Web Monitoring the Potential of Solar Power Plants Based on theInternet of Things

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Abstract. The market for renewable energy is expanding quickly to support power production, where solar energy is widely used and developed in applied technologies significantly. When assessing solar energy potential, one must consider natural energy resources based on the wind speed. As a result, the systems covered by this work feature two monitoring modes: on-site monitoring using a monitoring module and smartphone applications applied to the method, which can download data for Android smartphones or desktop computers. Technically, data monitoring is uploaded to a cloud database regularly through data updates for monitoring devices automatically that obtain and present the most recent information. Research indicates that solar radiation directly impacts electrical voltage, as it is precisely proportionate to the intensity of sunshine. In testing conducted from 07.00 to 17.00 WIB, the lowest solar panel output voltage of 20.4 V with a current of 0.2 A was obtained. The most outstanding result is at 12.00 WIB with a point of 23.59 V and 0.7 A. The study also demonstrates how the surrounding temperature influences the amount of electrical energy generated.

1 Introduction

Human survival depends heavily on electrical energy, and as the population grows, particularly in Indonesia, so does the need for electrical power. Petroleum continues to be the primary energy source to meet current energy consumption needs. New energy sources must be found due to the shortages and rising petroleum costs to meet the electricity demand. To satisfy the growing energy needs, alternative energy, sometimes referred to as new renewable energy, is one way to guarantee the stability of the energy supply. Being a tropical nation on the equator, Indonesia has a comparatively high potential for solar energy due to its average 6-7 hours of light per day, which is the ideal amount of light duration for solar power plants to produce electricity for 5–6 hours per day [1]–[3]. When this occurs, natural resources are

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abundant, particularly renewable energy, which has manageable primary energy sources that can meet all energy needs, including electrical power to reach remote and hard-to-reach places.

One of the new renewableenergies, namely solar power, is taking a large part of the total electricity generation, especially in the future.In the development of solar power, many factors must be considered, namely the equipment and components of the solar power plant, which includes solar modules, solar charger controllers, batteries, inverters, protection systems, and other supporting equipment [4]–[7]. Other equipment must be considered: thepower management monitoring system produced by solar power plants. In general, the operator carries out monitoring manually, and manual tracking will affect costs. It is less efficient, making it difficult for operators to monitor because they must come to each power plant. At present, with existing technological advances, namely wireless technology combined with cellular devices, namely smartphones that are connected to the Internet of Things(IoT) system, it makes it easier for operators to monitor the power management of solar power plants in real-time without visiting the location of each power plant in person [8], [9].

The need for monitoring a solar power plant and managing the power producedby the energy plant also determines the potential for solar energy by storing data on the power generated every hour. Information and communication technology in monitoring is the Internet of Things (IoT), an effective and efficient technology. IoT technology makes it easier to monitor electricityconsumption to obtain data related to electrical parameters, namely current, voltage, and power, in real-time [2], [10]–[13].

In this paper, research on the potential for new renewable energy, namely solar energy, uses the Internet of Thingsto measure solar energy potential. Monitoring tools are also made in modules using the Internet of Thingsfor real-time data retrieval. The data is in the form of voltage, current, temperature, and sunlight intensity. Fromthese measurement data, the effect of temperature and sunlight intensity on the power produced by solar cells for one day; from this data, it will also be known how much potential solar energy is in the research area [14], [15].

2 Methodology

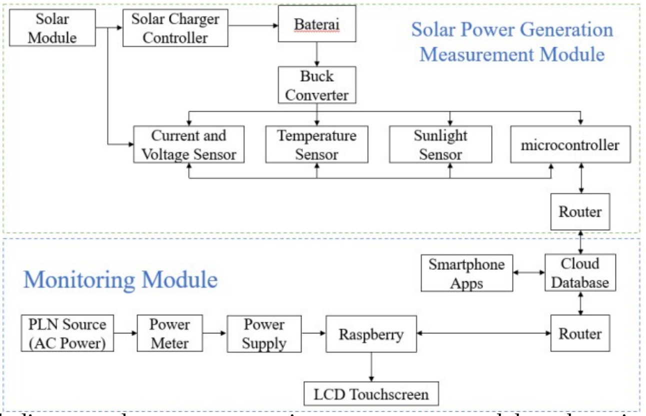

Fig. 1. Block diagram solar power generation measurement module and monitoring module

