DEVELOPMENT POSSIBILITIES OF DISTRIBUTION NETWORK SERVICE CHARGES OF LOW-VOLTAGE CUSTOMERS – APARTMENT HOUSES AS ENERGY COMMUNITIES

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ABSTRACT

This paper discusses the electricity distribution pricing for energy communities (ECs) in the form of apartment buildings in the context of the Finnish electricity market environment. The goal is to investigate if practical reasons can be identified for the distribution system operators (DSOs) to develop their pricing, and if the present electricity distribution network tariffs used for larger customers could be used also for the ECs. The paper includes a case study, in which real hourly energy readings of 6 apartment houses and the electricity distribution network tariffs of 9 Finnish DSOs are used to investigate the economic impacts of two different billing models. The results indicate that other tariff options should be considered and investigated for the ECs in the future to avoid any dramatic changes in the DSO turnovers while simultaneously ensuring that the ECs participate in the cost bearing of the system appropriately.

INTRODUCTION

The role of traditional passive customers is evolving toward being more active than before. Today, some of the small-scale customers already possess different distributed energy resources (DERs) such as photovoltaic (PV) panels or an energy storage (e.g., a battery). However, because the investments made to DERs can still be costly for individual customers, and not all customers are situated in optimal locations, e.g., in terms of renewable energy production, possibilities for small-scale customers to acquire and utilize DERs can be improved by forming energy communities (ECs) in which several customers, by open and voluntary participation, own and share the benefits gained from DERs jointly among the community members.

According to the European Solar Rooftops Initiative, the European Union aims to increase the share of renewables to 45%, make the installation of rooftop solar energy compulsory for all new residential and public and commercial buildings of a certain size, and, by 2025, set up at least one EC based on renewables in every municipality with a population higher than 10 000 [1]. Thus, the ECs will be common in the future, and they will have an impact on the electricity distribution network business operated by the distribution system operators (DSOs).

The motivation of this paper derives from the ongoing discussion in Finland related to the ECs in the form of apartment houses. However, it is important to note that the ECs may consist of other combinations of different customers (see, e.g., [2]), but the focus here is on apartment houses. From a DSO standpoint, especially in the Finnish electricity market environment, it remains to be defined what the electricity distribution network tariffs used for the ECs should be. In the case of ECs, the academic literature related to electricity distribution network tariffs is still developing. From a research perspective, in order to identify the potential issues, it is important to study if the present electricity distribution network tariffs used for regular customers could also fit the needs of the ECs.

In this paper, the economic impacts of two different billing models on the ECs formed by apartment houses are investigated and discussed. The paper includes a case study, in which real hourly energy readings of 6 apartment houses and the electricity distribution network tariffs of 9 Finnish DSOs were used to study the potential of using the existing pricing schemes also for the ECs in Finland or if practical reasons that would push the DSOs to develop their pricings can be identified. This paper is also a continuation for the work presented earlier in [3] and the research themes discussed therein.

The research questions, to which this paper offers answers, are as follows:

1. How would changing the billing model of electricity distribution network tariffs used for apartment houses as ECs impact the distribution fees paid to the DSO?
2. How the potential challenges, e.g., the changes in the DSO turnover, could be resolved?
3. What impacts would DERs, such as PV panels, have on the DSO turnover and the distribution fees of the ECs, and how could the potential issues be accounted for in the pricing of electricity distribution?

This paper is structured as follows. In the following sections, the ECs, and the electricity distribution tariffs used in Finland are discussed. After this, a case study is presented to answer the first research question by investigating two different billing models used for the EC. The last two sections of the paper provide the discussion and the conclusions, which answer the second and the third research questions.

ENERGY COMMUNITIES

In the recent European legislation, more precisely in the Directive (EU) 944/2019, citizen energy communities (CECs) are defined [4]. As pointed out, e.g., in [2], the definitions of ECs at an EU legislation level are vague, and they do not explicitly determine what the ECs could be in practice. In pursuit of clarifying the definitions, in [2], different types of ECs have been identified and discussed at a practical level.

