POWER-BASED TARIFFS BOOSTING CUSTOMER-SIDE ENERGY STORAGES

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ABSTRACT

This paper considers how power-based distribution tariffs encourage electricity end-users to invest in energy storages to reduce their peak loads. The study uses actual automatic meter reading (AMR) data from 30 000 customers the annual electricity consumption of which is less than 50 MWh. The customers locate in the area of a Finnish distribution system operator (DSO) operating in an urban environment.

The results of the paper indicate that the power-based tariffs provide incentives to customers invest in energy storages to reduce their peak loads. The energy storage investment can be paid back with the savings of a lower power costs in distribution fees.

INTRODUCTION

The power system is planned, constructed and operated to withstand the maximum loading hours. The present tariff structures are mainly based on energy (€/kWh) while the capacity (€/kW) have had a minor weight. This pricing model does not encourage the electricity end-users to capacity efficiency, which however can be challenging for the distribution utilities. For instance, at present the peak loads in the grid are increasing at the same time when the delivered energy may decrease leading to decreased peak operating time [1]. This is a consequence of adapting new type of devices such as energy efficient heat pumps, which can take high power input from the grid being thus problematic for the electricity distribution infrastructure.

Changes in the electricity sector are challenging for the DSOs business models, capacity efficient operation and dimensioning of the grid. A solution to increase the predictability of the business and the capacity efficiency of the electrical grid is to change the grid tariffs towards power-based structures.

Power-based tariff provides new opportunities and economic incentives for customers to optimize their cost of electricity distribution by reducing the peak load. However, customers' peak load shifting may also cause undesired effects by raising network loads on the system feeder level, but this viewpoint has been restricted out of the papers scope. A promising opportunity to optimize the load demand is to use a battery energy storage system (BESS) integrated on the customer side. An important driver for energy storage installations in the near future is the decreasing price of batteries that promotes the BESS. Combination of the inexpensive energy storages and a power-based distribution tariff may arouse interest in novel customer behaviour. For instance, even the power-based tariffs can be an important part to encourage electricity end-users to install energy storage capacity, the benefits of energy storages can be gathered from several sources or services such as minimizing costs of electrical energy, optimizing use of storage capacity in electrical power system balancing etc. However, the overall benefits of the storages have not been discussed more detail in the paper.

OBJECTIVE OF THE PAPER

The objective of the paper is to find out how the power-based tariff affects the electricity end-users profitability to invest in energy storages. The study considers the proportion of customers, who can pay the costs of the storage back by saving money in distribution fees by reducing their peak loads with the energy storages.

ANALYSES OF THE PAPER

The analyses of this paper are based on a power-based distribution tariff, which provides incentives for customers to optimize their electricity end-use. By calculating the potential to decrease their peak loads, the growth of energy storage potential can be estimated. This approach provides benefits for the DSOs also. The methodology is tested in the real case environment with measured AMR data.

Background data

The analysis is based on the AMR data of a Finnish DSO operating in an urban area. The AMR data consists of hourly measured annual energy consumptions of approximately 30 000 customers most of them of which are living in block of flats. The annual energy consumption of the customers in year 2013 is presented in Figure 1. It shows that the annual consumption of most of the customers is below 5 000 kWh/a.

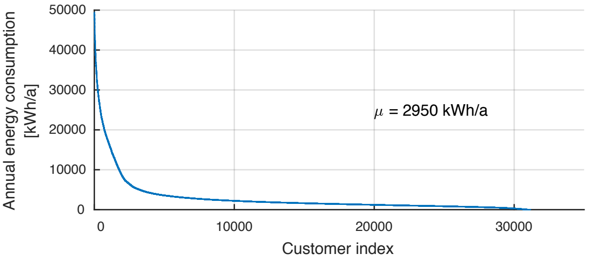

Figure 1. Annual energy consumption of the considered customers in year 2013.

Moreover, actual historical data of distribution tariffs are utilized in the calculations. The case electricity distribution network area is located in southern Finland.

Power-based distribution tariff

Smart metering may provide new options for the distribution pricing. An hour-based metering offers more accurate data of customers' electricity end-use. New metering infrastructure can enable a power-based distribution pricing. Previously, power-based pricing has merely been possible for the large-scale customers. There are a lot of possibilities for the power-based tariff scheme. For instance, the measured power, and the pricing mechanism may vary significantly between different models. In addition, the resolution of the AMR measurements sets a boundary for the study, because the peak powers within an hour are not known. Thus, the consideration of the customers' load demand has to be carried out with the hourly mean loads, not the exact peak load.

