Country-Specific Aspects of Operations of Wholesale Power and Capacity Markets

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***Abstract* — The modern energy sector, in both the Russian Federation and other countries, features the so-called "finer points," the challenging issues addressed in many analytical documents as well as in published research. The paper discusses key electric power market developments in different countries, the dynamics of indicators measuring their performance, the results of actions taken to date, as well as the approaches to their regulation and influencing the quality of power supplied. We consider the main features of the adopted regulatory models and the basic principles adhered to by electric utilities as means of successful expansion planning and operation under given conditions.**

The purpose of this research is to study individual elements of operations of energy markets and the features of regulation as applied to the models originating from abroad and from domestic wholesale electricity and capacity markets. The study also takes into account the technology-related aspects such as the level of reliability of the power system. The study outlines the development vector for the effective operation of generating companies in a given context. The focus is on the areas with the highest potential in terms of contributing to growth.

The scope of the paper also covers an overview of key trends of electricity market operations, both as practiced abroad and in this country. We present market models and discuss different approaches to determining the level of quality and reliability of electric power supply.

***Index Terms*: electricity market, market models, power and capacity market.**

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I. Introduction

The modern energy sector, in both the Russian Federation and other countries, features the so-called "finer points," the challenging issues addressed in many analytical documents as well as in published research. The challenges posed by the energy industry are amongst the most demanding but also rewarding from the standpoint of research. In the case of the energy industry, of particular interest is the interplay between domestic wholesale power and capacity markets, as well as the understanding of how the same mechanism is rendered in other countries.

This paper reviews the principles governing energy industry operations in different countries in the context of interaction and regulation of activities in the models of power and capacity market.

Each country has its regulatory framework, target parameters as well as specifics of market relations and development of industries. They are both a driving force for the development and modernization of interactions in the energy industry, but also a criterion to be considered when streamlining logistics and developing the regulatory principles. In what follows, we consider the domestic and international examples related to specifics of operation and analyze technical parameters and features.

The presentation of the aspects of development and regulation models of interaction from different perspectives benefits from consideration of several contrasting examples: hence, the paper covers case studies of the UK, Germany, and Russia.

II. Foreign Experience in the Construction of Electricity Market and Its Operation

The UK is an island country with its structure, historically established principles, and its industrial and energy sector.

The existing market model was adopted in 2000 by the Utilities Act. This has allowed the Pool to be replaced in March 2001 by the New Electricity Trading Arrangements (NETA), which evolved into the British Electricity Trading and Transmission Arrangements (BETTA) in 2005, when they were extended to cover Scotland. The Act is still in effect today.

