

DEVELOPMENT OF A MODEL OF A WEB-BASED SYSTEM FOR CONTROLLING ELECTRIC VEHICLE CHARGING POINTS

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Abstract

The preference for and increasing use of electric vehicles (EVs) has led to a rising demand for efficient, reliable, and scalable charging infrastructure. In the scope of this study we presents the design and development process of a web-based control system for managing EV charging stations. The proposed system integrates a PostgreSQL database, a FastAPI-based backend, and a React.js web interface to enable effective control and data analysis of charging points, which are often decentralized and lack centralized monitoring. The model supports charging session management, reservation handling and also real-time visualization. The system architecture, database schema, and key functional modules are discussed in detail. The results demonstrate the feasibility of implementing open-source, scalable, and interoperable EV charging management systems that can enhance both operational efficiency and user experience.

Keywords: EVs, Web Based Control Systems, MVC, PostgreSQL, API, Docker, DockMan.

INTRODUCTION

The widespread use of electric vehicles (EVs) has increased significantly over the past two years. Despite this progress, one of the main challenges remains the availability and effective management of electric vehicle charging infrastructure.

The primary problem addressed in this study concerns the need for efficient management and control of EV charging points. Existing systems often operate with limited interoperability, fragmented data structures, and minimal automation [1,6]. As the number of electric vehicles continues to grow, there is a growing need to develop web-based control and management systems that support the operation of charging infrastructure.

The main goal of this work is to design a model and develop a web application that addresses these challenges through the integration of modern web technologies and

reliable database systems such as PostgreSQL, which will be used as the core database system. The key challenges include the lack of centralized control, limited real-time visibility, inadequate data processing, and energy inefficiency [1,5]. This emphasizes the need for a web-based platform capable of managing distributed charging points, collecting operational data, and providing tools for real-time decision-making.

EXPOSITION

The rapid adoption of electric vehicles (EVs) represents a key component of global efforts to decarbonize the transportation sector. However, as the number of EVs increases, so does the demand for reliable, scalable, and intelligent charging infrastructure. Without effective management and control systems, charging stations may become congested, inefficient, or unreliable.

This project proposes the design and implementation of a web-based system for monitoring and controlling EV charging points. The system aims to enable centralized management of charging stations, facilitate real-time monitoring, and optimize the utilization of available energy resources.

The global transition toward sustainable transportation has accelerated the proliferation of electric vehicles, driven by policies intended to reduce greenhouse gas emissions and dependence on fossil fuels. Despite this progress, one of the main challenges remains the availability and efficient management of EV charging infrastructure.

Existing charging systems often suffer from limited interoperability, fragmented data architectures, and minimal automation. Consequently, both users and operators face issues such as charging delays, network inefficiencies, and suboptimal resource utilization.

The development of a web-based control and management system for EV charging points offers an opportunity to overcome these challenges. By integrating modern web technologies with robust database management systems, such a platform can provide centralized control, real-time monitoring, and intelligent decision-making capabilities.

This research focuses on developing a model of a web-based system for the control and management of EV charging points using open-source technologies. The proposed solution is based on the DocMAN [1] management model and is built upon a relational PostgreSQL database to ensure data integrity, scalability, and extensibility. DocMAN is designed following and according to a microservice architecture and adopts a Docker-based containerized structure [2,3], ensuring modularity, enhances modularity and ease of deployment.

The development of a web-based control and management system for EV charging points provides a practical approach to addressing these challenges. By integrating

modern web technologies with robust database management systems, the platform provides centralized control, real-time monitoring, and intelligent decision-making capabilities.

The proposed system includes a scalable and normalized relational database schema built using PostgreSQL and PostGIS to support spatial data operations. The backend is implemented using FastAPI, which manages system logic, communication, and API endpoints. A React.js-based web interface serves as the front end, offering intuitive user interaction, dynamic data visualization, and administrative control functionalities.

In addition, the system integrates real-time session monitoring and load management mechanisms to optimize performance and ensure reliability. Its performance is evaluated in terms of scalability, responsiveness, and data integrity, ensuring that the platform operates efficiently under real-world conditions.

