



Optimizing Electric Vehicle Charging Considering Driver Satisfaction Through ML Algorithm

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ABSTRACT

The rapid adoption of electric vehicles (EVs) has increased the demand for efficient and intelligent charging infrastructure. However, long waiting times, station congestion, and varying electricity prices often reduce driver satisfaction during charging sessions. To address these challenges, this study proposes a machine learning-based optimization system for electric vehicle charging that considers driver satisfaction as a primary factor. The system is implemented using a Django-based web framework integrated with advanced machine learning models to analyze charging conditions and predict driver satisfaction levels. The proposed system collects multiple parameters related to EV charging, including state of charge before charging, queue length, waiting time, electricity price, distance to charging station, station rating, charger power, historical satisfaction, price fairness, and charging speed stability, along with contextual factors such as weather conditions, crowd level, preferred charging time, charging station type, and trip urgency. These features are processed using data preprocessing techniques such as standardization, categorical encoding, and feature alignment before training machine learning models. Multiple algorithms, including Random Forest, Gradient Boosting, and XGBoost, are trained and evaluated to determine the most effective model for predicting driver satisfaction levels. The system compares models using performance metrics such as accuracy, precision, recall, and F1-score, and selects the best-performing model for deployment. Once trained, the system predicts the expected satisfaction level of a driver during a charging session and provides intelligent recommendations to improve the charging experience, such as selecting less crowded stations, choosing off-peak charging times, or using faster chargers. By integrating machine learning prediction with real-time user interaction through a web interface, the proposed system helps drivers make informed charging decisions and assists service providers in optimizing charging station operations. Overall, the proposed approach improves charging efficiency, reduces waiting time, and enhances driver satisfaction, contributing to a smarter and more sustainable EV charging ecosystem.

Keywords: Electric Vehicles (EVs), Electric Vehicle Charging Optimization, Machine Learning (ML), Smart Charging Systems, Driver Satisfaction Modeling, Charging Station Management, Energy Optimization, Intelligent Transportation Systems, Charging Demand Prediction, Load Balancing in Power Grids, Sustainable Mobility, Data-Driven Decision Making, EV Infrastructure Management, Reinforcement Learning for Charging, Smart Grid Integration.

INTRODUCTION

The rapid growth of electric vehicles (EVs) has become a key solution for reducing carbon emissions and promoting sustainable transportation. Governments and industries worldwide are encouraging the adoption of EVs to reduce dependence on fossil fuels

and minimize environmental pollution. However, the increasing number of EVs has also created significant challenges for charging infrastructure, such as charging station congestion, long waiting times, uneven distribution of stations, and fluctuating electricity prices. These factors



often affect the overall charging experience and driver satisfaction, which are critical for the continued adoption of electric vehicles.

Traditional EV charging systems mainly focus on technical aspects such as battery capacity, charging power, and station availability, but they often ignore the driver's experience and satisfaction during the charging process. Driver satisfaction depends on multiple factors including waiting time, queue length, electricity price, station reliability, distance to charging stations, and charging speed. Without intelligent optimization, drivers may face delays, higher charging costs, and inefficient charging decisions, which negatively impact the overall EV ecosystem.

Recent advancements in machine learning (ML) and data analytics provide an opportunity to improve EV charging management by analyzing large amounts of operational and user data. Machine learning models can identify patterns in charging behavior and predict outcomes such as driver satisfaction levels or optimal charging conditions. By integrating ML techniques into charging systems, it is possible to develop smart recommendation systems that help drivers choose the most suitable charging stations and charging times.

In this work, a machine learning-based EV charging optimization system is proposed that considers driver satisfaction as the primary objective. The system is implemented using a Django-based web application that allows users to interact with the system through a web interface. Various charging-related parameters such as state of charge, queue length, waiting time, electricity price, station rating, charger power, and environmental conditions are collected and processed. These parameters are used to train multiple machine learning models including Random Forest, Gradient

Boosting, and XGBoost to predict driver satisfaction levels and recommend optimal charging strategies.

The proposed system not only predicts satisfaction levels but also provides intelligent recommendations to improve the charging experience, such as selecting less crowded stations, choosing appropriate charging times, and using high-power chargers when necessary. By combining machine learning prediction, data analysis, and a web-based interface, the system aims to enhance the efficiency of EV charging infrastructure and improve overall driver satisfaction.

Ultimately, this research contributes to the development of smart EV charging management systems that support efficient resource utilization, reduce charging delays, and promote a more reliable and user-friendly electric vehicle ecosystem.

I. LITERATURE SURVEY

1. Title: Machine Learning-Based Smart Charging for Electric Vehicles

Author: Zhang, Y., Wang, J., and Li, H.

Abstract:

This research presents a machine learning-based approach for optimizing electric vehicle charging operations. The study analyzes different charging parameters such as electricity price, charging demand, and station availability to predict optimal charging schedules. The proposed system applies machine learning algorithms to analyze historical charging data and identify patterns that improve charging efficiency. The results demonstrate that intelligent charging systems can reduce charging congestion, balance energy demand, and improve overall charging performance.



