



International Journal of Innovative Research in Science Engineering and Technology (IJIRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 8.699

Volume 14, Issue 5, May 2025

IoT-Based Smart Charging Stations for Electric Vehicles with Solar Panel Integration

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ABSTRACT: The Electric Vehicle (EV) Charging Station is a critical infrastructure component supporting electric mobility by offering a safe, efficient, and user-friendly interface for charging two-wheelers and four-wheelers. It monitors key parameters such as voltage, current, power, and charging duration, with built-in protection against overvoltage, overcurrent, and thermal overload. Integration with solar panels enables the use of renewable energy, reducing grid dependence and enhancing sustainability. Communication protocols like CAN allow data logging, remote monitoring, and fault diagnostics. Its compact, modular design is both cost-effective and scalable for urban and rural deployment. Simulation and prototype testing validate the system's robustness and reliability, making it a forward-looking solution for green transportation.

KEYWORDS: Voltage Monitoring, Current Monitoring, Power Monitoring, Charge Time Tracking, IoT Integration, Mobile Connectivity, Overvoltage Protection, Overcurrent Protection, Thermal Protection, Short-Circuit Protection, CAN Protocol, AC Fast Charging, DC Fast Charging.

I. INTRODUCTION

The increasing adoption of electric vehicles (EVs), driven by environmental concerns and rising fuel costs, has underscored the importance of reliable and accessible EV charging infrastructure. Modern charging stations deliver regulated power while monitoring key parameters such as voltage, current, and charging time. Integrated IoT technologies and communication protocols enable real-time data logging, remote diagnostics, and user interaction. Built-in protections against overcurrent, overvoltage, overheating, and short circuits ensure safe operation. These stations support both AC and DC fast charging, offering flexibility for various EV models. A user-friendly interface, accessible via mobile apps or RFID, enhances convenience. Solar panel integration reduces grid dependency by utilizing renewable energy, improving sustainability and energy efficiency. Advanced features like load balancing and smart scheduling optimize performance. Designed to be compact, reliable, and cost-effective, these stations are well-suited for widespread deployment in both urban and rural areas.

II. LITERATURE SURVEY

The global shift to electric vehicles (EVs) is driving the need for reliable and accessible charging infrastructure. Modern EV chargers focus on regulated power delivery, real-time voltage and current monitoring, and charge time estimation for safety and efficiency. IoT integration enables remote monitoring, diagnostics, and control, with protocols like MQTT, CAN, and OCPP ensuring seamless communication. Safety features such as overvoltage, overcurrent, thermal, and short-circuit protection are essential. Support for AC and DC fast charging, along with user-friendly interfaces like mobile apps and RFID, enhances user experience. Integration with solar panels enables the use of renewable energy, reducing grid dependency and promoting sustainable operation. Energy management through load balancing and smart scheduling improves grid efficiency. Future trends point to intelligent, scalable, and cost-effective EV charging solutions powered by IoT and smart technologies.

III. METHODOLOGY

The proposed system is a comprehensive solution designed to support both AC and DC charging while incorporating advanced features for safety, connectivity, and efficiency. The development began with a thorough requirement analysis, identifying essential components such as safety protections, IoT integration, and mobile access. A modular system design approach was adopted, dividing the setup into distinct blocks for power delivery, control, communication, protection, and user interface. In the hardware setup phase, key components such as a microcontroller, voltage, current, and temperature sensors, as well as an ESP8266 communication module and protection devices, were selected. The software was developed using Embedded C/C++, enabling real-time monitoring and control of system parameters. MQTT protocol was integrated for secure data communication and remote control, forming the backbone of the IoT connectivity. Mobile integration allowed for data logging and system diagnostics, enhancing user interaction and maintenance capabilities. Rigorous testing was conducted under various load conditions and simulated faults to ensure system safety and reliability. Finally, optimization techniques like load balancing and smart scheduling were implemented to maximize energy efficiency and performance.

EXPERIMENTAL RESULTS



IV. CONCLUSION

The smart EV charging station was successfully designed and tested, meeting key objectives such as safe power delivery, real-time monitoring, and user-friendly operation. Integration of IoT and communication protocols enabled remote access, data logging, and efficient energy management. Solar panel integration allowed for renewable energy usage, reducing grid dependency and enhancing sustainability. Protection features ensured system safety under fault conditions, while mobile/RFID access improved user convenience. Overall, the system proved to be reliable, scalable, and suitable for modern, eco-friendly EV infrastructure.

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