Development of Low-cost Real Time Solar PV Power Monitoring System using IoT

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ABSTRACT

Renewable energy (RE) sources are the best choice for supplying our projected energy needs because they have been proven to be sustainable. Among the different kind of RE, one of the most interesting and promising clean technologies in the modern era with no carbon emissions is solar photovoltaic electricity. However, monitoring solar photovoltaic systems is crucial for maximizing their performance. The use of the Internet of Things to track solar photovoltaic energy production can considerably enhance plant operation, monitoring, and maintenance. Technological advancement is driving down the cost of renewable energy equipment globally, which is encouraging extensive solar photovoltaic installations. Because most of the solar PV installations are in inaccessible places like rooftop or hilltop or desert to access sufficient sunlight and cannot be monitored manually from a specific location; meanwhile, the advanced methods for automating the plant monitoring remotely utilizing IoT-based interfaces are required. The discussion on this paper is implementing a low cost IoT based real time solar PV power monitoring system for performance evaluation. This will facilitate preventive maintenance, fault detection, historical analysis of the plant in addition to real time monitoring.

Keywords: Internet of Things (IoT), Real Time Solar PV Monitoring, ThingSpeak

1 Introduction

Solar power is universally acknowledged as the most productive and trustworthy of all the renewable energy sources [1]. The sun's rays are estimated to provide 10,000 terawatts worth of energy to the surface of the planet every single day [2]. According to research, the total amount of energy that was consumed all over the world in 2019 was 580 million terajoules [3]. Every year, there has been just a slight rise in the amount of energy that has been consumed, which amounts to around 1-1.5 percent growth annually. Even though the overall energy usage has grown by approximately 5% because to the covid epidemic [4]. By the year 2050, it is anticipated that the total amount of energy that the world will consume will have increased by fifty percent. Hence the renewable energy can be the effective alternative to reduce dependency on fossil fuel. For instance, 200 square kilometres area of solar plant is enough to power the whole United States of America. This solar photovoltaic method is becoming more and more popular because it is widely available, inexpensive, simple to install, and requires little maintenance. The Internet of Things (IoT) is a developing technology that connects objects via communication protocols and cloud platforms to make them smarter and more user-friendly. The Internet of Things (IoT) plays a crucial role in solar energy by connecting all the physical equipment to the web to ensure maximum and optimal power generation. Power generation from PV plants is significantly varied due to changes in solar irradiance, temperature, dust accumulation, broken cell, partial shade, and other factors, thus continuous monitoring is essential to optimize the overall performance of the solar power plant and to maintain the grid stability. The efficiency of the solar panel is influenced by basic parameters such as current, voltage, irradiance, and temperature.

In this proposed paper the real time solar photovoltaic parameters called panel and ambient temperature, sunlight intensity, current, voltage, power is monitored through IoT.

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2 Previous Monitoring Work

There is a need for certain non-conventional resources that can be used forever because the conventional sources of electricity are running out. By turning sunlight into electricity, this system generates and supplies electricity. The batteries supply previously stored electricity when there is no sunlight to convert solar energy into electrical power. These IOT-based PV systems are the next-generation solution that will enhance solar system monitoring [5]. The author suggests a cheap IOT-based PV system. They employed a low-cost microcontroller that will receive all the information from the PV system along with a GPRS module. This system measures the PV system's current and temperature. A webpage is used to access the system's data [6]. The solar power panel is one of the non-conventional electricity resources, and now that the price of modern technology has dropped dramatically, these solar power systems are relatively affordable and widely available [7]. But for people to successfully track and regulate these systems, regular monitoring is required. Monitoring techniques and data loggers are crucial to the efficient operation of solar systems. These techniques allow us to get all the system information about malfunctioning before any more serious damages. Another research offered a raspberry pi-based IOT-based solar power system with component integration [8]. Additionally, this system offers ongoing statistics online. The data logger logs information on voltage, current, humidity, and temperature. Another cloud-based solar system monitoring method that sends continuous records over cloud after a set amount of time was proposed by Kishore et al. By tracking the power plant continuously, it becomes simple to analyse the current state of the solar system. The advantage of analysis is that it aids in locating or identifying potential system flaws and keeps a close eye on output from a great distance [9]. Another environmentally beneficial solar system was presented by Rakesh et al. Power generation is continuously tracked and updated in the server [10].

