STIMULATING THE EFFICIENCY OF THE ENERGY INFRASTRUCTURE BY DSO TARIFFS

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ABSTRACT

In this paper, we will study the role of DSO tariffs in promoting the energy efficiency of the energy infrastructure. The key problem with the present energy based tariff structure is that it is not cost-reflective and do not provide incentives for customers to optimize their consumption so that efficiency of the electricity distribution would be improved. Our conclusion is that power based pricing of the electricity distribution is more cost reflective than prevailing energy based pricing, and it incentivizes customers to decrease their peak powers, so that overall efficiency of the electricity distribution is improved. Moreover, this novel tariff structure provides a tool for avoiding the conflict-of-interests in demand response. In addition, tariff scheme meets the requirements of the legislation and regulation, and we have not discovered any major barriers for its implementation.

INTRODUCTION

At the moment, pricing of the electricity distribution is typically based on the amount of the transmitted energy, while the costs of the DSOs are in short-term fixed, and in long-term based on peak powers. However, missing cost-reflectivity has not been significant problem so far, as the development in energy and power demand have been quite stable and well-predicable for decades. However, energy sector transition is on its way, and such issues as microgeneration, demand response, increasing energy efficiency, and energy storages, will have substantial impacts on the power and energy transmitted through distribution networks. Eventually, the peak-operating time of the network is changing, and because of that, the inappropriate cost-reflectivity of the tariff structure is becoming a growing challenge for DSOs.

Moreover, although present pricing structure provides customers with incentives to decrease their energy consumption, it does not encourage them to optimize their loads from the perspective of the efficiency of the network infrastructure. Providing customers with incentives to cut their peak-powers would increase the utilization rate of the network, and thus improve the efficiency of the power distribution.

In this paper, we will study the role of DSO tariff in energy efficiency of the energy infrastructure. We will consider, whether replacing energy based component with power based element in DSO tariff would promote energy efficiency of the electricity distribution. Furthermore, we will consider whether the conflict-of-interests in demand response could be avoided by applying power based tariff, and whether such tariff structure is in line with present legislation and regulation. Power based tariff has been suggested as an alternative for present energy based tariff in earlier studies, see for instance [1] or [2]. Furthermore, its impacts have been studied by network simulations in [3] and [4].

Outline of the paper is following. In second chapter, we will discuss, in general level, how the efficiency of the electricity distribution can be improved. In third chapter, we will take a look on the challenges related to present DSO tariff structures. These challenges provide us a starting point to consider novel power based tariff structure, which will be discussed in fourth chapter. Finally, conclusions and future research questions within this topic will be presented in Chapter five.

IMPROVING THE EFFICIENCY OF ENERGY INFRASTRUCTURE

As illustrated in [5], energy efficiency means the ratio of output of performance, service, goods or energy, to input of energy. Improvements to energy efficiency reduce primary-energy consumption, greenhouse-gas emissions, and the need for imported energy; thus, it improves security of supply in a cost-effective manner. However, when considering the improvement possibilities in efficiency of the energy system, it is essential that we study the holistic impacts of the energy end use on the needed network and generation capacity and their costs, as well as on the demand of the primary energy. That is, we do not focus solely on the amount of the energy consumption in customer end, but study its impacts on the overall efficiency of the energy system.

In this case, we focus on the question how we can promote the improvement of the overall and energy efficiency of the electricity distribution. Based on the above described properties of the efficiency, we can conclude that we can improve this by; 1) minimizing energy losses in electricity distribution, 2) improving capacity utilization rate in electricity distribution, and 3) ensuring that electricity distribution infrastructure enable and promote efficient use and generation of the energy.

Energy losses in electricity distribution are typically at low level in Finland, since the network planning philosophy has been to minimize the network's life-cycle costs (i.e.

investment, losses, and interruption costs). This has resulted to use of the most cost-effective solutions in network. Hence, we can focus mainly on last two issues in above illustrated list, and combine them by considering, how we can promote the efficient use of energy, so that the capacity utilization rate in electricity distribution is increased. There are different measures for this, such as increasing customers' awareness by appropriate information, legislation and regulation, or incentive provision by appropriate pricing mechanisms. In this case, we focus on the latter of those, by considering how to provide incentives for efficient use of energy by appropriate pricing of electricity distribution. For this, we will focus first on present DSO tariff structures and challenges related to them.

CHALLENGES WITH PRESENT TARIFF STRUCTURES

At the moment, typical tariff structure of a Finnish DSO is energy based tariff combined with a fixed fee, which is typically dependent on the size of the main fuse. The proportion of the fixed and energy based fees vary between the companies and customer types.

One of the key problems in energy based tariff is that it is not cost-reflective. Majority of the DSO costs are capital costs, which are fixed in short-term and in long-term they are dependent on power demand. Although energy based tariff encourage customers to decrease their energy usage, it does not provide incentives to change their consumption so that capacity utilization rate of the network would increase. In other words, incentive provision properties of the tariff structure are insufficient.

