TAMPERE UNIVERSITY OF TECHNOLOGY

Attractiveness of demand response in the Nordic electricity market - Present state and future prospects

Citation
Rautiainen, A., Koskela, J., Vilppo, O., Supponen, A., Kojo, M., Toivanen, P., ... Järventausta, P. (2017). Attractiveness of demand response in the Nordic electricity market - Present state and future prospects. In *2017 14th International Conference on the European Energy Market, EEM 2017* IEEE. https://doi.org/10.1109/EEM.2017.7981925

Year
2017

Version
Peer reviewed version (post-print)

Link to publication
TUTCRIS Portal (http://www.tut.fi/tutcris)

Published in
2017 14th International Conference on the European Energy Market, EEM 2017

DOI
10.1109/EEM.2017.7981925

Copyright
© 2017 IEEE. Personal use of this material is permitted. Permission from IEEE must be obtained for all other uses, in any current or future media, including reprinting/republishing this material for advertising or promotional purposes, creating new collective works, for resale or redistribution to servers or lists, or reuse of any copyrighted component of this work in other works.

Take down policy
If you believe that this document breaches copyright, please contact cris.tau@tuni.fi, and we will remove access to the work immediately and investigate your claim.

Download date:19.02.2021

Attractiveness of demand response in the Nordic electricity market – present state and future prospects

A. Rautiainen[1], J. Koskela[1], O. Vilppo[1], A. Supponen[1], M. Kojo[2], P. Toivanen[2], E. Rinne[3], P. Järventausta[1]

[1]Laboratory of Electrical Energy Engineering
Tampere University of Technology
Tampere, Finland
antti.rautiainen@tut.fi

[2]Faculty of Management, University of Tampere,
Tampere, Finland
matti.kojo@uta.fi

[3]VTT Technical Research Center of Finland,
Espoo, Finland
erkka.rinne@vtt.fi

***Abstract*—During the past few years demand response (DR) has appeared in the spotlight in a new way. This is due to general technological advancement, development of electricity infrastructure, especially roll-out of smart meters, and rapidly increasing amount of renewable intermittent energy sources. This paper analyzes the attractiveness of DR in the Nordic electricity market. The results show that in many market places the attractiveness of DR is improving in the long term, although variations between different years exist. Two case studies presented in the papers show that DR has economic potential for some of the customers, especially for medium to large actors, but in a large scope, number of obstacles still hinder a wide scale deployment of DR solutions.**

***Index Terms*-- Demand response, electricity market**

I. INTRODUCTION

Electrical energy related demand response (DR) has long traditions both in practice and in research. However, the real DR applications of small electricity customers have been restricted mostly to time-of-use, mainly two-time type, products in the Nordic countries. During the past few years, DR in a wide scope, as defined in [1] has appeared in the spotlight in a new way. This is due to general technological advancement, development of electricity infrastructure (especially rollout of smart meters) and rapidly increasing amount of renewable intermittent energy sources. The attractiveness of DR from the electricity consumers' viewpoint in the North-European market has not been studied recently in a holistic manner. This paper tries to fill this gap and analyze the attractiveness in North-European electricity market putting special focus on the situation in Finland.

In this paper, real market and technical data related to different DR related market places in the North-European countries are analyzed together with two case studies, which concretize the results of the market analyses. The analyses focus on the today's potential economical attractiveness of different market places for DR, and also future development estimations for some of the markets are projected. In addition to market data study, there are two case studies in the paper. The first one is a simple Nordic day-ahead and reserve market related study of a mid-sized consumer having a large cooling load, which includes good control possibilities. The second case study includes large set of small electricity consumers doing DR in order to minimize their electricity costs with the day-ahead market price based electricity contracts.

The development of DR attractiveness has many aspects. One is the technological aspect. Especially the role of roll-out of smart meters has a significant impact in the DR possibilities. Due to the act in 2009 set by the Finnish Government almost all customers (about 98 %) are now provided by a new smart meter that features hourly energy measurements as well as registrations of quality of supply and DR functionality [2]. Remote readable hourly measurements of smart meters enable e.g. competition in retailer business by a flexible way for changing a retailer, new kind of dynamic tariffs of energy retailers (e.g. spot-price based prices) and DSOs (e.g. hourly power demand based pricing). The hourly electricity consumption data can be read from the meters once a day or even more often if needed. Also the balance settlement of the electricity market is made using the hourly smart meter data in Finland today. This enables the Elspot price based DR for every customer already today, and Elspot price based hourly contracts get continuously more popular in Finland. Another aspect in the DR market attractiveness is the development of the market places concerning the prices and the market rules. The historical development of the prices and projection for the future is presented in Section III. The market rule aspects are discussed in the Conclusions section.

