ON THE INTERACTION BETWEEN DISTRIBUTION NETWORK TARIFF DESIGN AND THE BUSINESS CASE FOR RESIDENTIAL STORAGE

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Overview

The use of volumetric distribution network charges (€/kWh) is being challenged in many jurisdictions around the world. Specifically, volumetric charges with net-metering, implying that a consumer's network charges are proportional with its net consumption from the grid over a certain period (e.g. month), are deemed inadequate with the massive deployment of solar PV. Consumers with solar PV pay significantly lower network charges but still rely on the distribution grid as much as they did before. In other words, such network charges serve as an implicit subsidy for solar PV which ends up being paid by consumers without solar PV.[1] Therefore, regulators in many countries are thinking to suspend net-metering and move more towards network tariffs which are capacity-based (€/kW) or stimulate self-consumption (e.g. bi-directional charging €/kWh) (Brown and Sappington, 2018; CEER, 2017; European Commission, 2015). Such types of charges are deemed to align better what consumers pay for the network with the costs they cause. Batteries are identified as a key enabling technology to allow the reduction of the capacity need of a consumer or to allow for more self-consumption. In this paper, we investigate the interaction between the distribution network tariff design and the business case for batteries. We show that depending on the assumed grid cost structure, batteries can be over-or under-incentivised by the design of the distribution network tariff, i.e. the network tariff can act as an implicit subsidy or a tax for storage adoption.

The paper is structured as follows. After the introduction, the modelling approach is described. Then, the setup and data for a numerical example are introduced. In the core of the paper, results are shown and discussed. The results are split up into two main sections. First, the results are shown for the case we assume that all grid costs are sunk. Second, the results are shown for the case we assume that grid costs are fully driven by the aggregated consumer peak demand. After, a sensitivity analysis is performed. Lastly, a conclusion is formulated.

Methods

A game-theoretical model is introduced to capture the interaction between the distribution network tariff design, decentralised decision making of self-interest pursuing active consumers investing in solar PV and batteries, and their aggregated effect on the network costs. The model has a bi-level structure which is transformed in an MPEC and finally reformulated as a MILP using the strong duality theorem. In the upper-level, a regulator can opt for different types of network charges to recover grid costs. The regulator anticipates the reaction of consumers represented in the lower-level and the network tariff is determined in a way that total system costs (incl. network costs, retail energy costs and DER investment costs by consumers) are minimised; subject to the constraint that the total network charges collected equal the total network costs.

The consumer reacts to the aggregated electricity bill, but the accounting of the cost components is separate as we consider an unbundled setting. Next to the endogenously considered network charges, the consumers buy electricity, the commodity, from a retailer who bought this energy in the wholesale market and sells it to downstream consumers for an exogenous price. Finally, next to the retailer energy price and the network charges, a consumer pays taxes and levies; the level of these costs is considered invariant and the way these are collected does not interfere with the analysis. Modelled consumers can be passive or active. Passive consumers are assumed not to react to prices; active consumers pursue their own self-interest, i.e. their objective is to minimise the cost to satisfy their electricity demand. They have the option to invest in two technologies: solar PV and batteries. The incentives of the active consumers will not always align with the objective of the regulator and can have negative distributional consequences.

We do runs with the model for two (extreme) states of the grid. First, grid costs are assumed to be 100% sunk, a short-term vision, i.e. the grid is over-dimensioned, and the electricity usage of consumers has no effect on the total grid costs. Second, the grid costs are assumed to be driven completely by the coincident consumer peak demand. In the very long run, grid costs are also variable as the network capacity will adjust to the coincident peak demand need

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[1] See e.g. the blog post by Davis (March 2018): https://energyathaas.wordpress.com/2018/03/26/why-am-i-paying-65-year-for-your-solar-panels/

from the consumers. Further, we assume 50 % active consumers and 50 % passive consumers. Results are shown by two metrics: the total system costs as a proxy for cost-efficiency and the capacity of storage adopted by the active consumers. As a benchmark, a centralised planner model is built. The difference with the game-theoretical model is that there is no network tariff formulated in the central planner case, as the consumers do not need to be coordinated. Instead of consumers reacting in their own interest, the central planner decides unilaterally about their actions.

Results

First, we show that if grid costs are sunk, capacity-based will be aligned with the business case but not with the system, i.e. capacity-based charges over-incentivise battery adoption. These results are in line with earlier work (Borenstein, 2016; Schittekatte et al., 2018). Similar results hold for network charges which stimulate self-consumption, but this over-incentive only occurs if solar PV is very cheap or already installed by an active consumer. We also show how much this over-incentive costs in terms of overall system costs compared to the benchmark.

Second, we show that if grid costs are fully driven by the aggregated consumer peak demand, capacity-based network charges will mostly under-incentivise battery adoption. Also, it is found that such type of charges will result in a suboptimal operation of the battery from a system point of view. Network charges which stimulate self-consumption will again over-incentivise battery adoption. Additionally, even though a higher storage capacity is adopted by consumers than in the central planner case, the overall grid costs reduction is much lower under this network tariff design than in the first-best central planner case with less battery investment. Again we show how much this under or over-incentive costs in terms of system costs.

Third, we show how time-of-use (TOU) retailer energy prices affect the analysis. In the previous results, we assumed retailer energy prices to be constant. However, of the energy prices a consumer sees vary in time, batteries cannot only be used to lower the grid charges but also to arbitrage energy prices.

Finally, we also demonstrate that there exists a distribution network tariff design that gives optimal incentives in terms of battery adoption and operation, so-called peak coincident pricing as also discussed in Pérez-Arriaga et al. (2017).

Conclusions

First, we show that if grid costs are sunk, capacity-based charges combined with affordable residential storage is as problematic in terms of cross-subsidies as volumetric charges with net-metering combined with solar PV were. Network charges which stimulate self-consumption are also not optimal from a cost-efficiency point of view; their results are very sensitive to technology investment costs.

Second, we show that if much future grid costs can be avoided by ‘’grid-friendly’’ consumer behaviour, capacity-based network charges are a step in the right direction but will not untap the full consumer flexibility potential. Network charges stimulating self-consumption are shown not to align private consumer benefits with system benefits. More DER technology is installed at the consumer premises than optimal, but the network charges do not give the right incentive to operate them in a way that the overall system costs are reduced. Other solutions than the two tested network tariff designs are needed. Examples are peak-coincident network charges or market-based procurement of grid services. Both options can lead to a cheaper system for all but have their own implementation difficulties.

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