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Development of Independent Solar Energy Performance Monitoring System

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Abstract: Solar energy is one of the most ecologically safe energy resources, contributing nothing to global warming. The benefits of properly utilising solar energy are numerous. There is no cost except for the initial installation of the device. Malaysia has a wide range of renewable energy resources, including solar, biomass, and wind energy, among others. Solar energy has huge power generating potential; nevertheless, new incentives must be devised to boost its economic feasibility. In recent years, there has been a tremendous surge in the construction of solar plants all over the world. The total energy output and performance of solar plants are dependent on the proper and timely maintenance of various components such as solar panel strings, inverters, and transformers. These devices can deteriorate over time or as a result of specific equipment failing. The purpose of this project is to develop the solar energy system to enhance energy management and efficiency contributing with the internet of things that can be monitored on performance of the solar energy such as power output and energy. This system was tested by connecting the photovoltaic panel in parallel. As a result, the resultant current equals the sum of all the panels in the parallel. The overall voltage will be the same as a single panel's output voltage. This approach does not need a series connection since it allows the panels to operate continuously even if one of the panels fails.

Keywords: Solar Energy, Internet of Things (IoT), Solar Panel, Energy Management and Efficiency

1. Introduction

Governments all over the world are increasingly focused on renewable energy generation as global energy demand rises in step with global population increase. Solar energy is often recognised as the most promising and dependable form of renewable energy [1]. In this context, certain governments have provided various incentives for the development of solar energy-based power plants to augment existing fossil-fuel-powered power plants. Photovoltaic (PV) technology converts solar energy into electricity.

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PV is built up of cells, which are layers of semiconductor material. When exposed to sunlight, it produces energy. Since the year 2000, PV distribution has grown dramatically. PV accounts for 2.6 percent of overall power consumption in Europe and 5.2 percent of peak electricity demand.

The connection of the PV module is depending on equipment use in the solar energy system. Although there are certain exceptions, completely parallel connections are typically used in smaller, simpler systems, particularly with PWM Controllers. Connecting your panels in parallel will enhance the amps while maintaining a steady voltage. Because connecting 12V panels in parallel retains your charging capability at 12V, it is commonly utilised in 12V systems with several panels. The disadvantage of parallel systems is that high current cannot be sent over long distances without using excessively large cables. Only series connections are frequently used in smaller systems that use an MPPT Controller. By connecting your panels in series, you may raise the voltage while maintaining the same amperage. Because MPPT controllers can accept greater voltage input while still charging 12V or more batteries, series connections are used. The advantage of series is that it is simple to send data across long distances. The disadvantage of series systems is that they have shading issues. When panels are linked in series, they all rely on one another. The entire string suffers when one panel is shaded. In a parallel connection, this will not occur.1.2 Additional introduction subheadings

Monitoring is essential in many technological systems, such as solar energy conversion systems. Monitoring is defined as "regular observation and recording of project activities through the acquisition of information on all areas of the project"[7]. Monitoring is required to track the development of the project [8]. Monitoring is also vital in making judgments on project improvement, which supports in project design and implementation [9]. Monitoring implementation offers vital information for data analysis, assuring target achievement, detecting problems and remedies, and verifying the system's operational soundness [10]. To guarantee that data is handled carefully, users should add a monitoring tool into their system [11].

The traditional wired monitoring system provides a dependable option for data delivery but has some disadvantages. Aside from the physical restrictions that come with installing data cables, the usage of these cables raises installation and maintenance costs [12]. Furthermore, for outdoor applications such as PV systems, continual exposure to solar rays and rainfall may shorten the system's lifespan. As a result, wireless monitoring systems are preferred over traditional cable-based monitoring systems. A web-based monitoring system can be an appealing monitoring approach since it allows data to be disseminated to remote users and allows users to examine data from any device with internet access [13].

Solar monitoring is becoming essential in photovoltaic systems. It is critical to assess the system's efficiency and the elements that contribute to system failure. When monitoring a solar system, several issues and restrictions arise. Traditional cable-based monitoring systems are expensive to install and require extensive maintenance over time. As a result, there is a research issue in the domain of methods utilised to monitor system performance, whether wired or wireless. Few studies used wireless technologies to monitor the performance of solar systems in unattended mode and from a distance. The monitoring system for the complete solar energy system has weaknesses that are difficult to identify. As a result, it may take some time to identify a flaw in each piece of equipment.In this study, solar independent solar energy performance monitoring system was designed and built as a solution for solar power plant. It has creating a new independent solar energy performance monitoring system. The system has internet capabilities and can monitor and operate the PV system from a distance. The Esp 32 Node Microcontroller Unit has been chosen as a data transmission medium. PV voltage, PV current, and power output for each panel are monitored and recorded, together with sensors as input signals such as the ACS 712 current module, voltage sensor module, and temperature sensor.