The paper gives an overview of DR attractiveness in the North-European market, but the focus of the paper is in Finland and especially in the day-ahead market. Day-ahead market is an interesting one, as in practice all the customers in Finland have the ability take full advantage from the market as explained above.

This work has been supported by the Strategic Research Council at the Academy of Finland, project "Transition to a Resource Efficient and Climate Neutral Electricity System (EL-TRAN) (2015-17)" (grant number 293437).

The paper is organized as follows. In Section II, the DR market places in the Nordic electricity market are presented. In Section III, the development of DR market places are being analyzed based on the historical market data and foreseeable aspects affecting the markets in the future. In Section IV, real life case studies are presented, and conclusions and future work proposals are made in Section V.

II. DR Market Places In the Nordic Countries

The Nordic countries have well-functioning, quite harmonized and sophisticated wholesale electricity market, which also sets a good framework for a dynamic retail market. There are number of market places where the owners of flexible loads and other flexible energy resources (e.g. battery energy storages) could use their resources as tools for DR in order to earn some money or to decrease their electricity bill. The main market places are the following.

1. Day-ahead and intraday markets on the Nordic power exchange operated by Nord Pool Inc.
2. Frequency containment reserve (FCR) markets: for normal operation (FCR-N) and for disturbances (FCR-D). These markets are operated by Nordic transmission system operators (TSO), but the procurement of the reserves vary between different countries.
3. Frequency restoration reserve (FRR) markets: automatic (aFRR) and manual frequency restoration reserves (mFRR). These markets are operated by Nordic TSOs.
4. Regulating power markets (RPM), operated by Nordic TSOs. Regulating power markets in the Nordics are used to acquire resources restoring the system frequency near the nominal value, but also to set the prices for economical imbalance in the balance settlement process.

Different market places set different requirements for the resources. The requirements differ mainly on two things: reaction time and required activation time. Reaction times vary between some seconds (e.g. FCR-D) and some hours (e.g. Elspot), and required activation times in practice are from some minutes (e.g. FCR-D) to an hour.

III. Development of the electricity markets from the DR Viewpoint

Different Nordic countries have different energy policies, which have impact on the potential of DR. Nordic governments all see DR having a role in the future electric energy system, both in national and regional levels. The national energy policies naturally have variation due to particular features of each state's energy systems, and therefore DR has a different potential in each of the Nordic countries. Still, each of the Nordic states see e.g. technological development, the increase of intermittent renewable energy production and the need to control peak loads creating both opportunities and need for the use of DR, see e.g. [3]–[6]. It should be noted, however, that the future potential of DR is largely dependent on implemented energy policies and technological developments, and therefore the current estimates contain uncertainty.

The four Nordic TSOs also share the view that the Nordic power system is changing. In addition to technological developments and increased share of renewable energy sources, the TSOs emphasize the common European framework for markets, operation and planning as one of the main drivers in the change [7]. The TSOs see automated DR as one of the key enablers in the restructuring of the Nordic power system [7]. However, although the changes (e.g. technological developments) are recognized, the TSOs acknowledge that "significant uncertainty attaches to the magnitude and pace of these changes, and how these will affect the power system". For instance, the forthcoming role of DR depends on the level of system automatisation [7].

The TSOs collaborate and they are planning the next phase for the future measures and solutions [7], but at the same time they call for broader collaboration. As it is stated in the report: "Nordic TSOs cannot achieve everything on their own. Successfully developing the power system, will require extended cooperation across the power sector [7].

In this paper, different market places for DR in the Nordic electricity market environment are being investigate in form of historical market data analysis and by projecting the factors, which potentially project the development of the markets in the future. The analyses are made with three different types of market places:

A. Day-ahead Elspot market.
B. Regulating power market
C. Markets for automatically controlled FCR for normal (FCR-N) and disturbance (FCR-D) operation in Finland.

