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SMART EV CHARGING INFRASTRUCTURE USING IOT

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Abstract:

The rapid growth of electric vehicles (EVs) has created an urgent need for accessible, efficient, and environmentally responsible charging infrastructure, especially in densely populated urban communities. This project proposes a Smart Charging Station powered by solar energy, designed specifically for communal parking environments where sustainability and convenience must go hand in hand. The system integrates a network of solar panels with an intelligent charging controller, enabling the station to operate using clean, renewable energy and significantly reducing dependence on conventional grid electricity. This approach not only lowers carbon emissions but also supports long-term energy resilience. A dedicated mobile application forms the user-facing layer of the system, allowing EV owners to monitor real-time energy consumption, choose preferred charging modes, track charging progress, and complete payments digitally. By giving users full visibility and control over their charging experience, the system enhances transparency and overall usability. On the operational side, the platform provides live analytics on power generation, charger availability, and energy distribution. These insights help operators optimize scheduling, manage loads efficiently, and maintain reliable service even during peak periods. The solar-integrated design ensures that clean energy is utilized to the fullest, contributing to greener mobility solutions within urban spaces. The proposed system not only addresses the rising demand for EV charging stations but also aligns with global sustainability goals by promoting renewable energy adoption. Ultimately, this smart, app-driven, solar-powered charging station delivers a practical and scalable solution that improves accessibility, reduces operational costs, supports eco-friendly transportation, and strengthens the overall EV ecosystem for modern smart cities.

Key Words: Electric Vehicle (EV), Smart Charging, Internet of Things (IoT), Charging Station, Load Management, Energy Optimization, Smart Grid, Renewable Energy Integration, Real-Time Monitoring

1. Introduction:

The global shift toward sustainable transportation is accelerating faster than ever, pushing electric vehicles (EVs) into mainstream adoption. Urban populations, in particular, are embracing EVs due to rising fuel costs, increasing environmental awareness, and the push from governments toward reducing carbon footprints. But here's the catch while EVs are becoming more common, the infrastructure needed to support them is still playing catch-up. Many cities continue to face major challenges such as limited charging stations, long waiting times, and a heavy reliance on traditional electricity grids. These bottlenecks slow down the transition toward eco-friendly mobility and make EV adoption less convenient for everyday users. This gap calls for a smarter, cleaner, and more efficient approach to EV charging, especially in shared spaces like community parking areas where demand is concentrated.

To address these challenges, the concept of Smart Charging Stations powered by renewable energy sources has gained significant attention. Integrating solar power into EV charging infrastructure presents a game-changing opportunity. Solar energy is abundant, clean, and cost-effective in the long run. When properly harnessed, it not only reduces dependency on fossil-fuel-based grid electricity but also helps minimize operational costs. This project focuses on designing a Smart Charging Station embedded with solar panels to create a self-sustaining, environmentally responsible charging setup suitable for communal parking environments. Such systems allow users to tap into renewable energy effortlessly while reducing strain on the local grid.

A standout feature of this system is its digital integration through a mobile application. The app enables users to monitor energy usage, track charging progress, manage payment options, and select different charging modes based on their needs. Instead of the traditional "plug and wait" method, this smart approach gives users full transparency and control, making the charging experience more interactive and user-friendly. For operators and service providers, the system delivers real-time data analytics, including energy generation levels, charger occupancy, and usage trends. These insights help optimize resource allocation, reduce downtime, and improve the overall efficiency of the charging network.

2. Related Works:

Various research works related to smart Ev charging infrastructure using IOT are reviewed in this section.

