# ANALYSIS OF TRANSITION STEPS TOWARDS POWER-BASED DISTRIBUTION TARIFF OF SMALL CUSTOMERS

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## *ABSTRACT*

*This paper discusses the development of distribution tariffs of small customers. Future changes in the electricity sector challenge the present distribution tariff structures and instead of a passive approach, the Distribution System Operators (DSO) have the opportunity to respond to the challenges by applying novel tariff structures. The movement towards Power-based Distribution Tariffs (PBDT) has been seen as a very potential development direction. However, before implementing PBDTs, or any other novel tariff structures, it has to be ensured that the change will not cause unwanted outcomes such as too aggressive an impact on the distribution fees of the customers or on the total revenue of the DSO. The main focus of this paper is on the transition viewpoints from present tariffs towards one selected PBDT structure.*

## INTRODUCTION

Tariffs related to electricity have been an increasingly hot topic in the recent years as much development has happened in the electricity sector. For example, on the European level, various countries have issued smart meter roll outs and in some countries, such as in Finland, the roll out has already been completed [1]. In practice, the consumption of every customer has a smart meter capable of remote reading of hourly energies and which includes also demand response functionality. Detailed information about the consumption enables the use of novel pricing schemes for the small customers. The consumption of the larger customers has been measured in more detail for a long time but this has not been the case for small customers.

The distribution tariffs have been under an active discussion also because of the future challenges which the Distribution System Operators (DSO) will be facing. For example, the increasing amount of distributed energy generation at the customer site does not fit in well with the present energy-dependent pricing schemes of the small customers. Additionally, the movement has been such, at least in Finland, that the DSOs have increased the emphasis of the fixed part of the tariffs. This direction is on the right track since the majority of the costs of the DSO is linked to the capacity (i.e. fixed) rather than on energy (i.e. variable). There are also alternatives such as developing alternative distribution tariff structures which could enable the customer to participate in the electricity market through demand response. By developing their pricing practices, the DSOs can also make their pricing more cost reflective and through different incentives included in the tariffs, they can encourage the customers towards more efficient consumption of electricity. By this we mean both the energy efficiency and the higher capacity utilization rate of the grid. Additionally, one aim is to produce a tariff structure which gives the customers better control over their distribution fees than today by their own actions.

Regarding the distribution tariffs of small customers, we aim to answer the following key research questions:

1. What alternative distribution tariffs there are for small customers?
2. How could the transition from the present tariff structures to alternative ones happen?
3. How would the transition affect the distribution fees of the customers and the revenue of the DSO?

In this paper, we investigate the transition process from present small customer tariffs towards an alternative tariff structure through a case study. The approach is based on forming the tariffs in a cost-causative manner.

The study presented in this paper is a continuation of a long term research work aiming to examine the effects of alternative distribution tariff structures. The earlier work presented in e.g. [2] and [3] has focused more on the perspective of the end results (i.e. the transition of tariffs is made overnight). The results presented in this paper are not final and as such, they do not propose what the pricing of the DSO should be in the future in a real implementation. Additionally, the data used in the case study represents only a part of the network of the DSO and thus the results do not suggest what the pricing should be for the whole DSO.

This paper is structured as follows. In the second section, the present pricing scheme of the electricity distribution in Finland is discussed. The third section discusses the transition process of distribution tariffs. In the fourth section, a case study is presented where the transition is made with different implementation levels of the power charge of the selected Power-based Distribution Tariff (PBDT) structure. In the fifth section, the results of the case study are presented. The last two sections provide the discussion of the results and the conclusion of the paper.

## PRESENT DISTRIBUTION TARIFFS

In Finland, the electricity market is unbundled and the customers pay separately for the energy and for the delivery. The retailer bills the customer through the energy tariffs and the DSO through the distribution tariffs. Both parties (i.e. the energy retailer and the DSO) have their own selection of tariffs, with possible limitations, from which the customer can select the most suitable option.

### Distribution Tariffs of Small Customers

The most typical composition of a distribution tariff of the small customer is the two-part tariff, which consists of a fixed monthly base charge (i.e. €/month) and of a volumetric consumption charge (i.e. cent/kWh). There are also options for small customers where the volumetric consumption charge has variations based on time (i.e. Time-of-Use (TOU) tariffs). The TOU tariffs are designed for customers who use most of their electricity during the night time. Due to historical reasons when the electricity market in Finland was not yet unbundled, the utilities wanted to even the production by encouraging the customers, through a cheaper consumption charge, to use large electrical devices, e.g. water boilers or electric storage heating, during certain times of day (i.e. night time). The TOU tariffs have remained in the tariff selections of the DSOs from the past.

