SUBSCRIBED POWER – TESTING NEW POWER BASED NETWORK TARIFFS STIMULATING FOR DEMAND RESPONSE

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ABSTRACT

This paper describes results from the national research and demonstration project DeVID (Demonstration and Verification of Intelligent Distribution Grids) in Norway. The project aims at demonstrating new smart grid technologies and methods for distribution networks, including how Demand Response can be realized through economic incentives, technologies and a new network tariff called "Subscribed power".

Results from the testing of the network tariff "subscribed power" at household customers in two different locations in Norway are described in this paper.

NOMENCLATURE

DR – Demand Response
DeVID – Demonstration and Verification of Intelligent Distribution Grids
DSO – Distribution System Operator
FEAS – Fredrikstad Energi AS (DSO)
NTE – Nord-Trøndelag Elektrisitetsverk (DSO)
ToD – Time of Day

INTRODUCTION

Demand Response (DR) is a response involving load reduction of limited duration in case of generation and/or capacity shortage in the electricity grid. DR is an important part of the development and deployment of Smart Grids technologies and solutions, supporting the vision of a sustainable and reliable future energy system with an increased share of intermittent renewable electricity generation and peak load capacity required for relatively few hours.

Smart meters are a key enabling technology for Smart Grids, and will be installed to all the Norwegian customers within January 1. 2019 – earlier compared to most of Europe (80% by 2020, 100% by 2022).

Investment needs of 100-140 billion NOK[1] are identified in the Norwegian power system for the period 2012-2021, of what 51-68 billions are expected to be invested in the distribution grid. New knowledge and technology contributing to smarter operation and investment are important and DR can be a cost-efficient alternative to traditional grid investments.

In Norway a lot of electricity is used for heating – both heating of tap water and space heating. For an average customer heating represents approx. 80% of the total yearly consumption (See Fig. 1) – representing a large potential for end-user flexibility.

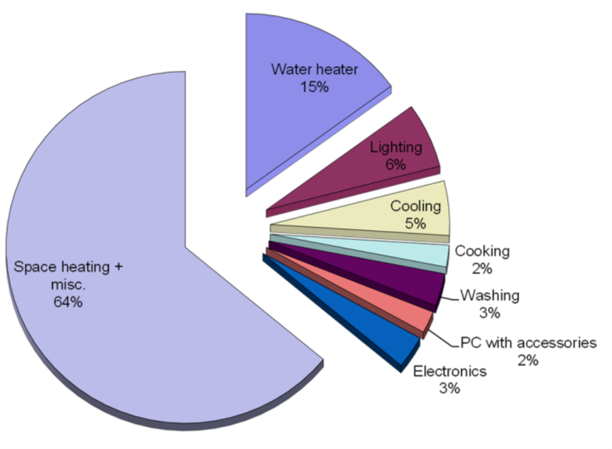

Fig. 1 Electricity consumption for an average Norwegian household customer, divided into different end-uses [1].

The trend in electricity consumption is towards more energy efficient appliances, but with increased power consumption (e.g. electrical vehicles, induction cookers,

[1] 1 Euro = approx. 8 NOK

instant water heaters, etc.). Future active customers can have facilities for controlling their consumption, local generation and storage of electricity. This provides the customer with flexibility in terms of demand and also to some extent supply.

The potential for demand response based on different incentives towards the customers have been tested in the DeVID project and in previous research project.

One example of a previous test is a Time of Day (ToD) energy tariff combined with remote load control from the research project "Market Based Demand Response" [2]. The ToD energy tariff had predefined periods (workdays 08:00-10:00 and 17:00-19:00) with high prices. The price level of the different parts was calculated in a way that gave the "average" customer the same costs if she/he did not change the consumption pattern. The customer then had an incentive to reduce consumption in the predefined peak price periods.

Results from other research projects are described in [3]. The results from the DeVID project are described in this paper.

RESEARCH PROJECT

The DeVID project aims at demonstrating new smart grid technologies and methods for distribution networks.

In order to investigate how DR can be realized through economic incentives combined with technologies, the project has explored the use of a new network tariff called "subscribed power". The network tariff was used in a field trial at two different demo sites (NTE/Steinkjer[2] and FEAS/Hvaler[3]). Both demo sites have household customers equipped with smart meters for hourly metering of their electricity consumption.

The field trial in Steinkjer is a part of Demo Steinkjer. The pilot area is in the city of Steinkjer, located about 120 km north of Trondheim. Hvaler municipality is located on an archipelago of islands in South-eastern Norway. Hvaler is a part of Smart Energy Hvaler.

Both areas are used as "living labs" for Smart Grid activities.

