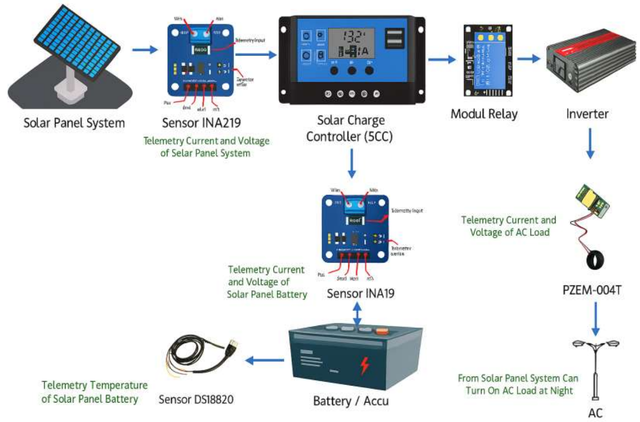


Figure 2. Electrical Design

2.3. Current and Voltage Sensor Circuit Design

This circuit functions as a measure of the output value of the battery, both the voltage value and the current value, because the INA219 sensor is a sensor that is specialized for measuring the voltage and current of DC electricity. Figure 3 explains how the connection between the ESP32 and the INA219 sensor on the system is made.

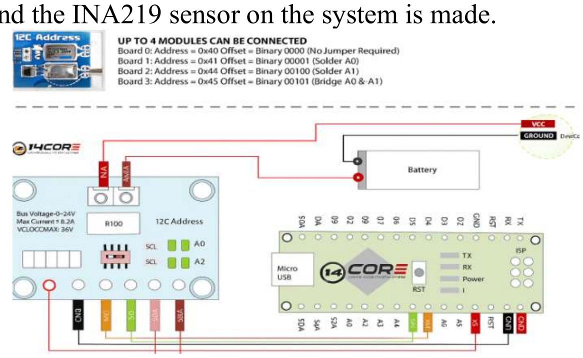


Figure 3. Electrical System Between ESP32 and Voltage Current Sensor

2.4. Temperature Sensor Electrical Circuit

This circuit functions as a measure of the temperature conditions of the battery environment. Figure 4 explains how the connection between the ESP32 and the DS18B20 sensor on the system is made.

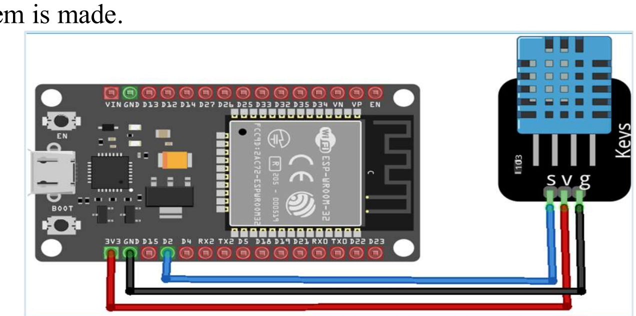


Figure 4. Electrical System between ESP32 and DS18B20 Temperature Sensor

e-ISSN : 2356-2579 | p-ISSN : 1412-2693, DOI :10.62411/tc.v24i3.13499

2.5. Website Design

The media used in the monitoring system is web-based, there are 2 parts of this website, namely the first part of the database and the second part of the web page. The database used is MySQL, the database functions as a data store from sensors, while the web page functions to display data stored in the database so that it is easy for the user to read. This first display will be directed to the HOME menu because this menu is a web page that displays the latest monitoring values. In the HOME menu, there are 4 data values displayed, namely Voltage in V, current in mA, and temperature where the battery is stored in ° C.

2.6. Software Design

This design starts with charging the battery using a solar panel system with an SCC controller. The battery connected to the SCC will activate the ESP 32 which then waits for the internet network connection to be transmitted through the website interface. When connected to the internet, ESP 32 directly processes the voltage and current measurement parameter data from the INA219 sensor. In designing this solar panel system battery telemetry uses 2 INA 219 sensors where one sensor is for current and voltage telemetry from the solar panel system and the other sensor is for telemetry current and voltage from the battery or Accumulator. The solar energy obtained is stored in a battery which can convert chemical energy into electrical energy.