2. Title: Intelligent Charging Management System for Electric Vehicles

Author: Chen, L., Xu, Q., and Zhao, M.

Abstract:

This study proposes an intelligent EV charging management system that integrates data analytics and predictive modeling to optimize charging operations. The system evaluates parameters including waiting time, queue length, and charging station capacity to guide EV drivers in selecting suitable charging stations. The research highlights the importance of intelligent decision support systems in improving charging infrastructure utilization and minimizing delays for electric vehicle users.

3. Title: Predictive Analytics for Electric Vehicle Charging Behavior

Author: Smith, A., Johnson, K., and Brown, T.

Abstract:

The research focuses on analyzing EV charging behavior using predictive analytics and machine learning techniques. The study collects historical charging data and applies classification algorithms to predict charging demand and driver preferences. The findings show that predictive models can significantly improve charging station management by forecasting user demand and recommending optimal charging times.

4. Title: Smart EV Charging Infrastructure Using Data-Driven Techniques

Author: Kumar, S., Gupta, R., and Sharma, P.

Abstract:

This paper introduces a data-driven EV charging infrastructure management system designed to improve charging efficiency and user experience. The system uses statistical analysis and machine learning algorithms to evaluate charging patterns, station utilization, and driver satisfaction levels. The study concludes that data-driven charging systems can improve infrastructure utilization while reducing waiting time and operational costs.

5. Title: Optimizing Electric Vehicle Charging Stations Using Artificial Intelligence

Author: Lee, D., Park, S., and Kim, J.

Abstract:

This research investigates the application of artificial intelligence techniques in optimizing EV charging station operations. The proposed model analyzes multiple factors including charging demand, energy pricing, and station availability. Machine learning algorithms are used to predict charging loads and recommend optimal charging strategies. The results indicate that AI-based charging systems can significantly improve the efficiency and reliability of EV charging networks.

II. EXISTING SYSTEM

The existing electric vehicle (EV) charging systems mainly focus on providing basic charging services through fixed charging stations without incorporating intelligent decision-making mechanisms. In most current systems, EV drivers select charging stations based on limited information such as location or availability. These systems generally do not analyze multiple factors like queue length, waiting time, electricity price, charging speed, station rating, or environmental conditions that influence the overall charging experience. As a result,



drivers often face congestion at charging stations, long waiting periods, and uncertainty regarding the efficiency of the charging process. Traditional charging management platforms also lack advanced data analytics and machine learning capabilities to predict driver satisfaction or recommend optimal charging options. Therefore, the existing systems provide limited support for improving charging efficiency and enhancing the user experience for EV drivers.

III. PROPOSED SYSTEM

The proposed system introduces an intelligent electric vehicle (EV) charging optimization framework that focuses on improving driver satisfaction using machine learning techniques. Unlike traditional charging systems, the proposed approach analyzes multiple factors that influence the charging experience, such as state of charge before charging, queue length, waiting time, electricity price, distance to charging station, charger power, station rating, and historical driver satisfaction. These parameters are collected and processed through a web-based platform developed using the Django framework, which allows users to interact with the system and input charging-related details.

The system utilizes advanced machine learning algorithms such as Random Forest, Gradient Boosting, and XGBoost to analyze charging data and predict the expected satisfaction level of EV drivers. The dataset is first preprocessed using techniques like data cleaning, feature scaling, and categorical encoding to improve the accuracy of the prediction models. Multiple models are trained and evaluated using performance metrics such as accuracy, precision, recall, and F1-score, and the best-performing model is selected for deployment.

Once the model is trained, the system predicts the driver satisfaction level during a charging session based on real-time input parameters. According to the predicted satisfaction level, the system provides intelligent recommendations to the driver, such as selecting charging stations with shorter queues, choosing off-peak charging times, or using higher power chargers to reduce waiting time. By combining machine learning prediction, data analytics, and an interactive web interface, the proposed system helps EV drivers make informed decisions and improves the overall efficiency of charging infrastructure.

IV. SYSTEM ARCHITECTURE

The diagram illustrates the architecture of a machine learning-based system designed to optimize electric vehicle (EV) charging while considering driver satisfaction. The system begins with two main actors: the Admin and the EV User. Both interact with the platform through a web interface developed using the Django framework. This web interface acts as the central communication layer where administrators manage system operations and EV users request charging services or view recommendations. It enables real-time interaction with the charging management system and provides a user-friendly environment for monitoring and controlling EV charging activities.

After user interaction, the system proceeds to the input data collection stage. In this stage, several important parameters related to EV charging are gathered. These include charging status, which indicates the current battery level or charging progress of a vehicle; queue length, representing the number of vehicles waiting at a charging station; electricity price, which reflects the dynamic cost of power at a given time; and environmental factors, such as weather conditions or temperature that may affect charging efficiency. Collecting these



parameters ensures that the system has sufficient contextual information to make intelligent decisions.

Once the data is collected, it moves to the data preprocessing stage. During this phase, the raw data is cleaned, organized, and transformed into a suitable format for machine learning models. Preprocessing may involve removing missing values, normalizing data, encoding categorical variables, and preparing datasets for training and testing. This step is crucial because properly prepared data improves the accuracy and reliability of machine learning predictions.

