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An Internet of Things based Solar Power Monitoring System using Node MCU

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Abstract— Solar power systems are increasingly being adopted as a renewable energy solution worldwide. However, effective monitoring and management of these systems are crucial for optimizing their performance and ensuring their reliable operation. In this research paper, we propose a solar power monitoring system using NodeMCU, an open-source IoT platform. Our system collects, processes, and visualizes real-time data from solar panels, batteries, and other qsystem components, providing comprehensive monitoring capabilities for solar power system owners. The system is designed to be cost-effective and scalable, making it suitable for both residential and commercial applications. Through our research, we demonstrate the feasibility and effectiveness of our solar power monitoring system using NodeMCU. The findings contribute to the field of renewable energy management by offering an innovative approach to monitor and optimize solar power systems, promoting the wider adoption of renewable energy sources for a sustainable future.

Keywords- Internet of Things, Solar monitoring, Sensors, Cloud, Node MCU

I. INTRODUCTION

Solar power [1],as a renewable and environmentally friendly source of energy, has gained widespread attention and adoption in recent years. With the [2] growing global demand for sustainable energy solutions, solar power systems are becoming increasingly popular for both residential and commercial applications. However, effective monitoring and management of solar power systems are critical to optimize their performance and ensure their reliable operation. In this research paper, we present an integrated solution for solar power monitoring using NodeMCU, an open source [3] Internet of Things (IoT) platform and deploying it onto ThingSpeak cloud server. We discuss the design, implementation, and evaluation of a solar power monitoring system that leverages the capabilities of NodeMCU along with voltage sensors to collect, process, and visualize real- time data from solar panels, and other system components. Our system provides a [4] comprehensive monitoring solution that enables solar power system owners to monitor and manage their renewable energy resources efficiently, leading to improved energy generation, consumption, and overall system performance.

The aim of this research paper is to design and implement a solar power monitoring system [5] using an Arduino board and ThingSpeak IoT platform. The system will be used to monitor the performance of a small-scale solar power system in real-time. The system will collect data on various parameters[6] such as the amount of sunlight, temperature, and voltage output from solar panels, and send this data to [7]. ThingSpeak for analysis and visualization. This research contributes to the field of [8] [9] renewable energy management by providing an innovative and cost- effective approach to monitor and optimize solar power systems, which can facilitate the wider adoption of renewable energy sources and contribute to a sustainable future.

II.LITERATURE REVIEW

Neelanshi S Palkar al [10] proposed a solar power monitoring system using NodeMCU and voltage sensors, which collects, processes and visualizes real-time data from solar panels and batteries. The methodology includes designing and implementing the system, testing and evaluating it. The technicalities involve using the Internet of Things (IoT) platform, ThingSpeak cloud server, and integrating various sensors to provide comprehensive monitoring capabilities for solar power system owners. Nehali Datar al [11] presented a solar power monitoring system using IoT technology to collect and process real-time data from solar panels, batteries, and other system components. The methodology involves the use of NodeMCU and voltage sensors for data acquisition, and ThingSpeak cloud server for data visualization. The system's performance is evaluated through experimental studies, and the results demonstrate the feasibility and effectiveness of the proposed solution. However, the paper lacks detailed information on the technical aspects of the system and the experimental setup, which may limit the replicability of the study.

Maisagalla Gopal al [12] proposed an IoT-based solar power monitoring system using Arduino and ThingSpeak cloud platform to measure and monitor the performance of a solar

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panel system. The system uses voltage and current sensors to collect real-time data from the solar panels, which is then processed and visualized on the ThingSpeak cloud platform. The authors also include a case study where the proposed system was successfully implemented and evaluated. Overall, the paper presents a practical and cost-effective solution for solar power monitoring using IoT technology. K.G.Srinivasan al [13] presented a solar power monitoring system using an Arduino Uno microcontroller and voltage sensors to measure the voltage and current of the solar panel, battery, and load. The system sends the data to a server using the GSM network for remote monitoring and control. The methodology involves the design and implementation of hardware components and software programming for data acquisition and communication. The results show that the system can effectively monitor the performance of a solar power system and provide real-time information on energy production and consumption. The paper provides a practical and cost-effective solution for solar power system monitoring, making it suitable for residential and commercial applications.

