"Real-Time Fault Detection and Energy Analysis in Rooftop Solar Systems Using IOT and WSN"

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Abstract - Rooftop solar panel deployment has expanded as a result of the rising reliance on renewable energy. Real-time monitoring solutions that are effective are necessary to guarantee their consistent performance. This study presents a smart monitoring system that tracks rooftop photovoltaic (PV) system performance by utilizing the Internet of Things (IoT) and Wireless Sensor Networks (WSN). To gather important operating information including voltage, current, temperature, and sun irradiance, the system uses a dispersed network of sensors. A centralized IoT platform receives these data wirelessly, processes them, and displays the results for users. The suggested approach improves system dependability and energy efficiency by facilitating remote access, real-time alarms, and data-driven maintenance choices. Widespread rooftop solar applications can benefit from WSN's scalability and low power usage. This strategy offers a workable and affordable way to raise the effectiveness and administration of solar energy systems in homes and businesses.

keywords:
IoT (Internet of Things), Wireless Sensor Networks (WSN), Rooftop Solar Panels, Smart Monitoring System, Photovoltaic (PV) Performance Tracking

1. Introduction:

Rooftop solar photovoltaic (PV) systems have become a popular option for sustainable power generation as a result of the worldwide trend toward renewable energy. They are essential to lowering reliance on fossil fuels because of their capacity to turn sunlight into power. However, regular monitoring and prompt repair are necessary to preserve their effectiveness and guarantee steady energy output. If ignored, environmental changes, dust buildup, and equipment malfunctions can have a detrimental effect on performance.

Conventional monitoring methods, which depend on human inspections or simple data collecting systems devoid of real-time functionality, are frequently narrow in scope. Advanced solar panel monitoring has been possible because to the development of smart technologies, especially the Internet of Things (IoT) and Wireless Sensor Networks (WSN). By enabling wireless connection, remote monitoring, and automated data collecting, these technologies offer a more intelligent and responsive approach to solar energy system management.

Using IoT and WSN integration, this project attempts to provide a smart monitoring framework or rooftop solar panels. The system will collect metrics such as voltage, current, temperature, and sunshine intensity in real time and send the data to a central platform for study. This makes it possible to identify problems quickly, improve system performance, and save maintenance expenses. The strategy supports cleaner, more efficient energy solutions by showcasing the possibilities of integrating renewable energy systems with contemporary digital technologies.

2. Literature Survey:

1) Integration of IoT in Solar Monitoring:
Several studies have explored the use of IoT in solar energy systems, highlighting its capability to provide real-time monitoring, remote access, and automated fault detection. Researchers have demonstrated that IoT-enabled platforms significantly improve system visibility and decision-making efficiency.

2) Role of Wireless Sensor Networks (WSN):
WSNs have been widely implemented for environmental data collection in solar applications. Literature indicates that WSNs enable cost-effective, low-power communication between sensors and centralized systems, making them that are ideal for rooftop solar installations.

3) **Performance Optimization Using Sensor Data:**
Research has shown that collecting key parameters such as voltage, current, temperature, and irradiance can help identify underperforming panels and system issues. These insights enable predictive maintenance and performance optimization.

4) **Energy Efficiency and Scalability:**
Existing work emphasizes the benefits of using low-power IoT devices and WSNs for scalable deployments. Studies suggest that modular and wireless systems reduce installation complexity and energy consumption, making them practical for large-scale rooftop solar networks.

5) **Challenges and Future Scope:**
Literature also points out limitations in existing systems, including limited sensor accuracy, data transmission delays, and lack of standardization. Recent research suggests future improvements using AI, edge computing, and more secure communication protocols to enhance reliability and scalability.

3. Problem Definition:

Rooftop solar photovoltaic (PV) systems are increasingly adopted as a sustainable energy source. However, their performance is often compromised due to factors such as environmental conditions, panel degradation, dust accumulation, and unnoticed faults. Traditional monitoring methods lack real-time insights, rely heavily on manual inspection, and often fail to detect inefficiencies promptly, resulting in reduced energy output and increased maintenance costs.

There is a critical need for a smart, automated, and cost-effective monitoring solution that can continuously track the operational status of rooftop solar panels. The lack of real-time performance data and early fault detection mechanisms limits the potential of solar energy systems. Therefore, this research aims to develop a smart monitoring system utilizing **IoT** and **Wireless Sensor Networks (WSN)** to enable real-time data collection, remote supervision, and timely fault detection. The objective is to improve energy efficiency, reduce maintenance efforts, and enhance the overall reliability and effectiveness of rooftop solar power systems.

4. Proposed Working:

The proposed smart monitoring system for rooftop solar panels integrates sensor technology with IoT and wireless sensor networks to enable real-time performance tracking. Sensors installed on each solar panel continuously measure key parameters such as voltage, current, temperature, and solar irradiance.

These sensors are connected to wireless sensor nodes that collect and transmit the data via low-power wireless communication protocols to an IoT gateway. The gateway acts as an intermediary, receiving data from multiple nodes and forwarding it to a cloud platform over the internet. The cloud platform stores, analyzes, and visualizes the incoming data, providing a user-friendly interface accessible through web or mobile applications. Users can remotely monitor panel performance, receive alerts on system faults or deviations, and make data-driven decisions for maintenance.

This system eliminates the need for manual inspections and allows early fault detection, ultimately improving energy efficiency and reducing operational costs. The use of wireless sensor networks ensures flexible deployment without extensive wiring, while IoT integration facilitates scalable and secure data management.

5. Result:

The proposed smart monitoring system was successfully designed and tested on a prototype rooftop solar panel setup. The integration of IoT and wireless sensor networks enabled real-time monitoring of key parameters such as voltage, current, temperature, and solar irradiance. The sensor data was accurately transmitted to the cloud platform using a low-power wireless communication module, and the values were visualized through a user-friendly dashboard.

During the testing phase, the system demonstrated reliable data collection and transmission over extended periods without significant latency or signal loss. The cloud-based interface provided continuous access to performance metrics and successfully generated alerts when abnormal values or potential faults were detected. This allowed timely intervention, reducing the risk of energy loss or equipment damage.

6. Conclusion:

An effective and dependable way to manage rooftop solar photovoltaic systems is through the creation of a smart monitoring system that makes use of wireless sensor networks and the Internet of Things. The system monitors critical performance metrics including voltage, current, temperature, and solar irradiance constantly, allowing for real-time monitoring and early defect diagnosis. Users may access system data remotely thanks to the combination of wireless connection and cloud-based analytics, which eliminates the need for manual inspections and increases maintenance efficiency.

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