Electricity retailer profit optimization in different operational environments

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Business process of the electricity retailer in smart grid environment

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1 INTRODUCTION

After the deregulation nature of electricity retail business has changed. Competition in the retail business is fierce, risks considerable high, but profit margins relatively low. In addition to market changes, the operational environment of electricity retail business is facing changes. Development of technology used in customer interfaces, large-scale implementation of smart metering and the changing over from traditional passive distribution networks to active smart grids will have growing impact on electricity retail business.

One reason for risks in the electricity retail business has been the disconnection between wholesale and retail markets (Caves & al. 2000). Electricity is sold to most retail customers with fixed rates, but electricity procurements in the wholesale markets are made with changing prices. Retailers have to also meet the load obligations set by their customers' electricity consumption, which cannot be forecasted precisely in advance. Consequently, retailers face a great challenge when they aim to hedge against these risks efficiently, but also avoiding overhedging, which results in extra costs.

Even though electricity retailers' opportunities to hedge efficiently against risks are limited at present power markets, the hedging, for instance by using physical and financial contracts, plays an important role in the retail business. The transition towards smart grids, and new functionalities and services which it enables, may also provide new tools for retailers' risk management and profit optimization. For instance, improved opportunities for large-scale customer load control can offer such tools.

Basically, the development of smart grids involves many changes which may have great influence on the retail business. The most interesting ones includes increasing amount DER (Distributed Energy Resources) and improving possibilities for these controls. For instance, improving opportunities for retail customer load control together with the generalization of energy storages in the power systems can help to promote DR (demand response) and improve utilities' opportunities for DSM (Demand side management). From the perspective of electricity retailer this can mean lowering risks and improving opportunities for more flexible operation. On the other hand, increasing amount of DG (distributed generation), consisted mainly on intermittently renewable production, can increase volatility of electricity prices and expose retailers' to higher risks.

In the literature can be found many definitions for above-mentioned terms (DG, DER, DR and DSM), which relates closely to smart grid environment. Table 1.1 presents the definitions used in the context of this report.

Table 1. Definitions for terms that relates closely to smart grid environment

Term	Definition	Reference
DG (Distributed Generation)	In general, DG can be defined as electric power generation within distribution networks or on the customer side of the network.	(Ackermann & al. 2001)
DER (Distributed Energy Resources)	The defining characteristic of DER is that they are active devices installed at the distribution system level. Distributed energy resources include small-scale generation resources such as fuel cells, micro-turbines, photovoltaics and hybrid power plants or storage technologies such as batteries. They may also consist of dynamic reactive power control devices and customer end-use load controls.	(Eto & al. 2000)
DR (Demand Response)	Demand response can be defined as the changes in electricity usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time.	(Albadi & El-Saadany 2007)
DSM (Demand Side Management)	DSM is the planning, implementation, and monitoring of those utility activities designed to influence customer use of electricity in ways that will produce desired changes in the utility's load shape, i.e. changes in the time pattern and magnitude of a utility's load.	(Cellings 1985)

This report examines electricity retailer profit optimization in different operational and market environments, but the main attention will be directed to smart grid environment and Nordic electricity markets. *The main aim of this report is to develop and introduce a basic methodology for electricity retailer short-term profit optimization in different operational environments considering opportunities to utilize different functionalities and services which each operational environment provides.* Even though the profit optimization methodology will be developed primarily for Nordic electricity markets, the same basic principles can be mainly applied also for other same type of market environments.

The structure of this report is the following. Second chapter describes the role of operational environment from the perspective of electricity retailer profit optimization. In this context the development of operational environment towards smart grid environment is divided to three stages, current operational environment, near future's operational environment, and finally the smart grid environment. Third chapter provides an overview of some interesting electricity markets, introduces their unique features, and considers the impact of market environment on retail business. Fourth chapter presents the main principles for electricity retailer short-term profit optimization in different operational environments. Fifth chapter examines the most important factors which should be considered in the planning of retailer short-term profit optimization. Sixth chapter introduces the principles for retailer profit optimization in the smart grid environment in more detail, and finally, in the chapter seven, the conclusions and guidelines for future research will be presented.

2 DIFFERENT OPERATIONAL ENVIRONMENTS

The move from traditional passive distribution networks to active smart grids will have great influence on electricity markets and market players' business. The development of smart grids can provide new opportunities to improve profitability of retail business, but it may also arouse new risks. This chapter examines the development of operational environment towards the smart grid environment, and in particular, its potential impacts on electricity retail business and retailers' profit optimization. The main focus is in the electricity retailer short-term profit optimization including trades in the day-ahead, intra-day and real-time (balancing power) markets, and the possible utilization of controllable DER close to the moment of delivery.

Electricity retailer profit optimization problem will be examined according to the stage of development of operational environment. The first stage is the current situation, in which retailers' opportunities to enhance their profitability in short-term markets by utilizing existing technology are rather limited. In the second stage, in the near future, the generalization of smart metering and development of technology used in customer interfaces enable more real-time data transfer between the customers and other electricity market parties. This makes possible to develop more sophisticated functionalities and services, which can be used to enhance retailers' profit optimization. In the third stage, in the future smart grid environment, new smart grid-based functionalities and services provide even better opportunities for the market parties, including electricity retailers, to enhance their business.

2.1 Current operational environment

In the current operational and market environment profits of the electricity retail business are fairly limited. Thus, retailers should minimize the risks in order to ensure the viability of retail business. The main tool for the minimization of risks is hedging by using financial instruments and bilateral contracts. The contractual position set by hedging secure that the retailer can procure electricity in the wholesale markets with fixed price which is known in advance. In addition to hedging of electricity procurements, the setting of retail sales price has high impact on retailer's expected profits. Electricity retail sales price should be set so that the sale incomes cover retailer's operational costs and set risk margin.

One of the basic problems in the long-term electricity procurement planning is that customers' future electricity consumption is not known in advance, and can be forecasted only with limited accuracy. The uncertainty related to consumption forecasts makes it hard to determine the optimal electricity profit optimization strategy. For example, as a result of unexpected cold or hot weather, the actual consumption can differ significantly from the forecasted. Unexpected variation in total consumption (actual loads) and retailer's load obligation, which oblige the retailer to provide customers with the energy needed to cover their consumption (loads), forms volume risk for the retailer. This combined with the price risk, caused by the variations of electricity prices in the wholesale markets, forms a substantial electricity procurement cost risk for the retailer.

In a long-term electricity retailers aim to hedge the major part of their electricity procurements based on estimations on future consumption. However, there is almost always some difference between the retailer's forecasted and actual electricity consumption, and consequently, the electricity procurements/hedging made in advance do not match precisely to actual consumption. Difference between secured electricity procurements in advance (contractual position) and expected electricity sales in the retail markets (tariff-based sales) forms the retailer's *open position*. The existence of open position together with the market price risk poses a subsequent cost risk for the retailer. Consequently, the management and fulfilling of open position prior to the delivery hour plays a central role in the retail business.

Electricity retailers long-term hedging is based on physical electricity procurements in the OTC market (Over-The-Counter) and 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 provides a number of different products including futures, forwards, options and CfDs (Contracts for Differences). Retailers can use the above-mentioned products to establish a contractual position, which decreases the size of the retailer's open position and ensures that at least part of the needed electricity can be procured at a fixed price known in advance. The level of hedging should be planned carefully, because overhedging reduces expected profits and too low hedge ratio exposes the retailer to high risks.

Even if the retailer has hedged by using financial products, it still has to procure the actual energy in the physical power markets. In addition, the variation in customers' electricity consumption may cause a need for balancing trades when the delivery hour approaches. The retailer can still make balancing trades in the day-ahead and intra-day markets, and thus manage its open position prior to the moment of delivery. After the intra-day trading, the retailer cannot anymore make trades in the short-term markets. The remaining (final) open position will thus form a *power imbalance* (difference between electricity procurement/production and consumption/sales) for the retailer. This imbalance has to be neutralized by the means of imbalance (regulating) power, which "trading" is done via imbalance settlement procedure.

The level and volatility of imbalance power prices can be rather high compared to spot prices. Thus, in order to minimize the risk related to power imbalance and its neutralization by the means of imbalance power, the retailer should typically aim to minimize the size of its open position by making balancing trades in the short-term markets. However, the actual consumption is not known precisely in advance, and thus, the retailer may not be able to manage its open position to zero level (electricity procurements match precisely to actual consumption) by making balancing trades. Moreover, the retailer may set relatively high open position also purposefully, if it has for example strong vision that electricity prices will lower in the future. In this case the retailer can achieve savings thanks to reduced hedging costs, and if the vision is right and the prices become lower, the retailer will also achieve additional savings. However, this alternative should be considered very carefully, since it exposes the retailer to high risks, particularly in the price volatile markets.

In a typical risk avoiding profit optimization strategy, which is particularly recommendable in the price volatile markets, the retailer aims to manage its open position close to the zero level (balance between electricity procurement/production and consumption/sale) when the delivery hour approaches. This typically inquire that the retailer makes balancing trades based on the latest consumption forecasts. In general, the closer the delivery hour is, the smaller the size of the open position should be so that the risk related on being in imbalance can be minimized. Figure 2.1 presents an example demonstrating this kind of risk avoiding electricity procurement strategy in a long term. The size of open position is aimed to set between the minimum and maximum limits of the retailer's hedged electricity procurements, set based on the tariff-based electricity sales. The red dashed line in Figure 2.1 presents the maximum hedging level, and blue line the minimum hedging level.

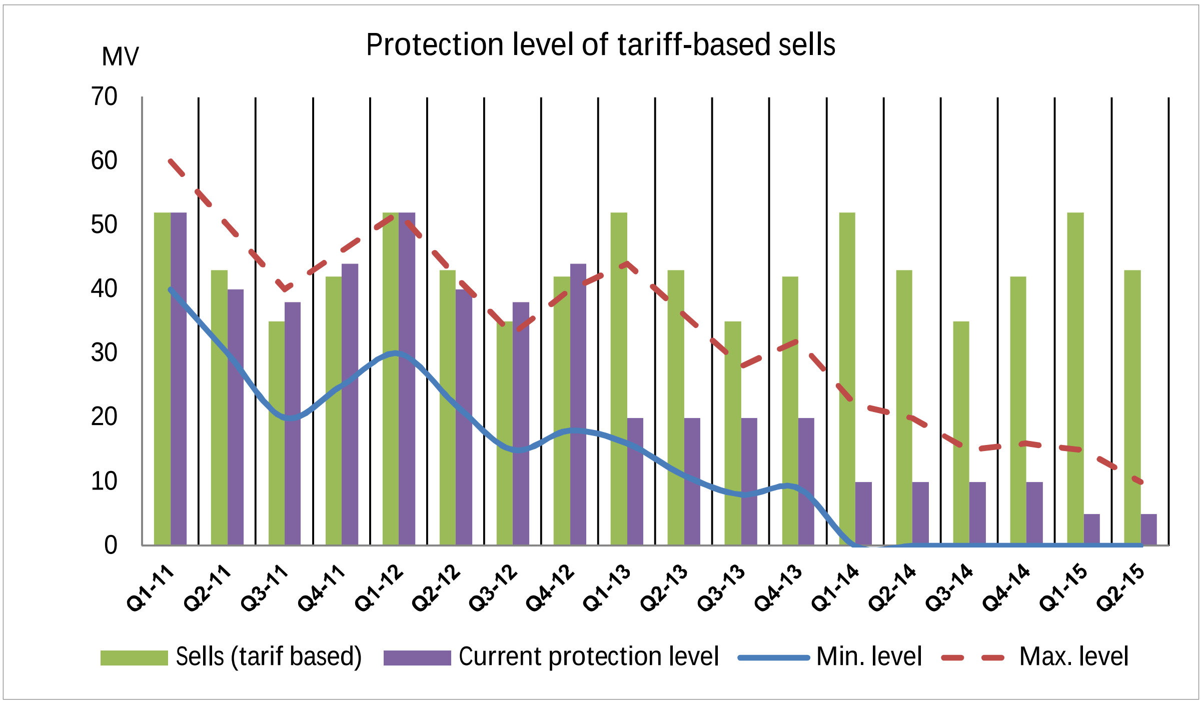

Figure 2.1.Hedging of retailer's electricity procurements in a long term

Figure 2.1 shows that this hedging strategy aims to decrease the size of open position when the delivery hour approaches. In other words, the longer the time span between the present moment and the delivery hour is, the less hedged procurements are made. By this way the risk caused by the variation of electricity prices can be kept within permissible limits without excluding the possibility to achieve savings in the case of lowering electricity prices.

In particular in the price volatile wholesale markets, the management and fulfilling of open position prior to the delivery hour has an important role in retailers' profit optimization. However, it is not typically possible for the retailer to forecast the demand of electricity with so high accuracy that the open position could be managed to zero level prior to the delivery (usage) hour. The power imbalance resulting from the retailer's remaining open position has to be neutralized by the means of imbalance power. The "trading" of imbalance power instead of making corresponding trades in the spot markets can result in significant extra costs for the retailer, because the price of imbalance power can be significantly higher than the corresponding spot price. Thus, even if the size of the open position and the resulting power imbalance would be rather low, the purchase of high-priced imbalance power can result in significant extra costs for the retailer.

2.1.1 *Short-term and long-term electricity procurement planning*

The planning of electricity retail business can be divided in the long-term and short-term planning. The long-term planning is also known as strategic planning and it includes ensuring of purchase price for most of the electricity procurements. In practice, this can be done for example by using physical and financial contracts such as futures, forwards and bilateral contracts.

The short-term planning in turn covers the management of open position that the retailer has after the long-term hedging. In practice, this includes trades in the day-ahead, intra-day and balancing power markets (and possible utilization of controllable DER such as load controls). Figure 2.2 illustrates the planning of retail business in a chronological order in Nordic electricity markets.

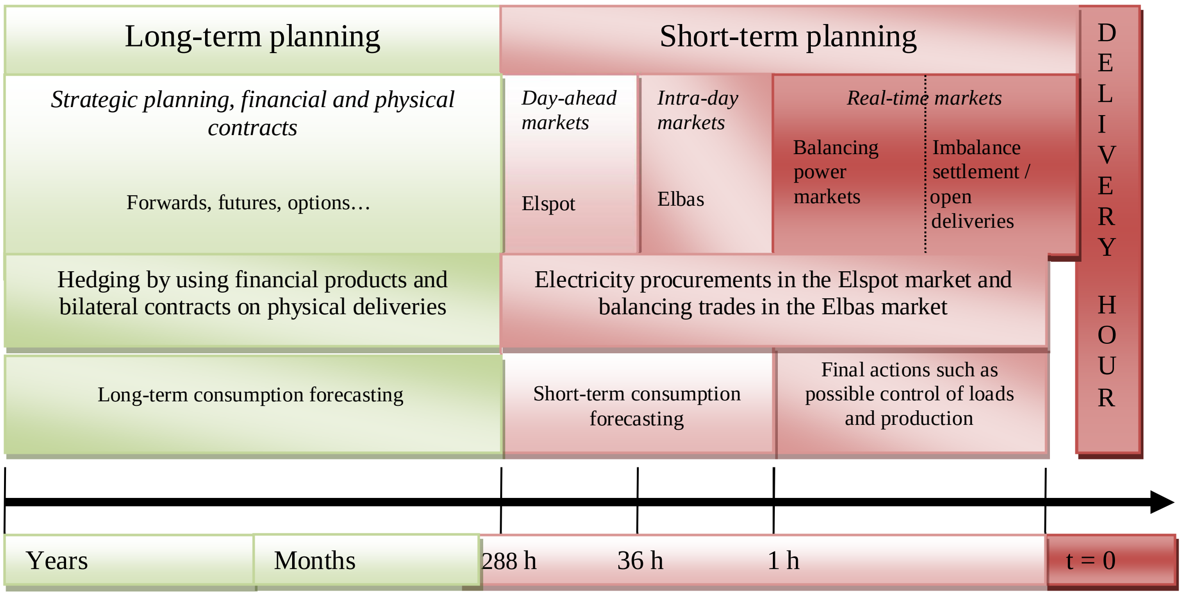

Figure 2.2. The planning of retail business in a chronological order in Nordic electricity markets

Figure 2.2 show that the planning of retail business is a long-term process which includes many sub-tasks. However, this report focuses mainly on short-term planning, presented as red in the figure 2.2.

2.1.2 *Consumption forecasting*

Consumption forecasting is of the most important individual tasks in the planning of retail business and it provides a basis for the retailer’s risk management and electricity procurement planning. In a principle the retailer profit optimization can be seen as long-term process, during which the retailer updates its consumption forecasts and manages its open position accordingly. This process starts from the long term-hedging and continues until the moment of delivery. Because the consumption forecasts can be regarded as main input for the planning of hedging and physical electricity procurements, the accuracy of consumption forecasts has high impact on the retailers’ profits.

Depending on the forecasting period and the usage purpose of the forecast, different source data may be utilized in the forecasting process. At present, electricity consumption forecasts are typically made based historical data of end-users’ consumption, customer- or customer group-based load models, weather forecasts and/or network measurement data. However, also other available data can be used.

Local weather forecasts have a critical role in the short-term consumption forecasting. In addition, for example accurate and real-time measurement data can be used to improve accuracy of consumption forecasts. However, so far the retailers have not typically been able to get this measurement data adequately cost-efficiently and fast, so that its utilization in consumption forecasting would have been reasonable. However, this situation is changing due to large-scale implementation of smart metering and transition towards smart grid environment.

2.2 Near future's operational environment

Recently, in many countries has been launched or already implemented smart metering projects. As a result of these remotely readable energy meters, which base on AMR (Automatic Meter Reading) technology, will be installed in the near future, or have been already implemented. For instance in Finland remotely readable AMR meters have to be installed at least 80 % of all end-users by 2014 according to the *Government Decree on Settlement and Measurement of Electricity Transactions.* (Degree 66/2009)

The main use of energy meters has been to gather up electricity consumption data for invoicing needs. However, the AMR and AMI (Advanced Metering Infrastructure) enable many new functionalities and characteristics that can be exploited in electricity distribution and retail business. Data and new functionalities provided by AMR and AMI can be utilized for example in the development of new ancillary services. These in turn can improve efficient use of electricity and produce added-value for the service user and the provider. (Valtonen & al. 2011)

Measurement data from AMR meters can be utilized in many ways in electricity retail business. However in practice, the problem has been in many cases that only the DSO, who is responsible from metering and meter reading, has been able to utilize this data adequately cost-efficiently.

In Finland the utilization of AMR data is promoted by the law. *The Act on Energy Efficiency Services for Companies Operating in the Energy Market* (Act 1211/2009) provides that the local DSO's have to provide the data needed for the customers' energy consumption reporting to the retailer without any payments. In addition, all electricity retailers are obligated to do the consumption reporting to their customers at least once in a year. The main aim of this customer reporting is help customers to improve efficient use of electricity, but this law will also contribute the mobility and availability of measurement data, and ease the utilization of measurement data in different functionalities and ancillary services. (Valtonen & al. 2011) Also in many other countries has been set near future's targets that aim to promote utilization of measurement data provided by new metering infrastructures. Thus, it seems that these aims will contribute different market players', such as retailers', ability to utilize AMR-data in their business.

Historical and real-time measurement data provided by the AMR meters can be used for example to develop state estimation, load modeling and electricity consumption forecasting applications. (Valtonen & al. 2011) Particularly interesting from the view point of electricity retailer profit optimization is the utilization of measurement data in the development of load forecasting accuracy. If the retailer can forecast its total loads more accurately, and manage electricity procurements accordingly, its ability to optimize the profits improves. Still, also many other factors have impact on the retailer's ability to operate profitably. For instance, the retailer's ability to manage its open position in an optimal way, existing market environment, and in particular electricity prices in different power markets has high impact on the final profits.

In addition to the opportunity to get more accurate and real-time measurement data, two-way communications and generalization of AMR and AMI technologies enable new functionalities. For instance, AMR meters that will be implemented in Finland have to be able to send and receive external control signals, and execute on/off-type load controls. Functionalities of this kind can also offer new opportunities to improve profitability of the retail business.

The ability to send external signals can be utilized for example in the realization of new pricing models and in the promotion of demand response. Based on the control signals, such as electricity price, customers' electricity consumption can be controlled in certain limits in a way that provides the optimal results. Some studies (Ilic & al. 2002; Caves & al. 2000) suggest that even a modest improvement of DR can significantly decrease electricity price peaks in the wholesale markets, which in turn decreases electricity retailers' price risk.

The development of network infrastructures and implementation of AMR provide also prerequisites for large-scale customer end-use load control. This can enable the utilities and market players, including electricity retailers, to implement DSM projects, promote DR and develop new business strategies.

In general, opportunities to utilize near future's network infrastructure in the retail business depend highly on the development of operational environment. The existing market model has an important role, because it can promote, but also complicate, or even prevent the utilization of new functionalities and ancillary services. In addition, the used technology and operational models have to enable adequate cost-efficient execution of new functionalities and services.

2.3 Smart grid environment

At present markets electricity retailers' possibilities to improve their short-term profit optimization are rather limited. Retailers can manage their electricity procurements prior to the usage hour by trading in the short-term markets, but typically there is no adequately cost-efficient way to manage electricity procurements by utilizing controllable loads or other controllable DER. In a principle, if the retailer has own controllable DER, it could use these to manage its open position prior to the delivery. However in practice, there are in many cases obstacles for that. Many market models do not enable cost-effective control of large production according to retailers' short-term profit optimization needs. In case of controllable loads and controllable small production, there is typically less market-based obstacles. However in practice, in the current operational environment, the lack of requisite systems and operational models makes these utilization as part of retailers' profit optimization typically very challenging, or even impossible.

Smart metering and development of network infrastructures are changing traditional passive distribution networks to active. This development enables a whole new interactive customer gateway, which makes possible more adaptable use of customers' loads, energy storages and distributed generation. Important part of this interactive customer gateway are two-way data transfer connections which make possible real-time data transfer between different market parties and control of electricity end-users' energy resources.

The development of interactive customer gateway increases customers' role as part of the power market and opens new opportunities for different market players to enhance their business. For example, the ability to use controllable in the management of retailer's open position and resulting power balance between electricity production/procurements and consumption/sales would improve retailers' ability to operate more flexible and profitable in the power markets. Moreover, for instance electricity end-users could benefit at the same by achieving savings in their electricity bills.

Figure 2.3 presents the concept of interactive customer gateway. Figure 2.3 also demonstrates how the interactive customer gateway enable different market parties to interact with each other and make possible the utilization of distributed energy resources such as controllable loads, distributed generation and energy storages by the market players.