2. Background of Study

The Edmond Becquerel, a French physicist, devised the method of harnessing sunlight to generate an electric current in a solid object in 1839. However, it took another century to fully comprehend this process. Photovoltaic technology, which was created in its present form in 1953, has been used to power space satellites [7]. Since the late 1970s, there has been a great deal of discussion on energy efficiency as a result of the 1973 oil crisis. Bunse and Vodicka [14] identify three causes for increasing energy efficiency in the industry: rising energy prices, environmental legislation, and increased customer awareness of environmentally friendly goods. Tiranni et al [15] and Rodhin and Thollander [16] outline and explore several challenges to energy efficiency in non-energy intensive and energy intensive businesses, respectively.

According to Garetti and Taisch [17] there is a lack of the needed level of control in energy utilisation. This limitation has prompted research into approaches for forecasting energy consumption patterns, including the use of data on machine tools to mimic energy profiles [18], and the "EnergyBlocks" Methodology for forecasting energy consumption in manufacturing activities [19]. There are two types of forecasting models used to estimate energy usage [18]. The first is based on driving variables, while the second is based on past data. The predicted energy usage, on the other hand, is erroneous and only available at long time intervals. As a result, the adoption of an energy monitoring system to measure energy performance with greater accuracy in real-time is critical. The Internet of things simply implies the physical item networks which are defined utilising wireless media employing software modules. In order to gather, manage and share data, some applications, such as gadgets and other objects, may include software and sensors [20].

There are few works that have been based on an Arduino Uno microcontroller. Arduino Uno is a microcontroller that can be developed using C/C++ software from Arduino IDE and exported over the USB connection straight to the board. Data can be played by different sensor kinds within the boundary depending on how the code is sent to the board [21]. A Wi-Fi technology module is used for wireless monitoring and control to link a microcontroller to the internet. The wireless internet (IEEe 802.11g) module is selected since it works on 2.4 GHz and provides a high data rate of around 54Mb/s in contrast to ZigBee (250 Kbps). Moreover, Raspberry Pi is the microcontroller board proposed for the most recent study. Python language is written for accessing data with the Modbus protocol to the raspberry pi. A number of sensors have been transferred to the database via the Wi-Fi module [22] attached to pi and the information. A voltage sensor is used to measure the DC voltage and supply data as an input signal to a microcontroller. Many types of voltage sensors were used to monitor the voltage of the system in the prior study. The sensor INA219 monitors voltage and current simultaneously and delivers data to Arduino in digital form, converting both voltage and current into power as needed for loading [23]. A voltages sensor, the LM24, can only be read from 0 to 35 volts and links with a mega Arduino by means of real differential input and short-circuit output [24]. There is also a voltage sensor. The current sensor is used to measure DC current, like the voltage sensor, and the data is recognised by the microcontroller as an input signal. There is an actual sensor known as ACS712 utilised for measurements of the DC output current with 3 pinouts according to the prior study: Vcc, off, and ground. The magnetic hysteresis and the very constant output offset voltage are very minimal [24].

A temperature sensor is an electrical component that monitors and transforms the temperature to record, analysis and monitor input data. The temperature sensors may be used for monitoring in numerous sorts. Most of them are connected with other sensors, such as moisture sensors, such as the DHT22, that measure Celsius and Fahrenheit temperature and incorporate the moisture sensor. The unit is sent in the form of a digital signal to the microcontroller [25].

3. Methods

3.1 Project Planning

This project planning comprises a flowchart that displays the work progression method for the proposal, as shown in Figure 1. As indicated, the project begins with selecting an acceptable title, study, technique, and result.

Start

Identify Project Title

Literature Review

Methodology

Result

Conclusion

End

Figure 1: Project Planning Flow process

3.2 Project Architecture

This schematic design of PV power system is designated. The connection from PV panel is connected to the solar charge controller to avoid the system being a failure if the solar panel is directly connected to the battery. The solar charge controller is also used to supply the direct current to the direct current load. For the system using alternating current will use an inverter to convert direct current to alternating current. Solar charge controller also used to charge the battery. In conclusion, the solar charge controller is one of the protection equipment that will protect other equipment from being a failure. Figure 2 shows the schematic diagram of PV power system.