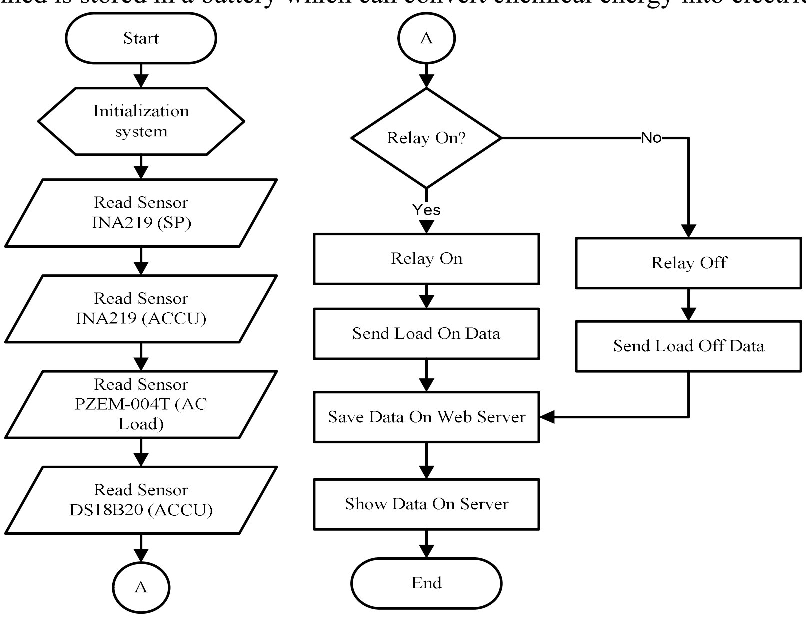


Figure 5. System Work Process Design

When the battery in the charging condition, it is fully charged with a voltage above 12 V, the user can control the on-off relay module which works to turn on the lamp load that was previously converted by the inverter to an AC load. The battery status on the website interface will change to Normal Battery. And when the battery voltage is less than 12 V, the battery status on the website interface changes to Battery Low. The parameter value of the AC load is also monitored on the website with the help of an AC Voltage Current sensor, namely the PZEM-004T sensor. The value of electrical energy stored in the battery or Accumulator and current and voltage parameters from the solar panel system to the AC load can be seen in real-time by the Internet of Things based users using the Website interface

e-ISSN : 2356-2579 | p-ISSN : 1412-2693, DOI :10.62411/tc.v24i3.13499

3. RESULTS AND DISCUSSION

3.1. 10 WP Solar Panel Implementation

This test is conducted to determine the characteristics of the solar panel against the output current and voltage on the solar panel. In designing a Solar Panel System battery, it receives input in the form of light which is converted into electrical energy. This test is carried out by placing solar cells under the sun exposure for approximately 8 hours of exposure from morning to evening so that the measurement results are obtained in the table in time units (seconds).

Table 1. Solar panel test results

15 Second to	Vsp (V)	Isp (A)
1	11.44	0.3
2	11.55	0.3
3	11.39	0.3
4	11.85	0.3
5	11.72	0.3
6	11.72	0.3
7	11.85	0.3
8	11.72	0.3
9	11.7	0.3
10	11.71	0.3
11	11.69	0.3
12	11.7	0.3
13	11.45	0.3
14	11.29	0.3
15	11.26	0.3
16	11.56	0.5
17	11.84	0.5
18	11.42	0.5
19	12.33	0.5
20	12.24	0.5
21	12.32	0.5
22	11.77	0.5
23	12.15	0.5

15 Second to	Vsp (V)	Isp (A)
24	11.96	0.5
25	12.3	0.5
26	12.31	0.5
27	12.21	0.5
28	12.15	0.5
29	11.96	0.5
30	12.3	0.5
31	12.55	0.6
32	12.34	0.6
33	11.88	0.6
34	12.31	0.6
35	12.34	0.6
36	12.31	0.6
37	12.13	0.6
38	12.21	0.6
39	12.31	0.6
40	12.3	0.6
41	11.96	0.6
42	12.15	0.6
43	11.77	0.6
44	12.32	0.6
45	12.24	0.6

