Short Term Electricity Price Forecast Model

By

Furong Yang

IEM-FEM

The University of Twente

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Acknowledgments

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Content

Abstract

The APX Forecast Model developed in this paper is intended as a fundamental tool for the Netherlands short-term electricity price forecast, to be used in a wide range of application. The main effort is placed on providing an indicator of market price spike, and the following day hourly APX prices estimation based on available information at hand.

The model is built on the 2005 historical data of the Netherlands electricity market, incorporating factors like national load, net import, APX price, imbalance price, wind plant generation output and etc. Research results illustrate that 63% of price spike hours could be caught by the forecast hourly prices, and 65.93% of total price spike hours could be alarmed by reserve index, but 30.56% of the total spike alarms really come true. The results could be different by taking different definitions of price spike and reserve index. In this paper, we define price spike as the moment actual APX price is 50 euros higher than the marginal cost, and reserve index equals (Available. capacity – National load) / Available. Capacity. For all the scenarios, model performance would decline with the worse data source.

1. Introduction

1.1 Electricity Market Liberalization

For most of the twentieth century, the electricity industry has been organized as vertically integrated monopoly. Monopoly electricity utilities either integrate the generation, transmission and distribution of electricity, or integrate generation, transmission and sell the energy to local monopoly distribution companies. Electricity market was under the strict regulation, and electricity prices were set by state public utility commissions in order to execute market power and ensure the solvency of the generation units.

This situation lasted until the late twentieth century when the ideological and political disaffection about vertically integrated monopolies grew and liberalization in other network industries succeeded, people began to concern and prompt the reform of the old framework of electricity industry. According to the overview of the regulatory reform in the electricity supply industry written by Carlos Ocana in 2002, the timeline of this change is summarized. First in 1978, the US adopted the Public Utility Regulatory Policies Act, requiring the utilities to buy electricity from "qualified facilities", mostly co-generators and small power producers. This was the initial step, the partial opening of electricity generation to new entrants. After that, a series of big changes occurred in Europe electricity market. In 1990, the England and Wales electricity market, or "pool", was established; in 1991, Norwegian pool was set up; the latter in 1996 incorporating Sweden found "NordPool". In 1997, the national electricity market of Australia was created form the merger of the Victoria Pool and the New South Wales Pool. With all these market changes, the EU adopted a directive in 1996 placing a responsibility on all Member States to open increasing share of their electricity markets to competition. By then, the liberalization of electricity industry began and electricity market in many countries started moving from a centralized operational approach to a competitive one with a long-term objective to increase the efficiency of production and distribution by means of an increase of competition on the electricity market, thereby reducing retail prices and hence increasing consumer welfare and improving the competitive position of the whole industry.

To reach the goal of electricity market liberalization, the reforming of four electricity market elements has been concerned:

1) Rapid introduction of full consumer choice;
2) An obligation to provide non-discriminatory 3^{rd} party access to the transmission and distribution networks;
3) Unbundling of transmission, production and distribution;
4) Liberalization of electricity trade so that electricity can be traded through organized power exchanges and on a bilateral basis;

As a consequence of the liberalization, on the demand side, end users are free to choose their supplier and to negotiate their contracts; on the supply side, generators can sell their electricity to any other market players. Electricity is transformed from a primarily technical business, to one in which the product is treated in much the same way as any other commodity. Electricity price are not regulated with a limited price variation any more, but only determined by the market interactions, which means under certain market situations, electricity prices at time point t could be significantly different from the price at the previous time point t-1, and the price of the next time point t+1. This is the so called “prices spike” phenomenon. Prices spike could last for several time-units and is highly stochastic. It has essential influence on profits of the market participants, and could be classified into three categories:

1) A price is much higher than the normal price, which is called an “abnormal high price”.
2) The difference between two neighboring prices is larger than a threshold; this is defined as “abnormal jump price”.
3) Prices lower than zero is called “negative price”.

After the introduction above, it could be seen that under this competitive framework, electricity industry participants have been forced to rethink their approach to a number of decision processes, like investment, speculation and risk management decisions in electricity markets. Knowledge of the future behavior of market prices as a basic requirement of all the business decisions has become significantly important, and led to a push in electricity industry to develop suitable models which can predict the future moving trend of electricity market prices.

For Essent EMG, an active Dutch electricity market participant, the demand of a model which could assist on daily trading strategy is urgent. Therefore, this research will be based on APX market to build a model which could meet this requirement by providing following day‘s hourly APX prices and spike probabilities.

The paper consists of 4 sections. The rest of this section discusses the characteristics of electricity and electricity prices, analysis the electricity market from both demand and supply side. The next section reviews the previous work has been done on electricity price forecast. Section 3 explains the structure of APX Forecast Model and the methodology used in this research. Section 4 illustrates the implementation process step by step and in the last Section 5 conclusions and recommendations about this project will be given.

1.2 Characteristics of Electricity

With the liberalization process of electricity market, electricity has been traded more and more as normal commodities. But electricity with its unique characteristics is always different from others. These specific features not only lead to the unique properties of electricity supply and demand, but the complex behaviors of electricity prices. What are the typical characteristics of electricity?

First, electricity is non-storable. This is its most important nature. It is this non-storability asks for the supply and demand of electricity to match at all times, and leads to many of the complicated and unique characteristics of price behavior.

Second, electricity is expected to be under certain loss during transmission. After electricity has been generated, it will be transmitted for over long distances to serve a wider network in high voltage. And before it reaches the end users, electricity has to go through transmission cables to reform from high voltage into low voltage. During this “low – high – low voltage” transmission process, part of the energy will be unavoidably lost, which is called transmission loss.

Third, electricity's demand is inelastic. With the development of society, electricity has already become a necessity of today's life. People's daily action can't be taken without electricity. As the result of the combination of this importance and electricity's non-storability, demand of electricity in an individual market always maintains at a certain level with a small volatility range.

Last, electricity utilities' generation abilities have the maximum constrain, which limits electricity production. Physical characteristic of transmission lines constrains the amount of electricity transmitted through also affect the available capacity of an individual market.

1.3 Determinants of Electricity Demand and Supply

Because of electricity's characteristics mentioned above, demand and supply of electricity are required to be matched at all the time. This requirement leads to the very important role of supply and demand in determining electricity's price behavior. Therefore, it is necessary to look into the determinants of electricity demand and supply before we begin our research in electricity market.

1.3.1 Demand

1) Highly cyclical

Cyclicality is a significant nature of electricity demand. Due to the patterns of human's economic activity, demand of electricity is highly cyclical over the day, week or year. For the short term, more electricity is required in day-time compared to night-time, and higher electricity demand in weekdays than in weekends. For the long term, during those yearly holidays like Christmas and New Year, people ask for more energy than the normal time.

2) Seasonality

Demand of electricity is highly seasonal. It depends primarily on weather patterns. Taking Europe as an example, normally demand of electricity is highest during the coldest months of winter and lowest during the warmest months of summer. The main driver of this seasonality characteristic is the need for residential and commercial heating, since the heating requirements are highest during the coldest months and lowest during the warmest months.

3) Other related physical factors

Electricity demand may also be affected by other physical factors significantly. Good cases in our normal life could be daylight, cloudiness, humidity, wind and etc.

1.3.2 Supply

1) Merit order

Existing electricity plants, which can supply the power in a region, make up a regional "supply curve" or "merit order" in the order of their marginal cost of the operation and maintenance. Market meets the demand by taking the units from the left side to the right. When demand is low, plants to the left of the "merit order" will be used. As demand increases plants further up the "merit order" to the right will be added to the dispatching stream.

2) "Base-load" units & "Peak-load" units

According to the place in "merit order", electricity units can be divided into two types:

“base-load” units and “peak-load” units.
“Base-load” units generally take the right side place of “merit order” with the characteristics of high fixed cost and low marginal cost. “Base-load” units are the plants almost always on the function like hydro, nuclear, and some kind of gas-fired units.
“Peak-load” units in the left side of “merit order” are normally with low fixed cost and high marginal cost, which determines that these units will only be online when there are high demand and market price. Most gas-fired units belong to this group.

3) Units outages
A certain area’s electricity supply is tightly related to electricity utilities’ outages. All the existing generation units subject to occasional planned and unplanned outages, will stop or partly stop running during this so called ”maintenance period”, and accordingly constrain the amount of energy generation.

1.4 Properties of Electricity Prices
The purpose of this research is to build up a model which could predict the moving trend of the following day’s APX price. But what are the typical properties of electricity prices? From the analysis of the characteristics of electricity, demand and supply, we can conclude that the behavior of electricity prices will not be the same as other commodities, but with some unique features. It is caused by electricity’s unique nature and it makes impossible to rely directly on models developed for financial or other commodity markets to forecast electricity price. The key properties of electricity prices are listed below:

1) Occasional price “spikes” jumps
Electricity prices exhibit occasional price spikes when either the generations suffer an outage or an unusual load condition makes demand reaching the limits of the available capacity. This price appears suddenly and lasts short term, when the relevant asset is returned to service or demand recedes, prices will quickly go back to typical levels.

2) Seasonal effects
In response to cyclical fluctuations in demand, the mean price of electricity in the market varies by time of day, week, and year. The precise shape and magnitude of the price cycles are affected by the patterns of economic activity, weather in the region, characteristics and ownership structure of the region’s generation assets.

3) Price-dependent volatility
Like the mean price of electricity, the volatility of electricity varies cyclically with price as fluctuations in demand move different generating assets to the margin. Since higher levels of demand bring assets on the upper, steeper portion of the supply stack to the margin, price volatility increases with price level.

4) Mean reversion
Electricity prices fluctuate around values determined by the cost of production and the level of demand. In the short run, mean reversion results from the cyclicality, mean-reverting nature of demand, while in the long run, it results from bounds imposed by the cost of new generation.

1.5 Dutch Electricity Market

In the Netherlands, the Dutch Electricity Act commenced in 1998 constituted the basis for the liberalization of the Dutch electricity market. This legislation set up a regulatory authority, DTe, which regulates access to the electricity transmission grids. It also established an independent administrator of the national high-voltage grid, namely, Tennet. From this act, the Netherlands opens up its electricity market step by step.

The Dutch wholesale market can be broken down into various submarkets:

1) The trade in bilateral contracts, alternatively, the bilateral market;
2) The OTC(over-the counter)market;
3) The day-ahead market (the APX spot market);
4) Tennet's balancing regime or market for regulating and reserve capacity.