Load demand pricing

In this paper, the load demand pricing method is used in the calculations [3]. The demand power is the highest measured hourly mean power of the customer that is the basis for the power capacity.

The present distribution tariff approach utilizes a capacity-based fixed charge in the distribution pricing; a fixed charge is normally based on the main fuse size. Unfortunately, if the lowest main fuse size is 3x25 A, the most of the customers have no motivation to decrease the peak loads. Hence, the growth of the distribution powers may be obvious.

The load demand pricing for small scale customers has already been applied in couple distribution networks in Sweden. Sollentuna Energi [4] and Sala-Heby Energi [5] have applied the load demand pricing in use and their distribution prices varies between 5–10 €/kW,month added with a fixed cost. Altogether, the power-based distribution tariffs are a current topic in Europe and Australia. The main driver is cost-reflectivity and new possibilities due to smart metering.

Regulated revenue to determine distribution tariffs

Electricity distribution business is a regulated monopoly being regulated by the authorities. For instance, Finnish Energy Authority supervises the operation of DSOs in Finland. The electricity distribution business regulation model determines the maximum allowed rate of return for the DSOs that determines the maximum allowed revenue that consists basically of the distribution fees. At present, the distribution fees are typically based on the distributed energy and monthly fixed cost.

The analysis is based on the assumed regulated revenue that the DSO collects from the customers. The regulated revenue is calculated using customers' hourly measured electricity consumption data. In Finland the DSOs operating mainly in urban areas have typically a fixed cost that is 3–5 €/month and an energy fee for distributed energy being 2–4 cnt/kWh.

The annual regulated revenue for the considered 30 000 customers is approximately 3.6 million € by using a monthly fixed cost (€/month) and a distributed energy cost (€/kWh). If this revenue would be calculated using the power-based tariff, where the customer's distribution fee is based on the load demand having a step of one kW, the unit price of the load demand tariff becomes 2.75 €/kW,month using the highest annual hourly mean power for each of the months. This approach benefits the customers, which have high demand throughout the year. It can be observed that the calculated price is modest compared with the examples from Sweden. However, it has to be noticed that there are few significant differences between of the cases. In the Swedish cases the applied peak is the average of three highest daily mean hourly powers and also the load demand is determined separately for each of the months that inevitably raises the price of the tariff.

If the consideration would be carried out for a DSO operating in rural areas, the load demand tariff could be much higher than the defined 2.75 €/kW,month. The main reason for this is the extensive network areas and relatively low amount of the customers.

Customer's peak cutting to meet lower load demand

To determine the customer's theoretical load demand the AMR data have to be analysed hour by hour. This way the highest mean hourly power can be found, and moreover the peak cut potential using energy storages can be found. Figure 2 illustrates the customer's peak cut approach to determine the required energy storage size to limit the load demand to a selected power, for instance to 8 kW. In the Figure 2, the existing peak power is 10 kW and it could be cut to 8 kW using 2 kWh energy storage. If the peak power was decreased to 6 kW, the energy storage should be 8 kWh.

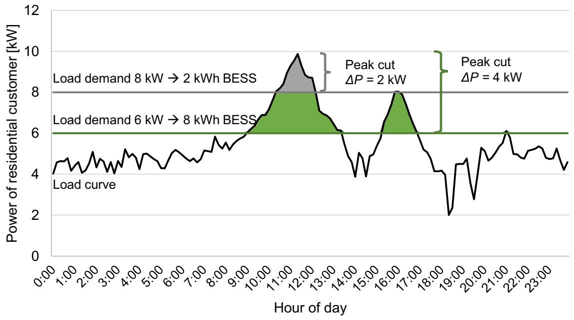

Figure 2. Example of a customer's peak cut approach to meet the load demand target.

Typically, the first kilowatts can be cut with a relatively small energy storage. A principled illustration of the peak cut potential of the customers' is shown in Figure 3. It shows the peak cut curve as function of the required energy for peak cutting. It can be observed that when the size of energy storage in kilowatthours is small the slope of the peak cut capacity grows fast.

