DEMAND RESPONSE: CONFLICT BETWEEN DISTRIBUTION SYSTEM OPERATOR AND RETAILER

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ABSTRACT

Demand response is becoming an important issue in electricity market and network nowadays. When customers get opportunities to control their load, network operator and retailer can benefit from it or they can loose some of their profit. In this paper conflict of interests between network operator and retailer is introduced and analysed. The reasons for it are explained and illustrated using AMR data and spot prices. Possible solutions to find the compromise are suggested and analysed. Finally, further research questions are opened up.

INTRODUCTION

Demand response will bring opportunities and challenges to the electricity market and network. After unbundling retailer and network businesses in 1995, responsibilities, interests and goals of electricity retailer and distribution system operator (DSO) have diverged. While a DSO is responsible to keep quality of supply by keeping the voltage and power level in the network within the set limits, a retailer is interested in maximizing his profit as the difference between sold and bought energy costs:

$$\max\int_0^T \mathrm{profit}(t)\mathrm{d}t = \max\int_0^T (E_{\mathrm{sell}}(\mathrm{t}) - E_{\mathrm{buy}}(t))\mathrm{d}t \qquad (1)$$

Basically, the retailer's goal results into procuring as much as possible energy at low prices from the Nord Pool Spot and as little as possible at high prices. The price risks connected with purchasing energy from Power Exchange and selling it at fixed prices to end-customers have been mentioned in [5], where impacts of smart grids on retail business were introduced. However, the spot prices on the Power Exchange do not necessarily follow the state of the local distribution network. In this regard, there emerges a question: is it possible to control the load of a customer so that the interests of retailer and DSO are met at the same time?

The target of the paper is to define the conflict of interests between DSO and retailer regarding demand response, and find the compromise to meet the goals of both parties. The measurement data from a typical feeder, located in a rural area where the majority of customers have electric heating loads, is used in calculations. The previous studies [1] show that spot prices do not usually follow the load curve of the feeder, especially in the evenings after 10 pm, when electric heating loads are turned on simultaneously. This is challenging for the DSO, however it is beneficial for the retailer since the area price usually goes down after 10 pm. In the paper DSO's and retailer's perspective on load control will be analyzed. The energy market prices serve as direct incentives for customers to reduce or increase the load, thus satisfying the retailer's goals. On the other side, the DSO's interests are not met, if the power level in the network approaches the set limit, most often during the low market price hours. Different incentives created from the DSO side for customers to reduce or shift their consumption will be described. The distribution network tariff consists of the power-based (€/kW) and energy-based (cent/kWh) components, which are fixed for a certain customer group within a DSO, depending on the fuse size. The incentives for customers to reduce the load in DSO's interests can be created through the change in the network tariff components. The change in the components can be, for instance, step-wise or linearly proportional to the consumption increase. However, there is still a conflict of interests, now the retailer being disadvantaged. The possible ways to find a compromise between the two parties are analyzed and compared.

PERSPECTIVES OF MARKET PLAYERS ON LOAD CONTROL

In this section retailer's and DSO's perspective to load control are presented. Both market players have the same objective and aim at maximizing their business profit. However, the way to reach it is different since their responsibilities and tasks differ. While retailer is interested in minimizing the energy costs, the network company's target is to keep quality of supply in short-term and reduce investment costs in long-term span.

Retailer

Basically, retailer and end-customer have the same objectives. In case of spot price-based contracts, risk of price peaks is transferred to end-customer. In case of flat rate tariff, price risk is transferred to retailer. But in both cases they are interested in minimizing the energy costs.

In the retailer's theoretical scenario customer's load is controlled according to the spot prices on the Power Exchange (Nord Pool Spot). The comfort of the customer is not taken into account, but maximization of retailer's profit is of the first priority.

The procured energy costs in short term can be expressed by equation:

$$E_{\text{procured}} = \int_{1}^{24} \text{Price}(t) \cdot \text{Load}(t)\text{dt} = \sum_{1}^{24} \text{Price}(t) \cdot \text{Load}(t) = \quad (2)$$

$$= \sum E_{\text{const}}(t)$$

Where

E_{produced}	Costs of energy procured from the Power Exchange, €
Price (t)	Hourly spot price on the Power Exchange, €/MWh
Load (t)	Hourly load values, MWh
E_{const}	Hourly energy costs same at each hour of the day, €

In order to obtain the minimum daily energy costs, the load curve should have such a shape that it follows the spot prices in inverse ratio. In other words, when the price goes down at some ratio, the load should increase at the same ratio. This can be obtained by assuming hourly energy costs equal to each other and being constant during the day. In order to find the value of hourly energy costs, the following expressions are used:

$$E_{\text{const}} \cdot \left(\frac{1}{\text{Price}(1)} + \frac{1}{\text{Price}(2)} + \ldots + \frac{1}{\text{Price}(24)}\right) = \sum_{t=1}^{24} \text{Load}(t) \quad (3)$$

where

E_{const} Constant value of energy costs within 24 hours, €

Now, the value of hourly energy costs can be calculated:

$$E_{\text{const}} = \frac{\sum_{t=1}^{24} \text{Load}(t)}{\left(1/\text{Price}(1) + 1/\text{Price}(2) + \ldots + 1/\text{Price}(24)\right)} \quad (4)$$

As a result, hourly consumption values can be recalculated:

$$\text{Load}(t) = \frac{E_{\text{const}}}{\text{Price}(t)} \quad (5)$$

Now it is possible to simulate price-based load control and form an optimized load curve for each customer group, which follows the price signals and minimizes the energy costs of the retailer.