In some cases, the DSO might have a tariff available in their selection for small customers which includes, in addition to the aforementioned tariff components, a separate charge for power (i.e. €/kW). However, typically in practice, the power in question is not the measured real power but a predefined contract power.

### Distribution Tariffs of Large Customers

For larger customers, such as industrial or larger commercial customers, the available distribution tariff option is typically the power tariff. The structure of the power tariff consists of a fixed monthly base charge, a volumetric consumption charge, with possible TOU features, and of separate charges for the active and reactive power (i.e. €/kvar). The larger customers have had these advanced consumption meters and tariffs already for a longer time.

## TRANSITION TOWARDS ALTERNATIVE PRICING SCHEMES

The change of a tariff structure is by no means a small operation from the DSO perspective since the distribution tariffs are the main source of income for the DSO and thus in the very core of the business. Before changes are made regarding the tariffs, it has to be ensured that the unwanted effects of the changes are minimized.

In the case of alternative tariffs, the key motivation is not necessarily generating the means to control the consumption. Instead, the change of a tariff structure is more of an act of preparation for the DSOs to respond to the future challenges caused by external factors e.g. the change of consumption habits due to the price signals of tariffs or the energy retailer or the increasing amount of small-scale distributed generation and energy storages. The DSOs have to be able to maintain a steady level of revenue also in the future and, due to the combination of energy-dependent pricing and the upcoming challenges of the energy sector, the DSOs have started to rethink their pricing practices.

### Alternative Distribution Tariffs

Regarding the development of alternative pricing schemes for small customers, at least the three main research questions presented in the introduction have to be answered. As it comes to the question number one, there are many alternative distribution tariff structures. For example, the tariffs can be more dependent on time (e.g. TOU tariffs) or they can depend on the state of the grid (e.g. Critical Peak Pricing (CPP)) or they can be in some way even more dynamic (e.g. different price for every hour). [4] The listed alternatives refer mainly to a two-part tariff where the volumetric consumption charge has a varying price level. Alternatively, the tariffs can include other components which make the tariffs more dynamic e.g. by taking into account the capacity demand (i.e. the hourly power) of the customer in various ways.

Selecting the tariff structure is not the only part of the problem. The tariff structure can have several variations which determine the mechanisms of how the distribution fee is formed in practice. For example, the fee formed by the power charge of the PBDT can be defined by the peak hourly power of the year or it can be defined by the monthly peak hourly powers or the combination of some hourly powers. The example cases affect differently the incentives of how the customers change their consumption patterns. For example, if the yearly peak hourly power defines the quantity of the "power part", the customer does not necessarily have the best incentives to think about the power during the other hours of the year.

In order to limit the scope of this paper, we have selected the studied distribution tariff structure to be a PBDT consisting of three components: a fixed base charge (i.e. €/month), a volumetric consumption charge (i.e. cent/kWh) and an active power charge (€/kW, month). The basis of the power charge is selected to be *the average of five highest monthly powers of the customer* (i.e. the unit price is the same, but the monthly averages define the fee for each month). This selection is based on the earlier work presented in [3] where this specific power charge basis option led to the closest revenue to the target revenue. In the small customer tariffs, no separate charges are assumed for reactive power to simplify the tariff structure.

The selected tariff structure is one variation of the PBDTs which generally refer to tariffs which take into account the power demand of the customer more specifically compared to the present small customer tariffs. The selection of the tariff structure in this paper is based on present tariffs of larger customers to see if the "*power tariff*" could also be applied to the small customers. This option would offer an opportunity to unify the price list of the DSO rather than to have many separate tariff structures to offer.

## Transition Process

The transition towards novel tariffs can be based on different premises. For example, the transition could be based on one of the next two starting points. Firstly, the transition can be based on the idea that the tariff and its target customers are selected specifically based on their consumption patterns and their potential for altering their habits. In practice, only the clear winners (i.e. the customers who would face smaller distribution fees) would be recommended to switch to the new tariff at the start and the losers (i.e. higher distribution fees) would be recommended to remain in their present tariffs.

Alternatively, the transition could be based purely on a cost-based approach. This means that every small customer would be merged from various tariffs into one group and the new tariff would be launched for every small customer simultaneously. In this approach, the changes in the consumption patterns would also be analyzed but there would nevertheless be both winners and losers. This approach would not please every customer but it would, in a sense, level the score between long time losers and winners by making the rules same for everyone (i.e. the customers who in the past have subsidized others and those who have been subsidized by others).