On the bilateral market, there are normally those non-standardized contracts which are entered into by producers, major buyers and suppliers for lengthier terms. The over-the-counter market is the one in which standard amounts of electricity are traded outside the APX. In this market power is often sold several times over by various brokers who settle these transactions. The APX (Amsterdam Power Exchange) is an independent fully electronic exchange for anonymous trading on the spot market, which was settled up in 1999. The occurrence of APX market has lowered the barriers to entry for market trading, and made the trading easier regardless of the size or origin of the trading party. This spot market is operational offering distributors, producers, traders, brokers and industrial end-users a spot market trading platform in the form of intraday, strips and day-ahead transactions: trading today for delivery of electricity tomorrow, provides its members standardized products to sell and purchase and is the central counter party in all electricity trades. APX price and volume indices are published on a daily basis and are used as a benchmark in, amongst others, bilateral contracts and by governmental bodies to monitor market development. Finally, there is Tennet, the operator of the national high-voltage grid, an organized market for regulating and reserve capacity. Tennet enters into annual contacts for specific amounts of regulating and reserve capacity. It calls for bids for reserve capacity when imbalances occur. The cost of energy used for this purpose is recovered from the undertaking that is responsible for it.

There is a strong relationship between the different markets referred to above within the electricity wholesale market. For most power suppliers, in order to satisfy their supply commitments, they would generally make their procurements in three stages. In the first stage the bulk of their anticipated demand is procured a year or a month before supply by means of the purchase of base and flexible load through bilateral contracts and imports. In the second stage (a week to a day prior to supply), it is possible to estimate the demand more precisely and the rough procurement profile is taken over with the actual supply profile by means of short-term contracts, the APX, Imports and exports. In the last stage, on the supply date, the supply profile is rounded off either by means of OTC contracts or balancing market based on the views of market players. From what have been discussed, it is clear that these markets are closely correlated.

Look at the supply side of the Dutch electricity market, we could find a number of major electricity generating enterprises such as Essent (market share 34%), Electrabel

(23%), E.On (9%), NUON (24%) and Delta (10%), as well as a large number of small producers. The latter mainly possess decentralized total energy plants many of which have been erected to satisfy their own demand for heating.

From the market share, it is clear that Essent is an active market participant in the Dutch electricity market. Actually, as an important Dutch energy company, it supplies electricity, gas and heat to private and business customers. Its operations cover the entire length of the energy chain, from the generating of energy to the supplying of products and services to the end-users. In the term of installed capacity, Essent takes a significant place in the Dutch energy market, which covers one fourth of the national installed capacity. Within Essent, the Energy Management Group (EMG) – under the legal entity of Essent Energy Trading B.V. – is internationally active as the portfolio and risk management organization that realizes maximum value out of the position of all Essent's assets, contracts and customer portfolios by managing and optimizing the entire commodity value chain from source to end –customers. It plays a key role in critical decisions across all time horizons from long-term (20 years) to short-term (one hour). With regard to the long-term, EMG provides market insights and supports the valuation of potential investments or acquisitions. For the short-term, EMG ensures short-term optimization by dispatching and gas nomination, balancing and intraday trading. As a consequence, EMG is best placed to mitigate the impact of risks endemic to the business as well as to capture synergies from Essent's growth.

I have spent 7 months in the department of market analysis in Essent EMG as the assistant of the short-term electricity traders. The main role of this position is to build this short-term electricity prices forecast model, which could provide traders with the accurate estimation of tomorrow's APX market, further, help them maximize their benefit by setting right bidding strategies.

2. Overview of models for electricity prices

Since deregulation liberalization, electricity price modeling has attracted great attention from both industry and academic researchers. People work hard to look for a good model, which can accurately capture the distinctive characteristics of electricity spot price. A lot work has been done, which can be divided into three different models according to information requirement.

2.1 Reduced-form models

Reduced-form models used for electricity price modeling require minimum available information. It tries to solve the problem from a mathematical prospective and has been worked long time by researchers since the liberalization of electricity market. Two popular approaches proposed in the literature are Jump-Diffusion model and Regime Switching model.

Jump-Diffusion Method models the spot electricity price with a continuous framework featuring a mean-reverting drift, a standard Brownian diffusion process and a Poisson Jump. It is proposed in the literature specifically for the purpose of capturing mean-reverting and jump behavior of electricity price. The Basic model of this method is generated by Clewlow and Strickland (2000).

$$d\log(S_t) = k\,(q - \log(S_t))\,dt + s\ dW_t + u\ dQ$$
$$dQ = 1\ with\ pba\ l\ dt$$

In the equation above, Q governs the jump occurrence, u represents the random size of the jump, and l is the intensity (mean arrival rate) of the jump. Other related researches included Knittel and Roberts (2001), Atkins and Chen (2002), Escribano, Villaplana and Pena (2002), Goto and Karolyi (2003) and Eydeland and Wolyniec (2003). The advantage of Jump Diffusion models is that they take into account spikes and are flexile with the jumps size and jump intensity. But meanwhile, Jump Diffusion models easily overestimate the jump frequency, jump size volatility and underestimate the mean jump size. Besides these, in order to fit the actual market, such models require a high speed of mean reversion to reduce the spot price following a large positive jump, and this has the effect of removing too much variability in the series over the “non-jump” periods.

Regime-Switching approach models the price behavior of spot electricity price by dividing the time series into separate phases or regimes with different underlying processes. A jump in electricity prices is considered as a change to another regime. The switching mechanism is assumed to be governed by a random variable that follows a Markov chain with different possible states, which means that unobservable variable in the time series switching between certain numbers of states is driven by independent stochastic processes. Clearly, there are various regime-switching models due to different number of regimes and different stochastic process for the price in each regime. For electricity analysis, Ethier and Mount (1999) assume two latent market states and an AR (1) price process under both the regular and the abnormal regime and constant transition probabilities. This new modeling framework is expected to be more suitable for actual price forecasting. But it retains the misspecification and imposes stationary in the irregular spike process, which is considered as the short-comings. Later, Huisman & Mahieu (2001) proposed a three-market regimes model, which allows an isolation of those two effects: normal electricity price dynamics regime, initial jump regime for the sudden price change and reversing regime that describes how price moving back to normal regime after initial jump regime. The new model however is restrictive, since it does not allow for consecutive irregular prices. This constraint is relaxed in the model research of De Jong & Huisman (2002). The two-state model proposed by them assumes a stable mean-reverting regime and an independent spike regime of log-normal prices.

Normal regime: $$\ln S_{M,t} = \ln S_{M,t-1} + a\,(m - \ln S_{M,t-1}) + e_{M,t}$$

$$e_{M,t} \sim N(0, s_{M})$$

Spike regime: $$\ln S_{S,t} = m_{S} + e_{S,t}$$

$$e_{S,t} \sim N(0, s_{S})$$

Regime independence allows for multiple consecutive regimes, closed-form solutions and translates to a Kalman Filter algorithm in the implementation stage. Comparing the two models made by Huisman & Mahieu and Huisman & De Jong, they are very similar to a certain extent, and highly interconnected. But the former deals with the market price change, while the latter more focuses on the market price level.

Looking into these statistical models, we could find that the construction of them is easy and simple but with a problem that there is no rigorous economic motivation for the parameters has been given in electricity markets. Compared to financial markets, electricity markets is lack of the long historical time series that would allow process parameter estimation. The continuous structural and regulatory changes in the electricity market would have a significant influence on the electricity prices. The historical estimate results are not necessarily valid in the future, and the affect of market changes to parameter values could be difficult to estimate.

2.2 Fundamental models

In the fundamental or structural models, which build the price processes based on equilibrium models for the electricity market, electricity prices are obtained from the supply-demand balance determination. Related researches have been done in this field could be listed below. Botnen et al. (1992) and Haugstad and Rismark (1998) presented a model for the minimization of the marginal generation cost of the whole generation system in the Nordic market with the assumptions that “in a competitive market, spot price equals the marginal generation cost”. Kosecki (1999) has built the fundamental model, in which, marginal fuel cost, load and available capacity are mentioned as factors that influence the relation between market prices and fundamental prices. Johnsen (2001) presented a supply-demand model for the hydro-dominant Norwegian electricity market by using hydro inflow, snow, and temperature conditions to explain spot price formation. Skantze and Ilic (2001) considered a fundamental model for the electricity price dynamics that incorporated the seasonality of prices, stochastic supply outages, and mean revision.

Comparing fundamental models with statistical models, it could be found that models including fundamental factors are more tractable than statistical models. Economic reasoning can be used to deduct the properties of those factors. The special characteristics of electricity prices and changing market conditions are better captured with fundamental models than with pure statistical models. But on the other hand, fundamental models require comprehensive data sets that are difficult to collect and maintain and it is often laborious to use the fundamental models to use the fundamental models to create numerous spot price scenarios.

2.3 Hybrid models

Besides what we have discussed above, a model that incorporates ideas from both reduced-form models and fundamental models is called a hybrid model. From reduced-form model's perspective, a hybrid model takes into account of additional information besides the price time series, for example weather or availability of power plants. From fundamental model's perspective, the role of marginal cost is fading. In the hybrid models, the individual power plants underlying the marginal cost curve are normally not specified.

Eydeland and Geman (1998), Pirrong & Jermakayan (1999), Skantze, Gubina & Ilic (2000), Skantze, and Eydeland & Wolyniec (2004) are examples of a class of hybrid models. Comparing these models, it is not difficult to find that they have a few in common. First, all these models are based on the assumption that there is an exponential relation between prices and load. For instance, Skantze, Gubina & Ilic's model focus on the supply curve with the form $S = \exp(aL+b)$, where a is constant and b is time dependent. Eydeland and Geman's model include both a base load price p and a fuel component w as in $S= p + w*\exp(aL+b)$. The reason for this exponential choice is that it captures the behavior of strongly increasing prices when national load is growing. Second, in their models, the approximation of the supply bid at the day-ahead market takes a central place. An underlying assumption is that there are a clear relation between price and volume on the day-ahead market. This makes them useful in so called pull markets, where all supply has to be offered in the day-ahead market. However, this is not the case in all electricity markets around the world.

3. APX Forecast Model

The purpose of this research is to investigate the relationships between important market fundamentals and electricity prices, and depending on the relationship to develop a model that can be used to predict the short-term electricity prices. Since the research is based on my intern project in Essent EMG, according to the project requirement, it will focus especially on Dutch APX market.

In Essent EMG, people have kept working on the different models for the energy world. In electricity field, there are various models based on different ideas with different parameters. Among these works, the marginal cost model build by Sander and the capitalization index research of Alex are thought to be most valuable. Our research depending on the basic ideas of these previous works, according to the situation of APX market, developed this APX forecast model. Why we choose a hybrid model to solve the research questions “how can we predict APX price?” The main reason is that from the analysis of the previous work in Essent EMG, we find that the pure fundamental model performance can not satisfy traders’ requirement and we believe that by taking into account of additional information, for example weather changes or power plants availability, hybrid model could give better results. The hybrid model consists of two parts: fundamental part and statistical part. Framework of our APX forecast hybrid model can be displayed below:

Fundamental Part + Statistical Part = APX Forecast Hybrid Model

3.1 Input Data

In this research, we are working with data from starting 01/01/2005 to ending 30/03/2006. According to the data source, all the data included in the model can be divided into internal part and external part. Besides the data from Essent EMG, the main two external data sources for this research are website Tennet[1], Genscape[2] which provide the information for the whole Dutch electricity market.

