ON THE ROLE OF RESIDENTIAL BATTERY STORAGE AND PHOTOVOLTAIC SYSTEMS IN SHAPING BEHAVIOURAL CHANGES AND GENERAL WELFARE

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Overview

Electricity markets are currently going through various changes: rapid increase in renewable energy, significant rise in carbon prices, appearance of new market players as well as more control being given to final users via smart meters which all create new challenges as well as opportunities in this multi-stakeholder grid. At the same time, we observe rapidly growing energy storage possibilities with the aim of providing some flexibility as well as new profit maximisation opportunity.

This means that decision making process in this changing environment has become even more complex, especially for final users. Domestic households are currently offered not only various electricity tariffs (i.e. Real-time pricing (RTP), Time-Of-Use (TOU) or fixed tariff), but they are also given many investment opportunities particularly in residential batteries energy storage system (BESS) and solar photovoltaic (PV) panels. This means that these electricity customers are gaining more power in controlling their daily electricity usage and thus the popular assumption of demand being inelastic is no longer valid.

The role of this paper is to research the impact of installing batteries and PV panels in households on the behavioural changes of final customers (demand curve and price of electricity). We assume that households use storage (batteries) for profit maximisation and react to the changing prices depending on their current tariff. We take into account the historical electricity prices and model the optimal price for final customers in different settings (maximizing social welfare) to compare the optimal prices for users with and without batteries and PV panels.

Apart from the intrinsic interest of understanding how equipping final users with above mentioned Distributed Energy Resources (DERs) changes the consumers behaviour, we model various different market set ups to present what-if situations including increasing storage and PV panels capacities and compare consumer surplus across different tariffs.

Methods

We present dynamic optimisation model that aims at maximising social welfare under different market settings. The primary purpose of the empirical analysis is to measure the effect of batteries and PV panels distributed among households as well as to identify the changes in consumer surplus across the groups.

Firstly, we assume initial market conditions where all households do not have neither storage nor PV panels. Next, we add storage unit and maximize households' energy cost savings by exploiting arbitrage – charging when the price is relatively low and discharging during peak hours. At the same time, we capture not only the effect of individual household's BESS on the daily demand curve and cost optimization but given the large amount of households we also observe the group impact on price levels as demand is significantly shifted from peak to non-peak hours.

Further, we equip part of the households with PV panels so that we can check what is the optimal usage of both Distributed Energy Resources together and how it impacts the households demand price. Additionally, we also allow some of our final customers to have only PV panels without any batteries installed. This way, we can check for times of energy excess and compare the daily prices and demand curves. We can also answer whether the simultaneous investment in PV panels and batteries significantly improves the daily energy savings.

We check the results for each scenario with different batteries and PV panels capacities to measure the prospective profitability of investing in additional units. Altogether, we provide broad outlook on final customers electricity market with storage and PV panels investments across various market set-ups.

Results

Our analysis show couple of interesting findings including the expected mechanism of reducing market prices in peak hours and increasing them in off-peak hours for customer with batteries. The preliminary results state that installing only PV panels brings around 10% savings on the electricity bill and adding BESS can increase the savings up to 45% compared to the households without any DERs. The shift in demand curve is substantial – the peak hours are barely distinguishable as consumer use mostly accumulated energy during the day.

We also observed that during the sunny day, batteries were usually charged at full capacity before the afternoon due to the excess of PV export and so the additional export directly to the grid or bigger battery is advised. Once we have refined our current scenarios, we will be able to optimize the capacity of BESS taking into account the initial costs of investments.

Conclusions

Storage can induce both private and social returns by creating profits or by impacting consumer surplus and social welfare respectively. In this paper, we research the impact of equipping individual households with batteries in PV panels to identify the changes in energy consumption and potential cost savings.

We present the model that not only simulates but also optimizes residential load profiles in the presence of DERs and different tariffs. The model is calibrated based on data from smart meters in UK households. We identified many benefits, especially for investment in battery systems which results in reduction of energy bill and consumption from the grid during peak hours.

At the same time, we observe that system of batteries is not currently economically competitive, and the policymakers should provide incentives in the form of subsidies to encourage customer to invest in storage. If that kind of subsidies are not possible for all potentially interested households, the group of particular customers with high demand profiles should be selected. We also found that the combination of both PV panels and storage system investment is yet not feasible due to very high initial costs but that may change soon due to technical advancements so researching that option is also vital.