Development and Analysis the Performance of E-Wakaf Solar System FKEE Monitoring using IoT Approach

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Abstract. Today, renewable energy systems are becoming the best way to generate electricity. Solar energy is one of the most attractive sources of renewable energy used for electrification. Harnessing solar energy needs a photovoltaic (PV) system that converts light energy from sunlight to direct electricity. Therefore, to evaluate its performance, real-time monitoring system is needed. This study briefs about using the Internet of Things (IoT) to performance monitoring and manage PV systems in real time. Thus, the project discusses the development of E-Wakaf Solar System Monitoring Using IoT developers using Arduino Uno as main controller of the system. For development of project, voltage sensor, current sensor and waterproof temperature sensor to monitor the performance of Solar panel system. Next, a NodeMCU ESP8266 device is used as an intermediary between device and ThingSpeak platform. The ThingSpeak platform is a website that functions to store data and this system is called as the Internet of the (IOT). The functionality of this system has been tested and compared with reading data manually and through ThingSpeak platform. Therefore, the data more accurate is reading through ThingSpeak platform in which the probability of human error when reading data manually is higher. Using IoT increases knowledge of the operating parameters in real time. This allows to gain control over PV systems installed in remote areas, easily and rapidly to analyze fault diagnosis, maintenance, generation recording and quality data.

1. Introduction

Solar energy is widely available throughout the world and can contribute to minimize the dependence on energy imports. In 90 minutes, sufficient sunlight strikes the earth to supply the energy needs of the whole planet for a year. A Solar Energy does not produce greenhouse gas (GHG) during operation and does not emit other pollutants. A Solar has many advantages, such as system-friendly deployment, improved operating strategies, advanced renewable energy forecasting and improved power plant scheduling. Additionally the solar energy is a flexible resources, including demand-side resources, electricity storage, grid infrastructure and flexible generation [1]. The photovoltaic panel (PV) consists of a series of photovoltaic cells mounted to convert solar radiation into electrical energy through a photoelectric effect. The Photovoltaic cells are made from silicon and extracted from the quartzite gravel raw material. In order to obtain silicon dioxide, the quartz is crushed during the process and the raw materials must be processed significantly before Photovoltaic cells can be made [2].
The monitoring systems of PV is very important for analysis the data, troubleshooting and decision-making [3]. Several monitoring systems have been developed using (IoT) to calculate solar panel quality parameters [4]. The Internet of Things (IoT) is a collection of interconnected computing devices, mechanical and virtual appliances, objects, people or animals with unique identifiers and the ability to transfer data over a network without needing communication between humans and computers [1]. In paper [1] focuses the monitoring using raspberry pi by renewable energy. The researcher concludes that implementing renewable energy technologies is one of the recommended ways to reduce the impact on the environment. Because of frequent power cuts, it is important to use and monitor renewable energy. Monitoring guides the user to analyze the use of renewable energy. This system is cost-effective and the efficiency of the system is 95 percent. This enables the efficient use of renewable energy. This reduces the electricity issues. In paper [2] discusses the comparison between the monitoring and measurement value of voltage. This research proposes a real-time monitoring system for the solar panel using the Atmega 2560 arduino connected to the voltage sensor, the current sensor and the temperature sensor. The conclusion is less 10% the average error rate of solar panel output. The monitoring the performance of solar panel using microcontroller-based smartphone can be done in real time. In paper [5], proposed a model of monitoring and controlling the voltage output of solar panel at distant location using IoT. A power generated by solar panel is monitored in real-time and updated in server. The researcher used the advanced PIC16F1947 processor, which is a 16-bit microcontroller. In addition, the project using GSM for controlling the load on the field and sending information through coded signals to the receiver. In conclusion for this paper, this system has a low operating cost, using a remote areas application and reduce the man power required. Paper [6] approach a Smart Power Monitoring and Control System through the IoT using Cloud Data Storage. This work was designed to implement smart power monitoring and control system through IoT using cloud data storage. The researcher used the Xively platform cloud database to monitor and store current sensors through an ARM-based controller interfaced with Hall Effect. The researcher concludes that the designed system enables client to monitor and control the appliances at home from anywhere availing the IoT features of the designed system thereby reducing the wastage of energy. Paper [7] presents the implementation and results of an environmental monitoring system using sensors for the surrounding area's temperature and humidity. This data can be used to trigger short-term actions such as remote control of heating or cooling devices or long-term statistics. The sensed data is uploaded to cloud storage and the cloud is accessed by an Android application and the results are presented to end users. The system uses Arduino UNO board, DHT11 sensor, ESP8266 WiFi module, which transmits data to ThingSpeak open IoT API service where it is analyzed and stored. In addition, an Android application is developed that accesses the cloud and displays end-user results via the REST API Web service. The experimental results show the system's usefulness. Next, paper [8] proposed about Monitoring of Solar PV Panels using Internet of Things. The power generated by the solar panel has to be monitored continuously. Using Internet of Things technology, the power generation can be greatly influenced by means of its performance, monitoring and maintenance. The present paper is based on the implementation of IoT monitoring of solar panel for maintenance and for improving the efficiency by detecting the fault. The project using ThingSpeak Platform as an IoT channel and IoT programming is dumped in the microcontroller where the ATP key of the channel is used in the program. This system is cost effective and the system efficiency is about 95%.

