International Journal of Advanced Research in Science, Communication and Technology



International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

Volume 5, Issue 9, May 2025



Sun Track: A Compact IoT System for PV Parameter Monitoring with NodeMCU

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Abstract: This project presents Sun Track, a compact and cost-effective IoT-based system designed to monitor key electrical parameters of a photovoltaic (PV) module using the NodeMCU ESP8266 microcontroller. The system utilizes voltage and current sensors to measure real-time output from a PV module, capturing essential data such as voltage, current, and power. A voltage divider and ACS712 current sensor are interfaced with the NodeMCU's analog input to gather sensor readings, which are then processed and displayed via serial output or transmitted over Wi-Fi for remote monitoring. The project aims to provide a scalable and accessible solution for educational, experimental, and small-scale solar power setups, offering insights into PV performance under varying environmental conditions. With its low power consumption and wireless capabilities, Sun Track demonstrates the potential of IoT in advancing renewable energy monitoring. The use of the internet of things (IoT) in solar photovoltaic (PV) systems is a critical feature for remote monitoring, supervising, and performance evaluation. Furthermore, it improves the long-term viability, consistency, efficiency, and system maintenance of energy production. However, previous researchers' proposed PV monitoring systems are relatively complex and expensive. Furthermore, the existing systems do not have any backup data, which means that the acquired data could be lost if the network connection fails. This paper presents a simple and low-cost IoT-based PV parameter monitoring system, with additional backup data stored on a micro SD card. A NodeMCU ESP8266 development board is chosen as the main controller because it is a systemon-chip (SOC) microcontroller with integrated Wi-Fi and low-power support, all in one chip to reduce the cost of the proposed system.

Keywords: NodeMCU's.

I. INTRODUCTION

As the demand for renewable energy sources continues to rise, solar energy has emerged as one of the most sustainable and widely adopted technologies for power generation. Photovoltaic (PV) systems are now increasingly used in homes, businesses, and remote locations due to their low operating costs and eco-friendly nature [1-5]. However, for these systems to function efficiently over time, constant monitoring of their electrical parameters is crucial. Monitoring parameters such as voltage, current, power output, and energy yield enables users to assess performance, detect faults early, and maximize energy harvesting [6-150]. Despite its importance, PV monitoring is often overlooked in small- to medium scale installations because existing solutions are either too expensive, overly complex, or lack IoT capabilities. Most traditional systems require manual data collection or are not scalable, making it difficult for users to access realtime performance data remotely. Sun Track addresses these limitations by offering a smart, compact, and cost effective IoT-based PV monitoring system. The heart of the system is the NodeMCU (ESP8266), a Wi-Fi enabled microcontroller capable of reading data from sensors[151-250].like INA219 to measure voltage and current accurately. The collected data is then processed and sent to an IoT cloud platform (such as Thing Speak, Blynk, or Firebase), where it can be visualized in real-time through dash boards or mobile apps. This enables users to remotely track their solar system's performance from anywhere in the world. It is particularly suited for educational use, small residential PV installations, off-grid systems, or DIY solar projects. By empowering users with better insights into their PV systems, Sun Track promotes more efficient energy management and contributes to the broader adoption of smart. The demand for renewable energy sources is growing in tandem with global energy demand. This is due to the worsening environmental

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DOI: 10.48175/IJARSCT-27037





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impact caused by the use of fossil fueled power plants, which cause a big air pollution and not environmentally friendly. On the other hand, there are several forms of renewable energy-based electricity generation, with technology that is constantly improving. Solar energy has recently emerged as the most appealing renewable energy source for bridging the gap between consumption and production of electrical energy [251-294]. This is due to the dramatic cost reductions and advancements in photovoltaic (PV) technology, which is still rapidly evolving. In addition, solar energy is also the cleanest, environmentally friendly, and abundant type of energy compared to other energy.

II. RESEARCH SYSTEM DESIGN

IoT technology is used in the proposed system to track parameter data from PV via internet connection, including both environmental data (metrology) and electrical data (I and V). The microcontroller is used in an IoT-based PV monitoring system to capture, process, store, and analyse data from sensors based on the calculated parameters in the system. The microcontroller will send the data to the cloud server through a Wi-Fi gateway after it has been processed.

