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Realtime Monitoring System of Solar Panel Performance Based on Internet of Things Using Blynk Application

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ABSTRACT

Renewable energy is one of the options to meet the increasing energy needs. As a tropical country, Indonesia has great potential for solar energy development. At this time, solar panels have been built in places exposed to direct light. However, monitoring solar panels is still performed manually using a multimeter by operators or field officers, so it cannot be performed in real-time. Real-time tracking is carried out to prevent damage and decreased performance of solar panels. Hence, we designed a real-time solar panel monitoring system based Internet of Things (IoT) using the Blynk application on a smartphone. Based on the test between the measuring instrument and the Blynk application, the error percentage is 0.59% for voltage testing, 0.0001% for current testing, 1.03% for power testing, and 2.09% for temperature testing. A strong internet connection will significantly affect the performance of solar panels in real-time. This research is expected to monitor solar panel parameters remotely via a smartphone without having to come to the location and make it easier for users to monitor.

Keywords*:* monitoring, solar panel, internet of things, blynk application

INTRODUCTION

Indonesia is a tropical country that gets sunlight throughout the year, with an average radiation intensity throughout the Indonesian archipelago of around 4,800 Wh/m2/day, equivalent to 112,000 GWp. However, the radiation intensity is only at 71.02 MWp [1]. Meanwhile, energy consumption in Indonesia continues to increase by an average of 8.1% annually. This increase in energy consumption is not matched by the growth of fossil energy which only reaches an average of 5.2% annually [2]. The utilization of solar energy is an option to meet increasing energy needs [3]. One way of utilizing solar energy is solar panels [4]. Solar panels absorb sunlight and convert it into electrical energy [5].

At this time, solar panels have been built in places exposed to direct sunlight. However, monitoring solar panels is still performed manually using a multimeter by operators or field officers, so it cannot be performed in real-time. Real-time tracking is carried out to prevent damage and decreased performance of solar panels. Therefore, this research aims to build an automatic solar panel monitoring system using Internet of Things (IoT) technology. The use of IoT technology will make it easier for users to monitor. In its development, the monitoring system was carried out locally using LabView [6]. Furthermore, monitoring was carried out using Web-SCADA via the internet network. Connection to the internet network was carried out through a server computer with communication between sensors, remote terminals, and server computers via a cable network using serial communication and Local Area Networks [7].

Furthermore, the solar panel monitoring system was carried out using the Wireless Sensor Network (WSN) [8]. The solar panel monitoring system has been developed using SMS gateway telecommunications media [9]. Currently, the monitoring system utilizes internet connectivity that can connect all devices or known as the Internet of Things [10], [11], [12], [13].

The Internet of Things (IoT) application is an appropriate real-time monitoring method. By implementing IoT, all devices will be combined into an embedded system that can interact and communicate with each other [14]. This technology has been widely used to solve various problems, including air monitoring systems [15], flood monitoring systems [16], and weather monitoring systems [17]. The air monitoring system was carried out by [18] using an air level sensor. When the surface reaches a certain point, the signal will be fed in real-time to social networks such as Twitter, and the cloud server will display the results via the dashboard. Research on the same topic was also conducted by [19] also proposed an IoT-based air monitoring system. This study uses an ultrasonic sensor to detect and compare the air's height with the container's depth. On another occasion, research on flood monitoring systems was carried out by [20] to provide early warning in flood-prone areas. Flood monitoring was performed in real-time using NodeMCU-based technology integrated into the Blynk Application.

Blynk is an interface platform that monitors and controls hardware projects from iOS and Android. In the Blynk application, we can create project dashboards and arrange buttons, sliders, graphics, and other widgets to the screen according to our wishes and needs. Users can use the widget to enable pins and turn off or display data from sensors. The Blynk application is perfect for interfacing with simple projects such as temperature and humidity monitoring in smart home systems [21] or electrical power control systems [22]. Blynk is an Internet of Things (IoT) designed to make remote control and reading sensor data from Arduino or esp8266 devices fast and easy. Blynk is not just a "cloud IoT"; it is an end-to-end solution that saves time and resources when building meaningful applications for connected products and services [23], [24], [25].

