DEMAND SIDE MANAGEMENT (DSM). WHAT ARE THE POTENTIAL BENEFITS?

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ABSTRACT

This paper discusses load profiles connected to the power system at different voltage levels and possible ways to utilize the inherent flexibility in demand. Utilizing demand flexibility benefits several players in the energy value chain, such as network operators, power generation companies, industry customers and wholesalers, among others.

This paper describes typical consumer demand profiles (individual and aggregated) in Norway, and the potential benefits for grid operators at transmission and distribution level, by utilizing demand side management or demand response.

BACKGROUND

The EED Energy Efficiency Directive (EED) requires EU member states to look for optimal utilisation of energy infrastructure assets, increased energy efficiency measures and demand side participation and upgraded or modernised infrastructure for the reduction of technical and operational losses. This, in turn, may reduce or at least postpone the need for new energy infrastructure investments. In Norway, customer incentives to reduce electrical demand and to allow an Energy Service Company (ESCO) to offer service to energy chain players are currently limited. This is partly due to tariffs on both energy consumption and the power system. In general, these are based on standard energy demand profiles and monthly consumption. Different studies have been carried out discussing possible savings by DSM [1] [2]. An important work on this has also been done by the IEADSM (www.ieadsm.org).

Utilities involved in the present study

Nord-Trøndelag Elektrisitetsverk Nett (NTE Nett)
NTE Nett is the distribution system operator in the County of Nord-Trøndelag in Mid-Norway. The company is responsible for the electricity power supply to 82.000 customers. NTE Nett is the owner of the 132 kV, 66 kV, 22 kV and low voltage power grid. Both planning, construction and operation including the customer service is its responsibility.

Statnett SF (Statnett)
Statnett is the Norwegian Transmission System Operator (TSO) and is primarily responsible for all high voltage electricity transmission and distribution in Norway. Such distribution is predominantly from the country's main hydro-electric power production plants countrywide. Statnett is not responsible for the generation of electricity, but it ensures that the electricity reaches the regional distributors, and thereby the end-users, at all times.

Statnett has the overall responsibility to coordinate the operation of the country's electric power system and maintain the continuous and correct balance between supply and demand. Statnett also regulates all electric power exchanges with other national grid systems, primarily involving the other Nordic TSO's.

In a Smart Grid framework, the utilities have to cooperate in a new way to ensure effective planning and operation of the whole power system both nationally and internationally. They must take into account all the players in the energy value chain.

DEMAND SIDE PARTICIPATION

Demand side participation can be achieved in several ways:

- dynamic pricing for demand response measures by end users (DR)
- demand side management from the network company (DSM)
- demand side management from the ESCO

However, today's pricing models are not designed to achieve sufficient DR nor are ESCO business models in place to take advantage of these technologies according to a Smart Grid framework.

Thus, price models must be developed, and the DSM must become more efficient not only to achieve benefits for customers but also for the players in the energy value chain on all grid levels.

Load profiles

Figure 1 shows a typical winter-month load profile for a typical residential end-user. The load profile was recorded by a smart meter with hourly reading. The typical day maximum peak is 10 kWh/h and the lowest night consumption is close to 2 kWh/h.

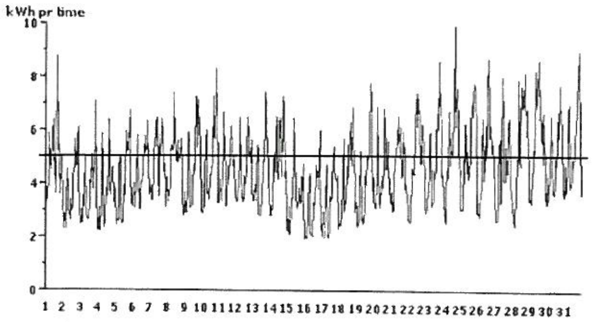

Figure 1. Demand profile for a residential customer for the month of January 2012 (hourly reading – kWh/h).

Figure 2 shows the 2010 annual demand profile at DSO level in NTE. The figure also illustrates the effect of DSM to reduce load peaks in periods with a high demand in service.

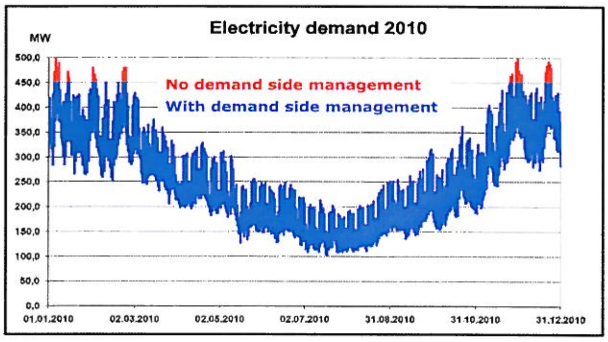

Figure 2 Annual demand profiles at DSO level for the year of 2010 (hourly reading – MWh/h).