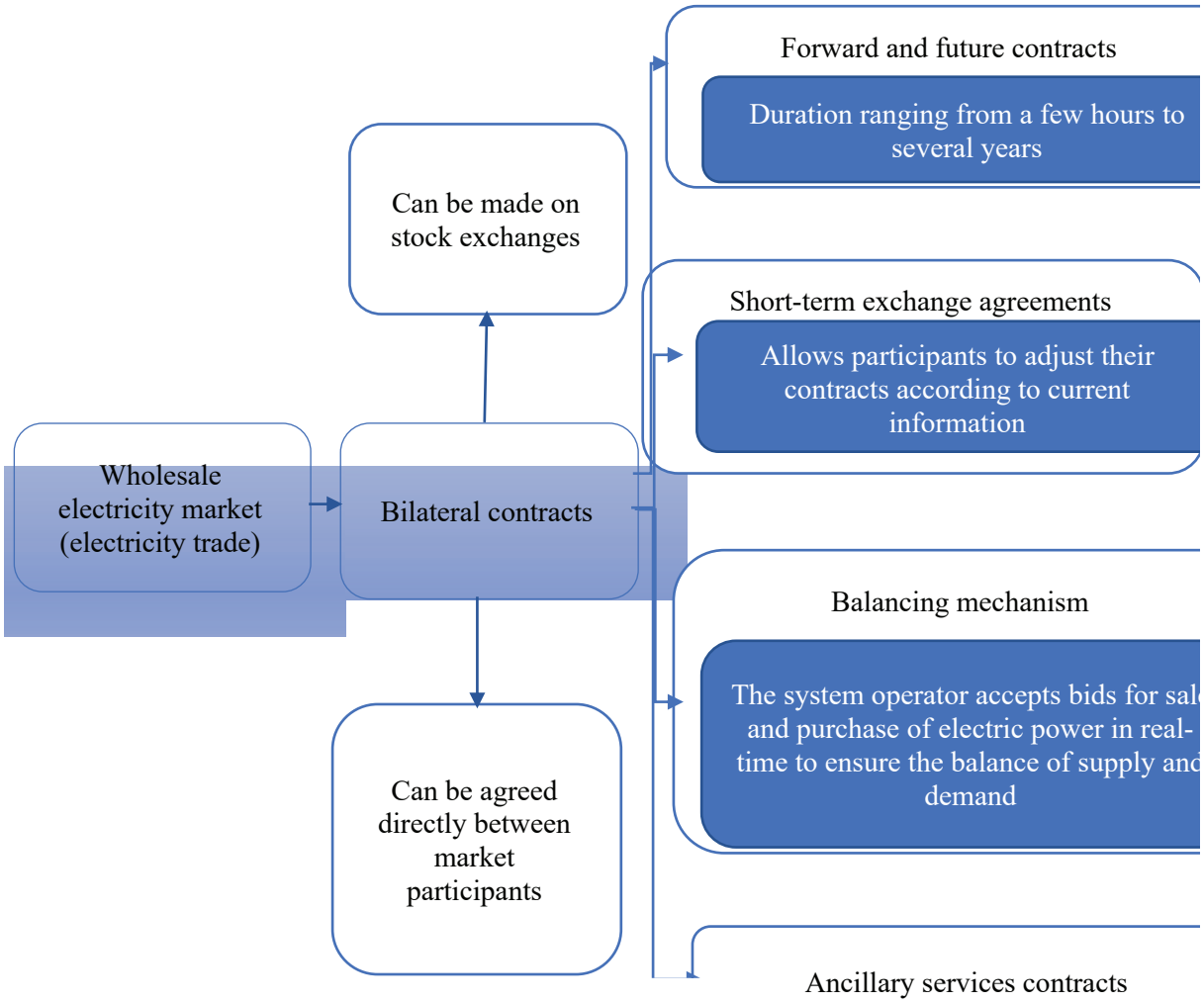

Fig. 1. Model of the UK wholesale electricity market (England and Wales).

The introduction of the rules was intended to increase competition in the wholesale electricity market while preserving the reliability of the power system, thus ensuring the transition from a centralized organization to decentralized market relations [1].

Energy is traded forward through bilateral over the counter trades between sellers and buyers or through direct exchanges between market participants, their duration varying from several hours to several years. Thus, the trades are treated as "forward" and "future" contracts.

The inclusion of short-term exchange agreements in the NETA allows sellers and buyers of electricity to cover their short-term demand in addition to having direct trades. The presence of a balancing mechanism (adjustment of power output and demand in real-time to match them) should also be noted. All generating companies with a capacity above 50 MW and supplying companies with a consumption capacity above 50 MW are required to notify the system operator of their production and consumption activities when using it.

- The factors that ensure the success of this system are the following:
- excess capacity in the UK electric power industry;
- state-of-the-art and flexible generating equipment;
- sufficient throughput capacity of the backbone grid;
- experience gained in a competitive environment;
- mature regulatory framework [1].

Based on the factors identified, the Government proposed a reform of the electricity market and passed the Electricity Act in December 2013 (Energy Act 2013), one of the main goals of which was the creation of a capacity market, which was approved by the European Commission in 2014.

The auction arrangements are as follows:

- The auction takes place over four days with four bidding rounds each day.
- In the first round, generating companies are offered a fee of 75 pounds per 1 kW of capacity. However, companies are expected to offer more than the required amount of capacity at such a high price.
- In the next round, the price is lowered by £5 and generators who are not ready to supply capacity at that price remove their bids.

- The price reduction continues in each subsequent round until the total capacity in all remaining bids equals capacity demand - the sum of the system's maximum load and the required capacity reserve [1].

