Potential analysis of a cost-reducing charging strategy at public charging stations for electric vehicles

Master‘s Thesis of Nicole Klopstock

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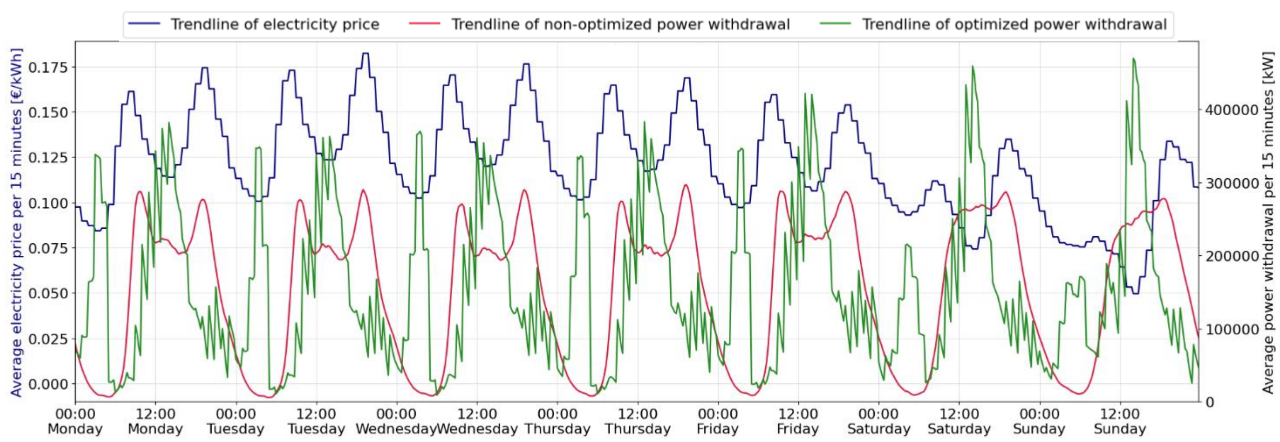
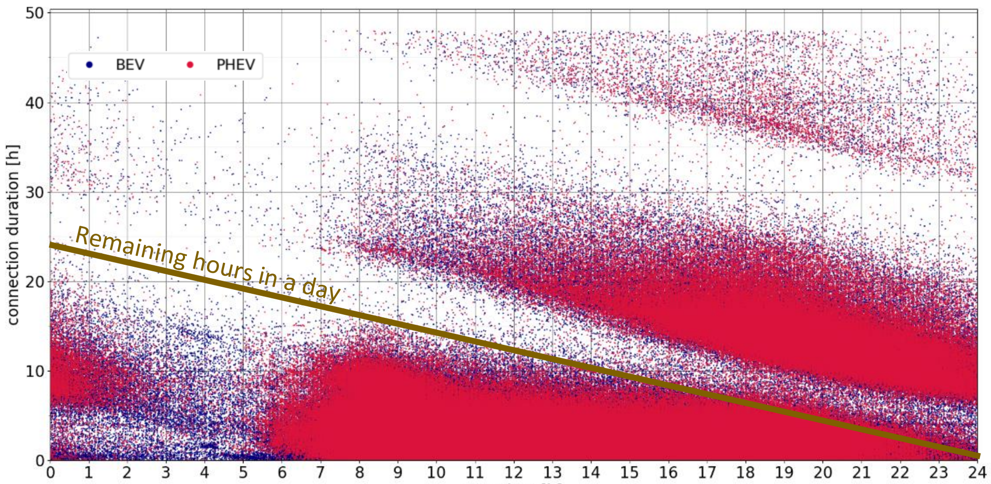
Motivation

The mitigation of climate change necessitates a transition to renewable energy sources. However, their inherent volatility creates a challenging energy market, requiring innovative strategies to balance supply and demand. Simultaneously, the mobility sector is undergoing a shift towards electrification, where the energy mix poses an important part of its decarbonization. To further promote the adoption of electric vehicles and help stabilize emerging grid fluctuations, grid-intelligent and cost-effective public EV charging pricing strategies are necessary. This thesis addresses this combination and investigates the cost optimization potential at public charging stations by analyzing historical charge detail records (CDR) from charging points of the Stadtwerke München (SWM) between 01.01.2020 and 31.12.2022.