The objective of the testing was to study to what degree and in which way a new network tariff combined with visualization technologies could provide DR from residential customers, as an alternative to grid investments. The network tariff was tested in 2014.

The network tariff "Subscribed power"

The objective of this network tariff was to stimulate to a smoothening of the consumption for the residential customers [3]. The network tariff honours moderate and levelled consumption patterns below a certain threshold, and flexible loads should be shifted in order to reduce the peak load for the customer.

The network tariff consists of a fixed part (The level of subscribed power), one variable part (The price per kW) and authority taxes (NOK/kWh).

The variable part is only activated if the hourly consumption is higher than the subscribed power level.

The actual tariff parts applied in the two test sites are shown in Table 1.

Table 1 Prices of the fixed part and k_1

	Fixed part [NOK/kW]	Variable part [NOK/kWh/h]
Steinkjer	750	7
Hvaler	500	10

Initially the households participating in the test had a network tariff with an energy part [kWh/year] and a fixed part [NOK/year]. The new tariff was designed to give unchanged costs for an average customer. The energy consumption per hour ([kWh/h]) was used as the basis for settlement of the consumption.

Based on the duration curve of the consumption for an average customer (Fig. 2), it was suggested to set the level of subscribed power approx. 70% of maximum hourly consumption in the previous year. For the duration curve presented in Fig. 4 this level will be exceeded about 200 hours during a year.

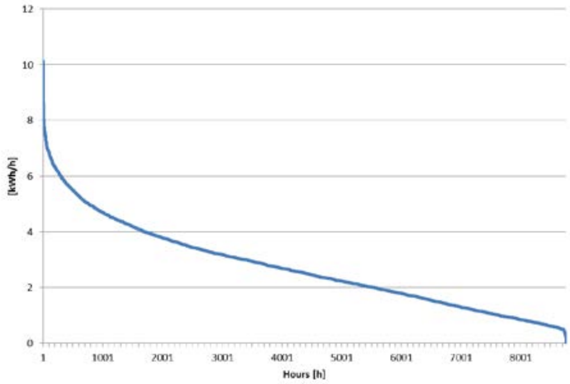

Fig. 2. Duration curve for a household customer

The customer pays extra for hours when the consumption is higher than the subscribed power. An example is presented in Fig. 3, where the straight line (green) is the subscribed power and the changing curve (blue) is the consumption. The customer pays extra for all hours where the blue curve is higher than the green line.

[2] www.demosteinkjer.no
[3] www.smartenergihvaler.no

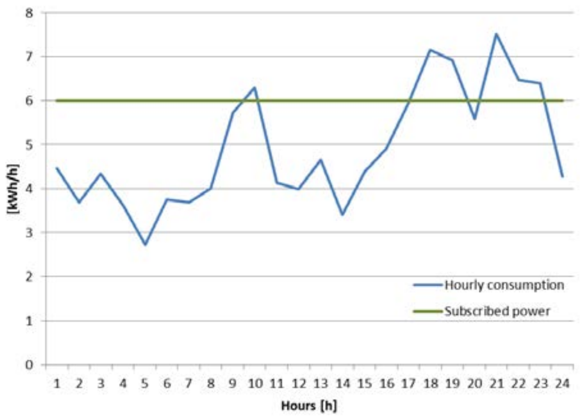

Fig. 3. Hourly consumption and subscribed power

This network tariff gives incentives for load reduction independent of the time when the consumption occurs. The tariff for subscribed power will in general overstimulate DR – and give incentives for load reduction also in periods when the benefit for the grid is limited.

The pilot test

In total 48 residential customers participated in the pilot test (See Table 2). To compare the results from the test group records from 30 regular subscribers were selected at random from the customer base at both Hvaler and Steinkjer. These customers constituted the control groups.

Table 2 Residential customers participating

DSO	Test group	Control group
NTE/Steinkjer	23	30
FEAS/Hvaler	25	30

Despite the challenge to explain the structure of the tariff to households that previously have focused on energy consumption, the participants were very interested. In the pilot tests the households received technology which made them able to follow the actual power consumption in their house.

For the households to be able to monitor their use of electricity, visualization technologies were offered together with the new tariff. In one test site (Steinkjer), a web-based system for continuous monitoring of both aggregated and specific electricity loads was introduced. In the other site (Hvaler) the participants were given a simple handheld display that allowed them to monitor their aggregated and hourly meter value.

The web based system allowed the user to monitor the loads of different appliances, each one plugged into sockets controlled by the system. Power and aggregated consumption expressed in terms of kWh/h and kWh as well as costs, were displayed by means of simple graphics on a PC or tablet. The handheld display communicated with the smart meter and showed only aggregated values. However, load changes due to changes in energy use were projected instantly on the display.