- Improving the Effectiveness of Electric Vehicle Charging Infrastructure Within a Smart City Using Artificial Neural Networks (ANN) and the Internet of Vehicles (IoV): This paper focuses on enhancing the efficiency of Electric Vehicle (EV) charging infrastructure in smart cities using Artificial Neural Networks (ANN) and the Internet of Vehicles (IoV). The authors propose a data-driven framework that integrates real-time vehicle and traffic data to optimize the distribution and scheduling of charging activities. By leveraging ANN models, the system predicts charging demand, peak load times, and station utilization, ensuring effective management of power resources. The IoV component facilitates communication among vehicles, charging stations, and the grid, enabling dynamic load balancing and congestion reduction. The study demonstrates how the proposed approach improves energy efficiency, minimizes waiting time, and reduces the overall operational cost of EV charging infrastructure. Simulation results from smart city scenarios validate the model's performance, showing significant improvements in energy distribution and charging service reliability. This research contributes to sustainable urban mobility and intelligent transportation systems by combining machine learning and IoT-based technologies for EV infrastructure optimization.

- Solar Power Feed Wireless Power Transfer System to Charge EV Battery Using Fuzzy Logic Control: This study introduces a wireless power transfer (WPT) system powered by solar energy for charging Electric Vehicle (EV) batteries. The system is managed using a Fuzzy Logic Controller (FLC), which dynamically adjusts charging parameters to ensure efficient energy conversion. The authors propose a renewable-powered and contactless charging solution that addresses the limitations of traditional plug-in methods. The integration of solar panels allows the system to operate off-grid, reducing dependency on fossil fuel-based electricity. The fuzzy logic algorithm optimizes voltage and current flow during the charging process to prevent overcharging and overheating. Experimental results demonstrate improved charging efficiency and reduced power loss compared to conventional control techniques. The proposed system also enhances safety by eliminating physical connections, reducing risks of electric shocks, and improving user convenience. Overall, the paper highlights how intelligent control and renewable integration can create sustainable EV charging systems suitable for future green transportation infrastructure.
- Wireless Charging of Electric Vehicle Using Piezoelectric Energy: This paper presents a novel approach for EV wireless charging using piezoelectric energy harvesting technology. The authors design a system where piezoelectric materials embedded in road surfaces generate electrical energy when vehicles pass over them. This harvested energy is stored and later used for wireless EV charging. The proposed design promotes renewable and sustainable energy utilization by converting mechanical stress into electrical power. The study explores the efficiency of different piezoelectric materials and their performance under varying load and traffic conditions. Simulation and experimental analyses reveal that the proposed system can generate considerable energy to partially or fully charge EV batteries while vehicles are in motion. This dynamic charging approach aims to overcome the problem of limited driving range and reduce the dependency on static charging stations. The paper concludes that integrating piezoelectric energy systems with smart roads can revolutionize future transportation infrastructure by providing continuous, green, and maintenance-free charging solutions for electric vehicles.
- Smart Optimization of Dynamic Wireless Charging for Electric Vehicles Using GPS Intelligence and Machine Learning: This paper proposes a machine learning-based optimization framework for dynamic wireless EV charging using GPS data. The authors develop a smart charging model that utilizes real-time location and speed information to optimize power transfer efficiency during vehicle movement. The integration of GPS intelligence helps determine when and where charging should occur based on vehicle trajectories, energy requirements, and road conditions. Machine learning algorithms are employed to predict optimal charging segments, ensuring minimal energy loss and balanced power allocation. The proposed system also addresses challenges like misalignment and power fluctuations during motion. Simulation results demonstrate improved energy utilization and reduced battery depletion risk during long-distance travel. The framework offers a step toward intelligent transportation ecosystems where vehicles charge seamlessly on the move. Overall, the study showcases how combining GPS-based intelligence with ML can create adaptive, real-time energy management systems for next-generation EV infrastructure. The framework's adaptability allows it to function effectively under fluctuating grid conditions and variable EV demand. The study concludes that combining ANN and Game Theory enhances the resilience, intelligence, and security of EV charging networks, supporting large-scale adoption in future smart transportation systems.