Objectives

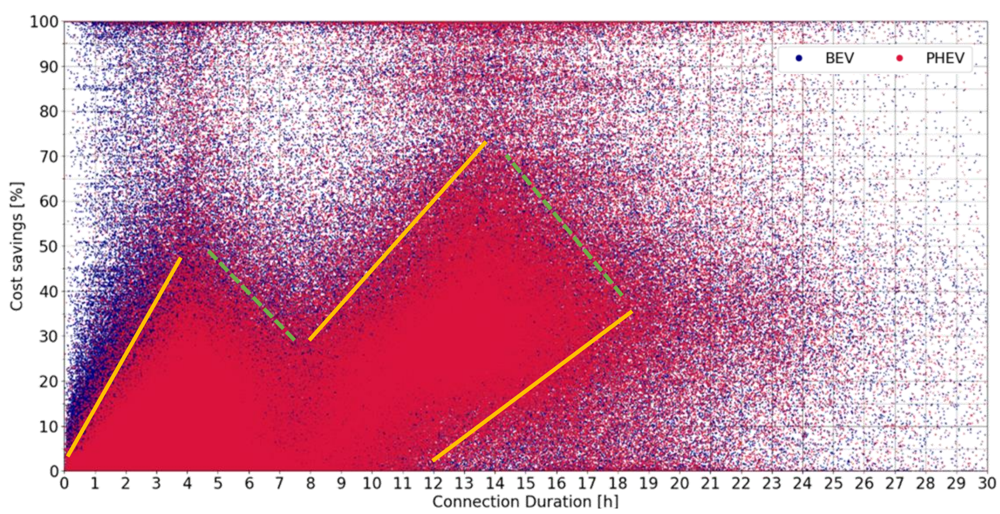
To estimate cost-saving potential, a comprehensive methodology was developed, encompassing data cleaning, classifying charging events into Battery and Plug-in-Hybrid EVs, and calculating status quo indicators, as well as unoptimized and optimized charging costs. Although a lack of detail in the CDR necessitated certain assumptions regarding EV models, their state of charge, and their charging curve, the research questions could be answered comprehensively. The principle of the optimization approach is based on shifting power withdrawal to time periods of minimal electricity prices within the vehicle's connection time. This is visualized by the diagram above, where the blue line represents the electricity price, the red line the non-optimized power withdrawal, and the green line the optimized power withdrawal over the average week of the study period.





Results

The analysis for the status quo of charging behavior in Munich revealed that, on average, 1,600 charging events occur daily while being connected for 5.12 hours but charging only for 1.45 hours. Thus, the charging-station utilization rate amounts to 29.12% and the rate for charging to 8.29%. The average energy transferred per session was 14.65 kWh at a cost of 0.165 €/kWh. The diagram to the left shows the connection duration of all events over their time of plug-in. The bottom cluster represents events within one day, and the top one overnight charging. The optimization analysis showed an average cost reduction of 15% across all events, though 30% of sessions were non-optimizable, and 35% achieved cost reductions of less than 10%. For all optimizable charging events, an average cost reduction of 18.87% could be achieved. Longer idle times significantly increased average optimization potentials, with events exceeding six hours, amounting to 33% on average. Along with idle times, the third diagram shows that the time of day also influences cost savings. The first corridor can be assigned to events during the day, using the midday price-valley for shifting power. Overnight connections form the second corridor, where prices are lower and connections longer, thus higher savings can be achieved. Both clusters, however, show that due to recurring price fluctuations, the optimization potential is not unlimited (green lines).



Conclusion

This thesis highlights the feasibility of using idle times and fluctuating electricity prices to reduce public EV charging costs without directly influencing user-behavior through incentives or penalties. Key benefits include greater appeal of EVs due to reduced charging costs, an increase of renewable energy share in charging of EVs, and potential grid stabilization due to power withdrawal shifts. However, challenges also emerge, like grid destabilizing demand spikes in periods of low prices, a fair cost allocation between operators and users, and a transparent implementation to prevent user concerns. Future research should, therefore, explore intelligent scheduling mechanisms to smooth demand peaks and align charging with renewable energy surpluses while minimizing prices, consequently advancing the sustainability and accessibility of electromobility.