METHOD OF APPROACH

Candidates for the new tariff were recruited on ordinary business terms. General information about Smart Grids, new meters and potential benefits were communicated up front to establish a context. This was followed up by a direct mail campaign describing an opportunity to try out a new tariff for a limited period. 230 and 379 subscribers received this at Steinkjer and Hvaler respectively. All of them had documented annual consumption higher than the national average of 15 000 kWh over the past few years.

The mail was followed up by physical meetings where great care was made to explain the new tariff in simple and straight forward terms. It was also explained that the number of test users were limited due to limited numbers of technical equipment. Test users at Steinkjer would borrow equipment while the same group at Hvaler would receive the display as a compliment if they changed to the new tariff. This resulted in full quota of test subjects in both regions. 36 signed on at Steinkjer and 66 at Hvaler. Members of the final groups were selected at random among the candidates. It should be noted that in both regions the average candidate was a typical a male between 45-60 years.

The new tariff was introduced at Hvaler in February 2014. Start-up at Steinkjer followed Hvaler by a few weeks. The first phase completed at May 31, 2014. Throughout the test period proper support was provided. Technical issues associated with the communication between the displays and the meters had to be sorted out early. However, invoicing proceeded according to plan and customers followed up accordingly. During the whole period subscribers had an open line to the DSO, either by phone or internet. Representatives from the DSO were also careful to build confidence from the beginning to the end of the trial.

Data were analysed on a continuous basis. At the end of the trial period the full set of records from the test groups were processed together with those of the control groups and compared with records from the year before. The average temperature during the test period was 4.2 °C (Hvaler) and 3.2 °C (Steinkjer) higher than during the same period in 2013. The necessary temperature corrections were made for all 2014 records to enable comparison with data sampled from 2013.

Once the final results were available interviews were conducted with customers who demonstrated reductions in both peak loads and overall consumption from 2013 to 2014.

RESULTS AND DISCUSSION

Hourly metering values and cost accounts was analysed for each participant and compared with hourly records for the winter 2013, and also with control groups in each region. The results were very encouraging. All participants could document significant energy reductions as well as lower power peaks compared to the year before. As an example meter values from one subscriber is shown in Fig. 4 It can be observed that meter values for the test period in 2014 are lower than for the same period in 2013.

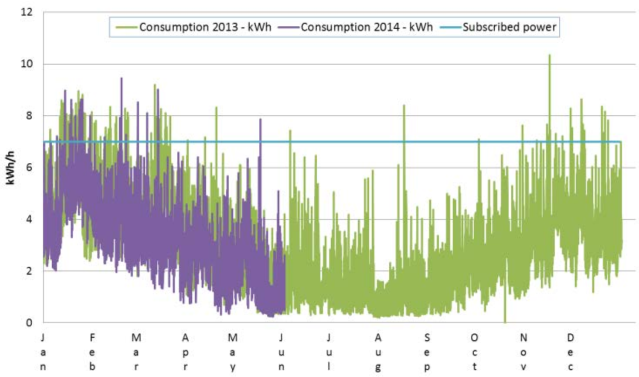

Fig. 4 Hourly meter values for a residential customers. Values from 2014 compared with 2013.

The overall results can be deduced from the histogram in Fig. 5. The X-axis shows different levels of savings even negative ones (increases). The bars indicate how many customers that achieved a specific level of reduction. The level of response varied among the two test groups with some interesting outliers in both areas.

A small subset of the two test groups accounted for very significant reductions in terms of energy use, reduced peak loads and costs. This contributed to a very high average reduction – more than 20% for the group at Hvaler. However, the average at Hvaler was much less, because a few customers increased their consumption.

The median for both test groups show savings in the range of 12-15% which is still substantial. This shows that the bulk of the test groups did indeed account for a substantial reduction.

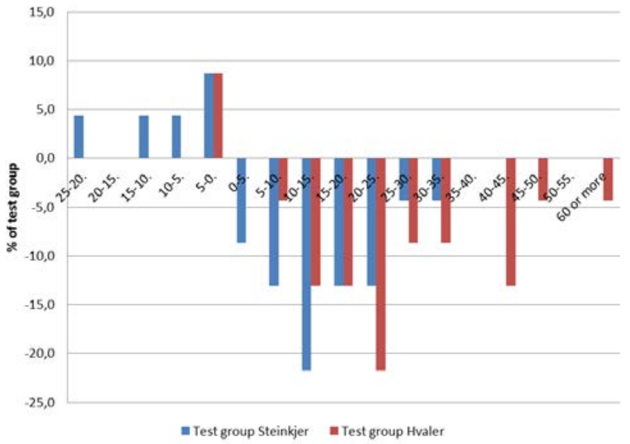

Fig. 5. Histogram representing the results (X-axis) for the households in the test groups at both Steinkjer (blue) and Hvaler (red)

Despite variations, more than 85% of the participants in both regions could document a net reduction. Some could even document savings of 40-50 % where electric space heating had been replaced by other heating sources (i.e. wood).

