Imperfection Of Electricity Markets

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***Abstract* — The paper shows the imperfection (in terms of microeconomics) of markets organized in the electric power industry. This imperfection is caused by special properties of the electric power systems (EPSs) that underlie the power industry. An analysis presented in the paper shows that these properties make it impossible to create conditions for perfect competition in the electricity markets. The imperfect markets require Government regulation of trade, including pricing. Deregulation of prices leads to negative consequences, which is the case in the power industry of Russia.**

***Index Terms* — Electricity markets, electyic power systems.**

I. Introduction

At the end of the 20th century, many countries of the world started restructuring their electric power industry with the organization of one or another type of market. Before this, in most of these countries, power industry was a regulated natural monopoly, i.e. an industry in which positive scale effect was so large that one firm could produce all products (electrical energy) at lower costs and prices than two or more firms. In other words, it was economically advantageous to have one company, and, for this company not to abuse its monopoly position, to introduce government regulation of its activities, including the establishment of rates for electricity supplied to the consumer.

In the early 1990s, during the privatization of state property, Russia organized the federal wholesale electricity market according to the "Single Buyer" model (see below), and then, in 2001, after the Russian Government issued Resolution No. 526, the transition to a competitive market began (with unregulated prices) [1]

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There are four main models of electricity markets that were established in different countries during the reform (they will be listed in the paper). In two of them (a regulated monopoly and a single buyer), the state regulates electricity prices. The two other models have a fundamental difference – there is no price regulation (deregulation) in the wholesale market or wholesale and retail markets. This deregulation of prices, which is effective and admissible only when competition in the market is perfect, is the main focus of this paper. These two models with free-of-control prices will be called competitive markets. The question is if it is possible to provide perfect competition in electricity markets and switch from regulated markets to competitive ones?

The causes of reforms in the electric power industry and the goals posed are country-specific. In developing countries reforms were a result of insufficient governmental funds to ensure the required power development, and the main goal, therefore, was to attract private (including foreign) investments. Some countries, however (for example, China and India), retained the regulation of electricity prices, as their liberation under the conditions of power shortage was just impossible. These countries did not deregulate the industry, i.e., did not make a transition to a competitive market. At the same time, some other countries (for example, Chile, Argentina, and Brazil) created competitive wholesale electricity markets.

In the majority of developed countries, the main cause of reforms was high electricity prices, and the reforms aimed to decrease them. Competition in electricity generation and sales was expected to enhance the efficiency and decrease production costs and, hence, the prices for the final consumers. Many developed countries (England, some states in the USA, Australia, and Scandinavian countries) have deregulated their power industries and organized competitive wholesale and retail markets with free prices.

Meanwhile, the experience of the past years [2–12] shows that electricity deregulation (or liberalization) often leads to the opposite results, i.e., to a price rise, lack of investments, power shortage, and decrease in electricity supply reliability (including blackouts). The initial concepts of reforms are revised (reform of the reforms), the process of reforms is delayed (none of the countries has completed reforms), electricity markets grow more complicated, the proposals are put forward to restore regulation, etc.

The main goal of this paper is to show a general imperfection of the electricity market, the flaws of the competitive market, and the necessity (inevitability) of state electricity price regulation. The problems arising from the deregulation of electricity markets include:

- An increase in the wholesale electricity prices from the level of average costs throughout the EPS (under price regulation) to the level of costs of the least efficient (marginal) plant. This leads to additional expenses for consumers and extra profits (so-called producer's surplus) for power generation companies (PGCs).
- Difficulties in financing the construction of new power plants, including the "price barrier" to new power producers, which may cause a capacity shortage and a greater wholesale price increase. This will place a further burden on electricity consumers, whereas producers will start to get a monopoly profit.

These and many other problems will be discussed in the paper. At first, the effects of the creation and integration of electric power systems will be shown. These effects are largely determined by the special properties of electric power systems, which determine the imperfection of the electricity markets and their differences from markets in other industries. An individual section of the paper is devoted to the EPS properties and their influence on various market models. Then, the conditions (requirements) under which perfect competition in the markets is ensured, and the possibilities (or rather impossibility) of their implementation in the electric power industry are specified in detail.

The paper relies on the studies conducted by the author ([13-22]), as well as publications of researchers from Russia and other countries.

II. Benefits of creating and interconnecting EPSs

It is well known (see, for example, [23–26]) that some objective reasons and factors have given rise first to the creation of, and increase in EPS capacity with an extension of the territory served and then to the expediency of their interconnection. On the whole, they impart a distinctive economic property to EPSs—economies of scale, i.e., an integral effect of a decrease in costs of production, transportation, and distribution of electricity (and its price) with growing EPS sizes. This property is seen in the case of both individual EPSs and their integration, encouraging the creation of power interconnections of increasingly higher levels.