A. *Day-ahead Elspot market*

In the Nordic day-ahead Elspot market, the potential economical benefits for a DR operator does not come from the average price level in the market, but from the short-term, e.g. intra-day, variation of the prices. The DR operator would shift the consumption from the expensive hours to cheap hours and in this way harvests the benefit. Therefore, for the Elspot market, the price volatility within the days are being investigated.

The future of Elspot price volatility is uncertain and depends on many things. In general, there are many factors affecting the volatility:

- New internal transmission lines within the Nordic system and stronger connection to continental European system. Transmission lines bind the system to more coherent system, which typically, but not necessarily always, decreases the volatility.
- Decreasing amount of condense power and combined heat and power plants. The decrease of flexible and dispatchable power plants increases the volatility.
- Amount of total capacity of nuclear power plants, which do not participate to regulation of the power balance in the system. These kinds of new nuclear units and the continuation of the existing units generally decreases the price level, but increase the volatility in proportional or even absolute manner.
- Increasing amount of intermittent (renewable) power. There is an existing trend and a strong vision of significant increase of wind and solar power capacity in

the North-European transmission system. This kind of capacity potentially increases the volatility, as the production is purely weather-driven, and does not depend on the power demand or other market related things.

The Elspot market includes different bidding areas. Fig. 1 presents the bidding areas in the North-European market including Nordic and Baltic countries. Sweden, Norway and Denmark have 4, 5 and 2 bidding areas, respectively. Finland, Estonia, Latvia and Lithuania all have only one bidding zone. The idea of the bidding areas is that producers and energy sellers/retailers make bids in their bidding areas out of which the system price for the whole market is calculated, and if the transmission capacity forms physical bottlenecks preventing the trading to be realized as such, different price areas are being formed based on the bottle necks. The price data of the four years, from 2013 to 2016, are mainly being used in the study with the exception that for Latvia the year 2013 is excluded as the Latvian bidding area of the Nordic electricity exchange Nord Pool Spot was opened in the mid 2013 [8].

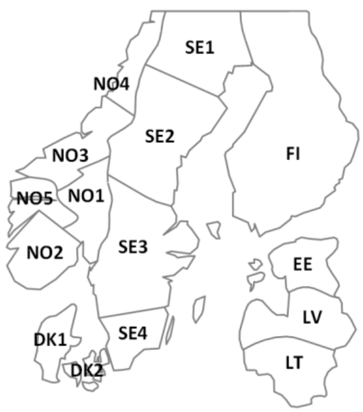

Figure 1. Bidding areas in Nordic/Baltic Countries in Nord Pool day-ahead market Elspot.

Fig. 2 shows the four price related quantities in the bidding areas of Fig. 1. The figure shows the annual averages of four Elspot price (C) based quantities calculated on daily basis over the years of examination. The first quantity is the annual average daily price range:

$$\mu_{\Delta C} = \frac{1}{N}\left(\sum_{day=1}^{N}(\max(C_{day}) - \min(C_{day})\right),$$

where C_{day} is the hourly prices of the day: $C_{day} = \{C_{1,day}, C_{2,day}, \dots, C_{24,day}\}$. The second quantity is the average daily standard deviations $\sigma_{\Delta C}$ of the prices over the year. The third quantity is the geometric mean of $\mu_{\Delta C}$ and $\sigma_{\Delta C}$: $\sqrt{\mu_{\Delta C}\sigma_{\Delta C}}$, which is simply called as "variability" in this paper. It is shown in the case study of [9] that the "variability" correlates strongly with the possible financial benefit of DR harvested from the Elspot market when using a battery storage as a tool for DR. The fourth quantity is the average annual Elspot price.

Fig. 2 shows that in 2016, among the Nordic countries Finland had the highest volatility, but the Baltic countries had the highest volatilities among all the bidding areas. Volatilities are also quite high also in Denmark, but in Sweden and especially in Norway the volatilities are low. Low volatility implies poor attractiveness of Elspot based DR. For countries which have very hydropower-intensive electricity production, like Sweden and especially Norway, the low volatility is quite a natural thing. Also, in Finland there is relatively high amount of temperature dependent load, which increase the volatility.