2.1. Solar Power Generation Measurement Module

The initial process is conducted in the solar power generation measurement module when sunlight is available. A 50-watt solar module serves as a device that converts solar energy into usable electrical energy. The power or output from the solar module is then directed to a solar charge controller, where the electrical energy is converted into a 12 V voltage and stored in a 12V 5 Ah battery. This solar module is equipped with four specialized sensors. Firstly, the current sensor is used to measure the electrical current generated by the solar module [16]. Secondly, the voltage sensor measures the electrical voltage produced by the solar module. Thirdly, the sunlight intensity sensor is utilized to gauge the extent of solar light intensity at that moment. Lastly, the temperature sensor measures the environmental temperature around the solar module. These four parameters are crucial for monitoring and optimizing the performance of the solar module. The data generated by these four sensors is then collected in the measurement process. This data is processed by a microcontroller, which functions as the system's central processing unit. The microcontroller processes information from these sensors and produces data that can be used for further monitoring and analysis. To secure the data and enable broader access, the data generated by the microcontroller is transmitted through a network using a router. Subsequently, this data is stored in a cloud database, allowing users or researchers to monitor and analyze the data remotely. Therefore, this system provides real-time monitoring and broader data access regarding the performance of the solar power generator.

2.2. Monitoring Module

The monitoring module is designed according to the Internet of Things working principle and is equippedwith a cloud database and smartphone application. Data is sent by the microcontroller from the solar power plant measurement module via a wireless network. The Raspberry is equipped with a touchscreen LCD running asmartphone app for on-site monitoring. Remote monitoring is done through an application installed on the user's smartphone. The application displays data in the form of numbers and graphics. This application also comes with a user guide. The monitoring diagram is shown in Figure 2.
Initial monitoring begins, namely setting up the network and connecting to the internet, which will be used by logging into the web server by filling in the username and password. After successfully entering the web server, the data obtained from sensor measurements of voltage, current, sunlight intensity, and temperature will be displayed on the web page [17], [18]. The web page also shows each measurement parameter through graphs and data. Displayed measurement parameters such as voltage, current, sunlight intensity, and temperature can also be downloaded. The downloaded data is automatically entered on the computer as a CSV file. Retrieval of downloaded and entered data on a computer device is routinely carried out once every hour.

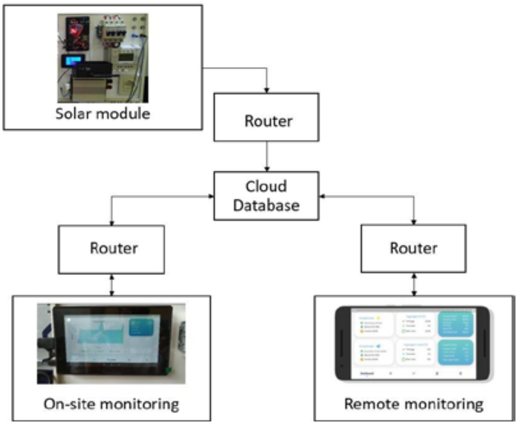

Fig. 2. Block diagram solar power generation measurement module and monitoring module

3 Result And Discussion

The testing process of the solar power plant monitoring device involves several crucial stages designed to ensure its performance and accuracy. The initial phase focuses on testing the solar power generation measurement module, where each component within the module is individually examined. This testing verifies current, voltage, sunlight intensity, and temperature sensors. Each sensor is calibrated and measured to deliver precise and accurate results. The subsequent phase involves comprehensive testing of the monitoring module as a whole. This encompasses examining all components within the module, including the solar charge controller, microcontroller, and router. Thorough testing is conducted to ensure that all features work in harmony and can transmit data accurately. The testing process results are presented in the form of measurement parameters obtained from the calibration and measurements of each sensor. Measurement data is of paramount importance as it forms the basis for understanding the performance of the monitoring device and effectively monitoring the solar power plant. Additionally, the testing results are used to validate the device's accuracy and ensure that the generated data can be relied upon for making informed decisions regarding solar power plant operations. Thus, the testing phase is critical in ensuring the device's reliability and functionality in practical environments.

3.1 Solar Powe Generazition Measurement Module

In the testing phase of the solar power generation measurement module, the focus is on measuring each sensor installed on the module. This module is equipped with various sensors, each with a specific role in monitoring the performance and environmental conditions surrounding the solar power generation system. The testing process includes measurements taken from several sensors, including a current sensor used to measure the magnitude of the electrical current generated by the solar module. A voltage sensor is employed to measure the electrical voltage produced by the module, while a sunlight intensity sensor is used to measure the intensity of sunlight during testing. Additionally, a temperature sensor plays a role in measuring the environmental temperature around the solar module. These four sensors are crucial for monitoring the operational conditions and performance of the solar module.