Flexible demand

End-users with flexible demand could be able to (or be willing to) participate in organised DSM solutions in service. Typical flexible demand is for electric boilers, water heaters and, in some cases, direct electricity space heating (in houses with alternative heating sources such as wood, oil or gas stoves). Air conditioning could also be considered as a flexible load, at least for shorter periods (a few minutes). This could apply as well to refrigerators and ice boxes (freezers).

Active use of flexible demand can reduce peak demand. To a certain extent, this is more beneficial than an increase in power generation. Reduced peak demand may save energy and reduce (or postpone) network investments.

Demand side management (DSM)

DSM may be carried out directly by the TSO and DSO, but in the future it is believed this can be done by a third party, the ESCO. Peak demand reduction can be beneficial for the utilities in terms of energy loss reduction and postponement of new investments. The ESCO will take part in the balancing markets and share its profit with the customer and power supplier. Figure 3 illustrates the roles different companies are expected to have in the near future.

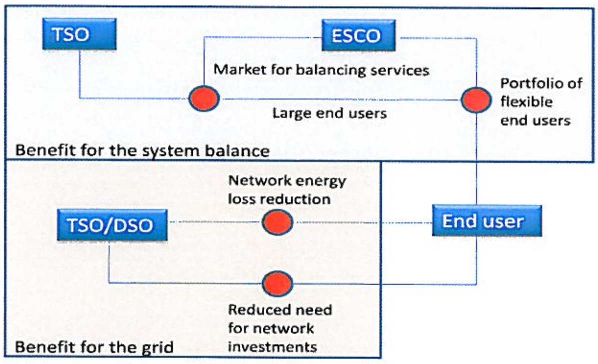

Figure 3. The ESCO activity benefits the power system balance and contributes to efficient utilization of the power system.

Network energy loss reduction

Disconnecting demand normally reduces network energy losses. However, this will also be the case if the electricity transportation is reduced. The distribution grid (22 kV) is mainly radial so the power flow is in only one direction (from the feeding point to the customer). In this case, demand reduction causes network energy loss reduction. The benefit will, however, depend on the season, low load or peak load.

The illustration in figure 4 indicates the energy loss change in the 66 kV (meshed network with a high degree of distributed generation, DER) and 22 kV radial networks in NTE on different demand situations.

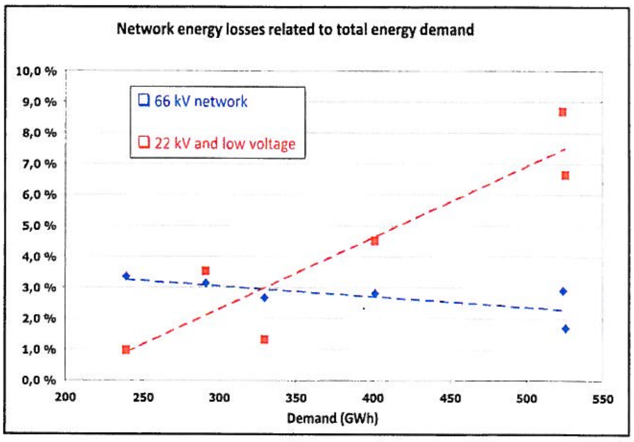

Figure 4 The energy loss change in the 66 kV (meshed network with a high degree of distributed generation, DER) and 22 kV radial networks in NTE on different demand situations.

NTE has carried out a simulation with a 10% reduction of the peak demands as shown in figure 2. As shown in figure 4, the energy losses in the 66 kV network shows a slight decrease with increasing demand. This is due to the fact that the energy losses in the 66 kV network depend on demand as well as the distributed generation (DER). This is of course not in general, but in the special case of a high degree of distributed generation. The average loss in the 66 kV network is about 2.7 % of the demand. The average energy loss in the distribution network is about 5 %.

For all of 2010, the energy loss changes due to peak reduction are:

- \+ 27 MWh in the 66 kV network
- \- 1000 MWh in the distribution network

Related to the overall energy losses in 2010 (175 GWh) this is a reduction of about 0.6 %. Assuming an energy price of 0.06 EUR/kWh, the annual cost savings for reduced energy losses will be about 58 000 EUR. However, taking into account an hourly based peak power price, the savings could be considerably higher.

Reduced need for power grid investments

In principle, reduced peak demand contributes to reduced grid investments, i.e., dimensioning for lower capacity in building new lines. According to the EED, the planning process should take that into account. However, new lines must be planned with a technical life-span of more than 50 years. The demand forecast will be very important planning criteria. The lines will always be built with extra capacity due to the following facts:

- increasing capacity is only a marginal cost
- increased capacity gives lower power grid losses
- long term demand forecast is uncertain
- the impact of charging EVs is uncertain
- the impact of future *prosumers* (small generating units in homes and businesses) is uncertain

Compared with today's demands, it will be more expensive to build lines and power cables with low capacity (early reinvestment) than to build them with extra capacity [3].

