Chapter 5
The functioning of power exchanges

The objective of this chapter is to provide a detailed description of the functioning of power exchanges or more precisely of the power exchanges' spot market. While in practice differences exist between power exchanges in Europe, some general common principles can be identified. Hence the general description given in this chapter can easily be applied to Nord pool, APX, UKPX, LPX, EEX and Powernext. This chapter starts with a general description of trading on a power exchange. Then the different types of bids and the price determination processes are presented, followed by an analysis of the interests of auction theory for the understanding of power exchanges. The issue of physical delivery of trading on a power exchange is addressed and the interactions between power exchanges and others market, such as the bilateral market or the balancing market, are analyzed.

5-1 Trading on a power exchange

5-1-1 Introduction

Electricity power exchanges are marketplaces, i.e. they are a third party which facilitate the transaction between a seller and a buyer. Hence, power exchanges have trading rules, which cover the setting of prices, delivery, clearing, type of product, timing…etc. The role of a power exchange is to facilitate the trade of short-term products. The aim is to help market participants balance their purchase and sale obligations in the short run. Concretely, a power exchange offers a neutral marketplace where all trading participants trade anonymously (Schulte-Beckhausen, 2001). One interest of power exchanges is that they provide a public price index which can be used for the whole power market.

5-1-2 Products

The main products exchanged on European power exchanges are hourly spot contracts. Spot contracts on a power exchange are agreements to buy or sell electricity for the following day for a certain price. These contracts specify the asset, the contract size, how the price will be quoted, where and when delivery will be made and how the price paid are be determined. The asset is clearly defined unambiguously as electricity on the high voltage grid. In practice, the contract size is mainly defined by a minimum value of 0.1 to 1 MWh. Power exchange's prices are quoted mainly in Euro per Megawatt hours in continental Europe, in Scandinavia and in the UK the price are quoted in national currency. The place for delivery is defined with the system operator[1].

5-1-3 Exchange clearinghouse

As for any organized market, e.g. stock markets, a clearinghouse is subordinate to the power exchange and acts as an intermediary for transactions. The role of the clearinghouse is to guarantee the financial reliability of the parties of each transaction. Its main task is to keep track of all transactions. The clearinghouse can then calculate the net positions of each participant which are required to maintain a margin account with it. Depending on their transactions, participants may have to add or remove funds to their margin. The principal objective of the margining system is to reduce the risk that market participants would not be able to pay for their transaction. In turn such a system hedges market participants against credit risk

5-1-4 Regulation

The purpose of market regulation[2], from a power exchange point of view, is to provide uniform, non-discriminatory rules for fair-trading on the power exchange. Power exchanges defined rules and instructions to provide an adequate functioning of their markets. Power exchanges monitor the trade of electricity on their spot market and supervise the observance of the rules by the participants in the same way that all organized markets do, e.g. like stock markets and financial markets. While classical organized markets are regulated by specific authorities, most existing power exchanges are not subject to the supervision of any external regulatory body. Regulatory bodies are responsible for licensing exchanges and approving contracts. They also deal with complaints and ensure disciplinary action when it is appropriate.

For instance, in the United States, futures markets are regulated by different bodies like the Commodity Futures Trading Commission (CFTC), the National Futures Association (NFA), the Securities Exchange Commission (SEC) etc. In Germany exchanges are considered to be institutions under public law and therefore they are subject to public law. The legal bases are the exchange laws under the supervision of the Exchange Supervisory Authority[3]. In the Netherlands, the Electricity Act 1998[4] which implement the EC Electricity Directive does not provide any rules with regards to the regulation of the Dutch

---

[1] See section 5-3
[2] See chapter 10
[3] See LPX-EEX website: http://www.lpx.de/organization/regulations/index_e.asp

power exchange (APX). Hence, neither the Dutch energy regulator (Dte) nor the Supervisor of financial institutions (Ste) are charged with the supervision of APX (Roggenkamp, 2001). The regulation of electricity trading on the French power exchange is based under financial regulation as, by a legal fiction, operators are supposed to trade only financial instruments but not physical electricity contracts[5]. Moreover, the French energy regulator has access to the data of the exchange[6]. In conclusion, it is worth noting that the regulation of most electricity power exchanges in Europe differs and does not have formal and direct legislation governing trade in spot trading.

5-2 Price formation mechanisms

5-2-1 Introduction

All power exchanges have trading rules. Amongst them, the method of setting the price, i.e. price formation mechanism is fundamental since it represents the heart of the exchange. Several examples are given below[7]. First we describe the two main categories[8] of bids, i.e. hourly bids/block bids, then we analyze the matching mechanism.

