SolarIQ: Smart Solar Energy Forecasting & Insights Dashboards

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Abstract - SolarIQ is an intelligent platform developed to enhance solar energy management through accurate forecasting and insightful data visualization. The system employs machine learning algorithms to predict solar power generation using historical datasets and real-time weather parameters such as temperature, humidity, and irradiance. The platform is built using Node.js and Express.js for efficient backend processing, with MySQL serving as the primary database to ensure secure and structured data management. Interactive dashboards display key performance metrics including energy output trends, efficiency rates, and predictive analytics, enabling users to make data-driven decisions and optimize solar resource utilization. Additional modules such as anomaly detection, predictive maintenance alerts, and performance comparison improve operational reliability. By combining artificial intelligence with real-time data integration, SolarIQ bridges the gap between renewable energy data and actionable insights. The system demonstrates how smart forecasting and user-centric dashboards can support sustainable energy practices and contribute to environmental efficiency.

Key Words: Solar energy forecasting, Machine learning, Weather data analysis, OpenWeatherMap API,Data Visualization,Predictive analytics.

1. Introduction

The increasing global demand for clean and renewable energy has positioned solar power as one of the most promising solutions for sustainable development.However the efficiency and reliability of solar energy systems largely depending on accurate forecasting,environmental conditions and effective data management.Traditional monitoring systems often provide static or delay insights lacking intellegent mechanisms for real time prediction performance evaluation and anomaly detection.This results in energy inefficiencies,maintenance delays and suboptimal utilization of solar resources.Recent advancements in machine learning IoT integration and data visulization technologies have created new opportunities for developing smarter data driven energy management systems.SolarIQ is designed as intellegent platform that forecast solar energy generation using historical data.

SolarIQ is designed as a smart platform that enhances solar energy management through intelligent forecasting, monitoring, and analytical insights. Unlike conventional systems that only display static generation data, SolarIQ integrates machine learning algorithms to predict solar power generation using historical datasets and real-time weather information retrieved from the OpenWeatherMap API.

The system architecture is developed using Node.js and Express.js for backend processing, with MySQL serving as a secure and reliable database for structured data management. Interactive dashboards visualize key parameters such as solar output, temperature, irradiance, and efficiency trends, allowing users to make data-driven decisions that optimize energy utilization.

By combining artificial intelligence, real-time data integration, and user-centric visualization, SolarIQ aims to improve the accuracy, transparency, and reliability of solar power systems. This research presents the project's conceptual design, system architecture, and practical implications, contributing to the advancement of AI-driven sustainable energy platforms.

2. Body of Paper

The proposed project SolarIQ is conceptualized as an intelligent platform that integrates machine learning (ML), real-time weather data, predictive analytics, and data visualization techniques to enhance solar energy forecasting and management. The methodology emphasizes modular system design, scalable architecture, and user-centric functionality to ensure a robust, efficient, and sustainable solution.

2.1 System Architecture

SolarIQ adopts a hybrid multi-tier architecture designed to ensure both scalability and reliability:

- Frontend Layer –A responsive web interface developed using React.js and Tailwind CSS ensures seamless interaction for users,providing real time visualization of solar energy data and predictive insights.

- Application Layer – Backend logic,machine learing-based forcasting models and real time data processing modules operate here to handle energy prediction.
- Database Layer – MySQL manages structured data such as user information, historical energy records, weather parameters, and prediction results, ensuring secure storage and efficient data retrieval for analysis and visualization.
- Forecasting Module – Uses machine learning algorithms to predict solar energy generation based on historical data and real-time weather parameters, providing accurate and data-driven insights.
- Cloud Services Integration – Hosting and data backup through scalable cloud servers improve system reliability.
- Security Framework – Includes secure user authentication,encrypted data transmission and role based access control.

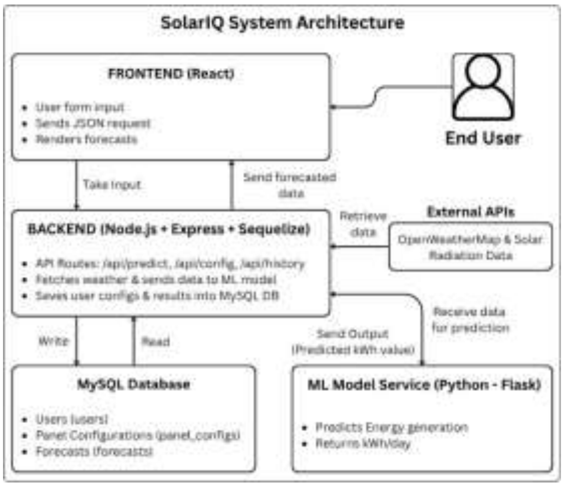

Fig. 2.1: System Architecture Diagram

2.2 Data Flow Design

The Data Flow Diagram (DFD) provides a detailed representation of how data moves across different system entities:

- Users input such as location,solar panel capacity and energy generation records..
- System collect real time weather data from the OpenWeatherMap API and processes it along with historical datasets.
- Machine Learing Module analyzes the combined data to forecast solar energy generation.
- Database (MySQL) stores user details, weather parameters,historical records.
- Outputs include energy forecasts,efficiency analytics,maintenance alerts and displayed through the React interface.

