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A NOVEL APPROACH TO ELECTRICITY MARKET EDUCATION

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ABSTRACT
This paper presents a novel approach to power engineering education, the basic idea of the new approach is provide the power engineering students at Lappeenranta University of Technology (LUT) with skills that are required in today's open power markets. These include, in addition to the basic power engineering skills, understanding issues such as risk management, financing, and sales and marketing. The approach consists of developing both the theoretical and practical teaching methods that are applied in power engineering education at LUT. The practical learning methods in particular have played a significant role as a so called Power Exchange Game has been developed. The game construction is based on the operation of the Nordic power exchange Nord Pool. The game enables the students to apply their theoretical knowledge about open electricity markets in practice. During the game the student teams act as portfolio managers of the electricity retail companies and they need to analyze and make decisions related to the operation in the Nordic electricity market. Students are expected to keep learning diaries during the game and analyze their own performance in a final report after finishing the game. In course's feedback, most of the students considered the course a very interesting and effective way to study electricity market operations.

KEY WORDS
Power Engineering, Education, Electricity Market, Power Exchange

1. Introduction

Competitive Nordic electricity market offers a very challenging operational environment to the various electricity market participants. Electricity demand depends highly on temperature, where as on the supply side, the generation of electricity is influenced, for instance, by the content of the water reservoirs as well as the prices of CO_2-allowances. Consequently, electricity prices are highly volatile and difficult to estimate exactly. The operational environment in open electricity market contain many business risks that originate from the special characteristics of electricity and, therefore, there is a need for professionals, who understand both the market functioning and methods to manage the electricity market risks. Others have coped with those issues with interesting methods and simulation tools for education [1-3].

This paper first discusses the Nordic electricity markets. Main emphasis is on the structure and special characteristics of Nordic electricity market. In addition, the functioning of the Nordic power exchange Nord Pool is briefly discussed. The second part of the paper deals with educational challenges related to power market operations and after that paper introduces a practical way to educate electricity market operations to power engineering students. Laboratory of electricity Markets and Power Systems at LUT has developed a game where students can apply their theoretical knowledge about the Nordic electricity markets in practice. This kind of practical education has got very good feedback from the student and also very good learning results. At the end of the paper, there is a discussion about the course's empirical results and feedback.

2. Background Information

Electricity supply chain consists of four parts; power production, electricity retailing, electricity transmission and electricity distribution. In open electricity markets, the production and retailing of electricity are open for competition. Electricity transmission within a country is usually operated by a national monopoly company, which is the transmission system operator (TSO). Electricity distribution is operated by local monopoly companies under government's regulation.

2.1 The Nordic Electricity Market

Between 1991 and 2000 the electricity markets in Finland, Norway, Sweden and Denmark were opened up for competition in generation and sales, and now there is a single multinational Nordic electricity market. In 1991, Norwegian power exchange Statnett Market AS was established. In 1996, a joint Norwegian-Swedish power exchange Nord Pool ASA was started. Following this, Finland and West Denmark became their own market areas within the Nord Pool in 1998 and 1999, respectively. Finally, the Nordic power market became fully integrated in October 2000, when Eastern Denmark joined the Nord Pool. [4]

In open electricity market there is a need for a market place for physical and financial power contracts. In the Nordic electricity market the market places are the power exchange Nord Pool and the bilateral over the counter (OTC) markets. The spot trade of electricity takes place in the Nord Pool where as the long-term bilateral contracts of electricity are usually traded at the OTC-markets. The Nord Pool also operates the financial market of electricity, and provides a reference price for other electricity trading and retailing.