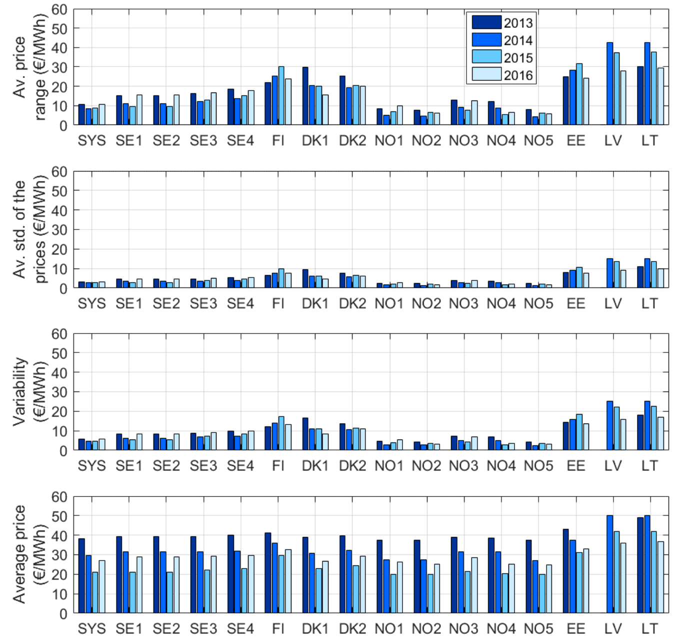

Figure 2. Average daily price ranges, standard deviations, "variabilities" and prices of the Elspot system price and the area prices in 2013–2016.

When looking at the Fig. 2, it can be observed that there is no clear trend in the volatility, which would apply to all the investigated countries. In Finland, there was a clearly rising trend between 2013 and 2015 in volatility, but in 2016 the volatility decreased. There are many potential reasons for this kind of development. Firstly, the amount of installed wind power capacity has increased from 448 MW at the end of 2013 to 1553 MW at the end of 2016 [10]. Increasing wind power capacity potentially increases the volatility, which is illustrated in Fig. 3 showing a real situation in the market in January 2017. The figure shows correlation between prognosis of wind power production and the Elspot price in Finland. The prognosis data of Fig. 3 is from the Finnish TSO Fingrid's open data service [11], and is updated at 12:00 for the next day, and is therefore a prognosis of the next 36 hours. Prognoses are used when a wind power producer plans the bids for the Elspot market. It can be seen from Fig. 3 that there are some periods of time where the wind power prognosis is very low and the Elspot price relatively high. For example, 16.1.2017 at 17:00–18:00 there is a price peak of 117.1 €/MW, and the wind power prognosis is only 94.65 MW for the same hour.

Another factor increasing volatility in Finland is related to the fact that the average Elspot prices (see Fig. 2) have been decreasing over the last years (although in 2016, the average price increased but remained still below the prices of 2013 and 2014). This has meant that especially the profitability of condense power plants but also combined heat and power (CHP) plants have decreased, and significant capacity of these power plants have been ran down and will probably be ran down more in the future [12]–[13]. As dispatchable capacity decreases in the system, this increases the price volatility.

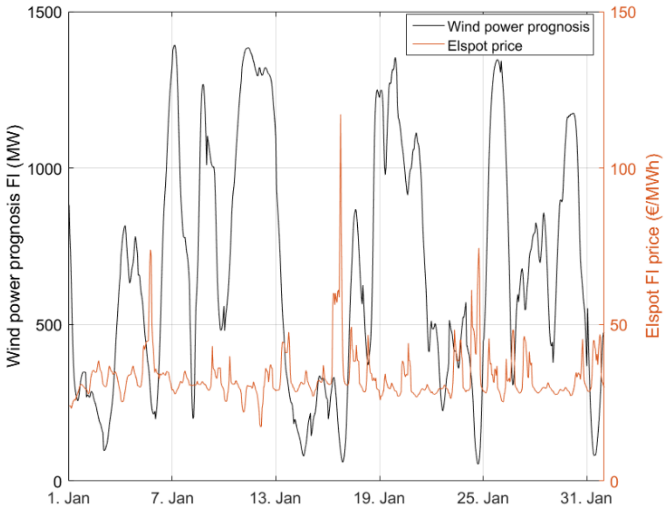

Figure 3. Windpower progosis and Elspot FI price during January 2017.

One significant factor decreasing the Elspot price volatility in Finland in 2016 was the commissioning of the 700 MW HVDC transmission line "NordBalt" between Sweden (SE4) and Lithuania [14]. NordBalt connection makes enables power transfer from Sweden to Finland through Baltic countries. Figure 4 shows the daily price range in Elspot FI price in 2015 and 2016 together with the hourly power exchange of NordBalt in 2016. The figure illustrates the fact that constructing new transmission lines potentially decreases the price volatility.