5-2-2 Hourly Bids

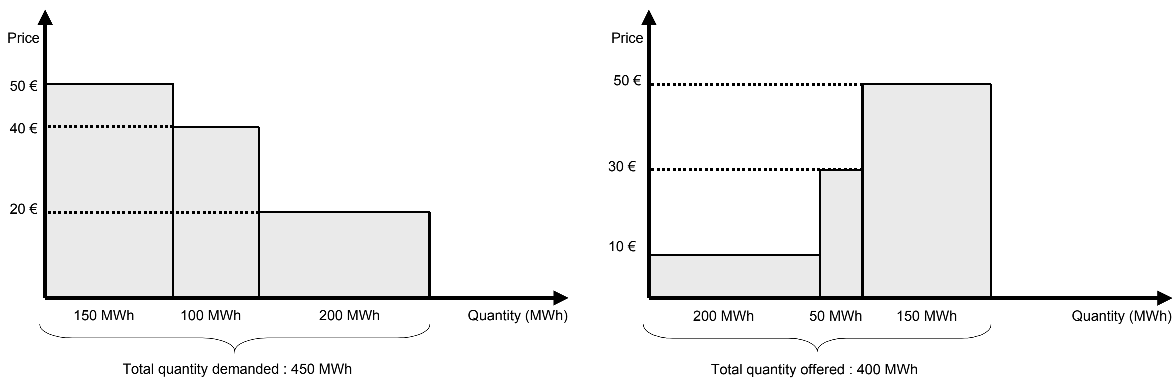
Bids are an offer made by markets participants addressed to the power exchange to buy or sell a certain quantity of electricity at a maximum or minimum price expressed in Euro/MWh. Hourly bids[9] are the basic type of power exchange order, representing the largest share of volume traded[10]. Each participant selects its own range of price steps and build its own bid based on consumption need, delivery obligations, cost of own production and position on the bilateral market. Hourly bids consists of five types of information: Name of the participant, type of

---

[4] Available at : http://www.minez.nl/energie
[5] Available at : http://www.powernext.fr/
[6] Article 4.5 of the exchange regulation
[7] The different examples are taken from LPX's, APX's EEX's UKPX, Powernext's and Nordpool's brochure, available on their respective website.
[8] Note that Nord pool also offers flexible hourly bids, see http://www.nordpool.no/marketinfo/index.html
[9] It is worth noting that unlike power pools, supply offers to power exchanges are not required to be linked to any production facility.

bid (sale or purchase), hour of the day (1 to 24[11]), quantity of energy and price. Within the same hour, participants are allowed to offer different price-quantity pairs.

Figure 5-1: Examples of bids on a power exchange



Player	Type	Hour	Quantity	Price
Company Y	Purchase	22	150	50
Company Y	Purchase	22	100	40
Company Y	Purchase	22	200	20

Player	Type	Hour	Quantity	Price
Company X	Sale	13	200	10
Company X	Sale	13	50	30
Company X	Sale	13	150	50

Figure 5-1 presents two examples of bids for a buyer and a seller for two different hour of the day. These bids can be read as follow. For hour 22, company Y is willing to buy until 150 MWh at a maximum price of 50 Euro/MWh, an additional volume of 100 MWh at a maximum price of 40 Euro/MWh and finally an additional volume of 200 MWh at a maximum price of 20 Euro/MWh. For hour 13, Company X is willing to sell up to 200 MWh at a price of 10 Euro/MWh or higher, an additional volume of 50 MWh at a price of 30 Euro/MWh or higher and finally an additional volume of 150 MWh at a price of 50 Euro/MWh or higher.

Within a single hour, each participant can also bid for sale and purchase. To illustrate the functioning of such bids, we will consider the case of a producer (hereafter producer P) that needs to cover, at hour 12 the following day, a

[10] See Nord Pool, *Bidding on the spot market*, available at http://www.nordpool.no/information/index.html

[11] Hour 1 refers to the time period between 0h00 and 1h00, hour 2 refers to the time period between 1h00 and 2h00 etc.

demand of 20 MW and has an available capacity of 30 MW at a variable cost between 20-25 Euro/MWh[12].

Table 5-1: Simultaneous sale-purchase bid

Player	Type	Hour	Quantity	Price
Producer P	Purchase	12	20	19
Producer P	Sale	12	10	26

In this example the producer will buy from the market, rather than use its own resources, if the market clearing price (MCP) turns out to be lower than its lowest production cost (less than 20 Euro/MWh). If the MCP is higher than its highest production costs (more than 25 Euro/MWh) the participant will use its own resources to satisfy the demand of 20 and will sell its extra capacity to the market[13].

5-2-3 Block bids

Block bids are unique to electricity exchanges compared to other commodity exchanges. They are designed to capture the peculiarity of electricity. Since electricity is traded on an hourly basis and since some power plant are not flexible at short notice, or the cost of starting and stopping the power plant is high, block bids allow participants to sell or buy electricity for a period of consecutive hours during the day. This kind of bid contains a “limiting price” that indicates that if the average clearing price over the period is lower than the limiting price, the trade algorithm will withdraw the whole bid.