Solar cells in this Solar Panel System battery use Polycrystalline or polysilicon solar cells. Based on the testing phase, this type of solar cell is capable of producing a voltage between 11 volts-13 volts DC with a maximum current of 0.6 A. The test results obtained are the results of tests carried out during the day with sufficient sunlight intensity, this proves that the amount of voltage generated by solar cells depends on the intensity of sunlight at that time.

e-ISSN : 2356-2579 | p-ISSN : 1412-2693, DOI :10.62411/tc.v24i3.13499

3.2. Implementation of INA219 Sensor Testing 10 wp Solar Panel

INA 219 sensor analysis by taking the value of the voltage and current on the Solar Panel System. Tests were carried out to find out how long it would take for a 12 V 9 AH capacity battery and this observation was IoT-based or could be accessed via the website so that the data obtained would be displayed as many as 15 real-time historical data updated for 30 seconds. Observation data on the time of charging carried out in the morning to noon starting at 07.00 until the battery is full. The data collection was carried out three times or three days. The following are the Observation Results on first daya shown in table 2, the second day shown in table 3, and the third day shown in table 4.

Table 2. First day solar panel observation results

First Day				
15 Seconds to	**Vsp (V)**	**Isp (A)**	**Weather**	**Vsp X Isp (Watt)**
1	11.44	0.3	Cloudy	3.43
2	11.55	0.3	Cloudy	3.47
3	11.39	0.3	Cloudy	3.42
4	11.85	0.3	Cloudy	3.56
5	11.72	0.3	Cloudy	3.52
6	11.72	0.3	Cloudy	3.52
7	11.85	0.3	Cloudy	3.56
8	11.72	0.3	Cloudy	3.52
9	11.7	0.3	Cloudy	3.51
10	11.71	0.3	Cloudy	3.51
11	11.69	0.3	Cloudy	3.51
12	11.7	0.3	Cloudy	3.51
13	11.45	0.3	Cloudy	3.44
14	11.29	0.3	Cloudy	3.39
15	11.26	0.3	Cloudy	3.38
Total Power that goes to the Solar Panel				52.21
Average power per 15 seconds				3.48

Table 3. Second day solar panel observation results

Second Day				
15 Seconds to	**Vsp (V)**	**Isp (A)**	**Weather**	**Vsp X Isp (Watt)**
1	11.56	0.5	Bright	5.78
2	11.84	0.5	Bright	5.92
3	11.42	0.5	Bright	5.71
4	12.33	0.5	Bright	6.17
5	12.24	0.5	Bright	6.12
6	12.32	0.5	Bright	6.16
7	11.77	0.5	Bright	5.89
8	12.15	0.5	Bright	6.08

e-ISSN : 2356-2579 | p-ISSN : 1412-2693, DOI :10.62411/tc.v24i3.13499

Second Day				
15 Seconds to	**Vsp (V)**	**Isp (A)**	**Weather**	**Vsp X Isp (Watt)**
9	11.96	0.5	Bright	5.98
10	12.3	0.5	Bright	6.15
11	12.31	0.5	Bright	6.16
12	12.21	0.5	Bright	6.11
13	12.15	0.5	Bright	6.08
14	11.96	0.5	Bright	5.98
15	12.3	0.5	Bright	6.15
Total Power that goes to the Solar Panel				90.41
Average power per 15 seconds				6.03

Table 4. Solar panel observation results the third day

Third Day				
15 Seconds to	**Vsp (V)**	**Isp (A)**	**Weather**	**Vsp X Isp (Watt)**
1	12.55	0.6	Bright	7.53
2	12.34	0.6	Bright	7.40
3	11.88	0.6	Bright	7.13
4	12.31	0.6	Bright	7.39
5	12.34	0.6	Bright	7.40
6	12.31	0.6	Bright	7.39
7	12.13	0.6	Bright	7.28
8	12.21	0.6	Bright	7.33
9	12.31	0.6	Bright	7.39
10	12.3	0.6	Bright	7.38
11	11.96	0.6	Bright	7.18
12	12.15	0.6	Bright	7.29
13	11.77	0.6	Bright	7.06
14	12.32	0.6	Bright	7.39
15	12.24	0.6	Bright	7.34
Total Power that goes to the Solar Panel				109.87
Average power per 15 seconds				7.32