Let us consider at first the factors contributing to the formation and expansion of EPSs. Among them are the following:

• *A decrease in the required capacity reserves.* The increase in the total number of power units is known to decrease the probability of simultaneous emergencies of their specified share (percentage) (see, for example, [27]). As a result, the share of standby units to ensure the same reliability level of the power supply is reduced with the growth of their total number. This concept is illustrated quantitatively in [24] Dependence of the required emergency reserve on the total installed capacity of EPS proves to be nonlinear, namely, the reserve required increases to a lesser extent than does the total capacity of EPS. This objective regularity gave impetus to EPS formation, increase in EPS capacity and territorial coverage, as well as the interconnection of EPSs.

Here we note the following factors:

— The considered effect is achieved by the increasing the number of units regardless of their capacity, i.e., the "scale" in this case emerges in the growing number of units (blocks) of power plants, rather than in their capacity.

— The effect is realized by the construction of transmission lines interconnecting power plants and consumer substations into the unified whole. Hence, this effect is typical of an EPS as a whole—in the interaction between the spheres of electricity generation and transportation (distribution).

— With an increase in the size (total capacity and area) of an EPS and preservation of its integrity, the effect will "fade away," i.e., it will decrease in the relative value but continue to increase in the absolute one. This regularity can be violated by splitting the EPS into spheres and the spheres into several individual companies.

• *Improvement in specific economic indices of EPS facilities* with the enlargement of power plants and an increase in transfer capabilities of transmission lines. This trend is well known. It showed up in the process of EPS dimensions growth when it became possible (and economically sound) to construct power plants of higher capacity with larger units and higher voltage transmission lines. At present, the unit capacity of blocks of coal-fired steam turbine plants and nuclear power plants with thermal reactors has virtually reached its economic limit. Further increase in their capacity does not lead to a decrease in their specific capital investments. However, it is still reasonable to construct such power plants with blocks of high (economically sound) unit capacity, if their commissioning is needed for the optimal EPS structure. Of special importance are hydropower plants (HPPs), whose capacity depends on specific river conditions (water heads and flow rates); gas-fueled combined cycle power plants (CCPPs), whose rather low specific investments can be achieved at low capacities of blocks; and also nuclear power plants (NPPs) with fast reactors, whose unit capacity has not yet reached an economic limit. The transfer capability of transmission lines, especially DC lines, can also increase.

Note that this factor is often considered as economies of scale in the electric power industry. It is asserted, in particular (for example, in [28]), that with the appearance of CCPPs the economies of scale have been lost. However, this is not so. Firstly, this factor is one of many considered here. Secondly, the emergence of highly cost-effective CCPPs cannot lead to the "destruction" of EPSs or stop the increase in their dimensions. CCPPs, on the contrary, increase the variety of types of generation capacities and possibilities for the creation of their more optimal structure, i.e., enhance the overall efficiency of electricity generation, in particular at EPS expansion.

Construction of CCPPs by independent power producers (IPPs) in regulated monopolies is a special case. The high efficiency of CCPPs makes it possible for IPPs using them to successfully compete with monopoly companies. In this situation, it is expedient to connect IPPs to the EPS networks owned by the monopoly company and conclude corresponding contracts for electricity supply. Such a condition is laid down by the Law in many countries (the USA, Japan, China, etc.). At the same time, the monopoly companies themselves can construct CCPPs, which is practically the case.

• *Improvement in economic indices of EPS as a whole owing to the technological progress in any sphere of electricity production, transportation, or distribution.* The impact of technological progress is observed constantly and the EPS (as a system) “accumulates” the effects achieved in any of the spheres. Specific technological innovations are highly diverse. However, on the whole, they improve the EPS efficiency (reduce electricity prices and tariffs for final consumers) and contribute to the growth of their scales in both territory and capacity. Examples of the latest achievements in technological progress are the creation of the aforementioned highly efficient CCPPs and the design of the FACTS (Flexible Alternating Current Transmission Systems), increasing transfer capability and controllability of AC transmission lines (see, for example, [29]).

When an EPS is split into spheres and numerous independent companies, as is the case at the transition to the competitive market, the effect of technological innovations can “remain” in the companies and not “apply” to consumers.

• *Optimization of structure, schemes, and operating conditions of EPSs*, whose possibility (and necessity) enhances the economic efficiency of power supply to consumers, reduces costs in the system and electricity prices. Optimization implies the selection of the most economically efficient power plants and transmission lines and the best modes of their usage. This factor, therefore, contributes to the formation of EPSs and assists their expansion (an increase in EPS dimensions).

• *A decrease in the share of administrative expenses* with the growth of EPS scales, which is typical of vertically integrated companies that monitor the whole system. Such a trend occurred everywhere in the last century. Nowadays, in the countries entering the competitive market, in which the single monopoly companies are split into sets of generating, network, and sales companies, these expenses have not fallen but risen instead.