If the average clearing price over the period is higher than, or equal to, the limiting price, the trade algorithm will take into account the whole bid. The bid will also have a volume condition: the whole amount of energy has to be accepted by the matching process. Block bids can be specified by the exchange or by

[12] For the purpose of this example technical aspects such as starting costs are ignored
[13] See chapter 6 for more about participants behaviors

players. For instance a “baseload” block bid consists of a bid for hour 1 to 24 while a tailor made block bid can be a bid for hour 9 to 12, 9 to 20, 16 to 24 and so on. For instance Nord pool has five different block periods:

- Block 1 Hours 1-7
- Block 2 Hours 8-18
- Block 3 Hours 19-24
- Block 4 Hours 8-24
- Block 5 Hours 1-24

Just as with hourly bids it is also possible to place several bids for the same block.

5-2-4 Matching

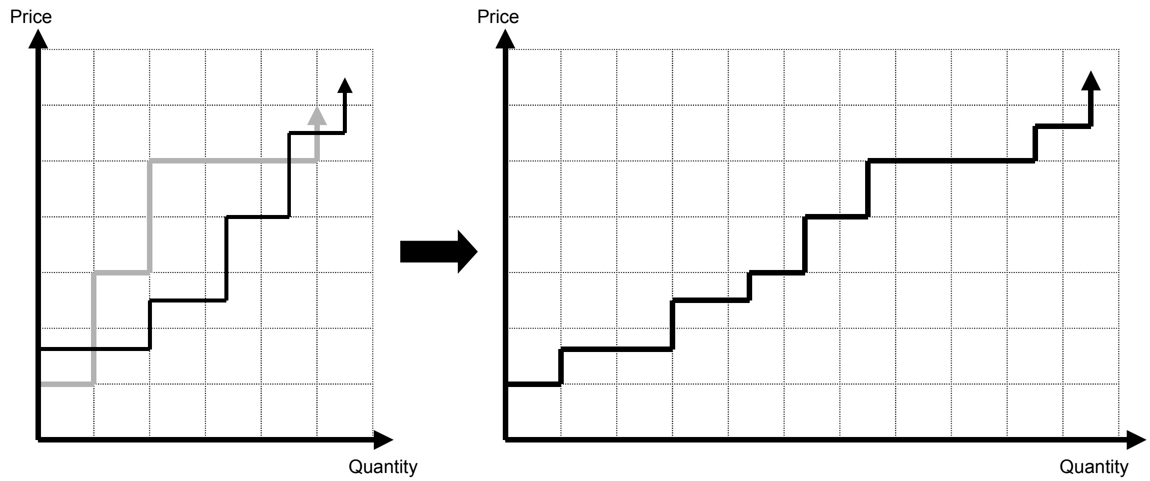
Most European power exchanges[14] are based on a two-sided auction. This means that both offers and demand are taken into account to fix the price. The auction is characterized by the fact that all bids are first collected and then used to determine the prices[15]. The bids are anonymous which means that bids of each participant are not revealed to any of the other trading participants.

The power exchange collects the bids for all players for every trading session and for each hour an aggregated purchase curve and an aggregated sale curve is obtained. The aggregated sale curve is obtained by adding the energy offered in increasing order of prices, regardless of participants. The aggregated purchase curve is obtained in the same way but in decreasing order of prices, see figure 5-2 for an example of the aggregation of two sale curves.

[14] APX, UKPX, LPX-EEX, Powernext, and Nord Pool

[15] Note that in addition to the auction EEX offers continuous trading mechanisms, see http://www.eex.de/spot_market/info/market_model/index_e.asp

Figure 5-2: Aggregation of sales curves



Sales and purchases bids are grouped and plotted as step functions (or curves) as shown in figure 5-2.

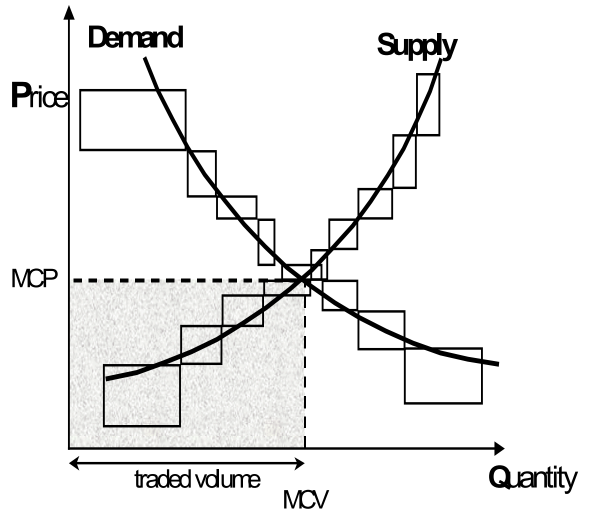
The intersection point of the two curves defines the market clearing price (MCP) and the market clearing volume (MCV) for each hour (figure 5-3)[16]. In other words, the sellers are prepared to offer MCV at MCP and the buyers are prepared to purchase MCV at MCP. The sale bids submitted with a price lower or equal to the MCP and the purchase bids with a price equal or higher than the MCP are accepted while the others are rejected.

