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The role and business potential of customer load control in an electricity retailer's short-term profit optimization

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ABSTRACT

The implementation of smart metering and transition from traditional passive distribution networks to active smart grids enhance the opportunities for large-scale residential customer load control. The customer end-use load control can provide various benefits, such as more efficient use of energy, a decrease in the need for peak power production capacity and mitigation of electricity price spikes. Moreover, it can provide new opportunities to enhance the market players' business activities and opportunities. From the perspective of an electricity retailer, the load control can for instance provide hedge against risks and improve the profitability of the retail business. This paper examines potential ways to apply large-scale retail customer load control as part of a retailer's profit optimization and evaluates the business potential that it can provide for the electricity retailer.

1 INTRODUCTION

The increasing amount of intermittent renewable energy production sets new challenges for the power systems and electricity markets and increases the need for Demand Response (DR). Traditionally, DR and DSM (Demand Side Management) programs in Europe have mainly considered large-scale industry. However, the need and interest towards programs for residential customer groups have been increasing. To enable large-scale end-use load control for residential customers, the required equipment and systems, appropriate operational and market models and adequate incentives are needed.

The wide-spread implementation of AMR (Automatic Meter Reading) is in progress in Europe providing a basis for the large-scale customer load control. In [1], a model is introduced for a market-price-based control of electric heating loads based on a hierarchical principle, in which the load control is carried out by the electricity retailer. This model, for instance, could allow the large-scale and market-base implementation of a customer end-use load control based on the utilization of the existing network infrastructure already in the near future. Moreover, changing over from traditional passive distribution networks to active smart grids can provide an environment that enables the execution of a more real-time and reliable customer load control, and can thus enhance the efficiency of the load control.

In addition to the technical requirements, the implementation of a large-scale customer load control calls for suitable market and operational models. The market model should promote market-oriented load control and enable its cost-effective implementation. The operational model in turn should be able to consider the needs and objectives of different market parties, promote co-operation between different stakeholders and enable cost-effective application of load control by the market players. Moreover, proper incentives for the load control are needed to arouse the market players' and customers' interest. The evaluation of the potential financial benefits could reveal the required load control incentive. In addition, the evaluation of potential financial benefits can provide important information to develop the market and operational models in a way that provides the best overall results.

Many studies, such as [2], [3] and [4], have reported that load control can provide numerous benefits, such as a decrease in peak loads, an improved demand response, mitigation of price peaks, a decrease in the need for higher marginal cost generation, and financial benefits for market parties. However, in practice, it has been challenging to efficiently exploit the potential provided by the load control. A key reason for this is that different market parties have different objectives for the load control, which can cause conflicts of interest between the market parties. In [5], a conflict between a distribution system operator (DSO) and a retailer is discussed. To solve problems of this kind, it is necessary to develop the operational, market and/or pricing models further. For instance, the use of power band pricing, presented in [6], could help to avoid these conflicts and thus enable efficient application of a large-scale load control.

Traditionally, the load control of residential customers has been based on a model in which the DSO has used a direct load control in order to limit the peak powers in the networks. However, in the liberalized electricity markets, this model may not be the most feasible and effective way to execute the load control. When the DSO controls the loads based on its needs to limit the peak powers, it is likely that optimal overall results will not be reached. In addition, from the perspective of the liberalized electricity markets, the customer load control should rather be market oriented, and not limited only to the DSOs. Moreover, load control actions executed by the DSO can cause problems for the retailers. The DSO's load control can disturb the retailer's power balance between the electricity procurements/production and the consumption/sales, and in the worst case, cause a significant damage to the viability of the retailer's business. Thus, alternative ways to implement a large-scale load control should be considered.

In practice, there are many alternative ways to implement the retail customer load control. However, it seems that the most cost-effective solution is to apply the existing electricity distribution infrastructure. Consequently, it can be assumed that a large-scale load control could be implemented with least costs by the DSO, because it owns and operates the related systems, such as AMR meters. On the other hand, it can be assumed that the market party operating actively in the wholesale and retail markets, such as a retailer, has the best ability to explore and utilize the business potential provided by the retail customer load control. Thus, in practice, the execution of a large-scale retail customer load control could be implemented so that the retailer defines and executes the control actions through the existing network infrastructure owned by the DSO. However, this requires active co-operation between the DSOs, retailers and customers.

This paper examines a retailer-based load control, in which the electricity retailer is the market party that executes the retail customer load control. The primary targets of the paper are to introduce different ways to use load control as part of the retailer profit optimization and evaluate the business potential provided by a large-scale retail customer load control executed by the electricity retailer. The evaluation of business potential is carried out based on the theoretical analysis and example cases, and it aims to give indicative results, which can be used to determine the need for further analysis.

2 INCENTICES AND LIMITATIONS ON LOAD CONTROL FROM THE PERSPECTIVE OF AN ELECTRICITY RETAILER

The key target of an electricity retailer is to maximize the expected profits in the market. In addition, the retailer aims to minimize its risks in order to ensure the viability of the business. The maximization of profits and the minimization of risks are contradictory objectives, which should be balanced appropriately. To this end, electricity retailers should have tools that can be used both to hedge against risks and maximize the expected profits. A retail customer load control could provide such a tool.

2.1 Incentives on load control

The ability to control customers' loads would provide a new tool for the electricity retailers to adjust their power balances between the electricity production/procurement and the consumption/sales even close to the delivery. This would improve the retailers' ability to operate in a more flexible way. Moreover, load control could provide new opportunities to use different strategies for the optimization of the retailer's expected profits. Figure 1 illustrates alternative strategies to use load control as part of the retailer profit optimization.