- **Net Import:** Balance of the programmed import and export with other countries, published by Tennet on a 15-minute basis.
- **National Load:** The sum of measurement data for each connected party with a generating capacity of 10MW, as reported by grid administrators, published by Tennet on a 15-minute basis.
- **Wind Plant Generation Forecast:** The forecast of national wind plant generation output, calculated by dividing Essent Numa output by 0.28, published by Essent EMG on a 15-minute basis.
- **Fuel Price:** Including CO2 price, Coal price, and Gas price published by EMG internal on a daily basis.
- **APX $_{(t-24)}$, APX $_{(t-48)}$:** History APX data published by Montel[3] website on an hourly basis one and two days ahead.

[1] As the Dutch Transmission System Operator, Tennet TSO takes responsibility on monitoring the continuity and security of the electricity supply in the Netherlands, 24 hours a day, 365 days a year. It publishes the important market fundamentals like Net Import, National Feed, and Imbalance Price on hourly basis after the execution day to public.

[2] Genscape Power Europe is a website provides similar transparency of power production and flow information for the major traded markets in Continental Europe. Essent EMG as a member of this website has the access to the data for the Dutch power market.

[3] A website publishes index hourly prices for different markets to its members.

- **Imbalance Market Long Price $_{(t-72)}$:** History Imbalance market long price published by Tennet on a 15-minute basis three days ahead.
- **Genscape units Available Capacity:** Available capacity of units on Genscape website (not included Essent units), modified based on traders inside knowledge, which takes around 42.40% of the national available capacity.
- **Essent units Available Capacity:** Available capacity of units from Essent, which covers around 25.55% of the national available capacity.
- **Other unknown units Available Capacity:** Available capacity of all the other unknown small units, which takes around 32.05% of the national available capacity.

As APX spot prices are published on an hourly scale, all the related data has been transformed into the hourly basis. Subsequent graphs and analysis are showed in hourly data as well.

As the main data source, first we will introduce Tennet and Genscape briefly below. Tennet, is the Dutch Transmission System Operator, which has the duty to monitor the continuity and security of the electricity supply in the Netherlands. In additional to administering the national transmission grid and safeguarding the reliability and continuity of the Dutch electricity supply, it also provides services and performs duties aimed at developing the electricity market and ensuring that it functions properly. Genscape Inc. is an originator of real-time power supply information to support decision-making for power marketers, regulators, utilities, distributors, and other energy market participants. Its founders identified the need for reliable, comprehensive supply-side information in the energy business, and settled it in 1999. By providing the reliable real-time power supply information, Genscape has increased the efficiency of electricity markets while reducing market risks created by the lack of transparency. After its 7 years development, its customers include the majority of the top 50 US and European power generating, trading and marketing companies, as well as the Department of Energy and the Federal Energy Regulatory Commission.

After checking these two websites, it is nice to note that Tennet and Genscape both provide the information about national available capacity. But in this paper, instead of taking the number published on Tennet as normal researchers did, we depend on Genscape and calculate the national available capacity ourselves. This is because Tennet as the TSO of the Dutch electricity market, its data is collected by the report provided by each unit in the country. Since there is no exact mechanism to check the accuracy of the information, it is imaginable that for the benefit purpose there could be the situation that the unit hides or weakens some abnormal operation situations like unexpected outage, short available capacity and etc. Therefore, compared to Tennet, the data on Genscape website seems to be more reliable in traders' opinion. By taking specific technique to monitor the big electricity utilities with the average installed capacity of 428 MWH and publish the new outcome simultaneously, the running condition of each unit could be obtained with a high reliability. Actually, in Essent EMG, Genscape has already become an important reference website for traders' daily work.

3.2 Data Assumptions

Dutch electricity market is on the way moving to a fully competitive market, certain information has been taken as business secret by market participants, not public any more. As a result, a few assumptions for those inaccessible data have been included. The important assumptions in the model are listed below:

Assumption 1: The latest units operation status published on Genscape website are valid for 24 hours. This is because no one would be able to know what each unit's running situation will be in tomorrow. Therefore, we have to make certain estimations about it based on the available information about today.

Assumption 2: The unknown units' available capacity equals 95% of their installed capacity. For the electricity generation units, it is impossible to run at the full production capacity. The available generation ability of units is always adjusted by factors like environmental conditions, technical defects, maintenance work, fuel supply and etc. Since, we could not identify these factors for some units, but still want to take them into account in our research, we take 95% of the units installed capacity as the available capacity for those unidentifiable units, which is the percent adopted by Essent EMG normally.

Assumption 3: The "base-run" units in marginal cost "stack up" curve only take into account of Essent units. Normally in the supply stack curve, "base-run" units with low marginal cost take the right side followed by those high marginal cost units only taken when there is high market demand. But during the research, it is hard to identify the operation type of those units outside Essent EMG, thus we only consider the "base-run" units owed by Essent EMG in the stack up curve.

Assumption 4: Units outside Essent have same non-fuel cost with Essent units, when they are under similar situations (plant efficiency, fuel type, operation, etc).

Assumption 5: When APX price is 50 euros higher than Marginal Cost, it is so called "Spike price". This is the definition of "Spike price" in this research, which is settled according to EMG traders' market knowledge.

Assumption 6: National Load is the sum of measurement data for each connected party with a generating capacity equals or bigger than 10MW. This is the definition published by the Dutch Transmission System Operator Tennet TSO, which is also the official publisher of this market data.

Assumption 7: Inside, Essent EMG, there is the wind group who generates the daily, one-day ahead, two-day ahead forecast report of the electricity generation output of Numa wind plant. Since the installed capacity of Numa wind plant takes 28% of the national wind plants installed capacity. In this research, we assume that wind affects on all the wind plants in the Netherlands are same. Therefore, the national electricity output generated by wind plant could be calculated from the report about Numa inside Essent EMG.

All these assumptions are essential in the research and come from the discussion with EMG electricity traders. They are expected to have significant influence on the result, and to improve the accuracy of the forecast by taking more accurate data source. For different scenarios comparison and analysis, the number inside each assumption could be adjusted, and different forecast result would be generated.

3.3 Fundamental Part

Fundamental part of APX forecast hybrid model consists of a marginal cost model. Economic theory states that serious competition will drive commodity's market price to marginal cost when there are many producers and consumers. This statement works in the energy industry most of time as well. What is marginal cost? As mentioned in the book of "Energy and Power Risk Management", marginal cost is the cost of an additional input incurred in the company to produce an additional unit of output. It is the derivative of the total production costs with respect to the level of output. In electricity industry, for each unit, marginal cost is defined as the operational and maintenance cost of the generating plant needed to produce the last kilowatt-hour of electricity to meet the immediate demand.

In our APX forecast model, each units marginal cost can be calculated by the equation below:

Equation 1: marginal cost = fuel cost + non-fuel cost

Fuel cost in equation equals per megawatt-hour primary fuel price divided by the electricity utilities' operation efficiency. Non-fuel cost represents start-up cost and other necessary operating expense.

After knowing each unit's marginal cost, we can form calculate the marginal cost for the market in a given region. By stacking all the generation units in "merit order", that is, from the lowest to the highest cost, we can form what we call a supply stack curve. It is constructed in the function of the form that price = F (volume), which determines that at which price a generator is willing to supply a given volume. For each hour, marginal cost model matches the supply volume against the national demand. It first accepts the lowest cost generation units and then "stacks up" those higher cost generation units until enough supply has been accepted. Once demand is met, marginal cost is set by the last and highest accepted cost on the system bid stack, market volume will get at this price is decided at the same time. In almost all regions, the marginal fuel – the fuel that sets the price most often – tends to be natural gas, and it is same in Dutch market.

It is notable that the process of marginal cost calculation is similar with the actual market clearing price setting. The latter is determined by ISO in the region through the bid stack curves for supply and demand, which equals the highest price on the system bid stack at the point the total generation will match the demand. Figure 1 gives the graph of the bid curves of supply and demand below. But it is not necessary for the marginal cost stack surface to be equivalent to the actual bid stack submitted for optimization by the units. The differences in the fuel and bid stack are due to several factors. The actual marginal costs of the different generators can be influenced by a number of physical constraints, and in some situations, this might make fuel cost an insufficient proxy for the actual marginal cost of generation. Furthermore, the differences can also be induced by strategic behavior by the bidders.

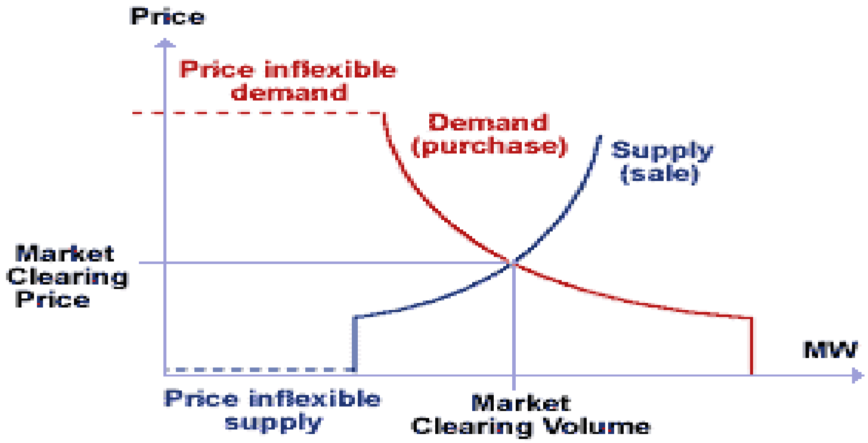
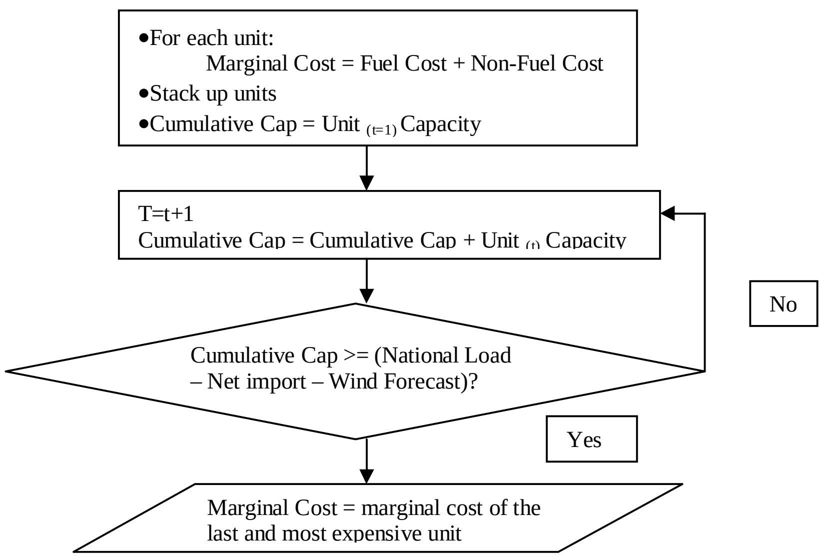


Figure 1: Graph of the principle for marginal cost calculation (source: www.apx.nl).



