IoT-Based Photovoltaic Performance Monitoring System Using Arduino Uno

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Abstract

Currently more than 80% of the world's energy needs are met from fossil energy sources (petroleum, natural gas, and coal). In the use of Photovoltaic, the resulting performance must be supervised in order to maintain the condition of the panel to reduce significant damage to the photovoltaic. Several studies have discussed various applications of electrical energy monitoring systems especially on photovoltaics. photovoltaic Performance Monitoring System Based Iot Using Arduino Uno on Pematang Johar has a problem formulation to know the performance of solar photovoltaics using internet methods, in order to facilitate remote surveillance. In this study, Voltage Divider, Current Sensor (ACS712), DHT22 Sensor, LDR Sensor (Light Dependent Resistor) and Blynk platform were used as sensor reading viewer. The research began with designing software and hardware circuits to test the success of the system, then designing the Blynk platform, as well as designing programs using arduino IDE software. In sending data using internet media, wi-fi module (NodeMCU) is used to send arduino reading results to Blynk platform with JSON program and the voltage sensor reading showed an error of 1.8 % on the current sensor showed an error of 3.3 %.

Keywords
Photovoltaic, Sensor, IoT, Blynk, Arduino.

1. Introduction

At present, more than 80% of the world's energy needs are met from fossil energy sources (petroleum, natural gas, and coal). The existence of an evergrowing industrial revolution resulted in the depletion of conventional energy supplies so that energy consumption rates such as electricity bills increased, plus the equipment needed now used large electricity consumption. Therefore, a reserve energy source is needed to minimize the use of conventional energy by utilizing available energy but is environmentally friendly.

Indonesia is a tropical country that has a contribution of solar energy that has the potential to develop large-scale solar power plants that they can replace conventional energy use which is not environmentally friendly and has limited availability. The use of solar energy by photovoltaic offers an environmentally friendly source of energy.
To prevent damage and degradation of photovoltaic performance, a device is needed to monitor performance and provide notification when photovoltaic performance has decreased, so that we can anticipate so that there is no damage and quality degradation of the photovoltaic. The factor that must be considered before implementing renewable energy sources is to accurately measure the potential of available resources, including the intensity of sunlight (Rimbawati et al., 2018)

Several studies have discussed various applications of electrical energy monitoring systems, especially in photovoltaics. In its development, the monitoring system is designed to be monitored locally (Zahran et al. 2010). In a research conducted by (Soetedjo et al. 2014), the web-scada implementation is used to monitor and control the solar-wind hybrid generator system remotely via the internet network. The connection to the internet network is carried out through a computer server with communication between sensors, remote terminals, and server computers in this study still using a cable network using serial communication and a Local Area Network, the monitoring system uses Wireless Sensor Network technology (WSN) (Pamungkas and Wirawan 2015), a monitoring system or monitoring using telecommunication media, namely the SMS gateway service (Fitriandi et al. 2016), while the latest is a concept to take advantage of internet connectivity which is always connected at any time, known as IoT or the Internet. of Things (Rohman and Iqbal 2016). Based on the above, the most appropriate method is to use the Internet of Think method which is able to monitor the performance of solar panels quickly and easily.

The purpose of this research is to find out the sensor reading error with a measuring instrument to compare the feasibility of the instrument under study and the results of data from photovoltaic performance monitoring which is useful as statistical data in determining photovoltaic quality in the area according to natural conditions

2. Literature Review

In 2018 Indonesia requires conventional energy (petroleum, natural gas, and coal) and renewable energy of 411.6 MTOE (Million Tonnes of Oil Equivalent). This results in a decrease in fuel production resulting in expensive resource prices. In 2018, oil production decreased from 346 million barrels (949 thousand bpd) in 2009 to 283 million barrels (778 thousand bpd), gas production which totaled 40% in 2009 to 40% in 2018, while there was an increase in the coal sector by 557 tons (Indonesian Energy Outlook book). This shows the very role of renewable energy in meeting energy reserves so as to minimize the use of conventional energy is starting to dwindle.

One of the renewable energy that is quite popular and effective today is Solar Panels because the energy used is the largest energy, easy to obtain, and also easy to use. Solar panels utilize solar energy as the main energy supplier which is then converted into electrical energy. As for its use, a tool is needed to monitor the performance of the tool so that the distribution of electricity produced can be maintained properly and the desired data management process can be monitored optimally.

