REFORMING DISTRIBUTION TARIFFS OF SMALL CUSTOMERS – TARGETS, CHALLENGES AND IMPACTS OF IMPLEMENTING NOVEL TARIFF STRUCTURES

Antti RAUTIAINEN, Kimmo LUMMI, Antti SUPPONEN, Juha KOSKELA, Sami REPO, Pertti JÄRVENTAUSTA
Tampere University of Technology – Finland
antti.rautiainen@tut.fi

Samuli HONKAPURO, Jarmo PARTANEN, Jouni HAAPANIEMI, Jukka LASSILA, Juha HAAKANA, Nadezda BELONOGOVA
Lappeenranta University of Technology – Finland
samuli.honkapuro@lut.fi

ABSTRACT

The paper discusses the targets, challenges and impacts of novel distribution tariff structures, especially power based distribution tariffs. The paper summarizes the aims and preliminary results of an ongoing Finnish national research project in which distribution tariffs are being investigated together with multiple distribution system operators (DSO), research institutes and other actors of the field. The reformation of distribution tariffs has some clear motivational factors, but at the same time, the topic is very multifaceted, as changes in the pricing of electricity distribution have different effects on different actors of the field like customers, DSOs, electricity retailers and other third parties in the electricity sector (e.g. different kinds of service providers, device manufacturers) and society as a whole. These topics are discussed in a qualitative manner in the paper but also preliminary numerical results are presented to elaborate the customer impacts of novel tariffs.

INTRODUCTION

During the past years, the discussion regarding the reformation of distribution tariffs of small customers has been increasingly active on the European level, see for example [1]–[5]. From the viewpoint of the development of the pricing practices, the participants in the traditionally slowly moving distribution network business have started to discuss different options concerning the distribution tariffs of small customers. This results partly from the challenges set by the changing operational environment of the future (e.g. increasing amount of demand response, distributed generation, electric vehicles and storages at the customer site). The practical implementation of these novel tariff solutions has not yet been reality in Finland (nor almost in any other county). The Distribution System Operators (DSO) collect their revenues mainly by fixed basic charge (€/month) and energy based consumption charges (cent/kWh), and they have preferred so far a more conservative approach regarding the changes in the very core of their business and revenue formation. Strongly energy based (with or without time-of-use property) distribution tariffs are not very cost reflective, as the cost of DSOs related to energy forms only a small proportion of their total costs.

One essential element in the reformation of the distribution tariffs is the selection of the tariff structure. In the end, the tariff structure defines the mechanisms of how the customer in practice pays for the network service. During the past years, the discussion concerning power-based distribution tariffs has increased and they are seen to include a great potential in activating and enabling the customer in the electricity market, and to be more fair and cost-reflective.

In Finland, a new research project funded by the Finnish Electricity Research Pool has just launched for aiming to study possible novel tariff structures of small customers, their impacts from customers, DSOs, electricity service providers, device manufacturers and the viewpoint of the whole society and to determine guidelines for a transition path for the implementation of novel tariff structures. The outcomes of the project include critical analysis of present tariff structures, ideas for novel tariff structures and their analysis, selection of most promising novel structures and their qualitative analysis from various viewpoints, and quantitative studies on some of the impacts of the selected novel tariff structures on the customers and distribution networks. This paper discusses the preliminary findings and results of the project.

The paper is organized as follows. In the second section, the changes in the operation environment of distribution system operators are discussed. The third section presents some novel distribution tariff structures and their characteristics from different points-of-view. In the fourth section, a distribution pricing case study with preliminary results are presented. The fifth section provides discussion about the results and conclusions of the paper.

CHANGING OPERATIONAL ENVIRONMENT IN THE ELECTRICITY SECTOR

The electricity sector is in middle of changes, and the actors of the electricity sector should have a clear vision on what is the role of distribution system operators in the operational environment of the future. The authors of this

paper think that the core task of the DSO is to offer reliable network service with reasonable and cost-reflective pricing. The tariffs might have various incentives included in the tariff structure, but in the end, the customer decides whether to utilize the incentives or not in order for him/her to lower the magnitude of the distribution fee. In addition to this, there are different opinions on other responsibilities which the DSOs should answer for. Some say that the DSOs should be, for their part, enablers of the efficient operation of the electricity market, in other words: to provide an infrastructure and a platform for a well-functioning electricity market. Another point-of-view is that the DSOs should encourage the customers to energy efficiency and to invest into more sustainable energy solutions. These kinds of additional tasks might be relevant as long as they do not disrupt the core task of the DSO. Focusing too much in these additional tasks obscures the roles between different actors of the electricity sector, and might lead the whole electricity system to a non-optimal direction.