The processed data is then fed into multiple machine learning models, including Random Forest, Gradient Boosting, and XGBoost. These algorithms are ensemble learning techniques known for their high predictive performance and ability to handle complex datasets. Each model analyzes the collected parameters and learns patterns related to charging behavior, waiting times, electricity costs, and user preferences. By using multiple models, the system can achieve more reliable and robust predictions regarding charging performance and driver satisfaction.

Following model processing, the system performs prediction and analysis. In this phase, the models evaluate incoming data and generate insights about the current charging environment. One of the main outputs is the prediction of driver satisfaction levels, which estimates how satisfied users will be with factors such as waiting time, charging speed, and cost. Understanding driver satisfaction is important because it helps improve the overall user experience and encourages the adoption of electric vehicles.

Based on these predictions, the system generates recommendations and optimization strategies. For example, it may suggest the best charging station, recommend an optimal charging time when electricity prices are lower, or distribute

charging demand across multiple stations to reduce queue lengths. These recommendations ensure efficient utilization of charging infrastructure and help maintain a balance between energy demand and supply.

Finally, the optimized decisions are implemented in the EV charging stations, where the system manages optimized charging schedules and resource allocation. By intelligently scheduling charging sessions and efficiently distributing energy resources, the system reduces waiting time, lowers operational costs, and improves driver satisfaction. Overall, the framework integrates machine learning with smart charging infrastructure to create an efficient, user-centered EV charging management system.

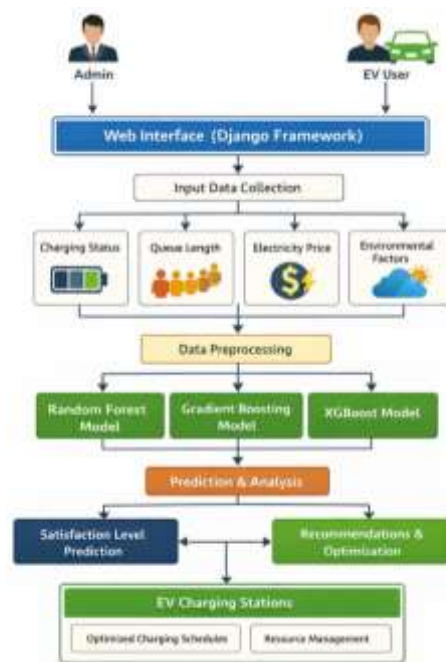


Fig 5.1: System Architecture Of Proposed System

V. IMPLEMENTATION



Fig 6.1: Admin Home



Fig 6.2: Load And Preprocess Dataset

VI. CONCLUSION

The proposed system, Optimizing Electric Vehicle Charging Considering Driver Satisfaction Through Machine Learning, provides an intelligent approach to improving the EV charging experience by integrating machine learning techniques with a web-based platform. The system analyzes multiple factors affecting EV charging such as queue length, waiting time, electricity price, charger power, station rating, and environmental conditions to predict the satisfaction level of drivers during charging sessions. By using advanced machine learning algorithms including Random Forest, Gradient Boosting, and XGBoost, the system is capable of learning patterns from historical charging data and generating accurate predictions.

The implementation of the system using the Django web framework enables seamless interaction between users and the prediction model through a user-friendly interface. The system not only predicts the satisfaction level of EV drivers but also provides recommendations that help users make better charging decisions. These

recommendations may include selecting charging stations with shorter queues, choosing optimal charging times, or using faster chargers to reduce waiting time.

Overall, the proposed system contributes to the development of a smart EV charging management solution that improves charging efficiency, reduces congestion at charging stations, and enhances driver satisfaction. By leveraging machine learning and data-driven decision making, the system supports better utilization of charging infrastructure and promotes the adoption of electric vehicles in a more efficient and user-friendly manner.

VII. FUTURE SCOPE

The proposed system for optimizing electric vehicle charging considering driver satisfaction through machine learning can be further enhanced by incorporating advanced technologies and additional features. In the future, the system can be integrated with real-time charging station data and Internet of Things (IoT) devices to monitor live information such as charger availability, real-time queue length, and energy consumption. This integration would enable the system to provide more accurate predictions and real-time recommendations to EV drivers.

Another possible improvement is the integration of advanced deep learning models and reinforcement learning techniques to further improve prediction accuracy and dynamic decision-making. These techniques can help the system learn complex charging patterns and automatically optimize charging schedules based on changing conditions such as traffic flow, energy demand, and driver preferences.

The system can also be extended by incorporating GPS-based navigation and mobile application support, allowing EV drivers to easily locate nearby charging



stations and receive optimized charging recommendations through their smartphones. Additionally, integrating the system with smart grid technology and renewable energy sources such as solar or wind power can help balance energy demand and promote sustainable energy usage.

Furthermore, future developments may include personalized charging recommendations based on driver behavior and historical charging patterns, as well as the implementation of dynamic pricing strategies to reduce congestion and encourage charging during off-peak hours. These improvements would enhance the scalability, efficiency, and intelligence of the EV charging system, contributing to a smarter and more sustainable electric vehicle ecosystem.

VIII. REFERENCES

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