In table 2, table 3, and table 4 it shows the maximum current 10wp solar panel is around 0.6 A and the total power is 109.87 Watt. The following is a comparison chart of Solar Panel Power. From the three-day observation, there is a clear correlation between weather conditions and solar panel output. The highest average power output (7.32 W) occurred on a clear day, whereas on cloudy days the value dropped to 3.48 W. This demonstrates the system’s ability to log and reflect environmental impacts on solar generation.. Telemetry on the first, second, and third day shown in the following graphic image:

e-ISSN : 2356-2579 | p-ISSN : 1412-2693, DOI :10.62411/tc.v24i3.13499

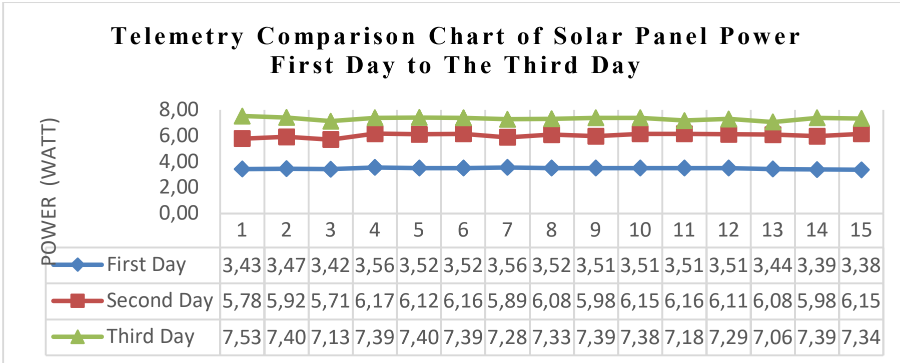


Figure 6. Comparison chart of solar panel telemetry power

3.3. PZEM-004T Sensor Testing Implementation to AC Load

The test was carried out with an AC load of 9 Watt using a 9AH battery. This observation is to find out how long the lights can be on at night and what is the current and voltage at the inverter input-output. The following are the results of the PZEM-004T sensor trial on first day which is shown in table 5, second day which is shown in table 6, and the third day which is shown in table 7.

Table 5. Observation results of load using the 9AH battery on the first day

First Day				
15Seconds to	**Vload (V)**	**Iload (A)**	**Weather**	**Vload X Iload (Watt)**
1	219,3	0,03	Cloudy	6,58
2	214,6	0,03	Cloudy	6,44
3	214,6	0,03	Cloudy	6,44
4	222,5	0,03	Cloudy	6,68
5	222,4	0,03	Cloudy	6,67
6	220,6	0,03	Cloudy	6,62
7	222,7	0,03	Cloudy	6,68
8	222,8	0,03	Cloudy	6,68
9	222,7	0,03	Cloudy	6,68
10	222,5	0,03	Cloudy	6,68
11	222,5	0,03	Cloudy	6,68
12	222,4	0,03	Cloudy	6,67
13	222,4	0,03	Cloudy	6,67
14	222,5	0,03	Cloudy	6,68
15	222,4	0,03	Cloudy	6,67
Total Power going to Load				99,51
Average power per 15 seconds				6,63

e-ISSN : 2356-2579 | p-ISSN : 1412-2693, DOI :10.62411/tc.v24i3.13499

Table 6. Observation results of load using 9AH battery on second day

Second Day				
15 Seconds to	**Vload (V)**	**Iload (A)**	**Weather**	**Vload X Iload (Watt)**
1	222,8	0,032	Bright	7,13
2	222,7	0,032	Bright	7,13
3	222,5	0,032	Bright	7,12
4	222,5	0,032	Bright	7,12
5	222,4	0,032	Bright	7,12
6	222,4	0,032	Bright	7,12
7	222,5	0,032	Bright	7,12
8	222,4	0,032	Bright	7,12
9	222,7	0,032	Bright	7,13
10	222,5	0,032	Bright	7,12
11	222,5	0,032	Bright	7,12
12	222,4	0,032	Bright	7,12
13	222,7	0,032	Bright	7,13
14	222,5	0,032	Bright	7,12
15	222,5	0,032	Bright	7,12
Total Power going to Load				106,82
Average power per 15 seconds				7,12