Actions targeting the climate change mitigation affect many areas of the electricity sector. There are a few individual changes, which affect the operation environment of the DSOs and induce new challenges to the pricing of electricity distribution.

One type of change comes from increasing energy efficiency and small scale electricity production. These factors mean that the customers will decrease their electricity consumption taken from the grid. In the present distribution pricing schemes in Finland there is a significant volumetric consumption charge (in cent/kWh) in the distribution tariffs. Decreasing energy consumption decreases the revenue of DSOs, but the costs of DSOs remain almost untouched as cumulative amount of supplied energy changes the costs of a DSO only a little. One could increase the price level of the volumetric energy charge, but this would lead problems in terms of customer equality: some customers would have to pay very high distribution fees and others much lower, even when their peak loads (e.g. in winter) could remain almost the same. As the real costs of DSO induced by these two customer sets are often close to each other, this situation would lead to high cross-subsidies between the customers. And actually, this phenomenon can be clearly seen also in distribution pricing today in Finland.

Another change in the operational environment is brought by the increasing demand response activity, the use of electricity storages, increasing amounts of electric vehicles and other new large electricity loads. High demand response activity, especially if electricity storages are used, and also high amount of new electric loads like electric vehicles, might lead to increasing peak loads in the distribution networks. Wholesale spot price based contracts induce same hourly prices to the customers. This means that all such customers have the incentive to consume energy during the cheap hours, and this might increase peak loads in the distribution networks and increase reinforcement investment needs. Same phenomenon can be seen with reserve markets. For example, if there is a need for down regulation in the power system, the need is the same and simultaneous for all the customers in the same distribution network. Also, large penetration level of electric vehicles might increase load in the network especially if high charging powers are used. All this means that without reforming the distribution pricing there is a risk of increase of peak loads and investment needs so that the additional costs cannot be targeted to the customers who are causing the investment needs.

FUTURE ALTERNATIVE PRICING SCHEMES FOR ELECTRICITY DISTRIBUTION

There are many possibilities for novel pricing schemes of the future which enable more cost-reflective pricing. In his section, four alternative tariff structures are chosen to be investigated in more detail and they are compared with present tariff structures used widely in Finland (a basic charge and a volumetric energy charge with or without time-of-use feature). The studied novel tariff structures are the Power Tariff, Threshold Power Tariff, Power Limit Tariff (referred also as Power Band Tariff [6]) and the Step Tariff. The tariff components of the studied tariffs are listed as follows:

1. “Power Tariff” (PT): in PT, there are three cost components for the customer:
    a. Basic charge (in €/month)
    b. Energy charge (in €/kWh)
    c. Power charge (in €/kW) based on peak power, which can be measured and calculated in different ways (e.g. highest hourly power of the month or mean of three highest hourly powers of the month etc.) [7].
2. “Threshold Power Tariff” (TPT):
    a. Basic charge (in €/month)
    b. Energy charge (in cent/kWh)
    c. Power charge (in €/kW), which is used if a predefined threshold power is exceeded. Powers that remain under the threshold are included in the basic charge.
3. “Power Limit Tariff” (PLT):
    a. Power charge based in pre-ordered capacity (in €/kW, month). This means that a customer selects a maximum power level for him/her, and commits to not to exceed the limit. And if a customer exceeds the limit, he/she has to pay an exceeding fee or alternatively select and pay for a higher power band.
4. “Step Tariff” (ST):
    a. Basic charge (in €/month)
    b. Consumption charge (in €/kWh), which is paid for every hour separately. The magnitude of the charge is dependent on the average power during the hour in the step-vise manner. This means that if the hourly average power would

exceed a certain predefined limit, the cost of the charge for that hour would much higher compared to the situation where the consumption would have been below the limit.