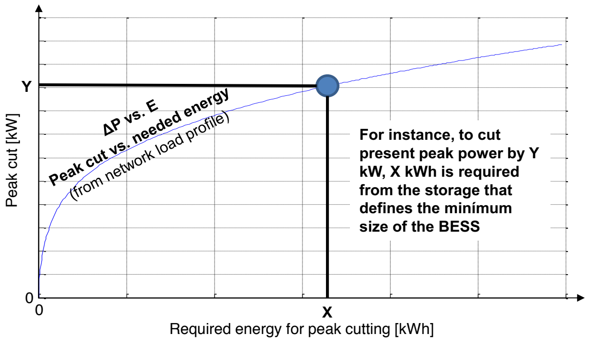

Figure 3. Customer's peak cut potential (kW) compared with the energy required for peak cutting (kWh). Adapted from [2].

The optimal size of the energy storage can be found when the benefits of the customer are the highest. The maximum benefit is found when the difference of the customer's distribution fee savings and the costs from the BESS investment and the operation is maximum. This has been illustrated in Figure 4.

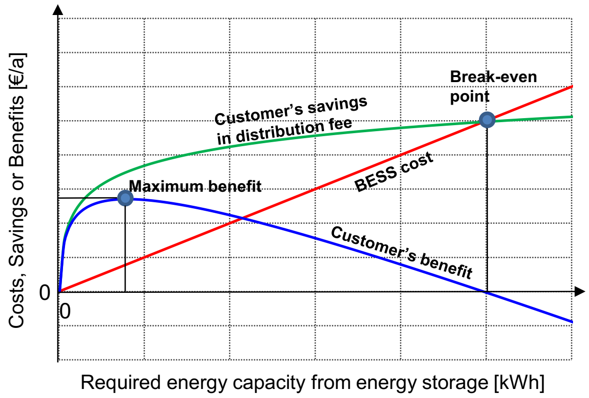

Figure 4. Illustration of the customer's savings in the distribution fee with the BESS investment, operating cost of the BESS during its lifetime and total lifetime benefits of the BESS installation. Adapted from [2].

The size of the BESS may vary significantly, and the size is dependent on the customer's load profile. The case area involves a lot of residential customers, whose electricity end-use is a relatively low, as illustrated in Fig. 1. However, there exist also customers with electric heating having a high electricity consumption, which provides an interesting research case.

RESULTS

The price of the BESS and the load demand tariff play key roles in the study. Together they determine the feasibility of the BESS implementation. At present the lowest prices for a BESS are around 500 €/kWh [6], [7], but in the near future the prices can be considerably lower, because the long-time trend of BESS prices is falling. In the case study, unit prices of 200 €/kWh, 400 €/kWh and 600 €/kWh for the BESS have been used. In the analyses, the lifetime of the BESS has been assumed to 20 years. The calculations are based on the assumption that customers will behave rationally so that if it is profitable they will invest in the BESS.

Load demand tariff

The load demand tariff has been determined from the calculated regulatory revenue. The regulatory revenue is approximately 3.6 million € for the analysed customers providing 2.75 €/kW,month for the load demand tariffs assuming that the customers do not change their consumption if the tariff structure is changed to power-based tariff.

Based on the calculated load demand tariff the customers annual load curves have been analysed, and BESS has been modelled for each customer if it is feasible. Table 1 and Figure 5 show the number of the customers BESS implementations, average size and average savings of the BESS implementations. The BESS unit prices are varied between 200 and 600 €/kWh.

Table 1. Numbers of the BESS installed, the average size of the BESS, and the average saving of the customers with different BESS unit prices. The load demand tariff is 2.75 €/kW,month.

	200 €/kWh	400 €/kWh	600 €/kWh
Number of BESS implementations	26 281	12 392	12 388
Average size of BESS (kWh)	2.28	1.52	1.52
Average saving of BESS (€/a)	27.62	19.73	4.56

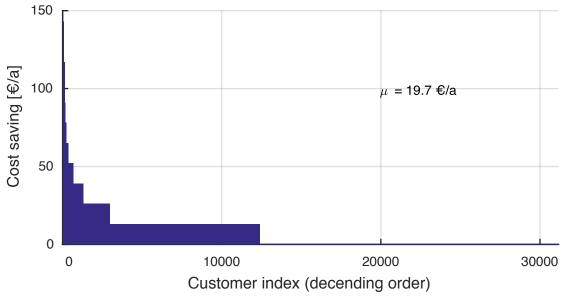

Figure 5. Customer's savings per year with the BESS (unit price 400 €/kWh). If the savings are zero, there is no profitability for the BESS. The load demand tariff is 2.75 €/kW,month.