It merits taking a closer look at each tool that enables negotiating and performing transactions for the supply of electric power:

1. The UK Power Exchange (UKPX) was established in June 2000 by a Swedish company (Finnish-Swedish stock exchange operator) and was the first independent British energy exchange. The system initially traded only forward contracts for the sale of electricity with a maturity of no more than 18 months, and all transactions were concluded online (online trading system). A year later, when NETA was launched, the UKPX started trading spot contracts for the next 24 hours. Meanwhile, the Dutch Amsterdam Power Exchange (APX), continental Europe's first energy exchange, established its UK branch in 2001 under the name of APX-UK, which began its operations in May 1999 [1,3]. This company is now called APX-ENDEX after several more mergers.

The exchange offers its participants daily electricity future contracts for 2 and 3 months, 4 quarters, and 4 seasons (winter, spring, summer, autumn), and demand-period supplies for 3 months, 4 quarters, and 4 seasons (8.3 to 17.3 CET).

2. NETA balancing mechanism is used as a way to reconcile the load levels of generators and demand in real-time, which matches the actual total consumption level. It may differ significantly from the forecast value, as well as in terms of the need to factor in the grid capacity limitations, since these limitations were not taken into account when entering into contractual relations between market participants [1]. Therefore, in addition to the calculation of imbalances, NETA also provides for the creation of a "Balancing mechanism". According to this mechanism, the system operator determines which actions to take to maintain the balance between consumption and generation. The rules governing the calculation of imbalances and actions to balance the system are established in the Balancing and Settlement Code. It is monitored by Elexon, a dedicated not-for-profit entity whose shares are owned entirely by National Grid Energy System Operator, that also provides market participants with technical opportunities to participate in this process.

The trading of electric power supplied in a particular half-hour period takes place before the so-called "Gate Closure", which occurs one hour before the start of that period. For example, in the case of the supply of electric power from 12:00 to 12:30 all market participants are required to notify the System Operator (National Grid Company) of their final positions. These data are called the Final Physical Notifications (FPN) and they determine the actual demand for electric power during a particular half-hour.

No further changes to these positions are allowed. If it turns out that the generating company has produced more electricity than declared for the given half-hour, or the supplier has overestimated their demand for electricity, the excess electricity is purchased from them at the System Selling Price (SSP). Similarly, additional, unanticipated demand for power is paid for by the buyer or by the generator who unexpectedly reduces their output at the System Purchase Price (SBP) [2]. In the early years of the adoption of this mechanism, the SSP was significantly lower than the market price and the SBP was significantly higher, but the prices eventually leveled off by 2005.

Today, the British grid has a more flexible mechanism for regulating deviations from the FPN. Each market participant can submit a request for additional capacity or offer possible "excess" power in advance, specifying the desired price, and the System Operator, according to the actual state of the power system, sets its price, which all companies that have applied with bids and offers are automatically forced to accept. It is assumed that the larger the deviation from the FPN is, the less favorable the conditions for the market participant who allowed this deviation are. This mechanism provides the system with extra flexibility and allows, in particular, creating a capacity reserve in case of unforeseen changes in demand. Moreover, the System Operator has contracts for balancing services with some producers and consumers of electric power, which can promptly adjust capacity. In particular, hydropower plants (HPP) play this role in Great Britain, although their share in the total power balance is only 3.5% [4].

The amounts of electricity that are traded through exchanges and on the basis of bilateral contracts must be communicated to the clearing house, which carries out the calculation of imbalances, so that the amount of imbalance for each participant can be determined.

The goal of implementing a balancing market is to ensure the physical balance of power and other critical parameters of the system operation. To achieve this goal, the system operator performs the following functions: maintains frequency in the power grid, adjusts power flows to ensure reliability, and provides ancillary system services by balancing market participants.

As soon as generators and sales companies determine their generation and consumption volumes, they are required to notify the system operator. This requirement applies only to generators whose installed capacity exceeds 50 MW and to consumption points that receive more than 50 MW from the grid. Along with communicating this information to the system operator, generators and sales companies may also communicate their willingness to deviate from the planned level of production or consumption in one direction or another for an appropriate fee. For this purpose, they can apply for an increase or decrease in generation and consumption (applications for participation in the Balancing Mechanism). The system

operator can accept such applications and use them to manage the balance between generation and consumption in real-time.

