Development A Portable Solar Energy Measurement System

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Abstract: This project presents the design and development a portable measurement device for measure and monitor solar panel parameters by using Internet of Things (IoT) concept. Solar energy measurement plays a very important role in the measurement of parameter reading for the determination of output generated, but the challenge is only performed manually at the work site using a clamp meter or a multimeter. Furthermore, it was very difficult to get the value at that time, and the data recovery error occurred. There are three specific objectives have been used for the project. Firstly, the relevant circuits for this project are design and built the circuit by using software. The output of the measurement solar irradiance, ambient temperature, solar panel temperature, current and voltage value were displayed on LCD. Next, IoT concept is used for solar panel measurement and monitoring. The value of the measurement and monitoring is used ThingSpeak cloud and ThingView application on the smartphone. It can be collected the portable solar for the energy measurement system can monitor on site, anywhere and anytime using IoT platform.

Keywords: Solar Energy Measurement System, Solar Panel, ThingSpeak, IoT

1. Introduction
Energy is well known as being able to bring about change or do work. For example, energy produces light, heat, sound, and motion. Furthermore, there are many types of energy such as electrical energy, kinetic energy, nuclear energy, sound energy and others. There are several renewable energies in this earth, which is wind energy, solar energy, biomass, geothermal and hydroelectric. Researchers have studied the economic feasibility of solar energy for domestic, commercial, and industrial use over the last two decades. Due to the limited supply of natural primary energy sources, industrial countries such as Japan and Germany are looking for alternative energy sources such as solar energy [1,2]. Solar energy is sustainable and clean source of renewable energy [3]. An electrical unit, solar cell is made by silicon that is a type of semiconductors for generating electrical energy. A large number of solar cells combine to form a solar panel. Solar power is a conversion of sunlight into electricity, sunlight is collect either directly by using photovoltaics or indirectly using concentrate of solar energy [4]. The conversion of solar energy into electrical energy may be used to meet the needs of household electricity or industries.
depending on low-power range electricity. Larger scale of solar panels connected to the grid that allows power to be transferred to the grid if the solar panel has excess power [5]. Solar system, panel or array that perform depends on many factors which is the solar irradiance received by the solar panels during the day on peak hours [6,7].

The output power generated by the solar energy conversion process is determined by certain environmental conditions in which solar panels are installed, such as the strength of the sun, temperature and environmental conditions that are constantly changing over time [8]. Therefore, developer, system owner and user need an equipment to observe and analysis the performance of solar system. Due to this reason, several researchers have been conducted investigations and innovation to solve this problem. Jumaat and Othman used Arduino Uno as a microcontroller for read the input from the sensor to display the parameter temperature, voltage, light intensity and current on the LCD [9]. On the other hand, another research was done by Othman et al. which was to show the digital value of the output voltage in numerical that not shown in line chart by using Raspberry Pi, Phyton language and Node.js application [10].

Isdawimah et al. was using LabVIEW software to show the solar monitoring system result graphs which were determined by electrical parameters. The result is indicated that the built real-monitoring system based on LabVIEW works efficiently and smoothly, allowing it to be easily applied and adapted to the PV system [4].

Next, another research was done by Amhani and Attia that was using lux sensor, dust density sensor, power supply, temperature sensor, Arduino, and data logger module as a component and method. On the result, the researcher was measured multiple parameters continuously, these parameters have effect positively or negatively on the total obtained power. Each parameter is measured separately through the related sensor, and the collected records were drawn to demonstrate their effects [11].

Furthermore, Adilah et al. was using humidity and LDR sensor, arduino mega and Global System for Mobile Communications (GSM) shielding. In the result, the efficiency of solar cell influence on the output value of the solar panel, where is the higher the efficiency the higher the solar radiation is produced. But the solar panel should be monitored in order to maintain the output value and the consistency of the value. By this monitoring system, the solar panel can be use at long term usage and the maintenance can be done at instant when the notification Short Message Service (SMS) system is installed on the system to the user [8].

Other than that, Kekre and Gawre was using current sensor, power supply to arduino, arduino controller, LCD and wi-fi module as a component and based on the result, this system keeps continues monitoring the solar power system, the daily, weekly, and monthly investigation become easy and efficient also with the help of this analysis it is possible to detect any fault occurred within power plant as the generated power may show some inconsistency in data of solar power system [12].

Apart of that, research was done by Sarswat et al. and Ghodake et al. which was creating mobile application with various sensors, plot of voltage, current, temperature and power plots are made to display the output on mobile application by backup in cloud using ThinkSpeak. Among of these both project, there have a different in the output part. Project that has been done by Sarswat et al. is only using LCD but project by Ghodake et al., the output is on LCD and Smartphone for monitor the solar panel performance [13,14].

