Electricity Markets in Russia, the US, and Europe

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Abstract— **An in-depth analysis of the restructuring processes in individual market areas requires knowledge of the initial physical and organizational state of the electricity markets. The differences in these initial states lead to a significant divergence in the restructuring processes between the different market areas. There are general textbook models for electricity market restructuring; however, more specific tools are required for a detailed analysis of the divergent market structures and restructuring mechanisms in individual market areas. To illustrate the differences in the restructuring processes, this paper provides a review of four different electricity markets; the introduced electricity markets include Russia, the Nordic countries, the France–the Netherlands–Belgium interconnection (known as the Trilateral Market Coupling area, TLC), and the Pennsylvania–New Jersey–Maryland interconnection (PJM). The Nordic countries and the TLC represent two different European market structures. Russia and the PJM market area in the US, on the other hand, are examples of different approaches in terms of pricing models and market structures compared with the ones commonly applied in Europe. In this paper, the development paths of the electricity markets in these target areas are analyzed taking into account the initial situation in each of these areas.**

Index Terms— **electricity markets, deregulation, liberalization nodal pricing, restructuring**

I. Introduction

IN many countries, the electricity market restructuring and liberalization process has taken place during the past two decades. In Europe and the US, the opening of the electricity markets has largely been carried out at the turn of the 21st century, whereas in Russia, the electricity market restructuring started in its present form in 2006. According to the current reform plans, the process will be completed by 2011.

The electricity markets in Europe, the PJM area in the US and Russia all have market models of their own. The differences in the market models mainly result from the different initial situations in the electricity market restructuring. For example, in the PJM area, nodal pricing is employed in the day-ahead market, whereas in Europe, zonal pricing is the principal pricing method. The Russian electricity market structure has been particularly influenced by the electricity markets of the PJM area in the US. There are also many other differences between the Russian, the PJM and the European electricity markets, each of them providing an interesting example of establishing a framework for a competitive electricity market. However, comparisons between market models applied in Russia, Europe and the PJM are largely absent in the literature.

There are several issues that affect the market restructuring process. For instance, the initial situation of the market (such as the existing intra- and interregional transmission capacity) has an effect on what kind of a pricing method (i.e. zonal or nodal pricing) can be applied. Second, the pricing method chosen has a significant impact on how the markets will be organized.

The main objective of this paper is to analyze and compare the similarities and differences between the electricity markets in Russia, Europe and the PJM. The paper is organized as follows. First, the key issues that define the structure of competitive electricity markets are introduced in Chapter II. Next, the European electricity markets are studied in detail in Chapter III. The Nordic electricity market and the TLC area are taken as primary examples of the European approach to the electricity market development. Then, the PJM electricity market structure is examined in Chapter IV, followed by an analysis of the current state of affairs in the Russian electricity markets in Chapter V. The differences and similarities between the electricity markets in the target areas of the paper are discussed in Chapter VI, and finally Chapter VII concludes the paper.

II. Structure of Deregulated Electricity Markets

The target of the electricity market restructuring is to establish competitive wholesale and retail markets. Competition in turn is expected to improve the efficiency of the electricity supply sector and thereby providing long-term benefits to the consumers [1]. When competitive markets are created, various reforms are required; these reforms are covered in the textbook models for electricity market restructuring. In general, privatization, vertical unbundling, and horizontal restructuring are mentioned in most of the textbook models [1]. It is, however, noteworthy that all these reforms are not required in every market restructuring process because of the different initial situation in the markets.

A. Organizational restructuring

Establishing competitive electricity markets requires that there are enough players in the market. The initial situation in the market restructuring processes is often such that the publicly owned electricity companies have a dominant position. In these cases, horizontal restructuring and

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privatization of the electricity generation assets are often carried out to ensure an adequate number of competing firms. However, if the ownership of the generation assets is diverse in the first place, horizontal restructuring and privatization of the assets are not a requisite for establishing competitive markets. The former case has been typical, for instance, for the TLC area and for Russia, whereas the latter case represents the situation in the Nordic countries prior to the electricity market restructuring. Vertical unbundling, on the other hand, is usually carried out regardless of the initial situation. In practice, this means separating the competitive electricity businesses (electricity generation and retail) from the regulated monopoly operations (electricity transmission and distribution).