There are also alternative ways to perform the transition of tariffs with respect to time. For example, the change of tariff structure could be made overnight. This approach would probably lead to high changes in the customer specific distribution fees since the change is made suddenly and the customers have little time to adapt to the new situation. It is possible that some customers would complain about their increased bills to the DSO or to the instances responsible of overseeing the rights of the customer.

Alternatively, the transition could be made in several steps. In this approach, both the customers and the DSO could have more time to adapt to the changes and the needed steps could be adjusted and made gradually over a longer period of time (i.e. years). It is also possible that in this approach, a balanced situation could be reached during the transition. For example, in the case of the PBDTs, this could mean that it is possible to reach a suitable implementation level for the power charge of the PBDT which would be smaller than 100 %. However, on this lower implementation level, the tariff could still encourage the customers towards an efficient consumption so that the load on the network level would be relatively even throughout the year and the revenue of the DSO would not fluctuate excessively between consecutive years.

## CASE STUDY

The study investigates the possible implementation levels of the power charge of the PBDT of small customers. The purpose is to study if it is possible to apply the PBDT for small customers in a way that the effect on the total revenue of the DSO is not too dramatic and the effects on the distribution fees of individual customers are more moderate than in the approaches presented in e.g. [2] and [3].

In the previous studies, it has been assumed that the PBDT would be applied to the small customers at full measure. Simply put, this means that the price level of the tariff component linked to the power demand of the customer would be quite high in these cases (i.e. roughly 53 % of the target revenue would be collected with the power charge).

## Data Used in The Study

The data used in the study covers over 32 000 customers, most of them being small customers living in apartment buildings in an urban area. With real customer, load and cost information, tariffs based on cost-causation were formed (i.e. the presently used tariffs and the PBDT). The formed present tariff structures are used to compare the impacts of the PBDT on the distribution fees of individual customers and on the revenue of the DSO.

In the customer data, there are also larger customers which were taken into account in the calculation to ensure that suitable portions of the annual costs are allocated to different customer groups accordingly. However, the case study focuses on the small customer tariffs and for this reason, the larger customers are excluded from the study. Based on the cost allocation phase of the tariff calculation process, the target revenue to be collected from the small customers is roughly 4.47 M€. We apply the consumption data from two consecutive years (i.e. 2013 and 2014). The data from the first year is used to form the tariffs for the next year and the data from the latter year is treated as the realized consumption. No changes in the consumption due to the PBDT were assumed to take place.

Due to the selected calculation principles, the formed present tariff structures emphasize the fixed part of the tariffs (i.e. nearly 90 % of the revenue demand is allocated to the fixed charges of the small customer tariffs). This would, to some measure, represent the case of the future where the present trend would be taken to the extreme (i.e. the emphasis of the fixed charge would be increased to its maximum level). In Fig. 1, the portions of the target revenue to be collected with different tariff components in each of the studied cases is presented assuming that every small customer would have the PBDT.

From Fig. 1, it can be seen that the PBDT cases, the power charge begins to be relevant after the implementation level of 30 % onwards (i.e. the price exceeds 1.00 €/kW). In the study, we do not consider values lower this implementation level of the power charge in the further examination.

## Transition Method

In the study, the transition is based on a cost-based approach, where every small customer would have the PBDT. The first transition step is examined so that the magnitude of the power charge is varied by allocating different portions of the target revenue linked to power either to the fixed charge or to the power charge of the PBDT. Simply put, this would mean that at the implementation level of 100 %, roughly 53 % of the target revenue would

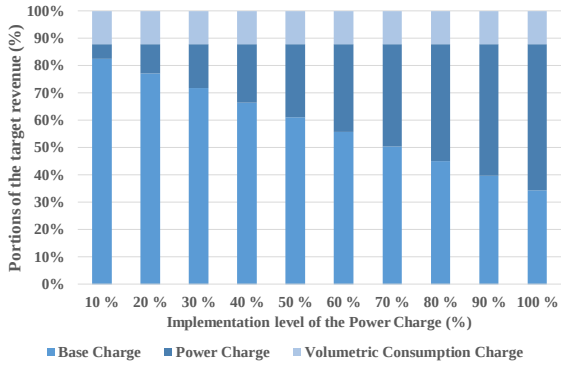


***Figure 1:****The portions of the target revenue to be generated with each tariff component of the PBDT with different implementation levels, in 10 % intervals, of the power charge.*

be collected with the power charge. On smaller implementation levels, portions of the mentioned 53 % are collected with the base charge of the PBDT (i.e. we vary only the levels of the base and power charge). The magnitude of the volumetric consumption charge remains unchanged in all of the studied cases. In the present tariffs, all the target revenue related to power demand is allocated to the fixed charges. The purpose is to investigate what the suitable quantity could be for the power charge that would not lead to too high changes in the customer specific distribution fees in the first phase of the transition. After the initial implementation level has been selected, a hypothetical transition process is presented to examine the possible length of the transition period to the full implementation level of the power charge.