The architecture promotes modularity, flexibility, and extensibility, allowing for future integration with external systems such as renewable energy sources, billing modules, or advanced analytics engines.

Overall, the system establishes a foundation for intelligent, data-driven management of EV charging networks that supports both operational efficiency and the long-term goals of sustainable transportation.

Electric vehicle charging systems consist of two primary components: hardware, include EV supply equipment and software where localized management platforms. According to the International Energy Agency (2023), efficient charging infrastructure is essential to meet the projected global EV demand [1,4]. Scalable and interoperable systems are vital to ensure accessibility, reduce congestion, and balance grid load, especially as adoption accelerates worldwide.

Web-based architectures systems continue to gain popularity due to their

platform independence, scalability, and modularity. Technologies such as FastAPI and React.js enable rapid development, lightweight communication, and flexible integration between frontend and backend layers. These features make them ideal for distributed control applications like EV charging management, where responsiveness and real-time data exchange are critical.

Modern EV infrastructures also generate substantial volumes of telemetry and transactional data. Efficient data management is therefore crucial. PostgreSQL, with support for JSONB, spatial data (PostGIS), and advanced indexing, provides an effective solution for handling structured and semi-structured information. Its open-source nature and strong community support make it particularly suitable for Internet of Things (IoT) and energy management applications that require reliability, scalability, and high data integrity.

Recent research explores areas such as the Open Charge Point Protocol (OCPP), smart charging algorithms and renewable energy integration. While these studies demonstrate significant technological advancements, many of the proposed solutions remain proprietary or vendor-specific, limiting adaptability and interoperability.

In contrast, this project emphasizes an open-source implementation, designed for transparency, flexibility, and broad compatibility. By leveraging open technologies, it contributes to the development of accessible, adaptable, and sustainable EV charging management systems.

The project model follows a structured software development methodology that includes four main stages: requirements analysis, system design, implementation, and testing. This approach ensures systematic progress, maintainability, and alignment with functional and non-functional objectives. The system fulfills

with the following key functions: registers, monitors, and controls EV charging stations and connectors. Provides user authentication and role and policy based access control for app admins, operators and user-drivers.

The system adopts a three-tier architecture of designed model: Web UI → FastAPI → PostgreSQL, consisting of presentation, application and data layers shown in Figure 1.

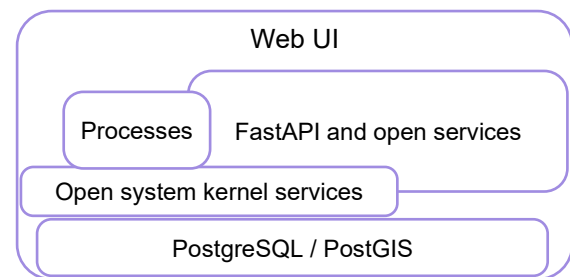


Fig. 1. System Architecture

Presentation Layer (Frontend) provides interactive dashboards for users and administrators. It supports visualization of charging activity, map-based station locations, and dynamic reporting. Application Layer (Backend) manages business logic, authentication, and RESTful API endpoints. It also supports WebSocket connections for real-time communication between clients and the server. Data Layer (Database) ensures reliable data storage, referential integrity, and high query performance.

In Figure 2 is shown database design with core entities and entity descriptions. Here we implement CRUD endpoints for managing stations, sessions, and users.

The proposed design:

- Integrates map-based visualization of charging stations using Leaflet.js or Google Maps API;
- Displays real-time charts for energy usage, connector status, and occupancy rates;
- Stores all operational data, including users, sessions, and telemetry;
- Supports geospatial queries for site and station management (via PostGIS).