Katyarmal [14] proposed a solar power monitoring system using IoT devices. The system involves monitoring and measuring solar panel parameters such as voltage, current, and temperature using sensors connected to an Arduino board, which is then connected to the internet to provide real-time monitoring. The data is then processed, analyzed, and displayed on a web interface using a cloud server. The author evaluated their proposed system by implementing a prototype and conducting experiments to measure its performance. The results show that the proposed system can accurately monitor solar power production and provide real-time monitoring and analysis of solar panel parameters. In terms of future enhancements, the author suggests incorporating machine learning algorithms into the system to optimize solar power usage and enhance its accuracy. The author also suggests incorporating a predictive maintenance model to identify any faults or issues with the solar power system before they occur. Overall, the paper presents an effective approach to solar power monitoring using IoT devices. The proposed system can benefit from the addition of machine learning algorithms and predictive maintenance models to improve its accuracy and efficiency. An IoT-based system that integrates solar power with soil and weather monitoring is presented by Kothapalli L. R. et al [15]. The study focuses on using IoT technology to gather and examine information about soil characteristics and weather patterns. The study emphasizes the system's solar-powered feature and prospective uses for efficient agricultural and environmental monitoring. The system's architecture and advantages are described in the context of better resource management.

An Internet of Things-based monitoring system for solar parameters is introduced by Sutikno, Tole, et al. [16]. The NodeMCU ESP8266 is used in the study to gather and transmit data from photovoltaic installations. The use of IoT technology for real-time monitoring of solar parameters is the main objective. In order to improve the performance and maintenance of solar systems, the paper describes the system's architecture and advantages. Hardas et. Al. [17] proposed solar panel monitoring system using IOT using ATmega328IC connection and using NodeMCU board for wi-fi connection. This document proposes low-cost real time solar panel monitoring system and useful for measuring PV array production.

V. Kavitha and V. Malathi [18] focus on IoT-based monitoring of solar PV connections. The system usages sensors to collect real-time data from PV panels and its apparatuses. Data is transmitted wirelessly for remote analysis. The system aims to improve performance, provide early fault detection, and offer remote access via a web interface. An autonomous solar-powered monitoring system for fertilization is presented by Abdullah et al. in [19]. The system gathers data from sensors and suggests remote monitoring by utilizing IoT expertise. Its main objective is to provide real-time data analysis that will enhance fertilization operations' efficacy. The system's design is described in the study along with any potential advantages for sustainable agricultural methods. IoT-based solar monitoring is covered by Vidyalakshmi et al [20]. In order to optimize efficiency, the study focuses on using IoT technology to monitor solar systems. This allows for real-time data collecting and analysis. The study has an emphasis on web-based remote accessibility. It describes the IoT-based system's architecture and advantages for improving solar energy utilization.

An Internet of Things (IoT)-based system that uses NodeMCU to monitor solar-powered street lighting is introduced by Dougani Bentabet and Sandeep R Sonaskar [21]. Through real-time monitoring and control, the system gathers data from the lights and wirelessly transmits it for study with the goal of improving energy efficiency. The system's architecture and advantages for better street lighting management are described in the article. Inayatul Inayah et. Al. [22] presents a real-time solar panel performance monitoring system utilizing IoT and the Blynk application. The study focuses on using IoT technology to gather and analyze solar panel data, providing remote accessibility through the Blynk platform. The paper details the architecture and benefits of the system for effective solar energy management.

A smart street light monitoring system[23] was created to increase lighting's energy effectiveness. The system uses cutting-edge technology to continuously monitor and control street lights. The emphasis is on energy efficiency and making a contribution to sustainable urban lighting. The study describes the architecture and advantages of the system, emphasizing its potential to achieve effective and efficient street lighting control. R. Ganesh's [24] research focuses on the prediction of battery residual energy using a CNN-BiGRU and attention mechanism model. The research uses cutting-edge deep learning methods to improve battery energy management. The paper describes the design and advantages of the suggested approach, highlighting its potential influence on enhancing battery performance prediction. An IoT-based battery management system using a machine learning model is presented by A. Prabha et al. [25]. The goal of the project is to improve battery management by combining IoT technologies and cutting-edge machine learning methods. The architecture and advantages of the suggested system are described in detail in the study, with special emphasis on how it might affect battery efficiency and performance forecasting.

