Solar Power Monitoring Based on IoT and an Android Application

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Abstract - This research delves into the relationship between energy and the Internet of Things in terms of transforming the renewable energy landscape. Solar energy, as a form of energy, plays a vital role in meeting the growing global demand for electricity. However, solar energy generation faces challenges such as unpredictability, intermittent supply, and inefficiency. The Internet of Things is a technology that enables devices, sensors, and data to connect and communicate across networks. This study explores using IoT to monitor power generation. The collected data, including current, voltage, power, and temperature, is transmitted to the cloud. Made accessible through an application for convenient analysis. A mathematical model is developed to establish the correlation between temperature, voltage, and current. The experimental results validate the reliability and accuracy of this model by showing alignment between predicted values and actual measurements. Furthermore, recorded power consumption readings during periods reveal fluctuating demand patterns throughout the day. By addressing challenges and opportunities arising from integrating energy with technology, this article underscores the significance of this interdisciplinary approach in promoting sustainable energy solutions for our rapidly expanding world.

Keywords - Internet of Things, Remote Monitoring, Renewable Energy, Solar Energy Monitoring, Thingspeak.

I. INTRODUCTION

Solar energy is a powerful source of energy that can be used to heat, cool, and light homes and businesses [1]. The total amount of solar energy incident on Earth is vastly more than the world’s current and anticipated energy requirements [2]. If suitably harnessed, this highly diffused source has the potential to satisfy all future energy needs [2]. It is expected to become increasingly attractive as a renewable energy source in the 21st century because of its inexhaustible supply and nonpolluting character [3].

Solar monitoring systems are used to gather and analyse data from solar systems to monitor and assess their performance. These systems may be used to follow trends in a single photovoltaic (PV) system, discover problems with or damage to solar panels and inverters, compare the performance of a system to design specifications to compare PV systems at various locations, and more [4]. There are three basic kinds of solar monitoring systems: hardware mounted either on each solar panel or beside a solar string inverter to record power flow, as well as software to preserve a record of the flow over time—all while giving the user an interface to check up on all the relevant data about their solar installation [4]. Solar monitoring technologies may provide essential information to the utility and give real-time data-driven insights [5]. Solar monitoring systems employ sensors and communication devices mounted to solar arrays to track production data from each panel and transfer it to a communication device like a gateway. These devices interact using hardwiring, an internet connection (either ethernet or wifi connections), or cellular technologies. The communication device subsequently delivers the acquired data to a cloud-based software application [6]. Therefore, a solar monitoring system may offer an interface for retrieving important data about a solar installation.

PV systems and the Internet of Things (IoT) are closely associated since IoT technology may be used to monitor and manage solar panels remotely, identify faults, and conduct remedial action in real time [7]. IoT-based solar monitoring systems give real-time insights into the operation of solar power installations, enabling the maximisation of energy production and improving the performance of solar installations [8]. IoT-based solar power monitoring devices employ sensors, communication protocols, cloud servers, and user interfaces to acquire and analyse data from solar power systems [9]. IoT technology enables the monitoring of solar panels from a distant place using sensors and other connected devices, allowing real-time monitoring of the operation of solar panels and aiding in optimising their output [10]. Therefore, IoT technology may be utilised to increase the efficiency, reliability, and cost-effectiveness of PV systems.

This paper is organised as follows: Section II describes the proposed methodology. Next, in Section III, PV system monitoring and IoT systems The experiment results are presented in Section IV. Finally, section V presents the conclusion.

II. PV SYSTEM MONITORING AND IOT SYSTEM

An Internet of Things (IoT) based monitoring system for solar PV plants can monitor and control solar panels remotely, detect failures, and initiate corrective actions [11]. IoT-based solar power monitoring systems are a smart solution for managing and optimising solar power installations. By using sensors, data can be gathered and analysed to optimise solar energy usage and improve the performance of solar installations [12]. The most used communication technologies for IoT-based PV monitoring systems are Wi-Fi, Zigbee, and SIM800L [13].

The research gaps in IoT-based PV monitoring systems include the lack of fault detection and diagnosis procedures, which are mainly used to monitor data and are not evaluated under climatic conditions characterised by severe sandstorms [14]. A low-cost, portable IoT-based PV monitoring system that can be easily extended to other applications in control and PV system characterization is needed [15]. The system should also integrate a PV fault diagnosis procedure to detect failures that may occur in the PV module [16].

A) PV System Design

Designing a PV system includes various variables that need to be addressed to guarantee that the system is efficient and effective. Here are some fundamental components of a PV system:

- PV array configuration: The electrical diagram depicting the PV array configuration, wiring system, overcurrent protection, inverter, disconnects, mandatory signage, and AC connection to the building should be examined.