After restructuring, the details of the market models may be different but similar elements can be found basically in all markets. For instance, there are usually bilateral markets and exchange trading with day-ahead and real-time and/or balancing markets. Financial markets are also common. Especially in connection with nodal pricing, there are often markets for financial transmission rights and capacity. Finally, system operators are responsible for operating the electricity transmission networks, and regulators supervise functioning of the market.

B. Transmission networks as a market place

The technical condition of the electricity transmission networks, and especially their ability to withstand extensive long-distance transmission of electricity across regions, are decisive factors when designing a market model for the restructured electricity markets.

In Europe, the transmission networks have enabled the national markets to operate as a single-price market. In contrast, the single-price market has often not been a viable option in the US. In the latter case, the electricity generation plants are typically situated close to the load centers, and the long-distance transmission networks have not necessarily been designed for extensive intra- and interregional transmission of electricity from remote power plants. The congested networks prevent the formation of a single market clearing price. This results in the adoption of the nodal pricing method.

C. Pricing methods

The price of electricity in the competitive markets can be determined by a uniform marginal price, a few zonal prices or a number of nodal prices. In the case of a uniform marginal price, the whole market area has the same price for selling and buying of electricity in the wholesale markets. Instead, when the market area applies zonal pricing, there is an opportunity to split the area into a few zones if there is not enough transmission capacity between the zones. In nodal pricing, the prices of electricity are calculated for a large number of locations (nodes) on the transmission grid. The nodal prices are calculated based on the actual power flows on the transmission grid. In Europe, zonal pricing is the most common pricing method. In contrast, in the PJM and in Russia, nodal pricing method is applied.

D. Market surveillance

The pricing method has an effect on the role of market surveillance in the electricity markets. A characteristic of nodal pricing is that generators by default have market power in the nodes that they are connected to. The legislative approach is to set offer caps, which effectively cut price spikes. However, while reducing the opportunities of market manipulation, the offer caps also reduce the necessary incentives for new investments in electricity generation. In zonal pricing, offer caps are usually not necessary because the large market areas do not create scope for market power abuse. Consequently, price spikes occur in tight supply-demand situations. These are signals for a need for new investments and separate capacity markets are therefore not needed.

The electricity markets in Europe can be classified as ‘energy only market’; that is, there are no separate capacity markets. In contrast, in the PJM and in Russia, there are separate capacity markets operating in parallel with the electric energy markets.

III. EUROPE

In Europe, the electricity market restructuring has mainly taken place during the past ten years. The main driver for this development has been the EU. The first step to open the electricity markets in Europe was taken in 1996 when the EU set a directive (96/92/EC) to open the electricity markets. A new directive (2003/54/EC) specifying the timetable for the market opening was set in 2003. Every EU country had to open their electricity markets by July 2007; however each country is allowed to independently choose the method of restructuring. The next step is to integrate the European electricity markets; this is also stated in the third legislative packet of the EU.

A. Market model

In Europe, the price calculation in the wholesale electricity markets is carried out by the power exchanges. Bilateral contracts between generators and buyers are also possible. Generally, there are day-ahead and intraday markets, which are for the physical electricity trade. The participants can freely set their bids. The financial markets usually include future, forward and option markets. Some of the financial markets are physical, meaning that the settlement is not made by cash but physical delivery of electricity. The TSOs (Transmission System Operators) co-operate with the power exchanges to take care of the transmission capacity and the transmission system. They also inform the exchanges about the amount of the daily transmission capacity amount.

The pricing method in Europe is zonal pricing. In principle, there are two different ways to calculate the zonal prices: market coupling and market splitting (Fig 1).