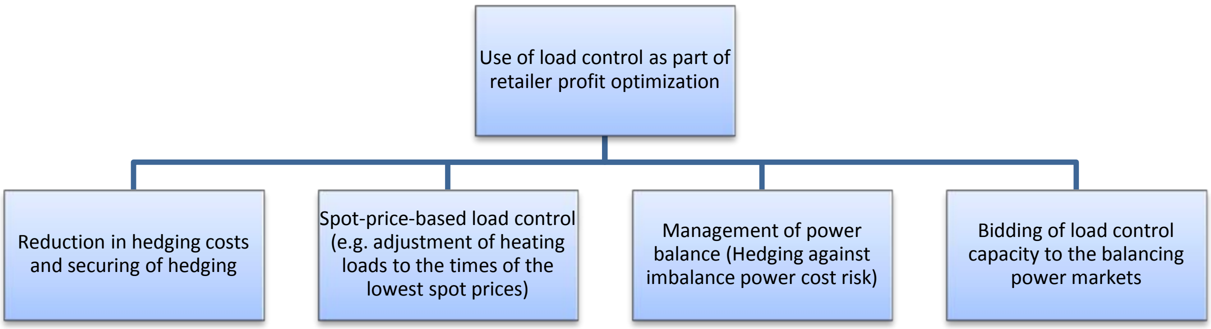

Figure 1. Use of load control as part of the retailer profit optimization

In the long term, hedging against risks provides a basis for a viable retail business. In practice, the retailer can hedge in the long term by making physical electricity procurements in the OTC market (Over-The-Counter) and using financial products provided by the financial market. In the OTC market, bilateral contracts are used to make agreements on physical deliveries of electricity between the market parties. The financial market offers a variety of different products including futures, forwards, options and CfDs (Contracts for differences).

The retailer can use the above-mentioned products to establish a contractual position, which ensures that the retailer can procure at least part of the needed electricity at a fixed price known in advance. When planning the hedging, the retailer should avoid overhedging, because it reduces the expected profits. On the other hand, if the hedge ratio is too low, the retailer is exposed to higher risks. The ability to control customers' loads would help the retailer to avoid overhedging and secure the hedging, because the retailer could disconnect its customers' controllable loads in order to decrease the need for electricity procurements in case that hedging has been inadequate and electricity prices are high in the physical markets.

Even if the retailer hedges by using financial products such as futures and forwards, it still has to procure the actual energy in the physical markets. In addition, the variation in the customers' electricity consumption can cause a need for balancing trades when the delivery hour approaches.

In the Nordic electricity markets, retailers can make physical electricity procurements and balancing trades in the spot markets. Trades in the spot markets allow the retailer to manage its open position, which is the difference between the electricity procurements/production in advance (contractual position) and the expected sales/consumption. In the Elspot market, trades can be done 12–36 hours ahead for the next day 24 hour period. In the Nordic market majority of physical electricity trading is done in the Elspot market, and thus, it provides reliable reference price (spot price).

Spot prices can also provide a solid basis for the load control. Hourly spot prices in the Elspot market are known in advance, which makes it possible to identify hours with the lowest prices in advance. Thus, the loads that have for instance some hourly requirement for daily connection time, such as storing electric heating loads, could be efficiently controlled based on spot prices. This type of spot-price-based load control would provide an opportunity for the retailer to achieve savings and/or hedge against market price risk depending on the principles of load control and retail pricing. In addition, it could provide opportunity for the customers to achieve savings in their energy costs. Spot-price-based load control will be introduced in more detail in Section 3.1

In the Elbas market, retailers can make balancing trades two hours after Elspot and one hour prior to the delivery. Thus, Elbas provides an opportunity for the retailer to manage the open position close to the delivery. Consequently, Elbas can be regarded as an alternative solution to the balancing power market, where the price volatility can be high and prices are known only after the delivery.

After the Elbas trading has been closed, one hour prior to the delivery, the retailer cannot manage its remaining open position anymore by making trades in the short-term markets. Therefore, even if the retailer identifies a need to manage its open position after the Elbas trades, it may not be able to do that. The customer end-use load control could provide a solution also to this problem. The ability to manage the open position by disconnecting (or reconnecting) customers' loads even close to the moment of delivery could provide an efficient tool to manage the retailer's volume and price risks.

The retailer's electricity procurements made in advance do not typically match precisely with the actual consumption, which results in a power imbalance between the retailer's electricity production/procurements and the consumption/sales. This imbalance has to be settled by means of imbalance power. From the perspective of the electricity retailer, imbalance power fees (imbalance volume fee, consumption payment, production payment) and the volatility of imbalance power prices constitute a risk of extra costs. Thus, in order to minimize the risks, the retailer should aim to minimize its need for imbalance power. However, as a result of the one-price system used for the pricing of consumption imbalance power, it may be also beneficial for the retailer to have an imbalance in the consumption balance. In other words, in order for the retailer to maximize its profits, it is not always the best alternative to aim to minimize the power imbalance.

The ability to control customers' loads close to the delivery combined with reliable electricity consumption and price forecasts could significantly improve the retailer's ability to minimize its imbalance power costs. However, this kind of a profit optimization strategy, in which the retailer actively manages its open position based on the latest electricity consumption and price forecasts, includes significant risks and limitations that are important to consider. More detailed information on the issue will be given in Section 3.2.

Moreover, if the retailer would have aggregated load control capacity that would meet the requirements set by the balancing power market and the system operator, it could bid it to the balancing power market. The prices of the balancing power are determined based on the regulations put in the practice, and the capacity offered to the balancing power markets is paid according to the use of capacity. The price volatility in the balancing power markets is rather high, and thus, the bidding of load control capacity could provide profit-making potential for the retailer. More information on the issue will be given in Section 3.3.

