Interactions between Electrified Shared Mobility and the Power Grid

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Background Electrification of shared mobility is considered as an important ingredient for future urban environments and is now taking place in several major cities around the world. Once electric vehicles replace traditional vehicles in shared mobility, they are expected to induce a significant burden on the power grid. Nevertheless, this burden can potentially be reduced by carefully controlling how electric vehicles are charged and rented. Imagine the following scenario. Suppose a certain station is not able to provide the charging capacity needed by the vehicles it carries. One straightforward but potentially costly solution is to increase its capacity by revamping the power systems infrastructure. However, in the context of shared mobility, nearby stations may carry unused charged vehicles. Then another solution can be to offer monetary incentives to customers at nearby stations so that they may choose to bring charged vehicles to this station.

Potential impact The goal is to design a control policy for charging and renting electric vehicles. This policy needs to be computationally tractable and scalable to large networks. If successful, this can reduce burden on the power grid and make electrified shared mobility more practical.

Related work The control policy needs to control both the vehicle distribution (among stations) and the energy distribution (among stations and within stations), whereas most previous work has only focused on one of these aspects. Previous work from one of the authors was on charging of electric vehicles[2]. The central issue is how to charge a pool of vehicles in order to meet certain specifications (e.g., the individual deadlines of vehicles) with minimum operation cost (e.g., minimum electricity bill amount). However, it ignores the energy transfer that is caused by vehicle movement between stations. Another related area is operation of traditional shared mobility (including bikes and gasoline-powered cars). Since bikes do not need to be charged, and gasoline-powered cars can be refueled quickly almost at any time, research in this area does not consider energy availability as a constraint in systems design. In contrast, charging time of electric vehicles cannot be ignored, and the vehicles are typically charged only at pickup/return locations. This limits the availability of vehicles both in time and locations and introduces additional complications in design.

Research questions What is the proper granularity to model the vehicles, individual entities or flows? Suppose centralized decision making is possible and all future customer demands are known. What is the optimal control policy for charging and renting? Is it computationally tractable? If not, what approximations can be made without losing much performance? How to decentralize the control policy when centralized decision making is not feasible (e.g., when the network becomes large)? If future customer demands are uncertain or even unknown, what should be a proper robust/online control policy? In the presence of other uncertain factors in the system, such as uncertainties in traveling time between stations, fluctuations in electricity prices, etc., how robust is the control policy against these uncertain factors?

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