3 System Architecture

As shown in Figure 1(a), this work suggests designing a real-time, updatable photovoltaic solar plant monitoring system that consists of industry-standard sensors and a cloud database. The system's front-end interface is represented by the sensors, while the communication server is represented by the cloud. The cloud makes it possible for the user to access a display remotely from any other location. The user can comprehend the power production situation and, if necessary, take appropriate action by studying the plant's data.

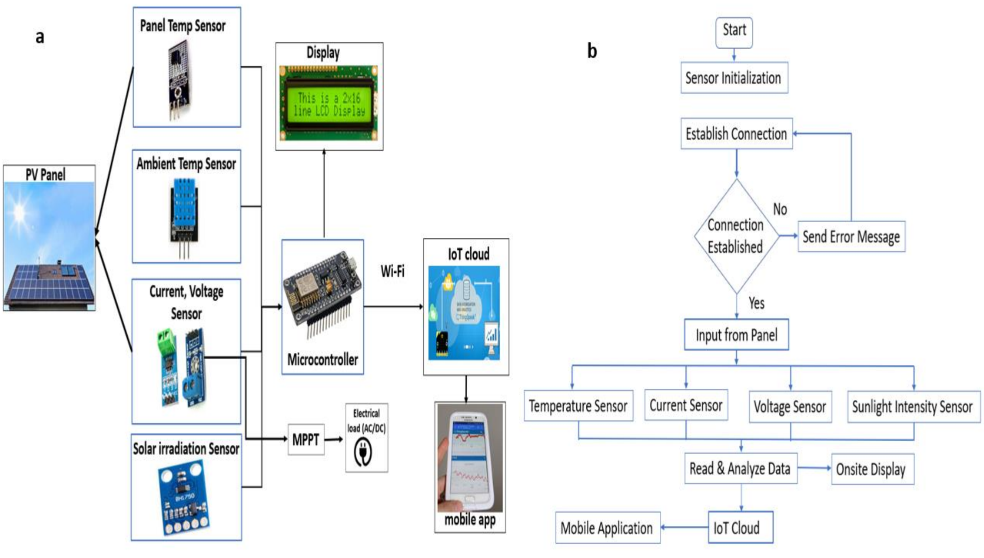

Figure 5: *(a) Proposed system architecture; (b) Workflow of the system.*

Local Wi-Fi is the method used to send data to the cloud. The full intended system's workflow, in which the sensors are initialized with the prototype, is depicted in Figure 1(b). Using a microcontroller, the sensors have been calibrated. Data will be sensed by the sensors and sent to the microcontroller, where it will be displayed on site using the LCD. The data will be transmitted from the microcontroller to the database and saved appropriately using the internet connection. The system will repeat if the microcontroller was unable to transfer the data.

4 Hardware Implementation

A photovoltaic (PV) module, commonly referred to as a solar panel, is a framework that contains photovoltaic cells. Solar cells use sunlight as a source of energy to generate electricity [11]. A PV module is a crucial part of any PV system that converts sunlight directly into direct current (DC) energy. In this paper, a 10-Watt mono-crystalline panel was used which consists of 48 cells. The maximum produced voltage by the panel can be 26 volts with an efficiency of 13%. Panel temperature monitoring is important to monitor because the efficiency of the panel is reduced while increasing the temperature. LM35 sensor (precision integrated-circuit temperature sensors) is used to measure the panel temperature. The output voltage is linearly proportional to Celsius temperature [12]. The ambient temperature monitoring is also essential to keep the prototype in a comfortable temperature zone. The DHT11 temperature and humidity sensor module with three pins- VCC, GND, and Data Pin has been employed which has also been used [13]. This sensor was created using a thermistor with a negative temperature coefficient, which decreases in resistance as temperature increases. To detect sunlight intensity BH1750 sensor is used. A simple microcontroller with an I2C communication standard has been employed. A photodiode is also used to detect light intensity. The photodiode generates electricity as a result of the internal photoelectric effect. The amount of light that is emitted determines how much electricity is generated [14].