## RESULTS

From Fig. 2 it can be seen that the change in the total revenue would not have been significant in the studied cases. In fact, in the case of the PBDT the "realized" revenue would have been closer to the target revenue than what the formed present tariff structures would have generated. It should however be emphasized that in the studied cases, no change in the consumption behavior due to the PBDT was assumed and the hourly consumption measurement were used as such. In a real implementation, at least some

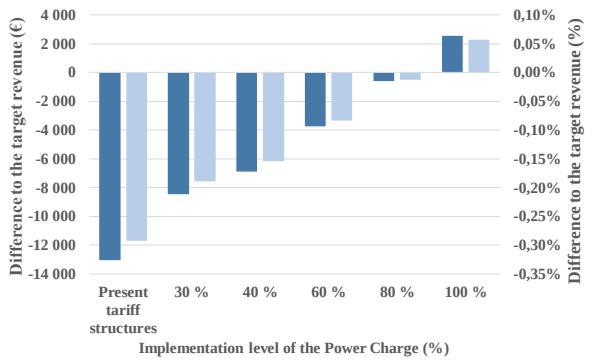


***Figure 2:*** *The absolute and relative differences between the target and the "realized" revenues in different implementation level cases of the PBDT and in the case of present tariff structures.*

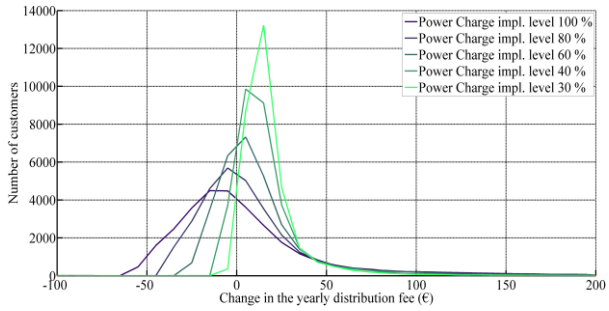


***Figure 3:*** *The distribution of changes in the distribution fees (compared to the formed present tariff structures) for the majority of the small customers (i.e. over 94 %) in different implementation level cases of the power charge of the PBDT.*

of the customers would aim to benefit from the power charge by altering their consumption habits in order to affect the size of the distribution fee.

It can be seen from the distributions shown in Fig. 3 that in all of the cases, most of the customers would have experienced quite moderate changes in their distribution fees. However, it is important to note that there are customers outside the range shown in Fig. 3. For example, there are customers who have in the past been assigned to a tariff which is not the most optimal (i.e. the cheapest option) based on their present consumption habits. The implementation of the PBDT would, in the case of the aforementioned customers, lead to a result where these customers would face much lower distribution fees. On the other hand, there are also customers who have quite high hourly demands and they have had a tariff which has been cheap for them. For these customers, the PBDT would result in significantly higher fees in all of the implementation level cases. The both ends of the distributions would have to be solved before the PBDT could be used in order to avoid the extreme changes in the fees of the customers.

For the next years of the transition period, the emphasis of the power charge can be increased gradually and the effects of the PBDT on the consumption behavior and on the revenue generation can be monitored. A hypothetical example of the development process of the PBDT is shown in Fig. 4, where the initial implementation level of the power charge was selected to be 60 %. This selection was

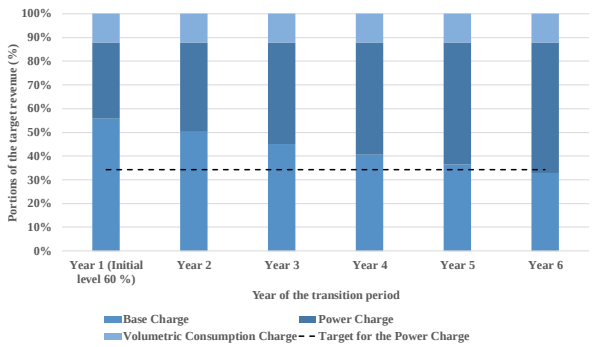


***Figure 4:*** *An example of a hypothetical development process of the power charge of the PBDT to reach the implementation level of 100 %.*

made for illustration purposes based on the results presented in Figs. 2 and 3 by taking into account both aspects i.e. the revenue generation and changes in the distribution fees of individual customers. In the following years, 10 % of the target revenue generated with the fixed base charges is shifted yearly to be generated with the power charges. Assuming that the total revenue would remain unchanged, it would take over five years to reach the 100 % implementation level of the power charge with this approach.