The objective of this research to develop a new monitoring solar system using Arduino approach, to monitor the performance of solar panel continuously using IoT application and to compare the performance of the solar panel between measurement and IoT approach.

2. Research Method
This session focusses on the methods in which this project is developed. In this project, the modification of hardware and software development will be described in two main parts. The project used the Internet of Things (IoT) to monitor the performance of the solar system. This project also divides into two parts, the first part being software development where the programming of Proteus
and Arduino was developed. Second, the hardware development is a Prototype setup and a measurement circuit that consist of sensors and Arduino board so that the sensors data will transfer and display to the PC connected. The Arduino then transfer data to the ThingSpeak platform using NodeMCU ESP8266 to display solar panel output. The project consists of the following components: solar panel, charge controller circuit, rechargeable battery, DC / AC inverter, meter, temperature sensor, Arduino Uno, voltage sensor, current sensor and NodeMCU. These are shows in the block diagram as shown in Figure 1.

![Figure 1. Process of PV Panel using IoT](image)

The block diagram in Figure 1 is the software development and hardware development combination. Photovoltaic panels are used to convert solar energy into electrical energy. The energy will then be stored inside the battery so that the supply of electrical energy will resume at night. Electrical energy is saved at an immense level by using the solar to power the charge while the solar charger device is used to secure the charging battery from excess current. Then, the output of battery, which is DC will change to AC using DC/AC inverter for load (240V AC) such as socket and lamp. The Figure 2 shows the picture of PV panel, which is located at G1, UTHM. The Figure 3 shows the location of E-Wakaf Solar System FKEE, UTHM.

![Figure 2. PV Panel at G1, UTHM](image)

![Figure 3. The Maps of PV Solar System FKEE, UTHM](image)
In Software development, the three main softwares are used in this project: Proteus, Arduino IDE and ThingSpeak Software. The Proteus software is used to design circuit for PV panel and simulation of the circuit to make sure all the system is functionable. The Proteus 8 Professional is produced by Labcenter Electronics Ltd in Yorkshire, England, with offices in North America and several sales channels in other countries [11] [12]. To draw schematics and model the circuits in real time, ISIS (Intelligent Schematic Input System) is used. The simulation enables human access to simulation in real time during runtime [13][14]. The Arduino IDE software for write the programming code to collect the data and transfer the data to cloud data storage, which is ThingSpeak platform. Arduino, Integrated Development Environment (IDE) is a cross platform software written in the Java language of programming. It is designed to introduce programming for new people to learn about the development of programming software. Arduino IDE is commonly used with Arduino board [15] [16][17].The ThingSpeak is a specifically designed middleware platform for any Internet of Things (IoT). The performance of this PV module will be much easier in the future to collect and store in the ThingSpeak platform. In ThingSpeak, execute MATLAB code and perform online data analysis and processing as it enters. ThingSpeak speeds up the development of IoT proof-of-concept systems, especially those requiring analytics [18]. The Figure 4 shows the simulation circuit using Proteus Software for the temperature sensor and LCD circuit. This simulation using Arduino UNO board and DS18B20 digital temperature sensor where the temperature value is displayed on 16×2 LCD screen and sent serially to Arduino IDE serial monitor.

Figure 4. Simulation Circuit Using Proteus Software for the Temperature Sensor and LCD Circuit.