In general, the ability to control the retail customers' loads could benefit retailers in many ways. In particular, an ability to hedge against high electricity prices, and in the best case even profit from them by the sell-back opportunities, could provide significant financial benefits. In addition to direct financial benefits, a large-scale load control could provide market-wide benefits, which could benefit the retailers indirectly. However, the consideration of market-wide benefits is outside the scope of this paper.

The business potential provided by the load control depends highly on the features of the existing market environment, and particularly on the variation in electricity prices in different markets. In general, the higher the volatility of electricity prices in the market is and the higher control potential is available for the use, the greater business potential can be found. In addition, costs resulting from the load control, compensation or other incentives paid to customers, and other similar factors have an impact on the final result achieved by the load control.

2.2 Limitations on load control

In general, the benefits achieved by load control depend on a number of different factors. On the other hand, the number of different factors set limitations on the controls actions. Thus, the limitations set by the different factors have to be determined before the potential benefits can be evaluated, and the use of load control as part of retail profit optimization planned.

The type of loads under control, external conditions such as temperature, and the equipment and systems used for the control mainly determine the available control capacities in different periods of time and set limitations on the controls. The greatest control potential among the residential customers' loads can be typically found from the heating and cooling loads. In addition, these can be controlled without a significant loss of customer's comfort, for instance based on the indoor temperature.

The existing market environment sets also its own limitations on the load control. Different markets have different limitations on the minimum contract sizes, trading periods and other relevant factors. Table 1 presents general instructions for the trading in the Nordic electricity markets. These trading instructions set the minimum requirements on the load control. In the case of balancing power markets there are some minor national differences between the Nordic countries. Therefore, the Finnish balancing power markets are under consideration in this context.

Table 1. Trading instructions for the Nordic electricity markets [4].

	Elspot	**Elbas**	**Balancing power markets**
Trading period	The trading horizon: 12–36 hours ahead for the next day 24 hour period. Gate Closure 12:00 (CET time)	2 hours after Elspot and 1 hour prior to the delivery	Binding production plans at least 45 minutes prior to the beginning of usage hour
Contract size	Trade Lot: 0.1 MW Min. Tick Size: Euro 0.1/MWh	Trade lot: 1 MW Min. tick size: Euro 0.1/MWh	Balancing power: Minimum capacity requirement of 10 MW Fast disturbance reserve: Minimum capacity requirement of 15 MW, minimum availability for use 7000 h/a and 3 h on non-stop
Order types	1. Hourly Orders 2. Flexible Hourly Offers 3. Block Orders (Volume Limit: 500 MW)	1. Fill: matching may be effected either for the full volume or for a part of the volume. Any remaining volume shall remain valid with the ranking of the original order. 2. All-or-Nothing: matching may only be effected for the full volume.	Actual consumption is determined in the imbalance settlement procedure. Production: Fingrid submits the regulation order when needed. Balancing power and fast disturbance reserves have to be activated on full power in 15 minutes. The power changes have to be verified in real-time.

Table 1 shows that different markets set different time, capacity and also other limitations on the load control. On the other hand, different markets also provide a different business potential for the load control, because the price of electricity and its volatility varies between the markets. Consequently, the business potential of the load control varies depending on the market and the period of time when the control is executed.

3 LOAD CONTROL AS PART OF RETAILER PROFIT OPTIMIZATION

This section examines the use of load control as part of retail profit optimization. The use of load control is examined in more detail in the following three example cases; load control based on spot prices, load control as a tool to manage the retailer's power balance and minimize the imbalance power costs, and bidding of load control capacity to the balancing power market.

3.1 Load control based on spot prices

In general, most of retailers' physical electricity procurements are made in the spot market. The spot prices can also be easily implemented as a basis for the retail pricing of electricity. Thus, from the perspective of an electricity retailer, the implementation of a retail customer load control based on spot prices would be relatively simple. In addition, a spot-price-based load control does not include a significant risk or set high requirements for the equipment and systems used.

In the Elspot market, the price of electricity is determined separately for each hour. Hourly spot prices are known in advance, which makes it possible to identify the most profitable control actions. Thus, for example storing electric heating loads, or other such loads which only set requirements for daily connection time, such as five hour per day, would be particularly suitable to control based on spot prices.

In addition, if the retail pricing is based on spot prices, the customer carries the price risk related to the volatility of spot prices, unlike in the traditional retail pricing based on fixed rates, in which the retailer has to carry the price risk. Consequently, spot-price-based electricity retail pricing and load control can provide an effective tool for the retailer to hedge against the price risk caused by the variation in spot prices. Nevertheless, the retailer will still be exposed to other risks, such as a risk caused by the trading of imbalance power.

In general, the business potential provided by the spot-price-based load control depends mainly on the level and volatility of spot prices. Thus, it may be difficult to find good business potential, if the price volatility is low in the spot markets (retail pricing based on spot prices), or the differences between fixed retail sales prices and spot prices are low (retail sales pricing based on fixed rates). On the other hand, if there is price volatility, the spot-price-based load control can provide business potential for the retailer and/or savings for the customers.

3.2 Load control as a tool to manage retailer's power balance

The volatility of imbalance power prices can be rather high compared with spot prices. This combined with the retailer's limited ability to forecast the future electricity consumption and imbalance power prices in the current operational environment poses a significant risk of extra costs to the retailers. In addition, in the present markets, the retailer's opportunities to hedge against this imbalance power cost risk are limited.

In addition to the risk of extra costs, the volatility of imbalance power prices can provide a saving/profit-making potential for the retailer. The retailer benefits from the trading of consumption imbalance power through the profitable sell-back opportunity if it has procured electricity in advance with a price that is lower than the price of the consumption imbalance power, and if the retailer has a surplus of electricity procurements. Correspondingly, the retailer benefits from the trading of the consumption imbalance power if it has a deficit of electricity procurements, and it can purchase the consumption imbalance power with a lower price than it could have procured energy elsewhere. Based on the above, it can be concluded that if the retailer can control its customers' loads close to the delivery based on relatively reliable electricity consumption and price forecasts, the retailer's opportunities to hedge against imbalance power price variations improve, and in the best case, the retailer can even benefit from these price variations.