For instance, an EC could consist of a group of detached houses, an apartment house (i.e., individual apartments and their common loads such as elevators, lighting, heating of common areas, etc.), or several apartment houses situated in the same quarter. The ECs could also have different common resources for clean energy production (e.g., PV panels) and energy storage (e.g., batteries), etc., and the benefits of those resources are shared between the members of the EC. The use of DERs can lower the need to acquire energy from the external electrical energy system in a traditional way.

A central notion when considering the different EC types is that a local ECs could operate over the existing public electricity distribution network that is owned and operated by the local DSO [2]. However, in the situation where the ECs operate over the public electricity distribution network or the EC has a connection to the public electricity distribution network, it must be ensured that the ECs participate in the sharing of the total costs of the system (i.e., in the context of this paper, the electricity distribution network) in a balanced way and are subject to cost-reflective electricity distribution network tariffs [4]-[5]. The pricing of electricity distribution in the case of ECs is thus a central topic and the related academic literature is still developing.

In the context of this paper, an EC formed by an apartment house that consist of several small-scale customers and the common loads of the apartment house is in a key focus. In this case, the EC would operate within its property boundaries. If the apartment house would form an EC and have a single contract with the local DSO instead of each individual customer, i.e., every apartment and the common loads of the apartment house, having their own contracts, then it could affect the total distribution fee at the apartment house level. Thus, if the EC still has a connection to the public electricity distribution network and the electricity is either bought from or sold to the public grid, then the EC imposes costs on the DSO and those costs should be covered by the distribution fees. From a DSO perspective, it is possible that the ECs may impose new challenges on the electricity distribution network tariff design because the ECs have different ways to produce and use electricity compared to the traditional passive customers.

ELECTRICITY DISTRIBUTION NETWORK TARIFFS IN FINLAND

Regular electricity distribution network tariffs used for small-scale and larger customers

For small-scale customers, who in the context of this paper as considered to have a maximum fuse size of 3x63A, present distribution tariffs consist of fixed charges (€/month) and volumetric charges (c/kWh). Depending on the operating environment of a DSO, the fixed charges may increase with the fuse size or not. Additionally, the different tariffs used for the small-scale customers can either have a single rate for the volumetric charge or different rates for different times of the day or different seasons [i.e., Time-of-use tariffs (TOU)].

In the recent years, in addition to fixed charges and volumetric charges, a few DSOs have also implemented separate demand charges for their small-scale customers. However, the billing practices of those demand charges range from a monthly peak hourly demand to the peak hourly demand of a sliding 12-month interval (see, e.g., [6]). In the recent years, many DSOs in Finland have also investigated the use of demand charges for their small-scale customers, and more DSOs are expected to reform their tariffs used for the small-scale customers in the future.

Tariffs used for larger customers consist of three main components: Fixed charge (€/month), volumetric charge (c/kWh) with possible TOU features, and demand charge (€/kW) for active demand with different billing practices between the DSOs. Additionally, several DSOs use separate charges for reactive demand (€/kvar) with different billing practices between the DSOs.

Other electricity distribution network tariffs

For the energy injected into the network, there is a separate electricity distribution network tariff. That tariff is based on energy volume (c/kWh) and its price level is set directly by the current legislation. From an EC standpoint, the energy transfers, which occur from the energy produced and shared within the EC, i.e., inside the property boundaries in the case of apartment houses, are not subject to electricity distribution network tariffs.

Currently in Finland, there are no specific electricity distribution network tariffs in place for the ECs. The reason is that the practical issues related to the ECs are still to be defined more precisely, and in Finland, the DSOs (i.e., 77 different DSOs during the year 2023) determine their electricity distribution network tariffs independently based on the conditions of their operating environments. However, the discussion related to the electricity distribution network pricing in the case of ECs is currently ongoing.

Table 1. Key information of the 6 apartment houses of the case study during the year 2018.