The measurement data obtained from the testing process holds significant value, forming the basis for analyzing and understanding the solar module's performance. The information derived from these measurements also aids in the operational monitoring of the solar module and helps identify whether the module operates following established standards. Figure 3 in the report illustrates a portion of this testing process. The overall testing process is a critical step in ensuring that the solar power generation measurement module functions effectively and provides accurate data, which, in turn, is essential for efficient operation and maintenance.

Fig. 3. Block diagram solar power generation measurement module and monitoring module

Testing the solar power generation measurement module as shown in Figure 3 above to measure the power of thesolar module as well as sunlight intensity and temperature, measurement tests are carried out using current, voltage, sunlight intensity, and temperature sensors for one day without load, solar power generation measurement module usedto view sensor parameter measurements contained in solar modules. The test results can be seen in Table 1 below.

Table 1. powe Measurements Form Solar Modules, As Wll As Sunlight Intensity, and Temperature

Time	Voltage Solar Module (VDC)	Current Solar Module (A)	Solar temperature celsius (°C)	Sunlight Intensity (Iux)
8:00:00	21.61	0.4	27.9	224.61
9:00:00	22.48	0.5	28.2	244.61
10:00:00	22.48	0.5	28.2	244.61
11:00:00	22.48	0.5	29.8	267.58
12:00:00	23.59	0.7	30.9	277.58
13:00:00	22.48	0.5	28.9	244.61
14:00:00	22.48	0.5	28.9	244.61
15:00:00	22.48	0.5	28.9	244.61
16:00:00	20.48	0.2	26.7	217.61
17:00:00	21.54	0.3	26.9	221.61

In Table 1 above, measurement tests were conducted for one hour each day, from 07:00 to 17:00. This testing aimed to measure several variables, including current, voltage, sunlight intensity, and temperature. The aim was to understand and determine the solar energy potential generated every hour by considering how sunlight intensity and environmental temperature affect the output power of the solar modules. The data from the testing results in Table 1 provides a deep understanding of the changes in solar module power during that period. This testing offers valuable insights into how variations in sunlight intensity and environmental temperature fluctuations can impact solar module performance. The data serves as a strong foundation for analyzing the potential of solar energy production under various weather conditions and temperatures. The testing results are then presented in graphical form in Figure 4, visualizing the influence of sunlight intensity on the power generated by the solar modules during the testing period. With this understanding, we can optimize the use of solar energy and plan the operation of solar modules more efficiently.

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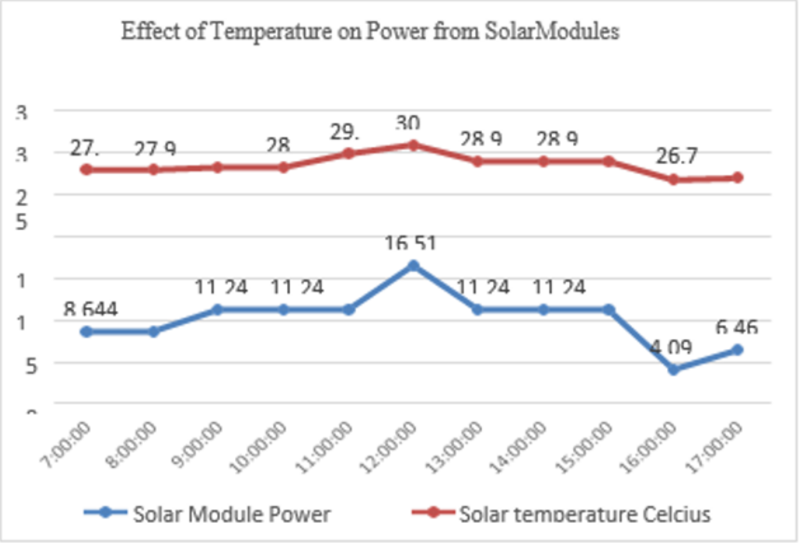