In general, as was already mentioned, the indicated factors create economies of scale, providing an incentive for the formation of EPSs, successive increase in their capacity, and territorial expansion. In the planned economy countries (including the USSR), this process was centrally managed. In the market economy countries, in the first half of the twentieth century, it brought the *natural monopolies* in the electric power industry into being that should be regulated by the State to prevent them from taking advantage of their monopoly position. Formation of the regulated natural monopolies was a structural transformation of the electric power industry in these countries in comparison with the free market that existed there previously. The deregulation of the power industry taking place in some countries is a reverse transformation (return to the competitive, though institutionalized, market). Now, we pass on to the *effects owing to the interconnection of EPSs* with the formation of interconnected EPSs (IPSs) within one country and the unified or national EPS of the country (UEPS or NEPS). These effects are also well known and studied. Therefore, they will be commented on briefly. Part of the effects is due to the same factors that were mentioned above; however, there are specific factors as well.

The key effects achieved owing to the interconnection of EPSs are as follows [24]:

1. Power transfer from an EPS with cheaper electricity to an EPS with a more expensive one
2. Reduction in the required emergency and repair capacity reserves
3. A decrease in coincident maximums and leveling of the joint load curves of consumers
4. Possibility of constructing large-scale power plants with larger units
5. Rationalization (coordination) of putting into operation large power plants in EPSs to be interconnected
6. Improved usage of power plants when interconnecting EPSs with different structures of generation capacities
7. Environmental, social, and other effects

A decrease in the necessary emergency reserves (point 2) and the possibility to construct larger power plants (point 4) were also important in the creation of individual EPSs. The rest of the effects may be treated as specific ones that emerge when interconnecting EPSs. In concrete IPSs or NPSs, not all the enumerated effects but only a combination of them or even only one key effect can naturally be found.

Each effect has to be estimated in monetary terms (in rubles, dollars, etc.) in one way or another, and if their sum exceeds the cost of an intersystem electric tie (ISET), it is advisable to interconnect EPSs. As a rule, the economic assessment of the effects, in particular, the environmental and social effects, proves to be difficult enough. It requires special calculations based on appropriate mathematical models [24]

Note that the specific features of realizing different effects are important for a further study of the electricity markets. These features are stipulated in particular by the fact that many effects owing to the interconnection of EPSs are expressed in generation capacity saving, and are achieved by the construction of intersystem transmission lines. Some market models propose the separation of the spheres of electricity generation and transmission (and distribution) and the creation of independent

generation and network companies. In this case, the network companies will bear the costs and the generating companies will take advantage of the effect. Such an inconsistency (in comparison with single vertically integrated companies) will complicate the substantiation of the ISET efficiency, and hence the interconnection of EPSs.

Transmission (export) of cheap electricity from one EPS to another will shift the construction of new power plants, and, as a result, the former EPS will become surplus and the latter will be deficient. At the same time, it may influence electricity prices: they can fall in the receiving EPS and, on the contrary, rise (electricity demand will increase) in the transmitting (exporting) one. In different models of electricity market organization, these factors will show up in different ways. In the markets with regulated electricity prices, such an export may be mutually beneficial if the export price is set within the range of prices of EPSs to be interconnected. Then, the consumer price can be reduced in the exporting system owing to the export earnings, and in the receiving system owing to cheaper electricity received. In competitive markets with free prices, electricity export will cause a loss to consumers of the transmitting system because of an increase in electricity demand and prices.

The following two types of effects—a decrease in the required reserves and a coincident maximum load (in comparison with the sum of maximums for EPSs at their isolated operation)—directly lead to savings in generation capacities. They may be called "capacity" effects of interconnecting EPSs. These effects are very substantial for some countries. They are typical of the EPS as a whole at joint consideration (efficiency assessment) of the electricity generation and transmission spheres when construction of transmission lines decreases demand for generation capacities of EPSs to be interconnected and the total costs for EPS expansion.

The capacity effects of interconnecting EPSs are observed at any type of generation facilities and transmission lines. This fact is often underestimated when one speaks of the loss of the economies of scale in the power industry. The economies of scale imply not only the economic feasibility of increasing power plant sizes and transfer capability of transmission lines. It is typical of EPS as a system, i.e., the costs in the transmission sphere decrease the costs in the electricity generation sphere. It cannot disappear and will constantly manifest itself with an increase in EPS scales if it is not split into spheres and sets of companies.

The considered three types of effects also occur when EPSs of different countries are interconnected. The intensive formation of interstate electric power interconnections (ISEPIs) in almost all world regions proves it [24]
Hence, the economies of scale are inherent in EPSs both at the national and at the interstate levels.