A peak demand reduction of 10% will not necessarily lead to very different planning methods and consequently no significant investment savings will occur due to that reduction.

Postponement of network reinvestments

For Norwegian DSOs, the typical life-span of lines and cables is about 50 – 60 years. The need for reinvestment in (renewal of) components is very often based on the age and reduced mechanical properties of the components. But in some cases, reinvestments are triggered by an increase in demand and the low transmission capacity of components. DR, or DSM, can reduce the peak load so planned investments may be delayed for a number of years.

Advanced models for grid tariffs

New price models for residentials are another instrument for utilities to reduce peak demand in the power system. This instrument can be based on hourly meter readings of electricity consumption. The new grid tariffs should reflect demand and give end-users incentives to reduce peak-hour demand. This incentive can be achieved by power grid tariff:

- with a higher peak-hour price
- with a higher price when the demand (kWh/h) exceeds a certain threshold.

As illustrated in figure 1, the horizontal line shows the threshold above which any demand will have a significantly higher price, typically 0.5 EUR/kWh. The customer should have a display (digital meter, smartphone, PC, etc.) to monitor his/her load to encourage demand reduction [4] [5].

Potential benefits for the TSO

The use of increased flexibility on the end-users' energy demand side is considered a constructive contribution to Statnett's obligations to ensure a well-functioning electricity market with high delivery reliability and cost effective power system operation. Stimulating increased demand side flexibility could ease the problem of large electricity demand during periods of electricity shortage. This challenge is important to handle because it affects factors such as cost of electrical energy and the ratio of available energy to demand.

In the coming decades, Statnett plans huge investments in the main grid to meet future increased load demand, to accommodate massive integration of renewables in the Nordic power system and to facilitate new cross border connections to Europe. Increased development and integration of small hydro power and wind power production may increase price volatility.

Currently, Statnett uses several market based instruments ensuring power and energy reserves from large industrial customers into the power system to gain flexibility in operation.

In Norway, the government has decided to roll-out Automated Metering Infrastructure (AMI) to all customers connected to the power system. The AMI will automatically collect periodic energy consumption data every 15 minutes. In addition, the AMI solution allows for automatic control by the utilities. This creates opportunity for flexibility in the customers' demand. End-users at the residential side alone will not be able to influence prices and reliability. These will probably respond "naturally" because of high transaction costs and little focus on the energy market. An "automatic market-based consumer response" seems necessary, through coordinated schemes between the TSO and DSO directly and/or activated through an ESCO on demand.

With its government mandate, it is important for Statnett to create this framework and, even with the help of incentives, promote development towards an automated market with an active consumer base within the frame of Smart Grid solutions.

Smart Grid solutions can be viable for both the planning and operational phases. Statnett is working with these issues in R&D projects and is currently implementing a Smart Grid Pilot to test different aspects of planning and on-line operation. This is important in normal operation as well as during disturbances or in severe situations with limited production sources available.

Another important R&D issue is to develop, together with the stakeholders in the energy business as well as with the governmental bodies, a well-functioning market design with viable commercial incentives.

Thus, important incentives to promote greater flexibility in end-users' electrical demand, connected market power from players in the energy value chain, economic issues for the TSO business, reputation, credibility and political signals are:

- Increased flexibility in the customers' energy demand increases competition and thus lowers procurement costs for reserves.
- Increased end user flexibility can reduce the risk and extent of energy not supplied by power shortages and disruptions. Consequently, this will help maintain a positive public opinion and profile for Statnett.
- The opposition's resistance to planned new transmission corridors may be decreased leveraging retail flexibility and may so strengthen Statnett's preferred solutions to the authorities.
- The TSO shall actively contribute to the further development of the flexibility of consumption as this may reduce the need for other means.
- An increased price flexibility of electricity consumption is important to balance supply and demand and is an important contributor to manage peak load situations in the Nordic market.

CONCLUSIONS

Adjusting the tariffs to affect consumer load behaviour may reduce energy loss and save costs for the distribution operators – but not at a significant level. Nor is the impact on planning of the grid of significant value for NTE Nett. The usage of DSM, however, might contribute to deferred re-investment of grid components.

These first studies of consumer behavior for electric loads and the introduction of DSM in the Norwegian market need greater study along with introducing further pricing simulations and other possible instruments. As for whether or not DSM or DR is beneficial for the grid operators, the various power grid typology challenges and diverse Norwegian consumer patterns must also be taken into account.

As described in this paper, effective use of DSM and DR should take into account the use of various instruments on several power grid layers in the energy market, also involving solutions effective for the TSO needs. These instruments must be coordinated with the necessary market framework, including development of effective market design, to ensure benefits for the entire market, including all the various players.

As of today, this work is at an early stage and may benefit from cooperation between the grid operators seeking effective development of tools and frames ensuring beneficial DSM and DR for the energy market as a whole.

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