Table 7. Observation results using 9AH battery on the third day

Third Day				
15 Seconds to	Vload (V)	Iload (A)	Weather	Vload X Iload (Watt)
1	222,7	0,036	Bright	8,02
2	222,5	0,036	Bright	8,01
3	222,5	0,036	Bright	8,01
4	222,4	0,036	Bright	8,01
5	222,4	0,036	Bright	8,01
6	222,5	0,036	Bright	8,01
7	222,4	0,036	Bright	8,01
8	222,8	0,036	Bright	8,02
9	219,3	0,036	Bright	7,89
10	214,6	0,036	Bright	7,73
11	214,6	0,036	Bright	7,73
12	222,5	0,036	Bright	8,01
13	222,4	0,036	Bright	8,01
14	220,6	0,036	Bright	7,94
15	222,7	0,036	Bright	8,02
Total Power going to Load				119,41
Average power per 15 seconds				7,96

e-ISSN : 2356-2579 | p-ISSN : 1412-2693, DOI :10.62411/tc.v24i3.13499

From table 5, table 6, and table 7 shows that a 9AH capacity battery, it can activate an AC load of 7 watts with the highest power of 8.02 watts. The AC load data shows that despite battery discharge during nighttime, the system maintains voltage stability at ~222V. The output current remains below 0.04A, consistent with a 9W load. The efficiency of the inverter and battery health is indirectly confirmed through consistent power delivery over three nights. The following is a comparison chart of Load Power Telemetry with 9AH Batteries on the first second and third days shown in Figure 7.

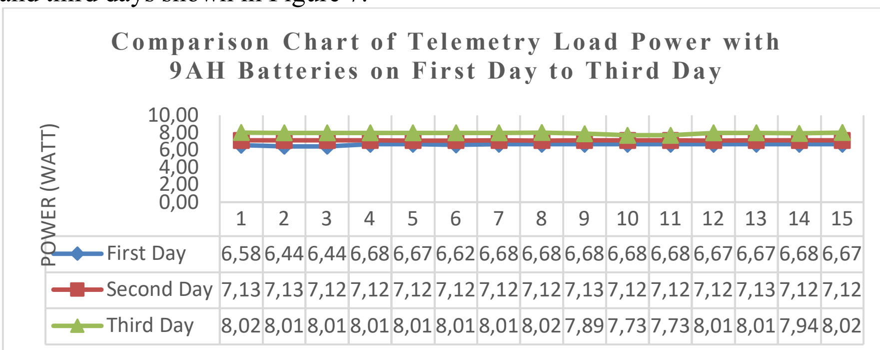


Figure 7.Comparison graph telemetry load power with 9AH batteries

3.4. Function Testing

In the interface, there are the results of telemetry on the output current and voltage from the solar panel, battery current, and voltage during the charging process, current and voltage from the AC load during the discharging process, the temperature around the Solar Panel System battery environment, low and/or normal battery status and relay control to turn on-off the light. The following is the overall website interface.