III. METHODOLOGY

The aim of this research paper is to design and implement a solar power monitoring system using an Arduino board and ThingSpeak IoT platform. The system will be used to monitor the performance of a small-scale solar power system in real-time. In the proposed system author proposes a system of smart streetlight which uses NodeMCU to send data to cloud platform to monitor solar volt and battery volt and to control the streetlights. Authors of present a system to monitor system of solar panel performance using blynk application. The system is pretty simple power generated by solar panel is used to charge the battery using solar charge controller, DHT22 sensor is used to measure temperature. Data is shown in simple way on blynk app which is simple to use. With the growing global demand for sustainable energy solutions, solar power systems are becoming increasingly popular for both residential and commercial applications. However, effective monitoring and management of solar power systems are critical to optimize their performance and ensure their reliable operation.

This research contributes to the field of renewable energy management by providing an innovative and cost-effective approach to monitor and optimize solar power systems, which can facilitate the wider adoption of renewable energy sources and contribute to a sustainable future. Taking all this into consideration, below is the system design that is implemented in the project:

A. System Design

To monitor the voltage and current of a solar panel, sensors such as a current sensor and a voltage sensor are used. The data from both sensors is sent to an ESP8266 module, which combines a controller and a Wi-Fi module. The module is programmed using the Arduino IDE software. Initially, the ESP8266 works as a microcontroller and retrieves the output data from the sensors via serial ports. This data is then displayed on an LCD screen as voltage, current, and power values. Subsequently, the ESP8266 operates as a Wi-Fi module, connecting to the internet through Wi-Fi, and sending the available serial data to the cloud ThingSpeak using the MQTT (Message Queuing Telemetry Transport) protocol. Using an API, we can access the data stored on ThingSpeak over the internet.

B. Implementation steps involved in creating Solar Power Monitoring System:

- Hardware Setup: The first step involves setting up the hardware components required for the system, which includes a NodeMCU board, voltage sensors, and other necessary components such as resistors, sensors, and
- connectors. The hardware components should be connected according to the block diagram, ensuring that all connections are secure and stable.
- Software Configuration: The next step involves configuring the software components required for the system, which includes programming the NodeMCU board with the necessary code and setting up the ThingSpeak cloud server account. The NodeMCU code should be written to collect data from the voltage sensors and send it to the ThingSpeak cloud server for visualization and analysis.
- The voltage divider circuit is connected to the voltagePin (D5), and it consists of a 10kΩ resistor (R1) connected in series with a 3.3kΩ resistor (R2), with the voltagePin connected between them. The voltage across R2 is measured using the analogRead() function and converted to a voltage value (vOUT). The input voltage (vIN) is then calculated using the voltage divider

$$vIN = vOUT\ /\ (R2\ /\ (R1 + R2) \qquad \text{.........(1)}$$

- The DHT11 sensor is connected to pin D4 and is used to measure temperature and humidity using the dht.readTemperature() and dht.readHumidity() functions.
- The measured values are displayed on an LCD screen using the LiquidCrystal_I2C library. The values are also sent to the ThingSpeak platform using the WiFiClient library and the ESP8266's built-in WiFi capabilities.
- Calibration: Once the hardware and software components are set up and configured, the system should be calibrated to ensure that it is collecting and sending accurate data. Calibration involves adjusting the voltage sensor readings

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to match the actual voltage readings from the solar panels and batteries.

- Testing: After calibration, the system should be tested to ensure that it is functioning correctly and sending data to the ThingSpeak cloud server as expected. Testing involves monitoring the data visualization on the ThingSpeak platform and comparing it to actual readings to ensure accuracy.

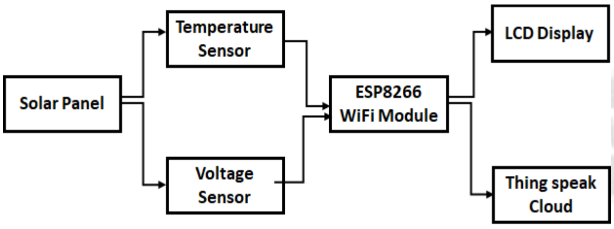

Fig. 3.1: Solar power monitoring system

The Fig. 3.1 represents a solar power monitoring system that includes a temperature sensor and a voltage sensor to measure the temperature and voltage of the solar panel. The system also includes an ESP8266 module, which is used to connect the sensors to the internet and send the data to the Thingspeak cloud. Finally, an LCD display is used to display the data locally. Overall, the system provides real-time monitoring of the performance of the solar panel, allowing for early detection of any issues or inefficiencies.

