NATIONAL SCALE IMPACT OF THE STOCKHOLM ROYAL SEAPORT PROJECT

Per GEBRO
Uppsala University – Sweden
per.gebro.3499@student.uu.se

Karin ALVEHAG
KTH – Sweden
karin.alvehag@ee.kth.se

Olle HANSSON
Fortum Distribution - Sweden
olle.hansson@fortum.com

ABSTRACT

This paper investigates how results from limited pilot studies concerning Smart Grids can be extrapolated to a Swedish national scale. The paper investigates the challenges with a national scale implementation of a proposed price model for electricity that combines the cost of energy with the cost of distribution that aims to encourage end-consumer Demand Response (DR). The estimated change in the national scale load-curve that may be achieved given high customer DR participation is analysed as well.

Numerous challenges of a national scale implementation are identified, mainly regarding the suggested price model's economic incentive and the Swedish apartment configuration of white goods that differs from that of the pilot studies. The estimated change in the national scale load-curve may also pose problems since the end-consumer behaviour that is desirable from a distribution grid point of view may differ from that of an optimal production capacity point of view.

1. INTRODUCTION

The EU has set a series of ambitious goals to battle climate change, summarized in the EU 202020 goals. In Sweden, a pilot study called the Stockholm Royal Seaport project is in progress to meet these goals. The Stockholm Royal Seaport (SRS) is an urban development project for a planned expansion of housing and services that are taking place in the district of Hjorthagen in Stockholm. The project has been designated as one of 18 projects in the world supported by the Climate Positive Development Program, part of the Clinton Climate Initiative (1) and aims to show that cities can reduce carbon emissions and facilitate climate-friendly growth. Innovative energy solutions will be used in the project. These solutions are often denoted as a *Smart Grid*, which usually refers to the drivers, technological solutions as well as market solutions that enable a more effective utilization of the electrical power system as a whole (2).

One of the most important aims of a Smart Grid implementation is to activate and enable end-consumers to participate more actively in the energy market. An active end-consumer could, for example, chose to postpone the use of a dishwasher or tumble-dryer from times of high electricity demand, called peak hours, to times of low electricity demand, called off-peak hours. This consumption postponement could by executed automatically by the machines themselves if they are equipped with necessary features. Machines with these features are often referred to as *smart machines*. The change in consumption allows the power system to be utilized in a more even manner while in the same time reducing the consumers own costs (3). Moving consumption in this fashion is called *Load-shift* (LS) and it is part of a group of intentional consumption modifications denoted *Demand Response* (DR) which is deemed to be one of the most important tools of the Smart Grid (4). Successfully implemented, DR could reduce the need for new investments in distribution capacity, as well as in peak production plants (5). Earlier estimates suggest that DR could result in savings of 14-67 billion € in the EU (6). The large uncertainty depends on how successful the implementation of DR will be. The cited savings mainly stem from a reduced peak production capacity but also from lower distribution costs and lower distribution losses (6). The total savings of a successful implementation of DR would benefit a diverse set of stakeholders such as grid operators, traders, producers as well as consumers.

Pre-studies for the SRS project was performed in 2010 and 2011 (7). In the pre-studies, a price model that support a development towards an energy system with active consumers resulting in a more efficient use of the electric power system with less environmental impact is presented. This new price model; denoted the *SRS price model*, will be tested on voluntary households in the SRS area, starting fall 2012 (7). The electricity price that the consumers normally face in Sweden consists of different components such as taxes, retail price and a network tariff. The retail price originates from the demand and supply of electric energy available in the system and is therefore subject to a competitive market since the re-regulation of 1996 (8). The network tariff is related to the cost due to the transmission and distribution of the electricity to the consumer and is subject to a natural, but regulated monopoly (8). The SRS price model combines all of these costs into a single model (7). The aim with testing the new price model is to investigate its impact on energy consumption and load-shifting which have been defined in an *Active customer scenario* and corresponding hypotheses listed in the pre-study. The hypotheses states that an Active customer will load-shift 5-15 % of his total yearly electricity consumption from peak hours to off-peak hours (3).

Even though numerous pilot-studies have been undertaken, both internationally regarding Smart Grids in general as well as nationally focusing on the SRS project (9), few of these studies have examined the national scale impact of such solutions and models. In order to put these results into perspective, the need to extrapolate results to a larger scale is evident. Such an extrapolation needs to take into consideration the difference between limited pilot studies and "real-world conditions". This paper, therefore, investigates the challenges with a national scale implementation of the SRS price model and DR, the end-consumers economic incentives of participating in DR and the estimated change in the national scale load-curve. The study focuses on Swedish apartments without electric heating with a yearly consumption of 1600-3400 kWh to mimic the SRS pilot study as closely as possible.

