IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

Impact Factor 8.414 ⪤ Peer-reviewed & Refereed journal ⪤ Vol. 14, Issue 4, April 2026

DOI: 10.17148/IJIREEICE.2026.14449

SOLAR ENERGY MONITORING SYSTEM

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Abstract—The rapid growth of renewable energy systems has increased the need for efficient monitoring and performance evaluation of solar photovoltaic installations. Traditional solar monitoring techniques rely on manual data collection and limited analysis, leading to inefficiencies, delayed fault detection, and reduced system performance.
This paper presents Solar Energy Monitoring System, a web-based solar energy monitoring and performance analytics system designed to analyze, visualize, and manage solar power generation data. The system is developed using Python with the Flask framework for backend processing, **HTML, CSS**, and **JavaScript** for **frontend** design, and **MySQL** for **Database** management. Solar Energy Monitoring System enables secure user authentication, centralized data storage, real-time performance visualization, and automated report generation. The proposed system improves accuracy, efficiency, and scalability in solar energy monitoring and provides a foundation for future real-time IoT integration.

Keywords: Solar Energy Monitoring, Photovoltaic Systems, Web Application, Python Flask, MySQL, Renewable Energy Analytics

1. INTRODUCTION

Solar energy has emerged as one of the most reliable and sustainable renewable energy sources due to its abundance and minimal

environmental impact. Solar photovoltaic (PV) systems convert sunlight into electrical energy; however, their performance depends on various environmental and operational factors such as irradiance, temperature, panel efficiency, and system health.

In many existing installations, solar monitoring is performed manually or through basic logging systems. These approaches lack real-time insights, centralized storage, and automated performance evaluation. As solar installations grow in scale, the need for intelligent and automated monitoring platforms becomes critical.

The Solar Energy Monitoring System addresses these challenges by providing a web-based platform that enables continuous monitoring, performance analysis, and visualization of solar energy data. By integrating modern web technologies with data analytics, the system supports informed decision-making and efficient energy management.

Early solar monitoring systems relied on manual measurements and offline analysis using spreadsheets. Although simple, these systems were time-consuming and prone to errors. Later, computer-based monitoring systems introduced automated data logging but lacked remote accessibility and advanced visualization.
Recent research emphasizes web-based and IoT-enabled solar monitoring solutions that provide real-time data transmission and analytics. While IoT-based systems offer improved accuracy, they often involve high implementation costs and complex hardware requirements.
The proposed Solar Energy Monitoring system builds upon these approaches by offering a cost-effective, software-driven monitoring solution that provides centralized analytics, secure authentication, and automated reporting without requiring complex hardware infrastructure.

2. LITERATURE SURVEY

The rapid growth of renewable energy has increased the need for efficient solar power monitoring systems. Early methods relied on manual data collection of voltage, current, and power, which were time-consuming and prone to errors.
Later, computer-based systems using microcontrollers automated data collection, but lacked real-time access and advanced analysis. With the development of web technologies, monitoring systems enabled remote access, real-time dashboards,

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and better performance tracking, though some faced scalability limitations.
The introduction of loT further improved solar monitoring by enabling real-time data transmission from sensors to cloud platforms. These systems provide accurate and automated monitoring but often involve higher costs and complex hardware. Recent studies highlight the importance of data analytics and visualization for improving system efficiency, detectingfaults, And supporting decision-making.

However, many existing systems lack integrated features such as user authentication, automated reporting, and comprehensive analytics. The proposed Solar Energy Monitoring System addresses these gaps by offering a web-based platform with real-time monitoring, data analysis, and report generation in a unified system.
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3. Problem Statement

Existing solar monitoring systems suffer from the following limitations:

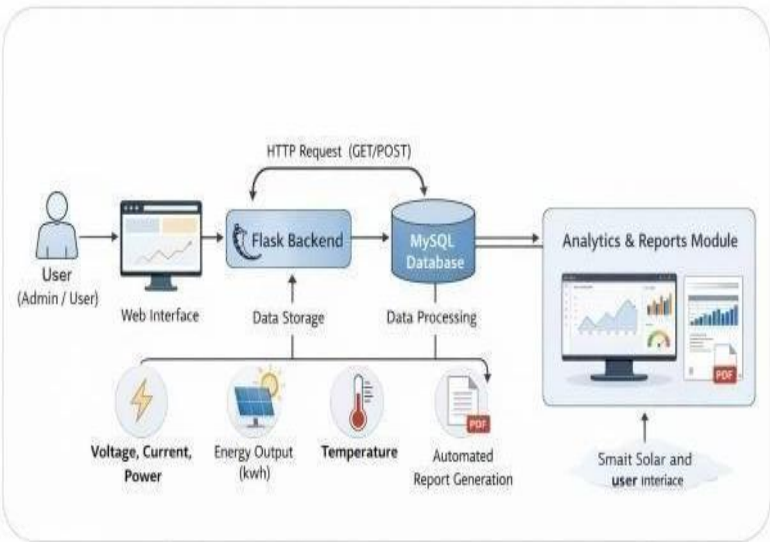
a. Manual or semi-automated data collection
b. Lack of real-time performance visualization
c. Absence of centralized data management Limited analytics and reporting capabilities

These issues highlight the need for a secure, automated, and web-based solar monitoring system that integrates data analysis, visualization, and reporting into a single platform.