2.1.1 Market Structure

There are a large number of participants in the Nordic electricity market. Generating companies and large end-users trade in the wholesale market, and the small customers have access to the market through their distribution and supplier companies. Most of the producers are distributors and almost all distributors are traders. All participants have free access to the power grids. Figure 1 illustrates the structure of the Nordic power market. [5]

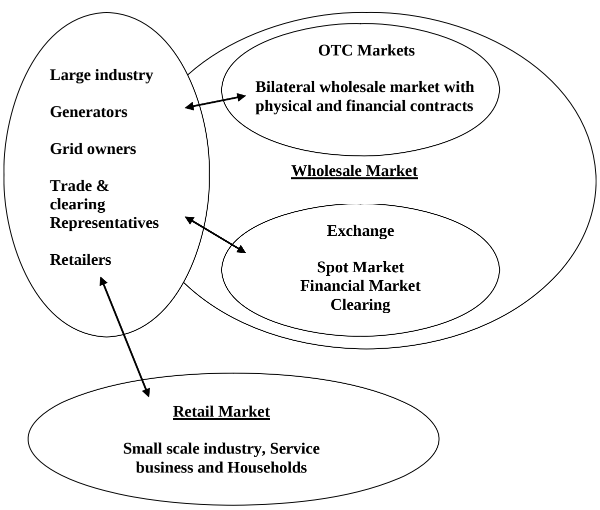
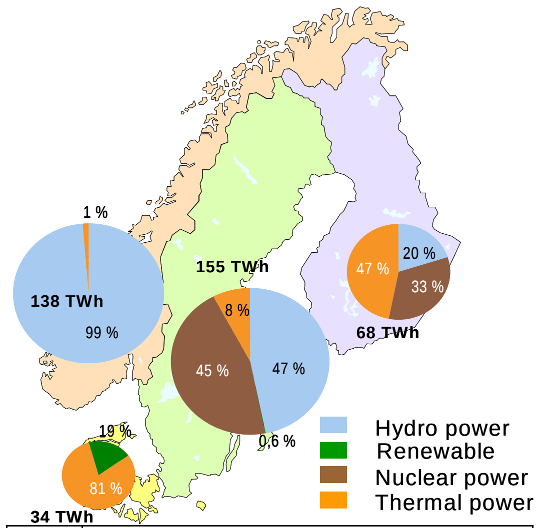


Figure 1. Overview of the Nordic electricity market [5].

Electricity production in Finland and Sweden is based on hydro power, nuclear power, thermal condensing and combined heat and power (CHP) production. In Norway, almost 100 % of electricity is produced with hydro power. In Denmark, most of electricity is produced with thermal power. Figure 2 illustrates electricity generation in the Nordic countries in year 2005.



Country	Generation 2005 (TWh)					
	Hydro	Thermal Condensing / CHP	Nuclear	Renewable	Total	Population (million)
Finland	13,6	31,8	22,3	0,2	**67,9**	5,3
Norway	136,5	1,0		0,5	**138,0**	4,6
Sweden	72,1	12,2	69,5	0,9	**154,7**	9,0
Denmark	0,0	27,7		6,6	**34,4**	5,4
Total	**222,3**	**72,7**	**91,8**	**8,2**	**394,9**	**24,3**

Figure 2. Electricity generation in the Nordic countries in 2005.

The total annual electricity production in the Nordic countries amounts to approximately 400 TWh per year. However, the year-to-year variation in reservoir content can amount to as much as ±80 TWh. This, along with temperature, causes significant seasonal spot price variations in the Nordic power exchange.

2.1.2 Price Formation

Electricity price formation in Nordic electricity market is based on the balance between supply and demand. Basics supply side variables that have a great influence on electricity price are the reservoir content, CO_2-allowances and fuel prices, while temperature and industrial consumption have a great influence on electricity demand side. Figure 3 illustrates electricity price formation in the Nordic electricity market.

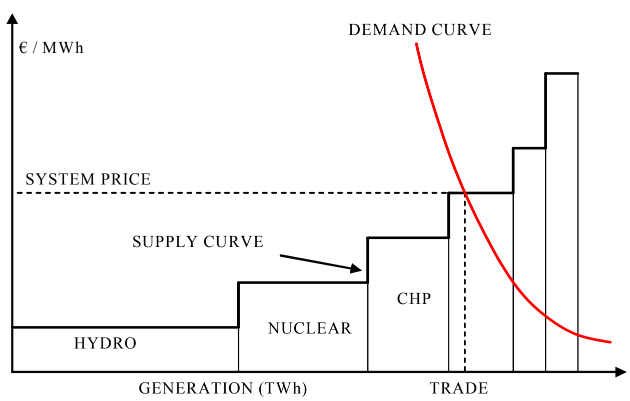


Figure 3. Formation of system price.