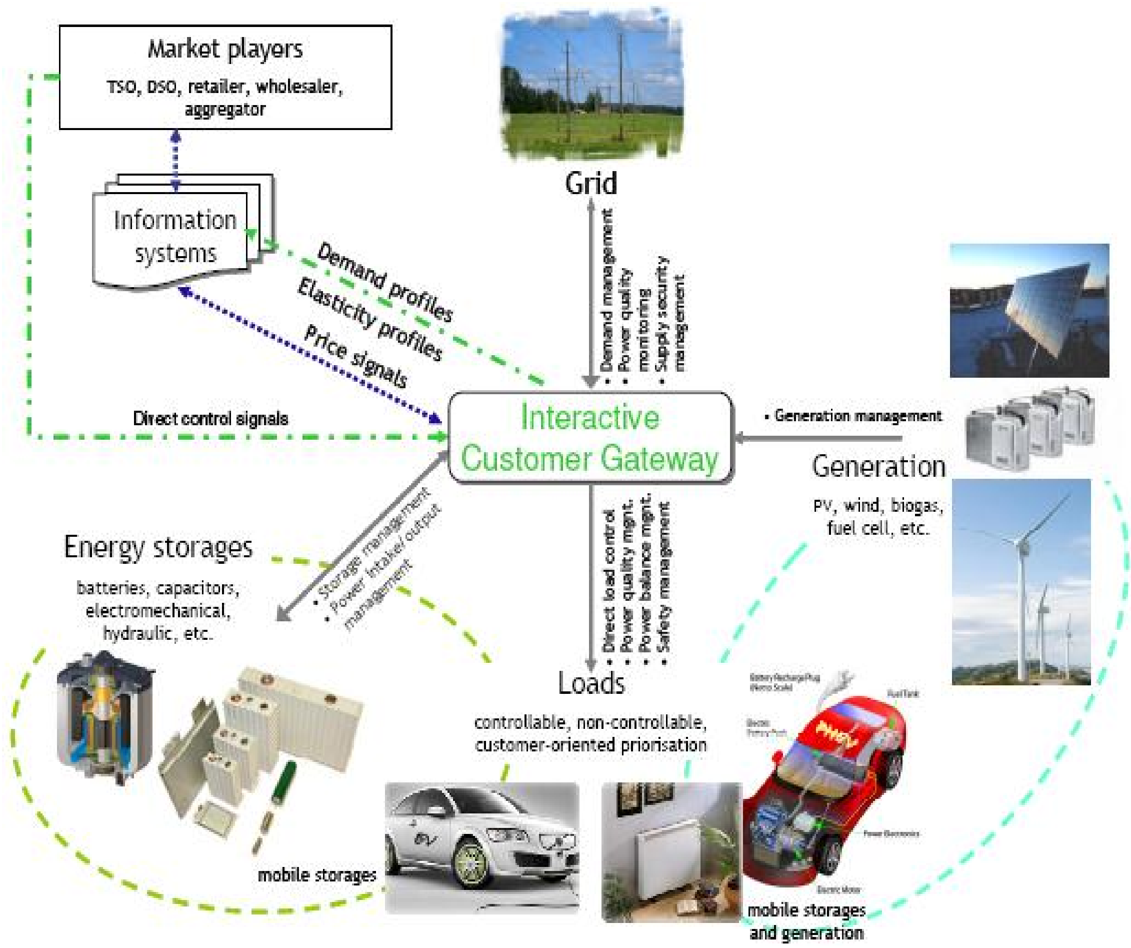

Figure 2.3. The concept of interactive customer gateway. (Kaipia & al. 2011)

Assuming that the market model or any other external factor will not prevent utilization of new functionalities provided by the smart grid environment and interactive customer gateway, these can open great opportunities for retailers to develop their profit optimization. In particular, the ability to utilize controllable DER could provide very useful tools for short-term profit optimization. The retailer could, for instance, manage its open position cost-efficiently by controlling customers' active loads, even if electricity prices in the wholesale markets would be high. In the best case, this could provide significant savings even in a short period of time. Moreover, the increasing amount of DER provides new opportunities to promote DR, which in turn can decrease price peaks in the wholesale markets and lower retailers' risks.

In addition to new opportunities, the development of smart grid environment provides also new risks. For example, the increasing amount of intermittently renewable generation, such as wind and solar power, increases the need for balancing power. This in turn can increase volatility of electricity prices, and thus expose retailers to higher risks. Therefore, it is important to examine the possible impacts of the development of smart grid environment so that the risks can be managed and opportunities exploited.

3 ELECTRICITY MARKETS AND RETAIL BUSINESS

Existing market environment has a high impact on electricity retail business. The used market model determines retailers' possibilities trade, manage electricity procurements and operate in the market. Thus, the operational principles and special features of the market have to be analyzed before the retailer's profit optimization can be developed accordingly.

This chapter provides overviews on some early deregulated electricity markets and considers each market's specific features and those impacts on retail business. The main focus is in the Nordic markets, but also some other interesting electricity markets are introduced shortly. These markets include some early liberalized markets, on which has been got already some experiences in practice, and some otherwise interesting or important markets.

3.1 Nordic electricity markets

During the nineties Finland, Norway, Sweden and Denmark were integrated into a single Nordic electricity market. In this integration these markets were deregulated and opened to competition. In addition, a common Nordic Power Exchange, Nord Pool ASA was established. In the resulting Nordic power system, the transmission network is owned and operated by a number of independent transmission system operators (TSO). This guarantees nondiscriminatory access to network for different electricity market parties. (Lucia & Schwartz 2002)

Nord Pool ASA was established in 1993. In 2002 the financial and physical markets was separated, and Nord Pool Spot were established for physical power markets. The market model to be applied was the zonal pricing (area-pricing). In 2011, after the joint of Estonia in 2010, a total of ten price areas exist. Today the Nord Pool Spot Group operates the spot markets including Elspot and Elbas markets. It consists of Nord Pool Spot AS and Nord Pool Spot AB operating the Elspot market, and Nord Pool Finland Oy operating the Elbas market. The Elspot market operates as a closed auction and in the Elbas market contracts can be traded up to one hour to physical delivery until a counterpart is found. (Nord Pool Spot 2011)

Nord Pool Spot provides a market place to producers, energy companies and large consumers, on which they can buy and sell electrical energy. Nord Pool Spot is the central counter party in all trades guaranteeing settlement for trade. Nord Pool Spot's system price is generally used as a reference price for futures, forwards and options traded in the financial market. The CfD products can be used to hedge against the price differences between areas.

The market price is formed according to the principle of marginal pricing, where the merit order of generation determines the use of generation so that the lowest price generation will be activated first and the highest price generation last. Thus, the price is formed based on marginal cost of the last activated production and is the same for all production and consumption. Based on the principle of marginal pricing the system price is determined by Nord Pool Spot. It is used generally as a reference price for the Nordic OTC markets (bilateral contract trade), as well used by the distributors as a basis for quoting prices to end consumers. About 72 % of electricity is traded through spot markets in the Nordic area while the rest is based on bilateral transactions (in 2009). Because the major part of the electricity is traded in spot markets, it provides reliable reference price for Nordic electricity markets. (Nord Pool Spot 2011; Viljainen & al. 2011)

3.1.1 *Elspot market*

Elspot is a day-ahead auction where hourly power contracts are traded for physical power delivery in the next day 24-hour period. The participants can place their orders, hour by hour, through Nord Pool Spot's web-based trading system, SESAM. Participants can place their orders up to twelve days ahead (288 h) while the gate closure for the orders for the next day delivery is 12:00 CET. (Nord Pool Spot 2011)

When all participants have submitted their orders, the spot price is formed based on the balance between bids and offers from all market participants. The equilibrium between the aggregated supply and demand curves is the spot price of the current hour. The system price and area prices for all bidding areas are calculated and published at around 13:00 CET. Figure 3.1 illustrates the forming of spot price. The intersection point between the market supply and demand curves is the spot price of the current hour. (Nord Pool Spot 2011)

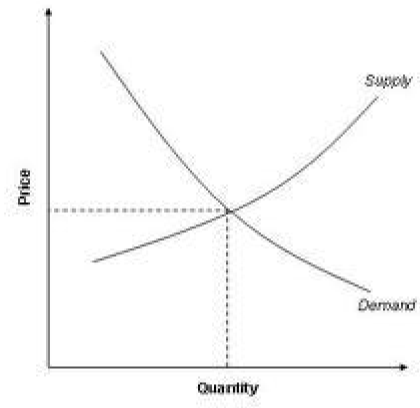

Figure 3.1. The forming of spot price based on the supply and demand curves.

The price mechanism in Elspot determines also the power flows across the interconnectors to the available trading capacity given by the Nordic transmission system operators. Thus, the Elspot is a common power market for the Nordic countries with an implicit capacity auction on the interconnectors between the bidding areas. The participants of Elspot market have to meet the requirements set by Nord Pool Spot to get the access to the market. Elspot market participants must also have a balancing agreement with the respective transmission system operator or through a third party. (Nord Pool Spot 2011)

3.1.2 *Elbas market*

Elbas market is a continuous intra-day market that covers the Nordic countries, Germany, and Estonia. In the Elbas market the balancing trades can be done until one hour prior to the delivery, after the day-ahead market is closed. At 08:00 CET the hour contracts for the next day are opened for trade in Germany. At 14:00 CET the hour-contracts for the next day are opened in Elbas market areas Finland, Sweden, Norway, Denmark, and Estonia. Because the capacities available for the Elbas trading are published approximately at 14:00 CET, Germany is treated as a separate bidding area between 08:00 CET - approximately 14:00

CET. The participants are obligated to report the trades done in the Elbas to their local TSO. (Nord Pool Spot 2011)

Elbas market provides instant access to counterparts from the whole Nordic, German, and Estonian power markets. It provides opportunity for market player's to produce electricity with lower price than the balancing market. Therefore, Elbas market can be used as an alternative to the balancing market for all or some of the imbalance that a market player may have after the day-ahead trades. Because the price is known prior to the delivery hour, balancing trades in the Elbas markets can be used to reduce retailer's risk related to being in imbalance.

3.1.3 *Balancing power market*

The last transactions in the physical power markets are concluded by the system operator during the actual hour of the operation to maintain the power balance in each country. System operator maintains a balancing power market because it does not have enough regulating capacity of its own to maintain the power balance. Holders of production and loads that meet the requirements set for the balancing power capacity can submit bids to the balancing power market concerning their capacity which can be regulated. At presents there are some minor differences between the national imbalance settlement procedures. However in 2010, the Nordic transmission system operators Energinet.dk, Fingrid, Statnett and Svenska Kraftnät launched a Nordic project on the harmonization of their imbalance settlement procedures. (Fingrid 2011) To avoid the possible misunderstandings related to the differences between national imbalance settlement procedures, it should be noted that the Finnish balancing settlement procedure with Fingrid (The Finnish system operator) will be under consideration in this context.

Each party operating in the electricity market has to take continuous care of its own power balance between electricity production/procurement and consumption/sales. In practice, an electricity market party cannot do this by itself. Therefore, it must have an open supplier which is responsible for maintaining the power balance of the party. A party whose open supplier is the system operator is referred as a balance responsible party. The agreement for open delivery between system operator and party is referred as a balance service agreement. This agreement gives balance responsible party a right to participate in the balancing power markets. Other market parties that own capacity can participate in the balancing power market through their balance responsible party or by signing a separate balancing power market agreement with the system operator. (Fingrid 2011)

The balancing power market in Finland is maintained by Fingrid and it is part of the Nordic balancing power market. A Nordic balancing bid list is drawn up of all balancing bids by placing the bids in a price order. To maintaining the frequency, the balancing bids are used in the price order as well as this is possible. The cheapest up-regulating bid is used first, and correspondingly, the most expensive down-regulating bid is used first. If some bid cannot be used because of the prevailing operating situation, it is neglected. Figure 3.2 illustrates the use of balancing bids in Nordic balancing power markets. (Fingrid 2011)

Figure 3.2. The use of balancing bids in Nordic balancing power markets. (Fingrid 2011)

Based on the regulations of Nordic balancing power markets and the bids, the prices of balancing power are determined both up-regulating and down-regulating power. "*Up-regulating price* is the price of the most expensive up-regulating bid used; however, at least Nord Pool Spot's price for price area Finland (Elspot FIN). *Down-regulating price* is the price of the cheapest down-regulating bid used; however, at most Nord Pool Spot's price for price area Finland". (Fingrid 2011) Those market players from whom Fingrid has ordered up-regulation during the hour obtain a fee for the agreed energy in accordance with the up-regulating price, and those from whom Fingrid has ordered down-regulation pay the down-regulating price for the agreed energy.

3.1.4 *Trading in the Elspot, Elbas and Balancing power market*

This section provides a summary of the trading principles of Nordic electricity markets including trading in the Elspot, Elbas and balancing power markets. General trading principles with the limitations set by the markets are presented in the Table 2.1. Since there are some minor differences between the national imbalance settlement procedures, in this context the regulations of Finnish balancing settlement and balancing power markets are under examination.

Table 3.1. Trading principles of Nordic electricity markets. (Nord Pool Spot 2011; Fingrid 2011)

	Elspot	Elbas	Balancing power markets
Trading period	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 through 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.

3.1.5 *Finnish imbalance settlement model*

Imbalance settlement is used to determine the deliveries of electricity between the parties operating in the electricity market, and it is based on a hierarchic imbalance settlement model and on chains of open deliveries. Fingrid's Balance Service Unit, which operates as an open supplier of a balance responsible party, is the highest party in the chain of open deliveries. The open delivery of a balance responsible party includes networks and parties, and the party's open delivery can further include parties and networks. Under the balance responsible party's balance responsibility are included all the parties and networks of chains of open deliveries. Therefore, each party engaged in electricity trade has one open supplier. The Figure 3.3 illustrates the chain of open deliveries. (Fingrid 2011)

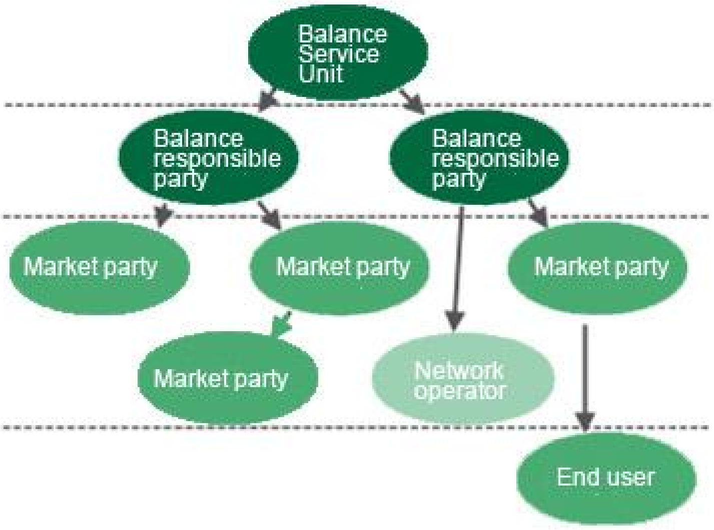

Figure3.3. The chain of open deliveries (Fingrid 2011)

The calculations of open deliveries under imbalance settlement are based on hourly energies. These are obtained from hourly energy measurements, load profiles, production plans and fixed deliveries. The deliveries can be measured deliveries or fixed deliveries agreed in advance for the particular hour. *The power balance of each party operating in electricity markets is obtained as a result of the imbalance settlement.*

The imbalance settlement connects the market parties and balancing power markets. Every market player, such as a retailer, has to have a balance responsible party who delivers the balance power (imbalance power) needed to cover up the imbalance between electricity procurements/production and sales/consumption. Thus, the balance power is the energy that balance responsible party has to buy from / sell to market party to neutralize his imbalance (NBS 2011).

The prices of balancing power serve as the basis of the pricing of imbalance power, which is the electric energy used for covering the difference between actual power consumption/sales and production/procurements of a party during an hour. Market parties trading the imbalance power are subjected to the balance service payments. The balance service payments in Finland in recent years are presented in the Table 3.2.

Table 3.2. Balance service payments in Finland without taxes. (Fingrid 2011)

Balance service payment	**Year 2010**	**Year 2011**	**Year 2012**
Fixed monthly payment	200 €/kk	200 €/kk	200 €/kk
Production payment	0,035 €/MWh	0,06 €/MWh	0,085 €/MWh
Consumption payment	0,075 €/MWh	0,115 €/MWh	0,145 €/MWh
Imbalance volume fee (consumption imbalance)	0,5 €/MWh	0,5 €/MWh	0,5 €/MWh
Energy payments in production and consumption balance as agreed in the balance model			

The market player’s total imbalance power costs are determined throughout the imbalance settlement process. The forming of market player’s imbalance power costs, and the connections between different market players’ in the chain of open deliveries are illustrated in the Figure 3.4.

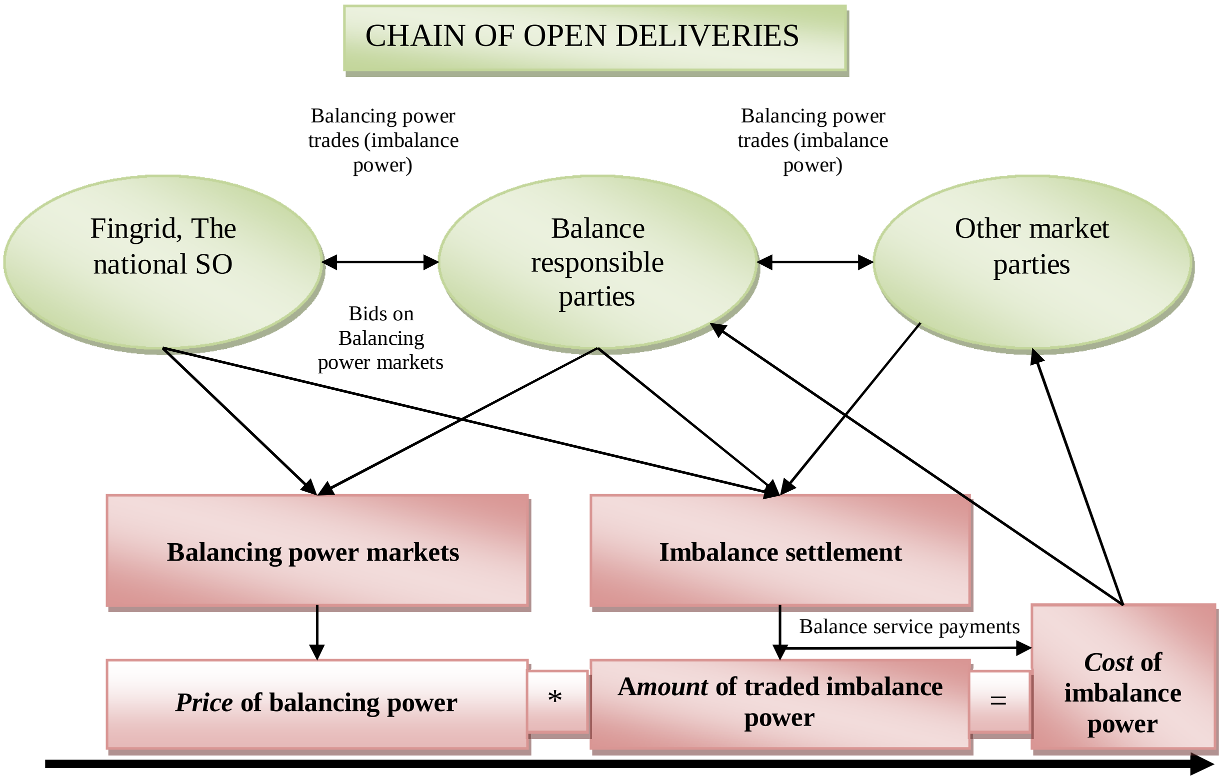

Figure 3.4. The chain of open deliveries and the forming of market player's imbalance power costs.

Figure 3.4 shows that market player's total imbalance power costs depends on the price of the balancing power, amount of traded imbalance power, and balance service payments.

3.1.6 *Nordic balance service model*

New Nordic balance service model was introduced at the beginning of 2009. This uniform model base on the introduction of two balances: production and consumption balance. In addition, general instruction for binging production plans and reporting of production plans and regulating bids 45 minutes before beginning of the specific hour was given.

This model of two balances divides generation in a one balance, and consumption, purchases and sales in another. In addition, the production plan given from the production balance before the beginning of the specific hour is included in the consumption balance in the balance settlement. Moreover, the pricing models of these two balances are different. In the two-price system is used the balance deviation in the production balance and in the one-price system is used the balance deviation in the consumption balance. Figure 3.5 describes the model of two balances. (Fingrid 2011)

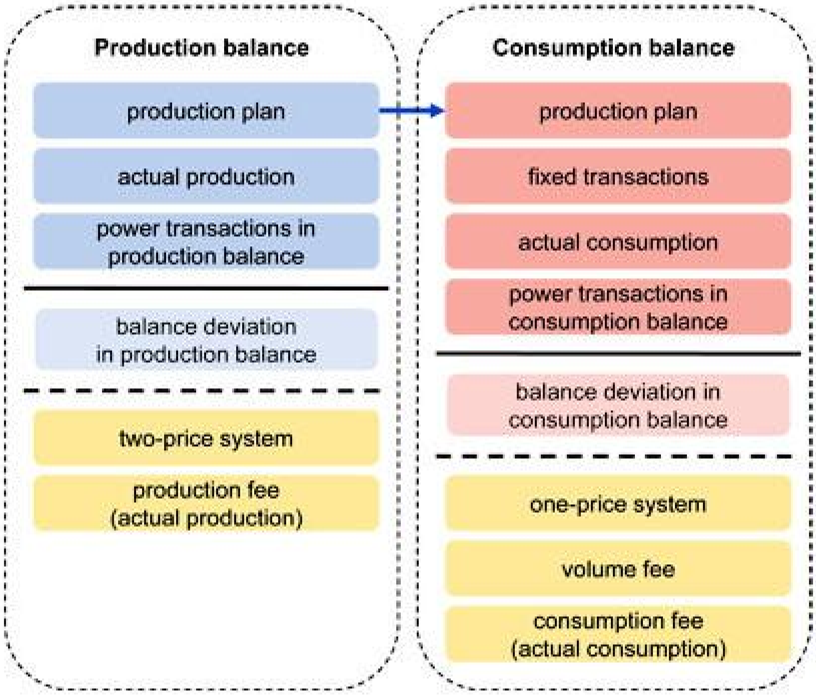

Figure 3.5. Model of two balances (Fingrid 2011).

The production balance is composed of a balance responsible party's total production plan and actual production covering the power plant generators with a nominal power of 1 MVA or higher. Generators under 1 MVA are included to be part of the consumption balance and are handled in the consumption balance so that they reduce the total consumption. (Fingrid 2011)

Production plans reported by a balance responsible party are summed up by Fingrid into the balance responsible party's total production plan. A balance deviation in the production balance arises if there is a difference between the actual production and the production plan. If the balance responsible party's actual production volume is smaller than the total production plan, there is a deficit in the production balance (negative imbalance), and the balance responsible party has to purchase imbalance power from Fingrid to cover the deficit. Correspondingly, if the balance responsible party's actual production volume is greater than the total production plan, there is a surplus in the production balance (positive imbalance), and the balance responsible party has to sell imbalance power to Fingrid in order to cover the surplus. Imbalance power in the production balance is not subject to a volume fee. (Fingrid 2011)

A balance responsible party's consumption balance is composed of the balance responsible party's total production plan, fixed transactions, and actual consumption. Consumption imbalance power is calculated as follows;

Balance deviation in consumption imbalance = Balance responsible party's total production plan + fixed deliveries + measured deliveries (actual consumption) + power transactions in consumption imbalance (3.1)

The balance deviation in the consumption balance arises if there is a difference between the actual consumption and electricity purchases (fixed transactions, production plan). When the balance responsible party's actual consumption is higher than the planned consumption, a deficit arises in the consumption balance (negative imbalance), and the balance responsible party has to purchase imbalance power from Fingrid in order to cover the deficit. Correspondingly, if the balance responsible party consumes less electricity than it has planned to consume, a surplus arises in the consumption balance (positive imbalance), and the balance responsible party has to sell imbalance power to Fingrid in order to cover the surplus. Imbalance power in the consumption balance is subject to a volume fee. (Fingrid 2011)

In the two-price system separate prices are calculated for the sales and purchases of imbalance power. In the production balance, the price of imbalance power sold by Fingrid to a balance responsible party is the up-regulating price of the existing hour. If up-regulation is not carried out or if the hour is defined as a down-regulating hour, the spot price is used as a sales price of imbalance power in the production balance. In the production balance, the price of imbalance power purchased by Fingrid from the balance responsible party is the down-regulating price of the hour. If no down-regulation is carried out or if the hour is defined as an up-regulating hour, the spot price is used as the purchase price of imbalance power in the production balance. (Fingrid 2011)

In the one-price system, the purchase and sale price of imbalance power are the same. During a down-regulating hour the price of imbalance power is the down-regulating price, and during an up-regulating hour the price of imbalance power is the up-regulating price. When no regulations are carried out during an hour, the price of imbalance power is the spot price. Figure 3.6 is illustrates the price forming of imbalance power in one- and two-price systems. (Fingrid 2011)

	2-price			1-price			
	Up-regulating hour	No regulations	Down-regulating hour	Up-regulating hour	No regulations	Down-regulating hour	
Up-regulating price	100	50	50	100	50	50	€/MWh
Spot price	50	50	50	50	50	50	"
Down-regulating price	50	50	20	50	50	20	"
Balance provider's purchase price for balance power	100	50	50	100	50	20	"
Balance provider's sales price for balance power	50	50	20	100	50	20	"

Figure 3.6. Price forming of imbalance power in one-price and two-price systems (Fingrid 2011)

3.2 Overview of different electricity markets

In the Europe goal has been to speed up electricity market liberalization and to promote the conditions of functional markets. The directive proposal for that was issued by the European Commission in the spring of 2001. The Nordic countries and UK have been forerunners in the liberalization of electricity market in Europe, and the others have followed their example.