Fig. 4. Graph of Effect of Temperature on Solar Cell Power

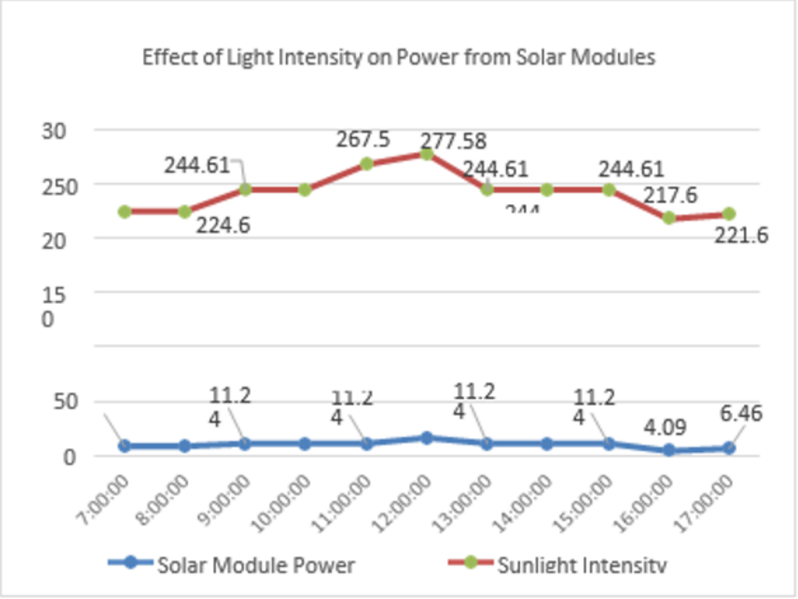

Fig. 5. Graph of Influence of Light Intensity on Solar Cell Power

Measurement of testing the data above in Figure 4, namely the influence of temperature or temperature, shows thehighest temperature at 12.00 PM with a solar panel output power of 16.51 Watt and a temperature of 30.9 0C, whilethe lowest solar panel output power is at 16.00 PM with a solar panel output power of 4.09 Watt with temperature 26.7 Celcius degree. In this measurement, it shows that the temperature affects the output power of the solar panel. The higher the temperature around the solar panel, the higher the power generated by the solar panel, and vice versa. The lower the temperature around the solar panel, the lower the energy released by the solar cell.

The measurement of the data test above is in Figure 5, namely the effect of temperature or temperature showing the highest temperature at 12.00 PM with a solar panel output power of 16.51 Watt and light intensity reaching 277.58 lux, while the lowest solar panel output power is at 16.00 PM with a solar panel output power of 4.09 Watts with a light intensity of 217.61 lux. In this measurement, it shows that the light intensity affects the output power of the solar panel. The higher the light intensity around the solar panel, the higher the power generated by the solar panel,and vice versa; the lower the light intensity around the solar panel, the lower the energy released by the solar cell. The measurement of the two variables above in the study shows that temperature and light intensity affect the power generated by solar panels, which shows that temperature and light intensity affect the output power of solar panels. The higher the temperature and light intensity around the solar panel, the higher the power generated by the solar panel, and vice versa. The lower the temperature or the temperature and light intensity around the solar panel,the lower the energy released by the solar cell.

3.2 Monitoring Module

Monitoring module testing is done by connecting and integrating solar panels and power generation measurement modules. After everything is secured and the sensors take measurements, the reading data from the sensors is sent through the router to the Raspberry, and the data from the sensor readings is displayed on the LCD and theweb, as shown in **Fig. 6.**