Each of the presented structures have their own advantages and disadvantages when observed from different aspects and viewpoints of different actors of the electricity sector. In Table 1, the main characteristics of the presented tariffs are listed from five different viewpoints.

The first point-of-view is cost-reflectiveness. This is an important aspect since the pricing of electricity distribution has to reflect the costs of the DSO. This motivates customers to lower the costs of the whole distribution system, which is good also for the national economy's point-of-view. Cost-reflectiveness of distribution pricing is a requirement set by European legislation [8].

Table 1. Characteristics of novel small customer tariffs from different viewpoints. As PT and TPT are quite close to each other, they are presented in the same column in the table.

	Power Tariff (PT) and Threshold Power Tariff (TPT)	**Power Limit Tariff (PLT)**	**Step Tariff (ST)**
Cost reflectiveness	Very good with the PT due to the existence of the three different cost components resembling the cost structure of the DSOs. With TPT this applies when the threshold power is exceeded.	Quite good compared to present tariffs, although not as good as with PT as there is no volumetric energy charge or a separate basic charge.	Moderate, as the power related cost component is paid for every hour separately, it cannot be very high and therefore the customer can have many high consumption peaks without very high related costs.
Incentives to change consumption behavior	Potentially good with both, but this depends on how the parameters are set. When the threshold of TPT is not exceeded, the incentives are lower.	Potentially very good but this depends on how the parameters are set. Also, below the selected power band, there is no incentive to consider the power levels.	Potentially good but this depends on how the parameters are set. Also, below the limit of higher price, there is no incentive to consider the power levels.
Compliance with the products of third parties in the electricity sector	Good, but the introduction of additional power charge increases the complexity from the customer viewpoint, e.g. electricity cost minimization task, investment calculations of energy efficiency and distributed energy resources.	A constant maximum power is a clear boundary condition for different actors like retailers offering for example DR services. However, a constant fixed limit might be too strict in some conditions.	A constant maximum power limit for cheaper power is a clear boundary condition for different actors like retailers offering for example DR services. However, a constant fixed "limit" might be too strict in some conditions, although not as strict as for example in PLT.
Simplicity seen from the customer viewpoint	Compared to the present structures, a new power charge component is added. The concept of power or "peak power" might not be easy to understand for all the customers, but the same challenge applies for all power based tariffs.	The basic structure is very simple, but when the rules on exceeding the pre-ordered band are considered, the cost formation principles become more complex. Generally, the potential of customers in understanding the concept of power includes some uncertainty.	Good, but generally, the potential of customers in understanding the concept of hourly power includes some uncertainty.
Easiness of transition from present tariff structures	Very good, as the weight of the power charge in total pricing can be increased and weights of energy and/or basic charge could be decreased gradually in the transitional phase.	Transfer aspects are more complicated with PLT, because the tariff structure itself does not well enable smooth transition or transition in small steps. However, this could be tackled by introducing some kind of structure for the transitional period. Another option could be change the tariff overnight, but this approach would require extreme carefulness.	Good, as the weight of the more expensive step can be increased gradually by modifying the power limit and price difference between high and low price areas.

The second point-of-view is the level of incentives to encourage the customers towards efficient consumption behavior. The change of consumption behavior is important for improving the economic efficiency of the whole electricity sector.

The third significant point-of-view is the compliance of the tariff structure with the products of third parties in the electricity sector. Such products are for example electricity contracts of the electricity retailers, demand response products and services, small scale power production units, energy efficiency related products and services, providers of new emerging large electricity appliances like electric vehicles. Distribution tariffs should not unnecessarily prevent the increase of for example solar power plants. Therefore, the tariffs have to be designed carefully to avoid unfavorable consequences.

The fourth aspect, is the simplicity of the tariff seen from the customer viewpoint. If the tariff is very complex, it is not very usable as it is crucial for successful tariff implementation that the customers understand how their electricity bills are formed.
The fifth viewpoint relates to the transitional phase from present tariffs to the novel tariffs. The transition should be fluent and the made changes would not be too dramatic and sudden to ensure the success of the new tariffs.