The rest of the effects will not be commented upon. As a rule, their realization depends on the electricity market type to a lesser extent. They are described in greater detail in the mentioned papers, in particular in [24]

III. Properties of EPSs

Sets of physicotechnical, economic, social, and environmental properties are surely typical of EPSs. In our discussion below, consideration is given to those influencing market organization in the power industry in one way or another. Based on the variety of possible market types (models), the display of these properties will be noted in different (and sometimes in all) market models.

Here, the most general idea about models of electricity market organization seems to be expedient for further illustration of the impact of different properties of EPSs on them. Figure.1 presents four major models of the electricity market [28, 31]:

1. *Regulated natural monopoly* (absence of competition), which was already mentioned above. In the electric power industry, these are the so-called vertically integrated companies embracing all the spheres of electricity production, transportation, distribution, and sale. This market form has given rise to restructuring or reform discussed in the paper. The following market models are characterized by successive separation and differentiation of the indicated spheres with the formation of the corresponding generation, network, and sales

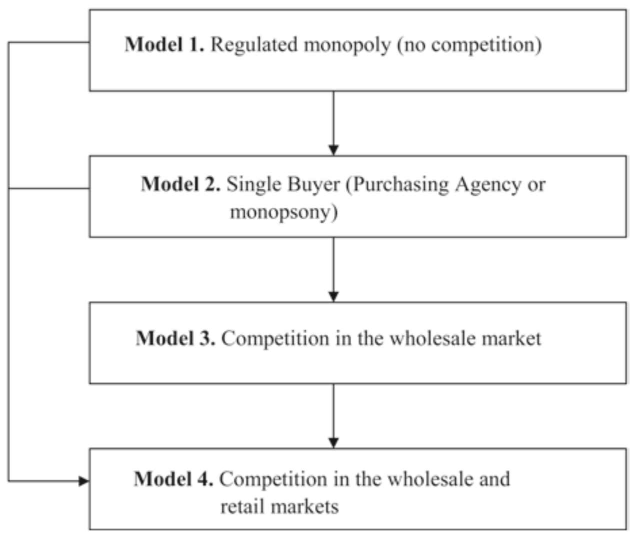

Fig. 1 Major modelsof the electricity market organization

companies.

2. *Single buyer* (Purchasing Agency, monopsony), when the generation sphere is divided into several separate (financially independent) power generation companies (PGCs) that start to compete with each other in electricity supply to the common Purchasing Agency. The other spheres remain vertically integrated into the agency and it is a monopolist with respect to consumers as before. The business of the Purchasing Agency, therefore, should be regulated by the State, including a price quotation of electricity purchased from producers and sold to consumers.

3. *Competition in the wholesale market*, when the electricity transportation sphere is separated, the spheres of electricity distribution and sale are split into territories and the wholesale market is organized. This leads to the creation of a transportation network company, territorial distribution-sales companies (DSCs), and specialized market structures. The wholesale market prices become free and the activity of DSCs and the retail prices are regulated as before.

4. *Competition in the wholesale and retail markets*, when the spheres of electricity distribution and sale are additionally divided with the formation of regulated distribution companies (by territory) and sets of independent sales companies. Retail electricity markets are organized with competition between sales companies (buying electricity in the wholesale market) and consumers. The retail prices are no longer regulated.

We should underline that all the enumerated models are market models, as often only the last two models are called markets. The first two models are markets with regulated prices—tariffs —and we will call them, for short, regulated markets, while the third and fourth models will be markets with free prices or competitive markets. For brevity's sake, these models will sometimes be referred to by the numbers under which they have been listed above (Model 1, Model 2, etc.).

The arrows on the left in Fig.1 show the transition at restructuring from the regulated monopolies at the regional level and the single-buyer model at the federal level to Model 4. The transition is stipulated by the Law of the RF "About electric power industry" [32]

Now we will address directly the properties of EPSs, which determine specific features of the electricity market.

The well-known properties and features of EPSs are:

- A special role of electricity in the economy and society; damage caused by the sudden interruption of electricity supply exceeds manifold the cost of undersupplied electricity, which requires special measures to support electricity supply reliability.
- The inability to store (accumulate) electricity in sufficiently large volumes.
- The necessity to balance electricity production and consumption at every moment.
- The inevitability of equipment failures, and hence the necessity of backup generation
- capacity and electric ties.

These properties undoubtedly influence and complicate market organization in the power industry to a varying extent in different market models. However, note some other features of EPSs that are also important in this context and are interrelated with the above properties in one way or another:

1. *Specialized electricity transport* (by wires). It excludes electricity delivery by general types of transport (railway, motor, water, air), which is possible for the production of the majority of other branches and renders a local character to EPSs. New electricity producers and consumers can emerge only by connecting them to EPS networks. This property leads to:

- The territorial limitedness of the electricity market: only consumers and producers directly connected to the EPS through electric ties with a sufficient transfer capability can participate in the market. In particular, there is no world electricity market or world electricity prices.
- Participation of only existing (operating) power plants in the market.
- Existence of the technological (physical) barrier to the entry of new producers into the market; to this end new power plants should be constructed and connected to EPSs. Thereby, one of the principal conditions for perfect competition — *free entry of new firms into the industry and free exit of existing firms from it* [30] — is not observed in the power industry.