This study focuses on a real-time Internet of Things (IoT) based solar panel performance monitoring system using an ESP32 microcontroller, current sensor, voltage sensor, and temperature sensor to monitor solar panel performance. This research is necessary because the monitoring method can be carried out in real-time using the Blynk application on a smartphone, making it easier for users to get real-time information about the performance of solar panels.

METHODS

The scientific method used in making the real-time monitoring system of solar panel performance based on the internet of things consists of a literature review, requirements analysis, system design, construction, and testing. The literature review is used to find alternative solutions to problems. Then, proceed with doing a requirements analysis. Requirements analysis consists of system requirements analysis and component requirements analysis. The design includes system design, hardware design, software design, and system flowcharts. Next, the design was realized at the manufacturing stage. A system test was carried out to determine the accuracy of the system.

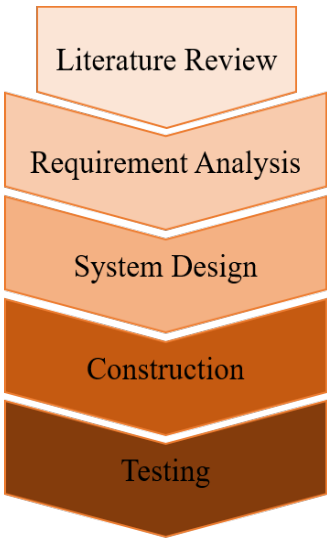

Figure 1. Monitoring System Development Stage

A. Design System

This research was designed using the INA219 sensor, DHT22 sensor, ESP32 microcontroller, and Blynk application. The INA219 sensor reads the voltage and current values generated by the solar panel, while the DHT22 sensor reads the solar panel temperature value. The ESP32 microcontroller functions to process input in the form of sensor readings generated by the solar panel. ESP32 has also To regulate the direct current charged to the battery and the incoming current from the battery to the load. The step-down module functions as a voltage reducer from 12V (Accumulator) to 5V, which becomes the input voltage (power supply) of the ESP32.

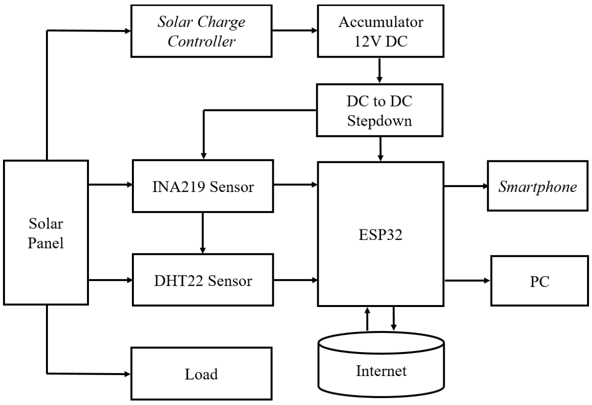

Figure 2. Block Diagram System of Performace Solar Panel Monitoring

B. Hardware Design

Hardware design is necessary for this research. This entire circuit functions to read the voltage, current, power, and temperature parameters of the solar panels in real-time through the Blynk application found on the Smartphone/PC. The solar charge controller regulates overcharging (excess charging because been equipped with a wifi module that can send data to the Blynk application on a smartphone/PC via an internet connection. Hence, users can find out the sensor reading data in real-time. This system was equipped with a solar charge controller (SCC) and a 12V DC accumulator. SCC serves
the battery is full) and excess voltage on the solar panel. The ESP32 gets its power supply from the Accumulator, which has been reduced in voltage from 12V to 5V.