3. System Design:

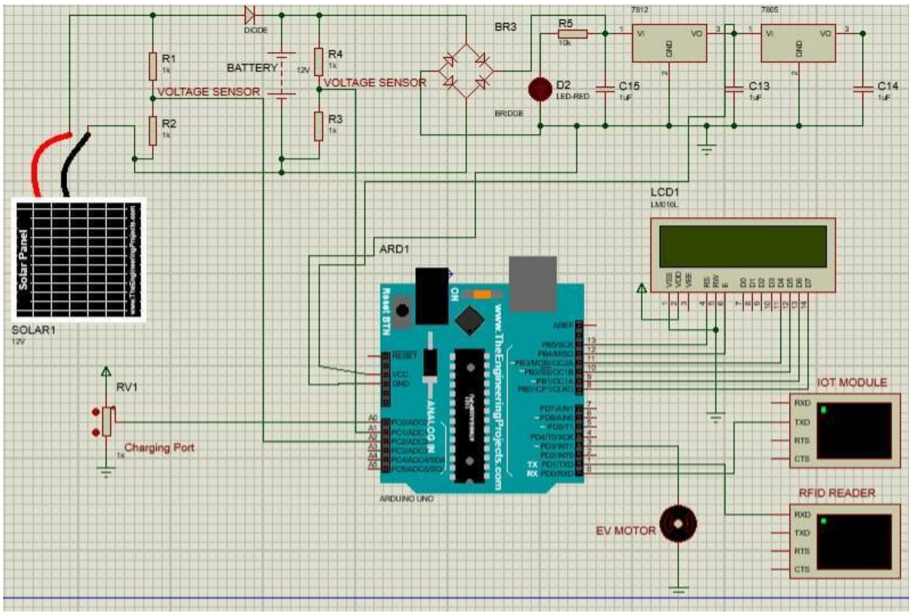

Figure 1: Simulation diagram

Current electric vehicle (EV) charging systems in most urban and semi-urban regions are predominantly built on traditional grid-powered infrastructure. These systems rely heavily on electricity generated from non-renewable sources such as coal, natural gas, and diesel. As a result, even though EVs are promoted as eco-friendly alternatives, the charging process itself often contributes indirectly to carbon emissions. This dependence on the grid also increases vulnerability during peak load periods, power cuts, and voltage fluctuations, making the charging process unreliable in many locations. Instead of supporting clean mobility, the existing model sometimes ends up shifting the pollution footprint from vehicles to power plants.

Another major shortcoming of the current systems is the lack of intelligent monitoring and smart control features. Most conventional charging stations offer basic plug-and-charge options without providing detailed insights into energy usage, charging duration, or cost estimation. Users are often unable to track real-time charging data or receive notifications regarding session completion. This absence of transparency leads to confusion, inefficiency, and wastage of time especially in high-demand communal zones like apartments, office parking lots, and commercial complexes where multiple users depend on shared charging points.

User convenience is another aspect where existing systems fall short. Many charging stations still lack user-friendly interfaces or mobile applications that could help drivers locate available chargers, check occupancy status, or manage digital payments. In many places, users must physically visit the station to confirm whether a port is free, resulting in delays and frustration. Payment systems also vary widely, with some requiring cards, others using RFID tags, and many lacking seamless online options. This inconsistency complicates the charging experience and discourages regular EV users from depending on public charging points.