Distribution System Operator

The perspective of DSO on load control is different from the one of retailer. The DSO aims at minimizing investment costs, outage, loss and maintenance costs in long-term [3]:

$$C_{\text{tot}} = \min \int_{0}^{T} (C_{\text{invest}}(t) + C_{\text{loss}}(t) + C_{\text{outage}}(t) + C_{\text{maint}}(t))\text{dt} \quad (6)$$

Consistent load control can reduce peak power of the network in long-term, but also increase it as a result of price incentives. The last can happen if retailer takes all load control power at his own disposal. The risk of exceeding the agreed power limit of a single customer as a result of price-based load control is demonstrated in this paper. So far, there have been rarely any incentives coming from the network for customers to adjust their load to network condition. This challenging question is considered in the next chapter.

COMPROMISE BETWEEN RETAILER AND DSO

In order to find the compromise between market players, it is important to find alignment between supply and network tariffs. There are several ways to create incentives from the DSO side for customers to reduce or shift their consumption. One of the ways is to set a dynamic network tariff for customers.

The previous studies [2] reported that hourly spot price tariff combined with dynamic network tariff give sufficient economic incentives to customers to reduce their consumption. Therefore, highest demand response is achieved due to those customers who have dynamic both network and supply tariff.

As already stated before, the incentives for customers to reduce the load can be created through the change in the network tariff components, both power-based (€/kW) and energy-based (cent/kWh) ones. Three scenarios are considered for a case family living in a detached house with direct electric heating load:

1. Energy-based component is variable, power-based component is fixed.
2. Power-based component is variable, energy-based component is fixed.
3. Both energy- and power-based components are variable when the power limit is exceeded.

It is assumed that a customer is supplied by three-phase 230 V voltage, and his maximum power is 17.2 kW. This limit is not related to the fuse size of the customer, but is defined by the contract between the customer and DSO. The scenarios are calculated for a cold winter day (-20-25° C) and a critical peak spot price.

Energy-based component

In this scenario, energy-based component is variable, while power-based component is fixed. Energy-based component increases as customer's power consumption exceeds the agreed power limit. The power-based component remains at the same level according to the heating type and fuse size of the customer, regardless customer's power level.

Figure 1 illustrates an AMR load curve of the case customer with limited peak power 17.2 kW. The critical spot prices, given on the chart, happened on the Nordic market on 17.12.2009. Then it happened once again in January and February of year 2010. On the same chart the load curve optimized according to critical peak prices (price-based load control) is presented with a new peak power of 18.1 kW. The energy costs for the customer are 60% lower after the price-based load control. However, with dynamic network tariff, the costs will increase during those hours, when the new optimized load curve exceeds the contractual power limit.

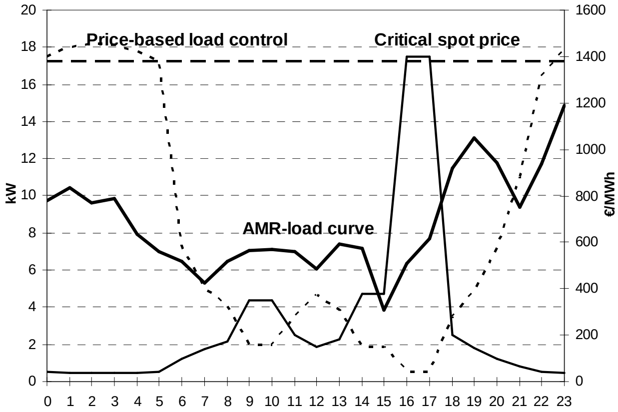

Figure 1. Example of a customer exceeding the contractual 25 A current limit as a result of price-based load control.

It is assumed that the energy-based component increases by 50% from 3.4 cent/kWh to 5 cent/kWh for those hours when the power limit is exceeded and for those powers which are over the power limit. Table 1 shows the calculation results.

Table 1. Daily energy costs from customer to retailer and DSO in different scenarios on a critical peak price day.

