IS ONE METER ENOUGH? ASSESSING THE IMPACTS OF DOMESTIC ELECTRIC VEHICLE-ONLY RATE ADOPTION VIA SUBMETERING.

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Overview

This research work aims to consider the novel challenges imposed on the management of the distribution grid as a result of the high penetration of electric vehicles (EVs) [1]. To avoid costly grid reinforcements and the risk of load curtailment due to high EV charging demand, indirect load control via adapted economic signals is a solution adopted by many utilities [2]. These economic signals, given to the EV users via a distribution network tariff and energy price profiles can have different structures, leading to a different final utilization pattern of the users who seek to minimize their electricity bills, among other objectives. Most household electricity meters do not separate the tariff used for household electricity needs and the one used to charge privately owned EV, leading to what is known as the "whole-house" rate. Nonetheless, a domestic time-of-use rate applied exclusively to EV charging has recently become an option. This "EV-only" rate can reduce charging costs and promote the flexibility offered by EVs via adapted price signals calculated based on a dedicated measurement method. Several pilot trials were conducted in the US, in places such as California, Minnesota and Texas, to test the technical feasibility and customer acceptance of these rates [3]. Californian state's electric investor-owned utilities (IOUs) are already offering these types of rates in their portfolio for dwellings. For instance, Pacific Gas & Electricity (PG&E) and San Diego Gas & Electric (SD&E) allow residential customers to be billed at tiered-rate for home appliances while for EV charging, a specific time-of-use plan is adopted [4, 5]. However, except for those cases where installing a second meter is mandatory, EV-only rates have not been widely adopted due to the high costs of the extra equipment. An alternative to avoid the upfront costs of a second meter for residential customers is *submetering*. In this case, the metering device inside the electric vehicle supply equipment (EVSE) can be used to measure the electricity coming from the grid specifically for EV charging. The technological progress of smart meters, communication networks, and data management will allow the submetering configuration to be adopted by many utilities for billing purposes. For the US case, an official decision on submetering by the regulator in California is expected in 2021 after the conclusion of the submetering pilots [6]. There is a vast body of literature investigating the impacts of different electricity rates, including energy prices and network tariffs, on specific end-users. The impacts on their decisions are assessed either with tariffs defined exogenously [7-9] or using equilibrium models in which grid tariffs are determined endogenously as the results of a bi-level approach [10-12]. In all those cases, only one tariff structure is analyzed at a time for users with only one metering scheme. To the best of our knowledge, no study assesses the effects on users and network tariff design of the adoption of two different rates for the same household simultaneously. We investigate this configuration supposing the submetering scheme has a dedicated protocol allowing the communication between the owner's EVSE and the utility for billing purposes.

Methods

To evaluate the tariff design which would result in an optimal social welfare, we develop a game-theoretical model, expressed, and treated as a Mathematical Program with Equilibrium Constraints (MPEC), to model the interaction between a National Regulatory Authority (NRA) and the dwellings. The NRA aims to maximize the social welfare subject to grid cost-recovery via network tariffs, the investment costs, and the cost of electricity usage of the dwellings. On the other hand, the dwellings seek to minimize their electricity costs according to the final tariff rate structure applied. The equilibrium solution for both NRA and dwellings will be the one in which no unilateral deviation in their decisions will be profitable. To analyze the results, first, we investigate the conditions in which EV-only rates can be applied for domestic slow charging sessions. We simulate three scenarios to compare the total costs for a dwelling: charging the EV under a whole-house rate, charging the EV under an EV-only rate, and charging the EV under EV-only coupled with DERs under a whole-house rate. Second, we compare several tariff structures for the three base case scenarios to identify the most efficient way to recover network costs. Assuming that all the grid capacity should be build, the economic feasibility of substituting grid capacity investments with demand flexibility under two tariffs is assessed. Finally, we derive policy implications from the results.

Results

The model successfully captures the interaction between the regulator setting the electricity rates (including energy charge profiles and network tariff) and the dwellings. For the consumers without the DER investment option, splitting the billing for the whole-house and EVs is the best choice to achieve bill reduction. The level of savings depends mainly on the profile for energy prices adopted. Practically, time-of-use (ToU) profiles with a higher weight on late afternoon and early night hours (17h – 21h) are more efficient for EV charging, whereas, for whole-house load, a flat energy profile is more adapted. In addition, the savings of using submetering instead of installing an extra meter incentivize even more the adoption of EV-only rates for consumers. Regarding the prosumers case, dwellings can invest in DER if it is profitable for them. The interaction between EV and DER becomes more complex since they can collect the spread between the two electricity rates buying prices by adopting storage and V2G. For example, either the EV charged under EV-only rate can be used as V2H, or investments in stationary battery can be made to power the EV and the house loads under whole-house rate. In this case, to increase energy savings, ToU energy profiles should also be adopted for the whole house but with different relative values along the hours. Concerning grid charges, two grid tariffs must be set since, in this case EVs are not directly part of the remaining household load. In all scenarios with EV-only rates, it is observed that the total costs of grid charges were reduced.

Conclusions

The adoption of an electricity rate designed specifically to charge EVs at home enables charging costs reduction for a myriad of dwellings. Assuming that household demand without flexible loads is quasi-inelastic, separating how EV charging is billed gives a fair incentive to adopt domestic EV-only rates. Customers are able to choose the best rate for their house loads without any changes in their demand profile. With the uptake of domestic EV-only tariffs, the grid operators will also have the necessary information about charging events and could better accommodate other EVs while avoiding costly grid reinforcements. NRAs on their end can adapt a tariff structure that gives incentives for DER and a separate one for EVs adoption, avoiding the conflict between EVs and DERs adoption through the network tariff design.

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