Previous studies have described methods of monitoring the performance of solar panels, such as that done by (Fitriandi et al. 2016) using a microcontroller with the SMS gateway method. This method shows a good system and sending data via SMS is done every five minutes and data logger storage is every one minute, but in this method there is no backup storage to store data as a whole for a longer period of time, so it must remain manual in recording received data and reports.

In the process of storing the data logger received is stored in the SD Card. So that data can be stored properly for a long period of time, as was done (Suryawinata, 2017) using the atmega328 showing the received data is stored properly on the SD Card. However, the ACS712 current sensor readings get an error of 2.01%, a voltage of 1.23%, a DHT11 temperature of 1.19%, and a humidity of 2.12%. The same thing also happened in research (Hadi et al. 2018) where an error occurred in the current sensor of 3%. while the test (Ningsih 2018) showed a fairly large error in the current sensor of 3.07%, the voltage sensor of 1.46% and the temperature sensor of 3.13%.

The method that is popular today and is also effective and efficient is to use the Internet of Think (IoT) so that the received data can be monitored very easily through internet media and web servers or applications as containers to store data. Research using the Internet of Think method using Arduino with the data displayed by the server is almost the same as the reading time by the Arduino, and the monitoring module can be used to monitor more solar panels because the data sent is in the form of an array (Rohman and Iqbal 2016). In some other studies, the data received by the web server can be sent and received and monitored properly, but still has a large sensor error. In this study the error that occurred in the entire system reached 1.69% (Winasis et al. 2016), while in a similar study also had a current and voltage sensor error of 3.61%, and a power of 0.36% (Tricahyono and Kholis 2016).

Blynk is a new platform that allows you to quickly build interfaces for controlling and monitoring hardware projects from iOS and Android devices. After downloading the Blynk app, we can create a project dashboard and set buttons, sliders, charts, and other widgets to the screen. Using the widget, you can turn pinning on and off or show data from the sensor. Blynk is perfect for interfacing with simple projects such as monitoring temperature or turning lights on and off remotely. Blynk is the Internet of Things (IoT) which is designed to make remote control and sensor data read from an Arduino or Esp8266 device quickly and easily. Blynk is not just an "IoT cloud", but is an end-to-end solution that saves time and resources when building applications that are meaningful to connected products and services (Shull 1977).

3. Methods

In this study using the following equipment: 1) The data logger, is an electronic instrument that has the ability to read quantities in nature (for example temperature, wind speed, gas content, current and electric voltage) which are read by electronic and electromechanical sensors, then write down the values of the readable quantities into memory (Mahzan et al. 2017). 2) Arduino is an open-source hardware prototyping platform based on flexible and easy to use hardware and software (Arifin, 2016). The main component in the Arduino board is an 8 bit microcontroller with the ATmega brand from the Atmel Corporation company. The various Arduino boards use different types of ATmega, this depends on the specifications of the Arduino used. Atmega specifications on the Arduino Uno are the ATmega328 type. 3) The current sensor used is a sensor with type ACS712 to detect the amount of current flowing through the terminal block of the solar panel. This sensor can measure positive and negative currents in the range -30 to 30 A. This sensor requires a voltage supply of 5V. To read the mid-value (zero amperes) the sensor voltage is set at 2.5 V (half the power supply voltage VCC = 5V). As with the voltage sensor, the current sensor has a reading range from 0 to 1023 (at 5 V input) with a resolution of 0.00489 V. 4) DHT22 is a sensor for measuring temperature and humidity. This DHT sensor has two parts, namely the capacitive humidity system and the thermisator. The digital signal generated by this sensor is easy to read by any microcontroller (Winasis et al. 2016). 5) LDR (Light Dependent Resistor) is a type of resistor that changes resistance due to the influence of light. Light sensitive resistors or photoresistors are electronic components whose resistance will decrease if there is an increase in the intensity of light hitting them. Photoresistors can also refer to Light Dependent Resistors (LDR), or photoconductors. Photoresistors are made from high resistance semiconductors that are not protected from light. If the light hitting it has a high enough frequency, the photons that are absorbed by the semiconductor will cause the electrons to have enough energy to jump into the conduction band. The resulting free electrons (and their hole pairs) will conduct electricity, thus lowering the resistance (Kamelia, 2017). 6) ESP8266 is a wifi module that functions as a microcontroller supporting device, namely Arduino so that it can connect directly to an internet or wifi connection and make a TCP / IP connection. This module uses a power of about 3.3 Volt by having three wifi modes, namely Station, Access Points and Both (both). This module is also equipped with a processor, memory and GPIO (Bei 2014). 7) The way the Internet of Things works is by utilizing a programming instruction where each argument command can produce an interaction between devices that are connected to each other automatically without human intervention. Even over long distances, the Internet can be a link between the two interaction devices. Meanwhile, humans only function as regulators and supervisors of the work of these tools directly. 8) Photovoltaic