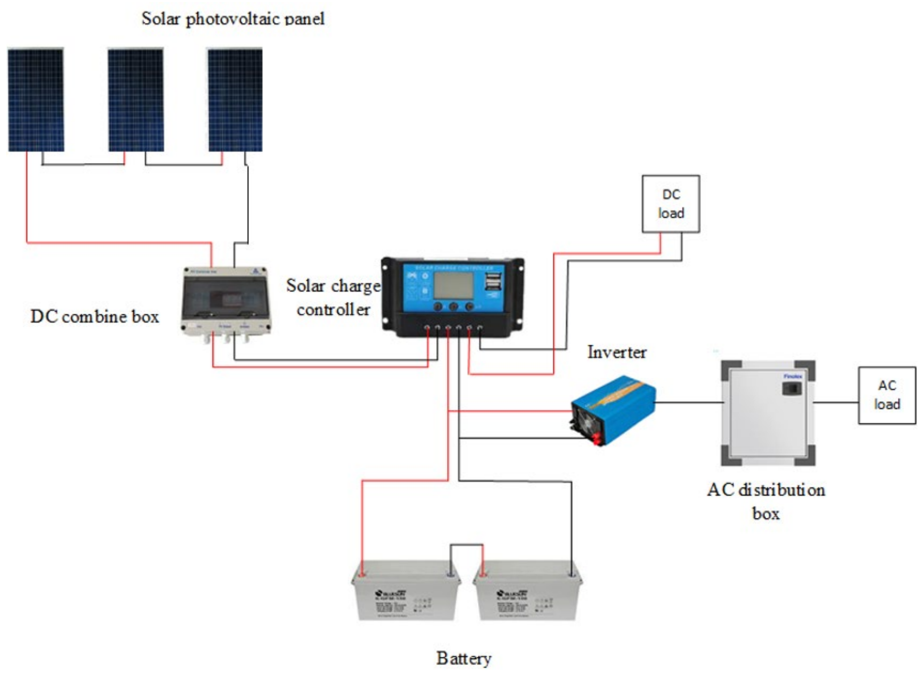

Figure 2: Schematic Diagram

The system is separated into two parts: input and output. The input portion is made up of sensors, while the output portion is made up of the parameter value of each PV panel. The ESP32 module serves as the primary microcontroller in this system. The ESP32 is linked to Wi-Fi, which allows network access and smartphone connectivity to the system. All data input will be sent to blynk application. The sensors utilised are the ACS712 current sensor, the voltage sensor, and the DS18B20 temperature sensor, all of which are powered by 5V sources. The sensor is placed between each component to readily discover faults that occur between the components. The Blynk application is used as an IoT platform to store and display data from sensing equipment. Figure 3 shows the block diagram of the system.

