

## DSO TARIFF DRIVEN CUSTOMER GRID DEFECTIONS – TECHNO-ECONOMICAL RISKS FOR DSO?

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### ABSTRACT

*Current trend, where customers reduce electric energy consumption, but on the other hand increase peak demand, is challenging from distribution system operator's (DSO) viewpoint. Meanwhile, alternatives to traditional grid connection are becoming feasible in some cases. Investments in distribution grid infrastructure are significant and expected to have a lifetime of 40–50 years. What happens if customers go off-grid?*

*This paper focuses on studying the risks that possible grid defection customers' decision to go off-grid would cause for DSO in rural environment. The study shows that risks for DSOs are different in different areas and DSOs can try to affect risk causing customers by changing distribution tariff system.*

### INTRODUCTION

Solar power systems such as photovoltaic (PV) panels with battery energy storage systems (BESS) are becoming common in customer side. At the same time rises a question that would it be more beneficial for the customers to go off-grid than to keep the grid connection. This can be a risk for the distribution system operator (DSO), because they have to invest in the distribution infrastructure to keep the system in order as well as to ensure reliable electricity distribution. However, this is one of the main targets of the electricity distribution. For instance, in Finland the government has set supply security targets, which all the DSOs have to fulfil. Often this means significant investments for the DSOs also in the rural area networks. Thus, often the risk that customers may not be there in the future concerns especially rural areas, where grid length per customer is high.

### Background of the study

In Finnish electricity distribution systems distances between customers can be long. Average total low-voltage (LV) line length per customer is approximately 69 m and medium-voltage (MV) line length per customer 42 m respectively. For DSOs operating in rural areas these numbers can be even 192 m for LV and 321 m for MV lines. Figure 1 shows the average grid lengths per customer for Finnish DSOs.

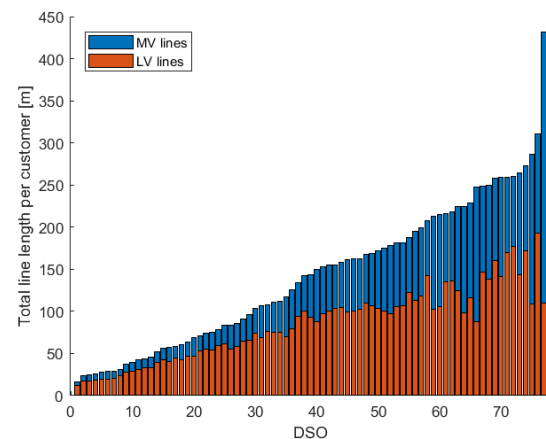


Figure 1. Distribution of total grid length per customer for Finnish DSOs. [1]

Figure 1 shows that average line length per customer varies significantly between Finnish DSOs. DSOs that operate on urban areas have even less than 30 m of distribution lines per customer, where as there are also DSOs, which have over 200 m of distribution lines per customer respectively. Figure 2 illustrates the cabling rates and grid lengths per customer of Finnish DSOs. The cabling rates shown in Figure 2 are average rates from low and medium voltage lines.

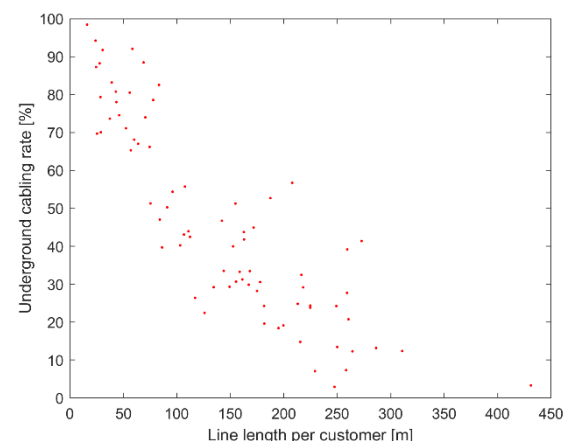


Figure 2. Finnish DSOs' cabling rates and total grid length per customer including LV and MV lines. [1]

Figure 2 shows how line length per customer is distributed between DSOs with high and low cabling ratio. DSOs with lower than 50% cabling rate have actually more than 80% proportion of the total Finnish distribution grid length. It is visible that DSOs which already have high cabling ratio have also low grid length per customer rate, which means

that urban DSO's have most likely filled supply security requirements or filling them does not require significant investments on grid assets. On the other hand, there are many DSOs which are operating on sparsely populated areas and whose grid infrastructures are so far more or less vulnerable to major storms. At the same time, the rural area population is decreasing. Figure 3 demonstrates regional population change in Finland from 1990 to 2017.