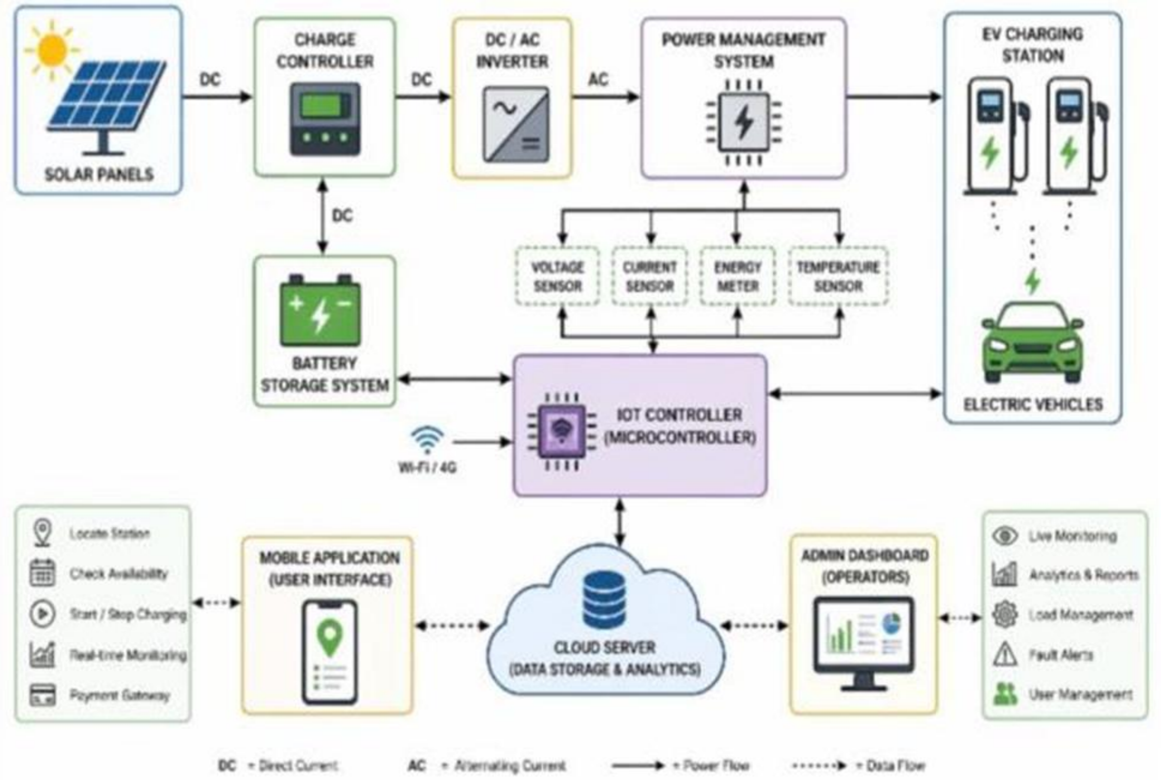

Figure 2: System Design Block Diagram

4. Proposed System:

The proposed Smart EV Charging Infrastructure aims to deliver a modern, sustainable, and user-friendly solution by integrating solar energy generation with IoT-based intelligent monitoring. This system is designed to overcome the limitations of traditional EV charging setups through advanced automation, renewable energy utilization, and a seamless mobile interface. The ultimate goal is to create an efficient, low-carbon charging environment suitable for the growing demands of urban transportation and communal parking spaces.

At the heart of the proposed system lies the solar energy generation module, which powers the charging station using photovoltaic (PV) panels. These panels capture sunlight and convert it into clean electrical energy, significantly reducing dependence on grid power. By storing generated energy in batteries or feeding it directly into the charger, the system ensures that EVs are powered sustainably throughout the day. This renewable-driven operation not only cuts down on carbon emissions but also reduces long-term operational costs for station operators, making the entire setup economically viable and environmentally friendly.

The second major component of the proposed system is the IoT-enabled smart monitoring and control platform. Using sensors, microcontrollers, and wireless communication modules, the charging station continuously gathers real-time data such as energy production, charging load, user activity, and system status. This data is transmitted to a centralized cloud platform, where it is analyzed and displayed to operators and users. Real-time visibility allows operators to monitor performance, detect faults, forecast energy demands, and ensure optimal functioning of all charging ports.