The adequacy analysis below takes into account the amount of capacity reserves exceeding the projected maximum consumption load (on the "de-rated" basis) and standard outages of power grid and generating equipment. In general, according to the analysis conducted by the system operator, the amount of available generating capacity for the winter period of 2021–2022 will amount to 103.2 GW; imported capacity during the peak consumption period – 4.2 GW; maximum consumption including ACS** (including 1.5 GW of required reserve capacity) – 59.5 GW; duration of possible capacity shortage – 0.3 hour per year [5].

In order to mitigate these risks, the National Grid Electricity Transmission (NGET) company, which is the operator of the main grid in England and Wales, has developed the Grid Code. The document regulates the operational processes and principles of managing the relationships between the operators of high voltage networks and all users of the high voltage system. The document covers the following:

- Planning Code (PC);
- Balancing Code (BC);
- Operation Codes (OC);
- Code of technical conditions for technological connection (Connection conditions – CC);
- Data Registration Code (DC), the Code of Rules for Provision of Information by Power Industry Entities and Consumers (Data Registration Code – DC).

Loss-adjusted bids accepted by the system operator are paid at the prices specified in those bids. Upward deviation bids are paid to the participant who submitted that bid at the price in the bid multiplied by the deviation volume, adjusted for losses. In the case of downward deviation bids, the bidder is paid by the Balancing Mechanism the price in the bid multiplied by the deviation amount, adjusted for losses.

As follows from the above, NETA lacks the centralized mechanism for selecting the mix of equipment, developing and maintaining the power flows of the power system that were characteristic of the Pool of England and Wales. Instead, the actions of both sellers and buyers are determined largely by the contracts they have been able to enter into. The possibility of functioning of such a system of trade relations, as well as ensuring the reliability of power supply, is based on the following features of the UK power sector:

- availability of excess capacity, much of which is state-of-the-art and flexible equipment;
- availability of a strong backbone network with sufficient capacity;
- accumulated experience during the recent years of operating in a competitive environment;
- a thoroughly developed legal and regulatory framework;
- perfect structure of financial relations;
- well-developed metering system and availability of ASEMM (automated systems for electricity monitoring and metering),
- almost completely liberalized fuel markets.

In particular, such a system as applied to electricity trading includes physical trading under bilateral contracts without taking into account network capacity limitations; self-dispatching. There is no dispatch schedule for the day ahead and centralized selection of generation equipment. The participation of the System Operator in eliminating power imbalances just one hour ahead is virtually impossible in Russia due to the much weaker power grids.

Thus, the success of the reform of the UK energy market is due to the following rather favorable factors: availability of significant capacity reserves with a moderate growth of electricity consumption; extensive use of (then) cheap natural gas as the main fuel for power plants (replacement of coal-fired power plants by co-generation plants); presence of sufficiently developed (in terms of capacity and reserve capacity) power grids, etc. As a result, the introduction of a competitive electricity market has helped to improve the efficiency of power generation and reduce electricity prices.

At the same time, it is worth noting that at first, almost the entire effect of deregulation was aimed at significantly increasing the profitability of generation, and sales prices significantly exceeded production costs.

In Great Britain, the energy exchange plays the role of a "fine-tuning" mechanism that allows electricity suppliers and buyers to adjust their current needs in addition to having direct contracts. In practice, traders can buy more or less electricity than they have sold, generators can physically produce more or less than they have sold, and end users can consume more or less electricity than their sales companies have purchased. NETA centralized systems are designed to measure these surpluses and shortages (imbalances) and determine the prices at which they are traded and send out bills for them. The processes by which imbalances are calculated and billed are called Imbalance Settlement. The purpose of Imbalance Settlement is not to set wholesale electricity prices, as it was previously, but to price and settle for deviations between planned and actual values with relatively small discrepancies between the contractual and physical positions of market participants.