Apartment house	1	2	3	4	5	6
Number of customers	24	24	59	43	49	29
Number of floors	2-4	2-4	> 4	> 4	2-4	2-4
E_{annual} (MWh)	38.12	80.90	261.50	187.06	119.77	81.64
Lowest $P_{max,month}$ (kW)	7.32	21.95	49.65	31.21	23.61	28.32
Highest $P_{max,month}$ (kW)	12.36	27.99	59.89	55.50	33.40	40.56

(Note: E_{annual} here signifies the total annual energy volume and $P_{max,month}$ signifies the peak hourly demand of the month.)

CASE STUDY

The goal of the case study was to investigate the economic impacts of different billing models on the distribution fees of ECs in the form of apartment houses in Finland. The purpose of the case study was also to investigate if reasons could be identified for the DSOs to consider developing their pricing in the case of ECs if they were to emerge in different operating environments in the form of apartment houses. The investigation was limited to the Finnish unbundled electricity market framework. The case study was made by applying the hourly energy readings of 6 apartment houses in the operating environments of 9 different Finnish DSOs by assuming that the apartment houses, i.e., the individual apartments and the common loads of the apartment house, could form ECs.

To quantify the economic impacts of the ECs on the DSO turnover, two billing models were investigated: (1) Individual billing model (IBM) and (2) collective billing model (CBM).

In the context of this paper, IBM was based on the prevailing practice used in Finland in which the DSO bills each small-scale customer, and the common load of the building, separately. The CBM was based on a situation where the apartment house would be classified as a single customer, and the DSO would bill the EC based on the aggregated load profile formed by the loads of individual apartments and the common consumption of the apartment house. The EC, in this case, was considered as a larger customer, to which the DSOs in Finland have different tariff formats and prices compared to those used for small-scale customers. The electricity distribution network tariffs used for "larger customers" typically concern the commercial and industrial customers, and in Finland, those tariffs are commonly known as "Low Voltage Demand Tariffs".

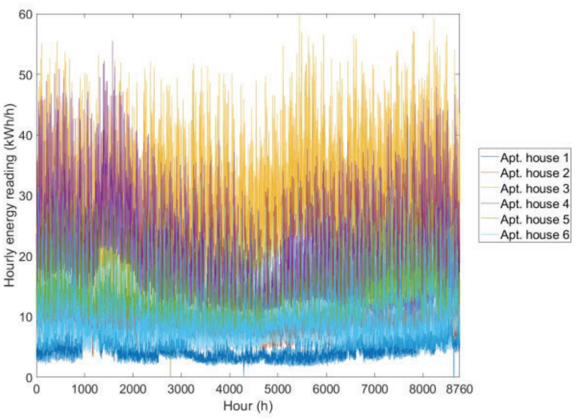

Fig. 1. Hourly load profiles of 6 apartment houses in Finland during the year 2018.

Data used in the case study

The data used in the study was based on the real hourly energy readings of 6 separate apartment houses situated in Finland. The number of apartments in each building and other relevant information related to the energy uses are shown in Table 1. The annual load profiles based on the hourly energy readings during the year 2018 (i.e., the sum profile formed by the individual apartments and the common loads of the apartment house) for each apartment house are shown in Fig. 1. To study the economic impacts of PV energy production units in ECs, optimally sized PV production units were determined for each apartment house based on the load profiles of the common loads of the apartment houses using a method described in [7]. The acquisition costs of the PV production units were not considered in the study. The study is limited on identifying if there are reasons for the DSOs to develop different electricity distribution network tariffs for the ECs.

As for the price data, the public distribution tariffs (excl. value added tax) of 9 different Finnish DSOs that were in effect during August 2022 were used. The DSOs were situated in different operating environments ranging from urban areas to sparsely populated areas, and the formats and prices of distribution tariffs varied between the DSOs. The reason for this selection was to investigate how the pricings of the DSOs in different operating environments affect the total distribution fees of the apartment houses as ECs in different settings. the electricity retail prices were not included in the case study.