## DISCUSSION

The aim of the study was to examine the effects of the PBDT with different implementation levels of the power charge. The results show that from the studied cases, the implementation level of 60 % would have produced a distribution where the positive and negative changes in the distribution fees of individual customers would be quite even and the peak is close to zero. This alternative also provided a revenue quite close to the target so no dramatic change occurred. If the goal of the DSO would be to make the change of tariff within a reasonable time frame (e.g. 5 years), the implementation level of the power charge in the first step of the transition should be relatively high.

It has to be noted that there are factors that create uncertainty for the results. For example, in the study it was not assumed that the PBDT would alter the consumption habits of the customers. However, since the power charge was not implemented at full measure in the calculation, there are less incentives for the customers to change their consumption habits in a dramatic way. If e.g. the implementation level would have been 30 %, the customers would have had a smaller incentive to alter their consumption behavior than in the case of 80 %. The changes in the consumption behavior and their anticipation in the tariff design are in a critical role, since they affect the price levels of the tariffs and they should be considered in the further work. The calculation process would require some iteration before real implementation in order to determine the proper price level of the tariffs due to the possible changes in the consumption. For example, if some of the customers would lower their monthly consumption peaks and the DSO was not prepared for this, the realized revenue would be lower. If this was to happen on a larger scale, the DSO might have to raise the price level of the power charge to ensure adequate level of revenue. Raising the prices would make not make the customers happy especially if some customers would have invested in load controlling devices in order to lower their distribution fees.

Additionally, more research work is needed to recognize what kind of customers would benefit from the change of the tariff structure especially in the early phases of the transition. The customers cannot just be seen as a collective group of customers as there are customers with different levels of expertise and interest to make the best out of the tariffs in order to minimize their distribution fees. It is also important to note that in this paper, only one of the many possible alternative tariffs, and only one variation of this specific PBDT structure, was studied. There are many other possible tariff structures each with their own variations left to be studied. These aspects are highly relevant topics in this field and they require further research work.

## CONCLUSION

This paper discussed the future of the pricing of electricity distribution of small customers. The transition from present small customer tariffs to novel tariffs, such as the PBDT presented in the paper, was examined through a case study where real data of a DSO was used. The main purpose of the study was to investigate the impacts of the PBDT on the revenue of the DSO and on the distribution fees of individual customers with different implementation levels of the power charge of the tariff. The results showed that the PBDT could be implemented with a more neutral customer impact, than implementing the power charge at full measure, with an implementation level of 60 % in the first phase of the transition. The impact on the revenue of the DSO was also reasonable in this case.

It has to be emphasized that the results presented in the paper are based on only a part of the network of the DSO and, as such, the results do not propose what the pricing should be for the DSO in a real implementation for all of its small customers. Additionally, there are also other factors affecting the tariffs than what is presented in this paper and there is no one size fits all solution for the pricing of electricity distribution. However, the PBDT proposed in this paper includes many benefits and due to its three-part structure, the tariff provides the customers a good control over their distribution fees through their own actions. Further work is required to study the effects of the proposed PBDT in more detail.

## REFERENCES

[1] European Commission, “Benchmarking smart metering deployment in the EU-27 with a focus on electricity”, Report, 2014.

[2] Lummi, K., Rautiainen, A., Järventausta, P., Heine, P., Lehtinen, J., Hyvärinen, M,, ”Cost-causation based approach in forming power-based distribution network tariff for small customers”, *13th International Conference on the European Energy Market (EEM 2016)*, 6-9 June, 2016, Porto.

[3] Lummi, K., Rautiainen, A., Järventausta, P., Heine, P., Lehtinen, J., Apponen, R., Hyvärinen, M., ”Variations of Power Charge Basis of Power-based Distribution Tariff of Small Customers”, *The IEEE PES Innovative Smart Grid Technologies Asia Conference (ISGT Asia 2016)*, 28 November-1 December, 2016, Melbourne.

[4] Hledik, R., Faruqui, A., Weiss, J., Brown, T., Irwin, N.,”The Tariff Transition – Considerations for Domestic Distribution Tariff Redesign in Great Britain”, Report, 2016.