Agent-Based Modelling of EV Charging for Optimized Charging Station Operation

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Abstract

Widespread adoption of electric vehicles (EVs) would significantly increase the overall electrical load demand in power distribution networks. Hence, there is a need for comprehensive planning of charging infrastructure in order to prevent power failures or scenarios where there is a considerable demand-supply mismatch. Accurately predicting the realistic charging demand of EVs is an essential part of the infrastructure planning. Charging demand of EVs is influenced by several factors such as driver behavior, location of charging stations, electricity pricing etc. In order to implement an optimal charging infrastructure, it is important to consider all the relevant factors which influence the charging demand of EVs. Several studies have modelled and simulated the charging demands of individual and groups of EVs. However, in many cases, the models do not consider factors related to the social characteristics of EV drivers. Other studies do not emphasize on economic elements. This thesis aims at evaluating the effects of the above factors on EV charging demand using a simulation model. An agent-based approach using the NetLogo software tool is employed in this thesis to closely mimic the human aggregate behavior and its influence on the load demand due to charging of EVs.

EV charging stations where the EV charging takes place will play an important role in the energy management of smart cities. Private and commercial EV charging loads would further stress the distribution system. Photovoltaic (PV) systems, which can reduce this stress, also show variation due to weather conditions. Hence, after the successful modelling of EV charging behavior using agent based approach, a hybrid optimization algorithm for energy storage management is proposed as an application. This algorithm shifts its mode of operation between the deterministic and rule-based approaches depending on the electricity price band allocation. The cost degradation model of the energy storage system (ESS) along with the levelized cost of PV power is used in the case of PV integrated charging stations with on-site ESS. The algorithm comprises of three parts: categorization of real-time electricity price in different price bands, real-time calculation of PV power from solar irradiation data and optimization for minimizing the operating cost of an EV charging station integrated with PV and ESS. An extensive simulation study is carried out with private and commercial EV charging load model obtained from the agent based modelling approaches, in the context of Singapore, to check the effectiveness of this algorithm. Furthermore, a detailed analysis of the subsidy and incentive to be given by the government agencies for a higher penetration of PV systems is also presented. This work would aid in planning of adoption of PV integrated EV charging stations with on-site ESS which would be expected to take place of traditional gas stations in future.