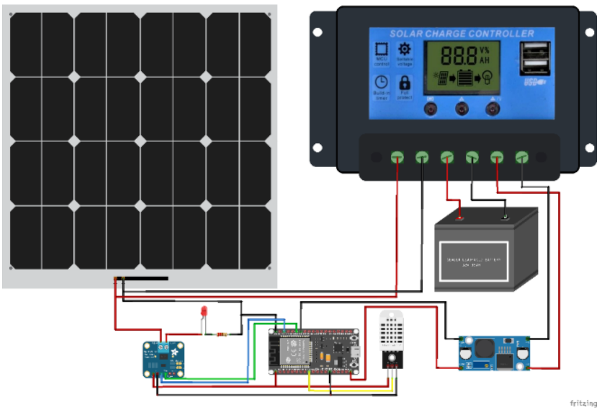

Figure 3. Hardware Design of Performace Solar Panel Monitoring

C. Software Design

Arduino IDE (Integrated Development Environment) and the Blynk application are used in this research. Arduino IDE is software used to create programming sketches on the NodeMCU ESP32 board. At the same time, the Blynk application is used to display output parameters in the form of voltage, current, power, and temperature from solar panels in real-time in the form of graphs and widgets.

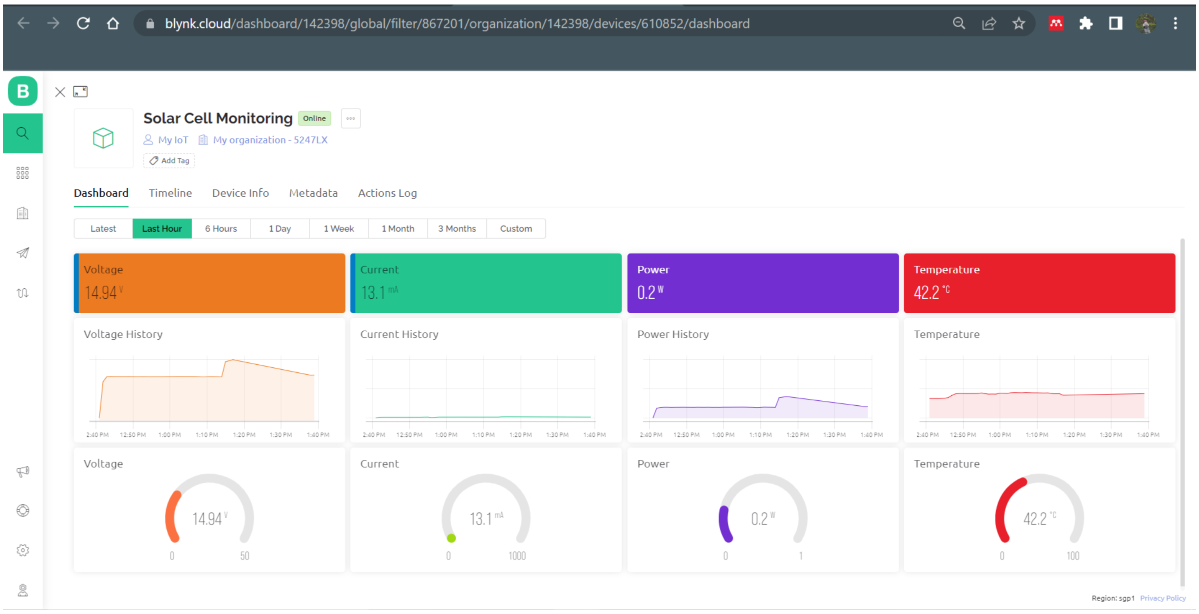

Figure 4. Performance Solar Panel Monitoring by Blynk App on PC

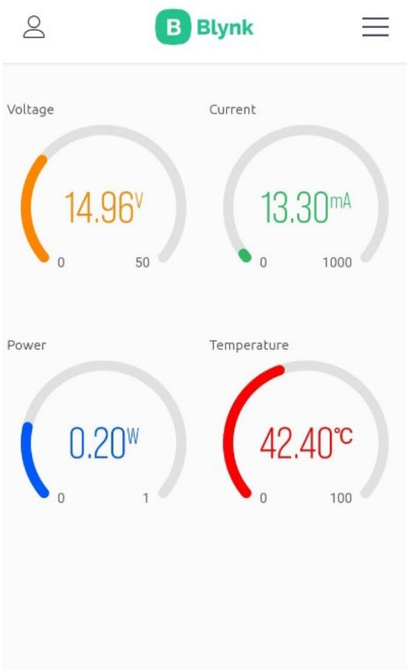

Figure 5. Performance Solar Panel Monitoring by Blynk app on Smartphone

D. Flowchart System

The following system flowchart shows a flowchart of how the entire system works. This system works starting with the initialization of the port. The system will read the sensor and obtain the value of the solar panel's voltage, current, power, and temperature. If the system is connected to the internet, the system will send data in real-time via the Blynk application on a smartphone/PC. Then the data will be stored in a database. The system will send data continuously as long as the system is connected to the internet.