It should be noted that a physical barrier for new power producers (NPPs) is especially important. It plays a decisive role in electricity markets in the short run (in the microeconomic sense). NPPs simply cannot appear in the market, because a new power plant should be designed, constructed, and connected to the EPS, which requires several years. In the shortrun electricity market, the operating producers are protected from the competition of NPPs and can raise prices. It is one of the basic reasons for electricity market imperfection and it cannot be eliminated (i.e., it is impossible to make the market perfect) by any organizational and methodological measures or rules.

2. *Daily, weekly, and seasonal load variations* that determine:

- The need to expand generation capacities according to an annual load peak (taking into account re-serves); in other periods of the year power plants will be underloaded and get lower revenues which may turn out to be insufficient to pay back investments.
- The economic viability to have different power plants (basic, peak, and semipeak) with various eco-nomic indices (specific capital investments and production costs).

- The need to optimize the structure of generation capacities (by type of power plants) and operating conditions of power plants for different periods of a year.

The presence of power plants of different types, in turn, leads to specific supply curves of producers and formation of marginal prices and producers' surplus [33] for more efficient power plants in the competitive wholesale market.

This feature of EPSs also caused the need for centralized dispatching control of the normal and emergency operation of the power system (which is foreseen in all market models) and also engendered the next property (or even paradox) in the electric power industry which is observed in no other industry.

3. *The need for optimization of the power system operation with regard to instantaneous (hourly) variable costs of power plants, while their total costs (and economic efficiency) are determined by integral operation results for the whole year with an account taken of fixed costs.* Load variations during a year cause changes in operating powers (load) of power plants, which should be optimized according to the criterion of the least hourly, daily, weekly, or seasonal variable (fuel) costs throughout the entire power system. While carrying out the optimization, we have to use hourly characteristics of power plants, which represent only variable costs.

Meanwhile, the real electricity value (and its price) is determined by the average total costs, including fixed costs of power plants as well. In the electric power industry, the average total costs can be determined only for the whole year. They will depend on an annual output of a power plant, its operation during a year (which determines annual variable costs), and annual fixed costs. This difference between hourly and annual costs influences essentially the organization of electricity markets and the process of price setting. In particular, the spot electricity markets organized in real time (with hourly or half-hourly intervals) are not real short-run markets considered in microeconomics, and their prices do not reflect the real value of electricity, which makes the spot markets inappropriate (see [21,22]). The real short-run electricity markets can only be the markets that cover the period of one or more years and are implemented through respective contracts.

4. *Great capital intensity, long periods of construction, and service of power plants and some transmission lines, which result in:*

• The impossibility of quickly eliminating shortage if it occurs for some reason. It will take several years to design and construct new power plants. Moreover, if power plants are constructed by private investors (Models 3 and 4), nearly 10 years more will be necessary to pay back the investments. Consequently, private investors should know the power system expansion conditions, including the prices in the wholesale market, 15–20 years in advance. These conditions are rather uncertain, which create a large risk for investors and make the construction of new power plants and elimination of shortage even more complicated.

• The need for prior planning and subsequent financing for the expansion of generation capacities in power systems to avoid shortage in the electricity market.

• Power plant service life (30–40 years) exceeding "reasonable" payback periods (10–15years), which will make private investors construct power plants (Models 2–4).

This feature of EPSs manifests itself to a greater extent under competitive markets (Models 3 and 4) when the criteria, incentives, and financing mechanism for construction of new power plants change dramatically as compared to the regulated monopoly and single-buyer market. These changes create problems of investing in the expansion of generation capacities, which are considered in [22]

Moreover, the competitive market concepts (including those in Russia) usually envisage no centralized planning of the generation capacity expansion. The generation capacities are supposed to expand based on "market signals." However, the experience of the countries that introduced the competitive electricity market and recent research have shown that the market does not generate these signals timely and special "non-market" measures are required to prevent power shortage.

5. *High level of mechanization, automation, and even robotization (at nuclear power plants) of electricity production, transportation, and distribution.* Normally, power plants and substations have only administrative, duty, and maintenance personnel. The number of personnel practically does not depend on the amount of actually generated and transmitted power. All process lines and units at power plants are designed based on their maximum (installed) capacity.

This feature of EPSs along with the said huge capital intensity of power plants leads to a high share of fixed costs in the total electricity production costs. At the same time, there are practically no variable costs at HPPs, and those at nuclear and thermal power plants are made up of fuel costs only. The characteristics (curves) of average costs of power plants, therefore, differ principally from the cost curves of "typical" firms considered in the theory of microeconomics. This makes the short-run competitive wholesale electricity market "nonstandard," i.e., different from the markets in other industries. In particular, power plants (or power generation companies) will have to enter the market with their supply bids reflecting the total costs rather than the marginal ones.