Figure 8. Website display when the relay is on normal battery status

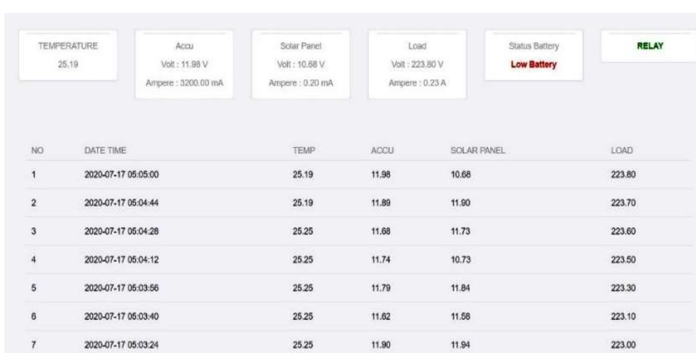
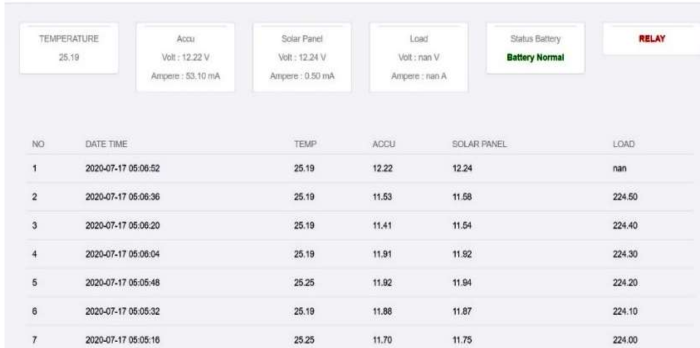


Figure 9. Website display when relay on low battery

e-ISSN : 2356-2579 | p-ISSN : 1412-2693, DOI :10.62411/tc.v24i3.13499



NO	DATE TIME	TEMP	ACCU	SOLAR PANEL	LOAD
1	2020-07-17 05:06:52	25.19	12.22	12.24	nan
2	2020-07-17 05:06:36	25.19	11.53	11.58	224.50
3	2020-07-17 05:06:20	25.19	11.41	11.54	224.40
4	2020-07-17 05:06:04	25.19	11.91	11.92	224.30
5	2020-07-17 05:05:48	25.25	11.92	11.94	224.20
6	2020-07-17 05:05:32	25.19	11.88	11.87	224.10
7	2020-07-17 05:05:16	25.25	11.70	11.75	224.00

Figure 10. Website display when relay off the normal battery

Figure 8 shows the initial display when entering the URL http://energi-terbarukan.info/ by inputting the username and password, namely 'admin' and 'admin'. In Figure 9, and Figure 10 are the overall display and when the relay control is on and off the lights are with two battery status indicators, namely normal and low. The telemetry system successfully visualizes key parameters in real-time, such as battery voltage, solar panel current, and AC load consumption. The relay module reacts to battery status thresholds automatically (e.g., <12V triggers 'Battery Low'). This proves the system can assist in preventive actions (e.g., reducing load before full discharge), validating the system's objective for continuous battery health monitoring. The following is a visual prototype of the solar panel system battery telemetry design.

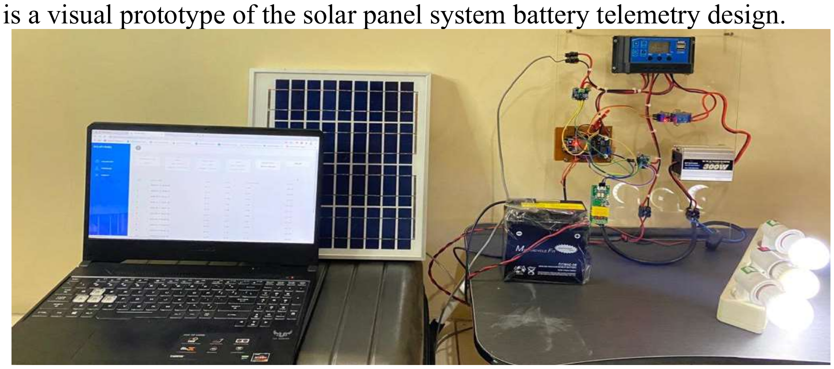


Figure 12. Setup components for testing

4. CONCLUSION

The telemetry results for the parameters of the Current, Voltage and Temperature of the Solar Panel System Battery which were carried out for the first 3 consecutive days for the measurement of 10 wp solar panels, the total average power was 3.48-7.32 Watt with a maximum current of 0 6 A and with measured solar panel efficiency of 0.82% under maximum irradiance conditions. Second, for the measurement of the 12V 9Ah battery, the total average power is 13.45-29 Watt with a maximum current of 1.4 A, and for the total average temperature is 26.23- 27.02 ° C. Third, to measure the 9 Watt AC load, the total average power is 6.63 - 7.96 Watt with a maximum current of 0.036 A. Fourth, the use of a solar panel system battery with a power requirement of 9 Watt 12V (lamp load) does not experience losses or losses during the charge process means the battery is functioning properly. The benefit of this research is that makes it easier for each user to check the condition of the battery, voltage, and others