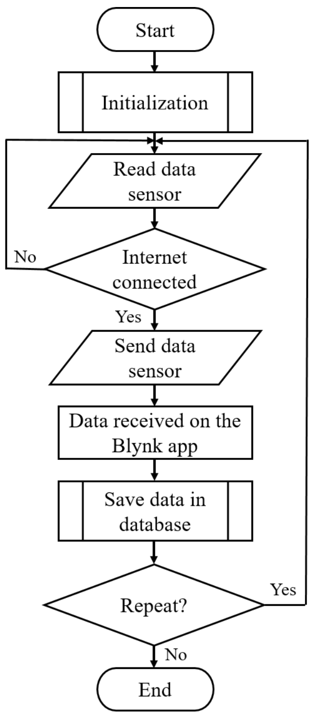

Figure 6. Flowchart System of Performace Solar Panel Monitoring

RESULT AND DISCUSSION

Testing of solar panel devices is carried out to determine the performance of solar panels through the Internet of Things (IoT). The test measured the solar panel's voltage, current, power, and temperature parameters. The test results obtained the percentage comparison between measuring instruments and blynk applications.

Figure 7. Performance Solar Panel Monitoring

A. Voltage Solar Panel Testing

This test aims to determine the performance of the voltage sensor in retrieving voltage data on the solar panel monitoring system. The test is carried out by reading the voltage value on the sensor through the Blynk application and measuring using a manual measuring instrument (Voltmeter). Tests are carried out every 30 minutes from 08.00 WIB to 17.00 WIB. The test results are shown in Figure 8.

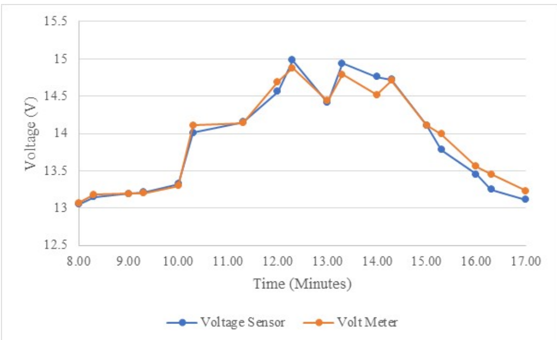

Figure 8. Voltage Solar Panel testing

For calculating the percentage error of measurement between the voltmeter and the voltage sensor, it can be calculated using the following equation:

$$error = \frac{voltmeter - voltage\ sensor}{voltmeter} x100\% \quad (1)$$

The percentage of error between the voltmeter and the voltage value read by the sensor through the Blynk application is shown in Table 1.

Table 1. Voltage Solar Panel Testing

Time (Minutes)	Voltmeter (Volts)	Voltage Sensor (Volts)	Error (%)
8.00	13.07	13.05	0.15
8.30	13.18	13.15	0.23
9.00	13.19	13.19	0.00
9.30	13.20	13.21	0.08
10.00	13.30	13.32	0.15
10.30	14.11	14.01	0.71
11.30	14.14	14.15	0.07
12.00	14.69	14.56	0.88
12.30	14.88	14.98	0.67
13.00	14.44	14.41	0.21
13.30	14.79	14.94	1.01
14.00	14.52	14.76	1.65
14.30	14.71	14.72	0.07
15.00	14.11	14.11	0.00
15.30	13.99	13.78	1.50
16.00	13.56	13.45	0.81
16.30	13.45	13.25	1.49
17.00	13.23	13.11	0.91
Average	13.90	13.92	0.59

B. Current Solar Panel Testing

This test aims to determine the current sensor's performance in retrieving current data on the solar panel monitoring system. The test is carried out by reading the current value on the sensor through the Blynk application and measuring using a manual measuring instrument (Amperemeter). Tests are carried out every 30 minutes from 08.00 WIB to 17.00 WIB. The test results are shown in Figure 9.

