

LOAD FLEXIBILITY OF HOUSEHOLD CUSTOMERS WITH REAL TIME CONSUMPTION DATA AND AUTOMATIC CONTROL OF ELECTRIC HEATING SYSTEMS

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ABSTRACT

Smart Customer Gotland is the market test within research and development project Smart Grid Gotland. The market test comprises almost 300 customers with electric residential heating, such as water boiler, electric heater, direct electric heating, electric floor heating and/or heat pump. About 50 of these customers are, in similarity to the larger part of the group, equipped with technical equipment for real time monitoring of the electricity consumption but lack the additional equipment for control of the heating system. The price signal consists of a reinforced spot exchange price for electric power, time of use grid tariff and a wind component, uniquely designed Smart Customer Gotland, in order to increase the Demand for electricity in situations of high production.

The primary ambition with the market test was to offer a technical and economic solution that attracts a large number of participants. The market test should give an active customer possibility to save money by shifting load towards periods when electricity are cheaper. The 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 started in late autumn 2013 and has, according to midterm analyses, so far been a veritable success. It still is too early to make statements on changes in consumption on a household level. But on an aggregated level it is clear that the consumption is both lowered and has shifted towards low price periods. The involvement and appreciation of the participating customers has exceeded every expectation. 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.

This paper will discuss the market test from a load flexibility view point - how to attract, maintain and decommission active customers and expected level of activity of different categories of customers. The paper will also include positive experiences, such as sudden increase in customer satisfaction index, and challenges, such as high demand for technical support.

INTRODUCTION

Smart Customer Gotland is 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, on a deregulated market, to a modern smart grid.

The overall objectives of the project is to:

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

Where the first and, especially, the third project objective are handled by Smart Grid Gotland and carried out as a market test called Smart Customer Gotland.

Smart Grid Gotland and its subprojects are conducted as a consortium between GEAB, 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 Authority.

Smart Customer Gotland

The initial idea behind the market test was to incite customers to turn on large electricity consuming equipment during periods of high load and low demand by use of price signals. 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 are 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 September 2013 and will be concluded in December 2016. There are considerable variations between households participating in the Smart customer Gotland This article will discuss shifts and

changes in consumption patterns on an aggregated level.

METHOD

In order to meet the project objectives, it was clear that the market test needed to focus 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 for the market test. To reach an acceptable number on participants in the market test was also 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 for customers who lives in detached houses on Gotland was switched to hourly resolution. An eventual change in consumption behaviour will 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.gotlandenergi.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 on customer evens 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 where 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 months later an additional 50 customers entered the test. Customer who enter in the later stage, was offered a slightly reduced technical installation which did not include the automatic control or the price signal.

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 clearness.

Technical Platform

The fact that Smart Customer Gotland involves real customers, installations and, not least, customers' real electric bill must be reflected and respected. This especially concerns the choice of technical platform, which should 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 three commercial products - Energy Watch, Smart Plug and Smart Temp - was after some adjustments considered the best technical set-up for the test.

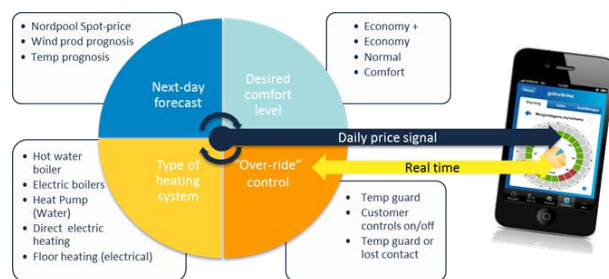


Figure 1. The technical platform in the market test is based on several commercially available products and can control a large range of different heating systems. The price signal is visualized by use of a Smartphone application, which is also used for control of the heating system.

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 comprises 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 and workdays between 6am and 22pm
3. A wind component, unique for Smart Customer Gotland

The wind component is a special discount when forecasts suggest 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 is limited to a maximum of 30 days per year and customers can chose to have day-ahead information about the wind discount by use of smartphone application push notices.