REFERENCES

[1] Matthias Günther,"A Hybrid Pv-Battery/Diesel Electricity Supply On Peucang Island: An Economic Evaluation," Journal of Mechatronics, Electrical Power, and Vehicular Technology,Vol.7,pp.113-122,2016.

e-ISSN : 2356-2579 | p-ISSN : 1412-2693, DOI :10.62411/tc.v24i3.13499

[2] Iwan Rohman Setiawan, Irwan Purnama, and Abdul Halim,"Increasing efficiency of a 33 MW OTEC in Indonesia using flat-plate solar collector for the seawater heater," Journal of Mechatronics, Electrical Power, and Vehicular Technology,Vol.8, pp.33–39,2017.

[3] Arif Rahman Hakim, Wahyu Tri Handoyo, and Putri Wullandari,"An energy and exergy analysis of photovoltaic system in Bantul Regency, Indonesia," Journal of Mechatronics, Electrical Power, and Vehicular Technology,Vol.9, pp.1–7, 2018.

[4] Boucetta Abd Allah and Labed Djamel,"Control of Power and Voltage of Solar Grid Connected", Bulletin of Electrical Engineering and Informatics,Vol. 5, No. 1, pp. 37~44, March 2016.

[5] S. Shanmugasundaram,"Solar Based Z Source Inverter for High Power Application,"Bulletin of Electrical Engineering and Informatics,Vol. 6, No. 4, pp. 343~347, December 2017.

[6] Hadi Suyono, Rini Nur Hasanah, R. A. Setyawan, Panca Mudjirahardjo, Anthony Wijoyo,and Ismail Musirin," Comparison of Solar Radiation Intensity Forecasting Using ANFIS and Multiple Linear Regression Methods," Bulletin of Electrical Engineering and Informatics, Vol.7, No.2, pp.191~198, June 2018.

[7] T.M.N.T.Mansur, N.H.Baharudin, and R. Ali,"A Comparative Study for Different Sizing of Solar PV System under Net Energy Metering Scheme at University Buildings", Bulletin of Electrical Engineering and Informatics,Vol. 7, No. 3, pp. 450~457,September 2018.

[8] Karmila Kamil, Muhammad Amirul Ashraf Ab Rahman, Chong Kok Hen, Halimatun Hashim, and Mohd Helmi Mansor,"Analysis on the voltage stability on transmission network with PV interconnection," Bulletin of Electrical Engineering and Informatics,Vol.8, No.3,pp. 1162~1168,September 2019.

[9] Nikita Rawat, Padmanabh Thakur, and Utkarsh Jadli,"Solar PV parameter estimation using multi-objective optimisation," Bulletin of Electrical Engineering and Informatics, Vol. 8, No. 4, pp.1198~1205,December 2019.

[10] Indresh Yadav, Sanjay Kumar Maurya, and Gaurav Kumar Gupta,"A literature review on industrially accepted MPPT techniques for solar PV system,"International Journal of Electrical and Computer Engineering (IJECE), Vol. 10, No. 2, pp. 21172127, April 2020.

[11] A. H. Sabry, Wan Zuha Wan Hasan, Farah Hani Nordin, Mohd Zainal Abidin Ab-Kadir, "Stand-alone backup power system for electrical appliances with solar PV and grid options," Indonesian Journal of Electrical Engineering and Computer Science, vol. 17,no. 2, pp. 689-699, 2020.

[12] Soumen Gorai1, D. Sattianadan, V. Shanmugasundaram3, S. Vidyasagar, G. R. Prudhvi Kumar, and M. Sudhakaran," Investigation of voltage regulation in grid connected PV system," Indonesian Journal of Electrical Engineering and Computer Science, Vol. 19, No. 3, pp. 1131~1139, September 2020.