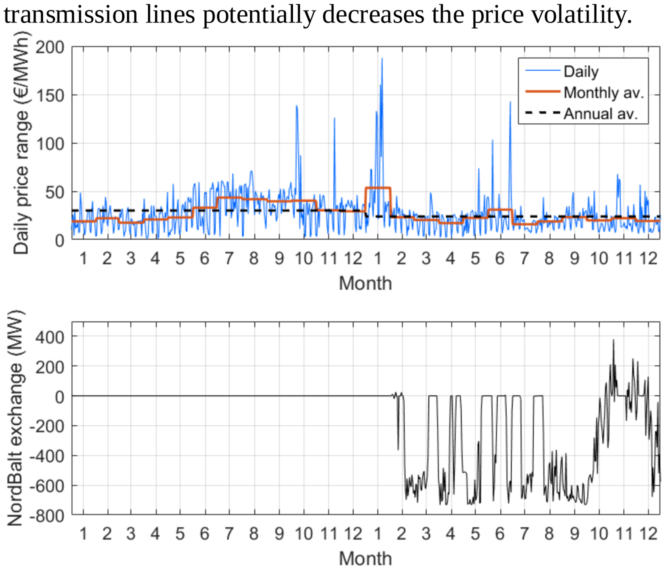

Figure 4. Price range of Elspot FI and the hourly exchange (negative power means export to LT) of NordBalt connection over years 2015 and 2016.

B. *Regulating power market*

Regulating power market is a very important market reflecting imbalance costs of producers and sellers/retailers and the cost of keeping the balance between power production and consumption. Fig. 5 presents the up- and down-regulation prices in the Nordic countries (Baltic countries are not today integrated to the Nordic Regulating power market) in 2013–2016 for those hours where the TSOs have activated market bids. Figure shows that the up-regulation prices are the highest in SE4, and SE4 is the only area where the prices of 2016 were higher than the prices of 2013. In Finland up-regulation prices have been quite steady in 2014–2016. Down-regulation prices, which the DR operator pays (price is the Elspot price or lower) for the regulation related electricity during the hour, are quite homogenous in all bidding areas, and the prices have decreased between 2013 and 2016 in all areas following pretty much the general Elspot price level development in the market. In general, the increasing amount of intermittent production potentially increases the up-regulation power prices and decreases the down-regulation prices in the future.

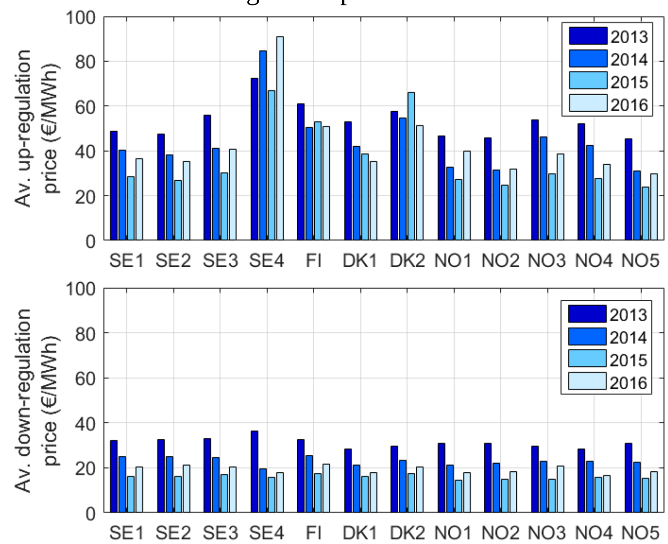

Figure 5. Average annual up- and down-regulation prices in different Nordic bidding areas regarding those hours where the TSOs have activated the regulating market bids.

