BEHAVIOR OF ACTIVE HOUSEHOLD CUSTOMERS ON THE ELECTRICITY MARKET – FINDINGS FROM MARKET TEST SMART GRID GOTLAND

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ABSTRACT

Smart Customer Gotland was a market test within research and development project Smart Grid Gotland, which aimed to achieve a load shift by enable control of residential heating systems, in private households, to a price signal. The market test comprised almost 300 customers with electric residential heating, such as water boiler, electric heater, direct electric heating, electric floor heating and/or water to air heat pump. The price signal was a combination of a reinforced spot exchange price for electric power, time of use grid tariff and a wind component, uniquely designed for Smart Customer Gotland. Each customers’ ability to shift load from hours with high electricity price to hours with lower price was presented on the households’ ordinary bill from the electricity sales company. The accumulated load shift should, at least theoretically, correspond to the overall goal of the project – to increase of Gotland’s capacity to host renewable power production.

The market test, which started in late autumn 2013 and ended in spring 2016, was, from a customer satisfaction point of view, a veritable success. A large part of the customers has decided to keep the service, including the technical equipment, at own expense, after the end of the project.

It was observed that the control system contributed to lower the households’ general energy consumption and that the automatic control based on price signals can be used to achieve a load shift from periods of high load to periods of low load, without affecting customers’ comfort. However, in order to achieve load shift in level with the overall project goal (+/- 10%), stricter control is needed.

INTRODUCTION

Smart Customer Gotland was the market test within research-, development-, demonstration- and pilot project Smart Grid Gotland. Smart Grid Gotland which have the ambition to upgrade an existing rural distribution system, to a modern smart grid has the following overall objectives:

1. Achieve a small but not insignificant increase of the hosting capacity for renewable power in the distribution grid by use of load shift from active customers

2. Improve the power quality for the customers by a decrease of the number and duration of power outages

3. Attract a large number of household- and business customers to become active on the electricity market

4. Where the first and, especially, the third project objective was handled by a market test called Smart Customer Gotland.

Smart Grid Gotland and its subprojects are conducted as a consortium between GEAB (Gotlands Energikåtebolag – the local distribution system operator and electric sales company on Gotland), Vattenfall, ABB, Schneider Electric, Svenska Kraftnät (the Swedish transmission system operator) and the Royal Institute of Technology. The project is co-funded by the Swedish Energy Agency.

Smart Customer Gotland

The initial idea behind the market test was to use price signals to incite customers to turn on large electricity consuming equipment during periods of high load and low demand. Periods when the grid risk to reach maximum load would consequently be shorter and fewer, which, in turn, would justify an increase of the hosting capacity of intermittent power production on Gotland.

In the project pre-study it was concluded that approximately 8600 electricity customers on Gotland had the potential (large enough consumption, controllable load etc.) to participate in the test. If a rough quarter of these customers were to be able to shift +/- 10% of their consumption, it would correspond to approximately 5MW, i.e. the overall goal of the project.

In addition to the overall project goal, the objectives of Smart Customer Gotland was to achieve better understanding of customers' behaviour, interest and acceptance of active participation and to lower electricity costs for active customers

The market test started in December 2013 and concluded in April 2016.

METHOD

In order to meet the project objectives, it was clear that the market test needed to focus on customers with a large (>8000 kWh/year) and controllable electricity consumption. Private customers in detached houses with electrical heating turned out to be a natural focus group. To reach an acceptable number on participants was defined as a challenge. Recruitment of, maintaining and decommissioning of customers thus became core issues.
Control and reference
Even before the start of the recruitment process, the consumption from all electric meters in detached houses on Gotland was switched to hourly resolution. An eventual change in consumption behaviour would be indicated by comparison with data recorded prior to the test.

Recruitment of customers
Recruitment of customers meant that, in first hand, to reach the customer with information about the market test and, secondly, making an offer that the customer would accept. Information, suggesting that a market test participation could contribute to a sustainable society, awareness of energy consumption and efficiency as well as a possibility to lower their expenses, was distributed to customers, by use of:

- Advertisement in local media
- Attachments to their electric bill
- Presence at various exhibitions on the island
- A priority channel for dialogue with private customers at www.gotlandsenergi.se

Additional information was distributed to members of the target group by use of direct mail. The relative technical complexity of the installation, however, meant that physical meetings with customer on especially dedicated events was the single most efficient way to spread the information.