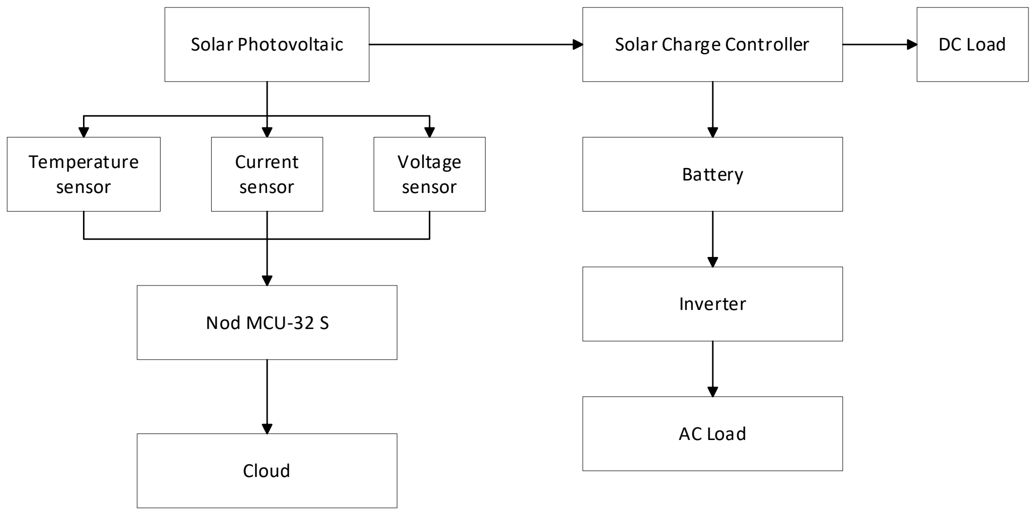

Figure 3: Block Diagram of The System

3.3 PV Power System Hardware Setup

The prototype project's designation layout was designed to ensure that every electronic device connection is correct and that the prototype functions properly. This project is based on an off-grid photovoltaic solar system that requires a battery to store energy. In this project, a 10 W, 18 V solar panel is connected to a 10 A charge controller, and a 12 V, 7 Ah battery is connected in parallel with the battery storage. The solar charge controller also included USB ports and a 12 V DC output for use with DC loads. Its purpose is to keep the battery from being overcharged or discharged. This charger controller was simple to operate and ideal for use in projects. Figure 4 shown the PV power system hardware setup.

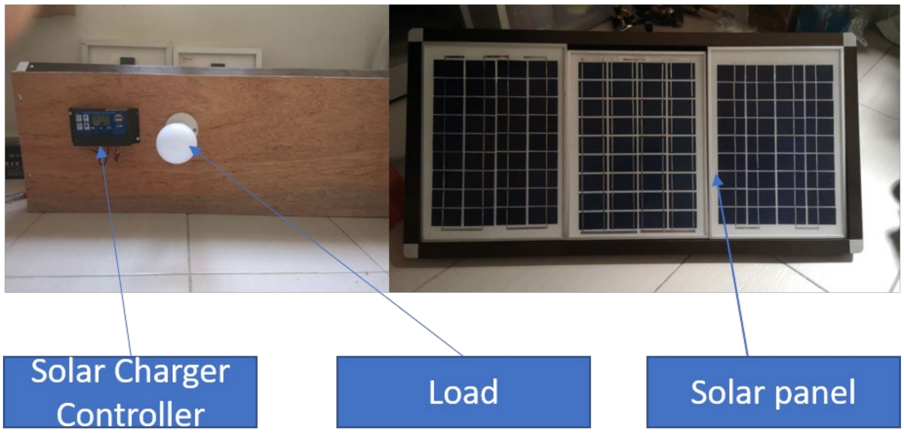

Figure 4: PV power system hardware setup

3.4 Iot Monitoring System Hardware Setup

Figure 5 shows a monitoring circuit with sensors that control the detection of faults in a PV solar system. The circuit connects the ESP32, voltage sensor, current sensor, temperature sensor. To measure voltage and current, this circuit consists of three pairs of voltage and current sensors, each of which is connected to solar panels, battery storage, and an inverter. Voltage and current sensors receive readings from the solar system and use them to display data to the Blynk application which is controlled by a microcontroller.

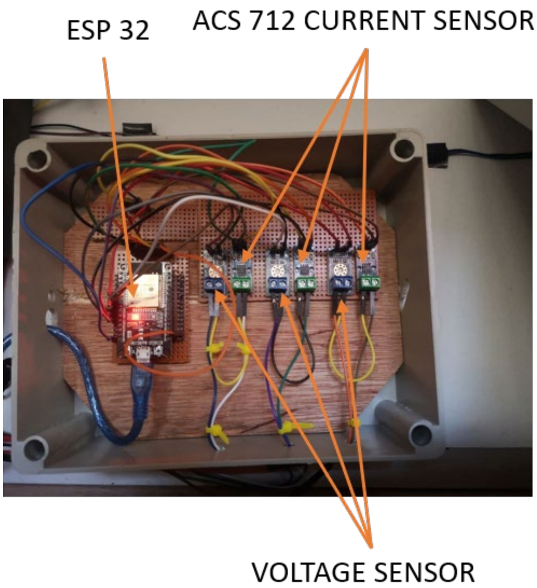

Figure 5: Iot Monitoring System Hardware

3.5 Application Interface for Monitoring System

For each component in this project, the results of testing for the PV solar system monitoring system were displayed. The solar system measurement was displayed using Blynk application displays. The app interface displays the solar panel's voltage, current, power, and temperature measurements. This Blynk application was able to extract sensor data and send it to a registered e-mail address. This data is then graphed to make it simpler to see the change in the output system. Figure 3.6 depicts the Blynk application's monitoring and problem alerting interface.

