NETWORK TARIFF DESIGN WITH DISTRIBUTED ENERGY RESSOURCES AND ELECTRIC VEHICLES: A CALIFORNIAN CASE STUDY

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Overview

The electric power system has been under an important transformation since the past few years due to the strong development of renewable energy resources which are becoming more affordable and cost-competitive with the traditional ways of producing electricity using fossil fuels, for example. The generation part of the system is undergoing a bottom-up transformation since a growing number of consumers are becoming prosumers, i.e. they are producing their own electricity and are not highly dependent on electricity from the grid like before [1]. The current network tariffs, however, are not adapted to recovering all the costs of the utility in a scenario with a high penetration of photovoltaic systems and decentralized electricity production for self-consumption [2]. Furthermore, the addition of a battery storage systems would increase the self-consumption rate, avoiding curtailment of the photovoltaic systems and saving even more money than before [3]. In fact, this is likely to happen due to the tremendous decrease in the costs of battery packs, cells and managements systems. The “spiral of death” is a classic problem inflicted on the network operator by the penetration of photovoltaic battery systems [4]. When prosumers are consuming less electricity than before, the energy volume sold in kWh by the utility decreases and so does its revenue, making a full cost recovery unlikely. Consequently, the tariff increases, giving even more incentive to install photovoltaic panels and become less dependent on the power grid. This is a case in which those who do not have PV panels will end up subsidizing those who have, raising an equity issue between consumers and an efficacity issue due to the high electricity prices if more panels are installed. Many researchers have suggested different tariff designs to break the spiral using a capacity-based tariff [5]; however, this type of tariff also has issues if badly formulated as it could overstate the value of the facility peak load and give even more the incentive for battery storage [6].

Electric vehicles (EV) are becoming a trend in the mobility sector, which is aiming to reduce CO_2 emissions generated by conventional vehicles by increasing the penetration of battery-powered vehicles in the market. In addition to their environmental contribution, electric vehicles could also play an important role in providing services to the electric power grid (if equipped with a bidirectional charger) and in attenuating the negative effect of increasing tariffs caused by photovoltaic panels. As the general electricity consumption would increase, the utility could recover its fixed and variable costs more easily and the tariff would tend to decrease for all customers [7,8]; however, knowing the quantity of vehicles needed to counterbalance the tariff increase caused by solar energy is very important and not obvious to determine.

Methods

This article follows the methodology proposed by *Boampong et al.* [6] in their article about tariff design with solar PV and stationary battery behind-the-meter. The high penetration of solar PV as well as the increasing number of electric vehicles in California make it the perfect location for the study. The well-known optimization software called Distributed Energy Resources - Customer Adoption Model (DER-CAM) [9,10], provided by Lawrence Berkeley National Laboratories, is used to simulate the investment scenarios in solar PV and stationary batteries, and, in our article, we include electric vehicles under various time-of-use tariff schemes (capacity or volume based). Firstly, the main inputs to the DER-CAM model are defined: the capital and operational costs of the distributed energy resources, real consumption data of commercial and industrial facilities recorded every five minutes, existing tariffs schemes from the local retailor Southern California Edison (SCE) as well as proposed ones. Then, an Avoided Cost Model is used to quantify the avoided network costs for prosumers regarding energy consumption aspects and capacity-related costs that should be later recovered by the network operator. Finally, the software runs the simulation showing the optimum investment in PV, stationary batteries or EVs for each of these facilities. EVs are treated as exogenous variables to the model, i.e., the main purpose of an EV is mobility, not energy storage or grid support, so as they belong to the people working in these facilities the cost to the facility owner will not be the vehicle cost itself, but the bidirectional charging station cost, and the electricity used to charge them. Finally, a complete techno-economic analysis using main indicators (energy savings, cost savings, net present value of DER investments for each facility) is made to verify under which tariff scheme we could notably arrive at less cost shifting and more general efficiency for all the facilities.

Results

The results show, firstly, that the use of real load consumption data with an acceptable resolution is important to emphasize the heterogeneity of investments among these facilities. Depending on which tariff scheme they are under, the optimum investment in PV, battery storage or EV could be completely different, i.e., the use of averaged load profile or synthetic load profile may hide the specificities of each building, giving inaccurate results. Secondly, the counterbalancing effect of EVs and PV on grid cost recovery is proven to be correct under all types of tariffs simulated, showing that higher penetration of EVs tends to attenuate network costs recovery shortfall caused by the solar generation. Lastly, it is found that capacity-based tariffs with a heavier weight on coincidental maximum demand charges (Coin. MDCs) can reduce cost-shifting effects, reduce solar PV investments and motivate investments in EV and battery storage. The solar electricity generation in these facilities is coincidental with EV charging time, so the vehicles can charge with a cheap carbon-free energy and target the discharge decision at private maximum demand or when the system is constrained to increase avoided network costs. Nevertheless, a volumetric tariff will incentivize solar PV investments and enhance savings but an efficient number of EVs can also prevent tariff increases due to cost shifting.

Conclusions

Efficient tariff design is the key to decrease the risk of the death spiral caused by DER incentives. The local regulations will decide who will win or lose more according to the tariff adopted in each area. If there is an area with already a high penetration of PVs, it could be wise to adopt a capacity-based tariff to reduce cost shifting; however, if the local government is willing to push the development of renewable energies, volume-based tariff can serve as an incentive policy to PV adoption. For commercial and industrial consumers, the role of EVs is crucial to prevent cost-shifting issues under almost all tariff schemes due to their specificities: their large consumption can compensate the relation between savings and avoided network costs under a volumetric tariff and can diminish maximum demand charges under capacity-based grid as well with bidirectional charging systems even if they consume a great amount of energy from the grid.

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