This section introduces some liberalized electricity markets in order to give a general understanding on different markets models and those unique features. From the European electricity markets UK have been chosen under examination, because it was one of the early market openers. Outside the Europe has been introduced Australia and Ontario, which are also included to some of the first liberalized electricity markets. In addition, the Russian electricity markets have been chosen under examination since its recent liberalization and increasingly important role in Europe.

3.2.1 *UK*

Originally, before the privatization, England and Wales were classic electrical industries, vertically integrated and government owned monopoly. The UK was one of the leading markets in developing spot electricity market trading which links the physical and financial domains. The electricity market was opened to competition in generation and supply progressively over a ten year period. In 1998 markets were fully opened, and also the retail competition for the small consumers was introduced. The original competitive electricity markets included electricity Pool of England and Wales, but after a review new electricity trading arrangements were developed. Electricity industry and the Review of Electricity Trading Arrangements (RETA) evolved slowly into New Electricity Trading Arrangements for England and Wales (NETA) which provided new structure and rules for England and Wales's electricity markets. This was done because in a number of respects the operation of the Pool had not been satisfactory and had inhibited the full development of competition. (Bajpai & Singh 2004; Stephenson & Paun 2001)

In today electricity is sold and purchased in NETA, which is significantly different from earlier structure. Transmission and distribution remain regulated monopolies, but competition in generation and supply includes a wide range of new market players. Electricity transactions are made in the NETA market. The functioning of NETA is based around the System Operator (SO) and the power exchange. Power exchange provides electricity trading mechanisms similar to those in financial markets, but direct bilateral contracts between generators and suppliers are also important. In the power exchange market players can trade electricity up to one day ahead of the requirement for physical delivery. Standardized contracts, futures and forwards, can be traded also. Trades are made on half-hourly basis in the spot markets, which provides possibility for short-term adjustment of the contractual position of market players close with the time of physical delivery. Transactions include price and quantity combinations.

National Grid Company (NGC), the System Operator of England and Wales manages the high-voltage transmission system as TSO, supply operational services and is responsible for generation forecasting, congestion management and ancillary service management. In addition, the balancing mechanism is maintained by the SO. By balancing mechanism it maintains local and national balances between generation and consumption to ensure that supply meets demand. The price and volume agreements are made directly with the SO. NGC acts on both a physical and a financial level through the balancing mechanism, selecting bids and offers to increase or decrease the supply of electricity in order to achieve physical balance between generation and demand.

3.2.2 *Australia*

Australia has been one of the global forerunners in introducing competition into the electricity industry. Before 1991, the Australian electricity supply industry consisted of a series of state-based, government owned, mainly vertically integrated electricity authorities. State governments began restructure their electricity authorities in 1991. Progress of these reforms has varied across the different states. Victoria was the first state that introduced a wholesale electricity market, which opened the Victorian Power Exchange in 1994. In 1996 Transgrid began to operate the New South Wales wholesale electricity market. These two major markets were combined in 1998. As a result of this The National Electricity Market (NEM) began operating as a wholesale market for the supply of electricity for retailers and end-users in Queensland, New South Wales, the Australian Capital Territory, Victoria and South Australia in December 1998. Tasmania joined in the NEM in 2005, and operations today are based on five interconnected regions that largely follow state boundaries. (Abbot 2006; AEMO 2010)

In 1996, The National Electricity Code Administrator Limited (NECA) and the National Electricity Market Management Company Limited (NEMMCO) were formed. NECA got the responsibility to supervise and administrate industry code of conduct, and NEMMCO to manage the wholesale electricity markets. NEMMCO was responsible for the day to day management of the power system until 2009, when its operations were ceased, and its roles and responsibilities transitioned to the market and system operator of the National Electricity Market in Australia (AEMO). (Abbot 2006; AEMO 2010)

Exchange between electricity producers and consumers are made in the spot markets where the output from all generators is aggregated and instantaneously scheduled to meet demand through a centrally coordinated dispatch process. This is operated by the AEMO. The operating systems of NEM balance supply with demand, maintain reserve requirements, operate power system components, determine spot price and facilitate the financial settlement of physical market. (AEMO 2010)

In the markets scheduled generators can submit offers every five minutes of every day. Based on the offers submitted, AEMO's determine generators required to produce electricity based on the principle of meeting prevailing demand in most cost-efficient way. AEMO then dispatches these generators into production. A dispatch price is determined every five minutes, and six dispatch prices are averaged every half-hour to determine the spot price for each trading interval for each of the regions of the NEM. The spot prices are used as the basis for the settlement of financial transactions for all energy traded in the NEM. The maximum spot price is set to $12,500 per megawatt hour. This market price cap is the maximum price at which generators can bid into the market. The maximum spot price is automatically triggered when AEMO directs network service providers to interrupt customer supply in order to keep supply and demand in the system in balance. (AEMO 2010)

In addition to physical spot trading through the NEM, there is a separate financial trading market for electricity. There are numerous variations on the standard hedging contract available in the market, often containing complicated financial arrangements, for example one way option, cap and collar contracts. The contract for differences (CfD) can be used to hedge against high volatile spot prices. It is an agreement that the purchaser agrees to buy a specified physical quantity of energy from the spot market at a set price. If the actual price paid in the spot market by the purchaser is higher than the strike price, the counterparty of the contract pays to purchaser the difference in cost. Conversely, if the price paid is lower than the strike price, the purchaser pays to the counterparty the difference. (AEMO 2010)

To maintain the supply and demand in balance, it is important for AEMO's planning processes to be informed in advance of any limits on the capacity of generators to supply electricity or networks to transport electricity. This enables market participants to respond to potential supply shortfalls by increasing their generation. Market participants are able to signal upcoming limitations on supply by means of a variety of forecasting tools designed to improve the overall efficiency of the market. (AEMO 2010)

In Australia is used ex-post price setting. Electricity pricing is implemented via economic dispatch algorithm which selects the cheapest available resource, indicated by the offers submitted by market participants, to meet incremental changes in demand experienced by the power system. Generators and consumers can offer power on the balancing market for use by control area managers to balance energy shortfalls or surpluses on network at short notice. Companies wishing to offer balancing power must register with the relevant settlement agency. The settlement agency draw up daily merit order lists on the basis of the offers received, and forwards these, omitting price information to the control area manager concerned. The settlement agency determines settlement prices paid for the balancing power on the basis of the offers called off. (Zhang & Lo 2009)

Pre-dispatch is a short-term forecast of supply and demand in the market. It estimates the price and demand for upcoming trading day. Generators and network operators are required to notify AEMO of their maximum supply capacity and availability. According to this information and regional demand forecasts, all offers to supply are then collated so that potential shortfalls of supply against demand can be identified and published. Market participants can use this information as the basis for any re-bids of the capacity they wish to bring to the market. In the five-minute matching of supply and demand generators are scheduled and dispatched into production to match supply with prevailing demand every five minutes of every day. This process produces dynamic price signals that guide market participants as they bid to supply electricity to the market. (AEMO 2010)

3.2.3 *Ontario*

Canada is a federal state, comprised of ten provinces. Canadian electricity industry is primarily organized along provincial lines, which have significant differences. (Blake et. al, 2008) The Ontario electricity market has many interesting features. For instance, about 70% of generation capacity is held by one single entity Ontario Power Generation (OPG), and there exist various price and revenue caps for wholesale market participants as well as for retail customers. In addition, Ontario is a single-settlement real-time market, unlike the other four adjacent North American electricity markets New York, New England, Midwest, and PJM markets. (Zareipour & al. 2007; IESO 2011)

Until 1998, the Ontario electricity sector was dominated by Ontario Hydro, which was a state-owned company that integrated generation, transmission system planning, and rural and remote distribution functions. Ontario Hydro produced over 90 percent of the province's electricity and controlled the balance of supply through non-utility generation contracts. (Blake & al. 2008)

In the late 1990's Ontario Hydro suffered major costs and excessive debt. Rates rose by almost 40 percent between 1990 and 1995. As a result, the provincial government deconstructed the company's monopoly, and Ontario Hydro was separated into five separate companies in 1999. Fully competitive wholesale and retail market were opened in 2002, but shortly thereafter the provincial government came under considerable political pressure due to volatile electricity prices, and electricity price and distribution rate freezes were enacted in December 2002. These freezes have since been lifted, but some elements of price smoothing and subsidy still remains. (Blake & al. 2008)

The Independent Electricity System Operator (IESO) administers physical and financial markets. The IESO operates the real-time wholesale market and the market for ancillary services. Offers are submitted by generators for each hour of the day and every five minutes in the real-time markets. The IESO is responsible for balancing the demand for electricity with the offers from generators. It also calculates the market clearing price for that in five minute dispatch interval. (Blake & al. 2008; IESO 2011)

The IESO procures also ancillary services through contracts with registered market participants. Contracted ancillary services include regulation, voltage control service and black-start capability. Generation units which have automatic generation control capacity provide the regulation service. This allows the total system generation to match the total system load minute by minute. Voltage control services involve the control and maintenance of prescribed voltages at specific locations. Black-start capability involves generation facilities that can be started without an outside electrical supply. (Blake & al. 2008)

The IESO also operates an operating reserve (OR) markets. OR describes the capacity that remains in a stand-by status for the event inquiring the use of reserve power. The OR market was established to efficiently purchase OR from market participants and activate it, when it is needed to quickly restore the balance between supply and demand. Market participants can offer OR to the IESO at the same time that they bid or offer energy. The price of OR is set by the IESO every five minutes, based on the offers in the market. (Blake & al. 2008; IESO 2011)

3.2.4 *Russia*

The aim of the energy reform in Russia, pre-designed in the late nineties, was to attract massive investments into depressed power sector and create conditions for future development of the power industry. Russia took the traditional approach of splitting vertically integrated monopolies into specific business oriented companies. In the reform were created Territorial and Wholesale Generating Companies (TGCs and WGCs), the OJSC Rosenergoatom Concern, the JSC Rus Hydro, and the JSC Inter RAO in sector of generation. The state Federal Grid Company (FGC) got the responsibility from the grid operator's functions, which included eight regional subsidiaries supervising the national grid. The state-owned holding MRSK united eleven interregional sub-companies each of those in turn pools several local companies responsible for running of distribution networks in regions. The restructuring process was virtually completed by 2006 with allocation of sale assets of monopolies to tens of power sale companies. (Abdurafikov 2009; Viljainen & al. 2011)

The Russian electricity market is currently in stage, since the restructuring of the sector has been completed and former public vertically integrated monopolies have been unbundled and partly privatized. The government retained control of hydro generation, nuclear generation, network companies and the system operator (SO). The liberalization is done within two price zones, Europe and Siberia, which covers more than 90% of Russian electricity consumption. In the rest of Russia, e.g. the Far East and isolated areas like Kaliningrad, electricity is supplied at regulated rates. The share of electricity traded at free market prices have been progressively increased according to the liberalization schedule. (Abdurafikov 2009)

In Russia is used a nodal market prices, which base on the aggregation of bids according to detailed power system model of the Russian power grid, taking into account the physical locations of the facilities. As a result, over 7700 nodal market prices, which take into account costs of congestion and load losses in the grid, are calculated for Russian market area. The price level of electricity is rather low compared to other Europe. On the other hand, wholesale market buyers have to pay for capacity availability. The increased share of electricity traded at free prices will increase the need to hedge against price risks, and therefore also the financial markets are applied. (Abdurafikov 2009; Viljainen & al. 2011)

Wholesale market model in Russia consists of regulated contracts, day-ahead markets, balancing markets, markets of derivatives, and a market of ancillary services. Furthermore, the market of Financial Transmission Rights (FTR) is on the reform list. The ATS, commercial operator is responsible for the day-ahead market and SO (the System Operator) organizes balancing trade of energy and conducts annual competitive selection of generators in the market of ancillary services. The Moscow Energy Exchange supervises the markets of derivatives. The capacity and energy under the regulated contracts have been reduced in the last years, and the complete liberalization of the wholesale market was reached by 2011. (Viljainen & al. 2011)

In the day-ahead markets of Russia the nodal price formation is used. It reflects the actual situation in the grid and represents adequate price signals for allocation of investments. This approach fits in terms of constrained transmission capacity and different cost of generation in the regions of Russia. In the day-ahead market producers submit to SO the data about their production on the next day and maximal price of production. Based on this data and the forecasts of demand, the SO selects the generators to produce and transfers the data to ATS that receives the price offers from the market participants in regards to planned consumption and generation. The ATS also organizes the marginal auction of offers and defines the amounts and prices of energy at each nodes of the system. The Federal Antimonopoly Service observes the day-ahead market for the purpose of market power detection. (Abdurafikov 2009; Viljainen & al. 2011)

The data from scheduled production and consumption are traded in the balancing market. The SO runs the market organizing competitive auctions of offers from generators and consumers with regulated load eight times per one trading day. As a result of this, prices and amounts of planned deviations at nodes are defined. In case that the actual consumption exceeds scheduled on the day-ahead market, there is a need to produce the corresponding amount of electricity to balance the system. The balancing effect is not reached only by way of additional generation but also through reduction of consumption, which typically represent large scale industrial enterprises able to respond on the SO's commands. One hour prior to the delivery, the SO chooses the nodal volumes included in hourly dispatching volumes (i.e. volumes balancing forecasted consumption in the following hour). In the market clearing is used computational model which determines dispatching volumes in every node, corresponding price indicators and prices for system balancing upwards or downwards. The ATS collects meter readings, information from the SO regarding deviations at external initiative and calculates volumes of deviations at own initiative for the financial results of the balancing market. If imbalance exists, then it is distributed among the agents in a way that creates additional incentives to execute external commands. (Abdurafikov 2009)

In the Russian markets also forward and future-contracts are used. Forwards for energy are financial, and all energy under the contracts is sold and purchased in the spot-market. The counterparties can set the energy prices and amounts in contracts freely. At the moment over-the-counter (OTC) and exchange contacts are used. The reference price under the OTC contract is defined at one of the counterparties' locations, and the reference price under an exchange contract is the average price of hundreds of nodes within the given part of the energy system (hub). The market of energy futures were opened in June 2010 by the Exchange. The underlying assets under the contracts are monthly average hub prices. The futures are traded until the last day of the delivery period and due date the final settlement takes place. (Abdurafikov 2009; Viljainen et al. 2011)

The main aim of the developed capacity market in Russia is to recover fixed costs of generators and encourage their investments in new capacities. Producers make offers to the market, and buyers have to purchase the amount of capacity that corresponds to their peak consumption. The SO runs the market organizing auctions of producers' offers and selecting capacities for the period of four years. Price caps are applied during these auctions. For example, the price cap for year 2011 was approximately 3000 €/MW per month. (Abdurafikov 2009; Viljainen & al. 2011)

Energy and capacity is supplied at the retail markets for end-users by suppliers of last resort (SLR) and independent sale companies (ISC). SLRs operate in certain territories only whereas ISCs can supply end-users in different areas of the market. Typically, SLRs supply small and medium end-users and charges the average monthly prices of procurements in the wholesale market added with regulated markup 2-3%. ISCs in turn, basically implement supply of big consumers, which are equipped with hourly consumption metering devices. Prices under the contracts with ISCs are set freely and usually follow spot and balancing market prices in the wholesale markets plus agreed markup of the supplier. Escape of small and medium end-users from their SLRs is rare since the absence of technical opportunity to start switching procedure. SLRs are local monopolies, which continue to supply absolute majority of the retail end-users. The price forming mechanism of SLRs does not allow demand response.

3.3 Impact of market environment on retail business

Electricity sectors almost everywhere evolved with vertically integrated monopolies which were typically state-owned. The primary components of electricity supply, generation, transmission, distribution, and retail supply were integrated within individual electric utilities. The efficiency of these monopolies was typically fairly poor, which in many case lead to high operating costs and high retail prices stimulating the pressures for changes that would reduce electricity prices. The resulting electricity market reforms have made major institutional arrangements for the electricity sector. The way how these reforms have been realized in different places have dictated the existing market environment and its unique features. The market environment in turn defines retailers' possibilities to hedge, trade and operate in the power markets. Consequently, the existing market environment has high impact on the whole retail business and principles used for retailer profit optimization.

This section concludes important features of different markets models from the view point of electricity retail business. Different market models and those characteristic features are compared in order to highlight the central elements, on which have impacts on retailers' business. In particular, the features of different pricing and balancing mechanisms, and those impacts on the retail business and a retailer's ability to operate profitable in the markets, are under special interest.

3.3.1 *Market model*

The electricity market reform includes typically restructuring, regulatory reform, wholesale and retail market design and deregulation of competitive wholesale and retail segments. The most successful reform programs have followed the "textbook model" which strives to privatization of state-owned enterprises, vertical and horizontal restructuring to facilitate competition, performance based regulation applied to the regulated transmission and distribution segments, good wholesale market designs that facilitate efficient competition among existing generators, competitive entry of new generators and retail competition. (Joskow 2008) England and Wales for example have followed this model, which lead to significant improvements of performance, even though some significant problems appeared in the first stages of the reform. In addition, many other countries, such as the Nordic countries, Ontario and Australia have applied many key components from the "text book market model" design.

The functionality of the wholesale markets has a direct impact on the retail business. Problems in the wholesale markets, such as high price volatility, may significantly increase risks in the retail business. The experiences from different wholesale markets show that some basic components are needed for well-functioning wholesale markets. These basic components include voluntary transparent organized spot markets for energy and ancillary services (day-ahead and real-time balancing) including self-scheduling of generation and locational pricing of energy reflecting the marginal cost of congestion and losses. In addition, the integration of spot markets for energy with efficient allocation of transmission capacity is needed. The markets without transparent locational pricing can work reasonably well, but those seem to be more likely to run into problems. (Joskow 2008)

3.3.2 *Electricity pricing mechanism*

Electricity price, and particularly its volatility, in the wholesale markets are central factors to be considered in the planning of retail business and retailer profit optimization. Variations in electricity prices and retailers' needs to hedge against these depends significantly on the existing transmission network (available transmission capacity), production structure (marginal cost of generation) and on the prevailing situation in the power system respect to the demand and supply of electricity (cost of generation). However, in the end, the applied pricing model determines the forming of market prices having a great influence on existing market environment and market players' business.

Marginal pricing is a commonly applied pricing principle in electricity markets. In the marginal pricing model the price formation is done based on the merit order of generation so that the production with lowest marginal cost is brought online first, and the production with highest cost last, determining the price of electricity.

Pay-as-bid is another well-known pricing principle. In the pay-as-bid mechanism generators are assumed to bid electricity to markets according to their marginal costs, based on which the merit order list is formed. In this mechanism the generators are paid according to their bid prices and no common market price is formed, but the price for consumption is determined as a weighted average of all generation bids. (Viljainen & al. 2011)

The applied pricing principle and its functionality have significant impacts on the final market prices. If the price formation functions properly, there is typically no major difference from the view point of functionality of wholesale and retail markets what pricing model has been applied. However, the characteristics of the used pricing model often affects electricity prices and markets indirectly, for instance through the market players' way to operate in the markets. For example, the markets players' possibilities to abuse market model or market power so that the regulatory cannot prevent it can vary between different models. The possibility to use market power in turn can lead to higher electricity prices than based on the marginal costs of the production can be expected.

In the pay-as-bid model one problem for the producers is that they cannot forecast the bids of other producers. This arise uncertainty from the form of merit order list, and the producers may try to protect themselves by adding a certain risk margin to their bids, which increases the average prices in the markets. Another problem related to pay-as-bid model is that generators may start to guess highest bid, and raise their bids accordingly to ensure that they will also get the highest price paid. (Viljainen & al. 2011) Above-discussed problems may be easier to avoid in the marginal pricing, however, also in this model can appear problems related to the price forming. For example, in some markets have been doubts that some producers are trying to increase market prices by offering their production capacity only limitedly to the markets at the times of high demand hours in order to raise the prices.

Above-mentioned examples illustrate the possible impacts of used pricing mechanism on retail business (through the market prices). However, it should be noticed that the problems related to the price forming in the markets result in typically rather from the abuse of market power, or some other corresponding reason, than directly from the used pricing mechanism.

3.3.3 *Locational pricing*

Electricity transmission network provides a market place for electricity and it has an essential role in the designing of the whole market model, including its vital role in the pricing of electricity. If electricity can be transmitted according to markets needs from production surplus area to deficit area, the transmission system can be regarded as functioning market place for electricity trade. On the other hand, if transmission congestions limit significantly the power flows in desired direction, tools to control power system congestions are needed. In the first case the *zonal pricing* is typically applied, and in the latter case the *nodal pricing* is natural selection. (Viljainen & al. 2011)

In general, the nodal pricing system can be regarded as a tool to manage transmission congestions and to optimize the use of power system. Thus, the nodal pricing is practically the only reasonable alternative in the areas where exists significant transmission constrains (e.g. Russia and Australia), and there are no plans to make sufficient investments on transmission capacity. Other significant market areas where nodal pricing is applied are for example PJM (Pennsylvania-New Jersey), Texas, and areas in the USA and New Zealand.

The zonal pricing (area pricing) model can be applied if available transmission capacity is adequate, borders of the price areas follows physical limits of the networks, and sufficient amount of competing generators exists in the area. The zonal pricing is generally used model in the European electricity markets (e.g. Central Europe and Nordic countries). The model aims to determine a uniform market price for the whole market area. If the congestions of the transmission networks prevent this, the market area is divided into separate price-areas (zones), on which each have its own price. The market area is divided based on the known congestions on separate areas, in which the intra-zonal congestions are rare. In many cases the main problem of this model is the formation of uncongested price areas. For example, in Europe price areas have been mainly formed so that the borders of the price areas follows national borders, but also smaller price areas exist.

When nodal pricing model is used electricity prices are determined separately for every node of the network. The amount of nodes can be significantly high, for example in Russia exist almost 8000 nodes. The price of electricity consists of the energy component, transmission congestion fees and losses. Typically one node is relatively small part of the market area with few producers, which increases market players' possibilities to abuse market power. Thus, in the nodal pricing model generators are supervised strictly and price caps have been set to cut peak prices.

A major risk in the nodal pricing relates to price differences between nodes. Market parties can hedge against this risk by using transmission hedge products such as Financial Transmission Rights (FTRs). Price control using price caps limits the price peaks, but is questionable from the view point of deregulated markets. Price peaks are important signals indicating needs for new investments on transmission capacity and necessary part of generator's incomes that quarantine new generation investments. Thus, to ensure investments on capacity markets with relatively low price caps, such as Russia, separate capacity markets have been created. However, for example in Australia, existing price caps are significantly higher and separate capacity markets do not exist. From the perspective of electricity retailer, high volatility of electricity prices combined with high price caps means high risks, and proper risk management is vital. On the other hand, low price caps decreases retailers' market price risk, but limits also profit-making opportunities.

One of the main differences between zonal and nodal pricing models is in the price calculation. In the nodal pricing model the transmission system operator is responsible for price calculation in addition to operation of transmission network. In the zonal pricing model in turn, the transmission system operator is responsible for the information about available transmission capacity, but price calculation is made by the power exchange based on the bids of the market parties.