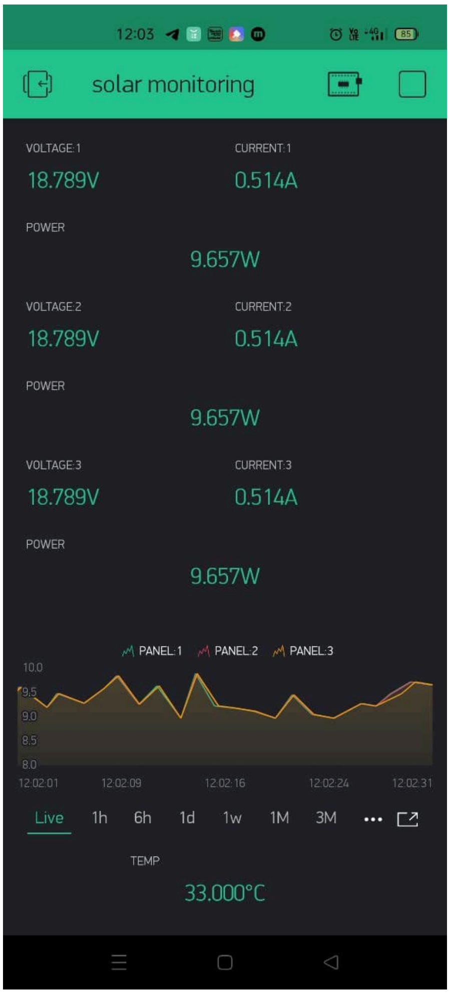

Figure 6: Blynk Application Interface

3.6 Calculation PV Voltage

Eq. 1 shows the calculation of the PV voltage for the voltage sensor. For the voltage scale is set to 7.911 as a constant. The constant is used as a scale for calibration for voltage sensor.

$$\text{Voltage(V)} = ADCvoltage \ \times voltage\ scale\ Eq.1$$

3.7 Calculation PV Current

Eq. 2 shows the calculation of the PV current for current sensor. For the current scale is set to 1.5 as a constant, ACoffset is defined as constant is et to 514, and the mVperAmp is set to 200. All the constant is used as a scale for calibration for sensor.

$$Amps(A) \ = \frac{(current \times current\ scale - ACoffset)}{mVperAmp}\ Eq.\ 2$$

3.8 Calculation of PV Power

Equation For power output the equation show.

$$Power(W) = current \times voltage\ Eq.\ 3$$

4. Results and Discussion

4.1 PV Power System Testing

The schematic diagram represents how the system is connected, as shown in Figure 4.1. Solar panels transform solar power into DC power. The task of the charging controller is to manage the solar panels' power which then is returned to the solar panel to discover the cause of the damage to the panel. The battery system works as an electrical power storage device when sunshine is not available (i.e. night). This system is connected to an inverter, which transforms Direct Current (D.C.) to AC. Figure 7 shows the working of PV power system.

Figure 7: the working PV power system

4.2 Result on daily power generation

Data processing is done by esp 32 when the monitoring hardware is connected with a power supply which is the battery. The data received from esp 32 and will display in blynk app. The data received from esp 32 through wifi indicates PV voltage and current ADC values, and panel temperature, and solar radiation. The data is displays through the blynk app and data will be sent to the email in CSV format. The reading was taken for a few days from 6.00 am until 8.00 pm at kolej kediaman pagoh, UTHM to observe the performance of the solar system. The collected data from the system operation is used the real time monitoring of power output of each panel. Figure 8 shows the result of the daily power generation of each panel.