2.1. The proposed IoT PV monitoring system

Figure 1 depicts a block diagram of the entire proposed system, which includes PV data in the form of environmental parameters collected from temperature and light sensors (to estimate the solar irradiance). The electrical parameters of PV, such as current and voltage, are obtained from the appropriate sensors. With the IoT protocol, the microcontroller collects, processes, data from sensors. Then the data transmit and store into offline data backup systems and cloud servers, respectively. The web-based and open-source software serves as a cloud database and visual data viewer can be accessed via Smartphone or personal computer (PC) via a web server.

2.2. Internet of things for PV monitoring system

The IoT allows smart micro grids to exchange information with more users and improves communication through a variety of infrastructures . IoT plays a significant role in human everyday life by allowing the integration of many physical devices via the internet, where devices are intelligently linked, enabling new forms of communication between devices and humans, as well as between devices and the system itself, to share data, track, and manage devices from anywhere in the world using only an internet connection .



Figure 1. Block diagram of a proposed IoT-based PV monitoring system

III. PRINCIPLE OF CONVERSION OF SOLAR RADIATION INTO HEAT

IoT technology is used in the field of renewable energy, especially solar PV systems, to track important parameters affecting PV system output in real-time and online. The sensor and transducer provide these parameters, which are then sent to the microcontroller for analysis. Furthermore, PV plants and other power generation systems can be tracked using an IoT-based monitoring system to enhance analysis, quality, and system maintenance.

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DOI: 10.48175/IJARSCT-27037





International Journal of Advanced Research in Science, Communication and Technology

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

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Volume 5, Issue 9, May 2025





Figure.2 solar test bench using NodeMCU



Figure 3 Actual PV Parameter Monitoring with NodeMCU Panel

The methodology for the solar test bench using NodeMCU with the Blynk app involves setting up a photovoltaic (PV) panel to generate electrical energy based on sunlight exposure. A voltage divider circuit is used to measure the panel's voltage, while an ACS712 current sensor is employed to detect the current output. These sensors are connected to the analog input of the NodeMCU ESP8266 microcontroller, which reads and processes the data. The NodeMCU is programmed using the Arduino IDE and connected to Wi-Fi, enabling wireless data transmission. The processed voltage, current, and calculated power values are sent to the Blynk mobile application, where users can monitor the PV module's performance in real time using visual widgets like gauges and graphs. This approach provides a compact, wireless, and user-friendly method to observe solar power behavior, suitable for small-scale, experimental, or educational setups. Above figure 2 shows solar test bench using Node MCU ,& figure 3 shows Actual PV Parameter Monitoring with NodeMCU Panel.

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DOI: 10.48175/IJARSCT-27037





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V. EXPECTED RESULT

To effectively identify and measure the electrical parameters of a photovoltaic (PV) module, a well-designed testbench incorporating both current and voltage sensors is essential. This experimental setup typically includes a variable resistive load or an electronic load, a data acquisition system, and precise sensors such as Hall-effect current sensors (e.g., ACS712 or INA219) and voltage dividers or differential amplifiers for voltage sensing. When the PV module is exposed to sunlight or a solar simulator, these sensors continuously measure the output current and voltage as the load changes. From this data, critical parameters can be extracted, such as the open-circuit voltage (Voc), which is the maximum voltage when the circuit is open, and the short-circuit current (Isc), which is the maximum current when the output terminals are shorted. By varying the load, the complete I-V (current-voltage) curve is generated, showing how current and voltage at each point, revealing the maximum power point (Pmax), where the module operates most efficiently.

VI. CONCLUSION

The solar test bench worked well and helped us check how solar panels and other parts perform. It allowed us to measure things like voltage, current, and power in a clear and easy way. This setup is useful for learning, testing, and improving solar energy systems. With some upgrades like automatic data recording, it can become even more helpful in the future.

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DOI: 10.48175/IJARSCT-27037





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International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

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DOI: 10.48175/IJARSCT-27037





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DOI: 10.48175/IJARSCT-27037





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DOI: 10.48175/IJARSCT-27037





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International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

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DOI: 10.48175/IJARSCT-27037





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