Each customer can 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)
- Economy+ (an extra high level to meet the need of customers who manually steered away additional consumption from high load hours on an regular basis and/or customers who leaves the house during longer periods)

By use of the smartphone application, every customer have the possibility to make changes to the pre-set levels by either activate or deactivate hours in the pre-set scheme.

Maintaining customers

Simplicity and user friendliness is 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, holds a rather high level of complexity. Malfunctioning equipment and discontent customers will furthermore contribute to unreliable results. A prerequisite was thus that the project should provide the customers with a high level of support, both actively (i.e. to respond to customer's needs) and pro-actively (i.e. to detect and attend problems before the customer becomes aware). 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 login)
- Customer support fast-lane

The substantial support has been both appreciated and utilized by the customers. Since the start of the market test, in 2013, there has been 239 registered customer cases. The steering equipment was the single most common cause for support matters, constituting almost half the total number of customer cases, and twice as common, than the closest follower. The second and third most common customer case included questions about specific parts of the technical equipment and questions regarding the installation respectively. Among the technical equipment the Energy Watch cared for the highest number of customer cases (51) followed by the temp-sensor (14). Only three customers raised questions regarding the price signals and, even more positive, only six customers asked about decommissioning (whereof two discussed changing residential address).

Decommissioning of customers

Also decommissioning of customers must be handled with great care. Not least in order to avoid the risk of discontent customers frustration affects the outcome of the market test. Fortunately the problem has been quite the opposite. Even including customers who changed residential address, only very few customers have chosen 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 wish to return the equipment will be able to do so. Customers who, on the other hand, wish to continue to control their electricity consumption have the opportunity to keep the equipment. Customers who had automatic control and price signal during the test, i.e. the first 214 customers to join the test, will be able to keep also the control. The price signal will however be replaced with a conventional electricity price. Support requests will be managed by GEAB's customer service department when the project organization cease to exist.

RESULTS

Comparisons with the electricity consumption of the same group of customers from periods prior to the market test, seen in figure 2, suggest a general reduction of the power consumption.

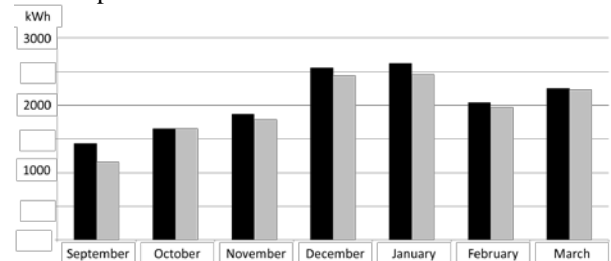


Figure 2. Comparison between the total power consumption per month, from September to March. Darker bars represent 2013 (prior to the test) and grey bars represent 2014 (during the test). Values are adjusted for differences in ambient temperature. Please note that the result for October is uncertain due to lack of measurement values.

The result is even more clarified when focusing on only the five most expensive hours during the day. Prior to the test, an average of 22.6% of the total consumption was carried out during the five most expensive hours during the day. During the first and second year of the test this figure was lowered to 18.9% and 20.4% respectively.

In a questionnaire handed out to the participants a vast majority of the customers stated that their own general energy consumption behaviour had been affected by the test (figure 3).

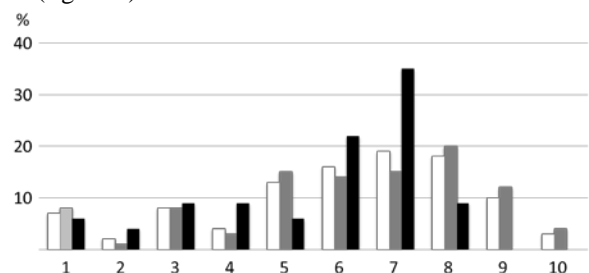


Figure 3. Answers to the question: "To what extent have your general energy consumption awareness changed since you entered the market test? "Awareness" meaning energy efficiency in general, not only manual changes to

the pre-set control levels (scale between 1= very little and 10 = very much)". Where grey bars correspond to the first group of 214 customers that entered the test, black bars correspond to the group with slightly limited technical set-up that joined later and white bars is the whole group together.