Both nodal and zonal pricing models have proved their adequacy as a base for functional electricity markets. However, the used pricing model has impact on market prices, and consequently, also on the retail business. In systems where nodal pricing is in use bottlenecks are common. This leads easily into a situation where power has to be generated locally and the wholesale prices are determined also locally, exposing market players to local price differences. The hedging against these local price differences may be challenging and complicate retailers' operation in some parts of the market area. In practice, if a retailer cannot efficiently hedge against some local price differences, it may cause a situation, in which the retailer's opportunities to operate profitably in some part of the market area suffers.

In the areas where zonal pricing is applied, the transmission system has to be able to provide adequate transmission capacity so that price differences between different areas can be equalized. However, if transmission capacity is not adequate to meet the demand for power transmission, the price differences cannot be evened, and a single price area cannot be formed. Likely than in nodal pricing, if there is significant price differences between different market areas, against which cannot be efficiently hedged, the retailer has higher risks in some market areas than in the others. Consequently, it may be more challenging to operate profitably in certain market areas than in the others.

From the point of view of electricity retailer profit optimization, one of the most important differences between zonal and nodal pricing is the volatility of electricity prices in different market areas. The importance of load and consumption forecasting is high in both pricing models, however, particular importance it has in the nodal pricing. In the areas of charge transmission capacity even a rather small variation in electricity consumption from the forecasted can cause high variation in electricity price, and expose retailers and other market players to high price risk. In the areas of zonal pricing, market price is typically the same in a larger geographical area than in nodal pricing. Thus, a small variation in electricity demand or consumption does not have so significant impact on electricity price, and the retailer has lower price risk. Still, the impacts of transmission constraints on electricity price are alike in both models and depend highly on the existing transmission network.

3.3.4 *Balancing system*

Electricity production has to match with the consumption every moment in the power system so that the system stability will not be jeopardized. At present, electricity storage costs are still high, and thus, the applications based on energy storages for balancing variation between the consumption and production are rare in the power systems. In order to evaluate the need for increase or decrease of consumption and/or production, electricity consumption and production forecasting is required. However, these forecasts include always some uncertainty, and the actual consumption and/or production can differ significantly from the forecasts. This results need for the balancing system which maintains the balance between consumption and production in the power system. Balancing system is maintained by the SO.

The final market-clearing prices are set based on the operation principles and regulations of the balancing mechanism and balancing power markets. Market clearing prices can be set in advance (ex-ante) or afterwards (ex-post). For example, in Scandinavia, England and Wales is used ex-ante price setting, and in Australia ex-post market-clearing prices. When the market clearing price is set ex-post, the price is set based on real, measured data. When the market clearing price is set ex-ante, a balance service is required. (Ackermann & al. 2000)

In the systems where nodal pricing is used, ex-post price setting is generally applied and balancing system is based on a dispatching mechanism (i.e. Australia and Russia). The information about available production capacity and forecasts on future consumption has a vital role in these balancing systems, because even relatively small changes in consumption can result in considerable variation on electricity prices in constrained areas. Based on the collected data the SO estimates the potential shortfalls or surpluses of production and re-dispatches the generation. After the final matching of supply and demand the final market clearing is done. In the market clearing is used computational model, which determines dispatching volumes in every node, corresponding price indicators, and prices for system balancing upwards or downwards. The final market clearing prices are calculated based on the actual, measured data.

Electricity markets using zonal pricing (i.e. in Nordic countries) include typically significantly different balancing mechanism than markets with nodal pricing. The balancing mechanism in zonal pricing systems is maintained by the local SO and based on the balancing power markets, in which the market players can set bids for the increase or decrease of supply of electricity. The SO determines the needed balancing power capacity and accordingly accepts market players' bids in order to maintain the power balance. The price of the balancing power is determined based on these bids.

In the Nordic markets for example, each market player is responsible for keeping its own power balance between electricity procurements and sales. If a market player cannot do that it has to pay "penalties" (balancing power fees). Thus, from the perspective of the market players such as retailers, it is important that the market model allows adjustments of electricity procurements close with the time of physical delivery so that each market player can maintain its power balance and avoid extra costs caused by the imbalance power. Moreover, compete imbalance settlement procedure has an important role from the view point of the whole market operation.

Actual electricity consumption and production can be typically forecasted relatively reliably if there are no such events or other factors which cause unexpected variation in electricity consumption/production. If variation in electricity consumption is rather low, also electricity prices can be forecasted more reliability. However, if there is high variations in electricity consumption and/or production, which are typically rather challenging or even impossible to forecast, significant price variations can emerge. Consequently, the features and functionality of balancing system (and the whole power system) has high impact on electricity prices and market players business.

In general, the consumption forecasting has an important role in all balancing and power systems. However, particularly important role it has in the constrained networks where the nodal pricing is used. In the nodal pricing systems the ability to forecast future consumption and production reliably is thus vital in order to avoid problems in the maintaining of balance between consumption and production, and to avoid the resulting price peaks. However, it should be noted that these price peaks also provides important signals for the markets indicating network and capacity reinforcement needs. In addition, price peaks gives high incentives for market parties to keep their power balances between electricity production/procurements and consumption/sales within permissible limits. On the other hand, price peaks causes high risk for the market players, and in the worst case, may threat the viability of business.

Two different balancing systems were presented, and both have been found to be functional solutions in practice. The basic principles are much alike, but also many differences exist. In practice, it is difficult to find one balancing mechanism that fits all market structures within different systems. Each restructuring market has to choose a different model based on their particular characteristics of the power system. In addition, the development of operational and market environment should be taken into account in the development of balancing system, as well as in the development of market models and market regulations.

The increasing amount of distributed generation, consisted mainly of intermittently renewable energy resources such as wind and solar power, creates new challenges for SOs and the market players' power balance management. On the other hand, the improving opportunities to control customers' loads, generation and energy storages can provide new tools for the maintaining and management of power balances. From the perspective of the electricity retailer, these tools can also offer great opportunities for more flexible operation and management of electricity procurements and sales, and open new possibilities to enhance profit optimization.

4 ELECTRICITY RETAILER PROFIT OPTIMIZATION

Electricity retailer's objective is to maximize its expected profits. A retailer's possibilities for profit optimization depend highly on the existing market and operational environment since these determine possibilities to hedge, trade and operate in the market. Consequently, pertinent features of the market and operational environment have to be analyzed before profit optimization strategies can be developed accordingly.

The main aim of this chapter is to introduce basic methodology for electricity retailer profit optimization in different operational environments. The main focus is in the short-term profit optimization in the Nordic Electricity markets. This includes trades in the Elspot and Elbas markets and possible trading of imbalance power for the purpose of maintaining the power balance. In addition, the possibility to utilize controllable DER as part of retailer short-term profit optimization has been considered in the context of smart grid environment.

This chapter presents first a short literature review from different approaches used to address electricity retailer profit optimization problem. The literature review and preceding descriptions from different market and operational environments provides a basis for the theoretical analysis, based on which the basic methodology for retailer short-term profit optimization will be developed and introduced. Even though the methodology is developed for Nordic markets, the same basic principles are valid in many respects also in other same type of markets.

4.1 Short literature review

In the literature, studies examining profit optimization of electricity trader/retailer focus typically on long-term or mid-term electricity procurement planning and portfolio optimization, evaluation of optimal bidding strategy, and determination of risk premium and electricity sales price. In addition, the studies related on demand response and utilization of controllable DER can provide important information for the development of retailer's profit optimization in the smart grid environment. The following literature review is categorized based on the used profit optimization approaches.

4.1.1 *Mid-term and long-term electricity procurement planning and portfolio optimization*

- (Xu & al. 2006) presents a mid-term power portfolio optimization problem with risk assessment. Key instruments are considered, risk terms based on semi-variances of spot market transactions are introduced, and penalties on load obligation violations are added to the objective function. In addition, numerical testing results of proposed model are presented.

- (Zare & al. 2011) address the electricity procurement problem of large consumers using the concept of information gap decision theory. In this approach, the uncertainty of the pool price and the expected cost of electricity procurements are modeled by using information gap decision theory-based uncertainty models. It is proposed, that this method can be used as a tool to assess the risk levels and consider whether a large customer is risk-taking or risk-averse regarding its mid-term procurement strategies.

- (Hatami & al. 2011) introduces a stochastic-based decision-making framework that retailers can use to determine the sales price of electricity for the customers based on time-of-use rates, and to manage a portfolio of different contracts in order to procure its demand and to hedge against risks, within a medium period. The CVaR methodology is used to measure the risks in this framework.

- (Carrion & al. 2009) presents a bi-level programming approach to solve the mid-term decision making problem faced by a power retailer. The aim is to maximize expected profits of the retailer with a specified level of risk that is modeled by using CVaR. This model can be used to decide the optimal level of involvement in the futures market in the pool, and to determine optimal sales prices for clients. Client response to retail price and competition among rival retailers are considered in the proposed model.

4.1.2 *Determination of optimal risk premium and electricity sale price*

- (Hatami & al. 2009) proposes a mathematical method based on mixed-integer stochastic programming to determine the optimal sale price of electricity to customers and the electricity procurement policy of a retailer for a specified period. The objective to maximize retailer's profits and minimize the risks is accomplished by determining optimal amount of power procured from each option (spot-markets, forward contracts, call options, self-production) and the sales price to customers. The impact of the competition between the retailers is applied in the model by adding market share function. Spot market price and retailer load are treated as mixed-integer stochastic programming, and the CVaR is used for risk modeling.

- (Bartelj & al. 2009) presents a model for evaluating sales contract maturity risk and a methodology for its use. The paper proposes a Fundamental Retail Market Model (FRMM) and a methodology based on Monte Carlo simulation to use it for risk analysis. The risk exposure is expressed by using the CVaR, and based on it the risk premiums for sales contracts are determined.

- (Bartelj & al. 2010) analyzes the influence of the stochastic parameters on the retailer's overall risk exposure. The influence of the wholesale forward price volatility in the combination with the maturity of the sales contract offer on the retailer's risk exposure is investigated. Retailer's risk exposure is expressed by using CVaR, based on which a risk premium that covers the risk resulting from the maturity of sales contract offer is determined.

- (Prokopczuk & al. 2007) provides a framework to quantify risks related to wholesale electricity contracts by using the RAROC methodology. The RAROC framework and the model for risk-adjusted performance measures in energy markets are introduced, and the risk premiums for full load contracts based on market risk, volume risk and correlation between these risk factors are determined. Also an empirical study on wholesale contracts for industry customers and public utility companies of a German energy provider is conducted.

4.1.3 *Optimal bidding strategies*

- (Hajati & al. 2011) presents a method for optimal retailer bidding in a day-ahead market considering risk and demand of electricity. In the proposed model retailer's demand curve is formed in both day-ahead and short-term balance regulating markets, with the aim of maximizing expected profits. The risk that retailer faces because of demand deviation is taken into consideration by adding penalty term on profit optimization function.

- (Fleten & Pettersen 2005) introduces stochastic linear programming model for constructing bidding curves for a price-taking retailer in the Norwegian electricity market and illustrates it by using a case study. The objective of the model is to minimize the expected cost of purchasing power from the day-ahead energy market and short-term balancing market. The study proposes that the retailer’s profit risk can be considered by modeling risk by using shortfall costs and adding penalty term for volume deviation in the objective function.

4.1.4 *DR, control of DER and other related topics*

- (Dahlgren & al. 2003) provides a summary of risk assessment in energy trading. This study provides a critical literature survey of what techniques has been applied in the power markets.

- (Pedrasa & al. 2011) proposes a decision support tool that aim to optimize the provision of residential energy services. The scheduling algorithm aims to determine, how distributed energy resources available to the end-users and under their control should be operated, so that the net benefit of energy services is maximized based on the energy service models and their technical characteristics and capabilities. In addition, a case study is presented, in which decision-support tool is used to optimize the provision of desired energy services in a smart home that includes a number of controllable loads, energy storage and photovoltaic generation.

- (Faria & Vale 2011) presents a demand response simulator (Demsi) that allows studying response actions and schemes in distribution networks. The use of Demsi by a retailer in energy shortage situation is presented. The load reduction is obtained by using a consumer based price elasticity approach supported by a real-time pricing. Retailer’s profits are maximized by using non-linear programming, determining the optimal solution for each envisaged load reduction.

- (Yousefi & al. 2011) presents a comprehensive demand response model for the purpose of representing customer response to time-based and incentive-based demand response programs. This model helps Retail Energy Provider (REP) agent in an agent-based retail environment to offer day-ahead real-time prices to its customers. Real-time prices are determined through an economically optimized manner represented by REP agent’s learning capability based on the principles of Q-learning method. In addition, numerical studies are presented to investigate the performance of the proposed model based on New-England day-ahead market’s data.

- (Pousinho & al. 2011) proposes a stochastic programming approach for trading wind energy in a market environment under uncertainty. Uncertain parameters are modeled by scenarios, where each scenario presents a plausible realization of the uncertain parameters with an associated occurrence probability. CVaR is used to measure the risk.

- (Coslovich & al. 2008) examine an opportunity that electricity traders can use load shifts to increase their profit margins, and in general, to set and validate their sales prices. Furthermore, the numerical experiments, and the results obtained by applying the model to a real world data set are illustrated.

4.1.5 *Summary on literature review*

In the literature, many different approaches are used to model and address electricity retailer profit optimization problem. In most approaches the consideration of uncertainties related to electricity price and consumption has a central role. Typical way to consider these uncertainties in the retail business is to evaluate electricity price and volume risk with some applicable method. These risk evaluations in turn provide a basis for further analyses and examinations, which can include, for instance, determination of optimal electricity procurement strategy, risk premium or electricity sales price.

Among the examined studies, CVaR was the most commonly used risk evaluation method. It is generally agreed that the greatest risks faced by the retailer in the power markets includes price risk and volume risk. However, risks, and those impacts on the retailer's profitability depend highly on the existing operational and market environment, even though this have not been considered adequately in most studies.

In general, many different approaches and techniques can be found for the modeling of electricity retailer profit optimization problem. Typically, these concentrate on long-term and mid-term electricity procurement planning and determination of optimal sales price. However, only few studies consider the possibility of improving retailer's profitability in short-term markets by utilizing controllable DER and DR. Thus, the approach used in this study contributes to the literature by considering the impacts of different operational environments and the possibilities of utilizing DER and DR.

4.2 Introduction to electricity retailer profit optimization problem

The aim of electricity retailer is to maximize expected profits in a specific time interval. The retailer's profits at the time interval t = 0…T are the difference between market revenues and operation costs, and can be expressed by equation

$$Max \int_0^T Profits(t)dt = Max \int_0^T (Revenue(t) - Costs(t))dt. \quad (4.1)$$

Electricity retailer's revenue in the power markets depends on the amount and price of sold and purchased electricity. Thus, the maximum profits at the time interval 0…T are

$$Max \int_0^T Profits(t)dt = Max \int_0^T \left(\rho_{sell}(t) * E_{sell}(t) - \rho_{buy}(t) * E_{buy}(t)\right) dt \quad (4.2)$$

ρ_{sell} – Price of sold electricity (€/MWh)
E_{sell} – Electricity sold in the retail markets (MWh)
ρ_{buy} – Price of purchased electricity (€/MWh)
E_{buy} – Electricity purchased in the wholesale markets (MWh)

In a general level, electricity retailer profit optimization can be divided in two main categories;

1. Minimization of electricity procurement costs
2. Maximization of sales incomes

Retailer's possibilities to maximize sales incomes are relatively limited when electricity is sold by using spot pricing or fixed pricing. The determination of optimal electricity sales price and promotion of electricity sales are typically the methods that can be used for the sales income optimization.

Numerous studies (Bjorgan & al. 1999; Gabriel & al. 2006; Hatami & al. 2009) introduce methods for contract portfolio and electricity sales price optimization. The main idea of electricity sales price optimization is to determine optimal sales price so that the demand and revenues are in the best possible balance. If electricity price is too high, the demand decreases, and if price is too low, the profit margin decreases. However, optimal contract portfolio and electricity sales price optimization are outside the scope of this study, and are not discussed more detailed in this report.

The minimization of electricity procurement costs in the short-term markets, in turn, can be further divided in two main tasks;

1. Long-term planning, which includes securing of electricity purchase price in advance. This can be done for example by using financial products such as futures and forwards, or by making bilateral contracts on fixed physical deliveries.

2. Short-term planning, which includes management and fulfilling of retailer's open position. This can be done by making trades in short-term markets, or if possible, also by utilizing controllable DER.

Figure 4.1 illustrates the elements of electricity retailer profit optimization.

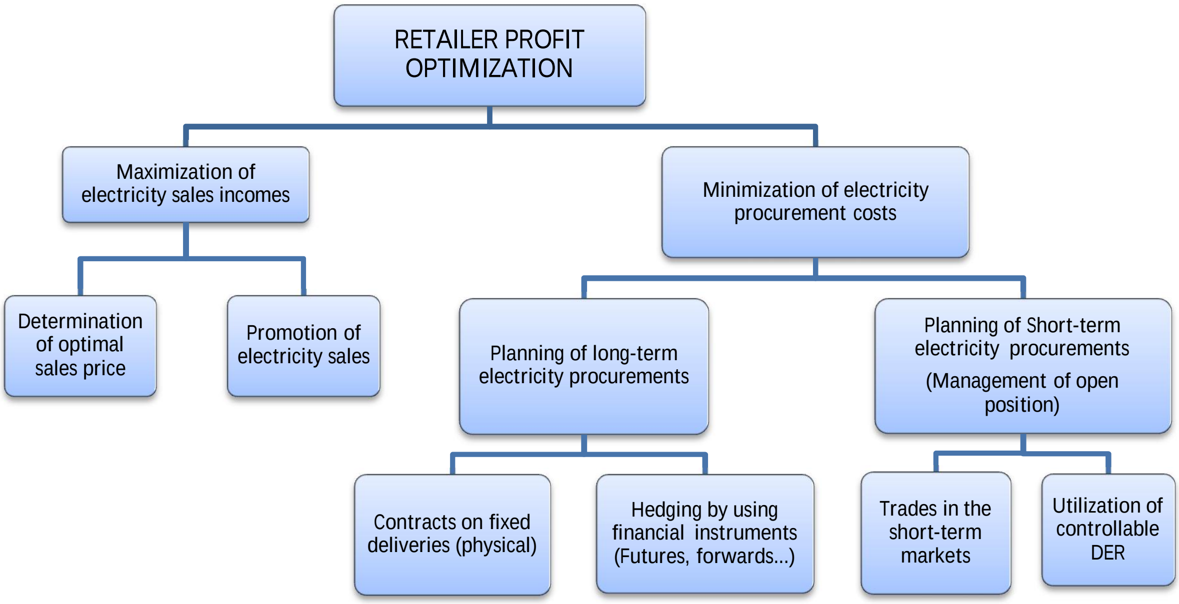

Figure 4.1 Elements of electricity retailer profit optimization.

In practice, the long-term electricity procurement planning plays an important role in the retail business. However, in this report the main focus area is short-term profit optimization including trades in the spot and balancing power markets, and the possible utilization of controllable DER.

4.2.1 *A basic short-term profit optimization problem*

A basic problem behind retailers' electricity procurement planning is the uncertainty related on future consumption. Thus, in a short-term electricity retailers have need to make physical electricity procurements in the spot markets in order to adjust their electricity procurements close to the actual demand. However, the actual electricity demand is not known precisely in advance, and thus, there is almost always some difference between electricity procurements/production and consumption/sales. This difference forms the retailer's power imbalance, and it has to be neutralized by the means of imbalance power.

The cost of imbalance power depends on price of balancing power (imbalance power), purchased amount of imbalance power (determined in imbalance settlement process), and balance service payments. The pricing principles of imbalance power are determined so that the higher the retailer's imbalance is, the higher costs the retailer will typically face. In other words, in order to minimize electricity procurement costs in a short-term, the retailer should avoid trading of extra imbalance power. However, in case of consumption imbalance power there are some exceptions on this, but these are discussed more detailed later in this report. Moreover, the closer to the moment of delivery electricity procurements are made, the higher the retailer's risk related to the variation of electricity prices is, because the possibilities to hedge against price variation weakens when the delivery hour approaches.

4.2.2 *Short-term profit optimization problem in the smart grid environment*

According to the basic hypothesis of this study the future smart grid environment includes significant amount of controllable DER such as customer loads, distributed generation and energy storages, which market-based utilization is possible for different electricity market parties. Furthermore, this includes the assumption that market models and general operational principles will be developed and updated so that those will not limit significantly cost-efficient utilization of DER. Based on the preceding, it can be assumed that in the future smart grid environment electricity retailers can utilize controllable DER in the management of their open positions. This can be done also close to the moment of delivery, which in particular can help retailers' to enhance their short-term profit optimization. Figure 4.3 illustrates the elements, on which electricity retailer's short-term electricity procurement costs forms in the smart grid environment.

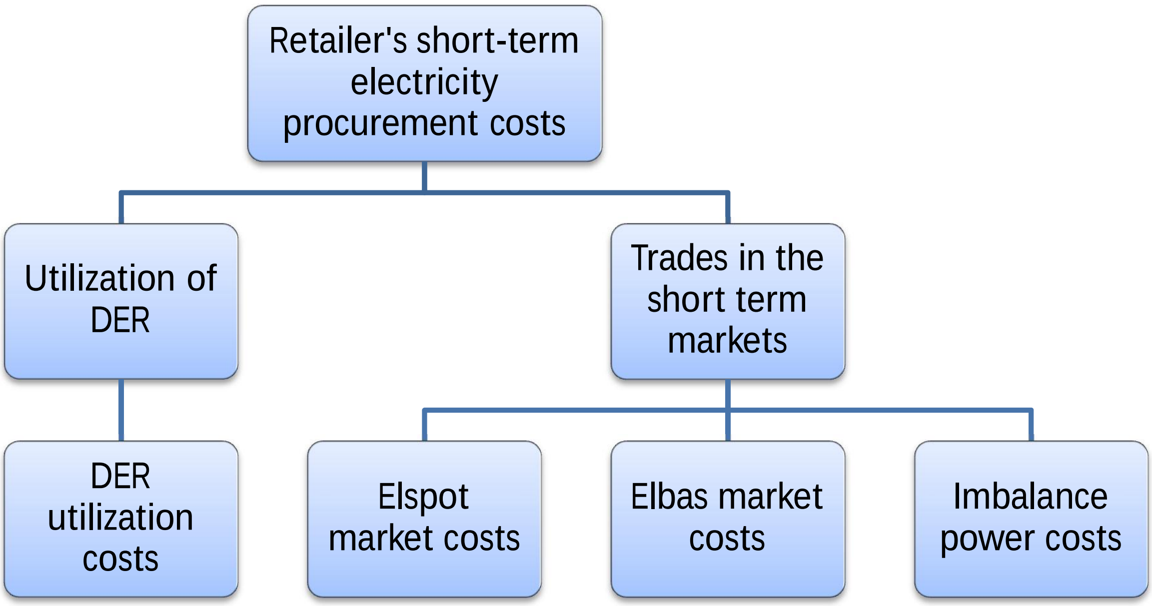

Figure 4.3. The elements, on which electricity retailer's electricity procurement costs forms in a smart grid environment.