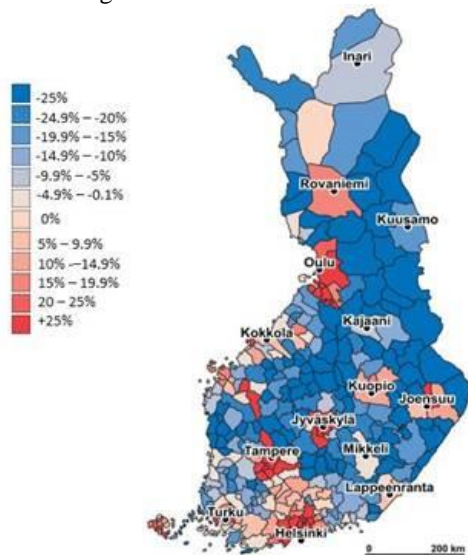


Figure 3. Regional population change in Finland from 1990 to 2017. [2]

It is visible that population has been moving from rural areas to population centres.

### Supply security investments

Finnish Electricity Market Act 588/2013 states that DSO's have to plan and construct their networks so that any storm should not cause supply interruption that lasts over 6 hours in urban areas and 36 hours in rural areas. [3] Networks have to be developed to fill these requirements before 2028. Some DSOs have applied and got time extension until 2036 to meet the requirements because of their exceptionally demanding operation environments. For most of the DSOs, these requirements mean massive investments for grid infrastructure. In principle, DSOs could solve the supply security requirements in some cases also by smart solutions, for example battery energy storage systems (BESS) or backup generators, but in practice DSOs are forced and incentivized to fill the requirements by traditional grid infrastructure investments. In other words, DSOs have to change overhead lines underground cabling quite widely.

### Grid defections

PV installations have been getting cheaper recently because of mass production and installation of PV systems. At the same time, also battery system prices have started to decrease and the development most likely continues when electric vehicles become more and more popular. On the other hand, DSOs have recently been

increasing electricity distribution payments and the proportion of fixed monthly payments. Increasing price of electricity taken from grid and decreasing price of alternative solutions makes off-grid solutions more and more interesting for the customers. In practice, the proportion of possible grid defection customers is limited especially in northern conditions because solar production is basically unavailable due to snow cover and low irradiance when household loads are typically peaking. Former study showed that there are differences between different Finnish rural areas, but in all case areas, the proportion of technically possible grid defection customers with 0–10 kWp PV system and 0–20 kWh BESS was 8–19%. [4] The number of profitable grid defection customers with current PV and BESS prices was very limited, but decrease of the prices can lead more and more customers to have profitable grid defections. DSO's can also affect the profitability by changing their tariff system, but significant tariff changes must be considered also from other viewpoints. Grid defections have been studied in literature before, for example in publications [5-6], but they are usually done from customers' profitability viewpoint and not covering analysis of effects on grid infrastructure.

### DSO's viewpoint

From DSO's viewpoint, possible grid defections form a risk for grid investments. If DSO now constructs the grid infrastructure filling the supply security requirements and customer no longer needs grid connection in near future, the grid investments might be done unnecessarily.

### METHODOLOGY

The methodology used in the study consists of defining the possible grid defection customers, their effects to grid components and studying possible solutions for the DSO.

### Grid defection customer data

Results from a former study [4] were used to define the grid defection customers. A group of these customers' hourly consumption is demonstrated in Figure 4.

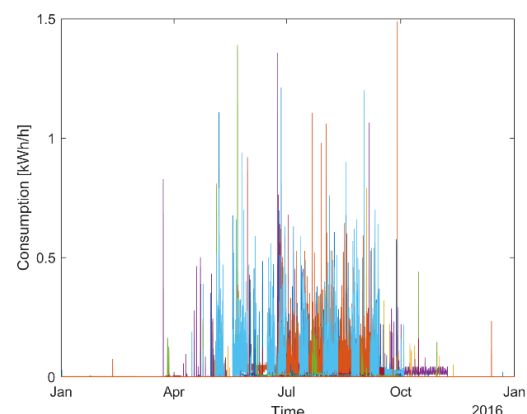


Figure 4. Customers', that were estimated to be possible profitable grid defection customers, load demand.

It is visible that these customers consumption occurs during summer and consumption is practically zero when there is snow cover blocking solar irradiance to solar panels.