At present, the British power system has a more flexible mechanism for regulating deviations from the FPN. Each market participant can apply for additional capacity or offer possible "excess" power in advance, specifying the desired price, and the System Operator, according to the actual state of the power system, sets its price, which all companies that have applied with bids and offers are automatically forced to accept. As a rule, the larger the deviation from the FPN is, the less favorable the conditions for the market participant who has allowed this deviation.

In what follows, we review the arrangement of market

operations in Germany.

Germany's national grid is largely integrated into the European grid. In terms of technical requirements for the security of energy supply, at the national level, the following codes have been effective since 2007: Transmission Code 2007 and Distribution Code developed by the Association of Network Operators (VDN – beim VDEW – Der Verband der Netzbetreiber e. V.) which now are no longer effective, and the association itself has been liquidated. The main statutory regulation in Germany for the safe and reliable supply of electricity is the Energy Act, which aims to ensure the efficient supply of electricity and gas based on the principles of competition as well as the safe, long-term efficiency, and reliability of the energy supply network. This goal is achieved by implementing and enforcing EU legislation in the field of energy supply [5].

The Energy Act establishes requirements for the compliance of power generation, transmission, and distribution equipment with the national technical regulations of the Association for Electrical and Information Technology [6].

Foundations of modern regulation of the wholesale power and capacity market were laid in 2009 and they built upon the use of existing experience and accumulated knowledge from previous periods, as well as analytical documents on the state of affairs in other countries. The main idea behind the transformation is that the physical volume of renewable energy transmission to sales companies should be in the range between the established minimum and maximum values. Consequently, there was a need for system operators to purchase additional amounts of electricity from power plants running on conventional fuels, which led to high costs and was not an effective regulatory lever. Due to this, a new mechanism of market operations was developed, which led to a change in the system operator's functionality. In the new model, the system operator trades electricity on the power exchange instead of the previously designated power supply to sales companies.

Sales on the spot market do not always reach the level that corresponds to the established remuneration for operator services. Distribution companies compensate System Operators for the difference between the established and actual cost of service (the so-called Renewable Energy Act payments). Sales companies include payments under the Renewable Energy Act in the cost of electricity, thereby transferring them to the consumer. For energy-intensive industries, the mechanism provides for a partial exemption from compensation payments [8].

In 2014, another reform of the Renewable Energy Act was carried out and changes were introduced into the vision of how to proceed with further development of renewable energy. Being only one part of the set of legislative acts on the "Energiewende" program, its amendments are treated accordingly.

The legal framework for the Energiewende consists of a series of laws regulating emerging relationships in the four main areas of the energy industry.

The reform of the energy market made it possible, according to one option available within this model, for electricity sellers to pay a higher price to the generation company because they were partially exempt from payments under the Renewable Energy Act if the structure of their energy portfolio met certain legal requirements. The System Operator could choose a different option – an individual markup model, under which it is entitled to claim compensation for the difference between the current market price and the amount of state payments, as well as the additional costs of direct sales through the state-imposed markup.

In this case, the main activity in the German electricity market is structured around the European Energy Exchange (EEX) AG – the central European power exchange located in Leipzig, Germany. It develops, operates, and ensures secure connections, liquid and transparent markets for energy and related products, including contracts for derivative capacity, emission allowances, agricultural and freight products.

EEX emerged from a merger between and Frankfurt-based EEX in 2002. The derivatives division of Deutsche Börse Group Eurex acquired a majority stake in EEX in 2002. The structure of the exchange and the contractual relationship models are given in Fig. 2.

1. The electricity spot market is operated by EPEX SPOT, a joint venture owned by Germany's EEX AG and France's Powernext SAS (its 100% subsidiary). EPEX SPOT conducts daily day-ahead auctions for three markets: Germany/Austria, France, and Switzerland. The physical delivery of electricity takes place the next day. EPEX SPOT also provides an intraday market for Germany, France, Belgium, the Netherlands, Luxembourg, Switzerland, Austria, and the United Kingdom. This market can be used to cover short positions, for urgent power needs or for short-term overcapacity sales. Market participants can buy electricity 45 minutes in advance of each hour at a certain hour. This market is open 24 hours a day, seven days a week. Electricity for the next day can be sold from 3 p.m. onward.