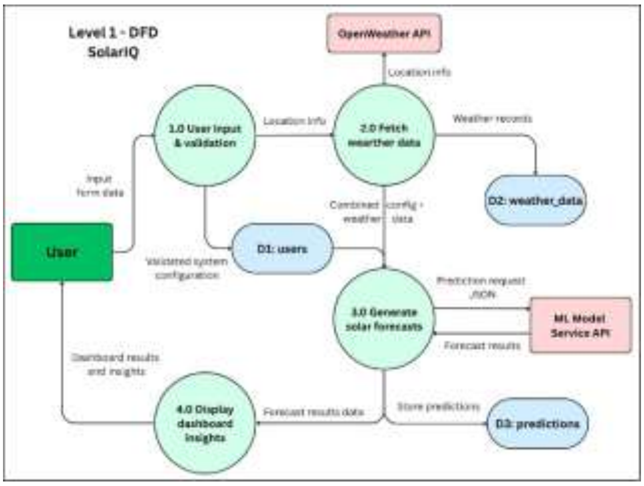

Fig.2.2: Data Flow Diagram

2.3 Functional Requirements

SolarIQ's functionality has been divided into User-Centric Functions,accuracy and performance efficiency:

User Functions:

- Register/Login through verified accounts.
- Input location,solar panel details.
- View real time and predicted solar energy output.
- Analyze historical energy performance through interactive dashboards.
- Receive maintenance based on prediction results.
- Access efficiency reports and comparative analytics for better decision making.

Charitable Trust Functions:

- Fetch and process real time weather data from the OpenWeatherMap API.
- Apply machine learing algorithms to forecast solar energy generation.
- Store user data,weather parameters and prediction results in MySQL.

2.4 Key Features of SolarIQ

SolarIQ includes several intelligent and user-friendly features that enhance solar energy monitoring and prediction:

- Real Time Solar Forecasting – Predicts solar power generation using machine learning models and weather data from the OpenWeatherMap API.
- Multi-User Access – Allow multiple users to monitor and manage systems with different access levels.
- API Integration Support – Allow integration with IoT devices or other smart energy platforms for automation.
- Dark and Light Mode UI – Enhance user comfort and reduce eye strain during extended monitoring sessions.

- Interactive Insights Dashboard – Displays daily, weekly, and monthly energy predictions with clear visual graphs.
- Weather Data Integration – Collects and processes temperature, humidity, and sunlight data for accurate forecasts.
- Alert System – Notifies users about abnormal drops in solar output or sudden weather changes.
- Explainable AI (XAI) – Explains how and why a particular energy prediction is generated.
- Sustainability Tracker – Shows total energy saved and reduction in carbon emissions.

Feature	SolarIQ	Existing Platforms
AI-Powered Solar Forecasting	✅	⚠️ / Limited
Real-time Weather Integration	✅	⚠️ / Limited
Predictive Maintenance Alerts	✅	❌
Energy Consumption Analytics	✅	⚠️ / Basic
Carbon Footprint Tracking	✅	⚠️ / Minimal
Dynamic Pricing Optimization	✅	❌
Smart Grid Connectivity	✅	⚠️ / Minimal
Custom Insights Dashboards	✅	⚠️ / Limited
Explainable AI (XAI) Models	✅	⚠️ / Basic

Chart 2.1: Feature Comparison btween SolarIQ and Existing Platforms

2.5 Methodology Flow

The methodology for developing SolarIQ follows a phased approach:

- **Requirement Gathering** – Studying solar monitoring systems and identidfying limitationsin forecasting accuracy.
- **System Design** – Creating system architecture, DFDs, and database schema for weather and energy data handling.
- **Module Development** – Implementing frontend, backend, AI models, and trust framework.
- **Integration** – Connecting OpenWeatherMap API, MySQL database, and ML models for real-time data flow.
- **Testing** – Performing unit testing, integration testing, and user acceptance testing.
- **Deployment** – Hosting on scalable cloud infrastructure.
- **Evaluation** – Collecting feedback from pilot users and charitable trusts for continuous improvement.

3. CONCLUSIONS

The SolarIQ platform is designed as an intellegent scalable and data driven system that integrates machine learing, IoT based weather data and real time visulization to enhance solar energy forecasting and mangement.Its modular architecture – comprising frontend, backend databse and prediction layers – ensures reliability. The System's well defined functional modules,Integration of the OpenWeatherMap API and interactive dashboards highlight its capability to deliver meaningful insighs. Following a structured methodology – from requirement analysis to testing and evaluation – SolarIQ demonstrates a practical and research oriented approach toward optimizing solar energy utilization improving forecasting accuracy and supporting sustainable energy development.

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