6. *The interdependence of electricity production processes of different power plants in the power system.* All power plants operate to cover the total EPS load which changes daily and seasonally. Their operating conditions are optimized centrally, depending on the mix of generation capacities in the EPS.

This feature of the power system brings essential features in the electricity market:

• Power producers (sellers) do not enter the market with already finished products with known volumes and prices. Electricity is produced jointly and simultaneously by all producers. Volumes and costs of each producer will depend on centrally assigned operating conditions for different hours, days, and seasons. The most economically important annual volumes and costs of each producer will be determined only at the end of the year by integral results.

• Thus, the uncertainty exists in the characteristics of short-run costs of power producers. This uncertainty is not observed in the industries where firms (companies) produce commodities independently of one another. The uncertainty of power plant costs makes the electricity market very special. In the regulated markets (Models 1 and 2), this creates difficulties in establishing tariffs by the regulatory bodies. The regulation should envisage adjustment of tariffs if the actual output of power plants deviates considerably from the planned one (this is particularly necessary for HPPs, whose output depends on the random inflow of water). In the competitive markets (Models 3 and 4), the situation is even more complicated — the electricity producers in the market do not know exactly how much electricity they will produce throughout a year and what total costs they will bear. Naturally, they will overestimate the prices both in the spot market (if it exists) and in the long-term contracts with buyers.

7. *Facility-by-facility expansion of power systems*. The market in any power system expands through the construction of individual new power plants and transmission lines. This property reveals itself differently in different models of electricity market organization.

New power plants can be funded and constructed by:

- Vertically integrated companies (VICs) (Model 1)
- Power generation companies (PGCs) (Models 2–4)
- New independent power producers (IPPs) (Models 1–4)

Financing mechanisms for the construction of power plants will vary. The primary distinction is that under regulated markets (Models 1 and 2) the investments in new power plants are paid back at the expense of the total electricity output generated by VICs (or in EPSs), whereas under the competitive wholesale market (Models 3 and 4) the investments in some power plant should be paid back at the expense of the electricity generated by only that power plant alone.

Under the competitive market, each new power plant constructed by a private investor, along with operation costs, will have its investment components required to pay back the investments. Therefore, the price to be offered by the new electricity producer in the wholesale market will be higher than the price offered by the operating power plant of the same type. This creates an economic (price) entry barrier for new producers in addition to the physical barrier mentioned above, which makes the electricity market imperfect in the long run as well.

Additionally, the facility-by-facility expansion of generation capacities in EPSs influences the shape and sense of the long-run cost curves of the electricity generation sphere. Under competitive markets, the short-run costs of new power plants should be considered as long-run production costs of IPPs and PGCs.

Moreover, the transition to the competitive wholesale market changes the mechanism of financing the intersystem and interstate electric ties, which makes it difficult to substantiate their efficiency (see [24]).

8. *Economies of scale.* This was already considered earlier. This effect is to the greatest extent realized in the regulated monopoly (Model 1). In other models, it subsequently decreases (Model 2) or is even lost completely (Models 3 and 4) due to the splitting of one company into several separate companies. It should be emphasized once again that this effect is typical of the entire EPS (as a system) and not only of power plants in the electricity production sphere as it is sometimes interpreted (for example, in [28]).

The overall analysis of power system properties shows, on the one hand, the principal distinctions of the electricity market from the markets in the other industries and, on the other hand, its obvious imperfection.

The main distinctions are:

- The territorial limitedness of the electricity market (within the territory covered by the networks of a specific EPS).
- The need for dispatching control of normal and emergency conditions of the power system.
- The need for centralized design and planning of the power system expansion with account taken of the required capacity reserves.
- The impossibility of organizing "normal" electricity spot markets (for more details, see [22]).
- The non-typical and uncertain costs in the generation sphere of EPSs, which makes the competitive (unregulated) wholesale electricity market "nonstandard" in light of the theory of microeconomics.
- Obvious uniqueness of intersystem electric ties that connect different territorial electricity markets (for more details, see [22,24).

The electricity market imperfection is first of all conditioned by the technological (physical) barrier to new producers in the short run and by the price (economic) barrier to them in the long run. Whether or not the other conditions (requirements) of perfect competition are met is analyzed in the next Section. The imperfection of the electricity market reveals itself under any models of its organization. In Models 1 and 2, its monopolistic character is obvious and this leads to the necessity to regulate electricity prices (tariffs). In Models 3 and 4, the electricity producers, on the one hand, may form an oligopoly and, on the other hand, maintain "market power," thus having the chance to create a shortage and raise electricity prices through cessation or delay in construction of new power plants. This is also facilitated by the economic barrier mentioned above.