The ACS712, a completely integrated, hall effect-based linear current sensor with an integrated low-resistance current conductor and 2.1 kV RMS voltage isolation, is used to measure current. It can be summed up by calling it a current sensor that uses its conductor to calculate and measure the amount of applied current. In current sensors that function by direct sensing, the voltage drop that happens when flowing current is sensed is measured using Ohm's law [15]. The straightforward voltage detection sensor module B25 is used to detect panel voltage employs a potential divider to reduce any input voltage by a factor of 5. It used the resistor that serves as a sensing element in a resistive voltage divider design as their foundation [16]. The power calculation is performed using multiplication of current and voltage.

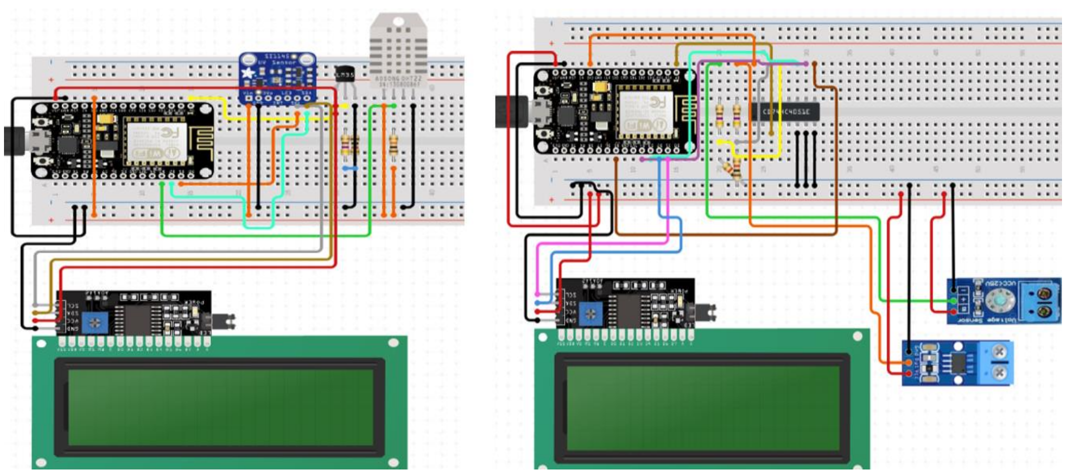

Figure 2: *Circuit diagram of the system*

A NodeMCU microcontroller is used to send sensor data to the cloud. The NodeMCU microcontroller is comparable and can be set up to connect to the Internet for the Internet of Things. To visualize data onsite, a liquid crystal display is used [17]. Liquid crystal displays are used to depict numeric and alphanumeric characters in the matrix and segmental displays. Crystal display for liquid and alphanumeric display can be made using a passive or energetic matrix display grid. Because a semiconductor unit is present at every intersection of an image element in an energetic matrix, less current is required to adjust a picture element's brightness [18].

ThingSpeak, a platform for the Internet of Things, is used to store and track data. It is an open-source Internet of Devices (IoT) programme and API for storing and retrieving data from things via the Internet or through a Local Area Network using the HTTP protocol. The account has separate channels for a variety of functions. Users can set the ThingSpeak channel's privacy preferences. The channel was kept secret for our application because it provides crucial information.

