



REAL-TIME SOLAR PANEL MONITORING USING IOT TECHNOLOGY

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ABSTRACT:

The rapid growth in renewable energy adoption, particularly solar photovoltaic systems, necessitates efficient monitoring mechanisms to ensure optimal performance and reliability. This study presents an Internet of Things (IoT)-based real-time solar panel monitoring system designed to continuously observe key operational parameters such as voltage, current, temperature, and irradiance. The proposed system integrates multiple sensors with an embedded microcontroller to acquire real-time data, which is subsequently transmitted to a cloud platform via wireless communication. This enables remote monitoring through web and mobile interfaces. Additionally, the system incorporates alert mechanisms for abnormal operating conditions, enhancing fault detection and system safety. The implementation demonstrates improved energy utilization, reduced maintenance effort, and enhanced operational transparency. The proposed approach offers a scalable and cost-effective solution for intelligent solar energy management in distributed energy systems.

KEYWORDS:

SOLAR MONITORING, INTERNET OF THINGS (IOT), EMBEDDED SYSTEMS, RENEWABLE ENERGY, SMART ENERGY MANAGEMENT, WIRELESS COMMUNICATION, SENSOR NETWORKS.

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INTRODUCTION

The increasing global demand for clean and sustainable energy has significantly accelerated the deployment of solar photovoltaic (PV) systems. However, the efficiency of these systems is highly dependent on continuous monitoring and timely maintenance. Traditional solar monitoring approaches rely on manual inspection or localized measurement systems, which are inefficient and incapable of providing real-time insights. Consequently, there is a growing need for intelligent monitoring frameworks that can ensure optimal performance and reliability.

Recent advancements in Internet of Things (IoT) technologies have enabled the development of smart monitoring systems capable of real-time data acquisition and remote accessibility. IoT-based solutions allow seamless integration of sensors, communication modules, and cloud platforms, facilitating continuous system supervision and data-driven decision-making [1]. These systems significantly reduce human intervention while improving operational efficiency.

Several studies have explored the integration of embedded systems and wireless communication technologies for renewable energy monitoring. For instance, IoT-enabled

solar monitoring architectures have demonstrated improved fault detection and predictive maintenance capabilities [2]. The use of cloud-based platforms for data storage and visualization enhances user accessibility and system transparency [3]. Furthermore, real-time monitoring systems enable better energy management by providing insights into system performance under varying environmental conditions [4].

Embedded controllers play a crucial role in IoT-based monitoring systems by processing sensor data and enabling communication with external platforms [5]. The integration of sensors such as voltage, current, temperature, and light intensity allows comprehensive performance evaluation of solar panels [6]. Additionally, wireless communication technologies such as Wi-Fi and GSM facilitate remote data transmission and alert generation [7].

Despite these advancements, existing systems still face challenges related to scalability, cost, and real-time responsiveness. Many conventional systems lack automated alert mechanisms and intelligent analytics capabilities [8]. Moreover, limited accessibility to real-time data restricts effective energy optimization and fault

diagnosis [9].

To address these limitations, this study proposes a real-time IoT-based solar monitoring system that integrates embedded processing, multi-parameter sensing, and cloud connectivity. The system aims to enhance efficiency, reliability, and usability of solar power systems by providing continuous monitoring and intelligent insights [10].

MATERIALS AND METHODS:

The proposed system is designed as an IoT-enabled embedded architecture that integrates sensing, processing, communication, and data visualization modules.

SYSTEM ARCHITECTURE:

The system consists of the following key components:

- Solar Panel (energy source)
- Microcontroller (Arduino-based controller)
- Sensors (Voltage, Current, Temperature, Light)
- Communication Modules (Wi-Fi ESP8266/ESP32, GSM)
- Cloud Platform (ThingSpeak)
- Power Supply Unit

The solar panel generates electrical energy, which is monitored using multiple sensors. These sensors continuously measure system parameters and send analog signals to the microcontroller.