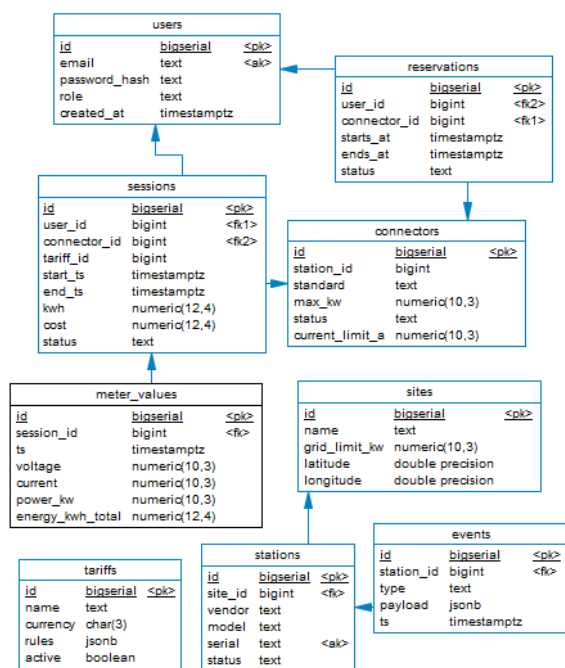


Fig. 2. Database Design for EVs Web Based Model

Testing and validation part are performed to ensure system reliability and performance. We parse the test part in three main blocks:

- Unit Testing verifies backend logic such as authentication, billing and load management;
- Integration Testing evaluates complete workflows, including session start and stop sequences;
- Performance Testing simulates concurrent charging sessions to assess system scalability.

RESULT AND DISCUSSION

The preliminary implementation results indicate that the proposed web-based system model performs successfully across key operational metrics. The platform displays real-time power and session data through WebSocket connections, manages user roles and charging sessions efficiently, and logs all operational and telemetry data in PostgreSQL with high reliability. The system demonstrates low-latency control, with an average API response time of less than 200 milliseconds, and maintains high

data consistency throughout all operations. These outcomes confirm that open-source technologies an effectively support complex electric vehicle (EV) infrastructure management tasks. Moreover, the system's modular design enables seamless integration with smart grid systems and demand-response control mechanisms, establishing a scalable and adaptable foundation for future energy-aware applications and intelligent transportation systems.

CONCLUSION

In the present work, a model of an innovative system has been implemented, offering a comprehensive solution for simplified management of electric vehicle charging stations, providing users with important information and functionalities. The system also ensures security and access control through specific user authentication based on the DocMAN AUTH Module [1,3]. For each station, detailed information is available, such as location, number of charging points, types of chargers, availability status, prices, as well as the option to make reservations. The extracted information is in real time, which is an essential feature for users. The system also offers a search and filtering function based on personal preferences and requirements. The developed system model emphasizes the importance of innovation in the field of electromobility. It facilitates the sustainability and efficiency of electric vehicle transport. The model makes significant contributions to efforts to promote the wider use of electric cars in everyday life. It improves the convenience and accessibility of charging stations. Supported by a mobile application with artificial intelligence, the model is easily accessible and user-friendly.

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REFERENCE

- [1] Lobato E, Prazeres L, Medeiros I, Araújo F, Rosário D, Cerqueira E, Tostes M, Bezerra U, Fonseca W, Antloga A. A Monitoring System for Electric Vehicle Charging Stations: A Prototype in the Amazon. *Energies*. 2023; 16(1):152.
<https://doi.org/10.3390/en16010152>
- [2] Özdikililer E., Role and Policy Based Authorization Microservice Module for Web Application Systems: DockMan©, *AIP Conference Proceedings*. 2nd International Conference on Electronics, Engineering Physics, and Earth Science, EEPES 2023, ISBN 978-619-239-635-0, Greece, 2024.
- [3] Özdikililer E., Design and Development of a Microservice Management Model for Distributed and Integrated Systems: DockMan©, ISBN 978-619-239-635-0, Avangard Prima, 2021.
- [4] N. Al-Dahabreh et al., "A Data-Driven Framework for Improving Public EV Charging Infrastructure: Modeling and Forecasting," in *IEEE Transactions on Intelligent Transportation Systems*, vol. 25, no. 6, pp. 5935-5948, June 2024, doi: 10.1109/TITS.2023.3337324.
- [5] TotalEnergies Charging Services, <https://chargingservices.totalenergies.com/en/find-a-charger> (Last read: 24.10.2025).
- [6] SAP Convergent Charging 4.1 Web Services, Chargeable Item Charging, https://help.sap.com/doc/saphelpiis_cc41_helpdata_en/4.1/en-US/e4/core_wsdoc/chargeableItemCharging/processcomponent.html (Last read: 22.10.2025).