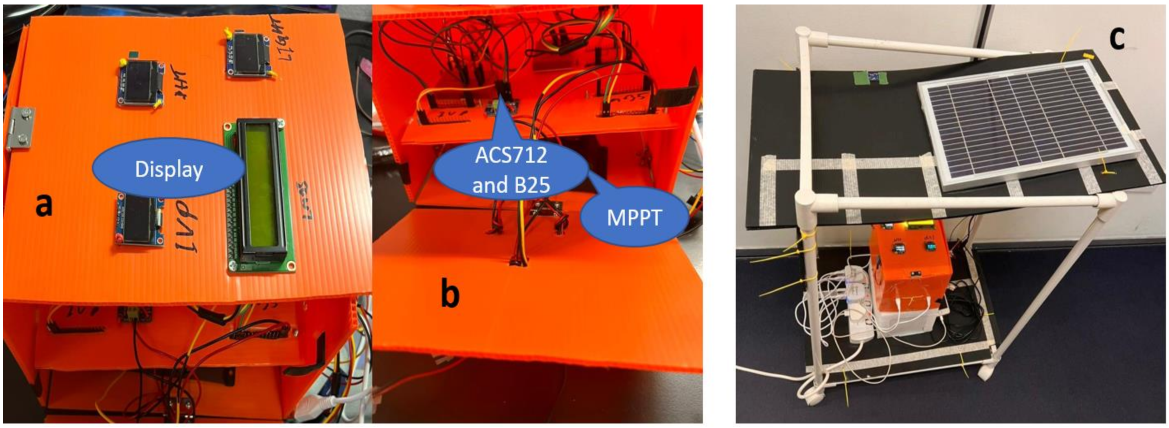

Figure 3: *Designed hardware prototype of the system*

In this proposed paper five different sensors (sunlight intensity, ambient temperature, panel temperature, current, voltage) must be activated to sense the data. The digital pins D1 and D2 are connected with BH1750, DHT11 and the analogue pin A0 is connected with the DATA pin of the LM35, ACS712 and B25 shown in figure 2. These sensors sense data in analogue mode and the ADC converter of the microcontroller converts that into an electrical signal to the output. The circuit configuration of the designed system is shown in Figure 3 shows the designed prototype box where all the sensors has been initialized with a microcontroller. The box has three layers. The bottom layer consists of an MPPT charge controller. The middle layer contains sensors and a microcontroller. The top layer has a display to view data onsite.

5 Results and Discussion

Figure 4(a-c) and 5(a-c) show the graphical representation of the solar parameters panel temperature, ambient temperature, sunlight intensity, current, voltage, and power. The sensor has been calibrated using nodeMCU. The microcontroller works as a media to transmit the parameter to the cloud using local Wi-Fi. The sensed data is visualized in the display and transmitted to the cloud with a 15-second delay.

The visualization in thinkSpeak is in the form of a trend line which helps to observe the production. From Figure 5(c), the sunlight intensity increased with time and at the same time, the panel temperature also

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increased and reached 54000 lux and 56 °C respectively. The produced voltage from the panel was 22 volts at the same time shown in Figure 4(a). The current flow was increased to 220 mA during that time. As a result, the maximum power produced by the panel was 4800 mW shown in Figure 4(c). The graph of current, voltage and power are well synchronized. Since the power production relays on the panel's capacity thus, the panel efficiency also matters to observe the overall performance. The ambient temperature is measured as shown in Figure 5(b) to maintain the equipment's temperature as controlled as possible. The monitoring has been conducted for seven days to obtain efficient data. ThingSpeak has multiple data analysis options.

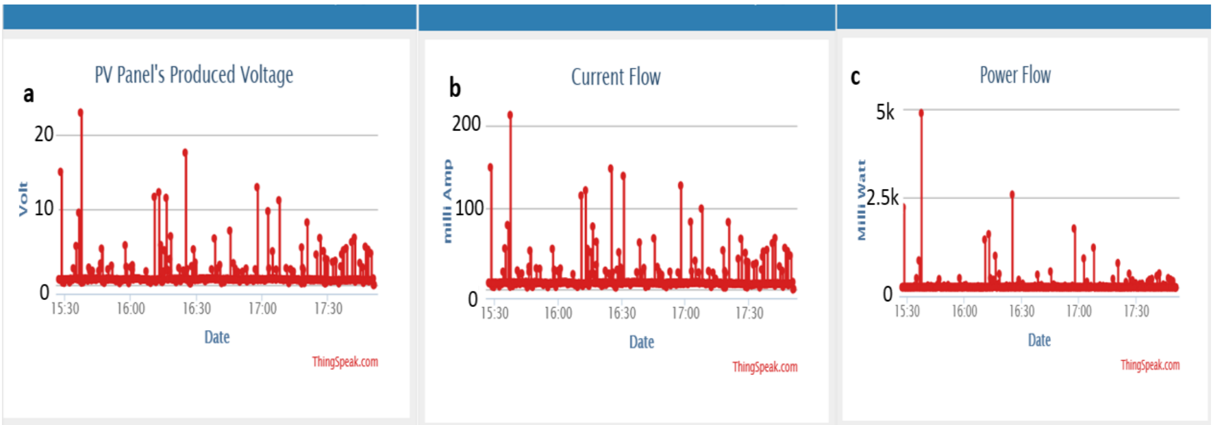

Figure 4: *(a) Current generation of the panel; (b) Measured voltage; (c) Measured power production of the panel*