For calculating the percentage error of measurement between the amperemeter and the current sensor, it can be calculated using the following equation:

$$error = \frac{amperemeter - current\ sensor}{amperemeter} x100\% \quad (2)$$

The percentage of error between the ammeter and the current value read by the sensor through the Blynk application is shown in Table 2.

Table 2. Current Solar Panel Testing

Time (Minutes)	Amperemeter (Amperes)	Current Sensor (Amperes)	Error (%)
8.00	0.0112	0.0111	0.001
8.30	0.0112	0.0112	0.001
9.00	0.0113	0.0113	0.000
9.30	0.0114	0.0114	0.000
10.00	0.0116	0.0117	0.001
10.30	0.0118	0.0118	0.000
11.30	0.0129	0.0129	0.000
12.00	0.0130	0.0129	0.000
12.30	0.0133	0.0132	0.001
13.00	0.0125	0.0125	0.000
13.30	0.0130	0.0131	0.001
14.00	0.0128	0.0129	0.001
14.30	0.0129	0.0129	0.000
15.00	0.0122	0.0122	0.000
15.30	0.0121	0.0120	0.001
16.00	0.0117	0.0115	0.001
16.30	0.0114	0.0113	0.001
17.00	0.0113	0.0112	0.001
Average	0.0121	0.0121	0.001

C. Power *Solar Panel Testing*

This test aims to determine the power sensor's performance in retrieving power data on the solar panel monitoring system. The test is carried out by reading the power value on the sensor through the Blynk application and measuring using a manual measuring instrument (Wattmeter). Tests are carried out every 30 minutes from 08.00 WIB to 17.00 WIB. The test results are shown in Figure 10.

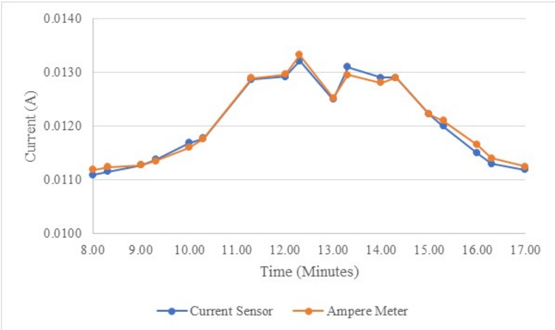

Figure 9. Current Solar Panel Testing

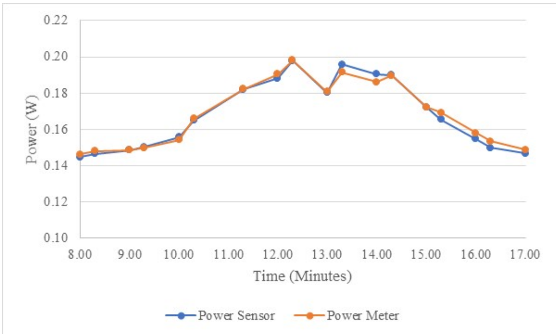

Figure 10. Power Solar Panel Testing

For calculating the percentage error of measurement between the power meter and the power sensor, it can be calculated using the following equation:

$$error = \frac{powermeter - power\ sensor}{powermeter} x100\% \quad (3)$$

The percentage of error between the wattmeter and the power value read by the sensor through the Blynk application is shown in Table 3.

Table 3. Power Solar Panel Testing

Time (Minutes)	Wattmeter (Watt)	Power Sensor (Watt)	Error (%)
8.00	0.15	0.14	1.05
8.30	0.15	0.15	1.03
9.00	0.15	0.15	0.00
9.30	0.15	0.15	0.34
10.00	0.15	0.16	0.93
10.30	0.17	0.16	0.62
11.30	0.18	0.18	0.08
12.00	0.19	0.19	1.19
12.30	0.20	0.20	0.16
13.00	0.18	0.18	0.37
13.30	0.19	0.20	2.18
14.00	0.19	0.19	2.37
14.30	0.19	0.19	0.07
15.00	0.17	0.17	0.00
15.30	0.17	0.17	2.32
16.00	0.16	0.15	2.09
16.30	0.15	0.15	2.35
17.00	0.15	0.15	1.44
Average	0.17	0.17	1.03

