Electric Car Users’ Time of Charging Problem under Peak Load Pricing When Delay in Charging Time Involves Uncertain Cost

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Abstract

The problem of peak load arises when demand fluctuates over time while the production technology is not flexible (or making it flexible is economically inefficient) and/or when a product is non-storable (or storage cost is huge). Peak load is a common problem in consumption of public utilities such as electricity, transport (congestion), water and telecommunication. Linear and non-linear peak load pricing alternatives have been suggested to curb this problem, particularly when demand is cyclical (Mohsenian-Rad and Leon-Garcia, 2010; Tan and Varaiya, 1993; Chao et al., 1986; Finsinger; Roberts, 1979). Peak load pricing (PLP) is an attempt to shift demand, or consumption of the good, to accommodate supply.

While peak load problem and PLP are well documented in the literature, this paper, to the authors’ knowledge, is the first to analyze the EV users time of charging decision problem under PLP of electricity. The electric vehicle (EV) users choice of time of charging problem under PLP is different from that of general households using energy for house appliances since there is uncertain cost to the former associated with likelihood occurrence of unanticipated trips such as visiting hospital and commuting to lately informed social events, etc. In this paper, we consider EV user’s choice of time of charging problem when there is PLP of electricity used for charging the battery of EVs. Specifically, this paper aims to present a model of optimal time of charging when EV users have to trade-off between, on the one hand, observed cost saving benefit of postponing the time of charging to off-peak lower fee of charging and, on the other hand, the cost of delay in departure time for planned trips and uncertain cost of late charging associated with likelihood occurrence of unanticipated trip before the car is charged due to non-spontaneous nature of charging the batteries of EVs.

The optimal time of charging is derived for EV users given such trade-offs when PLP is presented both as self-selection problem in which it is upto the EV user’s choice to decide the time of charging, and as contractual agreement between the EV user and the energy supplier in which the EV user, to benefit from off-peak load discounts, has to accept the contract that may include not being allowed to charge before a specified time. The contract can take different forms depending, among others, on who determines the time of charging (the EV user or electricity
supplier) and flexibility in charging time within the contract period. The paper also compares the EV user’s welfare changes under different contractual forms as well as when PLP is presented as self-selection problem. We are also to conduct experiments at the lab to observe how individuals behave when they are subjected to different forms of contractual agreements that resemble PLP.

Based on the analyses obtained from the model, we conclude that 1) Due to non-zero occurrence probability of unanticipated trips, the optimal time of charging is to charge immediately after the battery becomes flat (which usually occurs when EV users return back to home from work at which energy consumption is also at its peak, and thus worsen the peak load problem) under uniform pricing of electricity even when they do not have planned trips. 2) Unless either the duration of time at which the fee of charging is low is longer than the time it takes to charge the car, and the peak and off-peak load price difference is higher than the cost of delay in departure time for a planned trip, it is optimal for EV users to charge immediately when their car battery becomes flat. 3) Postponing the time of charging for lower fee of charging is optimal when the EV user’s planned trip is much later than it takes to charge the battery or if the cost of delaying planned trip is less than the peak and off-peak fee of charging difference and if unanticipated trip is unlikely to occur or is not costly relative to cost saving from postponing the time of charging. 4) Fixed contract with exemption periods in which the EV user chooses optimal number of days on which to charge at anytime and to have fixed time of charging for the remaining days is a practicable contract form which is better for both EV users and energy supplier.
References

Hung-po Chao, Shmuel S. Oren, Stephen A. Smith, and Robert B. Wilson. Multilevel


Amir-Hamed Mohsenian-Rad and Alberto Leon-Garcia. Optimal residential load control
with price prediction in real-time electricity pricing environments. *IEEE Transactions
on Smart Grid*, 1(2):120–133, September 2010. ISSN 1949-3053, 1949-3061.


Chin-Woo Tan and Pravin Varaiya. Interruptible electric power service contracts. *Journal