The Figure 5 shows the coding for combination such as voltage sensor, current sensor, power and temperature sensor connected with the LCD Circuit, the coding has been on testing to make sure it works properly and able to transmit data from Arduino to NodeMCU. The Figure 6 shows the coding for NodeMCU receive data from Arduino then send data to the cloud storage which is ThingSpeak platform.
In Hardware development, an Arduino UNO's function as a microcontroller to monitor the device to transfer data to the platform of ThingSpeak [19]. NodeMCU will be responsible for transferring data to the ThingSpeak platform. The data will display a temperature, a voltage, a current and a power of PV system. The type of PV panel that will be using in this project is Mono-crystalline 18.3 V, 95 W of maximum power. The maximum current of PV panel can be generating at 5.19 A and the dimension is 1191x541x35 mm. Then, the output of PV panel to load (240V AC) [20]. A several main electronic components have been included in this project such as a I2C liquid crystal display, a temperature sensor, voltage sensor and current sensor. DS18B20 Waterproof Temperature Sensor is the waterproof temperature sensor which is able to measure the temperature in liquid. It has an operating temperature range of \(-55^\circ C\) to \(+125^\circ C\) and is accurate to \(\pm 0.5^\circ C\) over the range of \(-10^\circ C\) to \(+85^\circ C\) [21]. Next, ESP8266 is the Espressif Systems designed micro controller. The ESP8266 is a self-contained WiFi networking solution that offers the ability to run self-contained applications as a bridge from existing micro controller to WiFi. This device features a built-in USB connector and a wide range of pin-outs. Just like Arduino, able to connect NodeMCU kit to laptop with a micro USB cable and flash it without any problems [22]. This voltage sensor uses the voltage divider concept, which can minimize the voltage input to 5 times the actual value. Arduino's maximum input voltage is 5V. This module can therefore only accept a voltage input of up to 25V [23]. The current sensor is used for making current measurements. There are three pins on this module, VCC, GND and OUT. When current flow is detected by the sensor, an analog output signal (voltage) will be given, which will decrease linearly with sensed current. This sensor can be used in a wide variety of applications including, over-current protection circuits, battery chargers, switching mode power supplies, digital watt meters, programmable current sources [24]. The pin I2C LCD and Just 3 microcontroller pins are capable of displaying a message on the LCD. The LCD display consists of two lines of 16 characters and provides basic text wrapping so that the text is displayed correctly [25]. All the configuration is designed and submitted to the Arduino board in a source code. Thirdly, the NodeMCU ESP8266 communication component continues updating the data to the ThingSpeak platform. Figure 7 and Figure 8 shows the hardware that have been develop.
3. Results And Discussion

In this section, it is explained the results of research in which comparison of PV Panel performance monitoring. The comparison between reading data manually with ThingSpeak Platform of the PV panel system such as voltage, current, power and temperature. Moreover, the comparison of methods collect data also will be analyzed. The temperature and solar panel provided the result, which is Celsius, voltage, current, and electricity, depending on the experiment that was performed. Besides that, reading from the solar panel, the parameter can be monitored from the Arduino IDE serial monitor. The data stream generated and saved in the ThingSpeak platform after a couple of seconds. The following Figure shows the example of the ThingSpeak platform data stream. The data that transmit to the ThingSpeak platform will saved in the data. All the data stored in the data stream will be compiled and show in graph in Figure 9 to Figure 12 shows output that gain from solar panel. Depending on Celsius, power, current and voltage, the result and graph are separated. Besides that, the data from ThingSpeak platform can be exported to Excel and the results can be analyzed. In addition, ThingSpeak platform also able to show the location of the project by set a Latitude and Longitude. Graphs emphasize the main point, it makes the data more convincing and
provide users with a concise way to present information. Graphs are actually plots for current, voltage, power and energy value. These graphs are available from anywhere via the internet.

