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AI-Driven Solar Smart Charging Infrastructure for EV Cars

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Abstract

The evolution of Electric Vehicles (EVs) represents a significant shift towards sustainable transportation systems. However, the demand for efficient, renewable, and smart charging infrastructure is growing. This paper presents an AI-driven solar-powered charging framework that integrates photovoltaic energy generation, battery storage, and IoT-enabled control for intelligent power management. The system employs artificial intelligence algorithms for predictive energy distribution, dynamic load balancing, and optimization of charging cycles. The integration of solar PV technology with AI ensures sustainable and cost-effective energy utilization, supporting the global goal of zero-emission mobility.

Keywords: Electric Vehicles, Artificial Intelligence, IoT, Solar Energy, Smart Charging, Renewable Energy Systems.

I. Introduction

Electric Vehicles (EVs) have emerged as an essential component in the transition towards sustainable mobility. However, challenges in energy availability, grid dependency, and charging delays limit their mass adoption. Conventional grid-based charging systems contribute to peak load demand, thereby stressing the electrical infrastructure. To address these challenges, renewable-based and AI-assisted charging solutions are gaining importance. AI-driven solar smart charging integrates renewable generation, intelligent control, and IoT-based management to ensure optimal energy usage, sustainability, and reliability.

II. Literature Review

Several studies have explored renewable-based EV charging mechanisms. Gupta et al. (2022) demonstrated a 20% improvement in grid stability using AI-controlled solar charging stations. Islam et al. (2021) applied neural networks for solar irradiance forecasting, improving power prediction accuracy by 15%. Kumar and Sharma (2023) introduced IoT monitoring for adaptive charging, highlighting its impact on real-time load control. However, prior works often lacked deep AI integration and adaptive control models for real-time optimization. This paper aims to bridge that gap.

III. System Design and Methodology

The system integrates solar photovoltaic (PV) panels, a Maximum Power Point Tracking (MPPT) charge controller, a battery bank, and an AI-based control unit. IoT-enabled sensors continuously monitor solar intensity, temperature, voltage, and current to ensure efficient charging. The AI controller utilizes historical and real-time data to predict solar availability and optimize the charging sequence dynamically. The control logic minimizes energy waste while maintaining consistent battery performance.

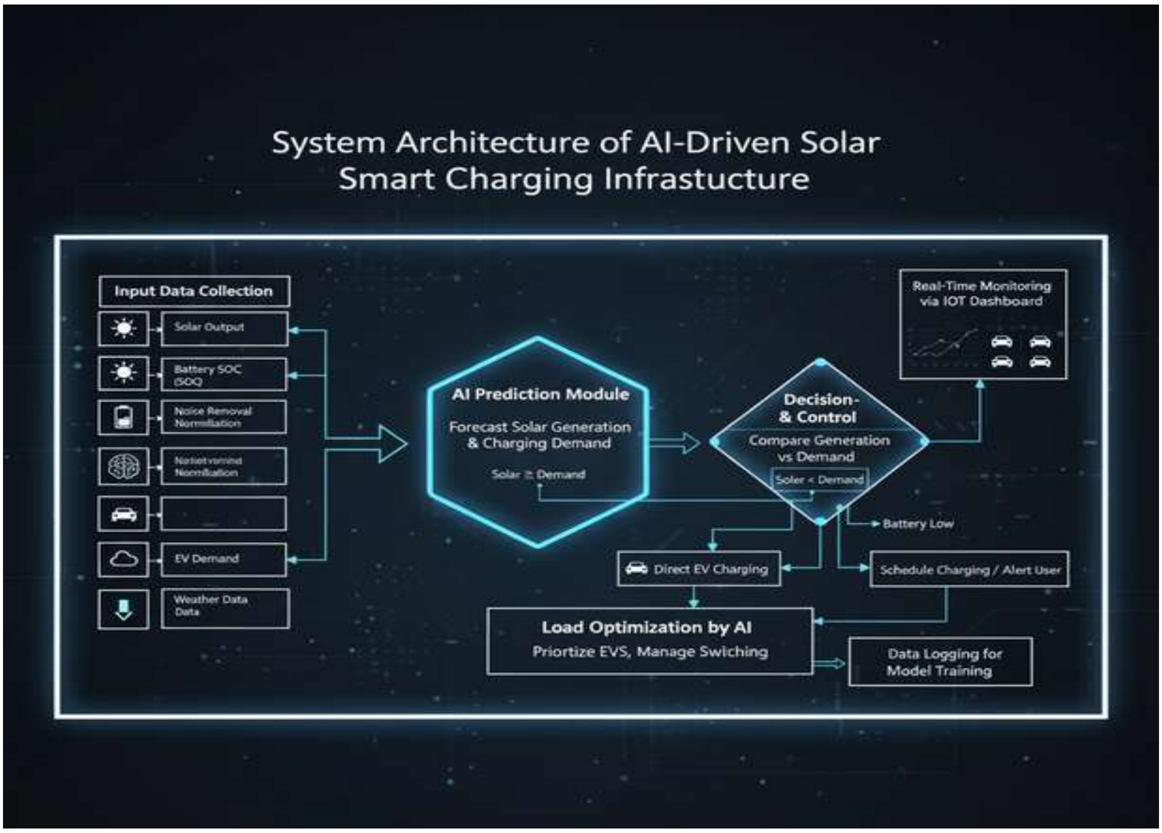

Figure 1: System Architecture of AI-Driven Solar Smart Charging Infrastructure [Insert Diagram Here]

IV. Hardware and Software Implementation

The hardware includes solar panels (100W each), lithium-ion battery packs, a microcontroller (Arduino/ESP32), sensors (DHT11, current, and voltage), and Wi-Fi communication modules. The software incorporates Python-based AI algorithms for load forecasting, MATLAB simulations for power analysis, and IoT dashboards via Blynk for real-time visualization. Machine learning models such as Linear Regression and LSTM are used to predict solar generation trends.