[13] Adeel Saleem, Atif Iqbal, Muhammad Aftab Hayat, Manoj Kumar Panjwani, "The effect of environmental changes on the efficiency of the PV system," Indonesian Journal of Electrical Engineering and Computer Science, vol. 18, no. 1, pp. 558-564, 2020.

[14] Renuga Verayiah, Anusiya Iyadurai, "A Comparison Study on Types of PV for Grid Connected Photovoltaic Power," Indonesian Journal of Electrical Engineering and Computer Science, vol. 6, no. 2, pp. 349-356, 2017.

[15] M. A. Jusoh, M. F. Tajuddin, S. M. Ayob & M. A. Roslan., "Maximum Power Point Tracking RCharge Controller for Standalone PV System," Telkomnika (Telecommunication, Computing, Electronics and Control), vol. 16(4), pp. 1413-26, 2018.

[16] Armstrong O. Njok, Julie C. Ogbulezie, Manoj Kumar Panjwani, Raja Masood Larik," Investigation of monthly variations in the efficiencies of photovoltaics due to sunrise and sunset times," Indonesian Journal of Electrical Engineering and Computer Science, vol. 18, no. 1, pp. 310-317,April 2020.

e-ISSN : 2356-2579 | p-ISSN : 1412-2693, DOI :10.62411/tc.v24i3.13499

[17] M.Z.M. Nasir, S. Salimin, B. Chan, and S.A. Jumaat,” Prototype development of smart parking system powered by solar photovoltaic,” Indonesian Journal of Electrical Engineering and Computer Science, vol. 18, no. 3, pp. 1229-1235, June 2020.

[18] B. Mohammed, et al., “Design and modeling of optical reflectors for a PV panel adapted by MPPT control,” Indonesian Journal of Electrical Engineering and Computer Science, vol. 16, no. 2, pp. 653-660, 2019.

[19] Freddy Artadima Silaban, Setiyo Budiyanto, and Wahyu Kusuma Raharja.”Stepper motor movement design based on FPGA “ in International Journal of Electrical and Computer Engineering (IJECE), Vol. 10, No. 1, pp. 151~159, February 2020.

[20] J. J. Michael, S. Iniyan, & R. Goic, “Flat plate solar photovoltaic–thermal (PV/T) systems: a reference guide”. Renewable and Sustainable Energy Reviews, vol. 51, pp. 62-88, 2015.

[21] J. Wu, X. Zhang, J. Shen, Y. Wu, K. Connelly, T. Yang, C. Chen, “A review of thermal absorbers and their integration methods for the combined solar photovoltaic/thermal (PV/T) modules”. Renewable and Sustainable Energy Reviews, vol. 75, pp. 839-854, 2017.

[22] N. S. Nazri, A. Fudholi, M. H. Ruslan, K. Sopian, “Mathematical modeling of photovoltaic thermal-thermoelectric (PVT-TE) air collector”. International Journal of Power Electronics and Drive Systems (IJPEDS), vol. 9, no. 2, pp. 795-802. 2018.

[23] A. J. Aristizabal, D. Ospina, M. Castaneda, S. Zapata, Banguero, "Optimal power flow model for building integrated photovoltaic systems operating in the andean range", Indonesian Journal of Electrical Engineering and Computer Science (IJEECS), vol. 16, no. 1, pp. 52-58.October 2019.

[24] Freddy Artadima Silaban, Setiyo Budiyanto, Lukman Medriavin Silalahi, ”Design of a conductive material detection system”, in International Journal of Robotics and Automation (IJRA), Vol.9, No.4, pp. 292~299, December 2020.

[25] B. Agrawal, GN. Tiwari. “Optimizing the energy and exergy of building integrated photovoltaic thermal (BIPVT) systems under cold climatic conditions”. Appl Energy, vol. 87, 417-26, 2017.

Junghoon Lee, Seong Baeg Kim,and Gyung-Leen Park,” Data Analysis for Solar Energy Generation in a University Microgrid,”International Journal of Electrical and Computer Engineering (IJECE) Vol. 8, No. 3, pp. 1324~1330, June 2018

e-ISSN : 2356-2579 | p-ISSN : 1412-2693, DOI :10.62411/tc.v24i3.13499