2.2 Power Exchange

An important part of the Nordic electricity market is the Nordic Power Exchange Nord Pool. It operates a spot market and provides a price reference to the whole power market. It also organizes a market for the financial products, such as forwards, futures, options and CO_2-emission contracts. One of responsibilities of the power exchange is to be neutral and reliable contract counterparty to the market participants.

Nord Pool's day-ahead spot market, where the system price is formed, is called the Elspot market. Elspot market's volume in 2005 was 176 TWh, which was about 44 % of total Nordic electricity consumption. Nordic electricity consumption in 2005 was 402 TWh [6]. Nord Pool also offers a power balancing market for hour-ahead electricity contracts with a physical delivery. The hour-ahead market is called the Elbas market. Finally, the Nord Pool offers a financial derivatives market, which volume in 2005 was 786 TWh. [4, 7]

Figure 4 illustrates Nordic system price and reservoirs content difference to median from year 2000 to present. It shows that electricity price in Nordic countries is very volatility and it has some correlation with reservoirs content.

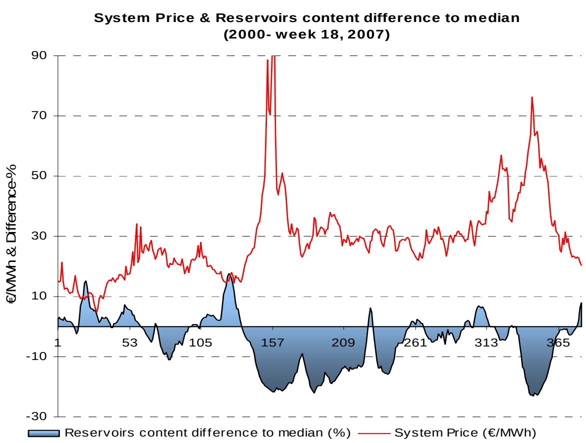


Figure 4. System price and reservoirs content difference to median in years 2000-2007.

High CO_2-allowances prices during year 2005 explain partly the high price of electricity at that time, in spite of quite good reservoirs content. During the years 2002, 2003 and 2006 very low reservoirs content raised the electricity spot prices.

In principle, the same spot price is applied throughout the entire market, if there is no congestion in the transmission networks. Should congestion occurs, the Nord Pool market area is divided into eight separate price areas. These price areas are: Finland, Sweden Norway 1-3, East and West Denmark and KONTEK (North Germany bidding area). If the sales between two areas is bigger that transmission capacity, power exchange reduces or increases area prices until the power flow matches allocated grid capacity during the system price calculation. The formation of area prices is discussed in more detail in reference [4].

3. Educational Challenges

Power engineering education today faces the challenge of teaching students both the functioning of the power systems and the principles of open electricity markets. In other words, in addition to the traditional power engineering skill, the students are now expected to learn about the structure and behavior of the open electricity markets and the associated business risks, and to understand the role and usage of physical and financial contracts in the open electricity markets.

It is also important that the students understand the meaning of risk management in the electricity retail market. It's a low profit business area that is open for competition. So, there is no guarantee that customers will not change the retailer if electricity price is too high. In the electricity retailing business, well implemented risk management is the key to success. The first step is to identify the risks, and this requires in-depth understanding of the special characteristics of the open electricity markets.

So, it is essential to create strong theoretical basics about power market fundaments, power exchange products and electricity trading risks management, that power engineering students are ready for real-life challenges.

3.1 Power Market Education at LUT

The goal of the power engineering education carried out by the Laboratory of electricity Markets and Power Systems at LUT is to give the students a comprehensive picture about the Nordic power market and its special characteristics, and to help them understand the functions and products of the Nordic power exchange. In order to achieve these goals, a course "Electricity Market" is arranged every year. The course introduces the students with topics such as the functioning of the open electricity markets, structure and characteristics of the Nordic electricity markets, and the role and operation of the Nordic power exchange Nord Pool. During the course, students get the basic theoretical knowledge about Nordic electricity markets.

In addition, power engineering students nowadays also need to have an understanding of issues, such as financing, risk management, and sales and marketing. The subject matter of the electricity market operations is quite wide, so it is necessary to also confirm the students' theoretical knowledge with practical exercises.