A. Hardware requirements:

- LCD Display: An LCD (Liquid Crystal Display) is a type of screen that can be used to display information related to solar power production, such as real-time energy generation, system status, or historical data. It provides a visual interface for users to monitor the performance of the solar power system. The LCD display is connected to Node MCU to display relevant data.
- Solar Panel: Solar panels are the primary component of a solar power system that captures sunlight and converts it into electrical energy. They are typically made up of multiple photovoltaic (PV) cells connected in series or parallel to generate the desired voltage and current. The solar panel's output can be monitored using voltage and current sensors to measure the energy production of the solar power system. In this proposed system 5V solar panel is used.
- WiFi Module ESP8266: The ESP8266 is a popular WiFi module that can be used to establish wireless communication in a solar power monitoring system. It provides WiFi connectivity and can be programmed to connect to a local WiFi network or act as an access point to create its own WiFi network for data transfer to a remote server or a user interface. The ESP8266 can interface with a microcontroller, such as an Arduino, to send and receive sensor data, commands, or display data on a web-based dashboard.In this system it is used to send the data received from temperature sensor and voltage sensor to ThingSpeak server.
- Voltage Sensor: A voltage sensor is used to measure the voltage output of solar panels or other components in a solar power system. It can provide data on the solar panel's voltage, battery voltage, or other relevant voltages in the system. The voltage sensor can be connected to the Arduino Uno to measure and process the voltage data for monitoring and analysis.
- Micro USB cable: Micro USB cable is a type of cable commonly used in IoT (Internet of Things) devices to transfer data and power. It has a small, compact design and is often used to charge and sync smartphones, tablets, and other portable devices. In IoT applications, micro-USB cables can be used to connect devices such as sensors, cameras, and controllers to a central hub or network.

B. Software requirements:

- Cloud setup: ThingSpeak is an open-source IoT platform that allows you to collect, store, and analyze data from sensors and other devices. It provides a cloud-based infrastructure that can be used to build real-time applications for monitoring and controlling devices remotely. ThingSpeak provides an easy-to-use web interface and a set of APIs that can be used to connect to various devices, including Arduino boards.ThingSpeak is used to collect data from sensors that measure parameters such as the amount of sunlight, temperature, and voltage output from solar panels. The data is then sent to ThingSpeak using an Arduino board that is connected to the sensors.
- Arduino Integrated Development Environment: Arduino IDE is an integrated development environment that is used to program Arduino boards. It provides a set of libraries and tools that can be used to write, compile, and upload code to Arduino boards. The IDE includes a code editor, a compiler, and a serial monitor that can be used to communicate with Arduino boards. Both C and C++ programming languages are supported in this environment.

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Table 3.1: Components and their Specifications.

COMPONENTS	SPECIFICATIONS
VOLTAGE SENSOR	Voltage input range: DC 0-25V. Voltage detection range: DC 0.02445V to 25V. Voltage analog resolution: 0.00489V.
DHT SENSOR	Power supply: 3.3 to 5V DC. Operating range: 20-80% RH, 0- 50ºC.
LCD DISPLAY(16X2)	Viewing area: 64.5 x 16.4 mm. Character size: 3.00 x 5.23mm.
NODE MCU	Operating voltage: 3.3V. Digital I/O pins: 16. Analog input pins: 1. Wi-fi Onboard.

The table 3.1 exhibits the specifications for several components used. The components listed include a voltage sensor, DHT sensor, and an LCD display module that is controlled by a NodeMCU microcontroller. Additionally, the table lists the measurement range and accuracy for each sensor.

IV. RESULTS

Our solar power monitoring system presents a viable alternative for enhancing the performance and dependability of solar power systems in light of the rising demand for sustainable energy solutions.