2. CHALLENGES OF A NATIONAL SCALE IMPLEMENTATION OF THE SRS PRICE MODEL AND DEMAND RESPONSE

Pilot studies always differ to some degree from real-life conditions. The aim, however, should be to mimic these conditions as well as possible and thus render the pilot studies results reliable. The SRS project will be using state of the art technology and solutions, some of which are untested and unproven. Before extrapolating ex-ante estimations of changes in consumption patterns, a gap analysis have been undertaken in order to elicit some of the most crucial challenges of a Swedish national scale implementation of the SRS price model and DR among apartment building households. Gap analysis as a tool stems from the field of benchmarking and process improvement and is used to elicit improvements that are necessary to go from one system state to another. This is done by comparing the different states with each other and documenting the differences; the "gaps" (10).

The biggest challenges of a national scale implementation of the SRS price model and DR in Swedish apartment households are deemed to be; *the lack of moveable loads in a foreseeable future*, *the heterogeneous cost of distribution*, *the suggested price models low peak to off-peak price ratio* and *the comparatively small cost of electricity of the consumers*.

Lack of moveable loads

Since approximately 80-90 % of all Swedish apartment building residents have access to a common laundry rooms and dishwashers are not as common in apartments as in houses, the possible and suggested loads that can be moved are limited (11). However, the appliances may be more common in the apartments themselves in the future. These possible changes in household white goods will probably take time to implement, especially if the economic incentives or other incentives are small.

Heterogeneous cost of distribution

Even though the utility price of electricity is traded on an open market (Nordpool), the cost of distribution operates under a natural monopoly. The costs of distribution are dependent on the configuration of the local distribution grid and differ greatly depending on location, see figure 1. Omitting the extreme high and low costs, the middle 80 % of the costs still ranges in a 50 % (58 €) interval. By introducing combined price models for electricity that includes both the cost of energy as well as the cost of distribution, new challenges will arise in how to market and explain these new price models to end-consumers. Customized price models that take geography into account are not an unreasonable solution but this places greater demands on the electric utility companies' communication and their transparency. An inability to market coherent electricity subscriptions across the nation will most likely lead to misunderstandings and low DR participation (6).

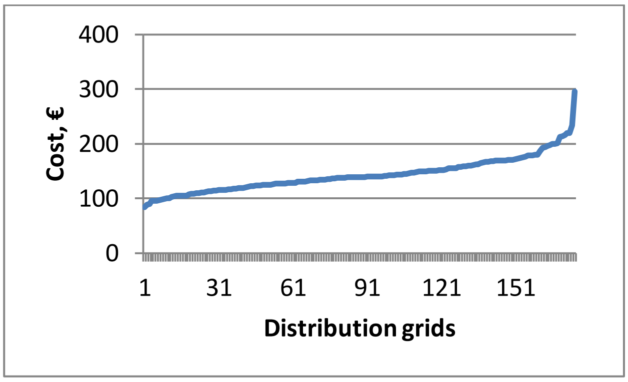

Figure 1. *Distribution of yearly costs of distribution for a typical apartment with a consumption of 2000 kWh per year (12).*

Low peak to off-peak price ratio of the suggested price model

An earlier meta-study within the SRS project suggested that in order for a price model to be effective, the cost of electricity should be divided into distinctive price blocks with the peak to off-peak price ratio preferably larger than three (9). The suggested SRS price model is divided into distinct price blocks but has a low peak to off-peak price ratio. Based on historical electricity prices between 2010 and 2012, it can be seen in figure 2 that the ratio is seldom above three.

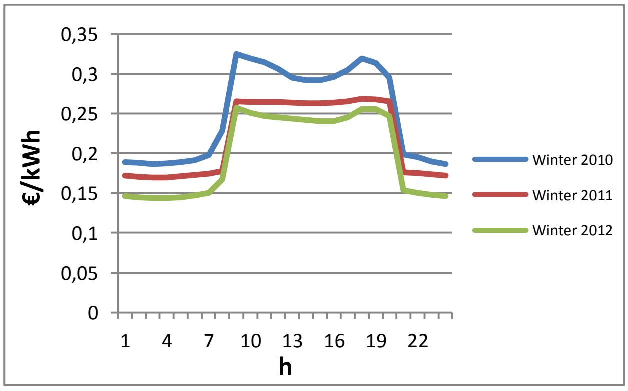

Figure 2. *Average hourly prices generated by the SRS price model, based on spot prices during the winter seasons of 2010-2012.*

Comparatively small cost of electricity for consumers

84 % of all Swedish apartments are heated solely by distributed heating (13). The yearly electricity consumption of an apartment is therefore low compared to that of houses that are often heated with electricity in

some aspect (13). The cost savings by participating in DR projects can therefore be unreasonably low, especially if participation has an impact on the experienced comfort of the customers, which may be the case if not smart machines, such as the before-mentioned white goods, are available.

