SDU
Faculty of Engineering

PhD Defence

by

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Title:

Smart electric vehicle charging

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POPULAR SCIENTIFIC ABSTRACT

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Smart Electric Vehicle Charging

The transportation sector significantly contributes to greenhouse gas (GHG) emissions. Electrifying transportation removes the direct dependency on fossil fuels and eliminates tailpipe emissions. However, a few concerns arise with the electric vehicle (EV) adoption. Uncoordinated EV charging can drastically alter the immediate demand shape, posing challenges to the electricity grid. Besides, ensuring a fair share of the supply power and maximizing the delivered energy to satisfy the EV users is also challenging, especially in charging networks with limited supply. Moreover, the energy sources to charge EVs must be sustainable so that EVs can really help reduce GHG emissions and improve air quality. Correspondingly, the synergy between the EV load and sustainable energy sources becomes critical.

This doctoral thesis contributes to modeling and optimizing EV charging at different scales. Local-scale EV charging simulations address the concern about the local grid, where the optimization objective is to flatten the overall charging load, and the concern from EV users, where the objective is to ensure a fair share of the supply energy and maximize the delivered energy to the EVs. Large- and urban-scale EV charging simulations focus on the synergy between EV load and renewable energy sources (RESs). The investigations were carried out in five studies.

Study I evaluated different online control strategies to flatten the overall EV charging load at the local charging network, considering the existence of different types of charging stations, namely uncontrolled, centralized, and decentralized. *Study I* found that with a small percentage of EV charging stations being uncontrollable, smart EV charging can still achieve good performance. ***Study I*** also found that simply utilizing the mean value of historical data to predict the charging behavior of the future arriving EVs can significantly improve the scheduling performance. ***Study II*** provided an accurate constraint modeling for smart EV charging to maximize the delivered energy to the EVs. Meanwhile, the fair share of the energy is assured. ***Study II*** found that, in a limited supply charging network, the improvement in energy delivery amount is insignificant by considering state-of-charge-dependent maximum charging power.

Study III aimed to simplify the charging and discharging model of a large number of EVs, which will be very useful in energy system evaluations that consider many EVs. ***Study III*** showed that the computation time was reduced significantly by simply aggregating the charging power and energy content. However, this simple model overestimates the energy system performance. On the other hand, the overestimation tends to converge when considering more and more EVs, and the values are small. ***Study IV*** aimed to achieve optimal EV charging and discharging on an urban scale and investigated how to size the RES to achieve the best energy system performance. ***Study IV*** found that, compared to smart charging, allowing vehicle-to-gird can achieve optimal energy system performance in a RES-powered net-zero energy city. Otherwise, net-zero leads to over-sized RES generation.

Study V aimed to provide a two-stage approach for large-scale EV charging with on-site PV

generation, where the first stage approximates the overall charging load and the second prioritizes charging. ***Study V*** found that the approach is applicable for large-scale EV charging where the objective is to maximize the PV-EV matching. Further, ***Study V*** applied the aggregated model from ***Study III*** to approximate the overall charging load and different sorting-based methods to prioritize charging. ***Study V*** found that the aggregated model can accurately approximate the load, and different sorting-based methods perform slightly differently when prioritizing charging but with other distinct behaviors.

In conclusion, the thesis shows the modeling and optimization of EV charging at different scales and the potential of smart EV charging in addressing different concerns regarding transportation electrification.