<u>Structural changes in electricity usage</u>

The lack of cost-reflectivity is becoming more severe problem, as there are on-going and forthcoming structural changes in energy end-use, which will change the ratio of energy and power distributed in network. Such changes as increasing amount of micro-generation, heat-pumps, electric vehicles, market based demand response, and energy storages will affect the amount of transferred energy and peak-powers, as analyzed comprehensively in [4].

Customers' own micro-generation based on photovoltaic decrease the amount of the energy distributed from network to customers. However, there is no remarkable power output from PV during the winter, when the peak-loads occur in Finland. Hence, such micro-generation do not decrease the peak-load of the network. Moreover, it has been illustrated in [4] that it is not likely that PV generation would either increase network loads during the time of the maximum generation in summer. Therefore, increasing amount of PV generation will decrease the amount of distributed energy, while it do not have any impacts on the peak power.
A bit similar impacts arise from increasing amount of the air-source heat pumps, as they decrease the demand of the electrical energy in heating, in case of electric heating, but they will need support of electric heating during the coldest winter days. Thus, the power demand may even increase, while the amount of energy supplied to customers decrease due to the increasing amount of heat pumps.

Flexible resources, such as demand response, electric vehicles, and energy storages, can be controlled based on the demands of different stakeholders. As illustrated in [6], the utilization of the demand response can be categorized to following types of services; (1) optimization of the portfolio of the market actors, (2) structural congestion management of the DSO and TSO, (3) occasional congestion management of the DSO and TSO, (4) balancing of the demand and supply in system level, and (5) ancillary services for TSO. As the requirements for the utilization of the DR may vary between stakeholders, there is a risk for conflict-of-interests (CoI).

This CoI can be seen clearly, when analyzing the impacts of the market based demand response on the peak powers of the network. In figure bellow, there is illustrated, based on simulations, how the control of electric heating loads, taking place in different market places, changes the peak-powers of the medium-voltage (MV) feeder (100 % represent peak power without load controls) [4].

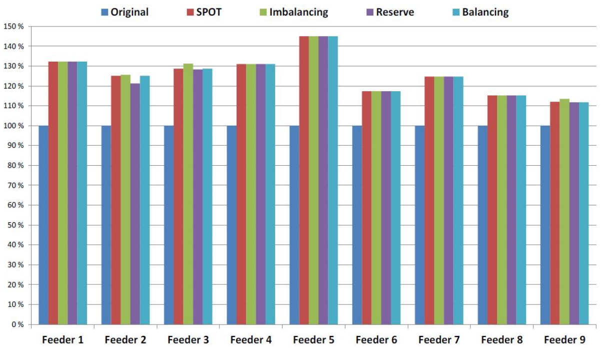

Fig. 1. Simulated impacts of market based load control of electric heating on the peak powers of the MV feeders [4].

As it can be seen from the results of the simulation, if the heating loads are shifted to low price hours, alternation between the loads of different customers decrease, and thus, peak-loads in network will increase, if there are no incentives for customers to avoid the power peaks. Hence, there seems to be conflict-of-interest in demand response between market side and network side.

POWER BASED DSO TARIFFS

As the peak power of the network is the key cost-driver in electricity distribution, cost-reflective pricing would be such that is based on the powers, instead of the delivered energy. However, cost-reflectivity is not only demand for pricing structure, as can be seen from figure below, where the desirable features of the electricity distribution pricing from the viewpoints of different stakeholders are illustrated.

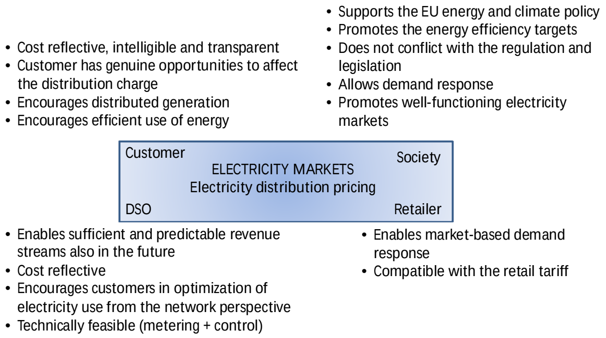

Fig 2. Desirable features of the power band from the perspectives of different stakeholders in the electricity market [1].

However, some of the presented features are a bit contradictory. For instance, if we would like to achieve a perfect cost-reflectivity, pricing should vary dynamically based on the geographical location of the customers and present load rate of the network. However, such tariff might not be intelligible for customers and would not meet the requirements of the spot pricing in energy market legislation. Hence, applied tariff system will be in any case a compromise between different demands.

Impacts of the tariff on demand response and energy efficiency

As illustrated above, there might be conflict-of-interests between market actors in demand response, as market based demand response might increase network loads. This undesired impact can be avoided by providing customers with incentives to decrease their peak loads, for instance by the power based distribution tariffs. This issue is proved by simulations for instance in [3] and [4].

Based on the simulations presented in [3], including power based component to distribution tariff mitigate the negative network impacts of the market based DR, and decrease the peak power of the customers and distribution transformers. Hence, such pricing scheme would encourage customers to optimize their energy usage and demand response actions so that the utilization rate of the distribution network would be improved.