4. METHODOLOGY

System Architecture:

The proposed Solar Energy Monitoring system follows a three- tier architecture consisting of presentation, application, and database layers.



System architecture of the SolarVista web-based solar energy monitoring and performance analytics system

Fig 4. system architecture

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4.1 Presentation Layer :

Developed using HTML, CSS, and JavaScript, this layer provides user interfaces such as login, dashboard, analytics, and report generation

4.2 Application Layer:

Implemented using Python Flask, this layer handles authentication, data processing, analytics computation, and report generation.

4.3 Database Layer:

MySQL is used to store user credentials and solar performance parameters such as voltage, current, power, energy, efficiency, and temperature.

5. IMPLEMENTATION

5.1 Authentication Module

a) Provides secure login and user session management

b) Restricts access to authorized users only

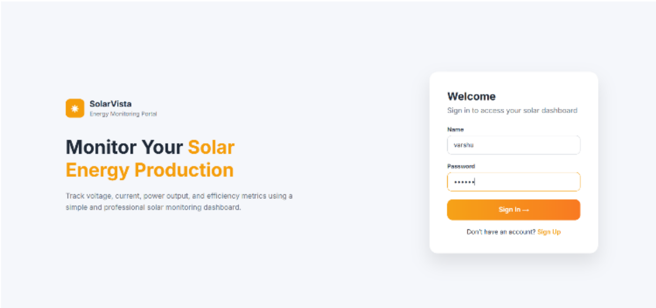

Fig 5.1 Authentication Module

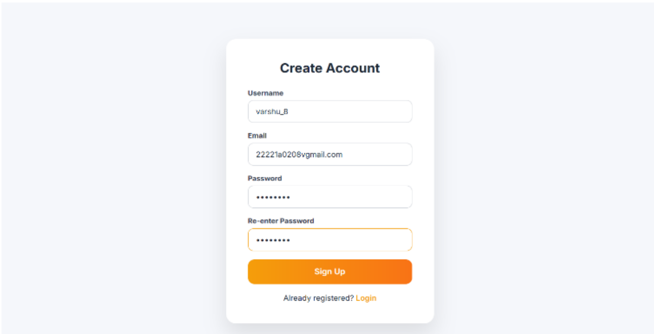

Fig 5.2 Authentication Module

5.2 Solar Data Management Module

a. Stores and manages solar performance parameters
b. Supports time-based data retrieval for analysis

5.3 Dashboard and Analytics Module

a. Displays energy generation trends
b. Visualizes power and efficiency metrics using charts

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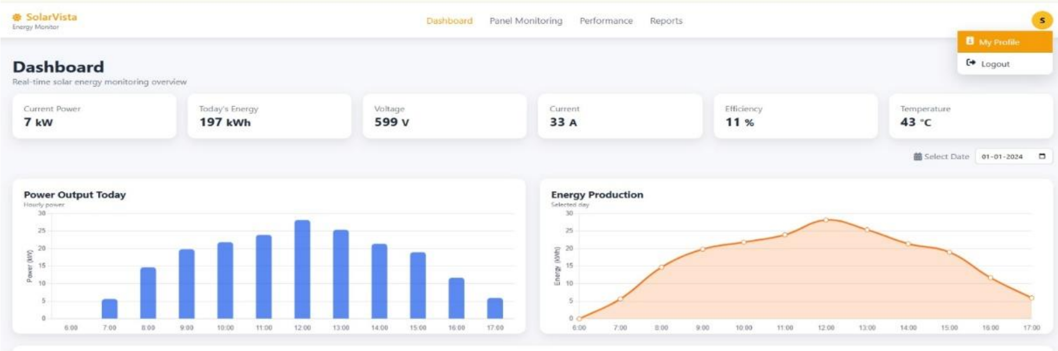
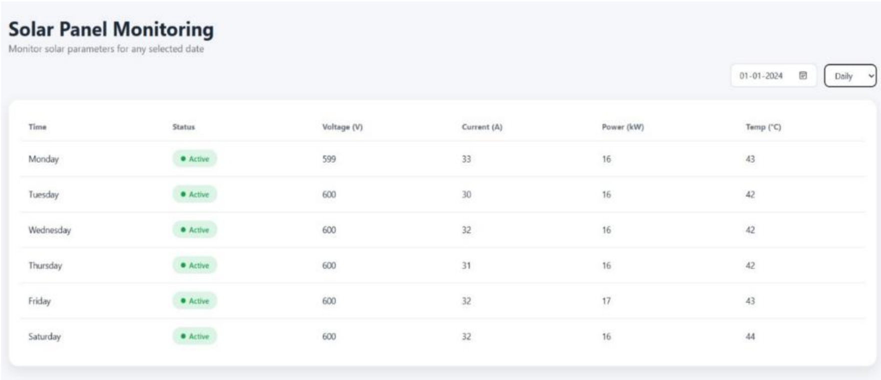


Fig 5.3. Dashboard and analytic module

5.4 Panel Monitoring Module

a. Monitors voltage, current, power, and temperature to evaluate panel performance.