Take 2005 historical data as dataset, the development over time of both the APX price and the market marginal cost are illustrated in figure 2. The correlation between APX price and marginal cost is 0.41 for the data sample of the whole 2005, this number increase to 0.72 for the non-spike hours. This is understandable, because during most time periods in the spot market, the generation price of electricity is set by the market marginal cost of production. A supplier will not be willing to sell power blow the market price of the most expensive facility operating at a given time, because consumers will be willing to the higher price. Similarly, consumers will be unwilling to pay more than the cost of the most expensive operating available generator, since other suppliers will be offering lower prices. Therefore, we could expect that most time the market prices are set close to marginal cost, at which prices all suppliers willing to provide power and all consumers willing to purchase power. But when the periods of extremely high demand come, typically on very hot summer or very cold winter days, when the demand for electricity approaches the available generating capacity. The prices would rise above the operating costs of the most expensive generator operating, and lead to the so called “spike price”. This is because the amount of capacity available at any point in time is fixed, and the new generating capacity can not be built quickly, therefore, the only way to keep demand and supply in balance during extremely high demand periods would be through an increase in the price, to the level that some consumers would like to pay anyway to be sure the obtain of the energy while others will choose to reduce their usage. However, from figure 2, the same changing trend could still be found in both the APX prices and the marginal cost. With the increase and decrease of the APX prices, the marginal cost goes up and down accordingly.

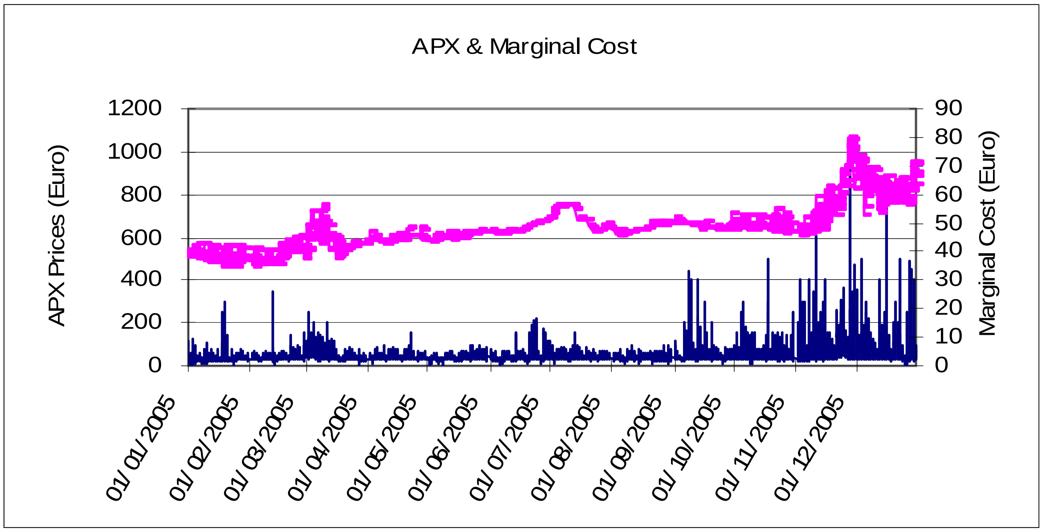


Figure2. APX price and marginal cost during our data sample from 01/01/2005 to 31/12/2005. The graph includes two different axes. The axis at the left side of the graph indicates the units of APX price, which is displayed in the dark color. The axis at the right side is for marginal cost, which is the line at the up part of the graph in the light color.

3.4 Statistical Part

3.4.1 Reserve Index

In the statistical part of APX forecast model, we defined an index named “Reserve Index“, which could indicate the remaining market generation ability to meet the additional demand. This reserve index is so closely related to the market tightness, and the calculation equations are listed below:

Equation 1:
National Unit Available.capacity = Essent Available.capacity + Genscape Available.capacity + Other unit Available.capacity

This is the first step for the reserve index. According to the data source, all the units (except wind power station) available in the Dutch market have been developed into three groups. By adding the available capacities of Essent units, Genscape units and those small units besides these two categories, we get the national units available capacity for each hour.

Equation 2:
Available.capacity = Net Import + Wind Energy + National Unit Available.capacity

Besides the unit available capacity, we also take the net import and the electricity volume that could be generated by the wind power plants into account when calculating national available capacity. .

Equation 3:
Reserve Index = (Available.capacity – National load) / Available.capacity

This is the final equation for the calculation of our reserve index. National load here represents the national demand for electricity. Since the reserve index will be present on an hourly basis, it is good to be sure that all the components in the above three equations are under the same hour.

3.4.2 Reserve Index & APX

As an indicator of electricity market reserving ability, this reserve index has close relationship with the hourly APX price. To study this relation, we begin by showing the development over time of the underlying data for this index. From the graph we can see the minimum amount of the national load maintains a stable level through the whole year, but the maximum volume is a little bit higher in winter than in summer. It coincides with the characteristics we talked about earlier that electricity's demand is inelastic and seasonal.

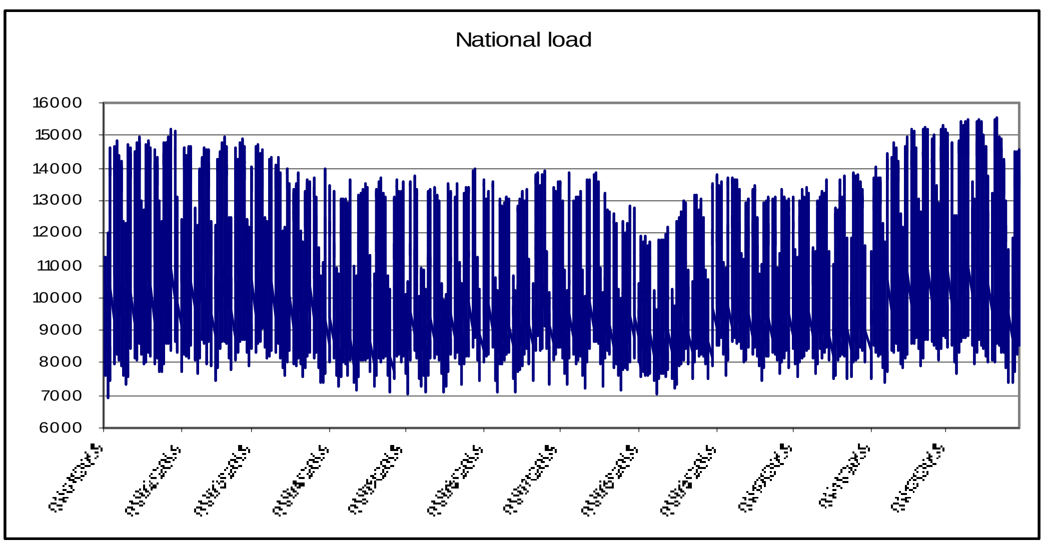


Figure 3: National load during the data sample from 01/01/2005 to 31/12/2005.

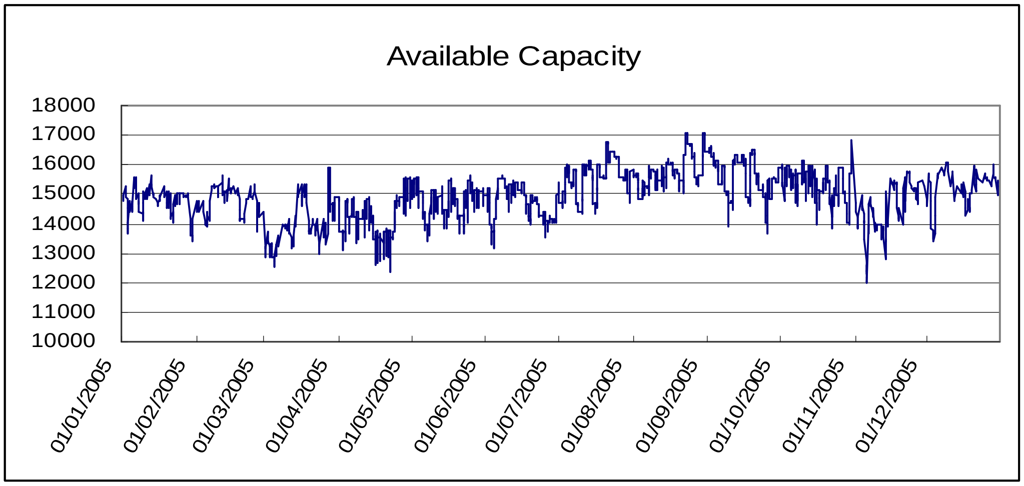


Figure 4: Available capacity during our data sample from 01/01/2005 to 31/12/2005

In figure 5 we show the development over time of both the APX price and the reserve index. From the graph, the relation does not seem strong enough. In order to display it more clearly, we introduce a scatter plot graph in figure 6, which reveals a strong relationship that APX prices increase with the decrease of reserve index. It is good to note that even though the whole trend is obvious, there are still some points, which indicate high prices but medium reserve index, and normal prices with very low reserve index. For instance, on 28th November 2005, the APX prices for the peak hours are so high with an average value of 420.73 and a maximum number of 1000.12. But the reserve indices for the same day's peak hour are not as low as we expect for these high prices. The average level of the reserve indices for the period from 9:00am to 20:00pm on 28th November of 2005 is 0.3443 with a minimum value of 0.2789. As it could be seen from figure 6, these numbers are much higher than they are supposed to be. In order to find out the reason for this phenomenon, we have checked the related market fundamentals like available capacity, national load, net import, APX trading volume, and imbalance market prices. The result is most of these fundamental data during the question period keep the normal level. Only in the imbalance market, we get the prices as high as 1102.15 with an average of 320. Unfortunately, according to these numbers we have collected from the market, for these specific hours, we can not make a good economic interpretation. Similar analysis for those points in the graph indicating the normal prices (around 200) with the extremely low reserve indices (below 0.1), we could find that most of these points represent the peak hours for common days. Looking into the market data for these particular hours, again there is no specific signals could be found to explain this situation. The analysis result may indicate that the reserve index in the model does not cover all the information, some parts of information related to APX prices may be missing. And this will be left for the further research later.