RESULTS

To study the economic impacts of different billing models,

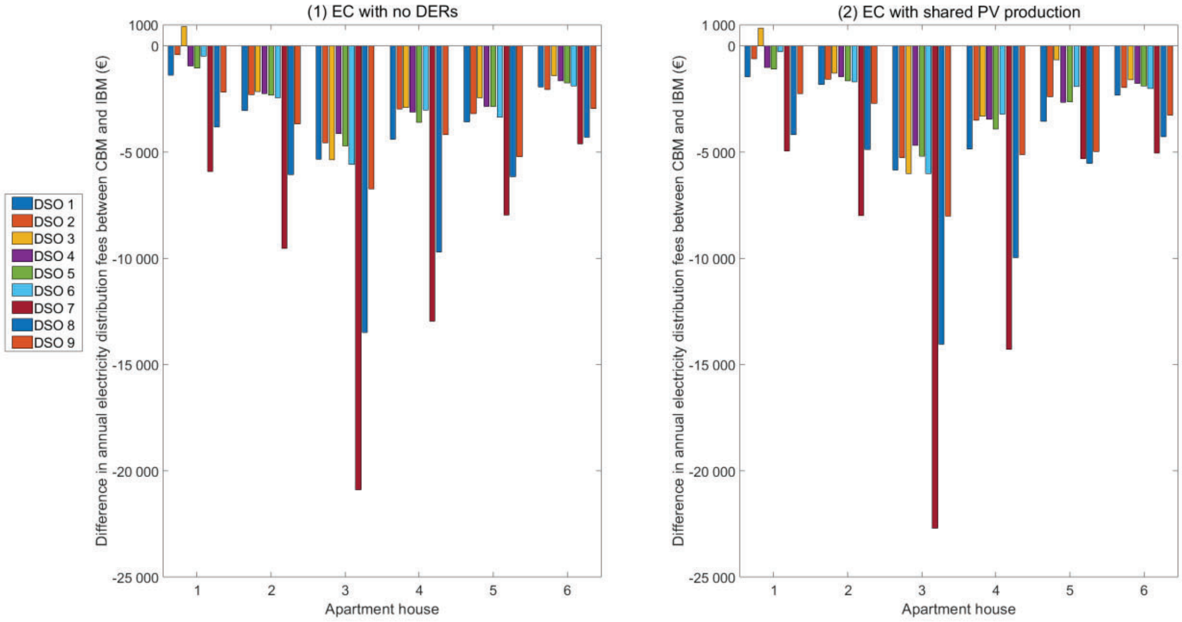

Fig. 2. Differences in annual electricity distribution fees between CBM and IBM for 6 apartment buildings under the electricity distribution network tariffs of 9 Finnish DSOs.

i.e., the IBM and the CBM, annual electricity distribution fees were calculated for the six apartment houses in two cases: (1) The apartment house does not have DERs and (2), where each EC has a shared PV production unit used for self-consumption for the common loads of the apartment house. The differences in the annual electricity distribution fees for each apartment house between the two models (i.e., the distribution fees based on CBM minus the distribution fees based on the IBM) are shown in Fig. 2. It is observed from Fig. 2. that the CBM resulted in a lower distribution fee in all the cases but one. From an apartment house perspective, the results indicate that the CBM offers the apartment house prospects to lower the distribution fee by forming an EC. From a DSO perspective, the results indicate that the present pricing schemes used for larger customers should be thoroughly reviewed to see if they could indeed operate as a long-term pricing solution for ECs that emerge in the form of apartment houses or not.

The depths of the economic impacts are different between the DSOs as observed from Fig. 2. The DSOs 1-6 are situated in a more population dense areas in Finland and the DSOs 7-9 are situated in mixed or sparsely populated areas. The results are also affected by several issues, such as the pricing schemes of DSOs used for both the small-scale customers and the larger customers, and the electricity use profiles of the apartment houses. For instance, the price levels of the distribution tariffs, i.e., the fixed and volumetric charges, may vary significantly between the urban and the sparsely populated areas.