C. *Markets for automatically controlled FCR for normal (FCR-N) and disturbance (FCR-D) operation in Finland.*

In Finland, the national TSO Fingrid Oyj runs the annual and hourly market for frequency containment reserves for normal operation (FCR-N) and for disturbance (FCR-D). Fig. 6a presents the average FCR-N and FCR-D prices in the hourly markets in 2013–2016 for those hours in which the system operator purchased capacity from the corresponding market in Finland. Figure 6b shows the annual market prices for the same reserves in 2011–2017. For FCR-N, the prices of the hourly market have been decreasing year by year, but the annual market prices have been rising excluding 2017. For FCR-D, the hourly market prices have mainly decreased between 2013 and 2016, but the annual market prices in 2011–2016 have been increasing year by year. Also, the volumes in different markets vary. The Finnish TSO wants to keep both of the markets (hourly an annual) alive, and considers year by year how the reserve procurement is divided between the markets.

IV. Case Studies

A. *Mid-sized customer with a cooling load*

The first case study is related to a mid-sized electricity consumer having a large cooling load (peak power ≈400 kW, energy consumption about 1000 MWh/a). Fig. 7 shows the hourly electricity consumption of the customer over the years 2014 and 2015. As can be seen from the figure, the customer of has had the cooling load down a few months during the two years. The process of the consumer is such that the cooling equipment can be shut down for many hours without the process being disturbed too much. This means that there is a significant DR potential in the cooling system, which is investigated in a form of a rough simulation in this paper.

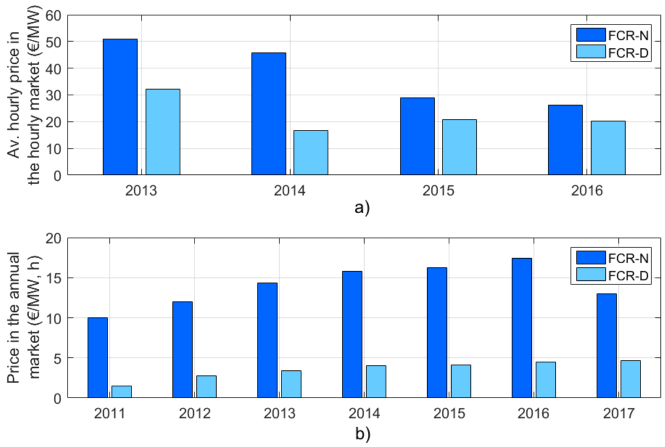

Figure 6. a) The average prices of FCR-N and FCR-D in the hourly market for those hours in which the system operator purchased capacity from the market in Finland. b) The prices of FCR-N and FCR-D in the annual market in 2011–2017 in Finland.

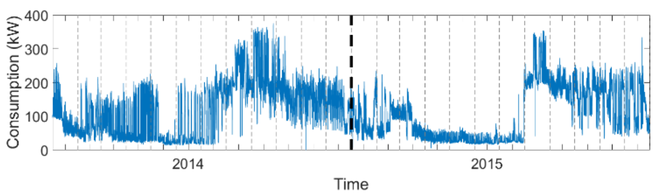

Figure 7. Hourly electricity consumption of the case study customer over the years 2014–2015.

Simple simulation studies were made, where the cooling load would do DR in two different ways: 1) in Elspot market alone, and 2) Elspot market combined with FCR-D market. The results of the studies are that the total saving/additional income of the resource owner would be of the order of 9,000 €/a (about 10% of the costs of the non-controlled case) on average with Elspot market alone, and 20 000 €/a (about 22% of the costs of a non-controlled case) with Elspot + FCR-D markets. The savings/additional income in this case can be considered non-negligible and the control related risks for the cooling process small, although there are some uncertainties in the simulations.

B. *Set of small customers with electricity heating*

The second case study is very different from the first one from two points-of-view. Firstly, the second case study comprises a large number (N = 1502) of real small consumers, which are located in the network of a Finnish distribution system operator (DSO). All the customers of the case study have 3×25 A main fuses and electric heating (average annual consumption of 14 MWh). Secondly, as the real load control possibilities now and in the future depend on many things and have many uncertainties, also the DR potential is very uncertain. Therefore, a theoretical extreme case is calculated. In the study, it is assumed that customers control their consumption in 24 h control periods and that the control system is theoretically the best possible one. Fig. 8 illustrates the control principle during one 24 h long period. In the system, the customer can freely shift all of his/her electricity consumption within a 24 h long period so that the only restriction is the maximum power limit of 18 kW set by the main fuse size. In the case study, the customers have an electricity contract, in which there is a separate price for every hour, and the price is composed of Elspot FI price + 0.4 cents/kWh marginal + 24% VAT. In the simulation, all the customers minimize their electricity bills by shifting all their consumption to the cheapest hours so that the daily energy consumptions remain the same as in their original consumption profiles. Simulation was made with data of hourly consumption data of 2014–2015.