EEX also offers a spot market for EU quotas. Since 2005, EEX has operated both a spot market and a derivatives market for emission allowances. All bidders admitted to auction emission allowances at EEX can participate in the auction without any additional licensing conditions. From the outset, this has also included all bidders who participated in the existing Eurex collaboration on the futures market.

The day-ahead markets are organized through an auction, which compares supply and demand curves once a day and thus fixes prices in an anonymous but transparent and secure manner. Exchange participants enter their hourly electricity bids into the order book, which closes at 11:00 a.m. for Switzerland and at 12:00 p.m. for all other

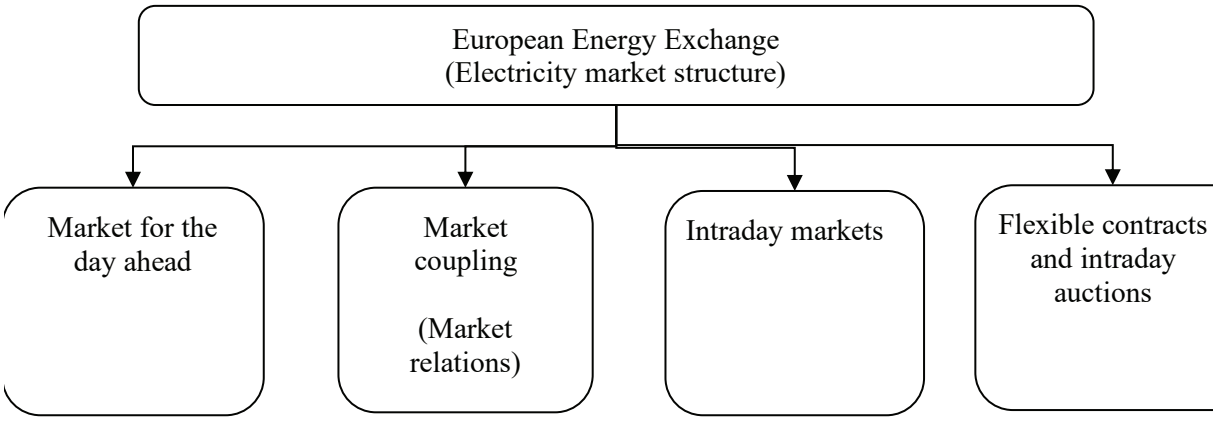

Fig. 2. Structure of the European Energy Exchange.

markets. EPEX SPOT calculates the supply and demand curves and their intersection for each hour of the next day. The results are published from 11.10 (Switzerland) and 12.55 (all other markets) [8].

2. Market coupling. The countries of Central and Western Europe, with the exception of Switzerland and the markets of the Nordic countries, are linked through a mechanism called Market Coupling. It links the member countries' electricity markets through a price-coupling solution in order to optimize cross-border capacity utilization between these countries, increasing public welfare gains in all markets.

3. Intraday markets. EPEX SPOT also manages the daily electricity markets for Austria, Belgium, Denmark, Finland, France, Germany-Luxembourg, Great Britain, the Netherlands, Norway, Sweden, and Switzerland. The intraday markets are organized according to the principle of continuous trading – participants' orders are continuously entered in the order book. As soon as two orders match, the trade transaction is completed. Hourly, half-hourly, and quarterly contracts can be sold 5 minutes before delivery [8]. M7, the intraday trading system used by EPEX SPOT, allows for simultaneous cross-border transactions on the exchange and through the OTC market. EPEX SPOT's permanent intraday markets, with the exception of the UK and Switzerland, are linked through the pan-European overnight link [8].

4. Flexible Contracts and Intraday Auctions. In December 2011, EPEX SPOT introduced 15-minute contracts in the German continuous intraday market. These contracts facilitate trading with intermittent energy sources and help cope with intra-hour fluctuations in generation and consumption [8]. With the launch of the intraday market in Switzerland, 15-minute contracts were extended to that market.