Although this change in tariff structure would decrease the proportion of the energy based component in the customer’s bill, there would still remain energy-based pricing of purchased electrical energy, and electricity tax, which is based on the energy consumption. Eventually, as presented in [1], 65 % of the customers’ electricity bill would still be based on the consumed energy, but now there would be also part of the bill depending on the peak power. Hence, this would provide incentives to decrease both energy and power.

Legislation and regulation

Article 15 in the Energy Efficiency Directive discusses the obligations of transmission and distribution system operators (DSOs) and the regulation of network activities [5]. According to the Directive, the authorities must pay due regard to energy efficiency in the performance of their regulatory tasks relating to the operation of the gas and electricity infrastructure.

What comes to pricing, it is stated that “*Member States shall ensure the removal of those incentives in transmission and distribution tariffs that are detrimental to the overall efficiency (including energy efficiency) of the generation, transmission, distribution and supply of electricity or those that might hamper participation of demand response, in balancing markets and ancillary services procurement.*”

In addition, it is required to ensure that network operators are incentivized to improve efficiency in infrastructure design and operation, and that tariffs allow suppliers to improve consumer participation in system efficiency, including demand response.

Moreover, in Annex XI of the Directive, it is required that:

Network tariffs shall be cost-reflective of cost-savings in networks achieved from demand-side and demand-response measures and distributed generation, including savings from lowering the cost of delivery or of network investment and a more optimal operation of the network.

Network regulation and tariffs shall not prevent network operators or energy retailers making available system services for demand response measures, demand management and distributed generation on organised electricity markets.

Based on the above illustrated requirements of the Directive, we see that power based DSO tariff fulfills the requirements for the cost-reflectivity, as well as demands to remove the incentives detrimental to overall efficiency and to allow the participation of the demand response.

In Finnish national legislation, it is required that pricing has to be reasonable. Moreover, economic regulation in Finland is focused on the revenues of the DSOs, and it does not set requirements for the tariff structures. Hence, it does not either prevent changes to prevailing tariff system.

CONCLUSIONS

Long-term objective of pricing of energy services should be to encourage end-users to behave so that the energy efficiency of the whole energy system, including generation, transmission and distribution, is maximized and the total costs to the national economy are minimized. In the case of DSO tariffs, this means that customers are incentivized to optimize their electricity consumption so that the utilization rate of the distribution system is increased, and thus the efficiency of the electricity distribution is improved.

The key problem with the present tariff structure is that it is not cost-reflective, as tariffs are based on the amount of distributed energy, while the costs of the DSOs are in short-term fixed and in long-term based on the power demand. From DSO viewpoint this is challenging, as there are structural changes in energy end-use, which in many cases decrease the amount of energy distributed, while power demand remains the same. Moreover, such tariff structure is not optimal from efficiency viewpoint either, as it does not provide incentives for customers to optimize their consumption so that efficiency of the electricity distribution would be improved.

Based on above presented, we can conclude that power based pricing of the electricity distribution is more cost reflective than prevailing energy based pricing, it incentivize customers to increase the overall efficiency of the energy infrastructure, and it provides a tool for avoiding the conflict-of-interests in demand response.

According to the Energy Efficiency Directive, tariffs must be cost-reflective and it must be ensured that incentives that are detrimental to the overall efficiency, including energy efficiency, of electricity generation, transmission, distribution and supply must be removed from transmission and distribution tariffs. Power-based tariff promotes the improvement of the overall efficiency of electricity distribution, as it provides customers with incentives to adjust their behavior so that capacity utilization rate in the distribution system is increased. The energy-based pricing of electricity sales and energy-based electricity tax will ensure that there are also incentives to minimize energy consumption.

Future work

There are not any clear barriers for DSOs to switch to power based pricing. Some of the remaining research questions, which are mostly related such issues as customer acceptance and long-term impacts, are discussed here.

There have been simulations concerning the impacts of the power based pricing on the behavior of the rationale customers. The assumptions of the rational behavior hold, if the load control is automatic. However, it is not sure how the real-life customers would behave, if they are provided with monetary incentives to decrease their peak powers. Furthermore, another relevant customer related question is the acceptance of novel pricing scheme among the customers. Both customer acceptance and behavior are relevant research topics, which most preferable should be studied by interdisciplinary approach.

Furthermore, it would be beneficial to study more detailed the impacts of the power based pricing on the availability of the different flexibility resources. In addition, there is a need to find out long-term impacts of the tariff structure. In other words, how the change in the tariff structure impacts in long-term to network loads and load forecasts, applied in network planning. By such studies, it would be possible to analyze the long-term holistic impacts of the tariff modifications.

In addition to above mentioned, there are some practical issues, which have to be solved in actual power based tariff implementation. These are, for instance, decision whether pricing is based on the measured peak powers or predefined power band, and in the case of the power band, how is the power limit supervised and regulated, and what is the procedure on the possible excess usage of the power. Most probably some kind of period of transition has to be also designed to switch from prevailing tariff structure to new one.

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