V. AI and IoT Integration

The AI engine analyzes sensor data to forecast solar output and adjust charging parameters automatically. IoT technology ensures data transmission between sensors and cloud servers. A user-friendly mobile application or dashboard enables users to monitor charging status, energy production, and storage levels remotely. The combined AI-IoT framework reduces human intervention and increases energy efficiency.

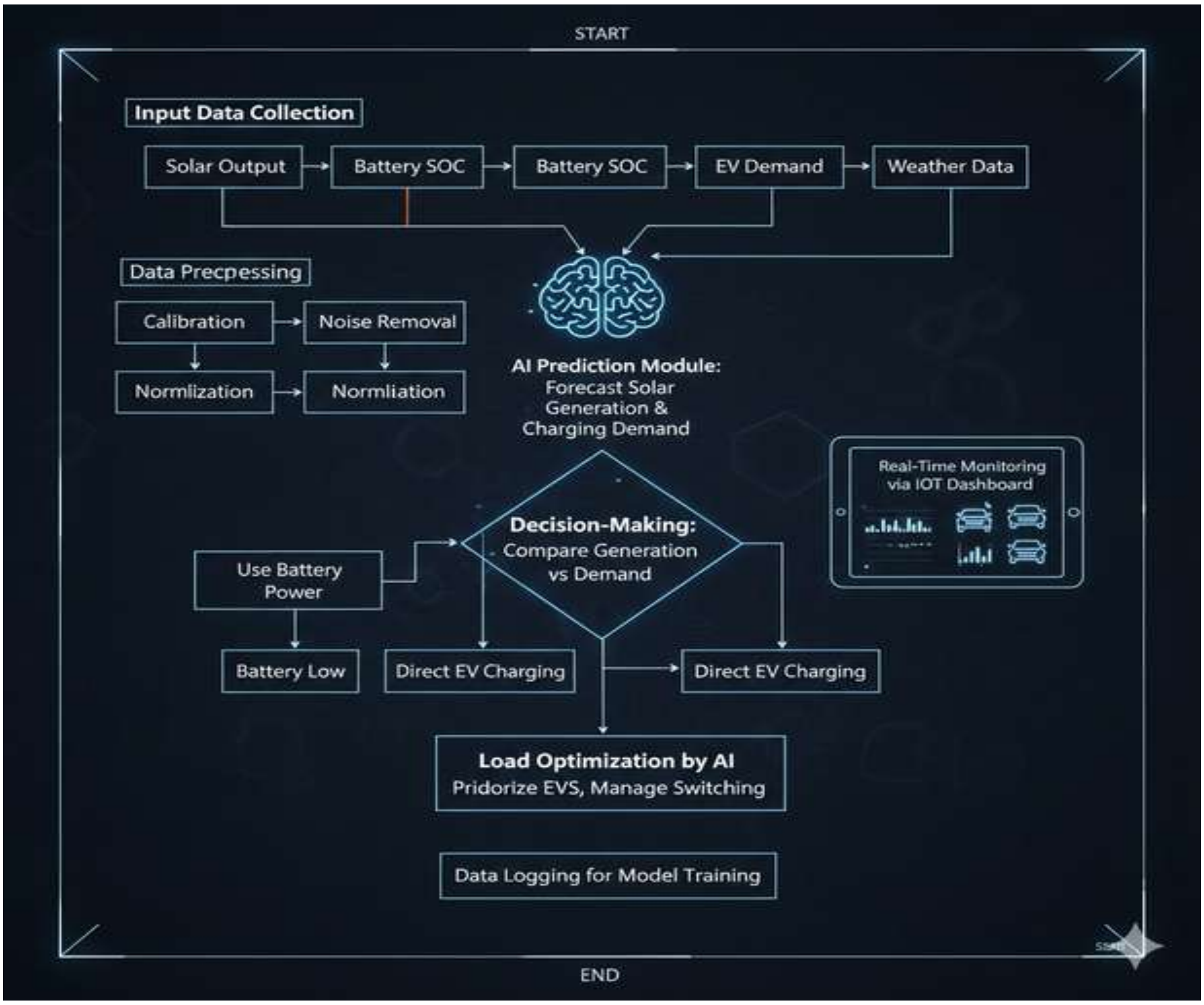

Figure 2: Flowchart of AI-Based Energy Management System [Insert Flowchart Here]

VI. Applications

1. Public and private EV charging stations.2. Smart city transportation networks.3. Fleet management for logistics and corporate vehicles.4. Rural areas with limited grid access.5. Highway charging hubs powered by renewable energy.

VII. Advantages and Limitations

Advantages:- Promotes renewable energy use.- Reduces dependency on conventional grid power.- Enhances efficiency using predictive AI control.- Real-time data monitoring via IoT.Limitations:- High initial cost of setup.- Performance dependent on weather conditions.- Requires continuous connectivity for IoT operations.

VIII. Conclusion

The AI-driven solar smart charging system offers a scalable and eco-friendly solution to meet the rising EV demand. By fusing solar power, AI prediction, and IoT-based monitoring, the system enhances energy efficiency and sustainability. The research emphasizes the potential for large-scale implementation to transform the EV charging landscape globally.

IX. Future Scope

Future developments include integrating Vehicle-to-Grid (V2G) systems, blockchain-based energy transactions, and advanced AI models for real-time adaptive control. Enhancing the infrastructure with predictive maintenance and cloud analytics can further improve reliability and scalability.

Acknowledgment

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