- Inverter: PV systems feature either an inverter that transforms the power produced by all modules into usable energy or a micro inverter that is connected to each module and converts the DC power provided by the module into AC power.

- Mounting structures: The mounting structures for the solar panels should be studied to ensure that the panels are put at the optimum angle and orientation to optimise energy production.

- Battery bank: A battery bank is used to store extra energy produced by the PV system for usage when there is no sunshine.

- Loads (appliances): The loads that will be powered by the PV system should be evaluated to ensure that the system is built to fulfil the energy demands of the appliances.

- IoT-based monitoring system: An IoT-based monitoring system may be used to remotely monitor and operate solar panels, identify faults, and perform remedial measures.

The suggested monitoring system Figure 1 may be a viable option for intelligent remote and real-time monitoring of a solar PV system.

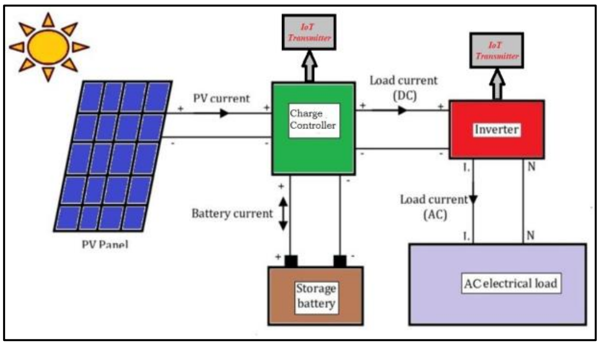

Fig. 1. PV System Design.

B) IoT Monitoring Design

An IoT-based monitoring system for solar PV facilities may be created utilising an Arduino and SIM800L module. Here are the steps to construct an IoT-based monitoring system using Arduino and SIM800L:

- Connecting the SIM800L module with an Arduino to activate the internet capabilities of the module.

- Using a simple serial relay sketch to interface with the SIM800L and give it AT instructions to test if users can send/receive an SMS.

- Using the SIM800L library example sketches for sending and receiving SMS to test the module.

- Adding sensors to the Arduino board to get data from the solar panels.

- Using the SIM800L module to transfer the data to a cloud-based platform for storage and analysis.

- Using an IoT-based monitoring system to remotely monitor and operate solar panels, identify faults and execute repair measures.

- Using an Android application to display the data obtained from the sensors and operate the system.

In summary, an IoT-based monitoring system for solar PV facilities may be constructed utilising an Arduino and SIM800L module. The SIM800L module may be used to activate the internet capabilities of the module, and sensors can be attached to the Arduino board to capture data from the solar panels. The data may be transferred to a cloud-based platform for storage and analysis, and an IoT-based monitoring system can be used to remotely monitor and control.

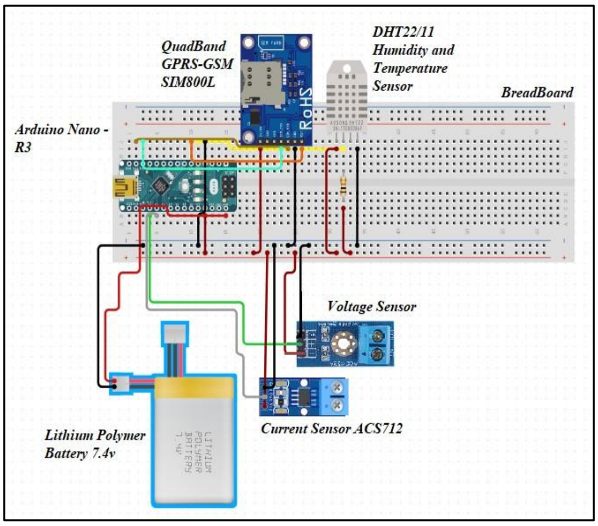

Fig. 2. IoT System Design.

The SIM800L is a well-known cellular connection module that may be utilised in Internet of Things applications. It is a small GSM modem capable of making calls, sending SMS texts, and connecting to the internet via GPRS. To create novel IoT applications, the SIM800L is frequently used in conjunction with the Arduino boards.

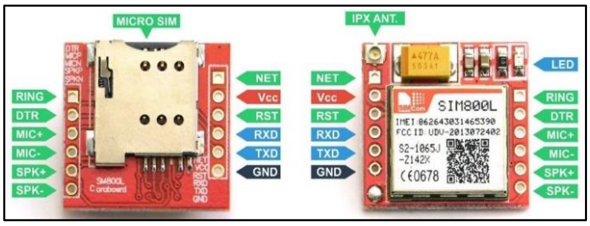

Fig. 3. SIM800L GSM-GPRS Module.