When the retailer's short-term electricity procurement costs are consisted of trades in the Elspot, Elbas, and balancing power markets and utilization of DER, as illustrated in the Figure 4.3, the maximum profits at the time interval 0…T can be expressed mathematically by Equation 4.3.

$$Max \int_0^T \left(\begin{array}{c} \rho_{sell}(t) * E_{sell}(t) - \rho_{spot}(t) * E_{spot}(t) - \rho_{elbas}(t) * E_{elbas}(t) - \\ \rho_{reg}(t) * E_{reg}(t) - \rho_{DER}(t) * E_{DER}(t) \end{array} \right) dt \qquad (4.3)$$

ρ_{spot} – Electricity price in the Elspot market (€/MWh)
ρ_{elbas} – Electricity price in the Elbas market (€/MWh)
ρ_{reg} – Price of imbalance power including balance power fees (€/MWh)
ρ_{DER} – DER utilization cost (€/MWh)

E_{spot}	– Energy purchased in the Elspot markets (MWh)
E_{elbas}	– Energy purchased in the Elbas markets (MWh)
E_{reg}	– Imbalance power trades (MWh)
E_{DER}	– The amount of energy controlled by using DER (MWh)

However, it should be noticed that equation 4.3 describes a simplified case, in which the retailer's possible own generation (<1 MW) is not taken into account in the profit optimization formulation.

4.3 Profit optimization in the current and near future's operational environment

The current operational and market environment determines retailer's ability to manage electricity procurements by trading in short-term markets and utilizing controllable DER. Therefore, profit optimization should be also developed based on the features of the current market and operational environments.

It is assumed that in the smart grid environment, a retailer can manage electricity procurements by utilizing controllable DER, and thus adjust electricity procurements more flexible prior to the delivery hour. In today's operational environment in turn, a retailer do not typically have ability to adjust electricity procurements by utilizing controllable loads, production, or other distributed energy resources. This limits retailers' possibilities to manage their electricity procurements in short-term markets, and typically, only the trades in the Elspot and Elbas markets can be used for this purpose. Consequently, in the current operational environment, retailers' short-term electricity procurement costs can be regarded to be consisted of Elspot, Elbas, and imbalance power costs.

4.3.1 *Impact of retail pricing*

In addition to existing market and operational environments, the model used for the electricity sales pricing has considerable impact on the retailer's risks. The most commonly used models for electricity retail sales pricing in can be roughly divided to following two categories;

1. **Fixed rates:**

   Energy is sold to retail customers using fixed rates which do not change, or changes only rarely. For instance, tariffs based on the day-time and night-time prices, which are commonly used by the electrical heating households, belong to this category. In case of fixed rate-based pricing electricity retail sales prices do not follow directly wholesale market prices, and thus, the wholesale market prices cannot be regarded to be transferred directly to the retail customers.

2. **Time variable rates based on the wholesale prices (spot pricing):**

   The retail sales price of electricity is set based on the wholesale market price, for instance based on the Elspot price in case of Nordic markets. This pricing model is generally referred as spot pricing. For instance spot price tariffs, in which the retail sales price of electricity varies hour by hour based on the spot market prices belong to this category. In case of spot pricing the wholesale prices can be regarded to be transferred directly to the retail customers.

Most of today's pricing models are included either one of the above-mentioned category, however, some pricing models may not suite directly to either one of the categories. These pricing models may have elements on both, fixed rates and spot pricing, and include for instance different type of Critical Peak Pricing (CPP) and Time of Use (TOU) tariffs.

Fixed rates and wholesale price-based pricing models differ particularly at the retailer's risk management point of view. In case that the fixed prices are applied, the retailer exposes to greater risks, caused by the variation of wholesale market prices. When retail pricing is based on the fixed rates, the retailer may face situations in which it has to sell electricity to retail customers with a lower price than the purchase price in the wholesale markets is.

If the retail pricing of electricity is based on the spot prices, the price risk caused by the variation of spot prices transfers from retailer to customers. In this case aforementioned situations, in which the retailer may have to sell electricity with a lower price than it has been purchased, can be eliminated. However, the transferring of price risk to customers may also cause some problems. For instance, price peaks in the wholesale markets can result very high costs to the customers during the peak price hours, and understandably, may arise dissatisfaction among the customers. In addition, it is important to notice that the use of spot pricing eliminates retailer's wholesale price risk in the spot markets, but does not eliminate imbalance power cost risk resulted from the retailer's power imbalance.

In the context of this study, it is assumed that the retailer sells electricity to its customers by using fixed rates or other corresponding pricing model, in which the wholesale price signals does not go directly through to retail prices. Thus, the retailer faces also the market price risk caused by the variation of spot market prices. However, it should be noticed that even if the retail pricing would be based on spot pricing, the principles for the minimization of imbalance power costs, presented later in this report, would be still mainly the same.

4.3.2 *Problem description*

To make the electricity retailer short-term profit optimization problem description more convenient, it is first turned into electricity procurements cost minimization problem. This is done based on the assumption that electricity is sold to retail customers using fixed rates. Fixed rates-based sales price can be regarded as constant in the retailer short-term profit optimization, and thus, we can conclude that in order to maximize the profits, the retailer should now minimize its total electricity procurement costs.

The retailer's spot market costs are determined by the price and amount of electricity purchased in the Elspot and Elbas markets. The retailer's imbalance power costs in turn depend on the amount of purchased/sold imbalance power, price of the imbalance power and on the balance service payments. The market parties trading imbalance power has to pay balance service payment, on which is included imbalance power fees (volume fee, consumption payment, production payment). In general, these fees make the trading of imbalance power more expensive than the corresponding electricity trades in the spot markets. Thus, in can be concluded that in order to minimize the electricity procurement costs, the retailer should also aim to avoid the imbalance power fees resulted from the trading of imbalance power.

In the existing operational environment a retailer do not typically have ability to affect amount of its power imbalance by controlling loads or production. In practice, this means that the retailer's only alternatives to manage its open position and resulting power imbalance close to the delivery hour are trades in the Elspot and/or Elbas markets. The management of open position close to the zero level (no power imbalance), however, inquires that the retailer is able to forecast its future electricity consumption with high accuracy.

In general, the better the retailer's ability is to forecast its future electricity consumption, the better basis it provides for the management of open position in a way that provides the optimal result. In the literature consumption forecasting is a widely studied subject. Many studies (Abdel-Aal 2004; Daneshi & Daneshi 2008; Valtonen & al. 2010) suggest that real-time measurement data can significantly improve accuracy of load modeling and load forecasting based on the load models. The implementation of AMR- and AMI-systems improves possibilities to retrieve real-time measurement data, for instance on customers' consumption, and can thus provide new opportunities to develop more reliable consumption forecasting methods. However, so far the retailers have not been able to utilize real-time measurements data adequately cost-efficiently so that its utilization in this kind of applications would have been reasonable. Still, in the near future the large-scale implementation of AMR can make it, and also many other useful applications, possible.

One of the electricity retailers' basic problems in today's electricity markets is that they sells electricity to retail customers mostly by using fixed rates, but electricity procurements are made on a changing prices in the wholesale markets. In addition, the retailers' possibilities to manage their electricity procurements close to the moment of delivery are limited to trades in the spot markets. Consequently, the retailers expose to significant risks caused by the variation of customers' electricity consumptions and electricity prices in the markets.

One solution to eliminate the risk related to changing prices in wholesale markets is to use spot pricing in which the retail sales prices are based on the hourly spot prices. In this case, the retailer purchases electricity in the power exchange with a spot price, and sells it to the retail customer with a retail sales price ρ_{sell} that consist of the spot price added with a risk margin. Mathematically the retail sales price can be expressed as

$$\rho_{sell} = \rho_{spot} + risk\ margin. \tag{4.4}$$

The risk margin can be set for example based on the retailer's expected yield and risks exposure.

Use of this type of *hourly spot pricing transfers the price risk from the retailer to the retail customers*. However, some retail customers may not be willing bear the price risk if they have other alternatives. Thus, in practice, some customers may rather prefer traditional fixed rate pricing models than spot pricing. However, spot pricing can modified so that it seems more attractive to the customers. One generally used modified spot pricing model is to sell electricity by using average spot price of a longer time period, such as one month, as a sales price. In this case, the high costs caused by the individual price peaks in the wholesale markets will be divided to longer time period which may seem more acceptable from the customer's perspective.

As a short summary, we can conclude that the price margins are rather low, but risks considerable high in the retail business. In addition, the retailer's main aims, minimization of risks and maximization of profits, are contradictory objectives which make it challenging to find a proper balance between them. Thus, a careful planning of profit optimization and risk management are prerequisites for profitable retail business.

4.3.3 *Problem formulation*

It was assumed that the retailer under examination sells electricity to retail customer by using fixed rates. Based on this can be concluded that electricity sales price does not vary during the short-term examination period, and thus, electricity sales price ρ_{sell} can be regarded as constant in the mathematical description. As a result of the constant sales price, the retailer's opportunities to improve its profitability are limited to the minimization of electricity procurement costs. Consequently, electricity retailer profit optimization problem can be regarded to be turned into electricity procurement cost minimization problem.

To simplify the examination, one day is selected as examination interval. Now, the retailer's daily electricity procurement costs, in the operational environment in which it do not have possibility to use controllable DER, can be expressed by using equation

$$C_{day} = \int_1^{24} \begin{pmatrix} (\rho_{spot}(t) * E_{spot}(t) + \rho_{elbas}(t) * E_{elbas}(t) + \\ \rho_{red}(t) * E_{reg}(t) \end{pmatrix} dt$$

$$= \sum_1^{24} \begin{pmatrix} (\rho_{spot}(t) * E_{spot}(t) + \rho_{elbas}(t) * E_{elbas}(t) + \\ \rho_{red}(t) * E_{reg}(t) \end{pmatrix}, \tag{4.5}$$

and the theoretical minimum value for retailer's electricity procurements costs in a day is

$$C_{min.day} = min \sum_1^{24} \begin{pmatrix} (\rho_{spot}(t) * E_{spot}(t) + \rho_{elbas}(t) * E_{elbas}(t) + \\ \rho_{red}(t) * E_{reg}(t) \end{pmatrix} \tag{4.6}$$

C_{day} – Retailer's electricity procurement costs in a day (€)
$C_{min.day}$ – Retailer's minimum electricity procurement costs in a day (€)

In the current operational environment the retailer does not have possibilities to control DER. It is also assumed that the retailer's possible own traditional generation cannot be used directly to cover the loads. Consequently, the retailer cannot impact on the sum of energy needed to cover the total loads at the hour t, and the sum of total electricity procurements can be thus regarded as constant in the optimization function. The energy used to cover the load obligation at the hour t consist on retailer's electricity procurements in the Elspot and Elbas markets, and from the traded imbalance power, and can be presented by the equation

$$E_{load}(t) = E_{spot}(t) + E_{elbas}(t) + E_{reg}(t). \qquad (4.7)$$

$E_{load}(t)$ – Sum of total energy needed to cover retailer's total loads at the hour t (MWh)

In a market environment where any retailer does not have dominant market power, the retailer cannot affect electricity prices. In other words, the retailer is referred as a price taker. Based on this assumption the electricity prices can be perceived also as constants in the mathematical model. Now, only variables that are not constant in the optimization function are the purchased amount of electricity in the Elspot market (E_{spot}), purchased amount of electricity in the Elbas market (E_{elbas}), and retailer's imbalance power trades (E_{reg}). Based on this, *it can be concluded that in a theory, the electricity prices in different markets determine on which markets the retailer should make its electricity procurements in order to minimize its short-term electricity procurement costs.*

4.3.4 *Comparative case example: Retailer's electricity procurement costs and trading in short-term markets*

To illustrate a basic profit optimization case in Nordic electricity markets, in the Table 4.1 is gathered a comparison from different short-term markets' average electricity prices at the price area of Finland at the time period 1May.2011 - 31 May 2011.

Table 4.1. Average electricity prices in May 2011 at the price area of Finland. (Zero values are excluded from the calculation of average Elbas price)

	Elspot FIN	**Elbas**	**Purchase price of production imbalance power**	**Sales price of production imbalance power**	**Price of consumption imbalance power**
Average price (€/MWh)	54,42	54,62	51,42	56,98	54,00

Electricity prices in the Elspot and Elbas markets vary depending on the supply and demand of electricity. Consequently, electricity price during the existing hour can be lower either one of these markets. Table 4.1 shows that the average Elspot FIN was a slightly lower in May 2011 than the corresponding Elbas price. Consequently, the retailer should have on average aim to make its electricity procurements rather in Elspot market than in Elbas market. However, the average price difference between Elspot and Elbas prices is rather small, on which reason it is in many cases beneficial for the retailer to make balancing trades still in the Elbas market, because it can help to avoid extra costs caused by the imbalance power trades.

When planning the trades in spot markets also other factors than electricity prices should be taken into account. When electricity trades are made in the Elspot market prior to the Elbas trading, the retailer's open position is reduced to a lower level, and the risk caused by the variation of electricity price lowers. In practice, it also has to be taken into account that the volatility of Elbas market is significantly lower than the volatility of Elspot market. Consequently, in some cases it may be challenging to find counterparty for trading within the given price and block limits in the Elbas market.

In some cases, for example at the times when there is significant uncertainty related on future electricity consumption, it can reasonable for the retailer to purchase the last needed megawatt hours in the Elbas market. If the retailer aims to fulfill its open position precisely already in the Elspot market, and the consumption decreases from the expected, it can result a situation on which the retailer has significantly positive imbalance as a result of the overestimation of total consumption. In this case, the retailer has to sell back the surplus energy in the Elbas market in order to avoid the realization of positive imbalance. This causes the need to make extra trades compared to situation in which the retailer purchases last needed megawatts in Elbas. Extra trades in turn complicate the whole procedure, and in many cases cause extra costs and extra work. However, the possible extra costs depend highly on the electricity prices in different markets.

Table 4.1 shows that the sales price of production imbalance power, which is the price on which imbalance power is sold by Fingrid to a balance responsible party in a production balance, is on average over 2 €/MWh more expensive than the corresponding Elspot and Elbas prices. The purchase price of the production imbalance power, which is the price on which imbalance power is purchased by Fingrid from a balance responsible party, is on average at least 3 €/MWh less than the corresponding spot markets prices. In addition, the imbalance power fees have to be paid to Fingrid from trading of imbalance power, which makes it even more expensive for the market party. Thus, it can be concluded that the retailer should have been avoid trading of production imbalance power in order to minimize its electricity procurement costs.

In the production balance, where the two-price system is applied, the purchase price of imbalance power is the down-regulating price during the down-regulation hours and otherwise the Elspot FIN. The sales price of the imbalance power in the production balance in turn is the up-regulating price of the hour during the up-regulation hours, and if no up-regulation has been carried out, or if the hour has been defined as down-regulating hour, the Elspot FIN. As a result of these pricing principles, if the retailer has to purchase or sell imbalance power, it will always cause extra cost compared to the situation where the retailer has no imbalance. *Thus, the retailer should always aim to minimize its need of imbalance power in the production balance in order to maximize the profits.*

In the consumption balance is applied the one-price system which makes the situation different from the retailer’s profit optimization point of view compared to the production balance. In the one-price system the sales and the purchase price of the consumption imbalance power is always the same. In the case of regulating hour, the regulation price of the hour is used. If no regulation has been made, the Elspot FIN is used as a purchase and sales price of consumption imbalance power. This pricing system makes it possible that the retailer can benefit from imbalance power trades in some cases. During some hours can result situations, on which the retailer can purchase imbalance power with a lower price than the corresponding Elspot Fin is, or “sell back” the imbalance power with a higher price than the corresponding Elspot Fin is. In the Section 5.4 this topic has been discussed in more detail. Despite the possibility that it can be beneficial for the retailer to purchase or sell imbalance power, in a basic risk avoiding strategy the retailer should rather aim to minimize its imbalance, since the imbalance power trades causes significant cost risk for the retailer.

Based on the preceding, *it can be concluded with some assumptions that in a basic risk avoiding strategy electricity retailer can minimize its average electricity procurement costs in short- term markets by focusing its electricity procurements in the Elspot market*. Assuming that $\rho_{\mathrm{spot}} < \rho_{\mathrm{elbas}} < \rho_{\mathrm{reg}}$, the theoretical minimum value for the retailer's daily electricity procurement costs is

$$C_{min.day} = E_{load}(1) * \rho_{spot}(1) + E_{load}(2) * \rho_{spot}(2) + \cdots + E_{load}(24) * \rho_{spot}(24)$$

$$= \sum_{1}^{24} E_{load}(t) * \rho_{spot}(t) \qquad (4.8)$$

Consequently, in a theory, the retailer should aim to make its electricity procurements in the Elspot market. However, in practice, it is not typically possible to forecast the future consumption with so high accuracy that there is no need for balancing trades in the Elbas market or need for imbalance power trades. In addition, it has to be taken into account that the risk caused by the positive and negative imbalance for the retailer is different. For example, in case that the retailer's consumption imbalance is positive, and the retailer can sell its surplus electricity back to markets on a higher price than it have procured it from the markets, it is profitable for the retailer to have a positive imbalance (surplus on electricity procurements), but unprofitable to have a negative imbalance (deficit on electricity procurements). Furthermore, the use of more risk taking strategy in which the retailer aims to identify the optimal direction of open position for each hour inquires further analysis, so that the risks can be managed within permissible limits.

4.4 Profit optimization in the smart grid environment

In the existing operational environment electricity retailers typically do not have possibility to control their customers' loads or utilize other distributed energy resources as part of short-term profit optimization. However, the development of smart grids may change this. Numerous studies (Caves & al. 2000; Ilic & al. 2002; Pratt 2008) introduces researches and pilot projects, in which have been studied possibilities to utilize DER in different applications, such as in reducing peak loads and promoting DR. In addition, already in today's markets some large industrial customers' loads are controlled based on electricity prices. Thus, it can be assumed that the transition to smart grids can enable cost-effective and large-scale residential customer load control.

In addition to customer end-use load control, the development of smart grids makes possible more cost-efficient utilization of other distributed energy resources such as energy storages and distributed generation. Improved opportunities for cost-efficient utilization of controllable DER can provide new tools for retailers' profit optimization. However, this inquires that technical requisites can be fulfilled adequately cost-efficiently, and that appropriate market and operation models will be developed.

The opportunity to utilize controllable DER could significantly improve retailers' ability to operate more flexibly and profitably in short-term markets. Retailers could, for example, control their customers' loads off during the times of high electricity prices, and by this way reduce the need to purchase high-priced electricity in the power markets. In general, the possibility to use controllable DER could provide new opportunity for retailers to manage their open positions close to the moment of delivery, and thus improve their ability to operate more profitably. In addition to potential financial benefits, this king of DER controls could provide many additional benefits, such as improve efficient use of electricity, decrease variations in electricity prices and reduce emissions caused by the use of peak power production capacity.

In the future the main focus of this report is electricity retailer profit optimization in the smart grid environment. It is assumed that in the smart grid environment electricity retailers can utilize controllable DER cost-efficiently to enhance their short-term profit optimization. To maximize profits in a smart grid environment, an electricity retailer has to aim to balance its electricity procurements and the utilization of available controllable DER capacity so that total electricity procurement costs will be minimized. Figure 4.4 illustrates the utilization of controllable DER as part of a retailer's short-term profit optimization in the smart grid environment.

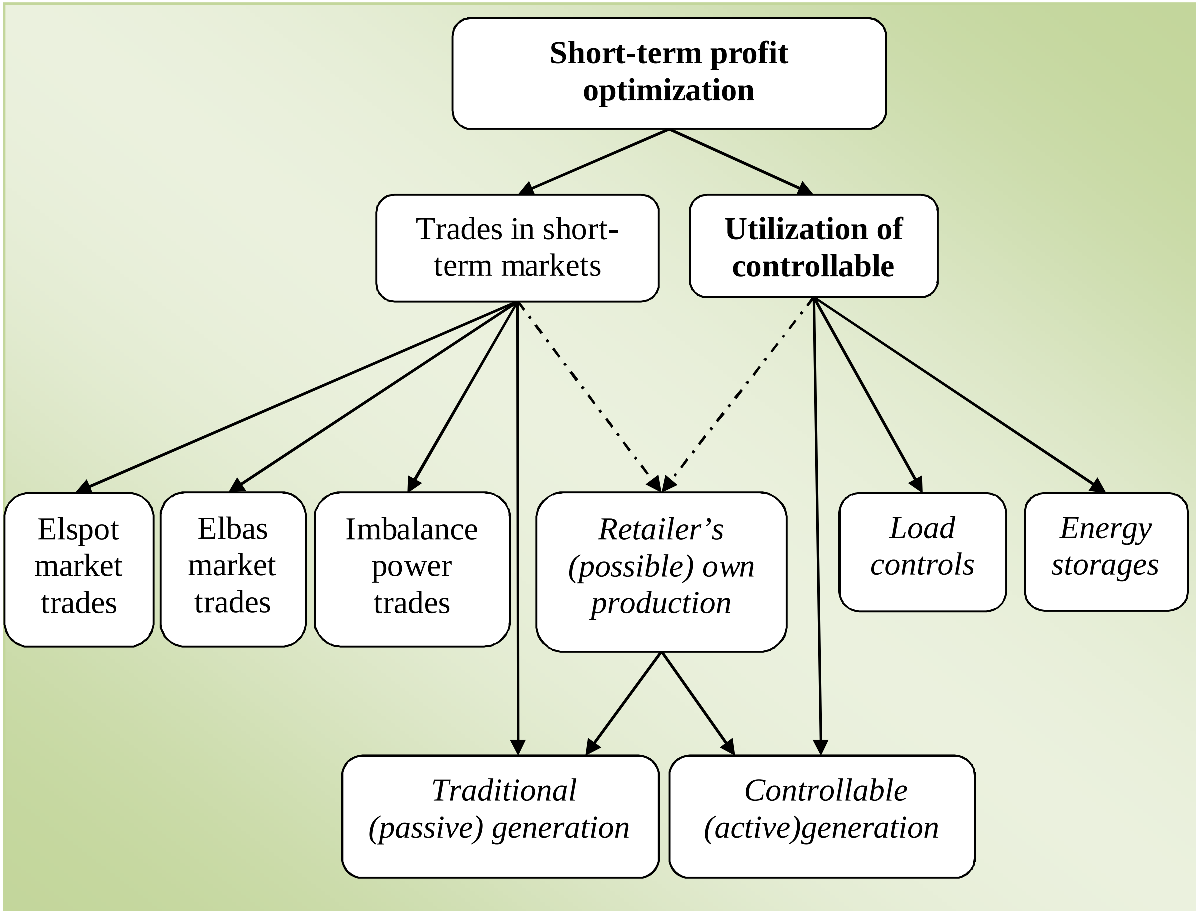

Figure 4.4. The utilization of DER as part of a retailer's short-term profit optimization in the smart grid environment

In the mathematical description retailer's controllable DER capacity has to be considered separately, and categorized based on the type of DER. First, the retailer's total loads are categorized to traditional static (non-controllable) loads and active (controllable) loads. Respectively, the retailer's possible own generation is divided to traditional (static) generation and controllable (active) generation. In addition, the retailer may have also different type of energy storages. In this context, it is assumed that the retailer's traditional generation is used based on the original production plan, and thus, it cannot be controlled as part of retailer's short-term profit optimization. Consequently, the retailer's traditional generation can be seen as static generation from the view point of short-term profit optimization.

The energy needed to cover the retailer's loads at the hour t is divided in the mathematical description as follows;

1. Static energy: Energy that covers retailer's static (non-controllable) loads. Retailer cannot impact on the amount of static energy by its actions.
2. Active energy: Amount of energy that can be controlled using DER. The amount of active energy varies depending on the use of DER.