The potential grid defection customers were estimated with two different PV and BESS price scenarios and five different DSO tariff scenarios. In more expensive price scenario prices were 1500 €/kWp for PV and 1000 €/kWh for BESS. Respectively in the cheaper scenario 1000 €/kWp and 250 €/kWh. DSO tariff scenarios were, a) present tariff, b) annual peak power tariff, c) monthly peak power tariff, d) annual peak power tariff with 5 kW threshold and e) monthly peak power tariff with 5 kW threshold.

### Effects on grid infrastructure

These predefined possible grid defection customers' feeding distribution grid was studied using grid topology information. Then, the grid components that would be without customers were defined. These grid components' age, type and installation environment was studied. Basic example of grid defections effects on grid components are shown in Figure 5.

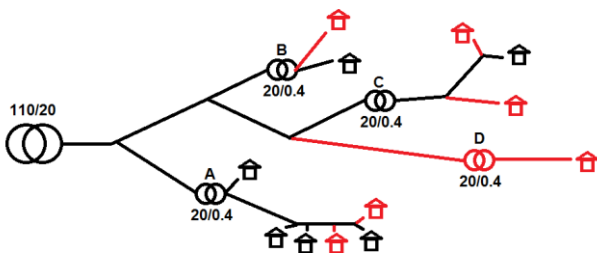


Figure 5. Example of grid defection effects on grid infrastructure. Red houses are potential off-grid customers. Grid components that are drawn red are under risk of customers' grid defections.

Although, grid defections cause risk or possibility for DSOs, the grid defections also decrease the incomes. In turn, decrease in grid infrastructure assets also decreases the allowed revenue and should affect the remaining customers' distribution payments.

There is always risk in regressive areas that some customers' electricity consumption ends even if it has recently been high. This can happen for many reasons, for example customers can move away. On rural areas of Finland population is forecasted to decline even 1–3.9%/a in some areas. [7] In this study grid defection customers are studied only based on load demand data analysis, other causes were not tried to be predicted.

### CASE STUDY

Case study was conducted for 4 case areas locating in rural areas in Finland. The case areas are described in more detail in publication [4].

### Grid infrastructure

From DSOs' viewpoint, it is very important to understand what kind of proportion of grid infrastructure is under risk of customer grid defections. First, case areas LV line infrastructure is studied in more detail. Figure 6 demonstrates case area's lines distribution based on how many customers are fed by the line.

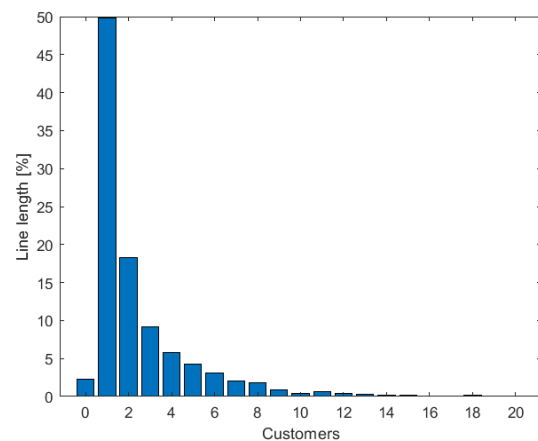


Figure 6. Distribution of LV line length by number of customers fed by the line.

It is noticeable from Figure 6 that there is significant proportion of LV lines that are there only for one customer. There are some lines in the model, which do not feed any customers, most likely because there are some connections under construction or some to be demolished. Figures 7 and 8 show age distributions of LV lines, feeding only one customer, from two different case areas.

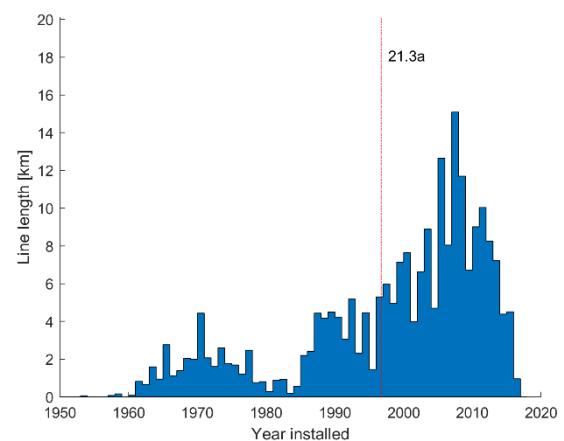


Figure 7. Distribution of installation year of LV lines feeding only one customer in case area A. The average age is shown with red line.