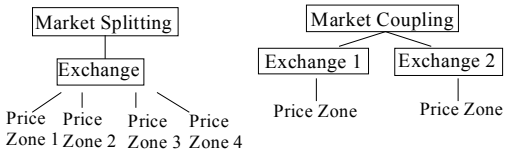

Fig. 1. Basic models of market splitting and market coupling.

In market splitting, one system price is calculated, and if there is not enough transmission capacity between the zones, the area is split into a number of zones each of which has a price of its own. In market coupling, there are several exchanges, all of which first calculate a system price of their own, and if there is enough transmission capacity between the areas, the zones can be coupled into a single market area.

B. Market integration

The goal of the single European electricity market requires that the national electricity markets in Europe are eventually all integrated. An intermediate step is to create seven regional integrated electricity markets. The development of the regional markets is already in progress; for instance, the Nordic electricity market and the TLC area can be classified as regional electricity markets.

At present, there is not yet a common view on the preferable market integration method for Europe. Market integration is always a challenging process, and it is even more challenging if the regional markets have created practices of their own. If the market models in the regional markets are too diverse, a lot of negotiations are needed to establish a single electricity market in Europe. Hence, when creating an integrated market area, it is necessary to find one common market model, which has to be accepted by every participant.

When developing regional markets, it is essential to decide how to calculate the price for the whole area, taking into account the available cross-border transmission capacities. The two approaches applied in Europe are market splitting and market coupling. The first one is applied in the Nordic electricity market, and the latter one in the TLC area.

Case I: Nordic Countries

Norway was among the first countries to open the electricity markets in Europe in the early 1990s. Soon after that also Finland and Sweden restructured their electricity markets before the EU legislation about the liberalization of the electricity markets came into force. The restructuring was made gradually in Finland and Sweden, similarly as in many other European countries. Norway, Sweden, Finland, and Denmark first had regional markets of their own, but markets were rapidly integrated into one market area. We may conclude from the swiftness of the change that there were no major problems related to the different action methods, which may be a possible source of difficulties when integrating regional markets. At present, there is only one power exchange in the Nordic countries that calculates the system price for the whole Nordic market.

Between the European countries, there are differences in how the market liberalizations have been carried out. The basic initial situation before the restructuring is the principal reason that leads to different development paths. These differences in the liberalization processes also affect the market structure. In the Nordic countries, the privatization process was not so wide-ranging, because there were already quite a few different actors in the field. The co-operation between the Nordic countries has been intensive for several years before the establishment of the integrated Nordic electricity market. Nordel (Organization for the Nordic Transmission System Operators) was established in 1963 and it provided a good basis for the Nordic electricity market.

The Nordic countries were among the first countries to introduce zonal pricing in Europe. This pricing method was partly chosen because of the sufficient transmission capacity between the countries. Thus, it was possible to obtain a uniform market clearing price for the whole Nordic area, or for quite large zones. The permanent boundaries of the zones were defined ex ante, and they obeyed the national borders to some extent. For instance, Finland and Sweden formed one price zone each. Norway, on the other hand, was divided into three price zones and Denmark into two zones. Since the establishment of the common markets, the transmission capacity has been (and will be) extended between the Nordic countries. Also the close historical co-operation between the countries, for example the interconnected transmission grid, has had an influence on the selection of the market model.

The Nordic TSOs and the power exchange work in close co-operation; the TSOs calculate the cross-border transmission capacity and the exchange takes care of the electricity trade. The structure of the market is illustrated in Fig. 2.

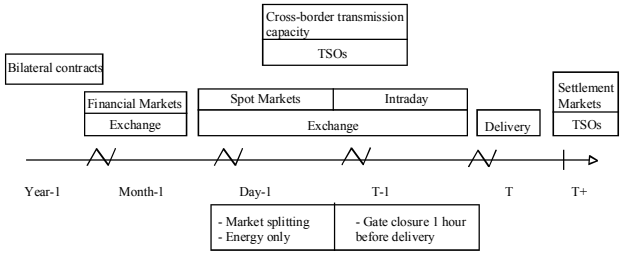

Fig. 2. Electricity market model in the Nordic countries.