3.1 Circuit Design

In the design, it explains the interaction of sensors contained in the solar panel performance monitoring system against the application so as to produce information to the user. The work system of the solar panel performance monitoring tool can be seen from the block diagram in Figure 1. The work system of the entire tool is centered on the Arduino Uno as the brain of a system that has input and output. The performance of the solar panel read by the sensor will send the resulting data to Arduino so that it can be sent to the Blynk application which is useful as an interface on Android via the wi-fi module esp8266 (NodeMCU) which is already connected via a user ID and internet connection. The process of sending this data uses serial communication between Arduino and NodeMCU using TX and RX pins.

This is done so that data stored on Arduino can also be connected to NodeMCU. The block diagram system shows a reading of the condition of the solar panel with a comprehensive reading of current, voltage, temperature and humidity and light sensor readings. The overall reading is changed in the form of a system on the Arduino system which is communicated in the form of data transfers using a wifi signal which is finally displayed on the IoS platform. The design is focused on realtime reading and comprehensive.

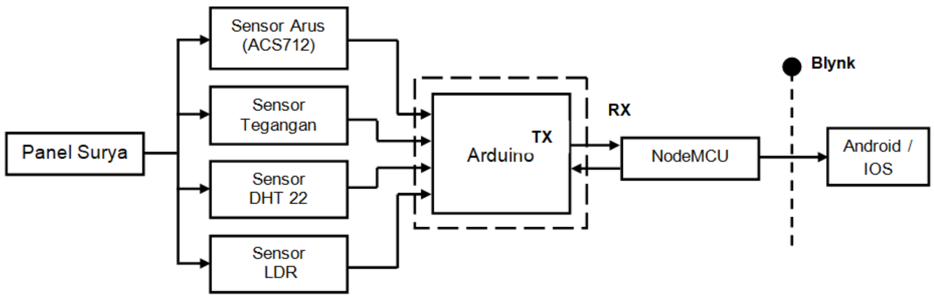

Figure 1. Block diagram of the solar panel performance monitoring system

The system design is carried out thoroughly using simple sensors with a good level of accuracy. Reading the monitor circuit system by transferring using the NodeMCU module. Figure 2 is a multi-line diagram in assembling the performance of solar panels. All sensors used are connected to the Arduino analog input so that they can transmit sensor data continuously.