![Figure 9. Graph of Voltage vs Time](image1)

![Figure 10. Graph of Current vs Time](image2)

![Figure 11. Graph of Power vs Time](image3)

![Figure 12. Graph of Temperature vs Time](image4)

3.1. **Comparison of PV Panel performance monitoring**

For this section discuss on the comparison of PV Panel performance based on the manually recorded and ThingSpeak platform at G1, UTHM area on 30 Nov 2019. The result is recorded every 30 minutes starting in 12.00 am until 3.00 pm. The objective is to collect the data of PV panel manually and through ThingSpeak platform which is monitor the performance of PV panel continuously using Internet of Thing (IoT) application to evaluate the data of PV panel system such as voltage, current, power and temperature. For both approaches, the comparison will be based on data and voltage vs time, current vs time, electricity vs time and temperature vs time. The Table 1 tabulated the data has been collect from reading data manually and ThingSpeak platform.
Table 1: Comparison of Reading Data Manually and ThingSpeak Platform on 30 Nov 2019

| Time (Hours) | Reading Data Manually | ThingSpeak Platform |
|--------------|-----------------------|----------------------|
|              | Voltage (V) | Current (A) | Power (P) | Temperature (°C) | Voltage (V) | Current (A) | Power (P) | Temperature (°C) |
| 12.00 pm     | 13.81       | 1.44        | 19.89     | 33.16            | 13.85       | 1.49        | 20.65     | 33.25            |
| 12.30 pm     | 16.29       | 3.51        | 57.18     | 36.38            | 16.32       | 3.54        | 57.83     | 36.43            |
| 1.00 pm      | 20.03       | 5.25        | 84.25     | 40.12            | 16.32       | 3.64        | 59.43     | 40.31            |
| 1.30 pm      | 16.03       | 4.72        | 75.61     | 38.93            | 16.17       | 4.72        | 76.27     | 38.12            |
| 2.00 pm      | 15.64       | 4.28        | 66.89     | 39.37            | 15.76       | 4.37        | 68.94     | 39.18            |
| 2.30 pm      | 13.26       | 0.56        | 7.45      | 31.12            | 13.29       | 0.56        | 7.47      | 31.18            |
| 3.00 pm      | 13.36       | 0.76        | 10.12     | 32.25            | 13.36       | 0.76        | 10.12     | 32.25            |

The result was recorded from different methods in which first method is collect data manually and the second method is collect data from ThingSpeak platform. From the observation on result at 1.00 pm, 30 November 19 get the higher percentage error. By using this formula \[\frac{|\text{ThingSpeak Platform} - \text{Reading Data Manually}|}{\text{Reading Data Manually}} \times 100\%\), based on voltage result from Figure 13 shows the difference in results from manually recorded data with IoT system is 18 %. Therefore, based on current results from Figure 14 shows the difference of results from manually recorded data with IoT system is 30 % and based on power output from Figure 15 the difference is 29 %. Lastly, based on result of temperature from Figure 16 shows the different of the result from manually recorded data with IoT platform is 2 %. It is because the possibility of human error and instrument error when human take a reading inaccurate. Therefore, it is because need the IoT approach to overcome this problem.

![VOLTAGE VS TIME](image)

**Figure 13.** Graph of Voltage Vs Time for 30 Nov 2019
Figure 14. Graph of Current Vs Time for 30 Nov 2019

Figure 15. Graph of Power Vs Time for 30 Nov 2019

Figure 16. Graph of Temperature Vs Time for 30 Nov 2019
4. Conclusion

As the conclusion, the E-Wakaf Fkee Solar System Monitoring Using IoT Application has been developed successfully. The objective has also been successfully achieved, which is who responsible to take care of the PV panel system is able to continuously collect the data through ThingSpeak platform. Besides that, the problem with wattmeter also can solve in which if wattmeter display blank, LCD able to replace and display the performance of Solar panel system. The monitoring system is equipped with NodeMCU ESP8266 to transmit data from the solar panel to the ThingSpeak platform. This system can work in one condition that the prototype will work within the WIFI coverage so that the user can connect the system to the NodeMCU ESP8266 and access the parameter of the solar panel via the ThingSpeak platform.

In order to determine the functionality of the system, a comparison of the reading of the data method has been made to determine either which one is more accurate. Therefore, the data more accurate is reading through ThingSpeak platform in which the probability of human error when reading data manually is higher. A performance parameter that can be enhanced in the IoT system in the future by improving or modifying the platform. Lastly, the good news is that we will see more IoT analytics demand in general. Organizations are under pressure to automate processes and services due to increased competitive pressure. IoT information itself is the key to finding opportunities for improvement and monitoring of changes. Using IoT increases knowledge of the operating parameters in real time. This allows to gain control over PV systems installed in remote areas, easily and rapidly to analyze fault diagnosis, maintenance, generation recording and quality data.

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