Block bids are integrated into the hourly auction by changing block contracts into price independent bids for the hours concerned. In the first phase of the calculation, the limit fixed by the participant is ignored. When the first price calculation is finished, the average hourly price of the corresponding block hours is compared to the price limit of the block bid defined by the participant. If the

[16] Some exchanges, like Nord pool and Powernext, make a linear interpolation of volumes between each adjacent pair of submitted price steps (which ensures only one intersection point) while others use the step functions directly (which involves a set of rules for when the supply and demand curves cross at many points)

average hourly price is equal or higher than the limiting price, the block bid is fulfilled.

Figure 5-3: Determination of MCP and MCV



5-3 An auction theory approach of power exchanges' functioning

Auction theory[17], with the development of organized electricity markets, i.e. power pools and power exchanges, that use auctions to determine equilibrium prices appears to be an interesting approach for analyzing these new markets. It is worth noting that most auction theory restricts attention to the sale of a single indivisible unit (Klemperer, 1999) and this cannot be applied directly to electricity. However recent researches on multi-unit auctions can be directly applied to power exchanges. In this section we present the main strengths of auction theory for analyzing a power exchange's functioning.

In auction theory terms, power exchanges are organized as first-price (or uniform), multi-unit (Kahn *et al*, 2001), double sided auctions (Wilson, 1985). In this type of auction, market prices are determined by the bid price of the marginal

[17] For an historical perspective on auction theory see Shubik (1983). Two very readable introduction are Maskin and Riley (1985) and Klemperer (1999)

accepted bid[18] (*first price*). In such an auction buyers bid demand curves and sellers bid supply curves for a homogeneous good (*multiunit*). Finally on power exchanges buyers and sellers are treated symmetrically[19] with buyers submitting bids and sellers submitting asks (*double auction*). While within this general framework many differences in auction design exist in practice, auction theorists have identified three features of electricity auctions that are crucial for the analysis: the number of bids that may be submitted, the duration of suppliers' bids, and the existence of binding constraints (Fabra *et al*, 2002).

Box 5-1: The four basic types of auction in theory (for a single object)

The ascending-bid auction:
In this auction, also called the open, oral or English auction, the price for an object is raised successively until one bidder remains, and that bidder wins the object. This auction can be run by having the seller announcing prices, or by having the bidders call out prices or by having bids submitted with the highest bid securing the object.

The descending-bid auction:
This auction works in exactly the opposite way to the ascending-bid auction. The auctioneer starts at a very high price and then lowers the price. The first bidder to indicate he will accept the current price secures the object at that price.

The first-price sealed-bid auction:
In this auction each bidder submits independently a single bid, without seeing others' bids. The object is then sold to the bidder who makes the highest bid at the price of this bid.

The second-price sealed-bid auction:
This auction (also called a Vickrey auction), works in exactly the same as the first-price sealed-bid auction, the object is sold to the bidder who makes the highest bid. However, the price paid is that of the second-highest bidder's bid.

Source: Klemperer P. (1999), "Auction Theory: a guide to literature"

[18] In contrast, in discriminatory auctions (or pay-as-bids), such as the England and Wales balancing market, suppliers are paid their bids and consumers pay an average price (see chapter 3)
[19] In standard auction theory a single buyer controls the trading mechanism while many buyer submit bids.

On a power exchange, the number of bids submitted is limited by time period. For each hour (or half-hour), suppliers can only submit a limited number of bids. For instance, on the Spanish electricity "pool" and on the Amsterdam Power Exchange 25 price-quantity pairs can be submitted by suppliers, 62 can be submitted on Powernext and Nord pool etc. Hence the bids consist of several price steps. These types of auctions are called *discrete* multi-unit auctions in contrast to auctions for perfectly divisible goods (Klemperer, 2000; Elmaghraby and Oren, 1999). Such a distinction is important because the output of auctions with discrete bid function can differ significantly from auctions working with a continuous bid system (Von der Fehr and Harbord, 1993; Nyborg 2001). Auction theory shows us that the design of the functioning of a power exchange has a large influence on the behavior of the exchange's participants:

"[…] in the continuous auction, suppliers can bid in very steep supply functions which eliminate a rival's incentive to bid more aggressively. Discreteness in the bid functions rules this out, however. When suppliers are limited to a finite number of price-quantity bids, a positive increment in output can always be obtained by just slightly undercutting the price of a rival's unit. Since this "quantity effect" outweighs the "price effect", the collusive equilibrium found in the continuous auction cannot be implemented" (Fabra *et al*, 2002).