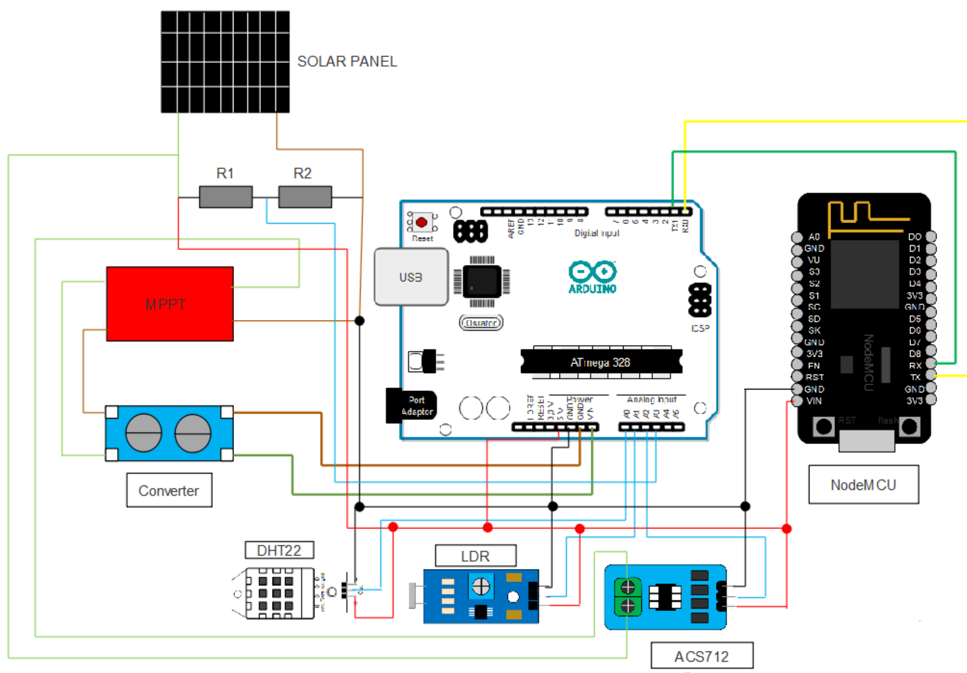

Figure 2. Monitoring circuit design of the performance of solar panels.

3.2 Platform Design

In designing the IoT platform for the Blynk application, the first thing to do is install the application on the available downloader platform. Next do the things described below:

1) ID registration

In registering user IDs, the IoT platform provides two alternative ways to enter the application, namely by using personal email or logging in with the Facebook application. After successful registration, the Blynk application will automatically send an auth token to the registered email. This token functions as a configuration when programming the wi-fi module (NodeMCU) to send data to the system that has been registered in the application.

2) Project creation

Making the project requires making the name of the system you want to create and selecting the wi-fi module to use, this is done so that there are no connectivity errors from the program and platform.

3) Display selection

The desired display can be selected in various ways according to system requirements. In selecting displays, the Blynk application provides a free option to choose the type of display you want to use, but it is limited by the price given. So that if the display selection is excessive, a fee will be charged according to the system being run.

4) Display Settings

In display settings, the first thing to do is assign a name to the system that you want to monitor. After that determine the pin you want to program. In this research, the pin used is a virtual pin, because the data to be sent is virtual data and must be connected correctly. Because if the connection match between the virtual pin and the data sending program does not match, the data will not be sent to the application. After that, the measurement range to be achieved is determined and the unit label is determined according to the sensor readings, for example in the form of percent, centigrade, amperes, and others.

3.3 Program Design

The program design for the solar panel performance monitoring system is carried out using the Arduino IDE software. The design applies the use of sensor measurements as a whole by sending via a Wi-fi module that is connected to a program that can be read over a long distance. The process of sending data from measurement results is carried out in real time with the conditions contained in the measurement. The flow of program design uses a combination of the basic program of each sensor with a customized display as figure 3.

The program display adapts to the IoT Platform system in the Blynk application. The surveillance display of the solar cell work system is monitored so that supervision can provide access to system performance as expected with optimal results.

1) Arduino program

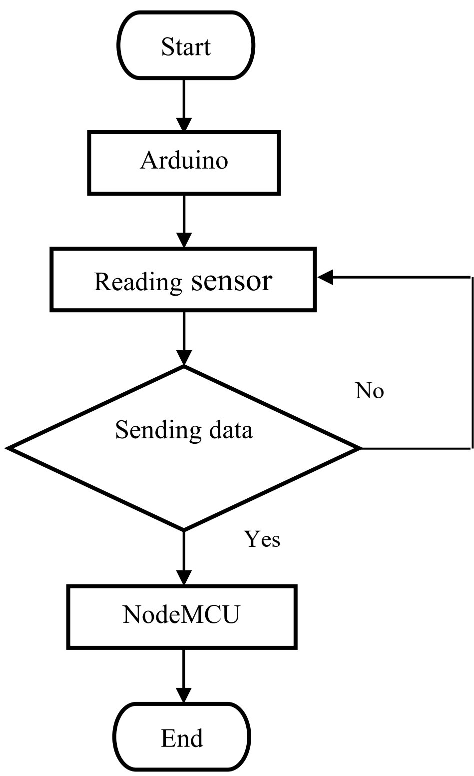

Figure 3. Flow diagram of the arduino program

In programming on Arduino, it is focused on reading the sensor according to the work of the system and then it is sent to the wi-fi module (NodeMCU) using the TX pin. In the process of sending the sensor data obtained, then stored in a JSON archive. JSON archive is like a suitcase to hold some data which is then sent and opened to NodeMCU. If there is no JSON data archive, the data cannot be sent to the Blynk application.