DATA ACQUISITION AND PROCESSING

The voltage sensor measures panel output voltage using a potential divider circuit. The current sensor monitors load current, while the temperature sensor (LM35) captures thermal variations. The Light Dependent Resistor (LDR) detects solar irradiance.

The microcontroller processes these sensor inputs using embedded C programming. Analog signals are converted into digital values using an internal Analog-to-Digital Converter (ADC). The processed data is used to compute power and efficiency metrics.

COMMUNICATION AND CLOUD INTEGRATION

The processed data is transmitted to a cloud platform using a Wi-Fi module. The system uses HTTP protocol for data communication with the Thing Speak platform. This enables real-time data storage, visualization, and remote monitoring. Additionally, a GSM module is integrated to send SMS alerts during abnormal conditions such as low irradiance or system faults.

POWER SUPPLY DESIGN

A step-down transformer converts AC supply to a lower voltage level. The rectifier circuit converts AC to DC, followed by filtering and voltage regulation to provide a stable DC supply for system components.

RESULTS:

The developed system successfully demonstrates real-time

monitoring of solar panel parameters. The measured values of voltage, current, temperature, and light intensity are continuously updated on the cloud platform. The system provides accurate real-time data visualization, enabling users to track performance variations under different environmental conditions. The integration of IoT technology ensures seamless data transmission and remote accessibility.

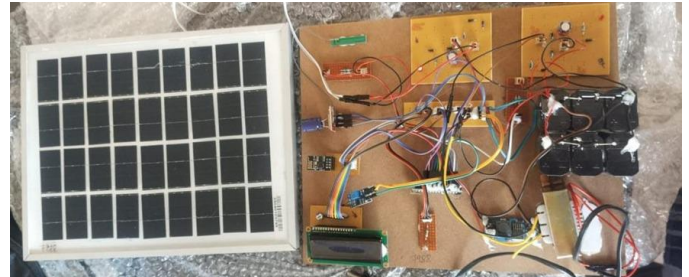


FIG. 1: REAL-TIME SOLAR PANEL MONITORING USING IOT TECHNOLOGY.

The GSM-based alert system effectively notifies users during abnormal conditions, improving system safety and reliability. The monitoring system shows improved response time and reduced dependency on manual inspection. The implementation confirms that the system can efficiently detect performance deviations such as reduced output voltage or overheating conditions. The continuous data logging feature allows historical analysis and performance comparison. The system demonstrates enhanced operational efficiency and reliability in solar energy monitoring.

DISCUSSION:

The proposed IoT-based solar monitoring system offers significant improvements over traditional monitoring approaches. The integration of embedded systems and wireless communication enables real-time monitoring, which is critical for maintaining optimal system performance. The use of multiple sensors ensures comprehensive monitoring of electrical and environmental parameters. This allows accurate assessment of solar panel efficiency under varying conditions. The cloud-based data storage enhances accessibility and enables long-term performance analysis.

Compared to conventional systems, the proposed solution reduces human intervention and operational complexity. The automated alert mechanism improves fault detection and reduces downtime. However, certain limitations exist, such as dependency on internet connectivity and potential data transmission delays. Future enhancements can include advanced analytics, machine learning-based fault prediction, and integration with smart grid systems. The system demonstrates scalability and can be extended to large-scale solar farms and distributed energy systems.

CONCLUSIONS:

This study presents a real-time IoT-based solar panel monitoring system that effectively integrates sensing, processing, and communication technologies. The system

enables continuous monitoring of key solar parameters and provides remote accessibility through cloud platforms. The implementation improves system efficiency, reliability, and fault detection capability. The integration of GSM alerts enhances safety and operational awareness. The proposed system serves as a cost-effective and scalable solution for intelligent solar energy management. Future work may focus on incorporating predictive analytics, artificial intelligence, and advanced optimization techniques to further enhance system performance and energy utilization.

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