Mathematically this segmentation can be expressed as

$$E_{load}(t) = E_{static}(t) + E_{active}(t). \tag{4.9}$$

E_{static} – Static energy (MWh)
E_{active} – Active energy (MWh)

Retailer's electricity procurements that are needed to cover static energy can be further divided on four sub-categories as follows;

$$E_{static}(t) = \sum E_{spot}(t) + E_{elbas}(t) + E_{reg}(t) + E_{sg}(t). \tag{4.10}$$

E_{sg} – Amount of energy produced by the retailer's static (traditional) generation (MWh)

The active part of the energy in the retailer's power balance in turn can be further divided on three sub-categories as follows;

$$E_{active}(t) = \sum E_{al}(t) + E_{ag}(t) + E_{es}(t). \tag{4.11}$$

E_{al} – Control capacity of active loads (MWh)
E_{ag} – Control capacity of active generation (MWh)
E_{es} – Control capacity of energy storages (MWh)

Now, the retailer's generation can be expressed in the form

$$E_g = E_{cg} + E_{ag}. \tag{4.12}$$

E_g – Retailer's total generation (MWh)

E_{ag} describes the active generation which the retailer can control with minor delays, and which can be used to manage retailer's electricity procurements close to the delivery. E_{sg} in turn describes the static generation, which the retailer cannot control based on its short-term profit optimization needs.

The retailer's total electricity procurements costs consist from the electricity procurement in the Elspot market and Elbas market, imbalance power costs, generation and DER utilization costs. Thus, the retailer's daily minimum electricity procurement costs can be expressed by the equation

$$C_{min.day} = min \sum_{1}^{24} \begin{pmatrix} (\rho_{spot}(t) * E_{spot}(t) + \rho_{elbas}(t) * E_{elbas}(t) + \\ \rho_{reg}(t) * E_{reg}(t) + \rho_{sg}(t) * E_{sg}(t) + \rho_{DER}(t) * E_{DER}(t) \end{pmatrix}. \quad (4.13)$$

ρ_{sg} – Generation costs of static generation (€/MWh)
ρ_{DER} – Average DER utilization cost (€/MWh)

Controllable DER in the equation 4.13 can be further divided to sub-groups according to equation 4.11. Now, the retailer's daily minimum electricity procurement costs can be expressed by equation

$$C_{min.day} = min \sum_{1}^{24} \begin{pmatrix} (\rho_{spot}(t) * E_{spot}(t) + \rho_{elbas}(t) * E_{elbas}(t) + \\ \rho_{reg}(t) * E_{reg}(t) + \rho_{sg}(t) * E_{sg}(t) + \rho_{ag}(t) * E_{ag}(t) + \\ \rho_{al}(t) * E_{al}(t) + \rho_{es}(t) * E_{es}(t) \end{pmatrix}. \quad (4.14)$$

ρ_{al} – Cost of utilization of active (controllable) loads (€/MWh)
ρ_{ag} – Cost of utilization of active (controllable) generation (€/MWh)
ρ_{es} – Cost of utilization of energy storages (€/MWh)

Mathematical description includes now all different type of electricity procurements and DER utilization cost. However, in practice, the retailer does not necessary have some of these.

Based on the preceding, it can be concluded that the optimal strategy for retailer profit optimization in the smart grid environment depends on the electricity wholesale market prices, generation costs and DER utilization costs. Assuming that the retailer has no own generation and that on average $\rho_{spot} < \rho_{DER}$, the retailer should aim to make its electricity procurements in the Elspot markets. However, in some cases, for instance during electricity price peaks can exists situations in which $\rho_{DER} < \rho_{spot}$. In cases of this kind, the retailer should utilize its available DER capacity to decrease the need for electricity procurements in the spot markets.

It can be concluded that in the smart grid environment the optimal electricity procurement strategy and optimal way to use controllable DER depends on the electricity prices, but also on the cost of the utilization of controllable DER and retailer’s possible own generation. However, there is also many other factors which are important to consider in the further development of profit optimization model. These important impacting factors will be examined in detail in the next chapter.

5 IMPORTANT FACTORS FROM THE VIEW POINT OF SHORT-TERM PROFIT OPTIMIZATION

Many different factors have impact on electricity retailer's profits in short-term markets. The consideration of possible risks and other factors, on which have high impact on the retailer's profits is a prerequisite of viable retail business.

Major part of retailer's risks can be eliminated at least partly by hedging, but not all. In addition, hedging induces costs, and thus overhedging should be avoided when aim is to maximize expected profits. Therefore, risks in the markets should be identified and evaluated so that the retailer's profit optimization can be developed accordingly.

This chapter examines important factors, on which has impact on the profitability of retail business. First, the factors that expose retailers to risks in the power markets are considered shortly. Second, the basic statistics needed in the risk evaluation will be described. Third, the methods for risks evaluation in electricity markets are introduced. Finally, the most important factors that have impact on the retailer's profitability in the short-term markets will be considered. In this context also the main principles for the retailer's imbalance power cost risk minimization are presented.

5.1 Evaluation of risks and expected electricity procurement costs

Electricity retailers are obligated to meet their customers' electricity demand. This load obligation combined with the variations in electricity prices and consumptions, and fixed rate-based electricity sales pricing exposes retailers to considerable risks. The identification and evaluation of these risks plays an important role in retailer's profit optimization. Many different methods have been developed for the risk evaluation purpose. The most common methods used for risk evaluation in electricity markets are introduced shortly in this section. However, prior that basic statistics needed in the risk evaluation will be presented.

5.1.1 *Basic statistics for the risk evaluation*

The variation of electricity price and consumption over the time can be described by using probability distributions. *Standard deviation* is a widely used measurement of variability. It shows how great the variation is on average (mean, or expected value). Technically, the standard deviation of a probability distribution is the square root of its variance. It is convenient to use standard deviation instead of variance, since it is expressed in the same units as the data. (Math 2011)

When X is the (random) variable with mean value of μ, the expected value of X is

$$E[X] = \mu. \tag{5.1}$$

When the X takes random values from a finite data set x_1, x_2, …, x_N, with each value having its corresponding probability p_1, p_2, ..., p_N, the standard deviation will be

$$\sigma = \sqrt{\sum_{i=1}^{N} p_i (x_i - \mu)^2} \tag{5.2}$$

where

$$\mu = \sum_{i=1}^{N} p_i x_i. \tag{5.3}$$

Respectively, the variance of X is

$$Var(X) = \sigma_x^2 = \sum_{i=1}^{N} p_i (x_i - \mu)^2. \tag{5.4}$$

(Math 2011; Dirac 2011)

In the financial world, volatility is generally used to measure the uncertainty of the expected value. It can be regarded as a measure for variation of price over time. Mathematically the generalized volatility σ_T for time horizon T in years can be expressed as

$$\sigma_T = \sigma\sqrt{T}. \tag{5.5}$$

(Hull 2003)

It is important to take into notice that the volatility does not measure the direction of price changes. This is because when calculating the standard deviation, all differences are squared, so that negative and positive differences are combined into one quantity. Even though the volatility expresses the expected change of the price, it is not good measure of risk.

5.1.2 *Methods for risk evaluation*

Different methods for risk evaluation purposes have been developed. These include for instance variance, VaR and CVaR. Value at Risk (VaR) is a generally used risk evaluation method in the financial markets. It can be assessed also in electricity markets to evaluate the risk caused by the variation of electricity price. Definitions of VaR vary across applications, but the standard definition of the VaR of a portfolio is the maximum loss that the portfolio is allowed to sustain over a specified period of time and at a specified confidence level. In other words, the *VaR measures the amount that firm can lose with α % probability over a certain time horizon*. For example, the VaR calculated with probability of 5 % over one day tells that the cost overruns the VaR on average 5 times during the 100 day. VaR has been used also as a base for the development of many other risk evaluation methods such as Conditional Value at Risk (CVaR), Cash Flow at Risk (CFaR), and Earnings at Risk (EaR). The applicability of the method for evaluation of risk in each situation depends mainly on the type of the asset and time horizon of examination. (Dahlgren & al. 2003)

Typical approaches of estimating VaR in practice can be classified as parametric and nonparametric. In the parametric approach, a specific distribution for asset returns has to be postulated. The normal distribution is typical choice for this. The historical simulation (HS) is one of the most common methods used to estimate VaR. It uses the empirical distribution of returns to proxy for the likely distribution of future returns. These both models are widely used in financial markets where extreme market movements are rare. However, in the electricity markets price volatility can be high and occasional price peaks can appear. This can make an empirical distribution of returns with a non-standard shape, making it difficult to specify parametric form. Consequently, in some cases the parametric approach may not generate accurate VaR measures for electricity markets. Therefore, there has been developed other methods which can be applied to evaluate the risks in electricity markets. Typically these methods aim to model specifically the extreme price changes (i.e the tails in the distribution). Thus, in electricity markets have been typically used other more attractive methods instead of VaR such as CVaR, which is a coherent risk measure. CVaR of the portfolio for a specified confidence level α, is defined as the expected value of the loss function in the (1- α) * 100 % worst cases. (Chan & Gray 2006; Hull 2003; Hatami & al. 2009)

As a summary, we may say that numerous different methods can be used for risk evaluation. The performance of these methods in different cases depends on the time horizon of the examination, and on the type of the asset, which specify its unique characteristics. Thus, the selection of most applicability risk evaluation method for each case demands a specific examination and comparison of different methods. However, in many cases, and particularly in short time intervals, the differences between methods' performance are typically relatively minor.

5.1.3 *Evaluation of expected electricity procurement costs*

I was concluded in the section 4.1 that price and volume risk are two main risks faced by the retailer in short-term markets. Thus, the variation in electricity price and consumption determine mainly the retailer's total risks and expected profits in the short-term markets.

Assuming that there are market quotes that give the expected values for

$E_{\rho,t}(X_t)$ – Expected electricity price at hour t (€/MWh)
$E_{ep,t}(X_t)$ – Expected (planned) electricity procurements at hour t (MVh),

the retailer's expected electricity procurement costs can be expressed by equation

$$C_t(X_t) = E_{\rho,t}(X_t) * E_{ep,t}(X_t). \quad (5.6)$$

$C_t(X_t)$ – Retailer's expected electricity procurement costs at hour t (€)

In practice, the evaluation of expected electricity price and needed electricity procurements (actual consumption) in advance is a challenging task in which is related significant uncertainty. Many factors such as weather conditions, price elasticity and forecasting errors has impact on the retailer's expected electricity procurement cost. Figure 5.1 illustrates the evaluation of retailer's expected electricity procurements in a short-term.

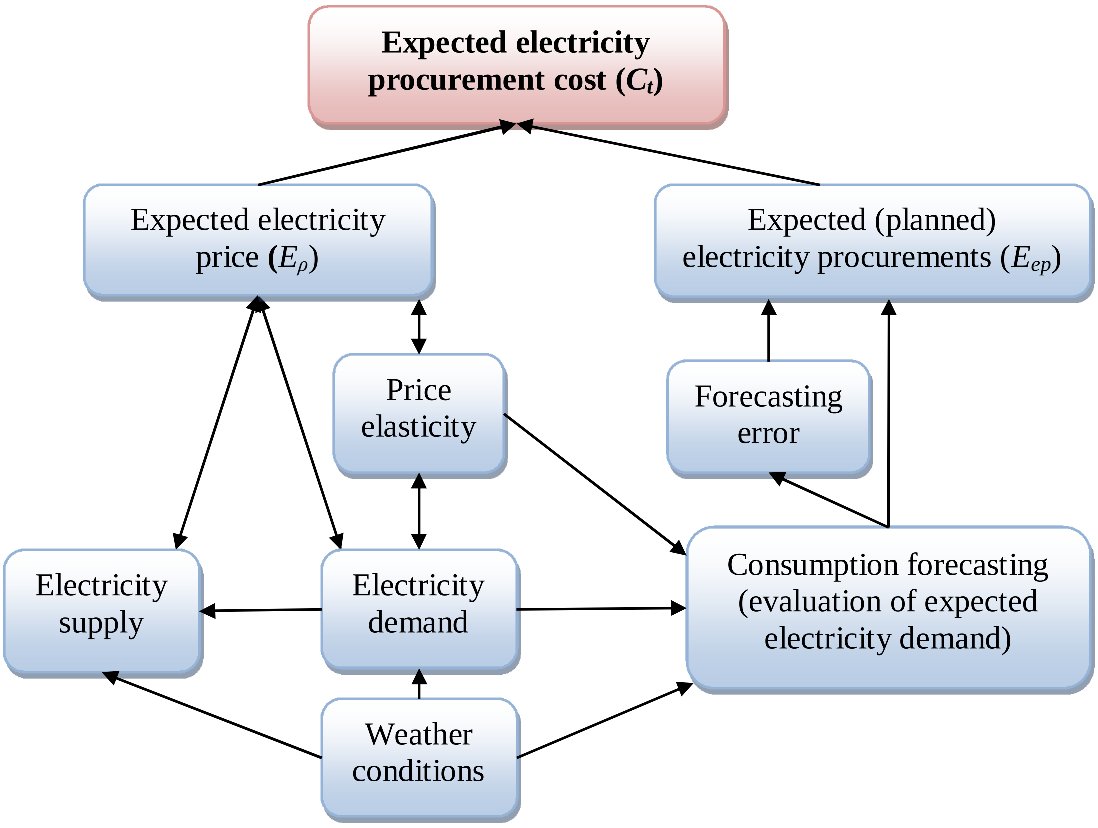

Figure 5.1 Evaluation of retailer's expected electricity procurements costs in a short-term.

5.2 Consumption forecasting and management of open position

Electricity consumption forecasting plays an important role in electricity retailer business. It provides a basis for the long-term planning as well as for short-term profit optimization. In this section the short-term consumption forecasting and management of open position based on this will be under examination.

The minimization of risks by minimizing the size of retailer's open position is relatively simple and effective profit optimization strategy. By using this strategy the retailer can manage its risks in the short-term markets within reasonable limits. However, in some cases this profit optimization strategy will not provide the maximum profits, and thus, also other profit optimization strategies should be considered. One alternative profit optimization strategy is to manage the retailer's open position more actively based on the latest electricity consumption and price forecasts/data. In this strategy the retailer may aim manage its open position to bit positive or negative level if electricity price and consumption forecasts/data indicates that this increases expected profits considerably.

In general, the optimal electricity procurement strategy depends on relative electricity prices in different power markets. In case that electricity price in the power market, such as in the Elspot market, is not particularly high, the retailer can purchase needed electricity with a low price in the specific market. Consequently, at the times of low market prices the retailer should rather have a bit negative open position (deficit in electricity procurements). Correspondingly, at the times high market prices the retailer should rather have a bit positive open position (surplus in electricity procurements), which provides a profitable sell-back opportunity.

In practice, however, many factors set challenges for the management of retailer's open position based on the above described principle. In particular, the variations in electricity prices and customers' consumptions make the evaluation of optimal amount and direction of open position challenging. In order to determine the optimal profit optimization strategy the retailer should be able to forecast future electricity consumption relatively accurately, and have at least a rather good indication on the level of electricity prices. Based on the preceding, it can be concluded that the better (more accurately) the retailer is able to forecast its future electricity consumption and electricity prices, the better basis it provides for profitable operation.

On average, the reliability of consumption forecasts improves when the time period between the moment of forecasting and moment of delivery contracts. The active management of open position is also based on the idea that when the moment of delivery approaches the retailer ability to forecasts its future consumption accurately improves, providing a better basis for the management of open position in a way that provides the highest profits. In practice, this type of active management of open position can be done by trading in the spot markets, and based on the basic assumption of this study, also by utilizing controllable DER in the future smart grid environment. In particular, the use of controllable DER close to the moment of delivery based on the latest consumption forecasts could provide great opportunities for retailers' to hedge against variations in electricity prices and consumption, or even benefit from the price fluctuations.

Although the active management of retailer's open position based on the latest consumption forecasts provides an opportunity to increase retailer's profits, it should be noted that it also includes considerable risks. The higher the retailer's open position is, the higher risks the retailer is exposed to. Moreover, the limitations set by the balancing power markets and the System Operator (SO) have to be also considered. For example, Fingrid, the Finnish System Operator, obliges the market parties to maintain their power imbalances at an appropriate level with respect to the extent of the operation of the party (Fingrid 2011). In addition, the market parties are not allowed to make electricity procurements or deliveries purposefully trough the contract-based open deliveries. On the other hand, if the market player is able to operate in a way that it does not violate aforementioned obligations, but still achieves financial benefits as a result of imbalance power trades, the market party's operation can be seen beneficial from the view point of the power system. This results from the pricing principles of imbalance power, which are set so that those give incentives for the market players to operate in a way that supports the operation of the power system.

5.2.1 *Short-term consumption forecasting*

Short-term consumption forecasts provide a basis for the planning of last few days' and hours' electricity procurements prior to the moment of delivery. Thus, short-term consumption forecasts are needed for the planning of electricity procurements in the Elspot market, balancing trades in the Elbas market and utilization of controllable close to the moment of delivery.

In the current market environment retailers' last possibility for balancing trades is the Elbas market. After the Elbas trades the remaining power imbalance has to be balanced by the means of imbalance power. The price of imbalance power can be significantly higher than the corresponding Elspot or Elbas market price. Thus, accuracy of consumption forecasts has significant impact on a retailer's ability to maximize its profits in the short-term markets.

The more accurately the retailer is able to forecast future electricity consumption, the better basis it provides for the maximization of profits. The time period between the moment of forecasting and the delivery has considerable impact on average accuracy of consumption forecasts, which has been illustrated in the Figure 5.2.

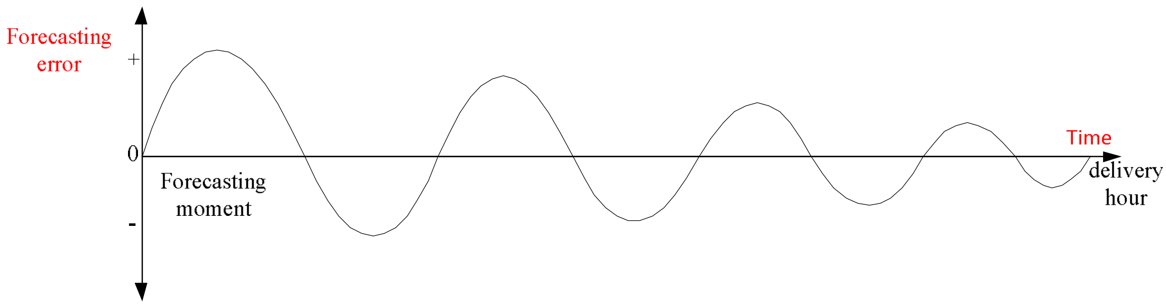

Figure 5.2. The impact of time period between forecasting hour and delivery hour on accuracy of consumption forecast

In Figure 5.2 can be seen that shorter the time period between forecasting moment and delivery hour is, the lower the forecasting error is on average.

In the Elspot markets the trades have to be done at latest 24 hour prior to the delivery hour, and in the Elbas-markets at latest one hour prior to the delivery. The consumption forecasts needed for the basis of trades in these markets have to cover at least the trading period, and have to be available for the use prior end of the trading period. Thus, in case of the Elspot market, the forecast should cover at least the 24 next hours, and in case of the Elbas markets at least one hour. The type of consumption forecasts that are used as a basis for the planning DER utilization in turn depends on the type and the control principles of DER.

5.2.2 *Accuracy of consumption forecasts*

Many different factors have impact on variations in electricity consumption which makes consumption forecasting a rather complicated task. Typically, consumption forecasts are created based on the measured data from electricity consumption in different parts of network, customers' load models and weather forecasts. In addition, other available data, such as data on special events can be used in consumption forecasting.

Consumption of an individual electricity end-user is challenging to forecast since it can vary significantly depending on the customer's daily operation. However, in most cases, a retailer has no need to forecast individual customers' consumption apart from the customer's with very high consumption such as some industrial companies, because individual end-user's electricity consumption has typically no significant impact on the retailer's total loads. Thus, for example in Finland, residential customers' electricity consumption forecasting has been based on the type load profiles which describes average consumption of the customer in a specific customer group. (Valtonen & al. 2010) In most customer groups average electricity consumption is highest during the morning and evening hours. In addition to customer's operation, for example time-of-use controls of electrical heating have significant impact on the deviation of electricity consumption and on the form of specific type load profiles.

The forecasting of peak load hours has an important role in the planning of retailers' electricity procurements. In addition to highest electricity consumption, also the highest electricity prices can be found typically during the peak consumption hours. Consequently, the retailer's ability to forecast electricity consumption during the peak load hours may have particularly high impact on the retailer's profitability. (Valtonen & al. 2010)

In many cases type load profiles have been used a base for consumption forecasts for many years. Consequently, the source data of load models can be rather old, which may significantly decrease the accuracy of consumption forecasts. Therefore, the re-creation or updating of type load profiles can help to improve accuracy of consumption forecasts. One potential alternative for the updating of type load profiles is to use measurement data provided by the AMR- and AMI-systems. Thanks to large-scale implementation of AMR and AMI systems the data on customer's consumption can be retrieved relatively cost-efficiently, making possible economical updating of load profiles. (Valtonen & al 2010, 2011)

Weather conditions have particularly high effect on total electricity consumption and its variation. Consequently, weather forecasts are important input data in consumption forecasting. Temperature is usually the most important individual input from the weather forecasts. However, also wind and sun condition data can be useful. In particular, if the retailer's customers' have considerable amount small-scale solar or wind power production, these should be considered in consumption and production forecasts. In addition, wind and solar conditions have some impact on heating and cooling needs. However, in general, temperature data has typically rather high impact on electricity consumption compared to wind and solar data. Thus, in many cases, temperature is adequate source data, and no other weather data is needed for the consumption forecasting.

Exceptions in the normal use of network, production and consumption can cause high variation on estimated electricity usage. Also special days such as Christmas, and some other events, may cause significant variation on typical electricity usage. Factors of this type are important to consider in the forecasting procedure. Table 5.1 presents important factors which have significant impact on electricity usage, and/or which consideration can help to improve accuracy of consumption forecasts.

Table 5.1. Important factors which have impact on electricity usage, and/or which consideration can help to improve consumption forecasting accuracy.

Factor	Description	Notes
Weather	Forecasts on temperature, but also on wind and sun conditions provide important data for consumption forecasting.	Temperature has a high impact on electricity usage. Temperature changes can be taken into account by using temperature coefficient. Forecasts from wind and sun conditions can also provide useful information, in particular, if electricity end-users' have significant amount small-scale wind or solar production.
Prior electricity consumption	Both, historical and "real-time" electricity consumption data can be utilized in load forecasting.	The more real-time consumption data is used in the creation of consumption forecast, the better the accuracy of the forecast is on average. However, also historical consumption data can be used for example to update the basic load profiles.
Unusual events	Events that can cause significant changes on typical consumption such as maintenance breaks and interruptions in big industrial processes.	Even a single unusual event can cause significant variation on electricity usage.
End users typical day-rhythm and exceptions on it	Typical working times, cooking, time of use controls (i.e. electrical heating), heating of electric saunas, charging of EVs, …	End users' typical day rhythm and operation dictate mainly the form of customer's load profile. In a large-scale the impact of individual customer's own actions on retailer's total loads is relatively insignificant. However, for example large-scale charging of EVs can significantly increase peak powers without proper control.

Accuracy and reliability of consumption forecasts depends highly on input data and characteristics of the network and loads, but also on the time period between the moment of forecasting and delivery. The longer this time period is the greater uncertainty is related to the forecast. Consequently, different consumption forecasts are needed for trading in different markets.

In general, consumption forecasts provide a basis for the planning of retailer's electricity procurements and operation in a short-term. Accurate consumption forecasts can provide an opportunity for the retailer to achieve savings. However, the proper level for consumption forecasting should be evaluated carefully. Saves achieved thanks to use of consumption forecasting should be greater than costs caused by the forecasting. For example, the use of

AMR data in improving accuracy of consumption forecasting should increase retailer's expected total profits more than resulting costs are.

5.2.3 *Evaluation of forecasting error*

Numerous different variables have impact on electricity consumption. Some of these have at least partly random nature, and thus, consumption forecasts include always some uncertainty. The level of consumption forecasting should be optimized between the benefits and costs provided by it. In some cases it can be more profitable for the retailer to take into account the uncertainty related on consumption forecasts than put efforts to the development of consumption forecasting procedure. In order to evaluate benefits provided by the consumption forecasts the accuracy of consumption forecasts has to be evaluated with some reliable method.