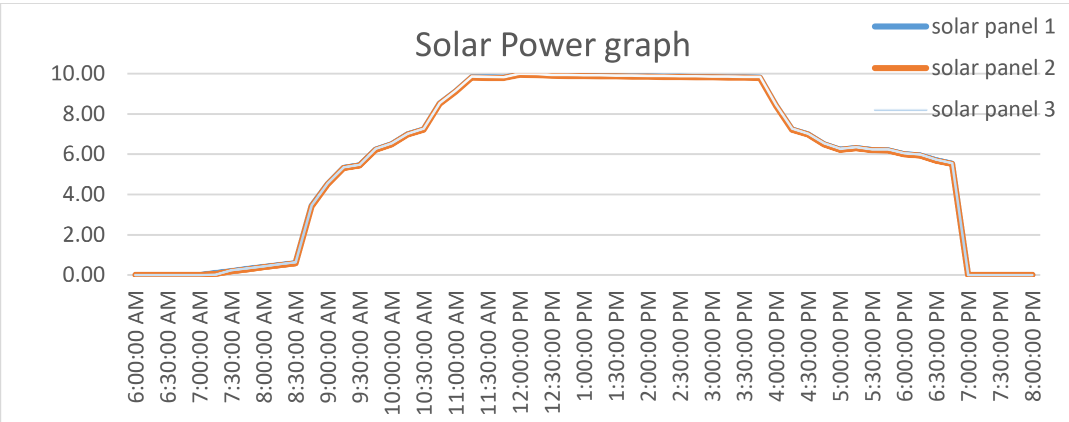

Figure 8: Daily power generation of each solar panel

The graphs above show the PV solar system in operation on a normal sunny day. This reading was taken between 6:00 a.m. and 8:00 p.m. The graphs show the ups and downs of the power readings from the solar panels on that particular day. Because it was still early in the morning, the power output of the solar panel was still in minimum power output generated by the solar panel, and when peak hour of sunlight, the power output reached the maximum demand of power output generated.

4.3 PV Power System Testing for Each Panel

Parameter values were critical in a PV solar system. To avoid solar components from being degraded while in operation, users must ensure that a solar system functions in typical circumstances that are within its specifications. Furthermore, to prevent losing the energy that solar panels may provide, make sure that the solar system is operating more efficiently. Solar panels may not get direct sunlight in a variety of scenarios. They may be shaded by nearby buildings or trees, tilted away from the sun, or simply impacted by weather conditions such as clouds, rain, or snow. The Figure 9 shows the PV power system does not get direct sunlight.

Figure 9: The PV Panel shaded condition

Solar panels generate power by utilising both direct and indirect sunlight as inputs. Both types of sunshine contain photons, which are converted into electric current by solar panels. If there is no direct sunshine, solar panels will generate power using just indirect sunlight. However, in the absence of direct sunshine, performance will decrease. This is due to the fact that solar panels require 1000 W/m^2 of sunlight to reach their peak output; this amount of sunlight can only be obtained when there is direct sunlight shining. The Figure 10 shows the power output of each PV panel if any obstacle prevents sunlight. The power output of each panel will be spiking and drop as shown in Figure 10.

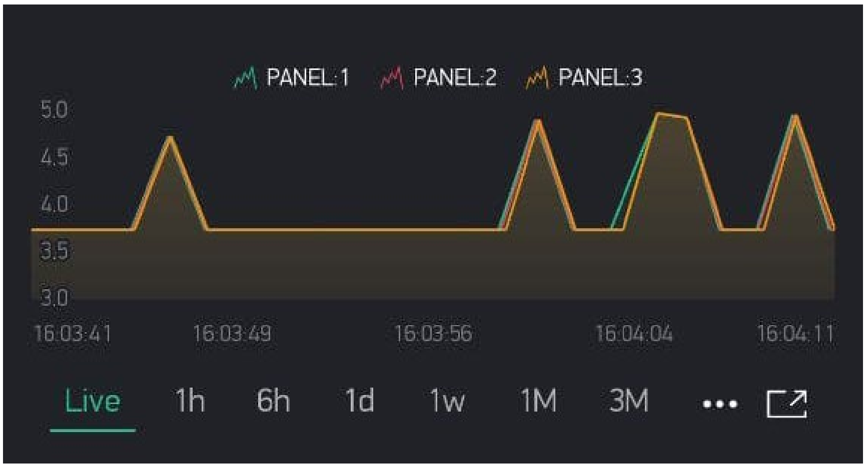

Figure 10: The Blnyk Application Graph

5. Conclusion

In conclusion, the development of an independent energy performance monitoring system is designed to enhance energy management and efficiency. Otherwise, the development of this system shows how monitoring system detect the failure on PV panels and the users can study on how the failure can be done such as dust, shading and many more. This system is completely connected with parallel connection of PV panel, battery, solar charger controller and bulb as direct current load. This system is designed with a monitoring system to help the user monitor the performance of PV panels from failure. The parameter measured is the current value, voltage value and power output of each solar panel. Hence, the PV panels are connected in parallel, it is easy to detect failure from the solar panel. The system still operates if one of the solar panels fail. As a result, the data has been displayed through blynk application on smartphone. Users can monitor the performance of the system from afar.

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