Despite variations in performance among members of the two test groups, they all came out significantly better than the control groups which were exposed to the regular tariff. When corrected for temperature none of the control groups showed any change.

The average results for the whole test period (6 months) and for the winter period are presented in Table 3.

Table 3 Test results – reduced consumption ([%])

		Test group		**Control group**	
		Actual	**Temp. Corr***	**Actual**	**Temp. Corr ***
NTE	2014	-9,7	-1,0	-6,3	+2,4
	Winter**	-14,8	-5,3	-9,2	0,0
FEAS	2014	-27,6	-19,6	-5,2	+7,6
	Winter**	-26,3	-16,3	-5,6	0,0

* Values corrected for different temperatures
** Winter period: 15 January – 1 April 2014

Although focus was on power peaks, the reduction in overall consumption is clear. This may be due to two reasons. One explanation is that decreased consumption is an immediate side-effect of an endeavour to balance out the peaks. Another explanation is that general reductions lead to peak shavings as well as decreased overall consumption. The latter seems to be the most probable. When interviewed after the trial period test users still demonstrated significant ignorance about the tariff itself. True understanding of power peaks still varied after the test. In fact, those interviewed were not particularly conscious about the magnitude of their overall reductions or the reasons for these. This seems odd given the reduction recorded. It might seem that the whole process around the recruitment, the contact with the grid company's representatives, information and support provided in association with the new visualisation tools had unleashed initiatives to just figure out where in the household energy was used.

The customers behind the records on the far right of the diagram (Fig. 5) accounted for such significant reductions that it was suspected that they had swapped to non-electric heating while being part of the test. This proved to be a false interpretation. Increased consciousness of general energy use and more focus on consumption seems to be the common denominator, although explanation varies.

A case in point is the person who accounted for the greatest reduction: As an owner of a large house with an electric boiler in the basement the process had stimulated an interest in the technical systems of the house. He began to study the piping and his twin-element boiler. The latter systematically tested out the branching. He realized that his system was heating areas that were not used and that only one boiler element needed to be used to maintain the necessary temperature around the house.

This saved a load of 4 kW. He also found that there was something wrong with his electric heated floor. By the help of his display he also realized that it would be fruitful to run only one major household appliance at a time. In 2014 the washing machine and the dishwasher was not used at the same time.

From the interviews we can settle that improved knowledge about their appliances' impact on the consumption had made people make minor or more significant changes to their heating and lighting practices. What is striking about these interviews is that none of the “reduction winners” were particularly aware of what new measures they had introduced to earn their savings. When shown their personal records most of them had to think carefully about what initiatives they had made. A few seemed to be almost unconscious about any change at all. In a particular case the subject felt even intimidated while interviewed as he insisted that very little had changed. In fact he seemed to resent the whole concept. Still his savings were close to the median. For the subjects represented on the negative side of the X-axis in figure 7 additional insight had been established. In the general case most of these claimed that the new tariff and the process around had helped them to change some habits.

In one case the recorded increase could be attributed to additional use of the premises. Originally a non-permanent residence, the house was used more in 2014 than before due to a change in life situation. Other increases were due to more people having moved in i.e. a family member or a tenant. A new member in the household is likely to increase consumption and therefore zero out minor efforts to change former energy routines.

Economically most of the subscribers came out well with the new tariff compared to the old one. Average economic savings among the test group at Hvaler were €62,5. A few would have spent up to €136 more had they stuck with the old tariff, despite their effort to reduce power peaks. Obviously the mild winter helped to ensure such a result. A very mild winter followed by a very cold season the year after could imply a different economic scenario. The reason, of course being that the base load related to space and water heating will increase and therefore push energy use related to daily chores upwards and more often beyond the subscribed limit. This must be assessed very carefully. Some of the test subjects did not benefit economically.

To sum-up this paper, the field trials with the "Subscribed power" network tariff tested at both Steinkjer and Hvaler show that a network tariff gives incentives for DR. During the field trial a reduction in power consumption of 5,3% (NTE) and 16,3 % (FEAS) were achieved.

When the results of the test are assessed against the interview it is clear that the introduction of the tariff and the visualization tools have had an impact. However, we suspect that most of the overall decrease can be attributed to the overall process that has taken place where closer contact between grid company and the customer has led to a kind of solidarity and more interest in the technical sides of their residence.

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