PRELIMINARY QUANTITATIVE RESULTS

In the numerical case study of this paper, a set of over 32 000 customers of a Finnish urban distribution network is analyzed. Most of the customers are small customers living in apartment buildings. There are also some larger customers in the data, but the focus of the study is on the small customer tariffs and thus the larger customers are excluded from the study. However, in the tariff forming process, the effect of larger customers is taken into account to ensure that the tariffs are based on cost-causation. The results presented in this section are the early phase results of an ongoing research project and, as such, they are presented in this section for illustration purposes only. The results do not represent the end results of the project.
The aim of the study is to investigate the impacts of the tariffs on the distribution costs of the customers and on the revenue of the DSO. The results presented here are the preliminary results of the project and, as such, they do not propose what the pricing of the DSO should be in a real implementation. Additionally, the studied area covers only a part of a larger network which only adds to the mentioned point. In the study, five different tariff structures are formed for the customers:

1. Present tariff structures
2. Power Tariff (PT)
3. Threshold Power Tariff (TPT)
4. Power Limit Tariff (PLT)
5. Step Tariff (ST)

The tariffs are formed using a cost-causative approach using the network, cost, consumption and other data of the DSO. In the tariff options TPT, PLT and ST, the tariffs are formed through a heuristic approach and consideration should be used when interpreting the results.
The first tariff structure illustrates the present structure used by the customers. The four other tariff present the novel structures discussed in the previous sections paper so that there are two different versions of the PT: one where a power charge is paid for peak powers of > 0 kW (PT) and another where power charge is in effect only when the monthly peak power of the customer exceeds 5 kW (TPT). In the PLT, an arbitrary selection of power limits is used. These limits are: 3, 5, 7, 9, 11, 14, 17, 20, 25, 30, 35, 40 and 45 kW. The power limit, and the yearly distribution fee, is defined for each small customer based on their annual peak hourly power. In the ST, there are two levels for the consumption charge. The first level is cheaper and applied when the hourly average power of the customer is 5 kW at the most. If the hourly power of the customer is higher than 5 kW, the consumption charge is significantly higher. After the formation of tariffs, the annual distribution costs are calculated for each customer using the four different tariffs. The hourly metering data is used in the calculations so that the tariff parameters are formed using a consumption data over year 2013 and the distribution costs are calculated using the hourly consumption data over year 2014. No changes in the consumption behavior due to the tariffs was assumed to take place. The changes in the yearly distribution fees is a good measure on the level of incentives to change the electricity consumption behavior of the customer, and gives some indication on what the customers might think about the change in their distribution fees. The proportions which are intended to use to collect the target revenue with different tariff components is shown in figure 1.

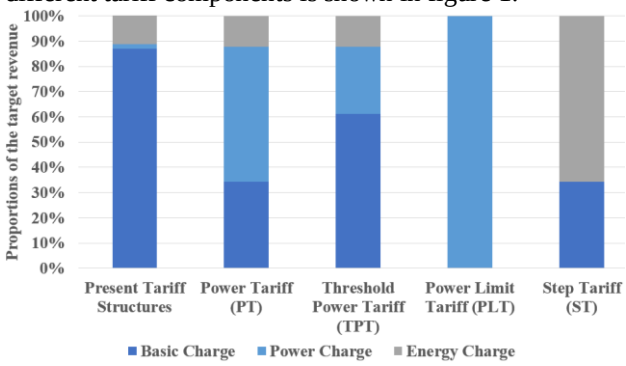

Figure 1. The proportions of different tariff components used to collect the target revenue.

In the tariff formation process, a target revenue over a year for the DSO is roughly 4.47 M€ which is based on the cost analysis and cost allocation phases of the tariff forming process. Figure 2 shows the deviation of the computational revenues with different tariffs from the predefined target revenue. It can be seen that the "realized" revenues with the novel tariffs are very close to the target revenue: the maximum deviation is less than 1 %. The PLT leads to a revenue closest to the target revenue, but this is necessarily not the case in every situation. It has to be emphasized that no changes in the consumption behavior was not assumed in this preliminary study. The results would in this case represent more the situation where the customer would not care about the tariff. In reality, at least some of the customers would try to attempt to minimize their distribution costs and this would affect the results.
Figure 3 shows the histogram of the changes in the yearly distribution costs of the customers with different novel tariffs compared to the present tariff structure. The centers of the histogram bins are set at 10 €/a intervals, but the first (from the left) and the last bins are set to cover the values ≤–195 €/a and ≥205 €/a, respectively. The distribution of the cost differences in the figure shows well the small differences, but there are a small numbers of very large deviations which are "packed" in the first and the last bins.

