Behind-the-Meter Energy Flexibility Modelling for Aggregator Operation with a Focus on Uncertainty

Data presentation

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Data Presentation

The data presented here is based on data from the Danish Elforbrugspanel project, which was a collaboration between the Danish TSO Energinet and Dansk Energi. The flexibility of consumers in response to different electricity prices is then synthesized using the method proposed in [1]. The electricity price is a combination of a baseline electricity prices, 2.25 DKK/kWh, and variable price component π_h, such that the total price is $2.25 + \pi_h$ DKK. The variable electricity price component is different for each hour and has a cap, such that $\pi_h \in [-0.75, 0.75]$. There are 29 different customer categories in the data with different responsiveness to dynamic prices (see Table I in [1] for details). In our work, 70 unique customers of each load category are exposed to 1000 price-sets for one day in a simulation study. As previously mentioned, a future scenario is assumed where the electricity customers have EMS, in which they can set their personal preferences. A static rebound effect is assumed when generating the data according to [1]. For further details on the data and the method used for synthesizing, the reader is referred to [1]. The reason for synthesizing the flexibility of consumers is the lack of available data for research on price responsive demand with automation. It is assumed that the methodology and analytical approach can be applied to real world data when available.

From the aggregators' perspective, the baseline consumption is not of primary concern, but rather the deviation from the baseline due to a given price deviation is important. Thus, we build our models for load deviation versus price deviation data in this study. An example of the data is plotted in Fig. 1, showing the flexibility from 70 customers of category 3 (house with heating) in hours 3, 6, 12 and 19. It can be seen that category 3 is not so flexible at late night (hour 3), but as the day starts there is more active energy consumption to be utilized as a flexible resource. Fig. 1 shows the aggregated flexibility for 70 consumers of categories 1, 2, 3 and 4 respectively. The four categories form the "residential cluster", as they all belong to residential categories including "Apartment without heating" (cat. 1), "House without heating" (cat. 2), "House with heating" (cat. 3) and "Cottage" or alternatively "Summer house" (cat. 4). It is clear that the variance of the flexibility increases when aggregating these consumers together. In the aggregated response in Fig. 1, it can be observed that the response to the negative price changes (i.e., down-regulation) are smaller than the flexibility achieved for up-regulation (i.e., positive price deviations), possibly due to a 'natural maximum energy consumption' for residential consumers. For example, a consumer would probably not start the dishwasher just because it is possible, but rather when it is needed.

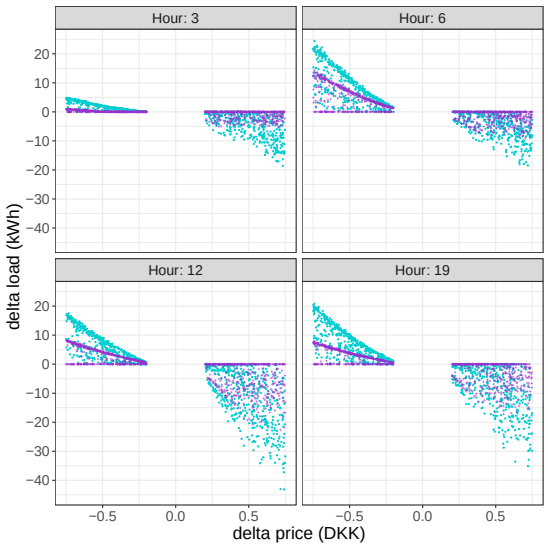

Fig. 1. **Purple**: flexibility of 70 customers in category 3 in hours 3, 6, 12 and 19. **Turquoise**: flexibility of consumers in cluster 1.

As previously mentioned, categories 1-4 are aggregated to create a residential cluster (cluster 1). Likewise, 70 consumers of categories 8-12 are aggregated to form a light industry cluster, called cluster 2 (including Food, Basic metal, Wood, Textile and Paper). 70 consumers of categories 13-15 are aggregated to form the heavy industry cluster (cluster 3), which includes Non-metallic, Chemical, and Other Industries.

References

[1] G. De Zotti, S. A. Pourmousavi, J. M. Morales, H. Madsen, and N. K. Poulsen, "Consumers' Flexibility Estimation at the TSO Level for Balancing Services," *IEEE Transactions on Power Systems*, vol. 34, no. 3, pp. 1918–1930, May 2019.