C) ThingSpeak Cloud for IoT

ThingSpeak is an IoT analytics platform service that enables users to collect, view, and analyze live data streams in the cloud [17]. It is a cloud-based platform that allows users to submit sensor data to the cloud, analyze and display their data using MATLAB or other tools, and develop their apps [18]. ThingSpeak features a web service (REST API) that helps users gather and store sensor data in the cloud and construct Internet of Things applications [19]. It works with Arduino, Raspberry Pi, and MATLAB, but it should work with many sorts of programming languages as it utilises a REST API and HTTP [20].

With ThingSpeak, users can store and analyze data in the cloud without establishing web servers, and users can develop complex event-based email alerts that activate depending on data coming in from their connected devices [21]. ThingSpeak is commonly used for prototyping and proof-of-concept IoT devices that need analytics [22].

III. PROPOSED METHODOLOGY

The approach of PV system monitoring and IoT comprises the use of sensors, communication protocols, cloud servers, and user interfaces to acquire and analyze data from solar power systems. The following techniques have been suggested for incorporating IoT in PV system monitoring:

- Detection, monitoring, and automated cleaning system for the soiling of PV solar panels.

- Installation of a cooling fan on the backside of the solar panel to avoid temperature rise and enhance the efficiency of the solar system.

- Monitoring and regulating fan-based cooling systems utilising an IoT system.

- Use of an IoT-based monitoring system to measure the power generated by a solar PV system live and evaluate current MPPT algorithms in real time.

- Monitoring and managing solar panels remotely, identifying faults, and conducting preventative maintenance using an IoT-based control system.

- Monitoring physical parameters such as voltage, current, temperature, and humidity, and monitoring the power produced by the solar photovoltaic panel using an IoT-based control system.

- Use of an IoT-based sensor system for remote monitoring of PV panels.

- Performance monitoring and real-time control of PV systems utilising IoT technologies.

The suggested approaches seek to increase the efficiency, dependability, and cost-effectiveness of PV systems by offering real-time insights into the performance of solar power installations and optimizing their output. These approaches may assist in discovering problems as they arise, taking remedial action swiftly, decreasing downtime, and boosting system efficiency.

IV. RESULTS AND DISCUSSION

The data was collected using MATLAB Simulink and shown on the Android application. The main diagram of the PV system monitored by IoT is shown in Figure 4. The data collected are Temperature, Humidity, PV Voltage, DC Bus Voltage, Inverter Power, Inverter Voltage, and Inverter Current.

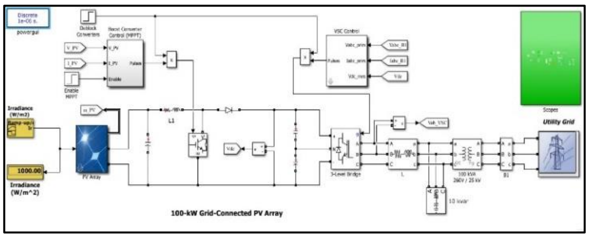

Fig. 4. PV System Simulation Blocks.

The data transmission from Simulink to the ThingSpeak cloud occurs based on the ThingSpeak Simulink block called ThingSpeak Output is shown in Figure 5. The ThingSpeak Output block is a Simulink block that outputs numeric data to 1-8 ThingSpeak channels [23]. This block may be used to transfer data from a Simulink model to ThingSpeak for real-time monitoring and analysis. The block may be made to use the public ThingSpeak server by default, but it can alternatively be configured to use a private ThingSpeak server [24]. The ThingSpeak

Write block is another Simulink block that may be used to write data to ThingSpeak. This block is part of the Simulink Support Package for the IoT library and may be enabled using the Write API Key from the ThingSpeak account [25].

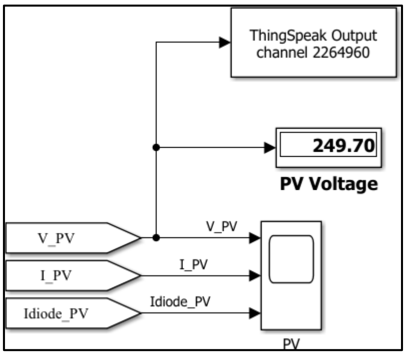

Fig. 5. Data transmitter ThingSpeak Simulink Block.

Figure 6 shows the Real-time monitoring of collected data based on an Android application. The displayed data in the Android application was obtained directly from the ThingSpeak cloud. So, there is no direct connection to the main circuit.