- In December 2014, EPEX SPOT launched an auction of 15-minute contracts on the German domestic market to provide a reliable price signal on a quarter-hour basis. This auction, which took place at 3:00 p.m. CET, provided balancers with an opportunity to adjust their portfolios on a 15-minute basis during times of increasing generation and deviations from forecasts. By doing so, the price signal of 15-minute contracts promoted additional flexibility while at the same time provided incentives to stabilize the system [8, 10]. In 2017, EPEX SPOT introduced 30-minute contracts in the continuous intraday market of France, Germany, and Switzerland, allowing for local and implicit cross-border transactions at their respective borders. These contracts were designed to better manage emerging flexibility issues in energy markets and helped market participants meet their balancing requirements via the French transmission system operator. EPEX SPOT has been offering additional intraday auctions in Austria, Belgium, and France since 2020, in the UK since 2018, and in Switzerland since 2019.

To sum up, the UK and Germany have fully competitive retail markets.

III. The Model of Electricity and Capacity Market in the Russian Federation

As for the domestic model, the creation of the wholesale power and capacity market depends on providing incentives to attract investment in the development of the industry as well as to increase the efficient use of available electric power by consumers.

According to the Federal Law "On Power Industry," the wholesale power and capacity market is defined as the scope of circulation of special commodities (electric power and capacity) within the Unified Energy System of Russia and the boundaries of the single economic space of the Russian Federation.

Wholesale market entities are entities that were legally authorized to participate in the wholesale market circulation of electric power and/or capacity under the Wholesale Market Rules [13]. Its main participants are power supply companies, generating companies, and large power consumers [9].

There are two commodities traded on the wholesale market – electric power and capacity. The electricity and capacity produced are then sold on the wholesale electricity and capacity market, which in turn represents a