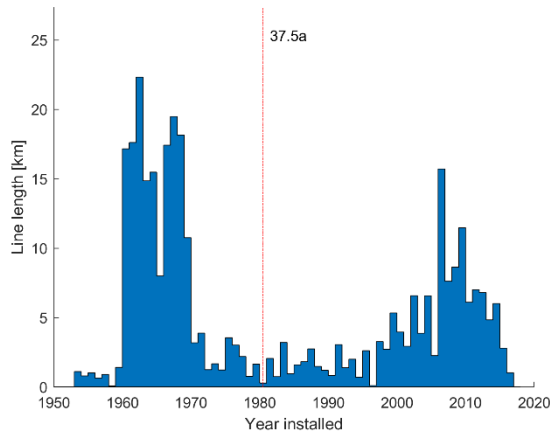


Figure 8. Distribution of installation year of LV lines feeding only one customer in case area B. The average age is shown with red line.

It can be seen by comparing Figures 7 and 8 that age distributions can be very dissimilar. In different case areas installation environments can differ significantly, which can affect notably on expected lifetime of overhead lines. Typical lifetime of grid infrastructure is 40–50 years but it is dependent on operating environment.

This has an influence on risks that possible grid defections cause to DSO. On areas like case area A, where most of LV lines have already been renovated quite recently, the risk is in the already invested assets. On case area B the risk is different. There a significant proportion of LV grid that has to be renovated in the short run because of high age. On this kind of area it would be even more important to recognize possible grid defection customers because significant investments have to be done in the near future and there is still possibility to avoid investing unnecessarily.

### DSOs' incomes

DSO's incomes from customers who are profitable for grid defection are almost purely fixed fees. The fixed fees from these customers were about 340 €/a and with the consumption-based fees 0–10 €. The total income from these customers was about 2.4% of total DSO's income from this case area.

## RESULTS

In this section results from four case areas are shown. Table 1 shows the proportion of LV lines that are under risk of customers' grid defection with different DSO's tariff structures and PV+BESS system price combinations.

Table 1 Proportion of LV lines that are only feeding possible grid defection customers.

|                             | Area A | Area B | Area C | Area D |
|-----------------------------|--------|--------|--------|--------|
| Tariff a), price scenario 1 | 2.2    | 2.4    | 7.5    | 3.2    |
| Tariff b), price scenario 1 | 1.1    | 1.4    | 3.6    | 1.5    |
| Tariff c), price scenario 1 | 1.1    | 1.4    | 3.5    | 1.5    |
| Tariff d), price scenario 1 | 2.7    | 2.7    | 8.1    | 3.4    |
| Tariff e), price scenario 1 | 3.6    | 3.2    | 8.4    | 4.0    |
| Tariff a), price scenario 2 | 7.4    | 4.2    | 11.9   | 5.7    |
| Tariff b), price scenario 2 | 3.6    | 2.6    | 7.7    | 3.1    |
| Tariff c), price scenario 2 | 1.5    | 1.4    | 3.8    | 1.6    |
| Tariff d), price scenario 2 | 8.3    | 4.6    | 13.3   | 6.4    |
| Tariff e), price scenario 2 | 9.2    | 4.9    | 14.2   | 7.2    |
| All technically possible    | 11.2   | 5.0    | 15.5   | 8.1    |

It can be seen that there are differences between effects on different case areas. It is remarkable that effects on LV lines would be higher on case area C than in other case areas even though the proportion of potential grid defection customers was estimated to be close to case area A's numbers. This is caused by the fact that grid topology can be very different. While case area A includes many leisure houses where connection points have relatively short lines feeding only one customer. On the other hand, DSO's incomes could decrease in the way shown in Table 2 if customers would go off-grid in different scenarios.

Table 2 Proportion of DSO's incomes from possible grid defection customers. Numbers in brackets show the proportion with current pricing system.