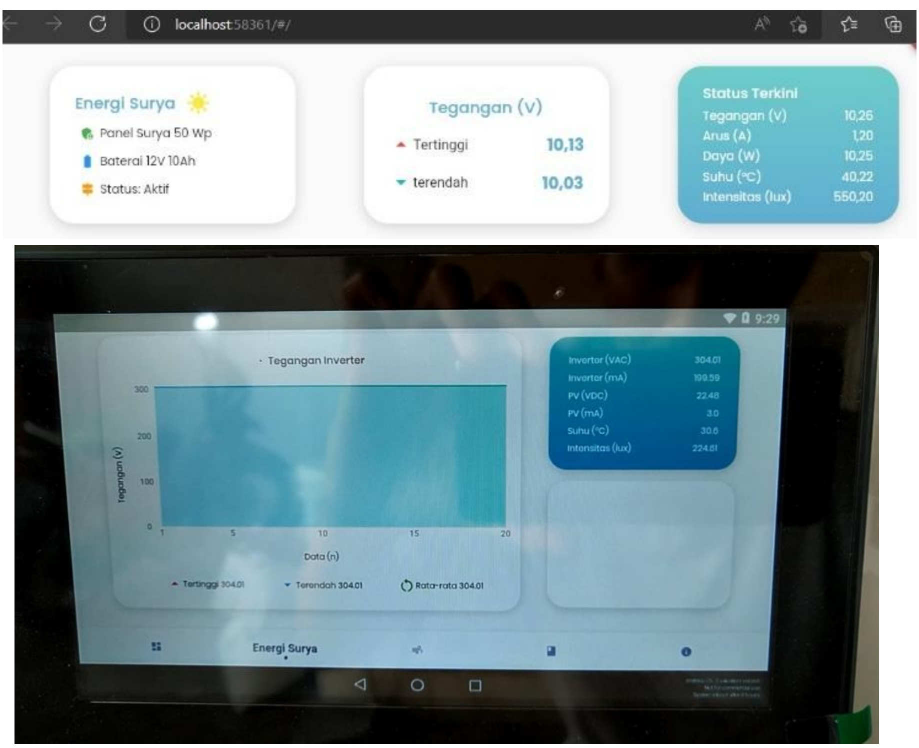

Fig. 6. LCD Display and Web Monitoring Module

Fig. 6 shows data logging from the web monitoring module utilized in the solar power generation measurement. The process of data collection is carried out periodically, with measurement data sent from the sensors installed on the solar power generation measurement module. Data transmission occurs hourly, starting from 7:00 AM to 5:00 PM.

The data received and displayed in the image depicts measurement results in the form of graphs and numerical values representing various measurement parameters. Furthermore, the monitoring test also involves using a 10 Watt lamp load with a testing duration of 10 minutes. The load test aims to determine the maximum voltage and current that the solar module can generate. The results of this test are crucial in assessing the performance and capabilities of the solar module in developing electrical power under specific conditions. The monitoring and testing processes are an integral part of understanding and evaluating the performance of solar power generation. The data obtained from these measurements aid in optimizing the system's operation and ensuring that the solar power generation operates efficiently following its specifications. Additionally, the information obtained from the load testing is valuable in identifying the capabilities and limitations of the solar module in handling various electrical loads that may be used.

Table 2. Power Measurement From The Solar Module With a Lamp Load of 10 Watt

Time	Load 10 Watt	Solar temperature Celcius (°C)	Sunlight Intensity (Lux)
7:05:00	10.64	26.9	224.61
7:06:00	10.78	26.9	224.61
7:07:00	9.56	25.2	214.61
7:08:00	10.13	28.2	244.61
7:09:00	10.77	29.8	267.58
7:10:00	10.79	30.9	277.58
7:11:00	10.64	28.9	244.61
7:12:00	10.64	28.9	244.61
7:13:00	10.78	28.9	244.61
7:14:00	10.64	26.7	217.61

In Table 2, the results of the testing using a 10 Watt lamp load are observed. The test findings indicate that the average load power is approximately 10 Watts under stable conditions. However, an exciting occurrence occurred in the 3rd minute when the load's power dropped below 10 Watts. It should be noted that this decrease happened under normal conditions and is a part of the standard system response. The testing was conducted over 10 minutes, and the results revealed that the solar cells are sensitive to changes in environmental conditions.

Furthermore, this testing also provides insights into temperature conditions and sunlight intensity significantly impacting the solar cells' output power. During the testing, changes in temperature and sunlight levels also influence the power generated by the solar cells. Therefore, a deeper understanding of how these variables affect the performance of solar cells is crucial in designing an efficient and reliable solar power generation system. The results of this testing offer valuable information to optimize the operation of solar cells and ensure that the solar power generation system can operate effectively under various environmental conditions.

4 Conclusion

Researh on the potential of new renewable energy, particularly solar energy, as presented in this paper, brings forth significant findings. The increasing intensity of sunlight has a substantial impact on solar energy production. More precisely, the higher the sun's power, the greater the voltage solar cells generate. Measurements conducted from 07:00 to 17:00 WIB reveal voltage variations in solar panels. The lowest recorded voltage was 20.4 V, with a current of 0.2 A. Conversely, the highest results were achieved at 12:00 WIB, with a voltage reaching 23.59 V and a current of 0.7 A. This study also underscores the influence of ambient temperature on solar energy production. Variations in environmental temperature affect the power output of solar panels, with higher temperatures resulting in greater power output. This implies that environmental factors must be considered when designing solar energy systems, especially in regions experiencing significant temperature fluctuations. The findings of this research have important implications for the development and utilization of solar energy in various areas. With a better understanding of the factors influencing solar panel performance, decision-makers, and renewable energy developers can more effectively harness the potential of solar energy to meet local energy needs. This conclusion provides valuable insights in support of sustainability and diversification of energy sources.

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