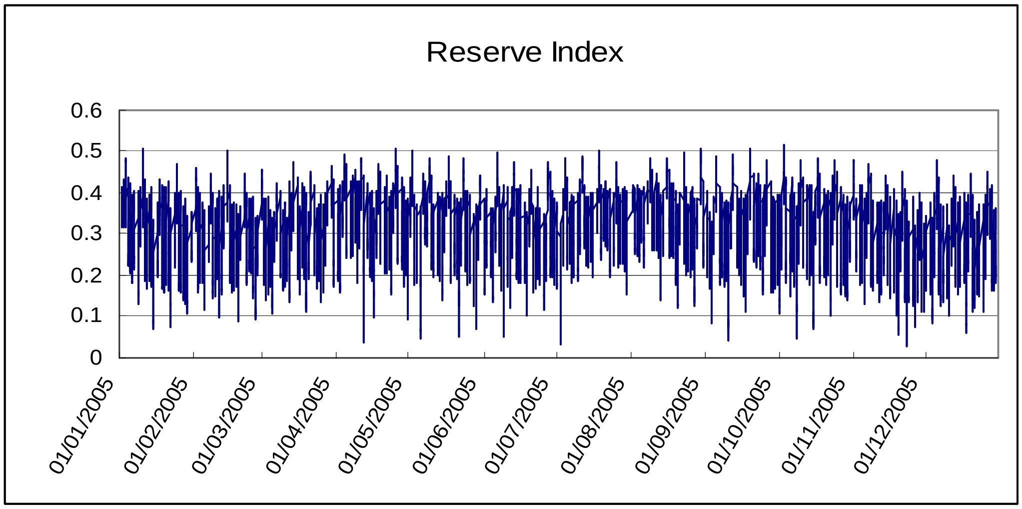


Figure 5-1: Reserve Index during our data sample from 01/01/2005 to 31/12/2005.

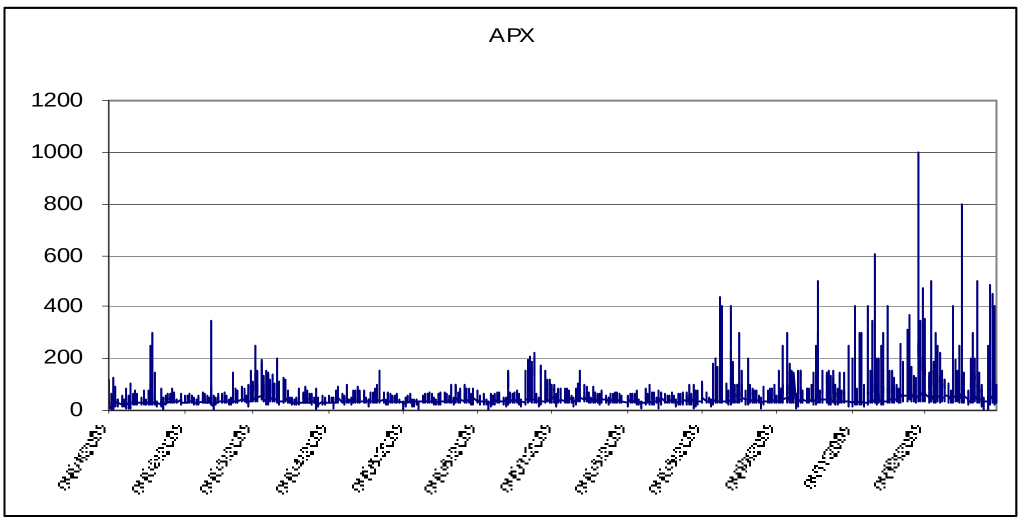


Figure 5-2: APX Price during our data sample from 01/01/2005 to 31/12/2005

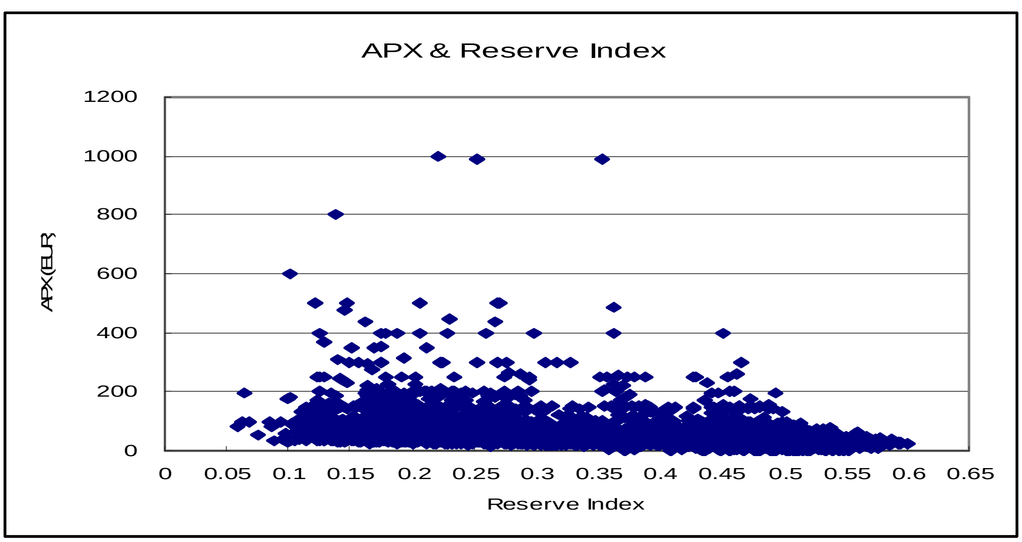


Figure 6: scattered graph of the APX & Reserve Index during our data sample from 01/01/2005 to 31/12/2005

3.4.3 Reserve Index & Spike Probability

How do we implement this "Reserve Index" into our APX forecast model? A few steps have to be taken in the preparation process. From figure 6, we could see that the reserve index has the maximum value of 0.6 and the minimum value of 0. So first, we divide all the hourly reserve indices for our data sample into 65 baskets with the lowest value of 0 and the highest value of 0.6. Each of the baskets has a width of 0.01. Then, we calculate the number of the total indices and the number of the indices especially for "spike moment[4]" in each basket respectively. Dividing the number of spike hour indices by the number of the total indices, we get the so called "spike probability", which indicates the possibility of prices spike. In this research, according to our definition of spike, it is the possibility that APX hourly price is 50 euros higher than the market marginal cost. As we discussed earlier, the reserve index would be helpful to give an accurate description of the market reserve capacity. When the reserve index is low, the market reserve capacity is expected to be low. Under this situation, consumers are willing to put more price premium in the market price because of the less confidence on the energy supply side. Therefore, we could expect that the lower the reserve index, the lower the market reserve capacity, and the higher the electricity market price. A scatter graph of Reserve Index and Spike probability in figure 7 supports this opinion. But it is also necessary to note that the relationship between reserve index and spike probability is not monotonic. The possible reason for this phenomenon could be the inaccurate national load data reported by each units, the assumptions included in our available capacity calculation, or the incomplete information that is missed by our reserve index. For the exact explanations, it will depend on further research. For now, in order to display our opinion on the relation between reserve index and spike probability, we will smooth the graph to a monotonic decreasing curve by taking a specific distribution that will fit the trend of figure 7 best. To do this, we begin by looking at the distribution for the number of underlying oberservations in each basket in figure 8. As can be seen, most observations come between 0.2 and 0.5. Outside this range, the number of the oberservations will decrease gradually. This has left us a question, how can we deal with those points with low frequency but high spike, for example, the points in figure 7 with the x-value 0.1? In this research, we have chosen two methods to solve this problem. In the first method, we discard those points with low frequency in the baskets, and only take the rest ones for the smoothing purpose. An exponential equation in the form of y = 0.859e-8.2158x has been adopted. The smoothing result is displayed by the thinner line. In the second method, we keep all the scattered points in figure 7 and take an equation in the form of $y = 47.873*X^{4} - 82.466*X^{3} + 51.859*X^{2} - 14.355*X + 1.5431$. A different smoothed relationship between reserve index and spike probability is displayed by the thicker line. Comparing these two methods, the smoothed curve generated by the first method is more flat than the second one. By taking the more flat curve, people will hold a more prudent opinion about the spike signals from our reserve index. While, the other smoothed curve obviously gives the more active information.

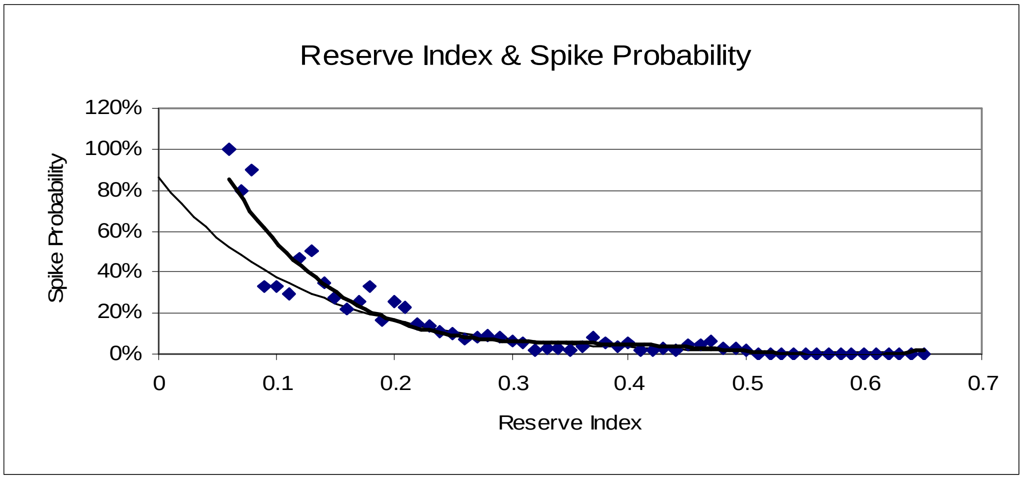


Figure 7: Scatter graph of the relationship between reserve index & spike probability. Two smoothing curves generated by different equations. The thinner curve discards those points with low frequency in baskets, while the thicker one depends on all the existing points.