The exchange is also responsible for the financial markets. The TSOs carry out the balance settlement.

Case II: Trilateral Market Coupling (TLC)

Our second example is the TLC area. This area comprises France, Belgium and the Netherlands. The Trilateral Market Coupling (TLC) started in 2006 after the merger of the electricity markets of these countries. The countries of the TLC area liberalized their electricity markets mainly between 1999 and 2007. However, getting enough players to the markets has been a problematic issue, and thus competition has been slow to emerge. Extending the market area has been one attempt to promote competition. The integrated market has required close co-operation between the national TSOs in the area. Historically, there has not been so intensive TSO co-operation in the TLC area as in the Nordic countries.

In the TLC area, market coupling is used to integrate the national markets. In the price calculations, the three markets

are first treated separately, and then connected into a single area with a uniform system price if there is enough transmission capacity between them. The market structure is illustrated in Fig. 3.

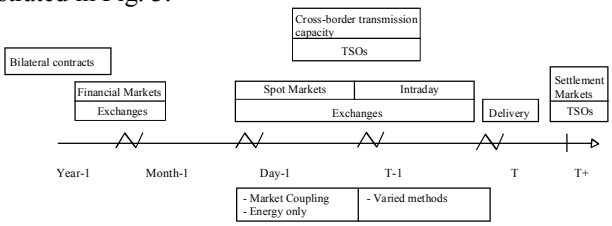

Fig. 3. Electricity market model in the TLC area.

There are three power exchanges in the TLC areas, which are each responsible for price calculation in one national market. The exchanges first calculate the system price for each country. The TSOs notify the exchanges of the amount of transmission capacity available between the countries. If there is enough capacity, the exchanges will merge the offers and get one or two area prices. Approximately 70 % of the time France, Belgium and the Netherlands have the same area price [2].

IV. THE US

In the US, there is no general law enforcing the deregulation of the electricity supply (in contrast to the electricity directives in the EU). The states can independently decide how they want to organize their electricity markets, and about half of the states have at least partly liberalized their electricity markets. In the US, the Federal Energy Regulation Commission (FERC) regulates and oversees the deregulated wholesale electricity markets in the US. It has also created a Standard Market Design (SMD) model which determines the rules for the markets.

In this paper, the PJM Interconnection is used as an example to illustrate the organization of the deregulated electricity markets in the US (although there are in fact several different regional electricity markets in the US). The PJM is, however, the largest and one of the oldest regional electricity markets in the US, and it is quite a mature market. At first, Pennsylvania, New Jersey and Maryland comprised the PJM market area. Nowadays also the states of Delaware, Illinois, Indiana, Kentucky, Michigan, North Carolina, Ohio, Tennessee, Virginia, West Virginia and the District of Columbia partly or completely belong to the PJM market.

A. Case: PJM

In the PJM market area, there has been an electricity pool already since 1927. In 1997, the independent system operator of the area, the PJM ISO, began to run the electricity markets [1]. Since then the independent system operator has developed into a regional system operator (RTO) that is responsible for operating the electricity system in the whole market area. The PJM market obeys the FERC's standard market design.

Market restructuring

When the PJM market was deregulated in 1997, the goal was to create a market model in which a uniform market clearing price (MCP) would be determined for the whole area. However, it soon became clear that this system did not perceive the congestion of the transmission grid, and consequently, the system failed [3]. The transmission lines between the states were not designed to withstand large-scale transmission, and there were congestions between the states; nor did the MCP system give good enough investment signals to the markets.

In 1998, the PJM reorganized its markets and adopted the nodal pricing method. After that, changes have been made to the market model but the pricing method has remained the same.