3.2 Practical Approach to Power Market Education – The Power Exchange Game

The Power Exchange Game for Electricity Market is designed to combine the theoretical studies of the power engineering education with relevant practical exercises. The game's main target is to teach the students to operate in open electricity markets, and to manage risks and analyze the power market movements. So, the game is developed as a teaching tool, but it is fully suitable for training purposes for the real traders also.

The game is a realistic description about the operations of the Nordic electricity market. The game is based on the idea that the students virtually perform various trading activities with the physical and financial products of the Nord Pool at their real daily closing prices.

The game is held between November and February, when the autumn changes to winter. Usually electricity price volatility is quite high during that time period and that creates many challenges and risks for the players. Obviously, similar risks are also present in the real business world. In order to succeed in the game, the students must understand how the different fundaments of electricity markets affect the market development, and utilize this knowledge in their decision-making.

3.2.1 Game Platform

The Power Exchange Game itself is implemented with MS Access, MS Excel and Internet. Figure 5 illustrates the architecture of the game. During the game teams analyze electricity market movements and fundaments and send their bids and other decisions to game operator through internet. Operator updates the game whenever it is necessary and also guides the teams if needed.

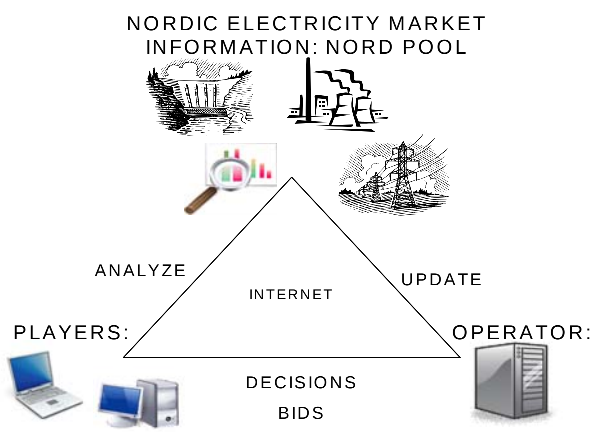


Figure 5. Architecture of the Power Exchange Game.

In the game, the student teams act as portfolio managers of electricity retail companies. In playing the game, the students are able to trade with almost all physical and financial products that are available at the Nord Pool during the same time period.

At the initial stage of the game teams focus on submitting the price bids for three different customer groups. The distribution of customer between the teams is decided based on the bids that they make at the initial stage. Once the teams know their customer portfolio, they have to hedge their electricity purchasing price for the delivery period by using the Nord Pool derivatives. A certain price level for exchange-traded electricity can be hedged by options, forwards and futures.

The teams can purchase in advance a small portion of their customer's forecasted total electricity consumption with OTC-traded long-term physical electricity contracts. The rest of the consumption is expected to be purchased in the spot market during the delivery period. Figure 6 illustrates the game schedule and operations.

November	December	January	February 1 . week	February 2. week
Price bids for consumer groups	Price bids for consumer groups	Price bids for consumer groups	DELIVERY PERIOD	
OTC-TRADING	OTC-TRADING	HYDRO POWER	ELSPOT by Tue 13h	ELSPOT by Tue 13h
OPTIONS	OPTIONS		ELBAS by Tue 19h	ELBAS by Tue 19h
FORWARDS	FORWARDS	FORWARDS	Balance settlement	Balance settlement
		WEEK FUTURES	2. WEEK FUTURE	

Figure 6. The schedule of Power Exchange Game for Electricity Markets.

At the final stage of the game that is during the delivery period, electricity is purchased separately for each hour of the day during two days; first on the Elspot market, and later on the Elbas market. Teams try to keep their customers' electricity consumption (which is adjusted for temperature variations) and their own electricity purchasing in balance. The team that makes the biggest profit wins the game. More detailed description of the game is presented in [8].

Risk management plays also an important part of the Power Exchange Game. In the game, there is a risk limit called open position, which limits price hedging power to ±25 % of the forecasted mean hourly power consumption. The limit reduces the amount of open position and risks, but does not eliminate them completely.