It should be noted that the electric power industry differs from other infrastructural industries, such as transport or telecommunications, in the production of commodities. It is the sphere of electricity generation that creates many of the foregoing EPS distinctions and makes the electricity market imperfect. This, in particular, relates to a nontypical character and uncertainty of costs in the sphere of EPS generation, to the impossibility of organizing electricity spot market, and to the existence of physical and price barriers to entry of new producers into the market. It is important to indicate this distinction, since in some countries (for example in the USA) one of the arguments for deregulation of the electric power industry was successful reforms in the air transport and telecommunications. This distinction of the power industry is analyzed in [3]

IV. Types of markets

Microeconomics [30, 33, 34] considers several types of markets:

1. *Markets with perfect (pure) competition*, which will be called shortly *perfect* markets. Such markets are considered most effective and are taken as a reference (sample), though in reality, they are quite rare (mostly in the agriculture). There are numerous conditions and requirements to be met in the market for the competition to be perfect: a great number of sellers and buyers, each being unable to affect the market price, their free access to the market and exit, etc.

2. *Absolute (pure) monopoly, when there is only one seller in the market.* This market is in absolute opposition to the previous one—an extreme case of an uncompetitive market. In particular, this monopoly can be observed in the power industry.

3. *Natural (regulated) monopoly,* which is effective if owing to economies of scale one firm in the industry can produce all the commodities at lower costs (and prices) than two or a larger number of firms. This situation, as was mentioned earlier, is characteristic of the power industry. In this case, the activity of the firm and prices of products should be regulated by the state (regional, municipal) bodies, for the firm not to abuse its monopoly position.

4. *Oligopoly*, when there are several sellers in the market and *entry of new sellers* into the market *is either complicated or impossible*. With "fair" competition, oligopoly can be very effective; however, there can be price manipulations—the use of market power by oligopolists, particularly under their collusion. The oligopoly situation is possible in the power industry if electricity prices are not regulated.

5. *Monopolistic competition* is typical of markets with partly interchangeable commodities (e.g., cars) which vary in quality and consumer properties. This kind of market is not characteristic of the power industry.

6. *Monopsony*, where there is only one buyer in the market. Here, unlike monopoly, it is the buyer, not the seller, who is in a privileged position (possesses market power). In microeconomics, this situation is considered mainly as applied to the manufacturer of some commodity, i.e., a firm which is the only buyer of a certain resource required for its production. Most often this resource appears to be labor. Meanwhile, in the power industry, the single-buyer market model is possible. This model implies that the sellers (many of them) will be producers of a ready product—electricity. However, the firm (power company) that performs the function of the "single buyer" (it is also called a "Purchasing Agency") will be a monopoly reseller for the final electricity consumers. Here, like in the case of natural monopoly, the state regulation of electricity prices is required.

7. *Oligopsony* is a kind of monopsony with several buyers in the market. This kind of market is seldom considered in the theory of microeconomics. The possibility of organizing such a market (regulated) in the power industry should not be excluded. For example, the electricity market that has emerged in the past years in Brazil (and is forming in Chile) represents, in general, the single-buyer market. There are several buyers there—distribution-sales territorial companies. Therefore, this market can be referred to as oligopsony as well.

There are also other types of markets (e.g., price discrimination) that are of no interest to the power industry.

All markets, except for the first one (with perfect competition), are imperfectly competitive or simply imperfect.

In the following sections, the first type of market will be considered in more detail to show the extent to which the electricity market does not meet the conditions and requirements for perfect competition.

V. Markets with perfect competition

Many conditions for perfect competition to emerge (to be provided) have been formulated. In [33], for example, the authors point out five such conditions:

1. *Many sellers and buyers participate in the market. The share of each of them is small with respect to the entire market, and therefore they cannot affect the price* (the price does not depend on supply or demand of individual market participants). In [23], this condition is interpreted as price-taking suppliers and buyers, i.e., those not trying to increase or decrease the price.
2. *Goods are homogeneous*, i.e., meeting the established standards. Therefore, the buyers do not care which seller to choose.
3. *Buyers are well informed about the sellers' price* — any seller increasing price loses its customers.

4. *Buyers and sellers act independently of each other*. They do not participate in price collusions. Each firm chooses the output volume that maximizes its profit on the assumption that it cannot affect the price. The buyers choose the volume of purchases acceptable for them at a given price.
5. *The firms can freely enter and exit the industry*. This condition is taken to guarantee that the firms existing in the industry cannot increase the price through agreement about output reduction since any price increase will attract new firms into the industry which will raise the supply volume.