|                             | Area A     | Area B     | Area C     | Area D    |
|-----------------------------|------------|------------|------------|-----------|
| Tariff a), price scenario 1 | 2.4        | 2.0        | 3.9        | 1.4       |
| Tariff b), price scenario 1 | 0.0 (1.2)  | 0.0 (1.23) | 0.0 (1.8)  | 0.0 (0.6) |
| Tariff c), price scenario 1 | 0.0 (1.1)  | 0.0 (1.23) | 0.0 (1.8)  | 0.0 (0.6) |
| Tariff d), price scenario 1 | 3.4 (2.8)  | 2.7 (2.3)  | 6.2 (4.3)  | 1.9 (1.6) |
| Tariff e), price scenario 1 | 4.6 (3.2)  | 4.1 (2.6)  | 8.1 (4.6)  | 2.1 (1.8) |
| Tariff a), price scenario 2 | 7.0        | 3.2        | 6.2        | 2.8       |
| Tariff b), price scenario 2 | 1.1 (3.5)  | 0.3 (2.1)  | 1.0 (3.9)  | 0.4 (1.4) |
| Tariff c), price scenario 2 | 0.1 (1.4)  | 0.0 (1.3)  | 0.1 (1.9)  | 0.0 (0.7) |
| Tariff d), price scenario 2 | 9.4 (8.0)  | 4.4 (3.7)  | 10.8 (7.4) | 4.1 (3.3) |
| Tariff e), price scenario 2 | 12.1 (9.3) | 6.5 (4.1)  | 14.1 (8.0) | 6.3 (3.8) |
| All technically possible    | 11.9       | 4.3        | 8.8        | 4.3       |

Tariff scenarios b) and c), where customers' bill for DSO is fully dependent on peak power, are clearly problematic. Significant weight on peak power tariff without threshold moves payments to other customers even though almost zero consumption customers' connection to grid causes as well costs. In short run moving towards power-based tariff with a minimum charged power, would increase the proportion that possible near future grid defection customers would have to pay of distribution systems costs. This would give higher incentive to go off-grid. In turn, DSO would prevent the risk that customers go off-grid just after grid infrastructure is renovated to meet the supply security requirements.

It is important to bear in mind if Tables 1 and 2 are

compared that the proportion of LV lines shown in the table consists only of the lines that would be left without customers if estimated grid defection customers go off-grid. There are also LV lines that supply electricity to these customers but have also other customers that would stay according to estimations.

### **Risks for DSOs**

Risks for DSOs on different areas are dissimilar. There can be many reasons for differences, for example historical reasons, differences in operating environment, DSO's regional planning sequence, customer base and distances between customers. From DSOs' viewpoint customers location compared to other customers is important factor. If example LV networks in Figure 5 are compared from DSO's viewpoint, it is most important to identify cases like secondary transformer D. There the number of customers is low and some MV network is under risk if customers choose to go off-grid. Secondary transformers like A can be the easiest from DSO's viewpoint because most of the LV lines are there for multiple customers. On the other hand, on rural areas, this kind of LV network can be for leisure houses, which can be more likely customers to go off-grid.

### **Tariff development as a solution?**

With current legislation, DSOs do not have possibilities to terminate customer's grid connection even though customer has not had any consumption during past few years. Tariff development is a possibility for DSO to affect these customers feasibility of keeping the grid connection. In practice, the tariff structure development has to be studied from various because the same tariff structure has to be available for all same type of customers.

### **Communication with customers**

While there is significant risk when DSOs are doing significant investments in grid infrastructure and alternatives for grid connection are becoming more and more attractive, communication between DSOs and customers becomes more recommendable. DSO can recognize more potential grid defection customers in advance and estimate risk, but importance of asking directly about customer's plans from customers becomes more relevant.

### **CONCLUSION**

Different electricity distribution areas have their own development history and so there are many differences in grid topologies, grid components' age distributions, installation environments and customer bases. Thus, risks for different DSOs are different. On areas where grid infrastructure is relatively new, already invested assets are under risk. Where grid infrastructure is old, the risk is that new investments would be made to customers that do not have grid connection in the near future.

From societal perspective the grid defections can be either high risk or significant possibility to affect the costs of electricity distribution. DSOs can try to affect customers by changing tariffs, but same tariffs have to be available for all of the same kind of customers. So tariffs structure changes should be studied from various viewpoints before introducing novel tariff system.

This study does not try to recognize customers whose consumption has lately been on normal household level, but who will stop consuming electricity in the near future for some other reason, like moving away. It is recommendable to interview customers about their plans before significant investments are done to LV networks, especially on areas with low customer density.

It is also good to notice that even though in this study the possible grid defection customers are expected to go off-grid by investing in PV and BESS combination, in reality some of these customers might be anyway stopping to use electricity on that connection point. The methodology used in this study still gives a good estimate of which customers are the most probable ones to go off-grid.

In overall, grid defections cause a risk for DSOs' infrastructure investments. DSOs can try to affect customers by changing tariff structures. On the other hand, developing communication with customers can help to manage the risks.

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