The duration of suppliers' bids represent an important characteristic of an electricity auction. In most power pool models, e.g. Australia, Argentina and the now defunct England and Wales pool, generators bids are valid for long period, e.g. bid valid for one week or one year. In contrast bids are only valid for a single period on most European power exchanges. Such differences between validity of bids greatly influences the functioning of the marketplace (Back and Zender, 1993). Finally, since in many periods, mainly peak hours, there is no excess supply when the capacity of a single firm is taken out of the market, there are binding constraints. The existence of these binding constraints has a strong impact in the formation of the equilibrium.

In conclusion, auction theory definitely provides us with a very interesting and promising approach for the analysis of price determination process on power exchanges. This approach is well suited because most of the electricity markets created to date are characterized by auctions. However it is worth noting that this approach has mainly been used for mandatory pools (Von der Fehr and Harbord, 1998; Green an Newbery, 1992) and when we use it for “European style” power exchanges we are confronted with a major difficulty (already mentioned in the previous chapter) regarding market modeling, i.e. power exchanges represent only a part of the market. Therefore relationship between generator production and bids on the power exchange is difficult to identify. In Europe the bilateral market represents an important part of the overall market and its functioning, and this influences the power exchange, yet it is not based on an auction but on bilateral negotiation. Moreover, the role of the block bid, that is interrelated across time periods, is specific to electricity power exchanges and their exact role in the price determination process remain difficult to assess from a theoretical point of view.

5-4 Physical aspects

5-4-1 Delivery

Once the market-clearing price and market clearing volumes have been determined, spot trades on a power exchange lead to physical delivery. The place of delivery is commonly defined as a hub. In most European markets the hub is a geographical area consisting of the national high voltage grid. This hub is determined in collaboration between the system operator and the power exchange. If players want to buy electricity on a power exchange for delivery on another hub or sell electricity from a different hub they have to enter the procedure for cross-border exchanges. For instance, a participant based in France that is willing to sell electricity on the UKPX in the United Kingdom must first acquire interconnector capacity on the auction[20] between France and the UK

[20] See http://www.rte-france.com/htm/an/offre/offre_inter_2.htm

which is run jointly by the French and the British system operator. Secondly when the desired volume of interconnection capacity has been secured, the participant has to enter the auction of the UKPX. If the offer of the participant is matched, according to the agreement between the power exchange and the system operator, and the British system operator is responsible for physical delivery.

Since electricity cannot be stored a high level of collaboration with the system operator is required for the good functioning of the exchange. On one hand the power exchange manages price determination, while on the other hand, the system operator is responsible for physical delivery. Technical aspects such as the capacities available for transmission at national and international levels are very important since they can have a great influence over prices. Each trading participant must be part of the balance area, or must have access to the balance area through interconnection capacities.

In practice, after matching, the power exchange transmits the trading result to the system operator. The power exchange is the counterpart in every trade and its net position is always neutral, i.e. the total volume sold always equal the total volume bought. The system operator can schedule physical flows[21] once they have received the market results.

5-4-2 Congestion management

From a technical point of view, one of the important characteristics of power exchanges in the Hybrid model is that they do not take into account technical constraints such as congestion[22] within the hub covered by the marketplace. Hence, all market participants can participate to the power exchange regardless of the place where they deliver or withdraw electricity within the hub. Such an approach has been possible in most European countries because national

[21] See chapter 9

[22] In other models power exchanges can play an important role with respect to congestion management (see chapter 9)

networks are relatively dense. The first strength of this approach is that participants on the exchange can consider all their production and consumption capacity as a single entity allowing them to trade their electricity globally on the market. In contrast to nodal pricing, such an approach increases the size of the market by allowing a large number of players to compete. This “single-hub” approach is made possible by the transmission system operator that ensures balancing of the system and handle transmission constraints within the hub.

Concretely, the power exchange submits the result of the matching to the system operator. This schedule is balanced since on the power exchange the aggregated supply equals the aggregate demand. However, transport of electricity follows the laws of physics. Hence the transmission system operator must determine the technical feasibility of the resulting flows of electricity for the submitted pattern of supplies and demand. When a flow is not feasible, the TSO uses different protocols to create a feasible flow. The balancing market is one of these protocol. These aspects are totally ignored by the power exchanges. This model is made possible by the fact that within each hub, which corresponds to one country[23], the transmission constraints are relatively low (EC, 2001g)[24].

