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Mechanisms for Generating Capacity Expansion and Power Market Structures: Russian Case Study

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OVERVIEW

Process of electricity markets liberalization has been proceeding in various countries of the world. Experience gained from the liberalization confirms that electricity only markets do not stimulate enough investments in new generating capacity (GC) beforehand. Under conditions of growing demand and phasing out retired equipment this will cause lack of GC and threat of reliable consumer's electricity supply in the long term. That is why mechanisms for stimulating investment and commission of new GC are required.

Various capacity expansion mechanisms (CEMs) are developed in different countries: capacity market (USA), payment for capacity (Spain, Ireland, Iran, Peru etc.), auctions for long-term contracts (Brazil, Chili, Columbia). Even at energy (electricity) only market (most part of Europe, Canada, Australia, New Zealand etc.), where price signal is the main mechanism for GC expansion, additional tools for providing GC adequacy are used (in particular, agreements between System operator and power plant owner, etc.).

Long-term capacity market has been operating in Russia since 2011. However mechanism of capacity supply agreements (CSAs) plays major role in GC expansion nowadays. CSAs oblige generating companies to invest in and build power plants according to national power industry development program to meet prospective consumer's needs. At the same time the final structure of the electricity market has not been formed yet and there are moot questions concerning the functioning of capacity market as an effective mechanism for the stimulating investment in generation.

Study of mechanisms for GC expansion under conditions of liberalized electricity markets is comprehensive problem, which requires considering physical and technical features of electric power systems as well as power market structures. Such studies are being conducted in France, Netherland, USA, etc. In Russia the studies are just commencing. However they are urgently needed particularly considering CEMs and power market structures specific for Russia.

METHOD

Studied in the paper were the following capacity expansion mechanisms and power market structures:

1) perfect electricity market; 2) oligopolistic electricity market; 3) perfect electricity and capacity markets; 4) oligopolistic electricity and capacity markets; 5) oligopolistic electricity and capacity markets with CSA; 6) oligopolistic electricity market with CSA.

To model CEMs under conditions of perfect electricity and capacity markets and find out optimal solutions linear programming models were developed.

To model CEMs under conditions of oligopolistic electricity and capacity markets equilibrium models were developed. Nash-Cournot approach is used in the models. This is flexible approach and allows taking into account many market participants. As far as long-term prospect is considered in the model when elasticity of power demand is quite high, market power is not overestimated by Nash-Cournot approach.

Equilibrium models consider separate generating companies (GenCos) and consumers represented by aggregated electricity (or electricity and capacity) demand function(s) (depending on the model). Behavior of GenCos is determined, on the one hand, by their pursuit to maximize profit (that is presented in the model as objective function for each GenCo) and, on the other hand, by necessity to observe balance and operating conditions constraints for electric power system. One node models are considered. All functions in the models are taken to be linear. Wholesale market is modeled.

The developed mathematical model realizes a two-stage approach. At the first stage we solve the problem of nonlinear programming to determine the total (annual) indices (of the installed capacity, annual output by company and by type of the installed capacities). At the second stage the obtained solutions are detailed by solving auxiliary linear programming problems of large dimension. As a result the obtained annual indices of electricity output are distributed by season of the year, day of the week and hour of the day to provide an hourly capacity balance in the electric power system.

Behavior of generating companies is determined by the intention to maximize their profit in the electricity and capacity markets considering balance and operation constraints of electric power system. To maximize their objective function the compa-

nies may put into operation new generating capacities and load the existing ones, limit commissioning of new capacities and loading of power plants (by exercising market power under the oligopolistic market).

RESULTS

The developed models were used to study Russian CEMs and power market structures. Considered was Central interconnected power system of Unified electric power system of Russia for the target year 2030.

The results show that the total price in the two-commodity market (models 3 and 4, see above) turns out to be higher than in the one-commodity market (models 1 and 2). This is conditioned by the following. In the one-commodity (electricity) market the equilibrium price is formed on the basis of marginal total costs (variable and fixed costs, including investment costs) of the marginal facility. When the power market is divided into two markets (electricity and capacity markets), the price in each of them is formed in accordance with marginal costs of different marginal facilities. As a consequence, the aggregate costs (per kWh) of two different marginal facilities prove higher than those of one facility. For instance, in one- and two-commodity markets different plants can appear to be the most expensive: in model 1 – cogeneration plants and gas-fired plants, and in model 3 in the capacity market – new nuclear power plants, in the electricity market – cogeneration plants. Therefore, even for the perfect competition the aggregate price in model 3 exceeds (almost by a third) the price in model 1.

As is seen, the division of the one-commodity power market into electricity and capacity markets increases prices and decrease the effectiveness of this form of power market structure for consumers. At the same time the capacity market stimulates generating companies to add more new capacities, that improves long-term reliability.

The resultant price even in the imperfect markets with CSA (models 5 and 6) is lower than in the perfect markets (models 1 and 3). This is explained by the difference in price-setting principles in the specified power markets. In the second case the price is formed by marginal costs (including investment costs); while in the first case the price is formed by marginal costs for operating power plants, and by average costs – for new power plants. Besides, the CSA mechanism eliminates the possibility of manipulating the capacity additions of generating companies by counteracting their long-term market power.

CONCLUSIONS

The results obtained in the study show the following. Introduction of capacity market in addition to electricity market increases capacity additions. However this also drives the total price (for capacity and electricity) up, decreasing effectiveness of this market structure.

Mechanism CSA provides required GCs accounting for reserves and besides drives the prices down comparing to other considered CEM and market structures. Besides it eliminates long-term market power of GenCos, preventing their manipulation of capacity additions. Coexisting of CSA and capacity market as it is currently in Russia is not feasible. Even under conditions of oligopolistic competition electricity only market in combination with mechanism CSA provide required GCs additions at comparatively low prices and guaranteed capital return.

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