Statistical methods are used for the evaluation of consumption forecasting accuracy. The comparison of MAPE (Mean Absolute Percentage Error) is one generally used method. The forecasting error at the hour t can be expressed using MAPE by the equation

$$\in = MAPE = \frac{1}{N}\sum_{i=1}^{N}\left|\left(\frac{L_{forecast}-L_{actual}}{L_{actual}} * 100\right)_i\right|. \quad (5.7)$$

N – The number of fitted examination points in time
$L_{forecast}$ – Forecasted loads
L_{actual} – Actual loads

The evaluation of average errors provides useful data on general level of consumption forecasting. However, also unusually high forecasting errors are important to identify, because these cause high cost risk for the retailer. Thus, also the peak values of consumption forecasting errors should be considered, and reasons behind these identified.

Typically, the retailer can forecast future consumption with relatively good accuracy, and in many cases, the highest forecasting errors are caused by the unexpected events such as interruptions in electricity usage or production. This type of events can be very challenging or even impossible to forecasts in advance, which make them problematic from the view point of consumption forecasting.

5.3 Demand response

Demand response (DR) base on the idea that electricity end users' electricity use changes from their normal consumption patterns according to the price of electricity over time. DR is used to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized. Most commonly customer response is achieved either reducing customers' electricity use during critical peak periods or directing customers' electricity use based on electricity prices. In some cases the DR can be achieved also as a result of the use of customer owned distributed generation or energy storages. (Albadi & El-Saadany 2007)

The generalization of AMR and AMI technologies improves opportunities to promote DR for example by utilizing basic control applications and different retail pricing schemes. Common pricing models used by electricity retailers include fixed pricing (fixed price for a specific period) and time differentiated pricing (time-of-use pricing (TOU), real-time pricing (RTP) and critical peak pricing (CPP)) (Hatami & al. 2009). In particular, the RTP has seen as potential alternative to improve the DR.

Large-scale implementation of AMR and AMI equipment opens great opportunity to improve DR. Electricity price signals can be transferred to customers with minor delays trough these systems, which makes possible simple and cost-efficient implementation of time differentiated pricing models in practice. In addition to price signals, customers' response on electricity price changes is needed. Customer response can be achieved by customers own actions or using automation system and/or external controls, on which the latter one provides typically the best results.

Development of smart grid environment and improving DR provides also new opportunities to develop electricity retail business. DR can benefit both, customers and retailers. Customers benefit by achieving savings in their electricity costs, and retailers by directing their customer's loads into desired direction. In addition, demand response can improve efficient use of energy and power system, for instance by decreasing use of typically more expensive and higher emissions providing peak power production.

5.3.1 *Price elasticity*

Demand of electricity has high impact on electricity price. If the demand responses to price changes, the change in the demand in turn may effect on electricity price. The impact of electricity demand (consumption) on electricity price can be described by using price elasticity term. Price elasticity can be expressed by equation

$$\varepsilon = \frac{\Delta q}{\Delta \rho}, \qquad (5.8)$$

when all prices and quantities have been normalized respect to a given equilibrium point.

ε – price elasticity
q – quantity of electricity (demand)
ρ – price of electricity

Electricity demand of an individual retailer is typically relatively low in the scale of whole market. Therefore, operation of a single small- or medium-sized retailer does not typically have significant impact on wholesale market prices. In a large scale, however, the variation of electricity demand has more distinct impact on electricity price.

The impact of DR on electricity price depends significantly on the specific features of the market and power system. Based on the principles of marginal pricing, the last accepted bid of available production determines the market price. Thus, even a rather small increase of DR can decrease electricity price significantly. For example, at the times of peak price hours, when more expensive peak power production capacity is in use, even a small decrease in total consumption can eliminate need to use a specific peak power production capacity, and result in a significant decrease on electricity price. Figure 5.3 been illustrates the correlation between electricity demand and production costs.

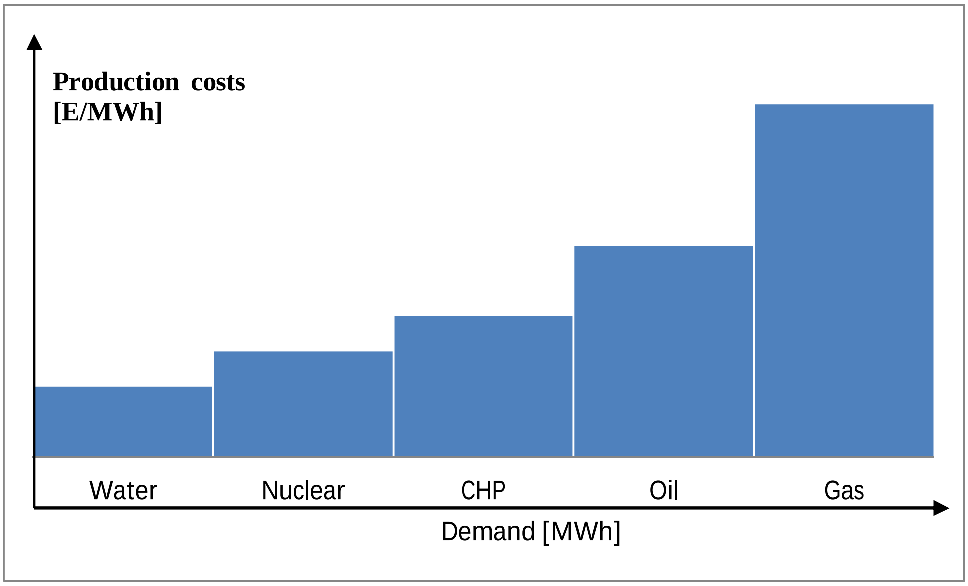

Figure 5.3. The correlation between electricity demand and production costs.

5.3.2 *Case examples on DR researches and projects*

This section presents DR case examples which illustrate impacts of DR. However, it is important to take into account that impacts of DR can vary significantly between different areas. Thus, accurate results can be perceived only in practice, and even then, impacts of DR can be challenging to evaluate accurately. However, introduced case examples provide interesting results from the potential of demand response.

Case 1: Olympic Peninsula:

In the Olympic Peninsula project significant demand response was obtained. (Pratt 2008)

Customers were offered:

- Opportunity for significant savings on their energy bill (about 10 % was suggested)
- A “no-lose” proposition – their bill could not be higher than the normal fixed rate
- Technology that automates their desired level of response and keeps it simple
- Complete control of how much they choose to respond

Achieved demand response:

- 15 % reduction of peak load
- Up to 50 % reduction in total load for several days in a row during shoulder periods

- Response to wholesale prices + transmission congestion + distribution congestion
- Able to cap net demand at an arbitrary level to manage local distribution constraint

Case 2: Residential AC load shifting in the area of California

In this case example a simple residential AC load shifting at the area of California is under consideration. A simple thermostat control device was used to shift peak load demand for residential air conditioning and water heating. (Ilic & al. 2002)

Calculated potential of 83 % load shift in air conditioning was extended to the entire residential loads over a 6 hour peak, which provided a calculated system wide peak load reduction of 12%. This effect on market clearing price was estimated based supply and bid data from the CA Power Exchange. The study suggests that during the price peak, the price could drop from $750 to $424/MWh at 20% estimated load reduction in AC peak power, and to $114 at 35% reduction. By simply shifting load from the hours 13:00 through 16:00, the resulting market cost savings would range from $50M at 20% to $100M at 35% in this area. (Ilic & al. 2002)

As a summary, it can be concluded that 20 % reduction in peak power during the price peak would have decreased electricity price by 33,5 %, and 35 % reduction by 74,8 %. However, it has to be remembered that the results of this study might be a bit distorted because the load pick-up effect have not been taken into account in the examination.

Case 3: Simulations from the Midwest regions of United States

This case example presents the impact of DR on electricity price peaks in the Midwest regions of United States. Results of this study base on the simulations. Analysis has been made by modeling the aggregate supply and demand curves. Table 5.2 presents simulated price spike scenarios in different price elasticity levels of demand and real-time price market shares describing the level of achieved DR. (Caves & al. 2000)

Table 5.2. Simulated price peak scenarios (Caves 2000)

Real Time Price Market Share	**Price Elasticity of Demand**				
	0	0.10	0.20	0.30	0.70
0 %	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000
5 %	$ 10,000	$ 6,189	$ 4,765	$ 4,063	$ 3,182
10 %	$ 10,000	$ 4,141	$ 2,656	$ 2,021	$ 1,253
15 %	$ 10,000	$ 2,945	$ 1,667	$ 1,180	$ 620
20 %	$ 10,000	$ 2,199	$ 1,146	$ 776	$ 373

Based on Table 5.2 can be concluded that significant decrease on price peaks could have been achieved. For instance, 5 % improvement in DR with price elasticity level of 0.1 would have decreased price peaks approximately by 40 %, and with 10 % improvement approximately by 60 %.

5.3.3 *Summary on DR case examples*

Results of different studies shows that demand response may have significant impact on electricity price. The impact of DR on electricity price depends significantly on the structure of production capacity and characteristics of the power system. In addition, for instance customers operation and willingness to promote DR in different areas can vary. Results of the introduced studies, presented in Table 5.3, shows that DR can have significant impact on peak loads and electricity prices during the peak load hours.

Table 5.3. Summary from introduced demand response case examples.

Study / project	Description	Achieved level of DR	Impact of DR on electricity price
Olympic Peninsula project	-Technology automates customer's DR according to desired comfort level - "No lose proposition" were offered to customers - Customers can choose how much they are willing to respond	- 15 % reduction of peak load - up to 50 % reduction in total load for several days in a row during shoulder periods	Not studied
Residential AC load shifting in the area of California	- Simple thermostat control device was used to shift peak load demand for residential air conditioning - The impact of DR on market clearing price was estimated based supply and bid data from the CA Power Exchange	-Results are based on the calculations, no real DR were achieved -The calculated potential of 83 % load shift in air conditioning was extended to the entire residential loads over a 6-hour peak, which provided a calculated system wide peak load reduction of 12%	20 % reduction in peak power during the price peak would have decreased electricity price by 33,5 %, and 35 % reduction by 74,8 %
Simulations in Midwest regions of United States	- Small fraction of retail loads is assumed to be sold at spot prices -Simulation analysis base on the modeling of aggregated supply and demand curves	-Real DR was not achieved, only possible methods for achieving it were considered -Results base on the simulations on different assumed levels of DR and price elasticity	5 % improvement in DR with price elasticity level of 0.1 decreased price peaks approximately by 40 %, and with 10 % improvement approximately by 60 %

5.3.4 *Impacts of DR on retailer's profit optimization*

In a large scale demand response may have considerable impact on typical electricity consumption and price deviations. In particular, at the times of peak consumption and peak prices increase of DR may have major impact on electricity price.

Electricity price and demand are main inputs in electricity retailer profit optimization, and thus, possible impacts of DR on these are important to consider. Figure 5.4 illustrate impacts of DR on a retailer's electricity procurements cost in short-term markets. In general level, the total impacts of DR depend highly on the methods used to achieve DR. In this case, it is assumed that DR can be achieve in the spot markets and balancing power markets, for instance through automated customer load control.

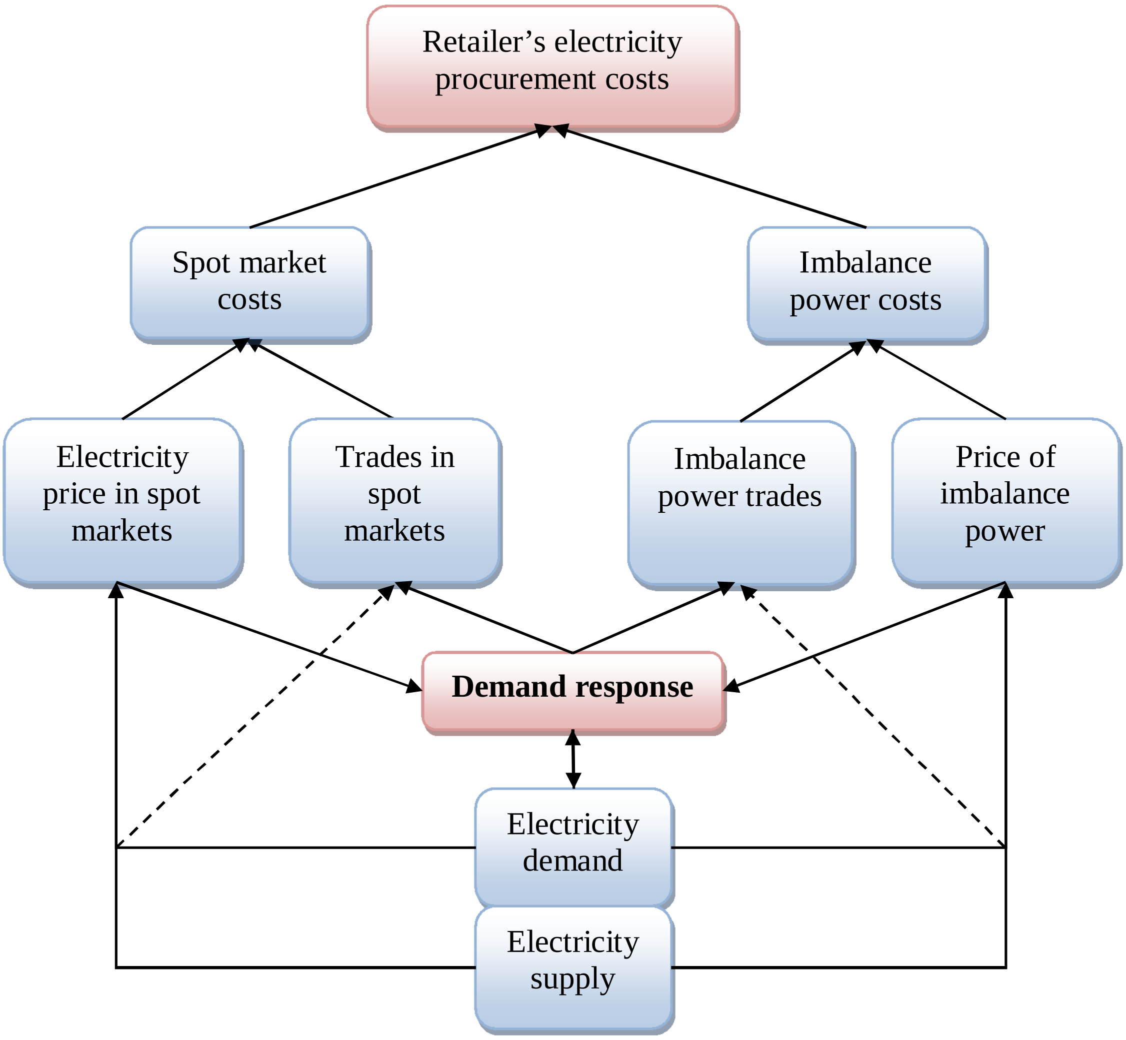

Figure 5.4 Impact of demand response on a retailer's electricity procurement costs in short-term markets.

Impacts of DR depend highly on the existing markets and features of the specific power system. In the best case even a small increase of DR may have a high impact on electricity price. Moreover, the knowledge from the existence of DR may also affect different market players' operation.

From the perspective of an electricity retailer potential benefits provided by the DR include;

- hedge against wholesale price risk
- possible profitable sell-back on high price hours
- increase of overall sales
- increased total margin
- opportunities to commit the costumers

DR may have also other impacts on market players operation and business, customers, and the whole markets. As a summary, it can be concluded that DR will have increasingly important role in the future smart grid environment and considerable impacts on different market parties' operation, which should be taken into account in the planning of futures market, operation and profit optimization models.

5.4 Price of imbalance power

The minimization of imbalance power costs plays an important role in electricity retailer short-term profit optimization. Retailer's imbalance power costs depend on amount of imbalance, price of imbalance power and direction of imbalance. The price of the balancing power in the Nordic power markets is determined based on the principles of marginal pricing. In addition, the direction of regulation and balance power fees affects price of imbalance power.

In general, the price of balancing power depends on the demand and supply of electricity during the specific hour. If demand is high compared to available supply, the price is high, and conversely. Demand and supply of electricity also determine whether the specific hour will be up-regulating or down-regulating hour. Moreover, the direction of regulation has direct impact on price of imbalance power. Table 5.4 presents the relations between price of imbalance power and direction of the regulation in production and consumption balances. Pricing principles of imbalance power are described in more detail in section 3.1.6.

Table 5.4. Relations between price of imbalance power and direction of regulation

	Direction of regulation during the specific hour	**Purchase price of imbalance power** (Price on which Fingrid purchases electricity from balance responsible party)	**Sale price of imbalance power** (Price on which balance responsible party purchases electricity from Fingrid)
Production balance	up	Elspot Fin	up-regulation price
	no regulation	Elspot Fin	Elspot Fin
	down	down -regulation price	Elspot Fin
Consumption balance	up	up-regulation price	up-regulation price
	no regulation	Elspot Fin	Elspot Fin
	down	down-regulation price	down-regulation price

Consumption and production balances have to be examined separately in the planning of retailer profit optimization, because a two-price system is applied in the production balance and one-price system in the consumption balance. However, it should be noted that there is a direct connection between these two balances, because the production plan given for the production balance prior to the delivery hour is processed in the consumption balance.

5.4.1 *Production balance*

In the production balance the pricing of imbalance power is based on the two-price system. Purchase price of imbalance power is at the highest Elspot Fin and sale price at the lowest Elspot FIN. In practice this means that if the retailer has to purchase or sell production imbalance power, it will always result in extra cost compared to the situation in which corresponding electricity trades would have been made in the Elspot market. This is result from the above described pricing principles and balancing power fees, on which the market parties are subjected as a result of imbalance power trades. Consequently, the retailer should always aim to avoid need for imbalance power in the production balance in order to maximize the profits.

During an up-regulating hour the sale price of production imbalance power is the up-regulating price. The highest imbalance power prices emerge during up-regulating hours as a result of high demand of balancing power. In most periods of times the sale price of production imbalance power is relatively close to the Elspot price, but at the times of high demand of balancing power the difference between up-regulating and Elspot price can rice to hundreds of Euro’s per megawatt hour. In the situations where the sale price of production imbalance power is high, it is important that the retailer’s production imbalance is near to zero-level, and rather a bit positive (surplus on production) than negative (deficit on production). However, if the retailer has negative production imbalance at the time of high sale price of imbalance power, the neutralization of imbalance can cause substantial extra costs for the retailer even in a short period of time.

During a down-regulating hour the down-regulating price is used as a purchase price of production imbalance power. The lowest imbalance power prices emerge at the times of down-regulating hours when there is a high surplus in the supply of electricity. Extreme high surplus in the supply side can result in even negative prices. At the times of low purchase price of production imbalance power the retailer’s production imbalance should be near the zero level, and rather a bit negative than positive. However, if the retailer has positive production balance in this situation, the retailer may have to sell back surplus energy to markets with a lower price than the purchase price was, which causes loses for the retailer.

Occasional high volatility of imbalance power prices combined with possible existence of open position poses a substantial imbalance power cost risk for the retailer. In a theory, the retailer can minimize its production imbalance power costs by minimizing the need of production imbalance power to zero level. However, in practice, the retailers are not typically able to do this. Forecasting of future electricity consumption and production is a challenging task, in which is related many uncertainty factors. For instance unexpected events, such as power plant failures, can lead to high forecasting errors and realization of high power imbalance. Consequently, the evaluation of cost risk and avoidance of extra costs caused by imbalance in the production balance is a challenging task in practice.

5.4.2 *Consumption balance*

The calculation of imbalance power cots in the consumption balance is based on the one-price system, and thus, it differs significantly from the calculation of production imbalance power costs. In the one-price system purchase and sale price of imbalance power are the same, during an up-regulating-hour the up-regulating price, and during a down-regulating hour the down-regulating price. From the perspective of an electricity retailer the most significant difference between one-price and two-price system is that in the one-price system, which is applied in the consumption balance, it can be profitable for the retailer to have an imbalance.

During the up-regulating hour the price of consumption imbalance power is at least the same or higher than the corresponding hour's Elspot price. If the retailer's imbalance in the consumption balance is positive in this situation, and the retailer has managed to procure its surplus electricity with a lower price than the price of imbalance power is, the retailer earns profits by selling the surplus energy back to markets. In the best case, for instance at the times of electricity price peaks, this kind of profitable sell-back opportunity can provide significant saving/profits for the retailer. However, if the retailer has, correspondingly, negative imbalance in the above described situation, the retailer suffer loses.

During the down-regulating hour the price of consumption imbalance power is the same or less than the corresponding hour's Elspot price. If the retailer's imbalance in the consumption balance is negative in this situation, and the retailer purchases consumption imbalance power with a lower price than the corresponding hour's Elspot price is, the retailer achieves savings. However, if the retailer has, correspondingly, positive imbalance in the above described situation, the retailer has to sell the surplus energy to Fingrid with a lower price than the Elspot price is, which causes loses for the retailer.

From the perspective of electricity retailer, it is important to consider that in the consumption balance it is not always optimal solution aim to minimize the amount of imbalance. During the up-regulating hours, when the price of the consumption imbalance power is high compared to Elspot price, it is beneficial for the retailer to have a positive imbalance, if the retailer can sell the surplus electricity back to the markets with a higher price than the purchase price was. Correspondingly, during the down-regulating hours, when the price of the imbalance power in the consumption balance is low, it is beneficial for the retailer to have a negative imbalance, if the deficit energy can be purchased from the balancing power markets with a lower price than elsewhere. However, it has to be taken into account that the retailer has to pay balancing power fees from imbalance power trades. Thus, in the preceding cases, the difference between the price of imbalance power without imbalance power fees and the price that the retailer would pay in the other market has to be larger than fees paid from the imbalance power, so that the trading of consumption imbalance power would be profitable for the retailer.

Despite the risk related to being in imbalance, the use of one-price system in the consumption balance may provide interesting opportunities for the retailer to increase profits. In particular, the ability to control DER near the usage hour could provide interesting opportunities for retailers' to develop management of their open positions and resulting power balances. Still, it should be noted that the system operator and regulations of balancing power markets sets limitations to market parties' operation. According to these regulations market parties are not allowed to purposefully make electricity procurements trough contract-based open deliveries (imbalance power trades), and the market parties are obligated to maintain their power imbalances at an appropriate level with respect to the extent of the operation of the party (Fingrid 2011). Even though, these limitations do not significantly limit the retailer's opportunities for active management of open position based on the market situation when it is taken into account that the retailer has to, anyway, keep its open position within reasonable limits in order to avoid possible realization high imbalance power costs.

5.4.3 *Imbalance power cost risk*

The price risk caused by the volatility of electricity prices is one of the greatest risks faced by the retailers in the power markets. In particular, the volatility of imbalance power prices can be high, and thus, the imbalance power cost risk is very important to consider in retailer profit optimization. In addition to the price of imbalance power, the amount and direction of imbalance has impact on the retailer's total imbalance power costs. Thus, in the evaluation of imbalance power cost risk should be taken into account that *positive and negative imbalance poses a different cost risk for the retailer*.

In order to minimize imbalance power costs, the retailer should have ability to forecast future electricity prices and the direction of regulation in the balancing power markets. However, forecasting of future electricity prices and demand is a challenging task, in which is related significant uncertainty. Therefore, one of the simplest ways to manage the imbalance power cost risk is aim to minimize the amount of imbalance. However, if future electricity demand and prices can be forecasted with adequate accuracy, the retailer may be able to improve its profitability by considering the impact of positive and negative imbalance, and planning its profit operation accordingly.

In some cases there are relatively reliable signals that give indication from direction of the regulation and electricity prices in the markets in near future. For example, if weather forecasts indicate extreme cold weather for next few days, it is very likely that electricity demand and prices will rise as a result of increased need of heating energy. Consideration of this type of cases can help the retailer to avoid the realization of imbalance power costs risk, and in the best case even benefit from the price fluctuations.