Therefore, this research focuses on developing a solar measurement prototype that can monitor the performance of the solar system anytime and anywhere. The solar energy measurement device is a system that can measure solar cell parameters and environment conditions, sure as solar current, voltage, solar panel temperature, solar irradiance, ambient temperature, and humidity. This proposed system is designed for site control and real-time monitoring of solar panel output performance where users can access data on their smartphone or computer via Internet. This system uses multiple sensors for measuring the output performance of solar panels in real time to take effective measures and is accurate and less manpower required.
2. Material and Method

2.1. Flowchart of Project

Figure 1 show the flowchart of overall project. The project is starting by reviewing previous study that related to this project. From the literature review, it can be obtained the optimum ideas and the circuits design. After that, the circuits will be designed and simulated to test the functionality of these circuits. When the circuits are malfunction during the simulation, the circuits will be redesigned to troubleshoot that problem. However, when the circuits are successful simulated, it will proceed to the next step which is to program for these circuits. Next, is to run and testing the functionality of the program coding. When the simulation fails, then the software will be reprogrammed again until the coding works as expected. On the other hand, when the circuits code is successfully developed, a hardware prototype can be developed in the next step. The first step in the hardware part is to build the circuits on the circuit board. Following this, programming a microcontroller by transferring the program from the compiler to the memory of the microcontroller. After that, this portable measurement device will be tested the functionality. When the portable measurement device fails to work properly, it will return to hardware part for troubleshooting until the desired function is obtained. While, the portable measurement device works normally, the measurement results are displayed on the Liquid Crystal Display (LCD) and smartphone. Lastly, the measurement data will be collected and saved in the cloud by using the concept of Internet of Things (IoT).

Fig. 1. The flowchart of project
2.2. Project Block Diagram

Figure 2 shows a project block diagram that designed and executed by using Arduino Integrated Development Environment (IDE) and Espressif 32 (ESP32). The main purpose of the project is to monitor the environment parameter and performance parameter of the solar panel. In this project, there are four sensors were used and combined with ESP32 microcontroller to form a solar energy measurement monitoring system. The first input is the MAX44009 sensor, which is used to measure the solar irradiation. Secondly is the ambient temperature and humidity sensor (DHT11) that used to measure the ambient temperature and humidity from the solar panel. Next is temperature sensor (LM35) that is used to measure the temperature from the solar panel. Furthermore, current and voltage sensor (INA219) is used to measure current and voltage generated from solar panel. A 12 V LED bulb is used as a load in this project. The function of the load is to get the load current and load voltage from the solar panel. Then, all the sensed data has been collected and sent to the ESP32 board that was powered up by using 5 V power bank. Arduino IDE has executed the instruction of written code in the program and sent to cloud interface by ESP32 Wi-Fi-module. Finally, it displays the respective values sensed by these sensors on terminal screen. For the output part, it classified in two terminal screens that is LCD and smartphone. ESP32 has wi-fi module that monitor that data from microcontroller to IoT platform and the output will display on smartphone using ThingSpeak and ThingView application as a cloud service to store and display the measurement or the data.

![Fig. 2. Project Block Diagram](image)

2.3. Outdoor Testing of Solar Energy Measurement System Portable Under the Outdoor Condition

Figure 3 shows an experimental setup of a portable and the prototype of solar energy measurement system. All the sensors will sense all the performance of solar panel. For the solar irradiance, the placement of MAX44009 sensor is the top of solar panel. So that, the radiation of the sunlight will fall on to that sensors and measured the parameter. Next, the placement of DHT11 sensor on beside the solar panel that measured the ambient temperature and humidity on that time. Other than that, the placement of LM35 sensor is placed behind of solar panel that was showed in Figure 4 and it measured the solar panel temperature on that time. Furthermore, the INA219 sensor is placed inside on the portable that as shown on Figure 5. A part of that, the performance of 20-Watt 12 V solar panel is connected direct to the 20-Watt 12 V<sub>DC</sub> load which is the bulb that shown as Figure 5. The tilt angle of the solar panel testing is at 15°, this is suggested by the researched conducted by Manun and his team [15].
3. Result and Discussion

In this section, it was divided with seven parts which is solar irradiance, ambient temperature, humidity, solar temperature, output current, output voltage, and output power generated by the solar panel. This measurement has been recorded in a day within 8.30 AM to 6.30 PM with the tilt angle of solar panel is 15 °. The result was recorded with 10 minutes interval through IoT concept by using Thingspeak and Thingview for measured and monitored. This data was collected from Thingspeak and converted to Excel file.
3.1. Result of Solar Irradiance

Based on Figure 6, the result shows that the highest solar irradiance was 712 W/m$^2$ at 2.00 PM while the lowest result on solar irradiance was 39 W/m$^2$ at 6.30 PM. In this result, the solar irradiance started increasing the peak hour at 11.00 AM until 2.00 PM and stating decrease at 2.10 PM. The solar irradiance on the starting and end of the graph is lower because of the sun position on sunrise and sunset condition while on peak hour, the sun on upward position. As the solar irradiance increases, the value of MAX44009 sensor will increase. This is also named photodiode that same with semiconductor diode. The spectral reaction of the chip photodiode is designed to replicate the human eye's experience of ambient light.