About half of the initial set of 1600 customers were, unfortunately, unable to participate in the test due to, for example, missing technical prerequisites or due to long term fixed electricity price agreements. The other half was identified as potential test pilots and invited to an open house event the project informed the customers about price models (see Price Models), technical equipment (see Technical Platform) and the project agreement. At the event the customers had the possibility to sign the project agreement. A real time electricity consumption meter and a time-slot for installation of the automatic control of heating devices were offered to each signing customer.

Initially 214 customers signed the agreement and entered the market test and about six month later an additional 50 customers entered the test. Customers who entered in the later stage, was offered a slightly reduced technical installation which did not include the automatic control and where the price signal was formed by the sport price only.

Although heavily integrated and visualized together in the customer user interface, the customer offer will be divided into the technical platform and the price signal and discussed separately, for cleanness.

Technical Platform
The fact that Smart Customer Gotland involves real customers, installations and, not least, customers’ real electric bill had to be reflected and respected. This especially concerned the choice of technical platform, which had to be able to handle a huge variety of different residential electric heating systems (direct electric heat, electric heaters, water boilers and heat pumps, as well as combinations thereof). The combination of four commercial products - Energy Watch, Smart Plug, Smart Temp and Smart Control – was after some adjustments considered the best technical set-up for the test. Also a temperature guard, for override in situations where faulty equipment or mistakes by users made the indoor temperature reach unhealthy levels, was added as a safety precaution.

![Figure 1. The technical platform in the market test was based on several commercially available products and can control a large range of different heating systems. The price signal was visualized by use of a Smartphone application, which also was used for control of the heating system.](Image)

Price Signal
A special retail price (called smart customer price) was designed in order to simulate a future situation when a large production from volatile energy sources give rise to a more volatile electricity price. The smart customer price comprised three components:

1. Spot price from the Nord Pool Spot exchange for electric power
2. Grid Tariff - Time of use tariff, i.e. higher tariff between November and March, during weekdays between 6am and 22pm
3. A wind component, unique for Smart Customer Gotland

The wind component was a special discount when forecasts suggested a high electricity production the following day. Since wind power constitutes a large part the total power production on Gotland, this generally occur during windy days. In the market test, such a wind discount was limited to a maximum of 30 days per year and customers could choose to have day-ahead information about the wind discount by use of smartphone application push notices.

Each customer could choose to have their control equipment remote controlled with four pre-set levels: Comfort (lowest level of control in order to prioritize comfort), Normal, Economy (high level of control in order to save money) and Economy+ (an extra high level to meet the need of customers who manually steered away additional consumption from high load hours on a regular basis and/or customers who leaves the house during longer periods).

In the smartphone application, every customer had the possibility to make manual changes to the pre-set levels by either activate or deactivate hours in the pre-set scheme.
Maintaining customers
Simplicity and user friendliness was important factors, both for recruiting and for maintaining customers. Not least since the technical platform, including wireless internet connection and smart phone applications, and the price signal, where both the spot price and time of use tariff are new to most customers, held a rather high level of complexity. It was also suspected that malfunctioning equipment and discontent customers would contribute to unreliable results. A prerequisite was thus that the project should provide the customers with a high level of, active as well as pro-active, support. In addition to the technical installation, mentioned in the recruitment section, the customer support included:

- To confirm correct behaviour, educate and advise customers
- A public web-based information bank easy for the customer to reach (no log-in)
- Customer support fast-lane

The substantial support was both appreciated and utilized by the customers. During the test there was 239 registered customer cases, whereof the steering equipment made up for almost half of the total number of support matters.

Decommissioning of customers
Also decommissioning of customers had to be handled with great care. Not least in order to avoid the risk of discontent customers’ frustration affecting the outcome of the market test. Fortunately the problem was quite the opposite. Even including customers who changed residential address, only very few customers chose to end the market test prematurely. Only one or two customers stated that the reason for leaving was that the market test failed to live up to expectations.

At the general decommissioning, any customer who wished to return the equipment was able to do so. Customers who, on the other hand, wished to continue to monitor their electricity consumption was given the opportunity to keep the equipment for a fee (approximately €10). Customers who had automatic control and price signal during the test, i.e. the first 214 customers to join the test, were able to keep also the control equipment for approximately €3/month. The price signal was however adjusted to conventional electricity spot price and support requests were to be managed by GEAB’s customer service department since the project organization ceased to exist.

RESULTS
In the results section Time period 1 refers to winter 2014/2015 compared to prior to the test, time period 2 refers to winter 2015/2016 compared to prior to the test and period 3 refers to winter 2015/2016 compared to winter 2014/2015.