Market structure

Nowadays the PJM market area covers 14 states (some of them only partly), and there are over 7000 nodes. Nodal pricing is applied in the day-ahead and real-time markets. As a result of the day-ahead auctions, a price for every node of the electricity system is obtained for each hour of the following day. In the real-time markets, the volume differences in the forecasted electricity consumption/production are adjusted. The day-ahead and real-time markets are organized by ISO/RTO. The structure of the PJM market is illustrated in Fig. 4.

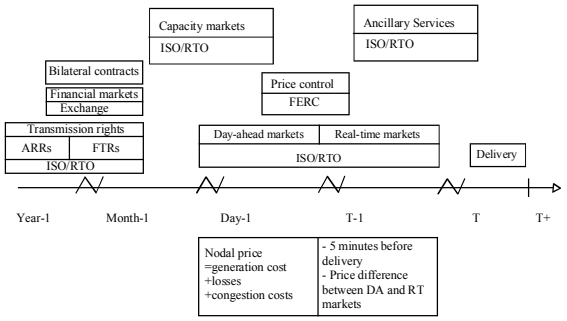

Fig. 4. Electricity market model in the PJM area.

Some hub and zone prices are also calculated. A hub price is a weighted average of the node prices it contains, and a zone price is an average of the node prices. The price of the eastern hub is used as a reference price, for example, in the financial markets.

In connection with nodal pricing, there is also a price control system. There are both price regulation and price caps. These systems are used to mitigate the market power at the nodes. The price caps and the regulation cut off price peaks, which are necessary signals to invest in new generation capacity. To compensate this, there is a separate capacity market. The capacity market of the PJM is called RPM (Reliability Pricing Model) and it contains, for instance, a three-year capacity forward and yearly products. The generators must offer their capacity to the markets, and the buyers must participate in the trade.

There are also ancillary services markets which include a spinning reserve. Also Financial Transmission Rights (FTRs) are used to hedge the price differences between the nodes. These differences are caused by the congestion on the transmission grid. Financial products for electrical energy can be traded at various commodity and other exchanges.

V. RUSSIA

In Russia, the electricity markets have been restructured twice. The first restructuring process took place after the collapse of the Soviet Union. The second process started in 2001, and it is still in progress.

The Russian electricity markets are composed of several territories, which constitute two price areas (the European part of the Russian Federation and Siberia). During the ongoing reform, a uniform market structure will be generated for the whole country. When the reform is completed and the Russian electricity markets are ready, they will constitute one of the largest open electricity markets in the world.

A. Restructuring process

The first electricity market restructuring in Russia was carried out soon after the collapse of the Soviet Union. Before 1992, the electricity industry in Russia was owned by the state and operated by Minenergo (Ministry of Power and Electrification) [4]. As a result of the first restructuring process, RAO UES (United Energy Systems) was established. RAO UES was a state-owned holding company that controlled the whole electricity system. RAO UES owned 160 GW of the generation capacity, took care of the transmission system, and was responsible for the wholesale of electricity [6]. In addition, RAO UES bought electricity from the other power generators and sold it forward. In this model, there were a lot of problems. For example, no new investments were made and the market entrance of new players was denied [5].

A new stage of restructuring started in 2001, when the government decided about the new restructuring process. In this new process, RAO UES was first divided into different sectors. Most of the generation was to be privatized with the exception of hydro power and nuclear power, which were to remain in the state control [7]. The System Operator (SO) and a part of the Federal Grid Company (FGC) were also to remain state owned. New market players are shown in Fig. 5.

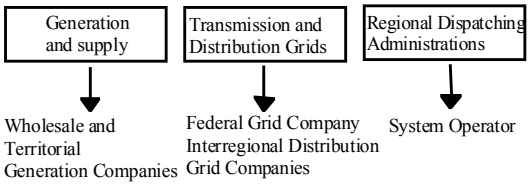

Fig. 5. Actors of the wholesale electricity markets in Russia.

The electricity markets were liberalized in 2006, when the new market model was adopted. Liberalization of the markets is carried out gradually. At present, 30 % of electricity is traded in the free market and the rest through regulated contracts. The regulated contracts should completely cease to exist by 2011 [7].