The transition towards the smart grid environment can provide the technical requirements for the use of load control as a tool to manage the power balance. It allows more real-time data transfer, thereby enabling the retailer to react to the changing market and operation situations. In addition, the real-time measurement data make it possible to develop more reliable electricity consumption and price forecasting applications. In general, the more accurately the retailer can forecast its future electricity consumption and electricity prices, the better basis it provides for the profitable operation.

The use of load control as a tool to manage a retailer's power balance, and the resulting imbalance power costs, is based on the idea that the retailer operates based on the latest available electricity consumption and price data. This data can provide a more reliable basis for the determination of optimal control actions needed for the maximization of expected profits. Retailers are typically able to forecast their total electricity consumption relatively accurately. The forecasting of electricity prices in turn is more challenging task, on which relates significant uncertainty. However, considering the management of the retailer power balance, the direction of the regulation during the specific hour is typically the most important price indication. The direction of the regulation has a high impact on the price of the imbalance power, because it determines whether the up-regulation or down-regulation price is applied as a basis for the pricing of imbalance power during the specific hour.

The business potential achieved by the use of load control as a tool to manage the power balance depends on the strategy based on which the loads are controlled. A retailer can determine it for instance based on the allowed risk level and/or expected profits. Alternative strategies could include for example a load control allocated to the reserve in the case of expected price peaks, the use of load control as a tool to minimize the amount of imbalance, and an active management of the retailer's open position based on the changing market situations.

If load control is used actively based on the changing market situations, the retailer aims to benefit from the volatility of imbalance power prices. This can be done if the retailer is able to manage its open position in the right direction by controlling the customers' loads based on the expected imbalance power prices/direction of the regulation. If the load control is used to minimize the amount of the retailer's imbalance, the retailer aims to minimize the risk caused by the volatility of imbalance power prices and costs resulting from the imbalance power fees (balance service payments). The load control capacity can be also allocated to the reserve, and used in the most critical cases, such as during the times of extremely high prices. More information of different profit optimization strategies and management of retailer's power balance can be found in [4].

When planning the use of load control as a tool to manage a retailer's power balance, it is important to consider the limitations set by the balancing power markets and the System Operator (SO). Fingrid, the Finnish System Operator, for instance, obliges the market parties to maintain their imbalance at an appropriate level. More precisely, the market party has to plan and control its electricity procurements in a way that the power imbalance can be maintained at an appropriate level with respect to the extent of the operation of the party [7]. Consequently, the retailer can manage its power balance only limitedly.

In general, the management of a retailer's power imbalance and the resulting risk of imbalance power cost play an important role in the retailer's profit optimization. The ability to control the customers' loads close to the delivery could provide an opportunity for the retailer to improve its profitability by managing its power balance based on the latest available data. In addition, it could provide an opportunity to hedge against high imbalance power prices, which emerge if the demand of the balancing power is high compared with the available supply.

3.3 Bidding of load control capacity to the balancing power market

The balancing power market in Finland maintained by Fingrid, the Finnish System Operator (SO), is part of the Nordic balancing power market. Fingrid maintains a balancing power market because it does not have regulating capacity of its own to maintain the national power balance. The holders of production and loads can submit bids to the balancing power market concerning their capacity that can be regulated. [7] Thus, in a principle, if the retailer has load control capacity that meets the requirements set by the Fingrid and balancing power markets, it can bid it to the balancing power market.

The market parties can participate in the balancing power market through their balance responsible party or by signing a separate balancing power market agreement with Fingrid. Balancing bids can be submitted of resources that can implement a power change of 10 MW in 15 minutes. The bids have to be submitted to Fingrid 45 minutes before the specific hour. In addition, the submitted resources have to be measured or otherwise verified in real-time. Moreover, the regulation has to be carried out for the whole operation hour, if needed [7].

In practice, the use of customer load control by the retailer as reserve power capacity in the balancing power market is challenging. The above-mentioned minimum requirements set by Fingrid and the balancing power markets set high requirements for the load control capacity and its controllability. Moreover, a high number of small-scale customers should be aggregated to gather up the minimum capacity requirement of 10 MW. However, if these requirements can be met, the balancing power markets could potentially provide significant business potential for the use of load control.

The prices of the balancing power are determined based on the regulations put into practice. For the regulation, the balancing bids are used based on the principles of marginal pricing in the price order as well as possible by taking into account the operating situation of the power system. The cheapest up-regulating bid is used first, and correspondingly, the most expensive down-regulating bid is used first. However, if a bid cannot be used because of the prevailing operating situation, it is neglected. The capacity offered to the balancing power markets is paid according to the use of capacity, and based on the above principles [7].

In general, the business potential provided by the bidding of load control capacity in the balancing power markets depends significantly on the principles used for bidding. Consequently, the evaluation of business potential is very challenging without the real-world data. However, by taking into account that the load control capacity provided by the disconnection of loads would be bid as an up-regulating power in the market, it can be concluded that in general this would provide greater profit-making potential for the retailer than spot market. This results from the pricing principles of balancing power, based on which the up-regulating price is at least Nord Pool Spot's price for price area Finland [7]. Consequently, the bidding of load control capacity as up-regulating power would always provide at least the same profits for the retailer than the use of load control capacity "against" the spot-price. Moreover, the price volatility in the balancing power markets is typically rather high compared with the spot markets, which gives a strong indication that the balancing power markets could provide a significant business potential for the use of load control capacity.