3.2.2 Market Conditions in Years 2005 and 2006

In this section we take a closer look at electricity market conditions during two quite different years 2005 and 2006 in the Power Exchange Game. In the first case, which is in 2005, there was an ascending market situation in the Nordic electricity markets. In the latter case, which is in 2006, the market situation was downward. Table 1 illustrates in principle the main differences between the electricity market outlook in years 2005 and 2006 in relation to the Power Exchange Game.

Table 1. Electricity Market outlook during Power Exchange Games in years 2005 and 2006.

Market Outlook	Game 2005	Game 2006
System Price	Ascending	Downward
Reservoir content	Over Median	Under Median
CO_2-Price	High	Very Low

Figure 7 illustrates the development of electricity market system price and the reservoirs content compared to its historical median in the Nordic countries between the years 2005-2006. In the game 2005 reservoirs content was generally good but in the game situation was just opposite. Actually, in the summer 2006 reservoir content was over 20 % under historical median.

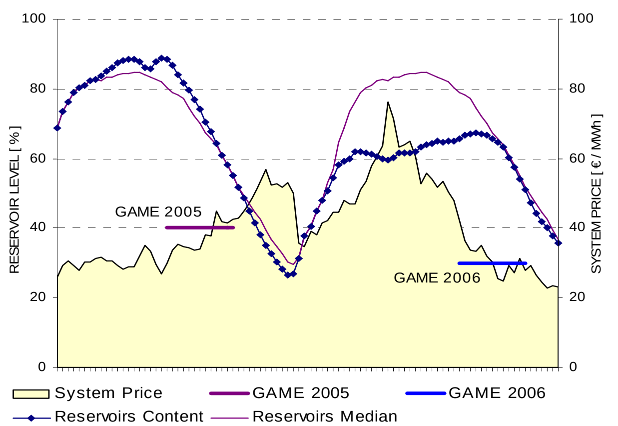


Figure 7. System price and reservoirs content and median over the game period in years 2005 and 2006.

Figure 8 illustrates CO_2-forward prices over the game period in both years. CO_2-allowances prices drop down in spring 2006 after EU countries published their emission balances.

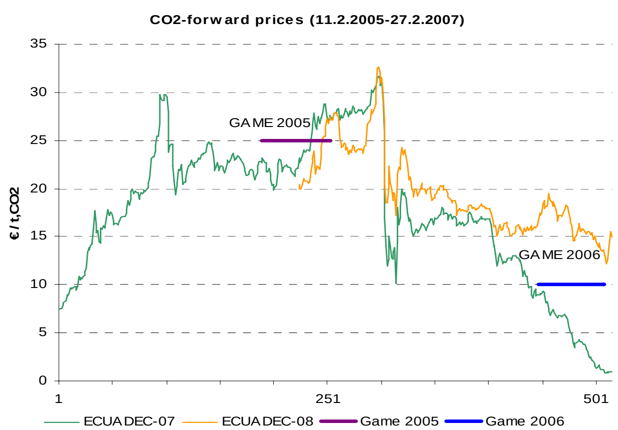


Figure 8. CO_2-forward prices over the game period in years 2005 and 2006.

In downward market situation, like in game and year 2006, there is a risk that the students get a wrong idea about the challenges associated with operating in open electricity markets. It's important to stress that there is not a single way that would guarantee success in all market situations, but that the success always depends on the players' ability to adjust their behavior to prevailing market conditions.

3.2.3 Game Results in Years 2005 and 2006

In year 2005, 12 teams took a part in the game but only two teams reached a positive financial result. The biggest mistake that many teams made was that they set too cheap customer bids compared to electricity purchasing price. Consequently, these teams did not get enough profits to cover their purchasing costs. Also derivatives prices were quite high before Christmas and that caused a negative income from derivatives that were netted against system price after Christmas. It is obvious that students learned the hard way the importance of the relation between the customer bidding price and the wholesale purchasing price, and how those two things influence the income of an electricity retailing company.

In year 2006, 16 teams took a part in the game. In this year all teams managed to make a positive financial result. The good overall result during the game 2006 was at least partially a consequence of downward market situation. In addition, before the game started the importance of price bidding and hedging was stressed. The main reasons for the downward market situation were ascending reservoirs content, downward CO_2-prices and the very warm last part of the year.