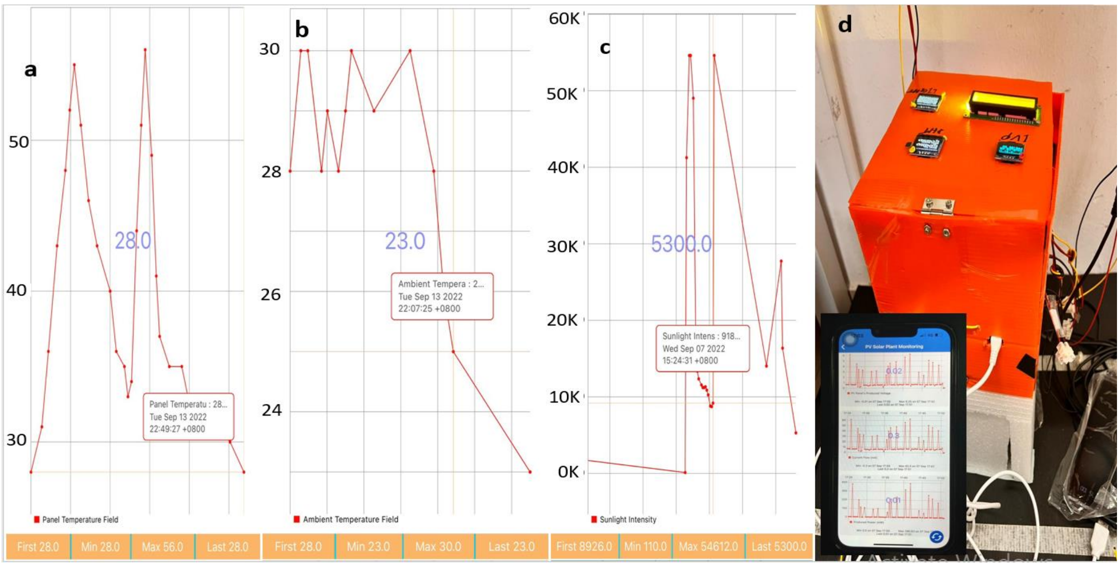

Figure 5: ***(a)*** *Ambient temperature;* ***(b)*** *panel temperature;* ***(c)*** *sunlight intensity;* ***(d)*** *data display from mobile phone*

From hourly to yearly data analysis, helps to estimate efficient results for further action. For a long period ThingSpeak stores data (for the paid version) from where future analysis can be performed. From all the Figures, it can be observed that the highest amount of power was produced when the sunlight was at its peak. At the same time, the panel temperature was increased. By reducing the panel temperature using a cooling system, power production can be increased. To store the data, different time interval has been used during data transmission. For ambient temperature, it is 30 minutes of a time interval where it is only 1 minute for current, voltage, and power data. 10-minutes of the time interval is used for sunlight intensity. Using Arduino coding, the time interval can be changed according to demand. It can be seen from Figures 4(a-c) that at a certain time the produced current and voltage and power are zero because of a lack of enough sunlight. ThingSpeak IoT cloud has its own mobile application. By downloading the software from the app store or Google play store, the monitored parameter can be accessed easily from anywhere on the globe. Figure 5(d) shows the mobile application's access to the monitored data.

6 Conclusions

Implementing Renewable Energy, especially solar photovoltaic (PV) technology is one recommended way of reducing the environmental pollution and green house effects. Because of frequent power cuts in PV system, it is important to monitor it. Smart monitoring makes it easier for the user to comprehend energy production, PV system health, and system optimization. In this study, the sensor reading is communicated in real-time to the cloud database by connecting to an internet of things application, from which the data can be seen with an active internet connection from anywhere in the world. The real-time implementation system with the cloud database comes with a login system where only an authorized person can access the system. As a result, the developed system is secure and can give users confidence. The system efficiency is about 96%. This enables the efficient use of renewable energy. Moreover, places like deserts or mountains where the number of the peak sunlight hour is much more than normal places, but these places are not easily accessible to human beings. Hence, this prototype can be an effective solution to completing prior studies for these places before implementing a solar plant. This is cost effective designed prototype can be around $30 so far.

7 Declarations

7.1 Study Limitations

The main limitation of this study is a lack of time. It should be noted that the system's performance should be monitored for an extended period of time. However, the work, including the system components, will be improved, and reported elsewhere in the future.

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7.4 Competing Interests

There is no conflict of interest.

7.5 Publisher's Note

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