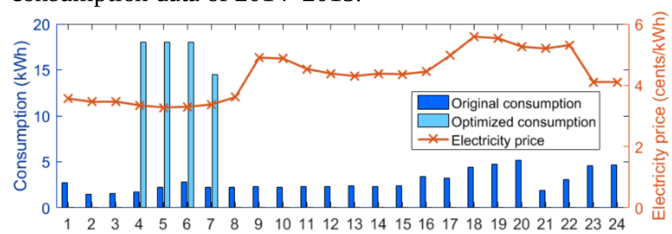

Figure 8. Example illustrating the main principle of a theoretically almost the best possible load control system during a 24 h long period.

Figure 9 presents the distributions of absolute and relative cost savings, which customers achieve by their DR efforts. On average the costs savings are 169 €/a (27%) and 187 €/a (37%), in 2014 and 2015, respectively. When expressed as monthly savings, the numbers are 14.1 €/month and 15.6 €/month. The savings correspond to the data of Fig. 2, which shows that the volatility and thus the DR potential of Elspot FI is higher in 2015 than in 2014. Although the simulation is a very theoretical one, it is still relevant in the following context: even with an extremely efficient load control system, the achieved savings are quite modest. Simply put, the Elspot based DR for small customers is not very attractive at the moment. However, if customers could do DR in many market places such as reserve markets and harvest benefit also from DSO tariffs, the attractiveness of DR could be significantly better. This is an important topic of further studies risen out of this paper.

V. Conclusions

The results show that in many market places, there is a non-negligible economical potential for demand response especially for mid-sized and large customers, but the situation might be improving also for the small customers in the long term, although Elspot price based DR is not very attractive at the moment. This is partly due to the long tradition of two-time (e.g. day-night) pricing: already today large proportion of the consumption of electric heaters is shifted to night-time when the Elspot prices are typically cheap too.

There are several uncertainties on whether DR markets could effectively be used in the future. One critical part is that

DR should be attractive enough in order to be applied, as for big consumers the risk of changing the consumption patter might pose a risk to the core process of their business. A small profit from DR cannot be exploited if it endangers or even complicates the core process too much.

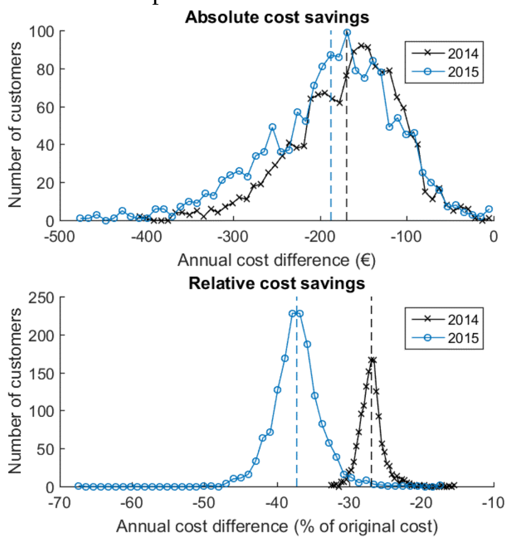

Figure 9. Absolute and relative cost savings of a set of small customers doing Elspot FI based DR with a theoretically almost the best possible load control system.

One piece in the puzzle is DR with the spot market based products. One fundamental aspect is how large proportion of the customers can do DR in the Elspot hourly market in the future. A great majority of the small customers today are buying their electricity with a fixed price. Fixed price contracts are very secure from customer point-of-view, and they can be very price competitive compared to spot price based contracts. This may be partly due to the fact that the retailer can use efficient electricity procurement methodologies and hedge its procurement. This is what the small customers cannot do. This means that the advantages of DR should be quite big in order to compete in price with the constant price contracts. Security/predictability is also a significant factor for the customers [15]. Constant price contracts offer stabile cost formation offering simultaneously competitive price. On the other hand, large customers, who buy electricity in a spot price based contracts, can also hedge their procurement by themselves (very big customers) or by using portfolio management services of the seller.