Time	Status	Voltage (V)	Current (A)	Power (kW)	Temp (°C)
Monday	Active	599	33	16	43
Tuesday	Active	600	30	16	42
Wednesday	Active	600	32	16	42
Thursday	Active	600	31	16	42
Friday	Active	600	32	17	43
Saturday	Active	600	32	16	44

Fig 5.4 Panel Monitoring Module

5.5 Performance Monitoring Module

a. Analyzes efficiency variations
b. Identifies underperformance patterns

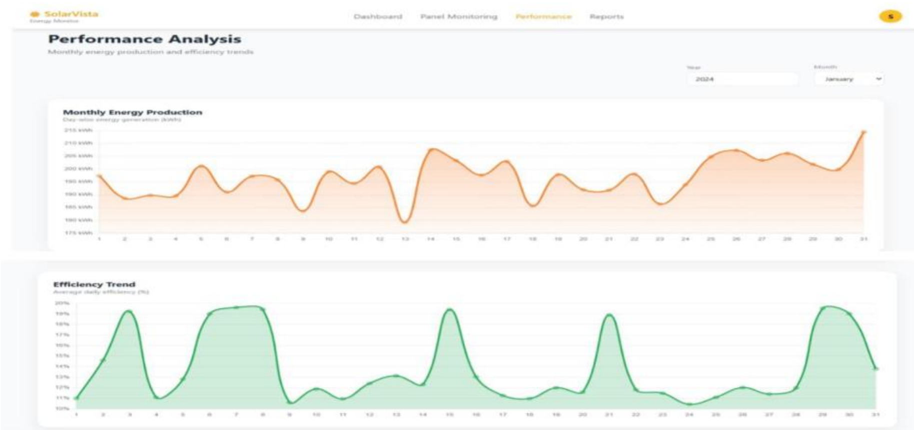


Fig 5.5 Performance Monitoring Module

5.6 Report Generation Module

a. Generates automated PDF performance reports

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b. Supports documentation and decision-making

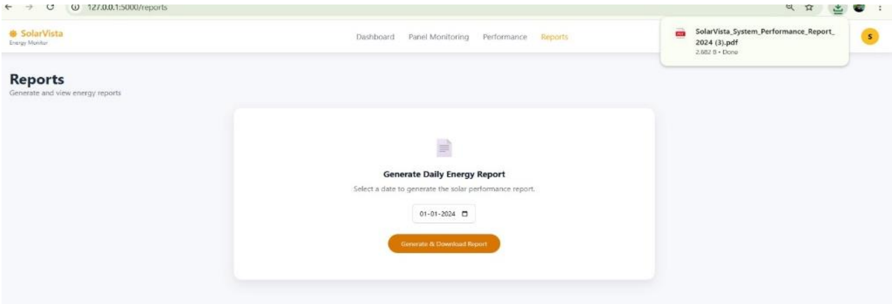

Fig 5.6 Report Generation Module

Python Full Stack with Flask:

The backend of Solar Energy Monitoring System is implemented using Python and Flask, which provides lightweight routing, session handling, and database connectivity. MySQL is used for persistent data storage, ensuring reliable and structured data management..

The frontend is developed using standard web technologies to ensure browser compatibility and responsive design. The integration of Flask with MySQL enables efficient analytics processing, secure data handling, and smooth interaction between system components.

RESULT AND DISCUSSION

The Solar Energy Monitoring system was tested using historical solar datasets under various scenarios. The dashboard successfully Displayed real-time analytics, including energy generation trends and efficiency metrics. Automated PDF reports accurately summarized yearly performance data. The results indicate that the proposed system improves monitoring efficiency, reduces manual effort, and provides reliable insights into solar system performance. The modular design ensures scalability and ease of future enhancement.

CONCULSION

This paper presented SolarVista, a web- based solar energy monitoring and performance analytics system. The proposedsystem effectively overcomes the limitations of traditional monitoring methods by providing a automated analytics, centralized data storage, and interactive visualization. The system Demonstrates reliable performace and offers a scalable foundation for future enhancements such a Real-time IoT integration and predictive analytics

ACKNOWLEDGEMENT

The authors sincerely express their gratitude to the project guide and faculty members of the Department of Electrical and Electronics Engineering, Bonam Venkata Chalamayya Engineering College, for their valuable guidance and continuous support. The authors also thank the institution and management for providing the necessary facilities to complete this project successful.

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