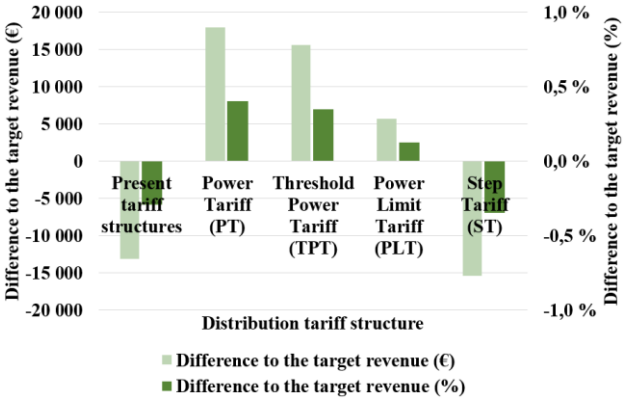

Figure 2. Differences between the target revenue and the achieved revenues with different tariff structures.

The proportions of customers with changes of <–200 €/a are 3.0%, 2.0%, 3.1% and 2.0% with tariffs PT, TPT, PLT and ST, respectively. Similar proportions for changes >200 €/a are 2.1%, 2.9%, 1.8% and 2.8%. Very large deviations should be treated separately, and most of them can probably be treated as outliers, as there might be for example some errors or inaccuracies in the data.

From the figure, it can be seen that the absolute changes are not that high for the majority of the customers. However, small absolute change does not guarantee a small relative change and it is possible that the relative changes are even tens of percent, which cannot be treated as very small. Small or moderate changes mean that for many customers, there are no clearly visible incentives to change consumption behavior as their bills would not change very much. However, many customers would have possibility to lower their bills from the present level with the presented tariffs. From the figure, it can be seen that with PLT the changes are typically very small. In case of PT, the changes seem to be quite symmetrical so that the number of customers whose distribution costs would decrease and the number of customers who would have to pay more are of the same order of scale. With TPT and with ST, the costs of most of the customers would decrease, and for those whose costs would increase, the increase would be quite high.

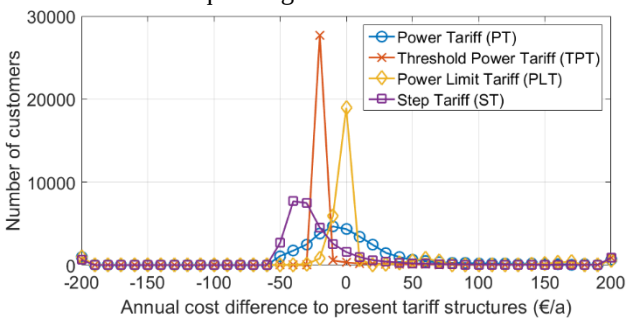

Figure 3. Annual cost difference distributions of customers with different tariff structures.

This might implicate, that there is a number of customers who could decrease their costs significantly by changing their consumption behavior, and for most of the customers, the reduction of distribution fees might be more difficult. However, yet highly relevant, the potential changes in the consumption behavior are not in the scope of this study.

DISCUSSION AND CONCLUSIONS

In this paper, the motivation, targets, challenges and impacts of novel type of distribution pricing is analyzed in qualitative and quantitative manner. Different aspects of novel distribution tariff structures are discussed and analyzed. Also, using large set of data of real customers, a numerical study is made concerning the revenue of the DSO and distribution costs of the customers is made.

The studies show that all of the presented novel tariff structures could be applicable in real life, but as the tariffs affect many issues and actors in the electricity sector, more information and research has to be made. For example, the following aspects need further studies and will be studied more in the project described in the paper:

- Consumer impacts and reactions to novel tariffs including potential changes in the electricity consumption habits. This aspect has high interconnection between the solutions of the future energy system like DR products and services.
- Quantitative impacts of novel tariffs on the profitability/attractiveness of small-scale power production units, demand response contracts, electric vehicles, energy storages
- Practical aspects of transition from the present tariff structures to the novel ones.

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