5-5 Power exchange and others markets

5-5-1 Interactions PX-bilateral market

Power exchanges and the bilateral markets (OTC) are rivals, yet complementary and interdependent. They are rivals because the coexistence of power exchanges and bilateral markets allows competition between the two types of market (Gjerde, 2002). From a participant’s point of view this competition is beneficial. Since power exchanges are voluntary markets, players can always use the bilateral market whenever the costs of trading on the organized market are too high. Hence if the cost of using an exchange does not reflect a real advantage, trading can be conducted outside the exchange. Such a system

[23] Except Nord pool

[24] The limits of this approach are discussed in chapter 9.

ensures that the power exchanges do not charge too high prices for their services.

The concept of transaction costs has been introduced by Coase (1937) n economic theory and developed by many economists such as Alchiam & Demsetz (1972), Williamson (1979), and Milgrom and Roberts (1991). Analyses of transaction costs have tried to explain why some transactions are organized within the firm and others in the market. For the purpose of this section, the transaction costs that are considered are related to two different markets: organized markets, i.e. the power exchange and bilateral markets. A complete estimation and comparison of these costs is beyond the scope of this work, the objective here is to present the main determinants of these costs.

From a market participant point of view, the choice between using the OTC market or a power exchange for spot trading is directly related to the difference between the transaction cost of using the exchange (C_{px}) and the transaction cost incurred with an OTC day-ahead transaction (C_{otc}). How those costs might be estimated is presented in table 5-1. Assuming that in a perfectly arbitraged market the spot price on the power exchange is equal to the spot price on the bilateral market, when $C_{px} > C_{otc}$ the market participant will use the OTC market and when $C_{px} < C_{otc}$ the participant will trade on the power exchange. The transaction costs are composed of two main elements[25] on a power exchange: the transaction fee and the time spent. On the OTC, market the transaction costs are related to the time spent and the risk and disadvantages of spot trading on a bilateral basis.

Calculating the transaction costs of using the power exchange is relatively straightforward. The transaction fees define the costs of using the exchange. On most power exchanges this cost is related to the volume of transaction (table 5-2

[25] Annual fee and entrance fee are not taken into account since they can be considered as sunk costs: they are paid for a year regardless of the volume of trading.

gives some example of transaction fees). Time spent refers to the time required to make the transaction. While it is quite difficult to estimate the cost related to "time spent" in money terms[26], it is easy to compare how much time is required to make exactly the same deal on the power exchange' s spot market compared to the OTC's spot market. On a power exchange the time required to close a transaction is very low since the contract terms, i.e. payment, delivery area, settlement, are already defined by the power exchange. Hence the time spent to obtain a contract on a power exchange is mainly the time necessary to place bids on the Internet interface. However on the OTC market the contract terms have to be negotiated for any new transaction. Even with standard bilateral contracts, simply filling in and checking the contract is more time consuming that placing bids on the power exchanges[27].

The OTC markets also involve searching costs, i.e. each buyer has to find a seller and vice versa. This searching phase increases the time necessary for closing a transaction. Additionally when two parties have met they have to determine the price for the transaction, this process induces bargaining costs (Williansom, 1979). Two others disadvantages of bilateral markets for spot trading should be included in the transaction costs. One, a premium for credit risk must be included. On a power exchange, credit risks are covered by the exchange. On the bilateral markets the recent collapse of Enron[28] has shown that credit risk is a very important issue. Two, there is the cost associated with the problem of "non-anonymity" on the bilateral market. Indeed the fact that on a power exchange the position of each company is confidential can be very valuable, especially when the market is tight. Hence it can be argued that, for a player, revealing its position to other players represent an additional cost of using the bilateral market.

---

[26] Number of hours time number of people time average salary of peoples involved can be a first indicator

[27] The standard contract defined by the European Association of Energy Trader contains 50 pages, see http://www.efet.org

[28] See http://specials.ft.com/enron/ for more information on the impact of Enron's collapse