D. Temperature Solar Panel Testing

This test aims to determine the performance of the temperature sensor in retrieving temperature data on the solar panel monitoring system. The test is carried out by reading the temperature value on the sensor through the Blynk application and measuring using a manual measuring instrument (Thermometer). Tests are carried out every 30 minutes from 08.00 WIB to 17.00 WIB. The test results are shown in Figure 11.

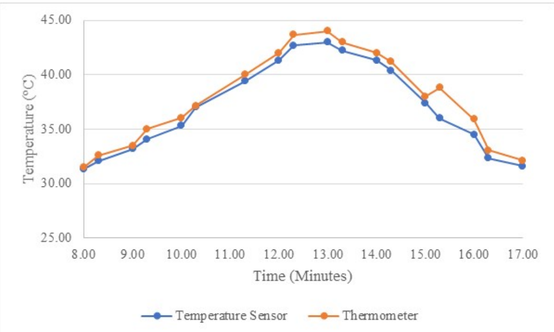

Figure 10. Temperature Solar Panel Testing

For calculating the percentage error of measurement between the thermometer and the temperature sensor, it can be calculated using the following equation:

$$error = \frac{thermometer - temperature\ sensor}{thermometer} x100\% \quad (4)$$

The percentage of error between the thermometer and the temperature value read by the sensor through the Blynk application is shown in Table 4.

Table 4. Temperature Solar Panel Testing

Time (Minutes)	Thermometer (ºC)	Termometer Sensor (ºC)	Error (%)
8.00	31.50	31.33	0.54
8.30	32.60	32.08	1.60
9.00	33.50	33.20	0.90
9.30	35.00	34.07	2.66
10.00	36.04	35.33	1.97
10.30	37.16	37.00	0.43
11.30	40.00	39.40	1.50
12.00	42.02	41.33	1.64
12.30	43.65	42.67	2.25
13.00	44.00	43.00	2.27
13.30	43.00	42.20	1.86
14.00	42.00	41.30	1.67
14.30	41.20	40.40	1.94
15.00	38.00	37.40	1.58
15.30	38.80	36.00	7.22
16.00	35.90	34.50	3.90
16.30	33.05	32.35	2.12
17.00	32.10	31.59	1.59
Average	37.75	36.95	2.09

A real-time Internet of Things (IoT) based solar panel performance monitoring system has been designed using the Blynk application on a smartphone/PC. This research is important to do to make it easier for users to get real-time information about the performance of solar panels. Based on testing the voltage, current, power, and temperature of the solar panel through the Blynk application on a smartphone/PC, the average voltage value are 13.92 Volts; the current is 0.012 Ampere, the power is 0.17 Watts, the temperature is 36.95 C. Percentage of error between measuring instrument and blynk applications for voltage, current, power, and temperature parameters, respectively, is 0.59%; 0.0001%; 1.03%; 2.09%. One of the factors that affect the error percentage is the internet connection. A strong internet connection signal will significantly affect the performance of the device for the better.

CONCLUSION

The research on real-time monitoring systems of solar panel performance based on the internet of things has been successfully carried out. Monitoring consists of solar panels' voltage, current, power, and temperature through the Blynk application. The testing was conducted by comparing the measuring instrument and blynk applications. Based on the tests, the error percentage is 0.59% for voltage testing, 0.0001% for current testing, 1.03% for power testing, and 2.09% for temperature testing. In this study, a strong signal of an internet connection will significantly affect the performance of the device in monitoring the performance of solar panels in real-time based on the Internet of Things (IoT).

This research still needs to be developed because the solar panels that have been installed are static or silent, causing less than optimal absorption of solar energy. The solar panel's position must be perpendicular to the direction of sunlight to get maximum solar energy. In future research, we will create a monitoring solar tracking system based on the Internet of Things which functions to move the position of the solar panels so that they can follow the motion of the sun source automatically.

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