4 Evaluation of business potential

The business potential provided for the retailer by the load control depends on many factors. These include for instance the amount of available control capacity in various periods of time, the limitations set by the markets and operational principles, the volatility of electricity prices in the markets, and the retailer's strategy for the use of load control. Because of the high number of factors having impact on the business potential provided by the load control, the evaluation of business potential is made based on case examples, to which some basic assumptions are applied.

The case examinations and basic assumptions used in the evaluation of business potential are made based on actual hourly data of a retailer's electricity sales, electricity wholesale market prices at the area of Finland, and the customers' electricity consumption. The customers' electricity consumption data are gathered in a pilot project, in which five electric heating customers were monitored and controlled. The retailer under examination operates in Finland, and its total electricity sales to the retail customers' during the examination period were approximately 250 GWh in total. In addition, daily retail sales prices of the supplier under obligation to deliver the energy are used to calculate the reference level for the spot-price-based load control. The evaluations are made within the time period of 1 Oct. 2011–31 Dec. 2011.

Because the objective of this paper is to evaluate the business potential provided by the load control for the retailer, it is not convenient to put effort to a detailed analysis of different factors, such as features of loads and variation in temperature, and their impacts on the control capacity available, load control responses, or other such factors. Nevertheless, these factors may have a great impact on the results obtained. Therefore, sensitivity analyses are made to illustrate the impact of different factors on the total result achieved by the load control. The sensitivity analysis makes it possible to avoid the above-described problems and simplifies the examination without distorting the results.

4.1 Basic problem assumptions and estimation of load control capacity

To simplify the evaluation of the business potential, some basic assumptions are made. First, it is assumed that the retailer can control its customer's loads cost-efficiently within the limits set by the customers, the market and the operational environment. This includes the assumption that there are no significant technical problems or other such factors that would significantly limit the use of load control capacity.

It is assumed that the retail sales of the electricity retailer consist of sales to residential retail customers. This assumption can be understood so that the retailer's sales to the retail customers during the examination period were approximately 250 GWh, and other possible electricity sales are excluded from the examination. The load control capacity of the retailer under examination consists of aggregated residential retail customers' electric heating loads including water heating, direct electric heating and storing electric heating. Because the examination of business potential is made by using aggregated total load control capacity, total and average values are used in the calculations.

The evaluation of potential aggregated load control capacity is made based on [8], in which Finnish households' electricity consumption in 2006 has been examined. In addition, other literature including [9], [10], [11] and [12], retailer's electricity sales data, and pilot customers' electricity consumption data from the pilot project are used to verify and complete the generated load control scenarios and assumptions.

One-family households and row-house households are considered to be potential targets for the aggregation of load control capacity. Table 2 presents the approximated proportions of different household types in Finland.

Table 2. Approximated share of different household types in Finland [8]

One-family households [%]	Row-house households[%]	Apartments [%]	Others [%]
41	14	43	2

In [8] has been estimated, based on the statistics of the Central Statistical Office of Finland, that a total of 37 % (8156 GWh) of residential electricity usage is consumed in electric heating systems. In addition, estimates of the electricity consumption of different household heating systems have been presented. Based on these data, and the average daily electricity sales of the retailer under consideration, the customers' daily energy consumption of the heating systems in one-family and row-house households has been calculated. The flow chart in the Figure 2 demonstrates the calculation of the heating system electricity consumption for different households.

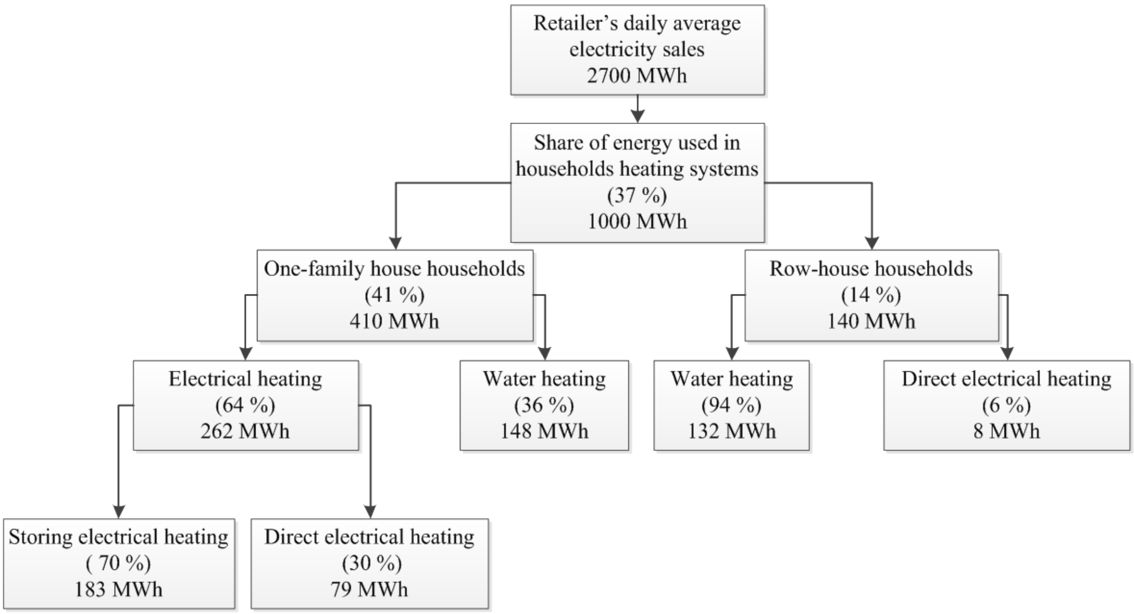

Figure 2. Estimation of average daily electricity consumption of heating systems in different households.

It is assumed that approximately 70 % of customers' electric heating loads can be controlled by the retailer. Based on that estimated daily load control capacities have been calculated and presented in Table 3.