Fig. 6. Result of Solar Irradiance

3.2. Result of Ambient Temperature and Humidity

The measurement for maximum value of ambient temperature is 42.8 °C at 3.20 PM and the humidity is 87 % at 8.30 AM, respectively. The minimum value for ambient temperature 24.6 °C at 8.30 AM, while humidity is 30 % on 3.20 PM. Based on Figure 7 and Figure 8, the graphs shows that the starting of measurement at 8.30 AM that the ambient temperature was lower, and humidity is higher. On the peak hour, the ambient temperature was increased until 3.20 PM while humidity was decreasing until 30 % on that time. From this pattern, the maximum value of ambient temperature on that day were attributed to the high solar irradiance obtained, the period when the atmosphere is mostly clear and clean, no clouds, dust free and low humidity and the minimum value of ambient temperature were attributed to low solar irradiance and high humidity.

Fig. 7. Result of Ambient Temperature
3.3. Result of Solar Temperature

Figure 9 shows the result of temperature from solar panel. The temperature of solar panel is the main part of generating energy such as voltage and current that are generated from the solar panel. The maximum solar panel temperature is 65 °C at 2.00 PM and minimum temperature on starting point of graph which is 22 °C at 8.30 AM. The solar panel facing the higher temperature than the ambient temperature, this is because the solar panel is manufactured by semiconductor. The semiconductor is sensitive to temperature. The bandgap of a semiconductor is reducing due to the increment in the temperature, thereby affecting most of the semiconductor material parameters. In this result, the solar panel temperature starting increased from 10.10 AM until the peak hour of sun. The solar panel temperature starting decreased 2.20 PM. It is because the decreasing of solar irradiance and the ambient temperature. The solar panel temperature is effect on the generating of solar energy.

3.4. Result of Current

Based on Figure 10, the result shows the output performance of current generated by the solar panel. This result is the load current from solar panel to the 20-Watt bulb load for measuring the load current from solar panel. The highest load current at 2.00 PM with 1.07 A that was generated at that time while the lowest load current is 0.08 A at the starting measurement of solar panel which is 8.30 AM. The result was shows in a graph that the load current was affected on solar irradiance and solar panel temperature. The highest value of solar irradiance and temperature of solar panel, the highest load current was generated.
3.5. Result of Voltage

Figure 11 displays the result for measurement the output voltage from solar panel performance. This result is the load current from solar panel to the 20-Watt bulb load for measuring the load voltage from solar panel. From this graph, the maximum output at 1.50 PM with 15.89 V on that time. The minimum output at 6.30 PM that only can generated 8.79 V. Based on this result, the pattern of the load voltage was stable on that range and does not have a very significant difference value on load voltage. The higher the voltage value, the solar irradiance also higher. The presence solar irradiance can influence the voltage generated by the solar panel.

3.6. Result of Power

Figure 12 shows the result or graph for output power performance that was generated from solar panel. This result is form from current and voltage field to get the value of output power. The highest load power was generated at 2.00 PM with 16.76 W and the lowest is 0.54 W at 6.30 PM. Based on this result, the power continuously increased from 11.20 AM to 2.00 PM and dropped on 2.10 PM because the position on the sun. According to this result, the solar panel failed to generate the actual power which is 20 W of the solar panel has a power losing. Besides, the power of solar panel also got affected due to the size of area as the bigger the area, the more energy can be absorbed. The output power was affecting by solar irradiance, current and temperature. The more the value of solar irradiance, the more the power was generated by solar panel. When the temperature gets high, it will affect the high in voltage that simultaneously will lower the current. Hence, the power will be increased.
3.7. Result on ThingSpeak Cloud and ThingView Application

Figure 13 shows the output performance by IoT concept on ThingSpeak open-source cloud service and Figure 14 shows the output performance on ThingView application.

![Power Vs Time](image)

**Fig. 12. Result of Power**

![Field Chart](image)

**Fig. 13. Result on ThingSpeak Cloud**
4. Conclusion

In conclusion, the development a portable solar energy measurement system was successfully designed and developed. This testing was carried out on the designed and developed the system that findings obtained showed the right functioning of solar energy measurement system. This portable measurement device that easy to use for measure and monitoring the performance of solar panel without using the analog or digital multimeter on worksite. So that, the user or consumer will get the optimum values without any error on data retrieval.

Other than that, the solar energy measurement system was measured and monitored the solar panel parameter by using Internet of Things (IoT) concept. The parameter was recorded on 10 minutes interval for each parameter for energy that produced from solar panel. On this IoT technology, user and worker will got the time saving, reduce the number of manpower and more effectively.

The results obtained by the solar energy measurement system show that the best output performance to generated of solar panel was at within 1.50 PM to 2.00 PM with highest load current value which is 1.07 A and 15.89 V and for the highest value for load voltage. The maximum output power which is 16.76 W that have been recorded. Currently, the solar irradiance was 712 W/m², the ambient temperature was at 41.1 °C and 33 % for humidity. The solar temperature is 65 °C on that time.

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