The study highlights that the decrease in the electricity distribution fees in the case (1) resulted simply from treating the apartment houses differently in the CBM by billing the ECs using the tariffs used for larger customers. In the case (2), the EC has a PV production unit that reduces the need to buy the electricity from the grid. In the future, the impacts of different DERs or load optimization on the distribution fees of the ECs should be studied.

From a tariff design standpoint, the accurate classification of customers is important because it is unclear if the ECs (i.e., the apartment houses) should be classified as small-scale customers or larger customers. The classification should be made considering that the ECs can be something in between those two customer groups. However, that aspect clearly requires further research.

DISCUSSION

Based on the results shown in Fig. 2., there is a clear motivation for the DSOs to investigate ways to develop the distribution pricing in the future. The reason is that, if the apartment houses could be billed collectively instead of individually, then the reduced turnover pressures the DSOs to increase the prices of tariffs in pursuit for cost recovery. This leads to a situation, where other customers experience higher distribution fees (i.e., a cross-subsidization that benefits the ECs with the cost of other customers.)

However, the ECs may in turn offer additional benefits, e.g., by separate demand response services, to the DSOs and other customers. The impacts of those aspects are of an interest that should be researched and quantified further in the future.

Additionally, if the ECs acquire DERs to further lower the need to buy electricity externally, then it may significantly lower the annual distribution fees paid to the DSO. This would subject the income of the DSO to a risk. However, the impacts depend on the scale. From a DSO standpoint, the overall impact would likely not be very severe if the number of ECs (i.e., in the context of this paper, an apartment house) is small. On the other hand, if there are several ECs operating over the same distribution network, then issues could emerge, e.g., in terms of how the costs of electricity distribution allocate between customers. As previously mentioned, in [4] and [5] it is stated that electricity distribution network tariffs must be cost-reflective, and it should be ensured that the ECs contribute to the cost sharing of the system in a balanced way. That requirement must be met, and thus, in order to mitigate and solve the possible issues, effort must be placed on appropriate electricity distribution network tariff design.

At a practical level, a possible solution could be to develop the distribution pricing by treating the ECs as a new customer group for which novel pricing schemes (i.e., separate tariffs for the ECs) are designed and used. However, the exact formats and price levels of those novel pricing schemes clearly require further research. It is also important to investigate the development possibilities of the methods used in electricity distribution pricing. If the present small-scale customers were to form ECs, it would affect the customer mix used in the tariff design process because the customer class of those customers changes. Overall, the ECs should be classified more clearly in the future, so that cost-reflective tariffs can be determined for them. Additionally, e.g., by adding a completely new customer group in the tariff design affects all customer groups through the cost allocation, not just the ECs.

CONCLUSION

This paper focused on the pricing of electricity distribution in the case of energy communities (ECs) in the form of apartment buildings in the Finnish context. The ECs and electricity distribution pricing practices used in Finland were discussed. The paper included a case study in which the data of 6 apartment houses and the distribution network tariffs of 9 Finnish DSOs were used to investigate the economic effects of using two billing models, the individual billing model (IBM) and the collective billing model (CBM). The study included two cases: (1) ECs without any distributed energy resources (DERs) and (2), where the ECs have an optimally sized shared photovoltaic (PV) production unit. Based on the results, it was observed that the present pricing schemes could offer the apartment houses an incentive to form ECs to lower their electricity distribution costs. In turn, from a distribution system operator (DSO) perspective, the present pricing schemes may be problematic in the long-term in terms of potential decrease of revenue in the case of ECs and developing the electricity distribution pricing is recommended. The ECs and DERs should be considered in the pricing of electricity distribution to mitigate the risks related to the DSO turnover and ensure that the legislative and regulatory requirements are met. Several further research needs were also pointed out in the paper.

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