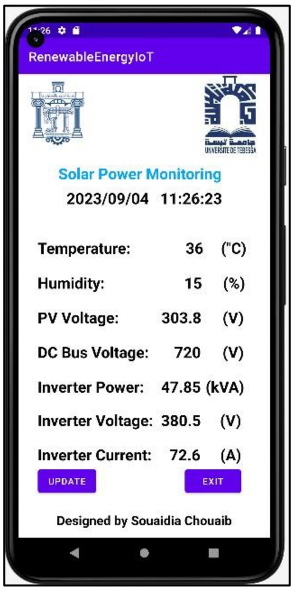

Fig. 6. Android application interface.

The ThingSpeak cloud receives the data from the circuit, whenever it's available and the Android application receives the data from the cloud whenever the application requests. In this project, there is no need for an IP address for the circuit or the cloud and even for the application. Instead, there is a key generated by the cloud to read and write the data.

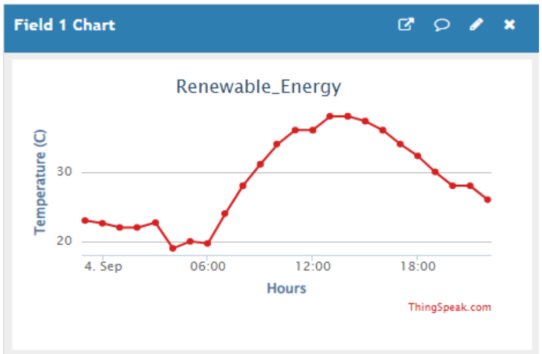

Fig. 7. Temperature measurement (◦C).

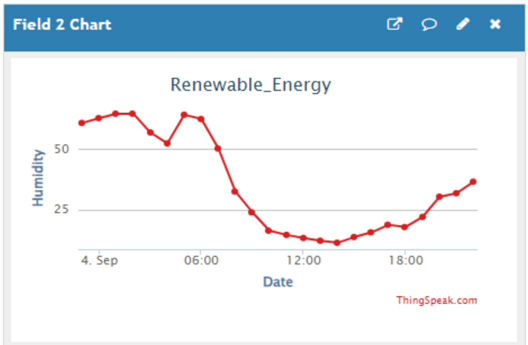

Fig. 8. Humidity measurement (%).

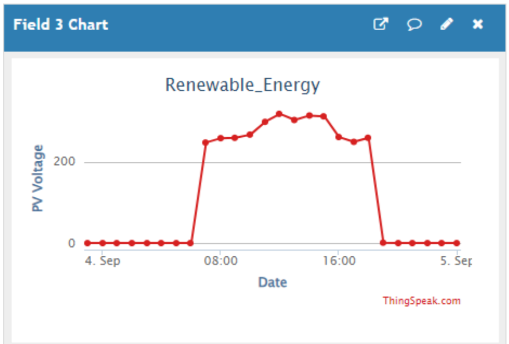

Fig. 9. PV Voltage (V).

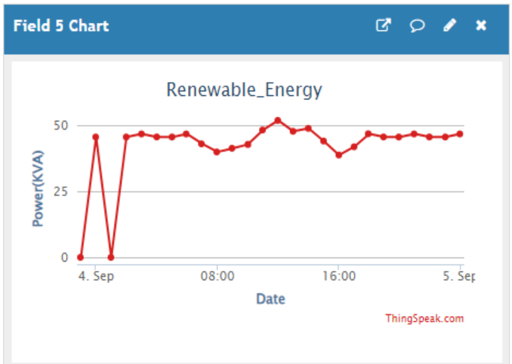

Fig. 10. Inverter Power (kVA).

V. CONCLUSION

IoT enhances the efficiency of PV system maintenance in various ways, including:

- Real-time monitoring: IoT-based monitoring systems give real-time insights into the operation of solar power installations, enabling the maximisation of energy production and optimising the performance of solar installations. This enables maintenance professionals to spot faults as they arise and take remedial action swiftly, decreasing downtime and enhancing system efficiency.

- Predictive maintenance: IoT-based monitoring systems may utilise machine learning algorithms to forecast when maintenance is necessary, based on data received from sensors.

- This enables maintenance professionals to plan maintenance proactively, lowering the chance of unexpected downtime and enhancing system efficiency.

- Remote monitoring: IoT technology enables the monitoring of solar panels from a distant location, allowing real-time monitoring of the operation of solar panels and aiding in optimizing their output.

- This enables maintenance employees to monitor many PV systems from a central location, decreasing the need for on-site visits and boosting the efficiency of maintenance operations.

- Reduced maintenance costs: By giving real-time insights into the operation of solar power installations and allowing predictive maintenance, IoT-based monitoring systems may decrease the need for expensive reactive maintenance.

In summary, IoT technology may assist in enhancing the efficiency of PV system maintenance by giving real-time insights into system performance, enabling predictive maintenance, permitting remote monitoring, and decreasing maintenance expenses.

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