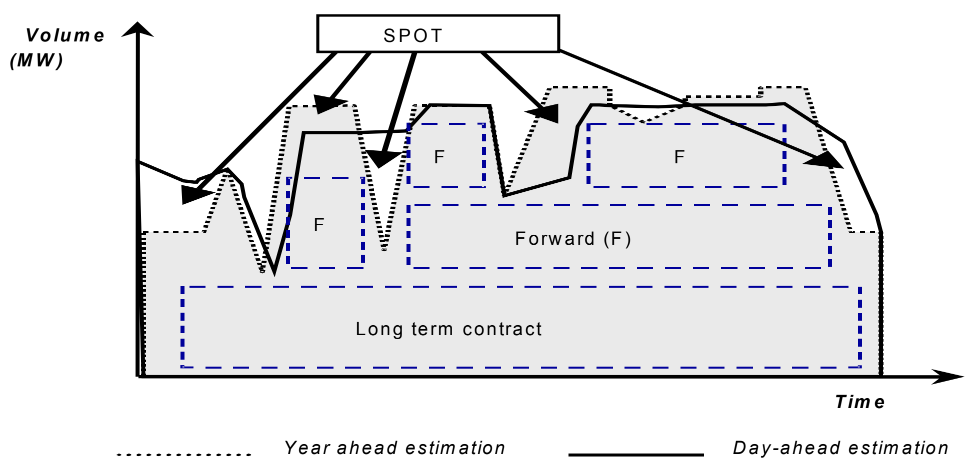
Table 5-2: Cost of trading

Power exchange	Bilateral market
• Time spent - Placing bids • Transaction fee - APX: 18 €/MWh - LPX: 4 €/MWh - Nord pool : 3 €/MWh	• Time spent - Searching costs - Contract definition - Bargaining costs - Premium for credit risk - Premium for "non-anonymity" - ...

Source: APX, LPX, Nord pool

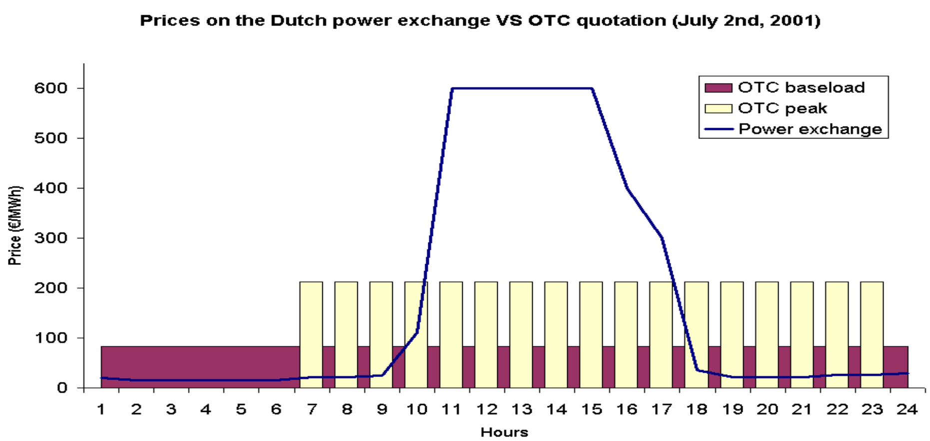
Bilateral markets and power exchanges are complementary because competition is limited between the two types of markets to day-ahead trading. Market participants mainly use the OTC market for forward contracts, which cover longer periods than one hour and are traded a long time in advance. For instance, a large consumer of electricity will contract different long term and forward contracts for its own consumption with respect to its estimation of its load curve one year in advance (figure 5-4). Since, day-ahead estimation are more precise than year-ahead estimations, any market participant may use the power exchange to adjust its portfolio.

Figure 5-4: Spot Trading and bilateral contracts



Power exchanges are complementary to OTC because they quote hourly prices while OTC prices are usually quoted for 2-3 periods (baseload, peak, off-peak). Hence, even if power exchanges only represent a small part of the total market they provide additional information about the market situation on an hourly basis. This information is especially relevant due to the large change in market conditions that may occur at very short notice. An example where information provided by the power exchange gives a better idea of market conditions than just the OTC quotation is shown in figure 5-5.

Figure 5-5: Additional information provided by a PX compared to OTC quotation



Source: APX, European Power Daily[29]

Power exchanges and bilateral markets are interdependent for two reasons. One, in the case of the OTC day-ahead market, the price between the power exchange and the bilateral market must be very close[30] otherwise arbitrage will occurs, i.e. buyers will go to the "low price market" and sellers to the "high price market" increasing the price on the first one and decreasing the price on the second one until they equal. Two, in the case of OTC excluding day-ahead, any contract sold or purchase on the bilateral market can be renegotiated on the

[29] European Power Daily , Volume 3, Issue 127, (July 03, 2001)
[30] See chapter 7 for empirical estimations

power exchange. Hence, participants “overcontracted” or “undercontracted” on the bilateral market can use the power exchange to balance their position.

5-5-2 Interactions PX -balancing market

So far little research has been done on the question of the interaction between power exchanges and balancing markets in Europe. The relationships between power exchanges and balancing markets depends mainly on the design of these two markets. However, there is a direct link between the level of demand and the level of capacity offered on the balancing market. Additional production capacity and possible consumption decreases, which are available but have not been matched either on the bilateral market or on a power exchange, can (or must[31]) be offered on the balancing market (Lapuerta, 2001). For instance, a producer with an installed capacity of 1000 MW may have sold only 980 MWh for hour H and to maximize its revenue might offer its remaining producing capacity on the balancing market (table 5-3).