Table 3. Estimated load control capacities of the retailer under examination

	Proportion of retailer's daily sales [MWh/day]			**Proportion of retailer's daily sales [%/day]**		
	One-family households [MWh/d]	Row-house households [MWh/d]	**Total [MWh/d]**	One-family households [%]	Row-house households [%]	**Total [%]**
Water heating	104	92	196	3,9 %	3,4 %	7,3 %
Direct electric heating	55	6	61	2,0 %	0,2 %	2,3 %
Storing electric heating	128	0	128	4,7 %	0,0 %	4,7 %

The estimations presented in Table 3 provide a basis for the following case examinations. In addition to the assumptions presented in this section, some other assumptions are needed in the case examinations. These have been presented in the context of the case examples.

4.2 Case 1: Load control based on spot prices

This case examination evaluates the business potential of a spot-price-based load control. As discussed in Section 3.1, the storing electric heating loads could be potential target for the spot-price-based load control. Thus, it is assumed that the retailer under examination uses its customers' applicable stroring electric heating systems for spot-price-based load control. The load control is made based on the principle that loads are disconnected at the times of the highest price hours and reconnected at the times of the lowest price hours in each day.

The evaluation of the business potential is made within the time period of 1 Oct. 2011–31 Dec. 2011, and assuming that five percent of retailer's daily electricity sales consist of the energy used in the storing electric heating systems. A sensitivity analysis is made by using average daily heating times of four, six, and eight hours. In other words, the calculation of business potential is made in cases where the customers' daily heating energy in each day is divided into four, six or eight hours with the lowest spot prices. In addition, the fixed retail sales prices of the supplier under obligation to deliver the energy are used to calculate the reference level for the evaluation of the saving potential. The results of the calculations are presented in Table 4.

Table 4. Estimated saving potential of the spot-price-based load control within the time period of 1 Oct. 2011–31 Dec.

Daily connection time for storing electric heating loads	Heating costs using a fixed price tariff [€]	Heating costs using spot-price-based load control [€]	Saving potential within the examination interval [€]	Saving potential/day [€]
4 Hours	691978	364202	327776	3563
6 Hours	691978	374600	317378	3450
8 Hours	691978	387662	304316	3308

Table 4 shows that the estimated average daily saving potential within the examination period was approximately between 3300 and 3560 € when the use of total heating energy was divided from four to eight hours. In addition to the saving potential, the number of customers the loads of which are controlled by the retailer should be considered in the evaluation of the business potential. The higher the number of controlled loads is, the higher the implementation and use costs of the load control are. For instance, if the number of customers the loads of which are controlled by the retailer in this case were 5000, 10 000 or 15000, the approximate average saving potential would be respectively 0.7, 0.35 or 0.18 €/day per customer. Hence, we may conclude that the load control cost per customer is lowest for the customers with the highest average load control capacity. Consequently, the customers with the highest load control capacity provide the greatest business potential for the load control.

The calculated total savings within the examination interval varied approximately between 304 000 and 328 000 €. The reason for this rather high saving potential is the low average level of the spot price during the examination period compared with the average fixed rate. The average spot price in the examination period was 37.4 €/MWh and the fixed rate 56.1 €/MWh. Particularly at the beginning of the examination interval, some days included hours with unusually low spot prices, even lower than 10 €/MWh. Such low-price hours provide an unusually high saving potential for the spot-price-based load control.

The results of the case examinations showed that the spot-price-based load control can provide some business potential for the retailer, if the load control costs can be kept at a low level. In addition, it is assumed that the electricity is sold to retailer customers at fixed rates, and that the customers' loads are controlled by the retailer based on spot prices. Alternatively, the same saving potential could be achieved by the retail customers, assuming that they purchase electricity at a spot-price-based tariff instead of a fixed-rate tariff and control their heating loads based on spot prices.

At a general level, the business potential of the spot-price-based load control depends highly on the implementation, use and other costs resulting from the load control. Thus, in order to obtain business potential from the spot-price-based load control, the load control should be possible to implement and utilize at low costs. If this can be done, for instance by utilizing the existing network infrastructure, the spot-price-based load control can provide some business potential for the retailer in the long term.

4.3 Case 2: Load control as a tool to manage a retailer's power balance

This case example examines the business potential of the retail customer load control as a tool to manage the retailer's power balance. The basic idea is that the retailer aims to achieve savings by shifting customers' loads from the hours with an unusually high consumption imbalance power price to later hours with lower prices.

In order to apply load control as a tool to manage the power balance, the retailer should be able to achieve load reduction if indications of high prices arise. The highest electricity prices occur typically during the peak consumption hours, which are typically found between 6 and 8 am and between 3 and 7 pm in Finland. Thus, the retailer should be able to achieve a significant load control response, particularly at these times, by giving a command to disconnect the loads. Sufficient residential customers' loads that could provide this response would be for instance water heating and direct electric heating loads.

It is assumed that the retailer can control its customers' applicable water heating and direct electric heating loads within the given limits in order to manage its power balance close to the delivery. Table 3 shows that the estimated share of water heating and direct electric heating loads of the retailer's total loads is approximately 10 %. Based on this, it is assumed that the retailer can expect a load reduction between two and five percents when a command for the disconnection of loads is given. In order to ensure that the load control does not cause significant inconvenience to the customers, the maximum continuous disconnection of loads is limited to one hour.

To make the case example more illustrative, the business potential of the load control is evaluated by the calculation of the maximum saving potential at the time of the highest consumption imbalance power price peak during the examination period of 1 Oct. 2011–31 Dec. 2011. This price peak occurred on 13 Oct. 2011, and is illustrated in Figure 3.