Also, for the sellers'/retailers' point-of-view, a customer doing DR increases the risks in the electricity market in the form of imbalance costs unless the seller/retailer can forecast and model the impacts of DR on the consumption behavior pre-hand during the bidding stage of the day-ahead market. If efficient DR tools existed, DR could also be a tool for a seller/retailer in order to optimize its operation in the market.

One important aspect in the future affecting the DR possibilities is the possible realization of common Nordic retailer market, which has been an aim for many years [16]. That would bring unpredictable changes in the DR field.

Regulating power market and reserve markets offer a new possibility for consumers, but especially for small consumers, the lack of clear rules related to aggregation of small resources is a significant obstacle in the development of DR in this markets. In addition, the changes in the distribution pricing towards more (peak) power based direction brings additional incentives for the customers to consider their powers too.

An important thing to remember too is that the benefits of DR for the consumers can be more than the direct monetary benefit: improved reliability of the power system, avoidance of price peaks, improved economical efficiency of the electrical energy system etc.

References

[1] A. Rautiainen, "Aspects of Electric Vehicles and Demand Response in Electricity Grids", Doctoral dissertation, 2015, Tampere University of Technology.

[2] Finnish Electricity market act 66/2009.

[3] Government of Finland. "Government report on the National Energy and Climate Strategy for 2030", 2016, http://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/79247/TEMjul_12_2017_verkkojulkaisu_korj.pdf?sequence=3

[4] Governent of Sweden. "Kraftsamling för framtidens energy", 2016, http://www.regeringen.se/48dd32/globalassets/regeringen/dokument/miljo--och-energidepartementet/pdf/sou-2017_kraftsamling-for-framtidens-energi.pdf

[5] Government of Norway. "Kraft til endring – Energipolitikken mot 2030", 2016, https://www.regjeringen.no/contentassets/31249efa2ca6425cab08130b35ebb997/no/pdfs/stm201520160025000dddpdfs.pdf

[6] Energinet.dk & Danish Energy Association,"Smart Grid in Denmark", https://www.energinet.dk/SiteCollectionDocuments/Engelske%20dokumenter/Forskning/Smart%20Grid%20in%20Denmark.pdf

[7] Svenska Kraftnät, Statnett, Fingrid, Energinet.dk. "Challenges and Opportunities for the Nordic Power System," 2016, http://www.fingrid.fi/fi/ajankohtaista/Ajankohtaista%20liitteet/Ajankohtaisten%20liitteet/2016/Report%20Challenges%20and%20Opportunities%20for%20_*ÄÖ%20Power%20System.pdf

[8] AST, "Electricity market in Latvia", http://www.ast.lv/eng/electricity_market/electricity_market_in_latvia/ Accessed 28.2.2017.

[9] J. Koskela. "Sähköenergian varastoinnin hyödyntämismahdollisuudet kotitalouksien energian käytön hallinnassa Suomessa (Utilization possibilities of electrical energy storages in households' energy management in Finland) (In Finnish), M.Sc. Thesis, 2016, Tampere University of Technology.

[10] Finnish Wind Power Association, "Tuulivoima Suomessa (Wind Power in Finland)" (In Finnish), http://www.tuulivoimayhdistys.fi/tietoa-tuulivoimasta/tietoa-tuulivoimasta/tuulivoima-suomessa-ja-maailmalla/tuulivoima-suomessa (Accessed 28.2.2017).

[11] Fingrid, Open data for wind power prognosis, Available: https://data.fingrid.fi/dataset/wind-power-generation-forecast-updated-once-a-day.

[12] Fingrid Inc., "Sähkömarkkinat korjauksen tarpeessa, – mitä voimme tehdä (The electricity market need to be repaired - what can we do?)" (In Finnish), Report, 20 p.

[13] Pöyry, "Suomen sähkötehon riittävyys ja kapasiteettirakenteen kehitys vuoteen 2030 (Suffiency of electric power in Finland and the development of capacity structure untill 2030)", Report, 2015, 54 p.

[14] Svenska Kraftnät, "NordBalt", http://www.svk.se/en/grid-development/Developmentprojects/nordbalt1/, (Accessed: 23.2.2017).

[15] E. Ruokamo, M. Kopsakangas-Savolainen, "Key elements and attributes affecting prosumers' behavior", FLEXe research report no 3.2-6 , Helsinki, 2016, 22 p.

[16] Nordic Energy Regulators, "Common Nordic End-User Market", http://www.nordicenergyregulators.org/projects/common-nordic-end-user-market/