Table 5-3: Example of contractual position for a peak hour

Contract Type	Volume
• Baseload 3 year	200
• Baseload 1 year	200
• Baseload 6 month	100
• Peak load 3 Year	200
• Peak load 1 Year	200
• Peak load Day ahead	30
• Matched on the PX	50
• **Not Matched on the PX**	**20**
Total	1 000

In this example, a part of the volume offered on the power exchange has not been matched (20 MWh) due to a low level of demand or to a too high price being asked. Hence, the results of the power exchange have a direct influence on the balancing market. If there is a high demand on the PX (involving high

[31] For instance the Dutch grid code requires that generators with more than 60 MW capacity should bid available unused capacity into the balancing market

prices), a lot of capacity will be sold on the PX and little capacity will be available for the balancing market leading to high prices on this market. Similarly, during period of low demand, typically off peak hours, prices are low on the power exchange due to a large amount of production capacity being available, which in turn involve low prices on the balancing market. Hence, similar to the relationship Power exchange-bilateral market, prices on balancing market and power exchanges needs to be very close otherwise arbitrage will occur[32].

5-5-3 Interactions PX –Cross border trade mechanisms

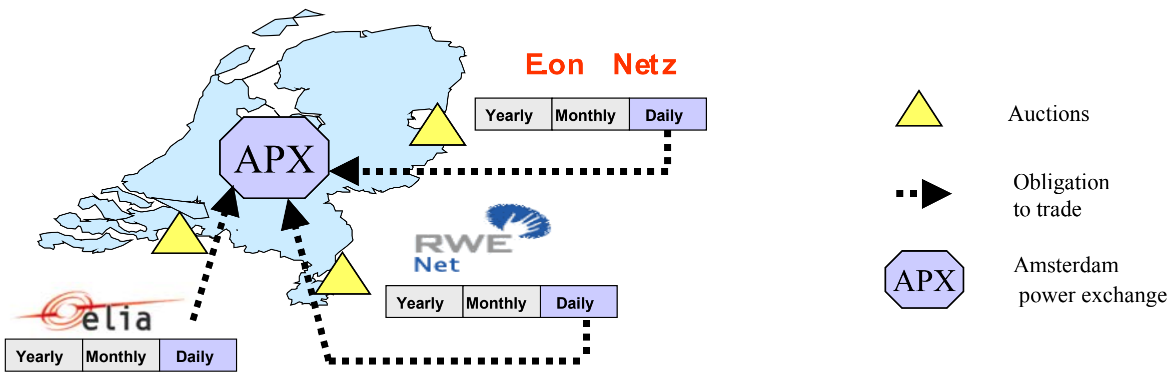
Most power exchanges do not differentiate between companies located within the delivery area of the power exchange and companies from outside this area. Hence, foreign operators willing to buy or sell on the exchange have to handle reserving interconnection capacity as they usually handle for bilateral trade. In general power exchanges are not involved in the management of interconnector capacity. However in Europe two exceptions exists: Nord pool and the Amsterdam Power Exchange. In Scandinavian countries, interconnection capacity are not allocated via a separated auction but directly by Nord pool[33] which handles congestion between countries by using market splitting.

In the Netherlands, the management of interconnector capacity is done by a specific entity, i.e. the TSO auction office[34], which regroups four Transmission System Operators (TenneT for the Netherlands, Elia for Belgium and E.on netz and RWE net for Germany). All available interconnector capacity is auctioned at the TSO Auction office, through a Day, Month and Year auction. Separate auctions are held for both directions on each Interconnector. A feature of the Dutch system is that parties who acquire import capacity at the daily auction are obliged, in accordance with Article 5.6.12.1 of the Grid Code, to trade the

[32] See the Enron's trading strategies for examples of arbitrage (chapter 6)
[33] See chapter 9 for detailed description
[34] See http://www.tso-auction.org/

electricity transmitted on the Dutch side through the Amsterdam Power Exchange.

Figure 5-5: Relationship PX-cross-border trade in the Netherlands



The object of this design was to promote market liquidity and transparency by supporting the power exchange[35]. This rule creates a direct relationship between the exchange and the daily auction for interconnector capacity. The shortcomings of this approach are discussed in terms of strategy on the exchange in chapter 6, and in terms of market design in chapter 9.

5-6 Conclusion

We have presented the way power exchanges function in general in this chapter. The different rules for bidding and the price formation mechanisms have been described. Since the heart of power exchanges is organized via auctions, auctions theory is of particular interest for analyzing power exchanges functions. Unfortunately, understanding of multi-unit auction is not well developed and has limited theoretical foundations. Subsequently, we presented the different interactions between power exchanges and others types of markets. Identification of the main aspects of how a power exchange functions is a necessary step to provide us with the “rules of the game”. The next step of the

[35] Comment 36 of the Dutch electricity regulator accompanying Article 5.6.12.1, available at http://www.nma-dte.nl/

analysis is to understand what types of behavior take place in such marketplaces.