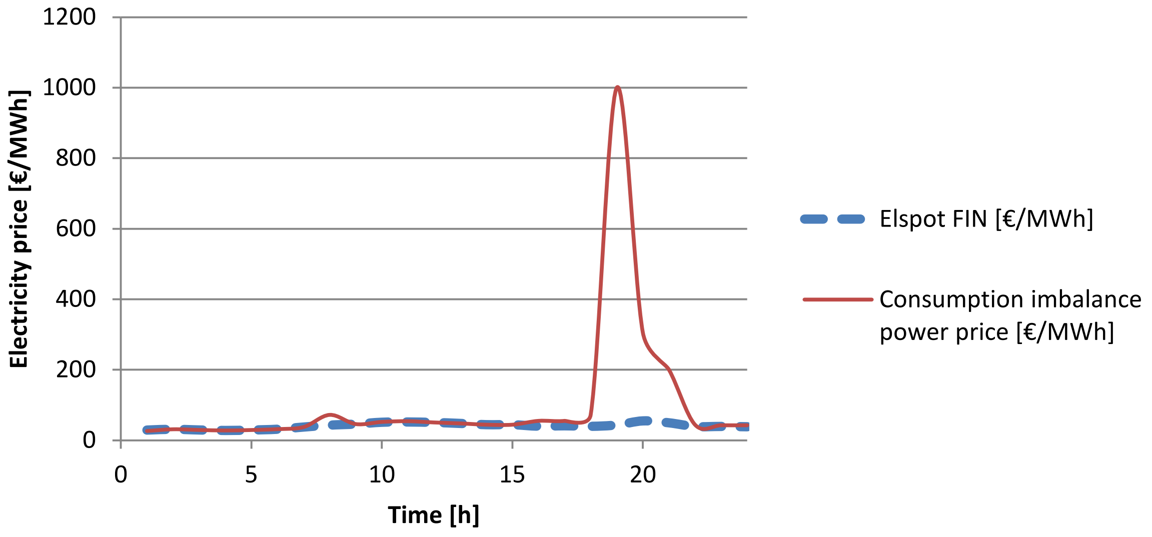

Figure 3. Price peak of consumption imbalance power on 13 Oct. 2011

The peak price of the consumption imbalance power occurred at 6 p.m. having a value of 1000 €/MWh. Table 5 presents accurate values for Elspot Fin and consumption imbalance power prices between 16:00 and 21:00 Finnish time on 13 Oct. 2011.

Table 5. Electricity prices between 16:00 and 21:00 on 13 Oct. 2011

Time	**16:00**	**17:00**	**18:00**	**19:00**	**20:00**	**21:00**
Elspot FIN [€/MWh]	41	39.52	43.25	54.92	49.47	39.02
Consumption imbalance power [€/MWh]	55	72	1000	305	200	43.87

The calculation of business potential has been made by using the actual power imbalance data of the retailer under examination, which is calculated based on the data of the retailer's actual electricity procurements and forecasted consumption. In addition, it is assumed that the retailer would have been able to indicate the coming price peak, and thus, would have given the command to disconnect the loads for the hour from 18:00 onwards. The retailer's imbalance for this hour was 10.65 MW. This approximates to a 8.8% deficit of electricity procurements for the hour. By switching customers' boilers and direct electric heating loads off, the retailer can reduce its imbalance, which decreases the retailer's need to purchase high-price consumption imbalance power.

It is assumed that the retailer disconnects the controllable loads for the hour 18 and reconnects those for the hour 19. The reconnection of loads induces a payback effect, because the disconnected loads starts to recover the energy that would have been used during the hour 18 without the disconnection. It has been estimated that the payback effect is divided into three following hours so that at the first hour 60 %, the second hour 30 %, and the third hour, 10 % of the shifted energy use will be recovered. To illustrate the impact of the payback effect on the total results, the calculation of saving potential is made also without a consideration of the payback effect. The calculated saving potential in relation to different expected load control responses is presented in Table 6.

Table 6. Calculated imbalance power costs and saving potential in relation to expected load control responses.

Estimated load reduction [MW], (%)	Consumption imbalance power costs without control [€/h]	Consumption imbalance power costs with control and with estimated payback effect [€/h]	Consumption imbalance power costs with control and without estimated payback effect [€/h]	Savings achieved with estimated payback effect [€/h]	Savings achieved without estimated payback effect [€/h]
2.4 (2 %)	24250	22428	21829	1822	2421
3.6 (3 %)	24250	21517	20618	2734	3632
4.8 (4 %)	24250	20605	19407	3645	4843
6.0 (5 %)	24250	19694	18197	4556	6054

The results presented in Table 6 show that well-timed load control at the moments of electricity price peaks could provide significant saving potential for the retailer even in a short time period. The maximum saving potential provided by one-hour load shifting varied between 1820 € and 4560 €, when the estimated hourly load reduction varied between two and five percents, with the payback effect taken into account. Consequently, we may state that the retailer would have benefited more than 900 €/h for each megawatt-hour load reduction. If the payback effect is excluded from the consideration, which would correspond to the situation in which energy consumption is reduced for the hour (loads are not shifted), over 1200 €/h saving potential for every megawatt-hour load reduction would have been achieved. Based on the above, we may conclude that the higher load control capacity there is available, and the lower the payback effect can be achieved, the greater the savings are.

However, when estimating the business potential, it should be borne in mind that this case example evaluates the theoretical maximum saving potential. In practice, many factors, such as mistiming of the load control, may lower the profits gained by the retailer. In general, the business potential of load control as a tool to manage a retailer’s power balance depends highly on the variation of electricity prices. Thus, in order to evaluate the business potential in a longer time span, the variation of electricity prices has to be examined. Figure 4 presents Elspot FIN and consumption imbalance power prices in the time period of 1 Oct. 2011–31 Dec. 2011.

