Electric Vehicle Charging Demand Forecasting

Abstract

This project explores the analysis and forecasting of Electric Vehicle (EV) charging demand using historical session data. The rapid adoption of EVs necessitates accurate demand forecasting to ensure efficient infrastructure planning, energy management, and policy-making. This study uses data cleaning, exploratory data analysis (EDA), and time-series forecasting techniques (ARIMA model) to model network-level demand and identify patterns across time, stations, and weather conditions. The insights provide stakeholders with actionable knowledge to optimize charging station allocation and manage energy distribution more effectively.

1. Introduction

Electric Vehicles (EVs) have emerged as a sustainable alternative to conventional fossil-fuel vehicles, contributing significantly to reducing greenhouse gas emissions. With the growing adoption of EVs, charging infrastructure must be optimized to meet fluctuating demand patterns. Accurate demand forecasting not only aids in minimizing waiting times at stations but also helps energy providers balance grid loads efficiently. This project focuses on analyzing session-level EV charging data, performing preprocessing, and building predictive models to forecast future demand trends.

2. Dataset Description

The dataset used in this project contains EV charging session-level data, including variables such as charging start and end times, energy consumed, charging station ID, temperature, and derived attributes like weather condition and charging duration. After cleaning and preprocessing, the dataset was expanded into hourly intervals to compute both network-level and station-level energy demand. The final dataset contained 1,320 session records and 3,516 station-level records, with a total energy consumption of 56,288.62 kWh.

3. Exploratory Data Analysis

Exploratory Data Analysis (EDA) revealed important insights into charging behavior. Peak demand was observed during early morning hours, particularly at 04:00 AM with approximately 2,562 kWh consumed. Weekly patterns showed varying demand by day of the week, and temperature analysis suggested higher usage during moderate (cloudy) conditions. Network-level demand trends exhibited clear temporal variation, underscoring the importance of time-based forecasting methods.

4. Forecasting Model

For forecasting, the ARIMA model (Auto-Regressive Integrated Moving Average) was applied to network-level hourly demand data. The dataset was divided into training (80%) and testing (20%) sets. The chosen ARIMA(3,1,3) model achieved a Mean Absolute Error (MAE) of 17.16 and a Root Mean Squared Error (RMSE) of 21.03, indicating a reasonably accurate forecast. The forecast captured the overall trend and short-term fluctuations, making it useful for operational planning of charging infrastructure.

5. Results

The analysis produced several key performance indicators (KPIs). The total number of sessions was 1,320, with a total energy demand of 56.29 MWh. The peak demand occurred at 04:00 AM with 2,562 kWh, while cloudy weather conditions were found to be optimal for higher charging demand. These insights highlight the importance of considering both temporal and environmental factors when forecasting EV charging demand.

6. Conclusion

In conclusion, this study demonstrates the potential of time-series forecasting methods such as ARIMA for modeling EV charging demand. By analyzing session-level data and incorporating weather factors, valuable insights into user behavior and demand fluctuations were obtained. These findings can assist policymakers, urban planners, and energy providers in optimizing EV infrastructure and ensuring grid stability. Future work can explore advanced machine learning models, such as Prophet, LSTM, or hybrid methods, for improved long-term forecasting accuracy.