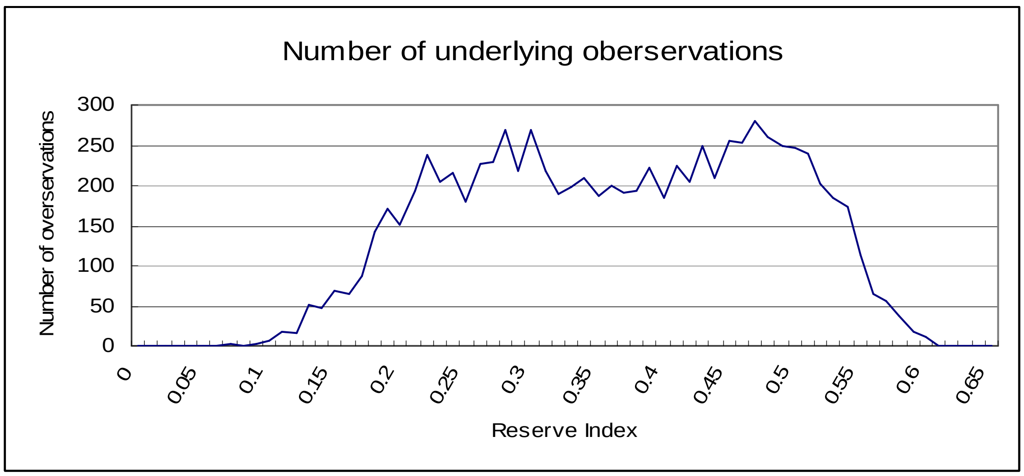
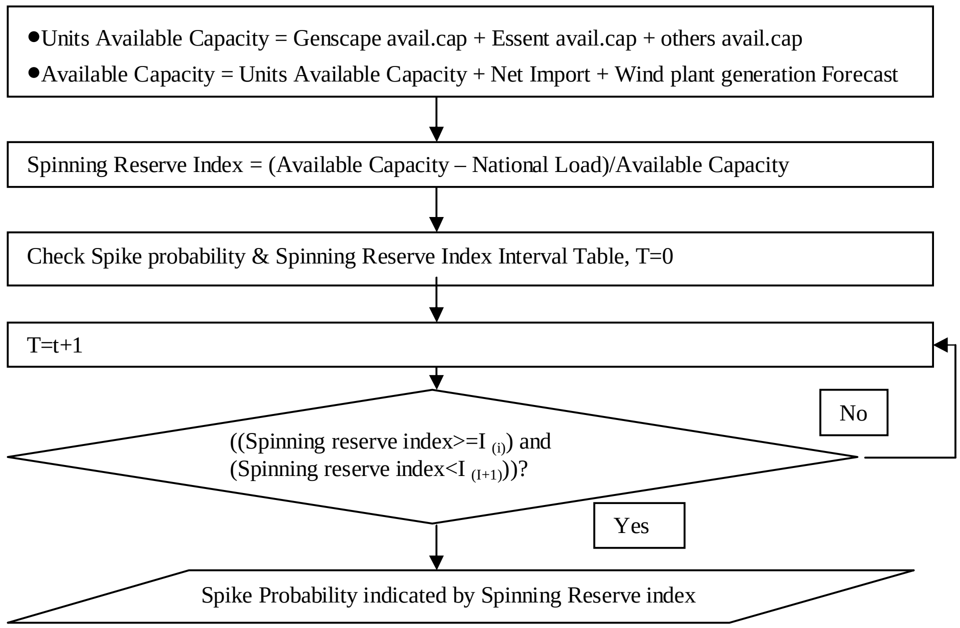


Figure 8: the distribution for the number of underlying oberservations in each basket.

In our model implementation, we take the second method to smooth the relationship between reserve index and spike probability. The smoothed curve is added to the APX forecast model database. For each hour, when we forecast the APX price, reserve index will be calculated and checked with the installed smoothed curve to identify the corresponding spike probability. The whole process is shown by the flow chart 2 below.



Of course, for different research purpose, we could also set different width for each basket. Actually, the smaller the width of the basket is, the more individual information will be presented. And the bigger the width is, the more general conclusion you will get. Figure 9 blow presents this statement by graphs comparison.

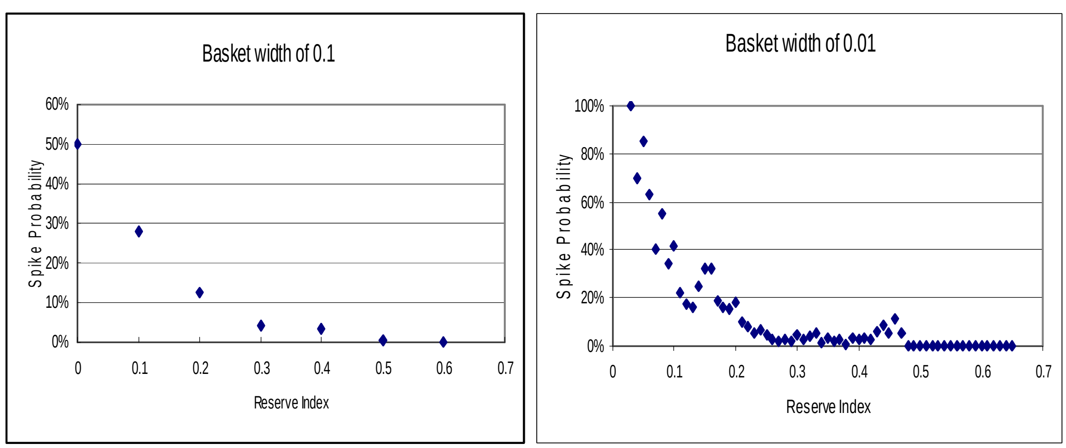


Figure 9: The difference comparison graph for basket width of 0.1 and basket width of 0.01.

3.4.4 Statistical Equation

Spike probability has given the prediction of the high APX price occurancy possibility, but it is also necessary for traders to get knowledge of the hourly APX price level. Therefore, a statistical equation is included in the APX forecast model.

$$APX_{(t)} = C_1{*}APX_{(t-24)} + C_2{*}APX_{(t-48)} + C_3{*}IBM_{(t-72)} + C_4{*}MC_{(t)} + C_5{*}Load_{(t)} + C_6{*}GAS_{(t)} + C_7{*}Time\ Index_{(t)} + C_8{*}Reserve\ Index_{(t)}$$

It is a modification form of the simple linear regression equation. Hourly APX price as dependent variable in the equation relies on the independent variables which could be divided into three groups.

Group 1: APX $_{(t-24)}$, APX $_{(t-48)}$, IMB $_{(t-72)}$

Group 1 consists of historical prices that we believe will have significant relation with our predicted APX price. APX $_{(t-24)}$ and APX $_{(t-48)}$ represent the same hour previous day price and the price the day before yesterday respectively. They are chosen in this equation because of the accepted statements in electricity industry that there is high possibility that high price will come out again the next day after the occurrence of the extreme value. During our sample period research, the correlations among APX $_{(t)}$, APX $_{(t-24)}$, and APX $_{(t-48)}$, are 0.57 and 0.49 respectively. The scattered graphs of the relationship are given below. It could be found that with the time lag getting bigger, the relationship trend is becoming weaker. For those extreme points, the explanation could be the electricity prices "spike" jump characteristic, which appears suddenly and lasts short term, then quickly go back to normal level.

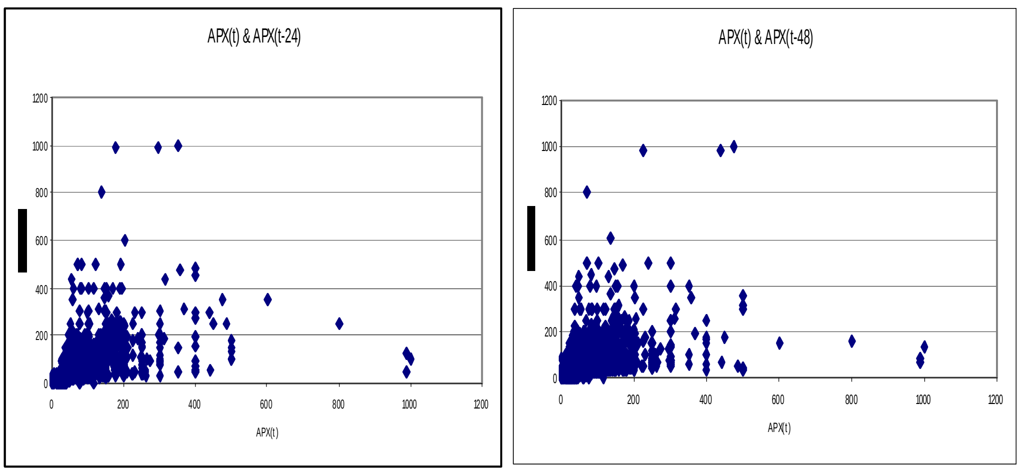


Figure 10: Scatter graphs of APX (t) & APX (t-24) and APX (t) and APX (t-48).

IMB $_{(t-72)}$ indicates the three days before long price of electricity on the imbalance market[4]. Imbalance market is a real-time market which market participants would have to use to make real-time transactions, because both production and consumption usually deviate at least slightly from the advance plan. As the place for traders to keep the balance of nominated volume and real – time generation, to some extent, we expect that imbalance market would have effect on the electricity spot market, which in the Netherlands is APX market. That means, when APX price goes up because of the high demand, low supply or utilities' unexpected outages, imbalance market should show the increasing trend in long prices. While in the opposite situation, when APX price goes down, there should be the decline signals in imbalance market long price as well. Even though this statement makes sense to the energy people, in our research on 2005 data sample, we did not find strong providence. The correlation among APX $_{(t)}$, IMB $_{(t)}$, IMB $_{(t-24)}$, IMB $_{(t-48)}$, and IMB $_{(t-72)}$ are 0.33, 0.20, 0.18, and 0.28. But as a potential related variable with high interest of traders, we keep IMB $_{(t-72)}$

[4] In this research, it is defined as the market for real – time adjustment and of appropriate monitoring of the electricity wholesale market. For the Dutch market, the volume of electricity that is traded on the imbalance market is about 3.5% of consumption in 2004.

in our equation. It could be too old data in the normal research to be taken, but since the only data source for this market fundamental – Tennet – has three days delay in publishing it to the public, IMB $_{(t-72)}$ is the best description of the imbalance market we could have at hand.

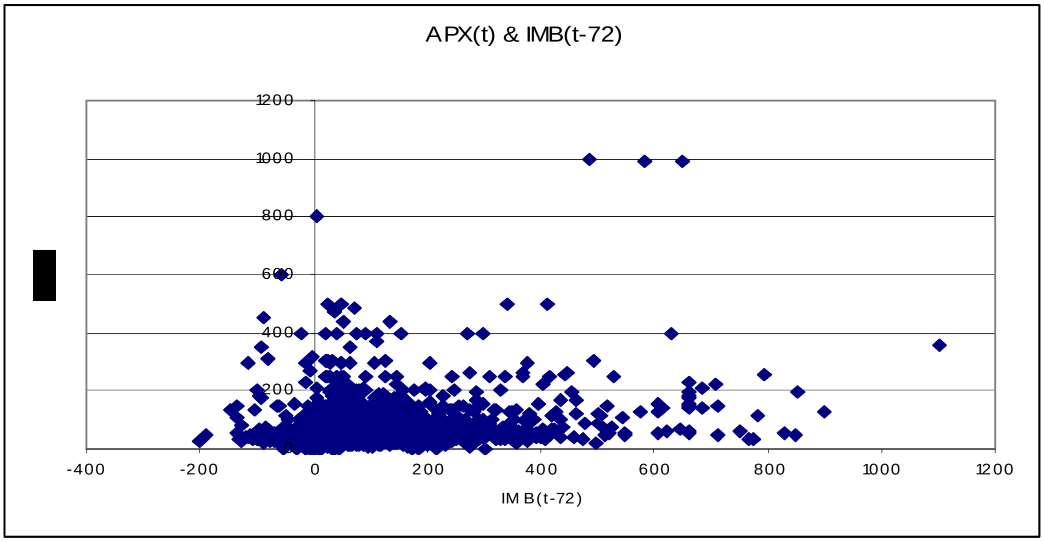


Figure 11: Scatter graph of APX (t) and Imbalance Market Long Price (t-72)

Group 2: Marginal Cost $_{(t)}$, National load $_{(t)}$, Gas $_{(t)}$

Group 2 include marginal cost, national load, and gas price. Since we have talked about the marginal cost model above, here we will focus on the explanation of the rest two items national load and gas price.

