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# ***ON THE FLEXIBILITY OF ELECTRICITY CONSUMERS – MODELLING, QUANTIFICATION AND ANALYSIS OF NOTICE TIME***

Lars Herre, KTH Royal Institute of Technology, +46700492047, lherre@kth.se

Tommy Kovala, Mälardalen University, +4621101470, tommy.kovala@mdh.se

Lennart Söder, KTH Royal Institute of Technology, +4687906510, lsod@kth.se

Christos Papahristodoulou, Mälardalen University, +4621103176, christos.papahristodoulou@mdh.se

## **Overview**

Power systems with a large share of inherently intermittent renewable energy sources require new approaches to system operation. Demand response is seen as a potential possibility for contributing to maintaining power balance in a future energy system with large amounts of volatile renewable energy generation (Bartusch et al., 2011; Torriti, Hassan & Leach, 2010). It would be a measure to reduce costs for maintaining the power balance, which is believed to become more expensive if traditional measures to handle the increasing intermittency (Albadi & El-Saadany, 2008; Kirschen, 2003; Siano, 2014). The study of the flexibility of electricity demand is an essential key to exploring the current and future potential of demand side response for power system services.

For both solar and wind power, forecasts for several hours ahead may have a lower accuracy. Statistically, the forecasts become better the closer they approach real operation. In practice however, this does not happen in each case. This means that the flexibility need for a certain hour will be different, depending on when the need is identified, i.e. different notice times.

For consumers to be flexible, there are several parameters that impact their ability and willingness to react to incentives with a change of load. Elasticity (self- and cross-elasticity) has been defined in literature to describe consumer flexibility with respect to a change of electricity *price* and is often referred to when modelling the flexibility of consumers (Albadi & El-Saadany, 2008; Lijesen, 2007). Flexibility with respect to electricity prices or other financial incentives has been widely studied in literature on smart grids and demand response.

Another important parameter for electric demand to be flexible is the *notice time*, i.e. the time span between informing the consumer about a future need for reorganizing their consumption and providing a change of consumption as a system service. The impact of notice time on the flexibility of electricity consumers has not yet been systematically researched. It is logical that the willingness and ability of certain consumers to provide flexibility decreases as notice time becomes shorter. There are, however, some loads that even may become more flexible, the shorter the notice time, such as e.g. the charging of electric vehicles.

An essential basis for flexible consumers is the communication infrastructure that is used for sending price signals, bids and further market parameters depending on the demand response program. The type and information content of such communication is enabled through technological devices. These smart devices – which in most cases must exceed the function of only smart metering (Siano, 2014) – can have different properties and requirements that are determined by the demand response program and its respective requirements on data exchange. Therefore, the technological implementation and the impact of the limitations originating from the same are discussed in this study as well.

For a quantitative analysis of customer flexibility, both price and notice time are imperative parameters. Former has been studied in numerous references (Bartusch et al., 2011; Gyamfi, Krumdieck & Urme, 2013; Kirschen et al., 2000; Lijesen, 2007) whereas the impact of the latter has not yet been examined in depth. In this paper, a study on consumer flexibility with respect to notice time is presented. It is analyzed how the ability to reschedule electricity demand during a time interval in the future is impacted by terms of notifying and updating flexible consumers. For this, a market and demand response program optimizing social welfare is developed that allows for an analysis of notice time dependent consumers.

## **Methods**

In order to obtain information on consumer flexibility with respect to notice time, a comprehensive literature review is conducted. This review reflects on the overall environment of previous flexibility studies. The market scheme and demand response program have significant influence on the results of consumer flexibility. These factors can be represented quantitatively and used to explain the differing results from previous elasticity estimations of consumer flexibility. Hence, a more generic mathematical representation of consumer flexibility can be achieved if the notice time and the demand response program type are considered. By relating the elasticity obtained in these studies to the respective market scheme and notice time, an estimate of notice time

dependence is obtained.

In order to model flexible consumers with respect to notice time, a market model is developed which involves updates of wind power forecasts. These updates statistically improve in accuracy. The model optimizes social welfare, while taking into account notice time dependence of elasticity and forecasts.

## Results

The results show a significant variation of elasticity values in existing literature. The paper relates this variance to the respective environment and reflects on influencing parameters.

From the simulations, the impact of notice time dependent consumers on the market equilibrium is demonstrated quantitatively. Furthermore, an estimate of the value of wind power forecasts and consumer flexibility is derived.

## Conclusions

From this investigation on notice time dependent consumers, it can be concluded that the market scheme and notification schedule within the respective study significantly impact the outcome with respect to the value of consumer elasticity.

A model is developed that considers uncertain wind power forecasts and notice time dependent flexible consumers. Simulation results show that both the forecast error and time dependent elasticity impact the market equilibrium, i.e. electricity prices.

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