NETWORK TARIFFS AND ENERGY CONTRACTS WITH INCENTIVES FOR DEMAND RESPONSE

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ABSTRACT

This paper presents principles related to different pricing incentives tested in previous, ongoing and newly started research projects, with main focus on the structure of the network tariff. The costs customers pay for access to the power system for use or feed-in of electricity, is decided by the costs of different energy contracts, network tariffs and taxes. The optimal segmentation of the different elements and the differentiation of these depend on the actual purpose of the incentive.

Three examples of different pilot studies are described, to show alternative for both differentiation and segmentation.

NOMENCLATURE

AMI	Automated Metering Infrastructure
BEMS	Building Energy Management System
DSO	Distribution System Operator
FEN	Fredrikstad Energinett (DSO)
FERC	Federal Energy Regulatory Commission
NTE	Nord-Trøndelag Elektrisitetsverk (DSO)
NVE	Norwegian Water Resources and Energy Directorate (Regulator)
ToD	Time of Day

BACKGROUND

New technology such as smart meters (Automated Metering Infrastructure – AMI) gives possibilities for developing new network tariffs. Usually the tariff contains several parts, and how these parts are structured and differentiated, depend on the purpose of the tariff. What incentives should the tariff give?

EU has required that 80% of the customers should have smart meters installed by 2020 [1]. In Norway the requirement is that smart meters should be installed to all customers by 1.1.2019.

The functional requirements for Norway are that the smart meter should: [2]

- Store the meter data with a registration frequency of a maximum of 60 minutes. It should be possible to change the registration frequency to a minimum of 15 minutes.
- Have standardised interfaces that allow for communication with external equipment based on open standards.
- Be able to connect different types of meters (gas, heat, water, etc.).
- Secure data storage in case of voltage outages.
- Disconnect or reduce ("electrical fuse") the total load at the customer, except customers metered with a transformer (large customers).
- Send and receive price information (from energy contracts and network tariffs) and signals for load control and earth fault detection.
- Provide security against misuse of data and unwanted access to load control functionalities.
- Meter both active and reactive power – in both directions (in/out).

During the last years there has been a trend towards use of new appliances that are more energy efficient, but at the same time have a higher peak power demand and higher variability in the electricity demand than previously experienced. Examples of such appliances are electrical vehicles, instantaneous electric water heaters, large heat pumps and induction cookers. In the future there will be larger variations between customers, where some will be more active with regards to consumption, production and storage of electrical energy.

In the years to come large investments in the power grid are expected, both related to installation of smart meters and reinvestments of ageing network components. In Norway the investments in the distribution grid for the period 2012-2021 are expected to be 35-50 billion NOK (4.4-6.3 billion €), including AMI [3]. The DSOs are responsible for handling these investments.

Bottlenecks in the distribution grid can be solved by investments in the grid, in order to make it always capable of handling the peak load. But if the peak load is continuously increasing, it is not necessarily socio-economic optimal to upgrade the grid capacity to handle the peak. Reducing the peak load trough demand response/load shifting might be a better alternative, incentivized through e.g. new network tariffs and dynamic price signals.

FERC[1] (USA) has defined demand response as:
Changes in electric usage by demand-side resources from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized.

In the Norwegian deregulated power system the DSO and the power retailer are two separate entities. The DSO is a monopoly, regulated by the authorities through NVE. The power retailers are market players. This organisation implies that all customers have two separate contracts: one for their use of the grid and one for their energy use [4].

The energy contract is between the power retailer and the final customer. The power retailers are free to develop various types of contracts to the final customers, for example fixed energy price for a defined period of time or a spot related price. In the long run the cheapest product will be an energy contract consisting of the hourly spot price, the mark-up paid to the power retailer and the taxes (VAT, etc.) [5].

The design of the network tariff is governed by the monopoly regulation. In Norway revenue cap regulation is used, where the Regulator (NVE) sets the maximum allowed revenue for each company.

The paper described principles related to different pricing incentives from previous and ongoing research projects, with main focus on the structure of the network tariff, and sums up the experience of what has been tested and for which purpose.

PRICING INCENTIVES

The costs customers pay for access to the power system for use or feed-in of electricity, is decided by the costs for different energy contracts (market based), network tariffs (monopoly) and taxes. In principle the network tariff can consist of different parts (energy, power, reactive power, firm part etc.) and the parts can also be differentiated based on time, customer type, load type etc.

