Reducing electricity system costs with energy storage: the role of consumer types and market coordination

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Overview

As electricity is increasingly generated by highly variable renewables, energy storage and consumers' demand-side generation resources could become a fundamental component of the electricity systems by facilitating the continuous balancing of supply and demand.

The purpose of this paper is to identify the impact that energy storage technologies may have on the electricity system by reducing the cost of electricity during periods of peak demand. By considering different potential evolutions of the UK electricity system during the period 2015-2050, we explore the impact of market coordination on electricity system savings from energy storage and demand-side resources, focussing on the implications of centralised and distributed approaches to demand scheduling. In addition, we consider how industrial, commercial, or residential electricity customers may affect savings from storage on the basis of their load profiles.

We use a dynamic optimisation model to minimise electricity system costs and assume perfect consumer behaviour. Consumers are assumed to react to an aggregator signal that coordinates electricity dispatch from their onsite technologies to smooth system residual demand. In the distributed scheduling case, consumers aim to smooth their residual demand curve.

Among our main results, we show that failing to coordinate demand-side generation can lead to increases in wholesale electricity prices by up to 7%. System-wide savings are the highest when the System Operator coordinates scheduling using residential customers' generation, and the least when it employs industrial generation. This occurs as a result of the flat electricity demands of industrial customers, which diminish the potential to induce savings.

Given the system cost reduction potential of demand-side scheduling coordination, we suggest that the System Operator could be willing to pay consumers a financial incentive in exchange for the ability to control consumers' technologies. We show that residential customers require the highest payment to forego control, whereas industrial users require the lowest payment due to their low electricity demand volatility. The results reported in this paper have wide implications for the way in which consumer-led storage and generation should be rewarded for allowing the System Operator to coordinate their technology for the benefit of the wider electricity system, as well as for policy considerations surrounding the utility of demand-side resources as the share of particular types of consumers increases.

Methods

Our aim is to derive the impact of scheduling coordination on wholesale electricity prices and that on annual savings of consumers' demand-side resources, including energy storage, under both regimes. We use a dispatch model of the UK electricity system during the period 2015-2040 and consider three types of electricity consumers: residential, commercial and industrial. A fraction of consumers owns both micro-generation and energy storage technologies. The System Operator (SO) matches supply and demand at minimum cost under two possible types of electricity scheduling approaches: centralised and a distributed. In the distributed coordination case, consumers aim to smooth their residual demand curve, as opposed to the centralised case, where a central coordinator is responsible for smoothing the system-wide residual demand. We assume perfect consumer behaviour, and that consumers react to an aggregator signal to coordinate dispatch from their storage devices, in the centralised coordination case. Consumer profiles are based on the demand profiles from Elexon (2017), which are scaled according to seasonal fluctuations. Electricity generation is calibrated against historical data of marginal electricity generation costs, while renewable generation profiles are based on historical generation levels, which are adjusted based on the installed capacity of each technology. Consumer-level storage is intended as the Tesla Powerwall 1 (Tesla, 2017). Future Energy Scenarios developed by National Grid (2016) (Gone Green (GG), Slow Progression (SP), No Progression (NP), and Consumer Power (CP)) are all considered, and provided installed electricity generation capacity, carbon prices, electricity demands, and storage capacities to 2040. Fuel prices are not specified for each scenario and are varied between low, medium and high levels as part of our sensitivity analyses. The model considers scenarios for different level of penetration of storage until 2040. The overall country projections were taken from National Grid, which provided the amount of storage installed.

On the basis of the estimated amounts of electricity stored by each consumer and the savings that these groups of consumers are able to generate, we derive the maximum average marginal amount that the SO is willing to pay, ignoring management costs, for controlling consumers' demand-side resources. This payment will be equal to the excess system savings in the centralized case over those in the distributed case, at each hour, because this is the difference between the financial utility of the System Operator in the two extreme cases from using consumers' resources. This analysis informs consumers and policymakers about the maximum rate per MWh that the system is willing to pay for the flexibility contributions ftom different types of consumers.

Results

By centrally scheduling demand-side generation resources, the System Operator can smooth aggregate electricity demand, making electricity more affordable for the whole power system. Yet, prosumers will likely their technology to minimize their own costs, regardless of the system-wide contributions they could make. We show that centralized scheduling is optimal for the power system, and could lower electricity prices by up to 7%. This suggests that the System Operator would be willing to pay individual users to control their technology for system purposes. Domestic users are found to require the highest payment, as opposed to commercial and industrial users. Our results have wide implications for the way in which consumers should be financially rewarded for enabling the system to use their flexible resources for the benefit of the whole power system.

Conclusions

As consumers increase their holdings of energy storage resources, it is crucial to ensure that their operation of the technology does not contribute toward higher electricity prices. This paper studied the implications of demand and storage scheduling coordination on the cost of electricity. Allowing consumers to control their own energy technologies is shown to be undesirable, leading to 4-7% higher wholesale electricity prices. This occurs as a result of the lower ability of the System Operator (SO) to smooth system demand. Yet, consumers will experience substantially higher financial benefits if they make a selfish use of storage and other demand side resources because it enables them to minimize their own costs, which is likely not to fully occur under centralized scheduling. We therefore suggested that consumers will be unwilling to forego control unless they are given a financial incentive, and showed that domestic customers must be paid the most by the SO to be nudged into giving away control of their technology due to their higher ability to generate savings from each unit of storage, as compared to commercial and industrial users. Despite the verified importance of energy storage technologies in reducing the future cost of electricity to all consumers in the electricity system, the technology faces a number of formidable barriers to innovation. Providing financial incentives to consumers for the flexibility they offer to the system could be a major step toward achieving a lower-cost and more secure, smart system.

References

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