National load as an important market fundamental can never be ignored in electricity industry's research. Actually, because of electricity's non-storability and limited generation capacity, people in energy world normally hold an opinion that the change in the load will have vital influence on the price. From our research, the plot result in figure 9(National Load & APX) and figure 10 (National Load & Reserve Index) tells the same story. But since the only data source for Dutch market national load is Tennet, who publishes the national grid feed at 3 o'clock the day after the execution, we could not have the actual national load to make the daily prediction. To solve this problem, in our APX forecast model, assumption of the national load will be used instead of the actual amount. When the previous day load is accessible[5], the model will take the latest actual market information as the new load base. Otherwise, when the data is delayed for some unexpected reasons, typical national load curves[6] for different seasons generated from 2004 and 2005 historical data will be added into the model automatically. Based on the national load curve presented on the operation worksheet, traders who use this model will have to modify each hour's load volume manually according to their market – inside knowledge to make it coincide with the actual market. Figure 14 present the typical national load curves of working days and weekend days for different seasons. Besides this method, there is another way for

[5] Tennet publishes national load one day delay, it is acceptable by EMG to be the national load base for the next day forecast.
[6] National load curves in the model is based on an assumption that everday in the group equal.

Essent EMG to predict national load deserving people's concerning. Since Essent EMG takes a stable 25 % of the Dutch wholesale market, it is also possible to make the prediction based on the customer forecast result from EMG internal. By this way, more factors have been taken into account; influences of weather, light length, holiday effects and etc have been concerned. The discussion of this method is that does it make sense to describe the whole Dutch market by one participant's situation, when there are significant differences between each market participants on customer structure, utilities styles, and operational strategies. In this research, we adopt the first method, and leave second one to a further thinking.

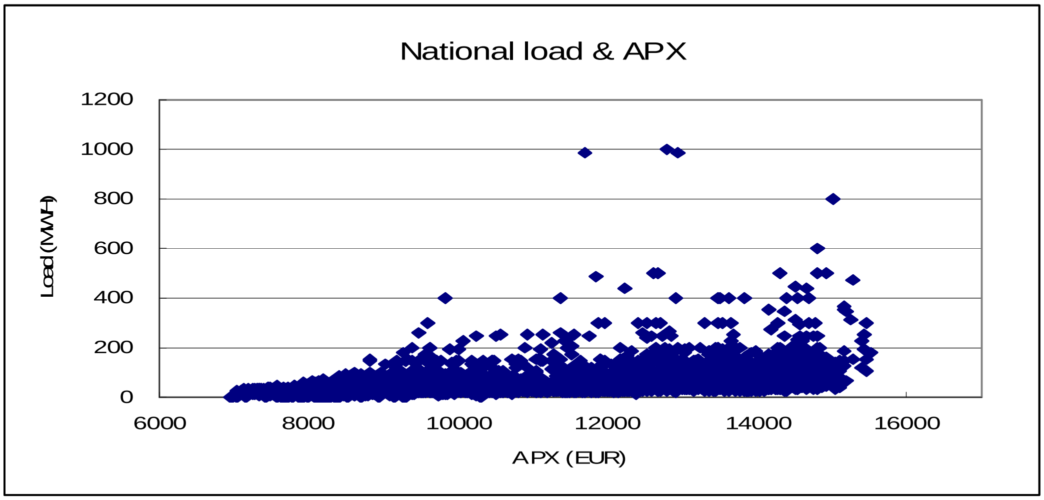


Figure 12: Graph of the relation between national load and APX prices during our data sample from 01/01/2005 to 31/12/2005

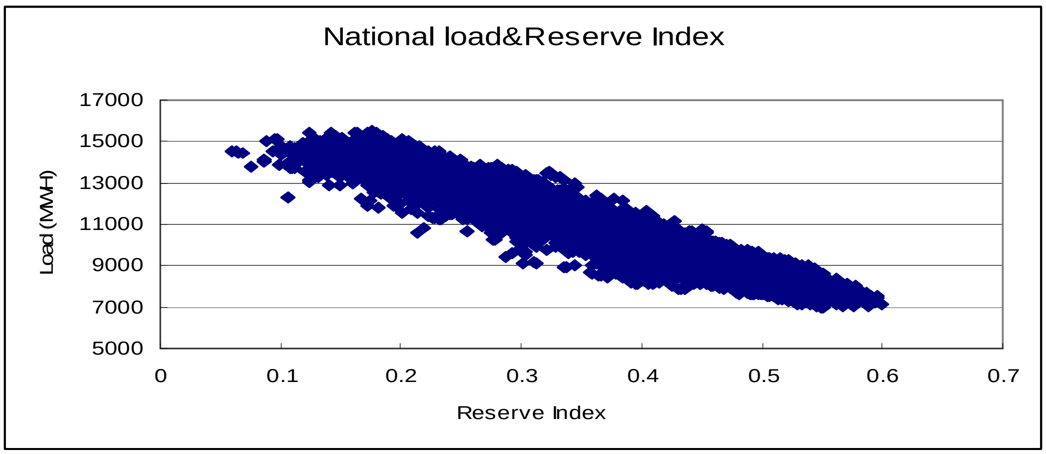


Figure 13: Graph of the relationship between National Load and Reserve Index during the data sample from 01/01/2005 to 31/12/2006.

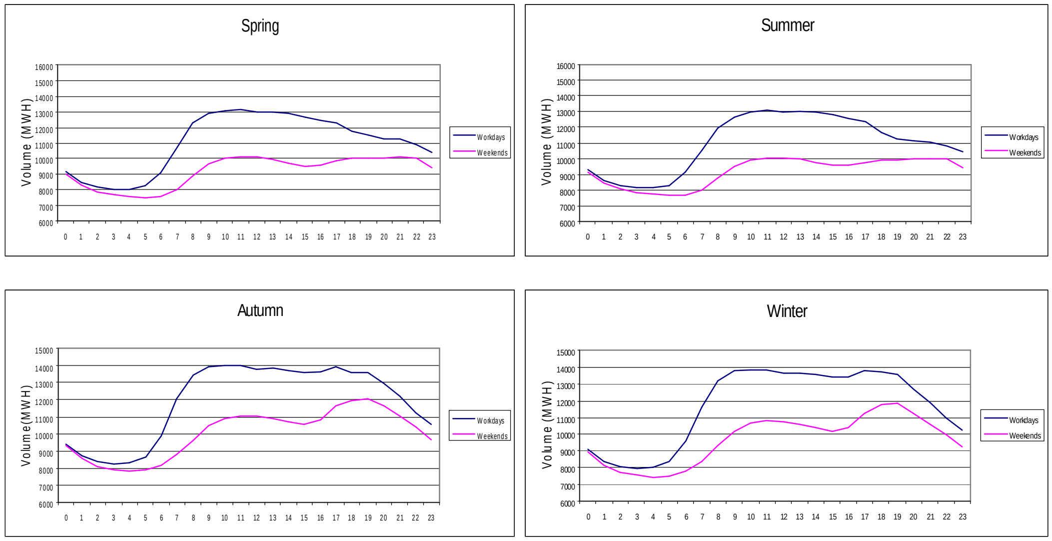


Figure 14: Market demands for workdays and weekends in different seasons.

Gas price is another important factor which will affect electricity's market price. It is mainly because in the Netherlands, gas-fired generation units are normally marginal units and the costs of electricity produced by these units depend on gas price. In our APX forecast model, even though there is high correlation between marginal cost and gas price 0.72, but since we believe gas price as an objective item will still be valuable in electricity price forecast and this is comparably high correlation between gas prices and APX prices during our sample (0.39), it is taken into account in our research.

Group 3: Time Index $_{(t)}$, Reserve Index $_{(t)}$

In this last group, there are two indices, time index and reserve index. Reserve index is the same one we have introduced at the beginning of the section 3. Time Index $_{(t)}$ here is the simple time dummy indicating whether the forecast hour is the peak hour or off-peak hour, working day or weekend. We include this index in the model is because electricity demand has the strong cyclical characteristic. Energy demands are different from peak hour to off – peak hour, from working days to weekend days, and from seasons to seasons. As it is well known that electricity price is closely related to its demand, all these differences in demand will also reflect in electricity market price. Therefore, it is reasonable and necessary to incorporate the time dummy into the forecast model.

3.5 Model Testing

APX forecast model in our research is generated based on data sample from 01/01/2005 to 31/12/2005. In order to evaluate this model, we take the periods 01/01/2006 to 31/03/2006 and 01/06/2006 to 31/07/2006 as our testing data samples. From figure 15 below, it can be seen the predicting result of APX forecast model fitting the actual market prices. During the first sample period, the maximum value of our forecast prices is 213.94, the minimum one is 18.01 compared to the actual values of 350 and 0.1. The average forecast price is 79.69, which is 6.3 euros lower than the actual average price. The correlation between forecast and actual prices is 0.79 with the standard deviation of 35. For the second sample period, the standard deviation value is even higher, because the extremely high price spike happened during this testing time.