1 https://www.ferc.gov/industries/electric/indus-act/demand-response/dem-res-adv-metering.asp

The optimal segmentation of the different elements and the differentiation of these, depend on the actual purpose of the incentive.

In the following sections three examples of different pilot studies are described.

For all the different network tariffs tested out in different research project, a special allowance from the Norwegian regulator NVE has been required.

Examples from different pilot studies

Remote load control and Time of Day (ToD) energy tariff

In the research project "Market Based Demand Response", a ToD energy tariff was tested among 41 household customers [6]. The ToD tariff consists of a fixed part, one part covering the network losses and one part with high price in the expected peak hours on working days.

The equation describing this network tariff is as follows [7]:

$$C_{EN} = \beta_{EN} + \gamma \sum_{d=1}^{365} \sum_{t=1}^{24} p^s_{d,t} W_{d,t} + \sum_{d=1}^{365} \sum_{t=1}^{24} \alpha_{d,t} p^* W_{d,t} \quad (1)$$

Where:

C_{EN} The costs with a ToD energy tariff [NOK/year]
β_{EN} Fixed part [NOK/year]
γ Marginal losses (part of $W_{d,t}$)
$p^s_{d,t}$ Spot price [NOK/kWh/h]
$W_{d,t}$ Energy consumption per hour [kWh/h]
$\alpha_{d,t}$ Factor used to make the variable energy part active/inactive (0/1). $\alpha_{d,t} = 0$ in defined off peak hours, and $\alpha_{d,t} = 1$ in defined peak hours.
p^* Price per kWh [NOK/kWh/h]

The energy part ($W_{d,t}$)was active 08:00-10:00 in the morning and 17:00-19:00 in the afternoon on work days. The customers got three small tokens, "El-button", to be reminded about the peak load periods to reduce their consumption in these periods.

The price level of the different parts is calculated in a way that gives the "average" customer same costs if she/he does not change the consumption pattern. The customer then has an incentive to reduce consumption in predefined peak price periods [8].

This ToD energy tariff has the following benefits [8]:

1. The ToD tariff provides the customer with a reliable and predictable price signal. The customer knows when the peak price periods occur.
2. Customers who reduce the load in peak hours are favoured by lower network costs because of reduced need for grid investments and lower marginal network losses.
3. The ToD tariff gives incentives to load reduction in all of the peak hours, since the customers pay for the actual consumption in each hour.

In this pilot test the network tariff was combined with an energy contract with the spot price on an hourly basis, resulting in a dynamic, but predictable price signal to the customers (See Fig. 1).

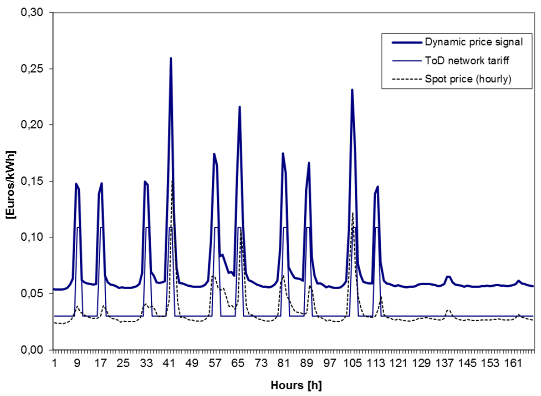

Fig. 1. Dynamic price signal to household customers (week 6-2007) [6]

ToD power tariff for an industrial customer

In the "Marked Based Demand Response" project a ToD power tariff was tested at an institution with Building Energy Management System (BEMS) for controlling the loads. The building used electricity for heating, representing loads suitable for demand response.

The ToD power tariff consists of three parts. The first is a fixed part for covering customer related costs, the second part is an energy part for covering network losses and the third part is for covering peak power payment.