3. END-CONSUMER COSTS

To estimate what economic incentives the current SRS price model could give to end-consumers, hourly consumption data of five type apartments have been used in combination with the historical electricity prices of 2010-2012. The type apartments are divided on Family apartments and Single and Couple apartments below and above the age of 64, respectively (14). The consumption data have been weighted by season for cold appliances, consumer electronics, cooking and lightning, all of which are highly seasonal (14). The yearly costs of the consumers using the price model with different degree of load-shift are presented in table 1. The cost savings generated by a 5 or 15 % load-shift is calculated by moving 5 or 15 % of the type apartment's consumption of each peak hour and distribute it evenly over the off-peak hours. The total yearly consumption is thereby constant.

Table 1. *Consumer costs generated by the SRS price model, based on spot prices of 2010-2012 and the possible savings generated by 5 or 15 % load-shift.*

Type apartment	Cost interval 2010-2012 (€) No LS	Savings interval with 5 or 15 % LS 5%	15%
Family	566-700	0,7-1.1	2,1-2,7
Couple, 64+	344-425	0,8-1,2	2,4-3,1
Couple, -64	384-475	0,6-1,0	2,0-2,6
Single, 64+	264-325	0,7-1,2	2,2-2,9
Single, -64	264-326	0,6-1,0	1,8-2,5

These savings are based on the type apartment's average load-curves where not all apartments have white goods such as dishwashers, washing machines and tumble dryers. The electricity prices are also often assumed to increase in the foreseeable future. To this end, cost calculations for two future scenarios have been performed, based on possible future prices of the year 2030 generated by an earlier MARKAL-study as well as assuming a greater distribution of white goods (15).

Scenario 1

The fluctuating price of electricity is increased with 40 % compared to 2011. Cost calculations for the different type apartments lead to lower percentage savings, even though the absolute savings increase with up to 8 % in comparison with the earlier savings for the same degree of LS.

Scenario 2

The fluctuating price of electricity is increased with 40 % compared to 2011. White goods; washing machines, clothes dryers and dishwashers are supposed to be fully available with one of each machine in every apartment. Cost calculations for the different type apartments lead to lower percentage savings, even though the absolute savings increase with 13-28 % in comparison with the earlier savings for the same degree of LS. More importantly; the increased frequency of white goods render the 15 % load-shift scenario more likely.

4. NATIONAL SCALE AGGREGATION OF POTENTIAL LOAD-SHIFT

The suggested SRS price model gives incentives to move consumption from the peak hours 08.00-20.00 during weekdays to the off-peak hours, which are all other hours. To extrapolate the *Active customer scenario* to a national level, first a national scale aggregation of the total consumption of all apartment households has been made. The aggregation is based on publicly available housing statistics (13) and a consumption study performed by the Swedish Energy Agency describing the specific hourly consumption of a number of type apartments, as described in Section 3 (14). Specific consumption is all consumption except that which is needed for heating purposes, which has not been included due to its infrequency in Swedish apartments (13). The resulting aggregated load-curve can be seen in figure 3, where the loads are divided on use.

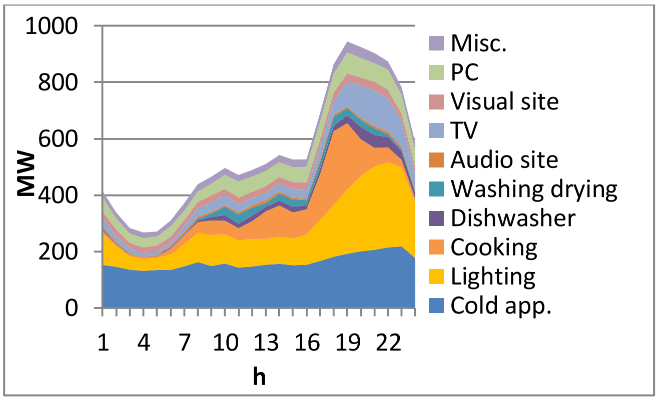

Figure 3. *National scale aggregation of the specific electricity consumption of Swedish apartments during a typical weekday.*

The load curve has a distinct peak at 19.00. By introducing a maximum 15 % load-shift from the predefined peak hours to the predefined off-peak hours, an estimated, updated load-curve can be calculated, see figure 4.