2) NodeMCU program

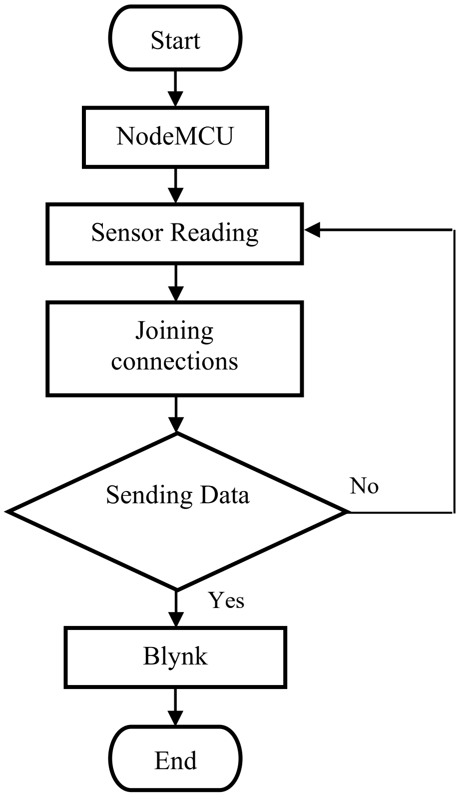

Figure 4. The flow diagram of the nodeMCU program

The design of the nodeMCU system as figure 4, after processing the sensor readings by the microcontroller then the data is sent to the Blynk platform for later realtime reading. The process of sending data after reading sensors that have been calibrated based on actual conditions. The designed display certainly displays the sensor reading process as a whole.

4. Data Collection

In the process of testing sensor accuracy, testing is carried out with two measurement variables. This is done to find out how big the percent error is and to see what the system is lacking. This can be seen in table 1.

Table 1. Sensor accuracy measurement results

No	Measurement	Current			Voltage		
		Blynk	measuring instrument	difference	Blynk	measuring instrument	difference
1	(1)	2,3 Amp	2,6 Amp	0,3	3,7.1	36,0	1,1
2	(2)	2,4 Amp	2,7 Amp	0,3	36,0	35,4	0,6
3	(3)	2,5 Amp	2,5 Amp	0,2	36,8	35,9	0,9
		Average		0,3	Average		0,9

5. Results And Discussion

The entire reading system design is then carried out system analysis based on the characteristics of the solar panels used. Remote reading of the IoT platform system will make it easier to carry out design analysis based on the conditions at the data collection coordinate points. Figure 5 shows the results of the IoT-based monitoring system design.

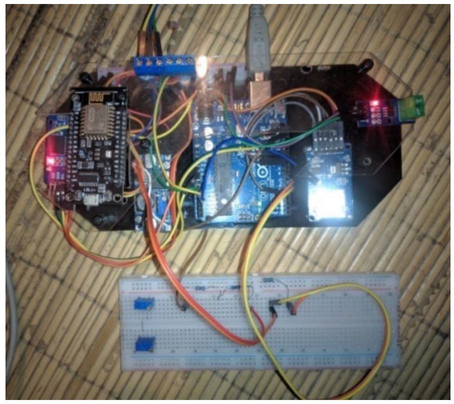

Figure 5. Result of tool design

In testing the Blynk application is showed figure 6, the displays used are in the form of four gauges and one display value of various types of displays provided by the Blynk application. For current, temperature, and humidity sensors using the display gauge type and the display value type for the voltage sensor. This is due to the limited capacity provided in using the Blynk application with the specified free project creation method. The following is a display of the photovoltaic performance monitoring system using the Blynk application.