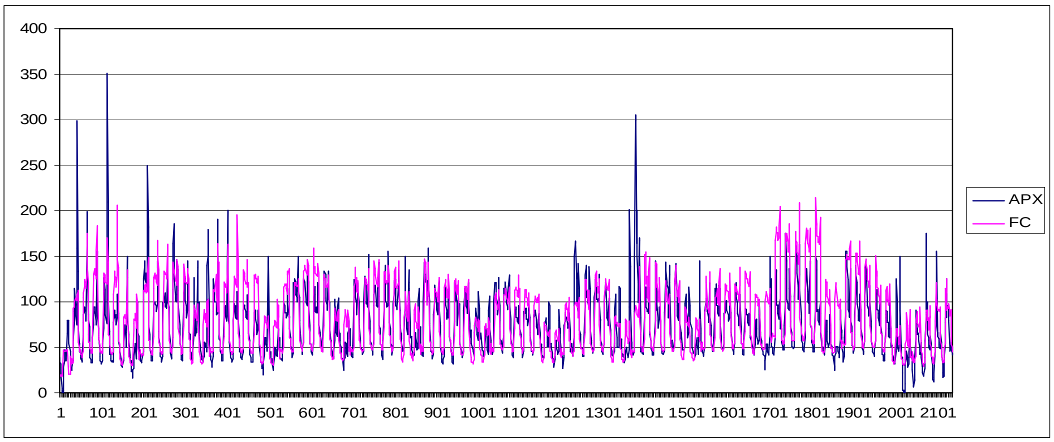


Figure 15: Model testing result during the testing period from 01/01/2006 to 31/03/2006

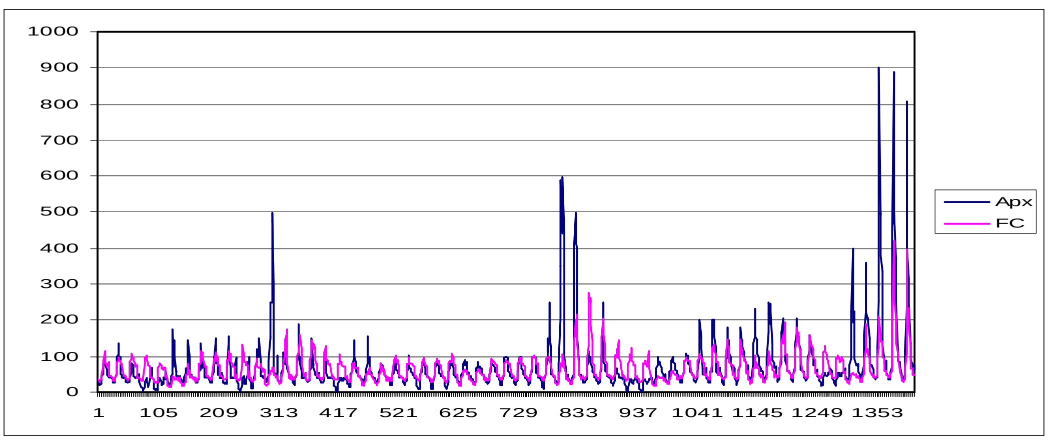


Figure 16: Model testing result during the testing period from 01/06/2006 to 31/07/2006.

For the "spike probability" alarm, we define different reserve index levels as alarm points, the results are different. In this model, after communicating with traders, we have chosen reserve index = 0.2 as alarm signal. According to traders' market knowledge, this level has been considered to be the market tightness beginning point which has to be paid attention. From our analysis on the reserve index in our data sample, this opinion has been approved by the result that 76% of the spike happened when the reserve index below 0.2. With this single, during our test period, 65.39% of the spike hours have been alarmed. It is very interesting to the people working on the trading floor, but it is also necessary to note that the signal alarm gives the wrong information often as well, that is it indicates the occurrence of price spike but actually nothing happens. The reason of this problem could either be the quality of our assumptions on national load, or the way we calculate available capacity. But even though, this alarm signal provides some new ideas to the trading floor which is attractive to people there, and it gives traders some kinds of feelings about the market situations when play different scenarios.

4. Model Implementation

In Essent EMG, most tools and self-developed software are in the form of excel sheet. The reasons could be listed as follows. First, people working there are very familiar with the basic operation of excel, most of them have to deal with the work in excel sheet everyday. There is no need to give the extra training to the people who will take the running responsibility of the new tool. Second, there is good and simple interconnection between excel and other Microsoft software like Access and etc. This characteristic makes it easy when we have to connect the tool to other software. The last reason is that running excel tool does not take up too much extra computer memory, it would not decrease the computer speed and not affect people's other work either. According to what we have discussed above, for the easy daily use purpose, this APX forecast model has also been implemented by Microsoft Excel and embedded VBA.

The tool mainly include two parts: one is the operation sheet where users fill in the information and run the model to obtain the forecast result and save it if necessary. We have adopted three colors in this worksheet to separate different input cells. The purple cells present the information that depending on the knowledge of the traders and therefore, have to be filled in manually to keep the accuracy of the running result. Those yellow cells give the data collected automatically from our internet data source by the embedded VBA programming. There is no operation needed to be done for them. The rest green ones are for the presentation of our model forecast result, which is generated according to the market information from the internet and traders. The operation of this tool is really simple. What users need to do is: put the required information into the model, and press the "run" button to run the model, result will be generated and displayed in tables. For later backward check or market analysis, you could save the result as well by the "save" button. Besides the operation sheet, there is the database part. There are 6 web queries set in the tool, which are connected to internet for the purposes of collecting data of net import, national load, APX prices, imbalance market long prices, wind plant electricity generation, and Genscape units' operation statuses. In order to obtain the fresh data and update our database on time, a timer has been programmed behind the database sheet, which activates all the web queries everyday.

VBA has played essential role in the implementation of the tool. It simplifies the users operation by providing a friendly frame and by ensuring the tool's automation. But the meanwhile, a lot VBA programming brings the danger into the tool as well. First, the programming could not evaluate the quality of the data. For the situation that the website makes the mistake by publishing the incorrect numbers, the tool will still copy and paste them into the database. This mistake can not be checked out automatically by the tool itself. Besides this, since traders work includes different excel workbooks and worksheets, VBA running behind this tool could be affected by the operations in other workbooks. This may cause the model low efficiency or even stop working.

For users of this APX forecast model tool, it is good to get knowledge of the implementation process and mainly issues included. This will be helpful for the understanding of the model's structure and application requirements. And it is good to communicate with the builder of the model and have some discussion during the implementation period. During this model's implementation, a lot discussion has been done between traders and IT supporters. It is interesting findings that sometimes people will prefer different ideas according to their standing positions. Take automation as an example, traders from the trading floor always would like to have the simple and easy tools. The highly automatic ones that would not take up them a lot operation and updating time is greatly welcomed. While, for the IT group, people concerning more about the whole system's safety, the integration of different models and the accuracy of the database, would keep conservative opinions for the same problem. What we have done and suggest is that it is good to hold a prudent opinion about model's automation. Actually, it is necessary to balance the benefit we could get from the model's automation characteristic and the model crashing danger we have to undertake before making the final decision. Only when you can be sure what is more important to you, you could get your idea what you should do. This opinion works for the other conflict during the work as well.

5. Conclusions

This APX forecast model is the first try in Essent EMG to combine all available electricity market information for APX forecasting purpose. The model has been put into daily use after it was finished. Since there will still be some time before traders planning their trading strategy depending on this APX model, we could not evaluate it by calculating the economic benefit from model. But still a few conclusions could be listed here.

About the performance, by defining “price spike” as “50 euros higher than the marginal cost”, 63% of the total spike hours during our testing sample have been caught and 65.39% of the total spike hours have been signaled correctly by spike alarm (reserve index =0.2). For the rest, we miss the spike price either because there is no signal reflecting the price sudden increase or influences of some other factors are not covered by the model.

The APX forecast Model results may underestimate the market on Monday. This happens because of two reasons. One is the so called “market fear”. It comes because as the first working day after the weekend, when people plan their strategy, they normally would like to pay a high price to make sure their demand will be met without any problem. In our research, even though it is an interesting factor that we believe has the influence on market prices, we did not add it into the model. Therefore, the forecast result of Monday may be expected lower than the actual price. The other reason causing this could be that in our model historical market information has played important role. But because the data publishing delay or inaccessibility, we have to depend on the data from the last week for Monday’s forecast, the too old data may not be able to provide the accurate information we need and lead to the difference of the forecast prices and actual prices.

Look at the graph of the model performance during the testing period, we could see that the model performs better for the off-peak hours than the peak hours, better for the relatively low spike price hours than the extremely high spike moment. The reason could be that during the off-peak hours energy demand maintains at a certain level, which is far from the limitation of market supply. Therefore, electricity prices also remain at a certain level with a small variation range. While in the peak hours, demand of the electricity is higher. In order to meet people’s work and life requirement, energy market participants will choose to run the high-cost units to meet the additional demand of the market. The high expense of these units increase the marginal cost of electricity, and lead to a higher price during peak hours in a day. When the demand as high as approaching the limited generation capacity of electricity market, to be sure to get the energy, people would like to pay even extra money on the energy. Therefore, under this situation, extremely high price will occur in the market, which is the so called “price spike”. Since the price premium put on the marginal cost by consumers for guarantee could not easily be added into the model, it is easy to understand the result that model performs better during the off-peak hour than the peak hour, better for the relatively low spike prices forecast than the extremely high ones.

The last and the most important conclusion is that the users of this model as an important component have significant influence on the forecasting result. It has been reflected in three aspects in our research.

First, traders' market – inside knowledge will help them make trading decision. Generally, as the trading strategy planner, in order to maximize their benefit, to earn money in the energy trading market, traders need to know as much as possible about the whole market, not only their own company, but also the other market competitors. There is direct and indirect way to get this kind of information in energy market. In our model, we have divided the whole Dutch electricity market participants into three groups. One part is those utilities belonging to Essent, which we obtain all the market data. One part is those big utilities monitored by Genscape, from which we have deleted those under Essent. The last part represents all the other existing units, which we have no access to any related data. During the operation of the model, traders given the operation signals of each unit have to manually put in the available capacity according to their knowledge. For example, when a unit is under outage or face certain operation problem to run with half capacity, traders would adjust the input data by their internal information. This would make the model fit the actual situation better and generate more accurate result.

Second, the normal check of people would promise the model's stability and accuracy. This APX forecast model is linked to internet closely by a few web queries contained in Excel worksheets. Everyday, the timer installed in the model would be activated automatically once to update our local database by the latest information published on the internet. This has simplified people's work of checking different website for the information, but the same time, introduce a danger into the daily forecast result because of the instability and unpredicted delay of certain websites. Therefore, in order to make sure the forecast results of the model is calculated by the correct data, it is necessary and sensible to check the installed database regularly.

Last, people's opinion about the model's result would lead to different trading strategy. Because this is the first forecast model for short term electricity market in Essent EMG, how to use the result is still under the discussion. Since different users would have different understanding on the same number, and further make different decisions during the trading, it may be necessary to set up certain standards after a period real operation.

As a summary, this APX forecast model has implemented some theories like "marginal cost" into application, introduced the new idea like "reserve index" to the trading floor. Of course, there are still places could be improved, and this APX forecast model has set up a beginning point for the further related research in Essent EMG.

6. Recommendations

At the end of this paper, there are recommendations on the further related research. First, instead of making analysis on the hourly prices, it would be interesting to look into the hourly prices difference. Questions like "whether the change of one factor would affect the change of the other one?", "how much the effects are?" are interested to traders. Second, take into account of the units' maintenance period. In this research, by the constraints of data source, we could only include some of the units' maintenance schedule, and assume that all the other units always under the ready condition for running. But it is expected by the traders that if we could specify each unit's maintenance schedule, we could give the more accurate description of market, and hence, get better forecast result.

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