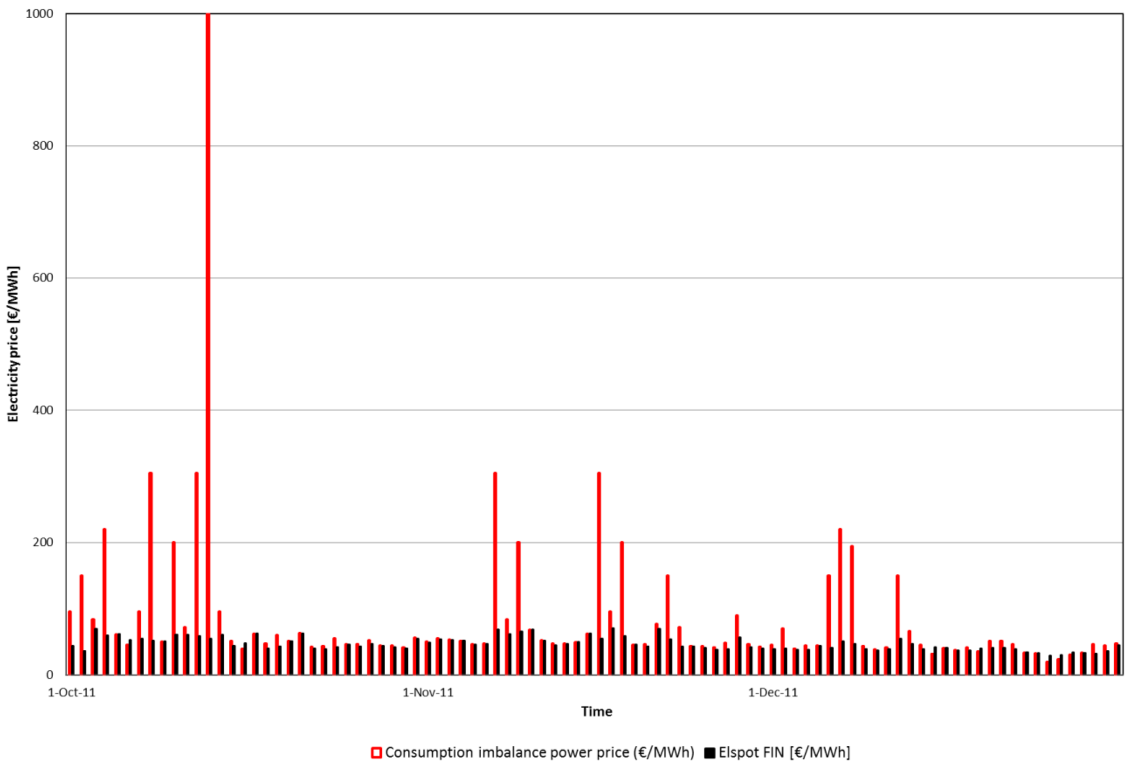

Figure 4. Elspot FIN and consumption imbalance power prices during the time period of 1 Oct. 2011–31 Dec. 2011.

The graph in Figure 4 shows that the variation in the imbalance power prices is quite significant during the examination period. This gives a very strong indication that there could have been considerable business potential for the load control.

In general, the business potential of load control as a tool to manage a retailer's power balance depends mainly on the variation of the imbalance power prices and the cost of load control. The lower the implementation and utilization costs of the load control are, and the higher price variations can be found, the greater business potential the load control can provide. In the examination time period of 1 Oct. 2011–31 Dec. 2011, there was considerable variation in the imbalance power prices, and occasional price peaks occurred, and thus, we may conclude that significant business potential could be found. In addition, the calculations based on the case example confirmed that significant savings could have been achieved even in a short time period, if the load control had been optimally timed for the peak price hour.

5 Conclusions

This paper examines the business potential of a retailer-based load control, in which the electricity retailer is the market party that executes the retail customer load control. Alternative strategies to use load control as part of retailer profit optimization were introduced, and the business potential of load control from the perspective of an electricity retailer was analyzed. It was found that a number of different factors have an impact on the business potential. The most important of these include the variation in electricity prices, implementation and utilization costs of the load control, the features of the controlled loads and timing of the control actions. It was also noticed that the high number of impacting factors makes the evaluation of the business potential challenging without real-world experiences and data on the load control of this kind.

The case examples used in the evaluation of the business potential were based on actual data. These data consist of electricity sales data of a retailer operating in Finland, customers' electricity consumption data gathered in a pilot project, and electricity price data for a period of 1 Oct. 2011–31 Dec. 2011. Despite the use of available actual data, some assumptions had to be made to complete the case example scenarios and evaluation of the business potential. These assumptions may produce some uncertainty in the results, and thus, sensitivity analyses were applied to model the impact of the most important uncertainty factors on the results.

The results of the case examinations indicated that load control could provide saving potential for the retailer. It was concluded that the spot-price-based load control could provide some business potential for the retailer in the long term, if it can be implemented and utilized at low costs. The use of load control as a tool to manage a retailer's power balance in turn could provide significantly higher saving potential, because the volatility of imbalance power prices can be significantly higher that the volatility of spot prices. However, in the latter case, also the utilization of the business potential is more challenging and risks higher than in the case of the spot-price-based load control.

The results of this paper indicate that customer load control can provide business potential for electricity retailers by bringing savings in electricity procurement costs and opening new opportunities to hedge against risks. However, it is important to take into account that, in practice, many factors have an impact on the business potential provided by the load control. Thus, the business potential of load control can vary significantly for instance between different time periods and depending on the implementation of the load control. Thus, future research work and actual experiences are needed in order to analyze in more detail the business potential provided by the load control for the retailers. In addition, the actual implementation still requires the development of operational and market models, which would enable more cost-efficient implementation and utilization of large-scale retail customer load control. However, the results of this paper show that a retailer-based load control could provide incentives for a large-scale retail customer load control and new tools for the retailer profit optimization.

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