B. Market structure

After the restructuring of RAO UES, the main actors in the Russian electricity market are nowadays the Territorial Generating Companies (TGCs), the Wholesale Generating Companies (WGCs), the Federal Grid Company (FGC), the System Operator (SO), the Distribution Grid Companies (DGCs), the Administrator of Trade System (ATS), the Federal Antimonopoly Service (FAS), and the Federal Tariff Service (FTS) [4], [8]–[10].

At present, there are 14 TGCs in Russia, and they form the basis of the regional electricity system. The TGCs produce both heat and electricity. The WGCs produce only electricity, and they are the main player in the wholesale electricity markets [7].

The FGC owns the electricity transmission networks, and the SO is responsible for operating the networks. The SO optimizes the use of the grid and sends the results to the ATS, which is the market operator in the Russian electricity market. The ATS organizes trades in the wholesale electricity markets and performs the balancing market calculations. It also controls the trades of the regulated and free bilateral contracts, and acts as a regulatory agency. The ATS and the SO work in close co-operation. The structure of the Russian electricity market is illustrated in Fig. 6.

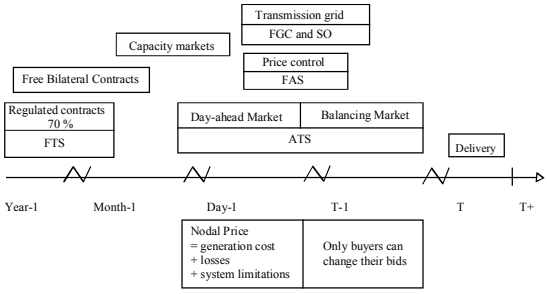

Fig. 6. Electricity market model in Russia.

The market surveillance in the Russian wholesale electricity market is carried out by the FAS, while the FTS determines the tariffs for the suppliers and consumers under the regulated contracts.

Day-ahead and balancing markets

In the day-ahead market, the generator submits the price and volume of the electricity it wishes to sell. After the gate closure of the day-ahead market, a balancing market opens. The ATS takes care of the price calculations in the day-ahead and balancing markets. As a result of the day-ahead auctions, prices are calculated for every node of the electricity systems. Altogether, there are 6040 nodes in the European part of Russia and 620 nodes in Siberia. The nodal prices comprise generation costs, load losses and system limitations [10]. Nodal pricing method is also applied in the balancing market [7]. In the balancing market, only the buyers can adjust their bids; the generators' offers are the same as in the day-ahead market [7].

Capacity and financial markets

The prices in the generators' offers are controlled to mitigate the market power. The generators' offers are compared with the offers of other nodes (reference price). These other nodes cover 10 % of all nodes in a certain area [12]. The generators' offers are not allowed to exceed the reference price more than defined in advance [12]. The price control prevents price spikes, which are necessary signals to invest in new capacity, and hence, other incentives for new investments have to be

created. To this end, a capacity market has been launched in Russia in 2008, but it is still in progress [11]. At present, capacity obligations are partially fulfilled through regulated contracts.

There are also financial markets in Russia but only a few actors in the market use them. There are only Free Bilateral Contracts (FBCs) in use [7]. The FBCs are financial products, and their logic is similar to the Financial Transmission Rights (FTRs). They are used to hedge against price differences between the nodes caused by the transmission congestion.

Experiences from the Russian electricity markets

The restructuring process has mainly proceeded in Russia as defined in legislation, and a new market structure has been established. To some extent, the market still suffers from problems that are typical for the initial stage of electricity market development. The most severe problem is perhaps the lacking transparency in the market (e.g. the market participants do not get adequate information about generation failures and repairs). Another problem is the lack of active financial markets, which reduces the opportunities to hedge against price differences. In addition, until the reform is completed, there is a political risk that the course of restructuring will change.