On another place in the same questionnaire, where each customer was asked to value a presumed changes in energy cost since the project start, almost 45% stated that the energy cost had decreased. However, 5% stated that the cost had increased and half of the group experienced no change at all or did not know (figure 4).

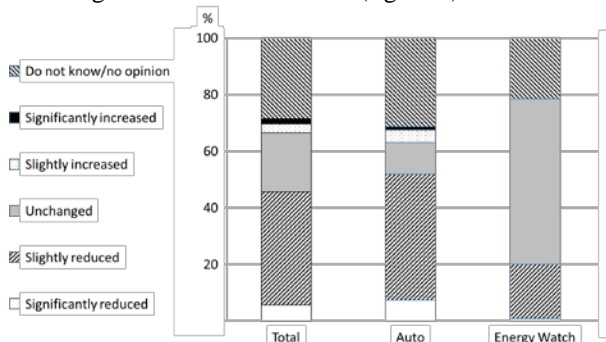


Figure 4. Answers to the question: "To what extent has the household energy costs changed since the start of the project?". Auto corresponds to the first group of 214 customers that entered the test and Energy Watch corresponds to the group with slightly limited technical set-up that joined later.

DISCUSSION

Although too early to make definite statements about customers' behaviour on an individual level, it is clear that most of the project objectives has been met.

High comfort and simplicity was identified as important prerequisites in order to achieve an efficient load shift. In the beginning of the market test a very high percentage (up to 70%) of the customers made manual adjustments to the pre-set control scheme. This figure is however declining, suggesting that most customers is comfortable and satisfied with the number and levels of the control schemes. A small number of customers are still making many manual alterations but an increasing number of customers states that they never use the smartphone application at all. A few interesting observations, so far, are that:

- The most common manual adjustment to the pre-set control scheme, during week days, is to disconnect hours during the following day
- Manual adjustments within current hour are very rare
- It is more common to reconnect consumption during weekends
- Water boilers are more frequently reconnected

- than systems for residential heating in general
- Spot price might be slightly too complicated for an arbitrary electricity customer and could possibly be replaced entirely with a time of use tariff.

The market test proves that price signals incite customers to turn off large electricity consuming equipment, i.e. shifting load from periods of high load to periods of lower load. The opposite, to increase the consumption during periods of low load, which is equally important from a grid stability perspective, has proven much more difficult to achieve.

Installation and customer support

Installation of the technical equipment and customer support was identified as a great challenge, but also a major contributor to the largest unexpected benefits of the project. One of the objectives of Smart Customer Gotland was to conduct a market test under market driven conditions. It is however clear that simply the cost savings achieved by a shift of electricity consumption cannot justify the cost of either the installation or the customer support. It is thus questionable if the conditions was really market driven. A very much simplified and streamlined process is needed in a full scale implementation.

The technical installations of the control and visualization system in households were carried out by the distribution system operators (GEAB's) own service personnel, the technical equipment used in the project, although slightly adjusted, is readily available from the GEAB/Vattenfall web shop and the price signal is delivered from GEAB to the customer, on the ordinary electricity bill. Taken together, this had the unexpected benefit that many customers were unaware of that they participate in a test project. Some customer has not paid attention to the technical equipment even once since the installation, which suggest a much normalized relation to the market test and consequently high expectation that the acquired data is reliable.

The possibility to become active on the electricity market, the positive reception by the customer support as well as prompt response to eventual problems (in combination with very low electricity prices) has led to an unexpectedly high increase in customer satisfaction index. The customers are in fact so satisfied with the market test that it is believed to be the reason for the whole company's leap in customer satisfaction index to, astonishing, 77.9.