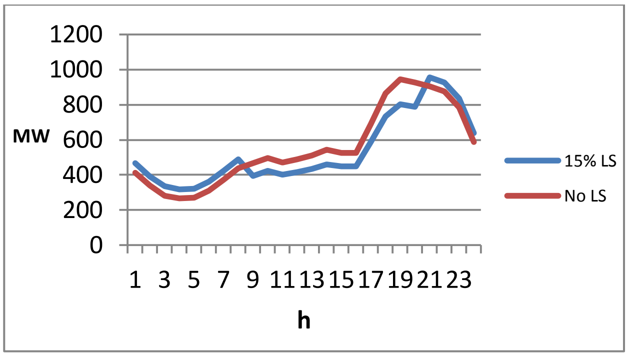

Figure 4. *Estimated load-curve with a 15 % load-shift.*

Apparently, the load-shift will *increase* the maximum peak demand with 10 MW during a 24 hour period, while at the same time shifting the hour of peak demand from 19.00 to 21.00. This does not, in itself, have to pose a problem from a distribution grid point of view since the consumption of apartment households only constitute a part of the total national consumption and the distribution grids all have different load profiles. The total national electricity demand usually decreases sharply after a peak at 18.00 (16). The estimated load shift would therefore not increase the national peak demand. It is, however, an interesting finding when considering the impact on the price of electricity, which is set by marginal pricing. A higher peak demand at a specific time would increase the price for all electric power consumed at that hour. Since the bulk of the proposed savings that could be made in the EU by introducing DR is said to stem from a reduced peak production capacity (6), an increased maximum demand will affect the overall profitability of a DR implementation.

5. CONCLUSIONS

The suggested SRS price model gives clear incentives to move loads from the pre-defined peak hours to the pre-defined off-peak hours. The price model's peak to off-peak ratio is however most often lower than the desirable 3:1. This fact, in combination with yearly savings of 3,1 % or less of the total electricity costs of a customer, suggests that the economic incentives could be considered small. Future developments with higher prices of electricity and more white goods in apartments will probably lead to higher absolute savings if DR is utilized, even though the percentage savings may decrease. The small economic incentives might not be enough to engage potential customers in DR, especially if not "smart" machines such as white goods are readily available. This can in itself pose a challenge, giving the current configuration of apartment buildings access to, or lack of, different white goods.

A 5-15 % load-shift can also potentially lead to higher peak hour demand from apartment customers. Combined price models that include both the fluctuating price of electricity as well as the cost of distribution should be set with the local distribution grid in mind, but also the overall national demand of electricity if the aim is to reduce peak capacity with low utilization factors.

6. REFERENCES

[1] Stockholms stad, 2009, *Norra Djurgårdsstaden Stockholm Royal Seaport – Vision 2030*, Alfaprint, Sundbyberg, Sweden (Only available in Swedish).
[2] European Regulators Group for Electricity & Gas, 2010, *Position Paper on Smart Grids*, ERGEG, E10-EQS-38-05.
[3] Hansson O, Faber K, Berglund C, 2011, *Stockholm Royal Seaport – New market models for committed customers*, Elforsk, Stockholm, Sweden (Only available in Swedish).
[4] International Energy Agency, 2003, *The Power to Choose - Demand Response in Liberalized Electricity Markets*, OECD, Paris, France.
[5] Energy Markets Inspectorate, 2012, *EI issues new rules concerning hourly metering*, Web site, online 2012, http://www.ei.se/sv/nyhetsrum/nyheter/nyhetsarkiv-2012/ei-ger-ut-nya-regler-om-timmatning/ (Only available in Swedish).
[6] Faruqui A, Harris D, Hledik R, 2009, *Unlocking the €53 Billion Savings from Smart Meters in the EU*, The Battle Group.
[7] Hansson O. *Interview*; 2012-10-05.
[8] Damsgaard N, Green R, 2005, *The new electricity market; success or failure?* SNS, Stockholm, Sweden (Only available in Swedish).
[9] Ibrahim H, Skillbäck M, 2012, *Evaluation methods for market models used in smart grids An application for the Stockholm Royal Seaport*, KTH, Stockholm, Sweden.
[10] Reider R, 2000, *Benchmarking Strategies*, John Wiley & Sons, Inc., USA.
[11] Lund K, 2009, *The laundry room – A Swedish history*, Nordiska Museets förlag, Halmstad, Sverige (Only available in Swedish).
[12] Energy Markets Inspectorate, 2012, Web site, online 2012, http://www.ei.se/sv/Publikationer/Arsrapporter/elnatsforetag-arsrapporter/ (Only available in Swedish).
[13] Swedish Energy Agency, 2011, *Energy statistics for houses, apartment buildings and commercial facilities 2010*, Swedish Energy Agency (Only available in Swedish).
[14] Zimmermann JP, 2009, *End-use metering campaign in 400 households in Sweden Assessment of the Potential Electricity Savings*, Swedish Energy Agency, Eskilstuna, Sweden.
[15] Profu, 2010, *Scenarios for the development of the electric and energy system to 2050*, Profu (Only available in Swedish).
[16] Edfeldt E, Glantz P, 2012, *Network pricing in smart grid project in Stockholm Royal Seaport*, Fortum Distribution AB.