VI. Discussion

In this paper, four different electricity wholesale markets have been introduced and discussed. The initial situation of the market, such as the features of the transmission grid, the number of actors, and previous co-operation of the TSOs has a significant impact on the development path. There are also differences in how the actual restructuring is carried out. For instance, in Europe, the deregulation first considered only the national electricity markets, and these will be gradually integrated into larger market areas. In the PJM area, the electricity markets were first established for Pennsylvania, New Jersey, and Maryland, and the other regions have joined in later. In Russia, open electricity markets covering a number of territories and a large geographical area are developed at one go.

Deregulated electricity markets can be distinguished according to the pricing method applied, the choosing of which is influenced by the characteristics of the transmission networks. For instance, in Europe, the transmission networks have enabled the use of zonal pricing. In Russia and the US, the congested transmission networks have led to the adoption of the nodal pricing method that takes into account the transmission constraints in price calculations right from the start. Nodal pricing is a complex model with thousands of nodes, and it requires price control. Nevertheless, a tight price control mitigates the risk of market power. Zonal pricing is a simpler method, but there is a risk of market power abuse because of the difficulties in developing adequate antitrust practices.

In Europe, the amount of traded power at the exchanges is often low, 10–20% of the total consumption. This may sometimes reduce trust in the price formation in the wholesale markets. However, obtaining liquid day-ahead prices would be important, because they are often used as a reference price in other electricity transactions. Liquidity is also a problem in Russia, because the free markets cover only 30 % of the consumed electricity and the rest is traded through regulated contracts. In the PJM area, the illiquidity of the nodal prices is tackled by taking rather heavy market surveillance actions. In addition, specific hub prices are calculated on the basis of the nodal prices to obtain a reliable reference price for other electricity transactions. The eastern hub in particular is considered to provide a rather good reference price.

Finally, creating a transparent open electricity market has proven challenging. In Russia, the lack of transparency is a serious problem. For instance, the market players are not able to get adequate information about generation disruptions. From time to time, the lack of transparency also becomes a topical issue in the European electricity markets.

VII. Conclusion

Four different electricity market restructuring processes (the Nordic countries, the TLC in Western Europe, the PJM area in the US, and Russia) were investigated. The basic building blocks of the market structures, such as the day-ahead, balancing/intra-day, and financial markets are quite equal in each area. Moreover, all four markets have experienced similar problems, for instance, relating to the liquidity and transparency of the markets. However, considering the market development paths in the above market areas, there are significant differences that are due to the initial state of the electricity supply sector prior to the restructuring.

There are textbook models for electricity market restructuring; however, to be able to analyze in detail the restructuring processes in divergent market areas, more specific tools are required. The vertical unbundling, which is mentioned also in the textbook models, is always a necessary process when opening the electricity markets. On the other hand, the horizontal restructuring and privatization are not always necessary actions, and these typically depend on the initial ownership structure. In Russia and the TLC area, these actions were necessary, whereas such measures were not required in the Nordic countries.

The physical transmission networks determine, to a large extent, the special features in every market area. In particular, the pricing method applied is significantly influenced by the physical characteristics of the electricity system such as the intra- and interregional transmission capacities of the electricity networks. In the Nordic countries, similarly as in the TLC area, zonal pricing is chosen as the pricing method; a key reason for choosing zonal pricing is the technical condition of the transmission networks. In the US instead, the market model chosen is nodal pricing, because the transmission lines between the states have not been designed to withstand large-scale transmission. In Russia, the nodal pricing method is used for the same reason as in the PJM area in the US. Finally, the chosen market model has an effect on the required market surveillance; in nodal pricing, the amount of market surveillance is considerably higher than in zonal pricing.

Usually, the extension of the open electricity market is carried out gradually by coupling smaller market areas into the existing one; for instance in Europe, the first step is to establish the regional electricity markets, and after that a single electricity market. In Russia instead, the world's largest open electricity will be established at one go.

Considering Russia and Europe, the differences in the market models will pose challenges to the process of developing market-based cross-border power transmission; answering these challenges in the development process is thus a worthwhile subject of further study.

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