The equation describing this network tariff is as follows [7]:

$$C_{EFF} = \beta_{EFF} + \gamma \sum_{d=1}^{365}\sum_{t=1}^{24} p^{s}_{d,t}\, W_{d,t} + \sum_{d=1}^{365}\sum_{t=1}^{24} \alpha_{d,t}\, \Gamma_{d,t} P_{d,t} \quad (2)$$

Where:

C_{EFF}	The costs with a ToD power tariff [NOK/year]
β_{EFF}	Fixed part [NOK/year]
γ	Marginal losses (part of $W_{d,t}$)
$p^{s}_{d,t}$	Spot price [NOK/kWh/h]
$W_{d,t}$	Energy consumption per hour [kWh/h]
$\alpha_{d,t}$	Factor used to make the variable energy part active/inactive (0/1). $\alpha_{d,t} = 0$ in defined off peak hours, and $\alpha_{d,t} = 1$ in defined peak hours.
$\Gamma_{d,t}$	Price per kW [NOK/kWh/h]
$P_{d,t}$	Power consumption in defined period [kWh/h]

The peak power payment part is only valid in defined peak periods (hours 08:00-11:00 and 17:00-20:00 on working days 1. Oct. – 31. March). The settlement of the peak payment is based on the average of the three hours with highest consumption in the peak periods.

This ToD power tariff has the following benefits [8]:

1. Customers who reduce the load in peak hours are favoured by lower network costs because of reduced need for grid investments and lower marginal network losses. The customer does not have to pay extra if the peak load occurs outside the peak hours.
2. With use of the average of three peak values for settlement, the customer still has incentive to reduce the consumption even if a peak hour has occurred earlier during the month.

Peak load reduction – Subscribed power

In an ongoing research project (DeVID – Demonstration and Verification of Intelligent Distribution grids) a network tariff stimulating to peak load reduction at residential customers will be tested. The background of this test is to study if a new tariff can provide demand response from residential customers, as an alternative to grid investments [8].

The DeVID project aims at demonstrating new smart grid technologies and methods for distribution networks [9]. The test will be performed in 2014 among residential customers located both at NTE/Steinkjer (Mid Norway) and FEN/Hvaler (Eastern Norway), and the objective of the test is to show how new and more customer oriented price signals can contribute to demand response and price elasticity in the power market.

The objective of this network tariff is to stimulate to a smoothening of the consumption for the residential customers. 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 (øre/kWh).

The equation describing this network tariff is as follows:

$$C_{SP} = k_0 + T\sum_{d=1}^{365}\sum_{t=1}^{24} p_{d,t} + \begin{cases}(p_t - p_{subscribed})\cdot k_1 & p_t > p_{subscribed}\\ 0 & p_t < p_{subscribed}\end{cases} \quad (3)$$

Where:

C_{SP}	The costs with a network tariff with subscribed power [NOK/year]
k_0	Fixed part (specific for the agreed subscribed power) [NOK/year]
T	Authority taxes [NOK/kWh]
p_t	Electricity consumption per hour [kWh/h]
$p_{subscribed}$	Subscribed power level [kWh/h]
k_1	Power price for consumption larger than the subscribed level [kr/kWh/h]

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 developed to give unchanged costs for an average customer. The energy consumption per hour will be used as the basis for settlement of the consumption.

Based on the duration curve of the consumption for an average customer (Fig. 2), it is suggested to set the level of subscribed power approx. 70% of maximum power: For the duration curve presented in Fig 2 this represents about 200 hours during a year.

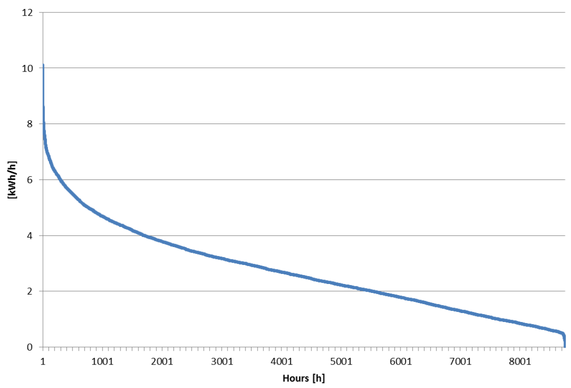

Fig. 2. Duration curve for a household customer

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.

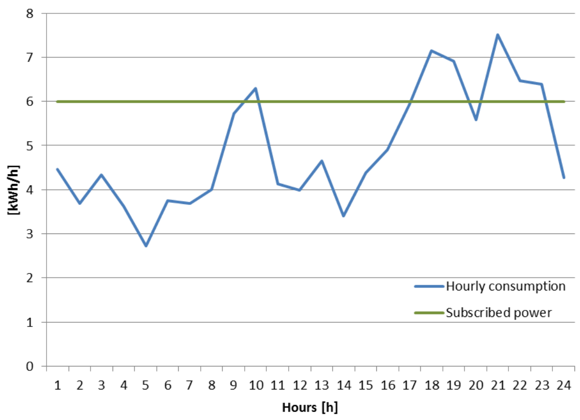

Fig. 3. Hourly consumption and subscribed power

This network tariff gives incentives for load reduction independent on the time when the consumption occurs. The tariff for subscribed power will unfortunately over stimulate demand response – also in periods when the benefit for the grid is limited.