It can be observed that it is profitable for the most of the customers to invest in the BESS. For instance, the highest annual benefits can be over 100 €/a, when the average benefit is 4.6–27.6 €/a. However, the saving is relatively high if it is compared with the average annual distribution fee that is 120 €/year.

Nevertheless, if the customers start to invest in energy storages and thus to reduce their highest loads, the revenue of the DSO decreases. This kind of development would take place in the long run. Thus, the DSO has a pressure to raise the price of the load demand tariff so that the regulatory revenue can be achieved. This at the same time increases the profitability of the BESS, and thus gives better incentives for the customers to invest in storages. This leads to an iteration, where the DSO raises the price of the load demand tariff and the customers invest in the BESS. Figure 6 shows the results from the iteration process. For instance, the price of load demand tariff is raised from 2.75 €/kW,month to 5.1 €/kW,month with lowest 200 €/kWh BESS price after two iteration rounds. Higher load demand tariff may also gain more savings for the battery owners. According to simulation the average annual saving may rise as high as 75 €/a with extremely inexpensive batteries (200 €/kWh).

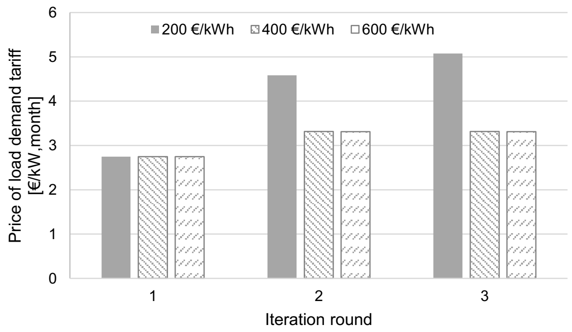

Figure 6. Development of load demand pricing when customers invest in energy storages to cut their peak loads.

Discussion

The study shows that power-based tariffs may encourage electricity customers to invest in energy storages. This can be a challenge for DSOs from the pricing point of view, because the revenue may vary if the customers aim at decreasing their peak loads actively. This can be observed in Figure 6, which shows the iteration process of the load demand tariff. However, in real life the customers do not probably behave as rationally as the study assumes, and thus the changes in the loads are smaller.

CONCLUSION

The power-based tariffs create considerable incentives for the customers to invest in customer-side energy storages. This paper shows that customers may achieve notable economic benefits even with relatively small BESS capacities. At the beginning of the applying the power-based tariffs in use, the pricing of the distribution can be challenging for the DSO, because the revenue depends on the highest mean hourly powers, which are decreasing. Furthermore this development accelerates the exploitation of the BESS in the customer-side. However, it can be concluded that this development would be advisable from the DSO's perspective, because it may decrease the network loads. Moreover, this would decrease capacity demand in power generation, transmission and distribution networks in the long term. Altogether, the most important issue related to the topic would be the implementation of the power-based distribution tariffs for all customers.

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REFERENCES

[1] J. Tuunanen, 2015, *Modelling of changes in electricity end-use and their impacts on electricity distribution*, Doctoral dissertation, Lappeenranta University of Technology, 2015.

[2] J. Lassila, J. Haakana, V. Tikka, and J. Partanen, 2012, "Methodology to Analyze the Economic Effects of Electric Cars as Energy Storages", *IEEE Trans. on Smart Grid*, vol.3, no.1, pp. 506–516, Mar. 2012.

[3] J. Pyrko, 2006, Load demand pricing - Case studies in residential buildings

[4] Sollentuna Energi electricity distribution network tariffs, 2016, http://www.sollentunaenergi.se/elnat/natavgift.asp

[5] Sala-Heby Energi Ab electricity network distribution tariffs, 2016, http://www.sheab.se/natpriser.aspx

[6] B. Nykvist and M. Nilsson, 2015, "Rapidly falling costs of battery packs for electric vehicles," *Nature Climate Change*, vol. 5, pp. 329–332, Apr. 2015.

[7] Q. X. Latour, G. Jarry, D. Laffaille, R. de Beaufort, N. Frizi, and D Theophile, 2015, "Electricity storage: how to enable its deployment?", in *Proc. 23th Int. Conf. and Exhibition on Electricity Distribution*, CIRED, Lyon, France, 15–18 Jun. 2015, pp. 1–5.