However, even if the retailer would be able to forecast the price fluctuation, the problem is that electricity prices in all short-term markets can raise at the times of high electricity demand, which eliminates the retailer's opportunity to achieve benefits by trading in short-term markets. Moreover, the increasing amount of intermittently renewable generation may increase the amount of exceptional low and high price hours, and make it even more difficult to avoid realization of price risk. However, the ability to utilize controllable DER as a part of retailer short-term profit optimization can open an opportunity to hedge against this risk and increase retailer's profits, even if electricity prices in all short-term markets would raise to high level.

In general, the price of imbalance power, and amount and direction of retailer's open position after balancing trades determines mainly the retailer's total imbalance power costs. The demand and supply of electricity during the specific hour, in turn, has impact on imbalance power prices and direction of the retailer's imbalance. Figure 5.5 illustrates the factors that have high impact on a retailer's imbalance power costs and relations between these factors.

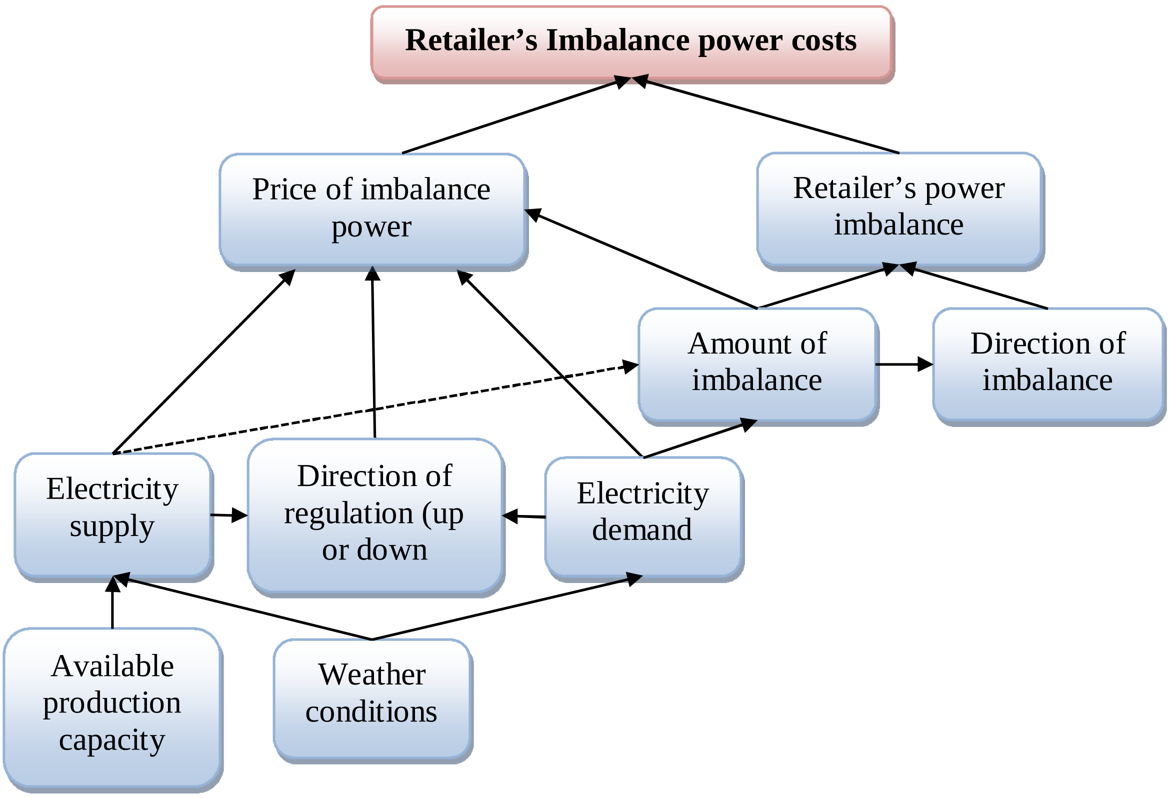

Figure 5.5. The impact of different factors on a retailer's imbalance power costs.

Figure 5.5 shows that many different factors have impact on a retailer's total imbalance power costs, which make the minimization of imbalance power costs a complex task. Forecast from most important impacting factors including electricity demand, supply and price provides a basis for the minimization of retailer's imbalance power costs. Based on these forecasts, and using afore-introduced statistical and risk evaluation methods, expected costs and risks can be evaluated and optimal profit optimization strategy determined for each case.

6 ELECTRICITY RETAILER PROFIT OPTIMIZATION IN THE SMART GRID ENVIRONMENT

The development of smart grid environment is changing fundamentally the nature of electricity retail business. In Particular, improving opportunities to control customers' loads, energy storages and distributed generation can open great opportunities for retailers to promote demand response, hedge against risks and enhance profit optimization. Moreover, new smart grid-based functionalities and services can benefit also other market parties and improve efficient use of energy and power system.

At present, highest obstacles for large-scale utilization of DER typically includes high costs of requisite equipment and systems, and lack of common operation models. In addition, market models should be developed, because some of today's market models may complicate, or in the worst case even prevent cost-efficient utilization of DER in some applications. However, ongoing worldwide research work aims to solve these problems.

So far, this report has examined electricity retailer profit optimization in different operational environments and introduced a model for electricity retailer profit optimization in short-term markets. In addition, the factors having a high impact on profitability of retail business has been introduced. Based on this work, a comprehensive model for electricity retailer short-term profit optimization in the smart grid environment will be developed and introduced in this chapter.

6.1 Minimization of electricity procurement costs

Smart grid environment provides new opportunities to enhance electricity retailer profit optimization. In particular, the utilization of controllable DER seems as potential tool to improve retailer's ability to actively manage open position based on the changing market situations, and thus, improve profitability of retail business.

The management of imbalance power cost risk plays an important role in retailer short-term profit optimization. Price of imbalance power can be significantly higher than the corresponding spot market price, and thus, it has a considerable high impact on retailer's electricity procurement power costs in a short-term. Moreover, the market players have to pay balance power fees from the imbalance power trades, which increase the cost of imbalance power.

As it was concluded in the previous chapters, a good alternative as basic risk avoiding profit optimization strategy is aim to minimize extra costs caused by the imbalance power trades by minimizing the amount of imbalance. In a theory, imbalance power costs are minimized to zero if the retailer is able to avoid the realization of imbalance. However, in practice, this is typically not possible as a result of variations in customers' consumption. Moreover, this basic risk avoiding strategy is not optimal in all situations, because the negative and positive imbalance cause different cost risks for the retailer, and do not provide maximal profits in all cases. Thus, also other profit optimization strategies should be considered.

As a result of the use of two-price system in the pricing of production imbalance power, the trading of production imbalance power creates always extra costs for the retailer compared to the situation, in which the retailer would make corresponding trades in the Elspot market. The pricing of the consumption imbalance power in turn is based on the one-price system, which means that the purchase and sale price of consumption imbalance power are always the same. Consequently, the retailer may get financial benefits through consumption imbalance power trades. The greatest benefits from consumption imbalance power trades can be achieved during unusually high or low imbalance power prices, but the retailer's risk for extra costs is also the highest at these times. Thus, the retailer's ability to manage open position in an optimal way prior to the delivery may have very high impact on the final result.

In the cases that electricity prices during the specific hour differ significantly between short-term markets, it has considerable impact on the retailer's profits how electricity procurements have been distributed between the markets. Thus, if the retailer is able to manage its open position actively by trading in short-term markets based on the changing market situations, the retailer may be able to increase the profits. In addition, the ability to utilize controllable DER in the management of open position can increase the retailer's profits even more. Table 6.1 presents principles for the management of retailer's open position in the cases that there is significant difference between the specific hour's consumption imbalance power price and spot price.

Table 6.1. The management of retailer's open position in cases that there is a significant difference between the specific hour's spot price and consumption imbalance power price

Spot price (P_{Spot})	Price of consumption imbalance power (P_{CIP})	Price difference between consumption imbalance power and Elspot price (=$P_{CIP} - P_{Spot}$)	Optimal direction (/ amount) of Open position
Average / high	Low	**Negative**	**Negative** (Deficit on electricity procurements)
Average	Average	**No difference**	**Zero** (No imbalance)
Average / Low	High	**Positive**	**Positive** (Surplus on electricity procurements)

Based on Table 6.1 can be concluded that if the price of consumption imbalance power (including balance power fees) is lower than the spot price, the retailer should aim to have rather a small deficit than surplus on its electricity procurements. If the prices are conversely, the retailer should aim to have rather a small surplus than deficit on its electricity procurements. In the case that there is no significant difference between different prices, the retailer should aim to minimize the size of its open position to zero level in order to avoid extra cost resulted from balance power fees.

In many cases high or low electricity prices exists at the same times on different markets, and the situation differs from the cases presented in Table 6.1. In cases that electricity prices in all short-term markets are unusually high or low during the specific hour the retailer cannot hedge against high (or low) prices by making trades in different markets, even if it would have ability to somehow forecast the future electricity prices in advance. This is also the reason behind one of the basic problems faced by the retailers in the power markets. Without an ability to control loads or production the retailer may be forced to purchase electricity with high price in order to fulfill its load obligation, which can result in high costs even in a short period of time.

Based on the basic assumption of this study, in the smart grid environment the retailer has ability to control its customers' loads, production, and/or energy storages with relatively low costs. This provides an opportunity to avoid the extra costs, even if electricity prices would be unusually high or low during the specific hour in all short-term markets. Table 6.2 presents the principles for control of DER in cases that electricity prices during the specific hour are at the same level in different short-term markets.

Table 6.2. The principles for control of DER in cases that electricity prices during the specific hour are at the same level in different short-term markets.

Electricity prices in the markets	Load control actions	Production control actions	Energy storage control actions	Open position (optimal direction)
Low	Loads on	Reduce production	Charge	Negative (Deficit on electricity procurements)
Average	No actions needed	No actions needed	No actions needed	Zero (No imbalance)
High	Loads off	Increase production	Discharge	Positive (Surplus on electricity procurements)

Table 6.2 shows that if electricity prices in the markets are low, the retailer should aim to have rather a small deficit than surplus on its electricity procurements, which can be achieved by increasing loads, reducing production and charging energy storages. When prices in the short-term markets are high, the retailer should aim to have rather a small surplus than deficit in electricity procurements, which can be achieved by decreasing loads, increasing production and utilizing the stored energy.

Based on the preceding, it can be concluded that adequate accurate forecasts on future electricity prices and consumption combined with the active management of open position can help retailers to improve their profitability. Thus, the future smart grid environment, and in particular improving opportunities to utilize controllable DER, provides an opportunity to develop and utilize more efficient short-term profit optimization strategies.

6.2 Active management of open position

Active management of open position based on changing market situations and utilizing controllable DER can provide many benefits for the retailer. However, it inquires input data on many variables so that the retailer can operate from the reliable basis and maintaining risk within permissible limits. For instance data and forecasts on electricity prices, electricity consumption and production, and available controllable DER capacity are needed for the planning of optimal electricity procurement strategy and DER controls. In addition, also other data such as weather forecast and customer load models are needed in different subtasks of this process. Figure 6.1 presents an example scenario from active management of retailer's open position in the smart grid environment.

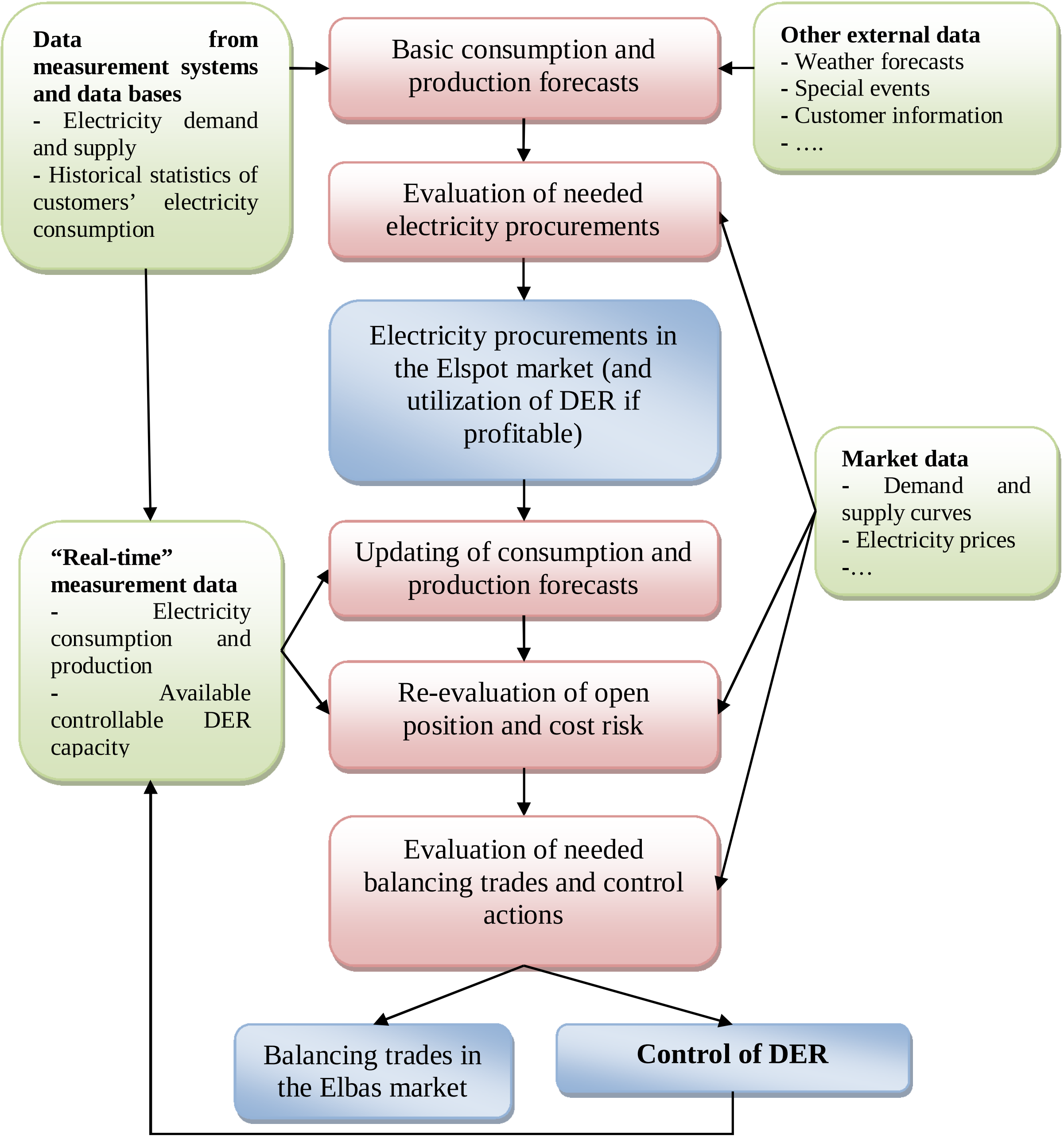

Figure 6.1. Active management of retailer's open position in the smart grid environment

Active management of retailer's open position starts from the evaluation of needed electricity procurements based on the basic consumption and production forecasts. In order to create adequately accurate and reliable forecasts on future's consumption and production, the available data from AMR/AMI systems and other external sources is utilized. Consumption forecasts and electricity market data provides a basis for the planning of electricity procurements in the Elspot market and possible utilization of controllable DER in this stage of the process.

After trades in the Elspot market latest available data from measurement systems and other sources can be used to update consumption and production forecasts. Based on the updated consumption and production forecasts the size of the retailer's open position will be re-evaluated. This information together with the forecasts from future consumption, production, and electricity prices in turn can be used to evaluate the retailer's cost risk and expected electricity procurement costs in the markets, and to determine balancing trades and control actions needed for the maximization of profits. Balancing trades in the Elbas markets can be done until one hour prior to the usage hour, but after that the retailer cannot make trades anymore in the short-term markets. However, the management of open position can be still done by utilizing available controllable DER capacity.

This type of active management of open position makes it possible to adjust on changing market situations. However, it inquires adequate accurate and real-time data on many variables. In practice, equipment and systems used for the DER control and the markets, in which the trades are done, sets the minimum limits for allowed data transfer delays and accuracy of the used data. In general, the more real-time and accurate data is used the better basis it provides for forecasts, evaluations and the retailer's whole operation.

6.3 Control of distributed energy resources

One of the greatest potential benefits for the retailer provided by the utilization of controllable DER would be the improved ability to manage open position (and resulting power balance) close to the moment of delivery. In a principle, DER control could be executed very close to the moment of delivery (after the Elbas trading has already been closed), if control commands can be put in practice with minor delays. This would enable the retailer to adjust flexibly on changing market situations and hedge against price risks, or even benefit from the price fluctuations, even if the market situation would otherwise prevent it.

In general, an ability to control DER would increase the flexibility of retailers' operation and provide an opportunity to use new kind of profit optimization strategies. However, the optimized control of DER is a complex process and inquires input data on many variables. Figure 6.2 presents a scenario which illustrates utilization of DER as part of electricity retailer profit optimization in the smart grid environment. In this scenario is assumed that market models, other market players' actions or other external factors will not limit the retailer's ability to utilize controllable DER as part of short-term profit optimization.

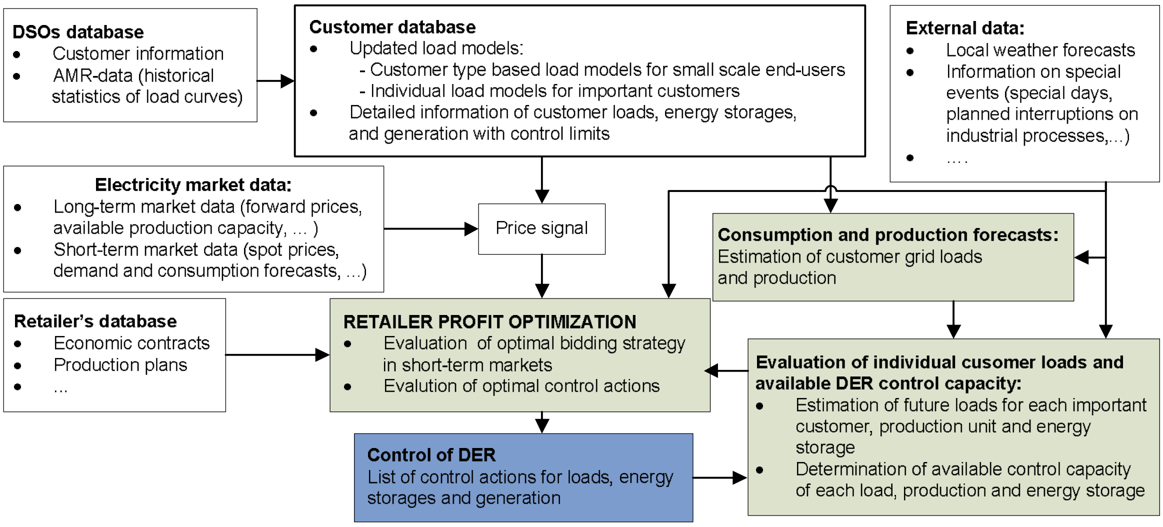

Figure 6.2. Utilization of DER as part of the retailer short-term profit optimization in the smart grid environment

Figure 6.2 shows that the determination and execution of optimal control actions inquires many inputs and subtasks. At the end, the use of DER controls is based on the retailer's profit optimization strategy, which also determines the retailer's bidding in short-term markets. The most important inputs for the determination of optimal profit optimization strategy in turn include price signals and forecasts from future consumption and production.

Typically the main input data for consumption forecasts has been the local weather forecasts and customer load models. However, in the smart grid environment also other data can be utilized in load forecasting. For instance, AMR-data on customer's historical statistical load curves can be used for detailed classification of customers, determination of basic customer type load profiles and creation of individual load models for important customers. Real-time measurement data on customers' recent loads, in turn, can be used to update load forecasts close to the moment of delivery. The retailer can benefit from the updating of load forecasts, in particular, in case that there is strong indication from possible electricity price peak, high uncertainty related to accuracy of load forecasts or indications on other corresponding events which could lead to realization of high risks, or offer an opportunity to achieve additional benefits through active management of open position.

In a theory, the maximization of retailer profits is done based on the Equation 4.13. In practice, however, the evaluation of optimal profit optimization strategy is a complicated task because of high number of input variables, on which many includes significant uncertainty. Thus, in order to maximize the profit and maintain risks within allowable limits the retailer needs accurate and up to date data on many variables. For example, information on economic contracts and production plans, estimated and known electricity prices, load and production forecasts, and detailed data from customer's loads, production and energy storages is needed for the determination of optimal profit optimization strategy and DER control actions. Moreover, the retailer has to also consider possible special events and other factors which can result in extra costs. These include for instance electricity price peaks, which are hard or even impossible to forecast in advance. Allocation of controllable DER capacity in the reserve in case of this type of events could be, for instance, one way to hedge against this type of risks.

Example scenario presented in Figure 6.2 is based on the assumption that the retailer can utilize controllable DER without any significant limitations set by the market or operational models. However, it is not known how the smart grid environment, including the operational and market models, will develop in the future. Changes in the market and operational models can set new limitations, but also open new opportunities for retailers. Moreover, different market players have different interests for the utilization of DER, and thus, possible conflicts of interest between the market parties should be taken into account. The solution for these conflicts can be found for instance trough the development operation, market and/or pricing models. These models should be developed so that the conflicts of interests between the market players can be minimized and the best overall benefits will be achieved.

Anyway, the utilization of controllable DER as part of electricity retailer/trader profit optimization could provide numerous benefits. In general, it would increase the retailer's ability to operate more flexible and provide new avenues to hedge against risks and improve profitability of retailer business. In particular, the use controllable DER close to the moment of delivery could provide whole new opportunities to improve retailers' short-term profit optimization. The more detailed analyze from business potential of DER control as part electricity retailer short-term profit optimization would, however, inquire further study, which is beyond the scope of this study.

7 CONCLUSIONS AND FUTURE RESEARCH

This report presents a comprehensive model for electricity retailer short-term profit optimization. The model is created based on the theoretical analysis which considers the most important factors having an impact on retailer's profitability in short-term markets. In addition, the distinctive features of different operational and market environments have been presented in the report and taken into account in the model building. The model is created for Nordic electricity markets, but the same basic principles for retailer profit optimization can be applied also in other same type of markets in a great extent.

In the literature many different approaches are used to address electricity retailer/trader profit optimization problem. The most commonly used include optimal portfolio planning, evaluation of optimal bidding strategies, and determination of optimal risk premiums and electricity sales prices. Among the examined studies can be found many different techniques to present and solve electricity retailer profit optimization problem. For instance stochastic programming, decision making support tools and decision making frameworks has been used. However, this study presents a new approach for electricity retailer profit optimization problem by presenting a comprehensive model for electricity retailer short-term profit optimization, in which have been considered also the use of controllable DER as part of electricity retailer profit optimization.

The main results of this study include the presentation of basic methodology for electricity retailer short-term profit optimization. However, many problems remain still unsolved and needs a future research. At the below is presented some important research questions which inquire further study:

- What kind of data transfer, cost sharing and benefit sharing models or other solutions is needed to enable large-scale utilization of DER?
- How the implementation of DER controls could be realized in practice considering all different market parties' interests?
- What kind of business potential the utilization of controllable DER can provide for the retailer?
- How large controllable DER capacity the retailer would need in order to maximize its profits?
- On which market situations controllable DER should be utilized, and how?

When technological requirements and needed operation and market models exists, utilization of controllable DER can offer a great tool for electricity retailers to hedge against risks and improve profitability of electricity retail business. In addition, new functionalities and ancillary services enabled by the smart grid environment can provide many other benefits such as improve efficient use of energy, help retail customers to achieve saves in their electricity bills and to decrease use of typically more expensive and higher emissions providing peak power production capacity.

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