In total 55 household customers participates in the pilot test. Despite the challenge to explain the structure of the tariff to households that previously have focused on energy consumption, the participants are very interested. In the pilot tests the households received technology which makes them able to follow the actual power consumption in their house. Some customers are very active to achieve demand response.

The winter 2013/2014 has not been as cold as usual, which will give an extra challenge when calculating the benefit of the new network tariff with subscribed power.

SUMMARY

Three different network tariffs from different pilot tests have been described in this paper. The common objective of these tariffs is to stimulate to demand response, but in different ways.

The ToD tariffs (both energy and power) give the customers incentives to reduce the consumption in peak price periods. In this case the peak price periods were defined when the peak load periods in the power system occurs, to reduce peak load and thereby reduce network losses. The network tariff with subscribed power gives incentives to reduce the peak load in all hours – independent on the actual situation in the power system.

With the ToD energy tariff and the network tariff with subscribed power the customer pays for the consumption in each hour. With the ToD energy tariff the customer has incentive to shift load from peak periods, but with the subscribed power tariff the customer has incentive to smoothen out the consumption. If all customers have the subscribed power tariff the coincidence load will also be smoothen out and network losses will be reduced.

A disadvantage with the subscribed power tariff is that the customer has to pay extra if the consumption exceeds the subscribed level – even if this happens during low load periods in the power system.

CONCLUDING REMARKS

This paper presents work from both previous and ongoing pilots in research project, where focus is on incentives stimulating to demand response.

Pilot studies have shown that the different elements in network tariff and energy contract can be differentiated to stimulate to different alternatives of demand response.

Traditionally, the grid capacity has been upgraded when bottlenecks occur, but this is not necessarily always socio-economic optimal. New technology such as smart meters will enable new services towards the customers, and allow for new incentives with at least hourly resolution.

A new research project "Smart Tariff" (2014-2017), will focus especially on network tariffs and discuss how these can be structured to achieve different purposes.

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REFERENCES

[1] R. Hierzinger, *et al.*, "European Smart Metering Landscape Report 2012 –update May 2013," 2013.

[2] *FOR-2013-06-19-663, Forskrift om måling, avregning og samordnet opptreden ved kraftomsetning og fakturering av nettjenester,* *http://lovdata.no/dokument/SF/forskrift/1999-03-11-301*, 2013.

[3] P. Sanderud (NVE), "Utfordringer i bransjen (Challenges in the power business)," presented at the KS Bedriftenes Møteplass 2013, http://ks.event123.no/ksb2013/pop.cfm?FuseAction=Doc&pAction=View&pDocumentId=45889 (Accessed: 2014-03-19).

[4] O. S. Grande, *et al.*, "Market based demand response. End user involvement and experiences from Norwegian pilots," presented at the CIRED - 19th International Conference on Electricity Distribution, Vienna, Austria, 2007.

[5] O. S. Grande and H. Sæle, "Market based solutions for increased flexibility in electricity consumption," presented at the Market Design 2005 - Conference on Security of Supply in Competitive Electricity Markets, Stockholm, Sweden, 2005.

[6] H. Sæle and O. S. Grande, "Demand Response From Household Customers: Experiences From a Pilot Study in Norway," *IEEE TRANSACTIONS ON SMART GRID, MARCH 2011,* vol. 2, No. 1, pp. 102-109, 2011.

[7] A. Hunnes and O. S. Grande, "Price signals and end-use flexibility in shortage periods (In Norwegian)," TR A5668, EBL-K 80-2002, SINTEF Energy Research2002.

[8] J. A. Foosnæs, *et al.*, "Demand Side Management (DSM). What are the potential benefits?," in *CIRED, Paper 0377, Stockholm, 10-13 June 2013*.

[9] M. Istad, *et al.*, "Scenarios Describing Smart Grid Technologies applied to Electricity Distribution Systems," in *CIRED, Paper 0314, Stockholm, 10-13 June 2013*.