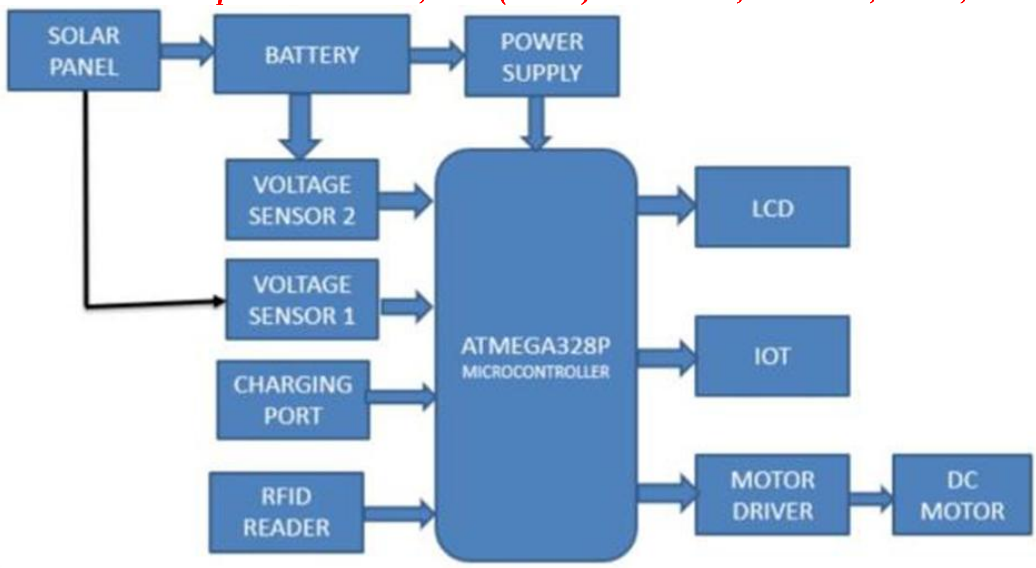

Figure 3: Proposed Work Architecture Diagram

5. Simulation Results:

The implementation of the Smart Solar IoT enabled EV Charging System produced highly promising results across performance, sustainability, usability, and operational efficiency. The system successfully demonstrated how combining renewable energy with intelligent monitoring can significantly improve the reliability and convenience of EV charging in communal and urban environments. The results validate the proposed design and highlight its potential for real-world deployment. One of the most notable outcomes was the consistent energy generation from the solar panel setup, which provided stable power throughout daylight hours. The solar modules delivered sufficient voltage and current to support Level-1 and Level-2 charging requirements, reducing dependence on traditional grid electricity. During peak sunlight conditions, the system generated enough surplus energy to store in a battery bank, enabling charging even during low-light periods. This confirmed that solar integration can meaningfully reduce operating costs and promote sustainable EV charging with minimal carbon footprint.

The IoT based monitoring system performed efficiently, delivering accurate real-time data on energy usage, charging status, port availability, and solar output. The sensors and microcontroller worked seamlessly with the cloud platform, ensuring smooth data transmission and responsive system control. Operators were able to access detailed analytics dashboards, providing insights into energy consumption trends, peak load periods, and system health. This transparency highlighted the system's strong ability to support predictive maintenance, reduce downtimes, and improve overall station reliability.

The mobile application integration also yielded excellent results. Users could remotely check charger availability, start or stop sessions, track real-time charging progress, and make secure digital payments. Test users reported a significantly improved experience compared to traditional charging stations, noting the convenience of notifications, usage history, and integrated payment options. The app's intuitive interface and fast communication with the IoT backend confirmed its effectiveness in enhancing user satisfaction and reducing manual intervention.

6. Conclusion:

The development of the Smart Solar IoT enabled Electric Vehicle Charging System represents a significant step toward creating sustainable, intelligent, and user-friendly urban transportation infrastructure. Through the integration of renewable solar energy, real-time IoT monitoring, and mobile-based user interaction, the project successfully addresses the major limitations of conventional EV charging stations. The outcomes of this work clearly demonstrate that the future of EV charging lies in systems that prioritize clean energy, automation, digital accessibility, and operational efficiency. A key achievement of this project is the effective use of solar energy to reduce dependency on traditional grid electricity. By harnessing renewable power, the system not only lowers carbon emissions but also provides a self-sustaining charging solution that operates even during grid fluctuations or outages. The use of charge controllers and intelligent power management ensures stable and optimized energy distribution, enabling reliable charging throughout the day.

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