	Payments to retailer	Payments to DSO	Total payments for customer
Without load control	44 €	7 €	51 €
Price-based load control	16.8 €	9 €	25.8 €
Price-and network-based load control	17.3 €	7 €	24.3 €

The table shows how much the customer has to pay to the retailer at critical spot market prices and to Network Company at the energy price on a winter day. In case of no load control, the costs are highest for the customer. For the case of price-based load control, customer can save up to 60% of money paid to retailer. This case requires from the customer shifting most of his consumption to evening and night time from morning and day-time, which severely disturbs his comfort of living. However, customer can use energy storage, or delay functions of washing or dishwashing machines. Although the customer pays 60% less to the retailer if price-based load control takes place, the payment to DSO increases (from 7 to 9 €) because customer's power limit is exceeded and the energy-based component has increased during those hours by 50%, as assumed earlier.

For the third case, when price-based load control is limited by the network, i.e. by 25 A contractual power limit, customer pays a bit more to retailer, but no extra payments to the DSO for keeping power below the limit.

Comparing the total payments, it is clearly seen that there is almost no difference in payments in the second and third case. This means that the customer may not have enough incentives to keep his power consumption below the limit, which poses risk to the network company. If customer regularly exceeds the power limit and if it has effect on the feeder peak power, the DSO has to invest more money in the network to keep it in appropriate shape with the new peak power.

Power-based component

In this scenario it is assumed that power-based component of the distribution fee is variable, while energy-based component is fixed. Power-based component is fixed for agreed contractual power limit, but increases when the limit is exceeded. Energy-based component remains low regardless power level.

The analyses of profitability for customer and effects on the network are carried out considering long-term perspective. In this work, one-year period is taken as a reference level. At the end of the year, the network company calculates how many amperes (A) the customer has exceeded over the contractual current limit. It should be born in mind that the cost of one ampere is different for different customers depending on two factors:

1. The contribution of customer's peak load to the feeder load at the hour of exceeding customer's power limit:

$$k_1 = \frac{P_{\text{max, customer, hour i}}}{P_{\text{feeder, hour i}}} \qquad (7)$$

2. The contribution of the feeder power value at the hour of exceeding customer's power limit to the set maximum power of the network company:

$$k_2 = \frac{P_{\text{feeder, hour i}}}{P_{\text{max, feeder}}} \qquad (8)$$

Based on the above mentioned factors, the network company should calculate, how much and how the customer has to pay for exceeding the contractual current limit.
For simplicity, in this paper the cost of amperes on a distribution system level has been calculated for an average customer. Let us consider a network with 10 000 customers. It is assumed that all customers have contributed to the peak power increase on the distribution system level by 1 MW in one year. It is assumed that the present value of the example network is 1000 €/kW [4], which includes 400 V low-voltage networks, 20 kV medium-voltage networks, and 110/20 kV primary substations. Based on the assumed value, the increase in peak power would mean additional cost for the network company equal to 1000 k€. Hence, the average additional payment from a single customer to the network would be 100 €/customer per year. This is close to the basic payment of an average customer to the network company. That exposes customer to a high risk of loosing much money if exceeding the current limit. Now customer has good incentives to keep his consumption under contractual limit.

Energy- and power-based components

As it was discussed in the previous subchapters, increasing of energy-based component exposes Network Company to the risk of high investment costs, while increasing power-based component exposes customer to the risk of high electricity bill. Therefore, a tariff should be developed so that it creates equal conditions for DSO and customer. It should be attractive and understandable for customer so that he easily accepts it. At the same time, it should be cost-reflective for the network.

One suggestion could be that both power- and energy-based components change with network condition and customer's consumption level, respectively. The change in energy-based component should be such as to give incentives to customers to change their consumption. That way the risk that customers do not answer to power signals will be lower for the DSO.

The change in power-based component should give some freedom to customers to exceed the current limit, especially in the off-peak power hours in the network.

CONCLUSIONS

The main results of the paper are:

1. Perspectives of retailer and DSO on load control are presented. The algorithm of simulating price-based load control is developed and given in the paper.

2. Conflict of interests between the two market players is illustrated using AMR data and spot prices in Finland. However, it is important to emphasize that the main target of the paper is to show methodology to analyze the conflict of interests. The results are rather case-specific, and depend strongly on the input data. For example, some customers might have more incentives than others for energy-based than power-based tariff and vice versa. However, the idea of setting dynamic network tariff for end-customers is important for both customers and Network Company, and therefore tariff requires development so that it satisfies both interests of customers and DSO.

Further research questions are:

1. Developing a dynamic tariff structure for customer groups depending on their consumption level, load groups and technical possibilities for load control.

2. Important question is what is the cost of exceeding one ampere for an average LV-network customer, so that the customer has incentives to keep his power under the limit during the year?

3. Developing a solution for customers to cope with both price and power signals. This kind of task supposes studying customer's willingness to have dynamic tariff with both retailer (spot price-based contract) and DSO (dynamic network tariff). Is it possible to make it attractive for a customer without strongly disturbing his comfort and at the same time bringing financial benefits to him?

4. It is useful for a DSO to know what will be the effect of dynamic tariff on the network load curve in long term. How it would affect the network company profit, and finally change the end-customer distribution fee?

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