Consumption Reduction
Variations in overall consumption for the customers that participated in the test can be seen in figure 2 and 3. Please observe that only periods and populations with complete data series are presented, meaning that only 146 (of totally 214) customers with automatic control during time period 1 are displayed in figure 2 and only time period 2 is displayed for the customers that joined in the later stage (figure 3).

The customer with automatic control that counted for the largest increase (no. 146 to the far right in figure 2) almost doubled the power consumption at the same period as another customer (customer no. 1 to the far left in the same figure) decreased the consumption with almost 70%. The population as a whole lowered the consumption with 4% compared to prior to the test.

The customers that lacked the automatic control, as a group, did in fact increase the consumption with 6% the second time period. There are however examples of individual customers that lowered the consumption (customer no. 1, in figure 3, who consumed almost 40% less) as well as increased the consumption (customer no. 22 to the far right in figure 3 that increased with almost 50%).

The average changes in consumption within the different groups and periods can be seen in table 1.

<table>
<thead>
<tr>
<th>Customer group</th>
<th>Average change in consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automatic Control</td>
<td>-4% 1% 6%</td>
</tr>
<tr>
<td>Monitoring only</td>
<td>6% 6% 4%</td>
</tr>
<tr>
<td>Reference</td>
<td>2% 3% 19%</td>
</tr>
</tbody>
</table>

Load Shift
The change in percentage of the total consumption that occurred during the days five most expensive hours gives an indication on how the market test affected the...
customers’ ability to shift load. Table 2 shows the number of customer that lower the consumption during the most expensive hours.

<table>
<thead>
<tr>
<th>Period</th>
<th>Number of customers</th>
<th>More than 5%</th>
<th>More than 10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>146</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>146</td>
<td>30</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>185</td>
<td>87</td>
<td>15</td>
</tr>
</tbody>
</table>

Table 2. The number of customer that, during the test, managed to steer consumption away more than 5% and 10% of their total consumption, respectively.

Lowering of the electricity costs

The number of customers who lowered the electricity costs with more than 10% varied over the time periods. The average change in electricity costs can be seen in figure 4. The result is affected by the drop in electricity price during the test. It should also be noted that the figure includes calculated figures. Differences between calculated and real costs might occur.

![Figure 4. Variation in electricity cost for different customer groups and time periods.](image)

DISCUSSION

Primarily it must be said that the measured data from all the analyzed areas, such as total consumption, load shift and changes in cost is very scattered. Differences between time periods and between test groups (i.e. customers with or without automatic control) is equally scattered. With the rather limited number of customers in mind, this means that all conclusions made from the provided data must be made with great caution. Obviously, the most extreme changes in consumption (such as customer no. 1 and no. 146 in figure 2) is due to considerable changes in family structure (teenagers moving out), house renovation (installation of a spa) or similar and not an effect of the test itself.

Large differences in customers’ willingness to make manual changes to the pre-set control level has also been detected. Differences in heating system, building insulation etc. means that there also are large differences in how big impact deactivated hours has on the total energy consumption and/or electricity cost. From surveys and from personal contacts, it is clear that the test participants have confidence in the automatic control. This is further proved by the fact that manual changes to the control pattern was more common in the beginning of the project.

Regarding residential heating systems, it seems like manual changes to the pre-set control pattern often involves deactivation of hours while the behavior is the complete opposite when it comes to systems for heating of tap water (i.e. manual activation of hours that was deactivated in the pre-set control pattern). Based on the results from surveys this must be regarded as an act of safety precaution since it hardly ever occurred that a customer suffered from a lack of hot water.

Over a length of time it can be observed that customers’ make more manual changes to the control pattern during weekends and that customers with pre-set control level Economy+ makes more alterations to the control pattern than other customers. Ironically, however, is that it seems that highly active customers (i.e. many manual changes to the control pattern) have higher electricity costs than less active customers with the same control pattern. This leads to suspicions that stricter control (i.e. fewer possibilities for the customers to adjust the control pattern) would lead to higher customer satisfaction and higher goal achievement in terms of load shift.

Independently of savings in energy consumption or cost, it can be concluded that the participating customers are very satisfied with the test. Despite the rather high technical level of the equipment and modest savings, only very few customers chose to end the test prematurely, about half of the customers decided to keep the control equipment and almost as many decided to keep the monitoring device, at own expense. Only about 50 customers chose to return all the equipment.

CONCLUSION

It can be concluded that automatic control based on price signals can be used to achieve a load shift from periods of high load to periods of low load, without affecting customers’ comfort. The control of the heating system did contribute to lower households’ general energy consumption but, in order to achieve load shift of +/- 10%, stricter control is needed.