Figure 9 illustrates Nord Pool month forward prices before and during those two years. These prices were the main driver for student's customer's bids.

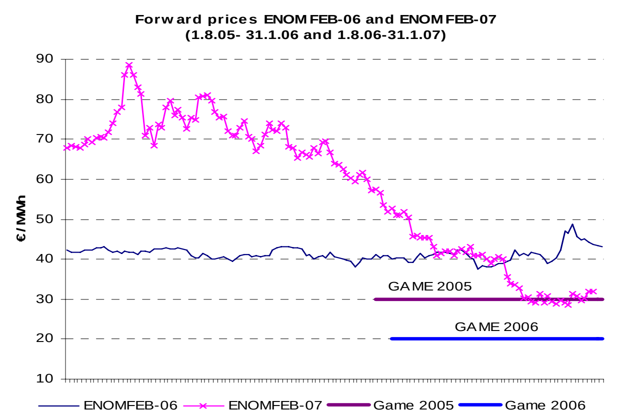


Figure 9. Nord Pool forward prices during the game period years 2005 and 2006.

In year 2006, students made their customers bids based on forward prices over 45 €/MWh in November. In February 2007 the spot purchasing price was around 35 €/MWh. In the previous year, the forward price in November was around 40 €/MWh and the spot purchasing price in February was over 50 €/MWh on average.

In both years, the weather was quite cold during the delivery period in February. In Finland, for instance, the temperature has been between -10ºC and -27ºC. The low temperature increased consumption significantly and affected the need of spot trade.

Regardless of the market conditions, the students were expected to analyze the markets and try to make reasonable financial hedges and customer bids. It has proven to be possible for students to make profits in all kind of market situations if they plan their electricity sales and purchase well.

3.2.4 Learning Results and the Student Feedback

One obvious learning result of the Game is that it clarifies the difference between the physical and financial electricity trading. Before the game starts, students always know this difference quite well in theory, but not necessarily in practice. In contrast, during the game, when electricity is purchased in the physical spot markets, and the financial products are used for price hedging, the difference becomes very clear for the students also in practice. In addition, the game manages to clarify the difference between system and area prices, because the electricity spot purchase is made at Finland area price and the electricity derivatives are netted against the system price. In other words, the financial contracts do not automatically give a 100 % hedge to electricity purchase.

After the game, an anonymous feedback is always collected from the students. In the feedback form, the students are asked to give their overall evaluation of the game on a 1-5 scale, where 1 indicates dissatisfaction and 5 indicates satisfaction. In years 2005 and 2006, the overall average scores for the game were 3.9 and 4.2, respectively. The students also found the game very interesting (with respective scores of 4.5 and 4.7). In addition, they believed that they will be able to exploit and apply the knowledge that they had learned during the game in their future work. According to feedback, the most important targets for development of the game were better instructions and also increased tutoring during the game. The game will be further developed based on students' feedback and course's empirical results. Feedback reply percent in both years was over 50 %. Complete feedbacks reports are published in the game's homepages [9].

4. Conclusion

The Nordic power market offers a challenging operational environment with high volatile electricity prices and many business risks. In order to succeed in this kind of business environment, it is important to understand the special characteristics of electricity markets as well as the price formation mechanism in today's open electricity markets.

The acknowledged challenges of the open electricity markets also create need for developing the traditional power engineering education. The Power Exchange Game is a novel way to educate power engineering students to apply their theoretical knowledge in practice.

Based on the empirical experience and the students feedback it can be said that the Power Exchange Game has proven to be a very useful tool to teach power engineering students the operations of the open power market. Students have a possibility to apply their theoretical knowledge in practice without "real-world" risks. Students also learned to use the power exchange products in managing the electricity trading risks.

It is of course obvious that the Power Exchange Game is just a snapshot of reality. Therefore, it is necessary to remember and understand that there are certain limitations related to the game. For example, the time period of the game is too short to give a complete overall picture about the annual volatility of the electricity prices. However, compromises and simplifications have to be made in order to develop any practical learning methods at all.

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