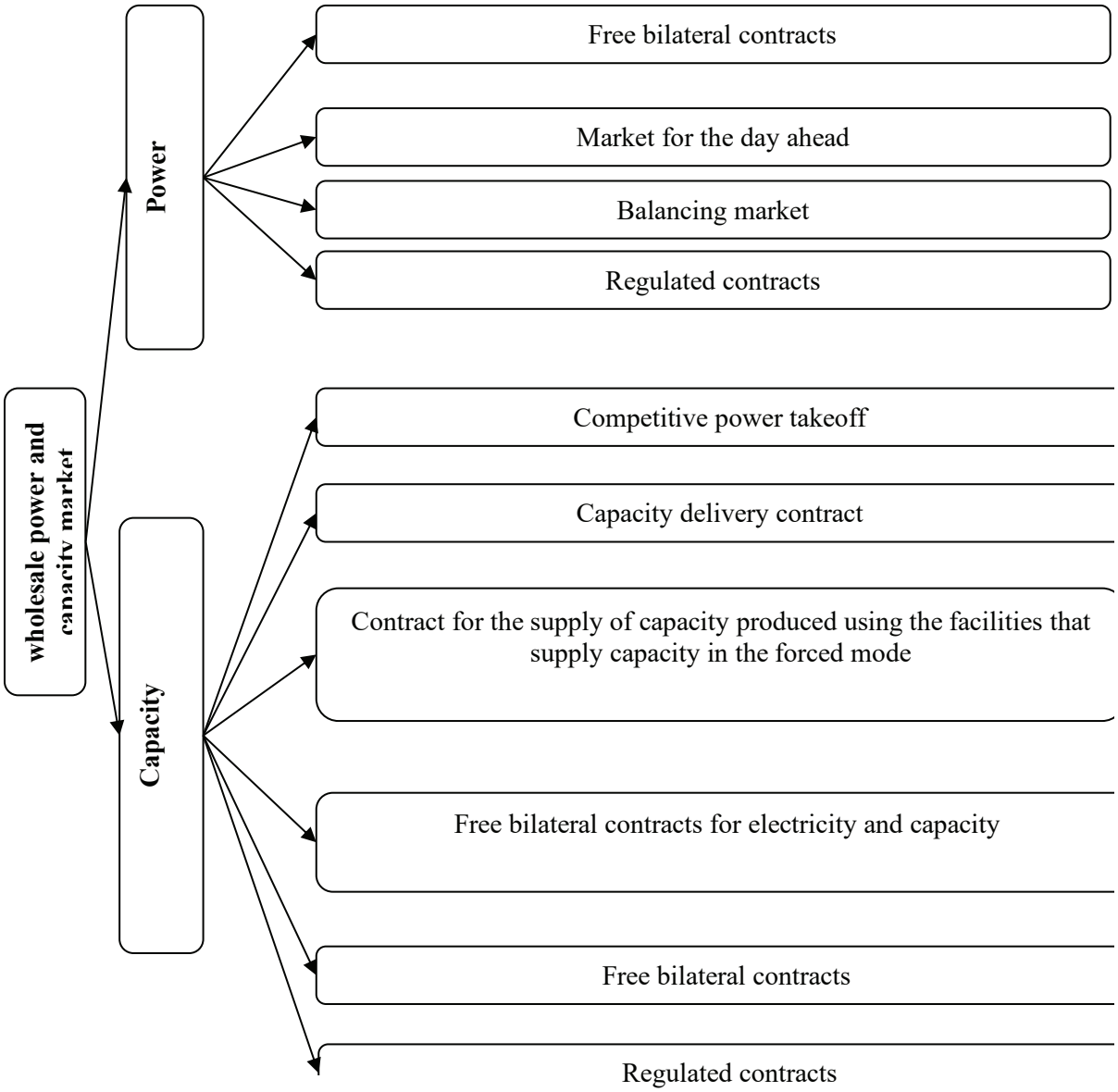

Fig. 3. Structure of the wholesale power and capacity market depending on the pricing mechanism in the electricity and capacity market.

structure consisting of several sectors differing in terms of transactions and delivery terms: regulated contracts sector, free contracts sector, day-ahead market, balancing market, and others (Fig. 3).

Since January 1, 2011, the market of electric power and capacity in Russia has been completely liberalized [14], except for the supply of electric power and capacity to the population and consumer groups deemed equivalent to them under regulated contracts.

The DAM (day-ahead market) accounts for the largest amount of electric power supplied. To participate in the DAM, it is necessary to submit price bids (in what follows, referred to as PB). The PB is a 24-hour sub-application that contains up to three monotonically increasing "price – electricity amount" steps. If zero price is indicated in the step, such a step is considered to be "price-accepting," and after the competitive selection the corresponding amount is paid at the price established at the market at the given node [10, 11, 12].

The bilateral contract is, first of all, a tool of hedging the spot price risk, because it allows one to fix for a long period of time the price of the commodities sold (electric power and/or capacity) [15].

Balancing market (BM) reflects deviations from the planned schedule of consumption/production of electric power, allowing to provide balance between production and consumption in real-time. The price is formed by means of competitive selection of suppliers' bids. Participation in the balancing market is mandatory for everyone, but the financial obligations/claims within this market arise only for the participants who have actual deviations from the planned schedule, as formed in the DAM [11].

IV. Conclusion

The wholesale power and capacity market in the Russian Federation is a rather young, complex, and poorly researched market in contrast to the electricity market of the UK and Germany. The market has a multi-stage organization based on certain rules, regulations and principles. The wholesale power and capacity market acts as an intermediary between producers and consumers, while maintaining the balance of the entire power system.

In preparing materials on this topic, the author has consulted various sources – published research, data from official websites. A detailed study proved that the models of power markets shared similar parameters, which allowed markets to operate successfully, while taking into account geographical features. It is necessary to stress the differences, which are something also related to geographical features and in spite of which the level of quality of services delivered along with the reliability and efficiency of operation ensure successful development. While recognizing the benefits of the models, one should also consider their downsides, namely the role of the "fine-tuner," whose decision-making may be opaque with subjective factors involved.

Future research could investigate the regulation from the standpoint of technology, including artificial intelligence and computer modelling.

Yulia Dobrynina received a bachelor's degree in Economics of Energy Enterprises in 2016 and a master's degree in Energy Conservation and Energy Efficiency in 2018 from Irkutsk National Research Technical University, Russia. Since 2019, she has been a postgraduate student at Meletiev Energy Systems Institute SB RAS. Her research interests include the wholesale market of electricity and capacity, optimization of modes, reliability of the energy system, and unit commitment.

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