In addition to the enumerated conditions, some papers name other conditions for perfect competition. For example, in [23] the author gives two more conditions:

6. *A good shape of the firm's short-run cost curve* ("well-behaved costs")—short-run marginal costs start rising while average costs stop shrinking after the firm reaches a certain (not very large) volume of production (i.e. the U-shaped forms of average variable and total cost curves are provided).
7. In the long ru*n, the characteristics of production costs of a firm should not create conditions for the natural monopoly.* This implies that the curve of long-run average costs (LAC) does not have a descending form, but on the contrary, an ascending one. In other words, there should be diseconomies of scale in the industry.

In [35], the author points out one more condition for the perfect competition that was determined by Nobel Laureates Gerard Debreu and Kenneth Arrow.

8. *Every market participant can buy insurance against any possible risk.* This condition can be considered rather important. Analysis of these eight conditions as applied to the electricity market shows that only condition 2 (a homogeneous or standardized product) is met in full measure. It should be noted, however, that some market organization models in the power industry foresee, along with the electricity market, the creation of markets for capacity, ancillary services, derivatives, etc., i.e., markets for several "products." This makes the market in the electric power industry imperfect and more complicated.

Conditions 5 and 7 are not met in the power industry at all. Free entry of producers into the industry is physically impossible because this will call for the construction of a power plant and its connection to an EPS. The physical barrier for new electricity producers makes the market imperfect in the short run when the installed capacities of power plants are fixed. Besides, in some models of the electricity market organization (Models 3 and 4), the economic entry barrier is created in the long run. The economies of scale that foster the formation of natural monopolies in the power industry, as was discussed earlier, are typical of the EPS. In this connection, it should be admitted that the electricity market is imperfect. This circumstance, by the way, is not disputed by anyone. However, the efforts to introduce competition are persistently made either in the hope to overcome this imperfection or for other reasons.

It is very difficult to meet condition 3 (buyers know well the prices of sellers) in the electric power industry (and not only in this industry). This condition is considered to be particularly important. It is discussed in all the papers devoted to perfect competition. In [23], the author points out adequate information available for all market participants, the author of [35] talks about perfect information, etc. In 2001, Joseph Stiglitz was awarded the Nobel prize in economics for his theory of "information asymmetry," i.e., the demonstration of the fact that information is not equally distributed among the market participants [35] Hence, we can consider that this condition for perfect competition is not met everywhere. The difficulties in providing adequate information in the electricity markets are considered in [4, 23], and in other papers.

It may seem that conditions 1 and 4 can be met since in large EPSs (and markets on their territory) there are many power plants and the number of power consumers is even larger. However, as a rule, power plants belong to a relatively small number of generating companies. In the competitive electricity markets with unregulated prices (Models 3 and 4), these companies retain market power to one extent or another and can even form an oligopoly. The examples of market power and its analysis are presented in many publications [9, 23, 36]

The short-run cost curves of power plants (condition 6) are studied in [21, 22] It is worth noting that the minimum point of average costs practically for all types of power plants is reached at their maximum annual output, i.e. the shape of these curves is not "good" (U-shaped).

Finally, to meet the last condition (insurance against any risk), it is necessary to create a special system of insurance.

Thus, we can state that the *electricity market is not a market with perfect competition*, and the organization of free competition (electricity price deregulation) can lead to undesirable consequences.

If competition in the market is imperfect, then without state regulation this market will be a kind of imperfect market: a monopoly or an oligopoly with dominating (market power) sellers and a monopsony or an oligopsony with dominating buyers. In the electric power industry that has the features of a natural monopoly, market power belongs to sellers (producers). As the experience in the early twentieth century shows, without regulation (under "spontaneous" market) this will lead to the formation of a monopoly. However, if the generation sphere is forcedly split into several independent power generation companies, then without regulation it will be an oligopoly.

VI. Conclusion

1. The analysis has shown that the special properties of electric power systems impede the fulfillment of several important conditions (requirements) of perfect competition in electricity markets, and exclude even the possibility of creating such conditions when organizing the markets. The conclusion can and should be drawn that electricity markets are imperfect in their nature, and no organizational and technical measures can make them perfect.

2. The main feature of the electric power industry is the use of power lines for electricity transmission, which territorially limits electricity markets, and creates difficulties in expanding the market (for new producers to enter the market) and the need to maintain a balance between electricity production and consumption at any given time, etc.

The main condition for the perfect competition that cannot be created in the power industry is free market entry and exit for the firms. In the short term, these are hampered by a physical (technological) barrier - it takes a new producer several years to enter the market (the power plant must be designed, built and connected to an EPS). In the long term, there appears an economic (price) barrier for new producers. They require market prices that exceed the costs of existing producers by the amount of the investment component necessary to pay off the investment in a new power plant.

3. In imperfect markets, government regulation of electricity prices is required. The absence of the regulation can lead to rising prices, power shortages, etc. There were such troubles at the beginning of the century in various countries of the world (starting with the California crisis in the USA) but their analysis goes beyond the scope of this paper. Similarly, the consequences of the transition to the competitive electricity market in Russia require special consideration.

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