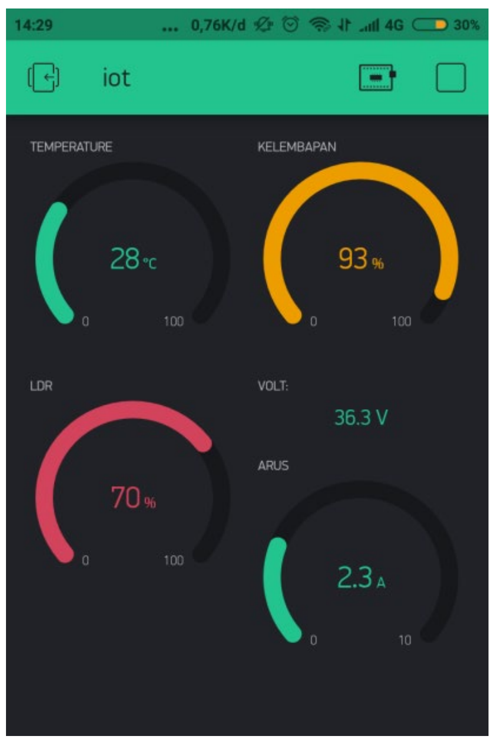

Figure 6. Results of data on the Blynk platform display

In the process of testing the sensor accuracy in table 1, testing is carried out with two measurement variables. This is done to find out what the percent error is and to see what the system lacks. In the measurement process, there is a difference between the sensor readings in the Blynk application and the reading of the measuring instrument. Based on the table 1 above, the Blynk application provides readings that deviate from the measuring instrument of 0.9 on the voltage variable and 0.3 on the current variable. To find out the amount of error in the system, then enter it into the formula.

But before calculating the percentage error, you must put the highest number in the system and subtract the measurement result. This is because the photovoltaic works at the highest voltage of 48 V and a current of 9 A, this is done to show the true error result. Then the calculation is obtained as follows:

Voltage on Blynk = Data– Measurement Range
= 48 V - 0.9
= 47.1 V
Current on Blynk = Data– Measurement Range
= 9 A - 0.3
= 8.7 A.
Based on the data above, the error percentage results are as follows:
Voltage % Error = (47.1-48) / 48 x 100
= -0.012 x 100
= -1.8% (negatives are negligible)
Current % Error = (8,7-9) / 9 x 100
= -0.08 x 100
= -3.3% (negatives are negligible)

The process of monitoring the performance of solar panels is carried out for one week from 09.00 WIB to 15.00 WIB. This is because the most oprimal radiation process occurs between the following hours. The results of the average data that have been obtained from the monitoring process can be seen in table 2. below:

Table 2. Average results of data for seven days

Day	Voltage (V)	Current (A)	Power (W) (VxI)	Temperature (°C)	Humidity (%)	LDR (%)
1	36.6	2.8	105.2	31.4	67	60
2	37.9	3.3	124.6	35.4	54.9	74.8
3	34.6	1.1	38.8	27.6	82.6	52.1
4	31	2.5	80.7	28.1	88.7	50.7
5	35.4	2.1	75.2	29.8	62.3	59.7
6	39.1	1.1	44.6	30	61.9	54
7	33.5	2.4	80.2	26.6	95.2	59.9

Based on the data in table 2, the average results on the measurement for seven days are with a voltage of 35.4 V, a current of 2.1 A, a power of 78.4 watts, a temperature of 29.8 ° C, a Humidity of 73.2%, and an LDR of 58.7%.

6. Conclusion

From the results of the Design and Testing, it can be concluded that the design of a photovoltaic performance monitoring system using the blynk platform uses serial communication between the TX and RX pins on Arduinouno and the wi-fi module (NodeMCU) with the JSON program method for data sending systems on the Blynk platform. . Programming is done twice on Arduino and NodeMCU because both are microcontrollers then the design of an IoT-based solar panel performance monitoring system using Arduino Uno on PLTS runs well with an error reading of 1.8% for the Voltage sensor and 3.3% for the Current sensor (ACS712) and the results of the average sensor reading for seven days with a voltage of 35.4 V, a current of 2.1 A, a power of 78.4 watts, a temperature of 29.8 ° C, a Humidity of 73.2%, and a weather of 58.7%. In the future, it is expected that the sensor reading error will not be more than 3% so that the data received is closer to the original data of the solar panels.

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