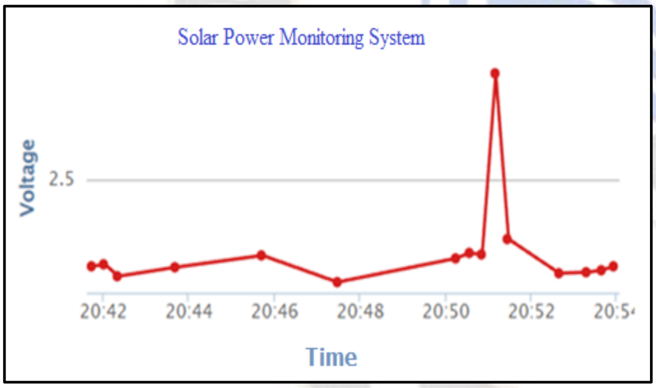

Fig.4.1: Voltage generated over the Time

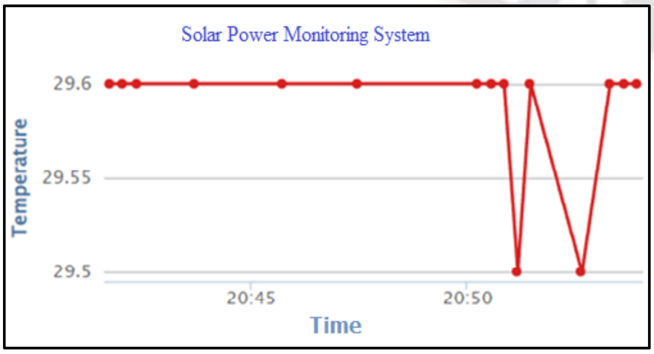

Fig.4.2: Temperature variation over the Time

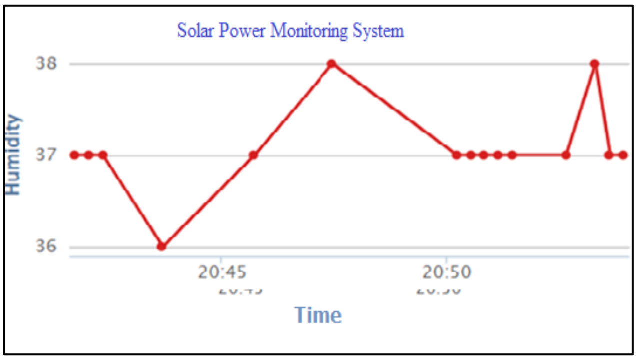

Fig. 4.3: Humidity variation over the Time

The Fig.4.1 displays the voltage over time. The Fig.4.2 displays the temperature over time. And Fig 4.3 displays the humidity over time. The table4.1 exhibits the voltage, temperature, and humidity readings for a given set of measurements.

Table 4.1: Measured Parameters

Voltage	Temperature	Humidity
1.0V	29ºC	62g/kg
2.4V	31ºC	65g/kg
4.9V	33ºC	65g/kg
5.0V	33ºC	63g/kg
3.0V	31ºC	60g/kg

The Fig 4.1 displays an LCD screen that is showing readings for temperature, humidity, and voltage.

Fig 4.1: Output on LCD display

V. FUTURE SCOPE

One potential future direction for our solar power monitoring system using NodeMCU is to incorporate machine learning algorithms to enable predictive maintenance of solar power systems. By analyzing historical data and identifying patterns, machine learning models can predict when maintenance is required, allowing system owners to perform proactive maintenance rather than reactive maintenance, which can improve the overall system reliability and reduce downtime.

Additionally, integrating our solar power monitoring system with smart grid technologies can enable solar power system owners to participate in demand response programs, which can provide financial incentives for reducing energy consumption during periods of high demand. This can help reduce stress on the power grid and contribute to a more sustainable energy future.

LDR can also be used if there were more analog pins on board to calculate light intensity to get light intensity graph. It can be calculated using below equations.

$$Vout = (sensorValue * 0.0048828125) \quad ......(2)$$

$$LUX = (20 * (3 - Vout)) / Vout \quad ....(3)$$

Finally, our solar power monitoring system can be extended to support peer-to-peer energy trading, where excess solar energy generated by one system can be sold to other users in the community, creating a more distributed and decentralized energy system. Overall, our solar power monitoring system using NodeMCU has great potential for future research and development, providing a platform for innovation in the field of renewable energy management

VI. CONCLUSION

In conclusion, our solar power monitoring system using NodeMCU offers a comprehensive and cost-effective approach to monitor and optimize solar power systems, contributing to the wider adoption of renewable energy sources for a sustainable future. The future scope of our system includes incorporating machine learning algorithms, integrating with smart grid technologies, and supporting peer- to-peer energy trading, providing opportunities for further research and innovation in the field of renewable energy management. With the increasing demand for sustainable energy solutions, our solar power monitoring system offers a promising solution for optimizing the performance and reliability of solar power systems.

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