Journal of Engineering and Applied Sciences 12 (19): 4889-4893, 2017
ISSN: 1816-949X

Simulation Models in Terms of Integration of the Energy Markets

[1]A.A. Ajupov, [2]Iu.A. Anisimova, [2]N.N. Bykova, [3]A.G. Savin and [4]E.S. Kolesov
[1]Kazan Federal University, 420008 Kazan, Russia
[2, 3]Togliatti State University, 445020 Togliatti, Russia
[3]Samara National Research University Named after Academician S.P. Korolev, 443086 Samara, Russia
[4]Surgut State University, 628400 Surgut, Russia

Abstract: Study considers to the modeling of wholesale energy markets in the context of implementation of the roadmap. We use a comprehensive simulation model to study the influence of structural factors on the development of national and regional energy. In addition, we evaluate the impact of the generating companies specifically its impact on prices, offers and sales of electric power on the market without a reaction from competitors. The results of the study are discussed in relation to the road map in energy. Our findings are also applicable to wholesale energy markets, the EU and Russia.

Key words: Roadmap, energy market, financial instruments, simulation model, market strategy, generating companies

INTRODUCTION

This study analyzes the conditions and structural factors of influence on the search for the optimal strategy of generation company in electricity market. Currently, the development of the global energy complex has seen a new strategic trend of the solution of problems of organization and functioning of electricity markets. The new collection targets a wide variety of technologies use of energy resources and the impact of the institutional environment, requires careful analysis. The growing needs of the world community in energy resources require changes in existing national energy systems. The main direction of development is to provide accessible, reliable and safe energy services. This requires the solution of target tasks, the relevance of which in the future will only increase (Alexeev and Pyle, 2003; Schneider, 2012).

Note that modern energy markets are large-scale mechanism which is impossible without the existence of a developed institutional environment. The majority of researchers point out that the established margin strategy of generating companies in the electricity market is not optimal. Target installation of generating companies in a competitive environment is to maximize profits. So, the generating companies there are more opportunities to use a market force which allows them to influence the offer price and conditions of sale of electricity on the market. The study, shows that the integration of the generating companies leads to the formation of a new institutional environment (Ajupov and Polteva, 2014; Roth and Erev, 1995).

The attractiveness of the market to create complex models in energy motivates to use mathematical instruments for designing technological infrastructure models and strategies of behavior of market participants. In the simulation environment, market participants can often interact with each other and reproduce realistic techno-economic dynamic model.

Recent work in the field of modeling the wholesale electricity market show that the basic direction of researches is connected with studying of behavior of participants of the wholesale electricity market. Many studies over the last decade, refute the main provisions of classical economics about rational behaviors of economic agents (Groenveld, 2007; North *et al*., 2002; Tesfatsion *et al*., 2006). In reality, the behavioral component of the subjects is influenced by many factors in particular, the interaction between actors. The understanding of this fact led to the creation of new simulation models of the electricity market which are based on a new methodology, based on agent-based modeling. The electricity market model is formed from the interaction of many market agents each of which has certain specific of behavior.

MATERIALS AND METHODS

Agent-based models usually consist of computing built the virtual world consisting of multiple agents (encapsulated software) various interactions which affect all events in the world for some time. Agents in the models can describe structural elements (e.g., nodes,

Corresponding Author: Iu.A. Anisimova, Togliatti State University, 445020 Togliatti, Russia

networks) organizational structure (e.g., markets) and cognitive structures (e.g., the behavior of traders and market operators and energy brokers) (Borenstein, 2002; Groenveld, 2007; Weijermars, 2014; Weijermars and Dorssen, 2012).

The agent approach allows to predict the development of events under given initial conditions and make a better decision. In the study, simulation and optimization approaches to modeling economic systems, it was concluded that for the study of strategies for generation companies in electricity market the most appropriate to use agent-based approach because:

- There is the possibility of modeling individual behavior strategy behavior to describe the process of interaction with other agents
- Subjects active, dynamic system that allows to assess the impact of decisions of individual agents on the system as a whole
- There is the possibility of adapting and building on past experiences, agents for shaping their behavior (learning agents)

RESULTS AND DISCUSSION

Currently, a simulation approach to modeling energy markets became widespread mainly in the works of foreign scientists. There are a variety of commercial agent-based models to investigate economic processes in energy markets (Capros and Weijermars, 2012; Ajupov *et al*., 2015; Phaal *et al*., 2008; Tesfatsion *et al*., 2006). In addition, the integration of economic interests of partner countries is based on the development and strengthening of mutually beneficial relations and further development. Anyway, all the types of roadmaps in the enterprise form the information base for its management through strategic planning.

One of the main advantages of the formation of Roadmaps is to participate in its development. As a result of constructing models of the organization of national energy markets revealed that they are all based on common principles (Kahneman and Tversky, 2000; Roth and Erev, 1995).

For the purposes of the study were chosen open software environment, AMES University of Iowa, USA (Tesfatsion, 2007). One of the advantages of the model, AMES is a reproduction of the system of self-training of traders in the energy market which is based on the results of the experiments of multi-agent games company and yerevan (Ajupov *et al*., 2015a, b). Used learning algorithms allow the generation to choose the best method of formation of bids for the supply of electricity, they are served daily to the system operator AMES to participate in the WPMP market for the day ahead.

The problem of finding the best strategy of generating companies in the electricity market today is one of the most important in the context of ongoing market liberalization. The most important sector from the point of view of price formation in the market and flexible management of production schedules is the market “day ahead”, namely the sector of free trade, being the most competitive, enables participants to extract the maximum possible revenues (Stoft, 2002).

The basis of the spot electricity market is the auction mechanism for bilateral trade, establishing a single equilibrium price for each node of the computed model for very hour of the day taking into account losses and system restrictions.

In the electricity market, generating companies can apply a number of strategic innovations which are based on the market power of the enterprise, allowing them to maximize their income. The basic strategy of using market forces given in Table 1.

Despite the differences in the mechanism of these strategies, their use leads to the same results and consequences of the shift in the supply curve to the left and up, respectively, increased market prices for electrical energy (Iliadis and Gnansounou, 2016).

The possibility of efficient application of market forces generating companies due to external and internal factors presented in Table 2.

To evaluate the effectiveness of strategies to market forces by using the following result indicators:

Table 1: The basic strategy of using market forces

Strategy	Sphere of application	Results
Financial withdrawal	The formation of bids for the supply of electricity at a higher price (particularly above the marginal costs of electricity generation)	With the prevalence of market demand (inelasticity of demand) this should lead to an increase in the equilibrium market prices and thus potential income generation
Physical withdrawal	Submission of bids for the supply of electricity with a reduced amount of compared to those that can be produced on the generating equipment of the company	The removal of a certain amount of power from the market and thus also increase equilibrium market price
Physical withdrawal with the help of free bilateral contracts	Are free bilateral contracts which removed part of the “cheap” scope	The resulting gap in energy capacity leads to an increase in the equilibrium market price

Table 2: The factors that determine the efficacy of market forces generating companies on the market

Factors	Description
Internally	
Cost structure	Function, variable and fixed costs of the generating company, applying market power
External	
Network structure	The number of nodes and branches network, their configuration
	The bandwidth of the branches of the network,
	The distribution of suppliers and consumers in network nodes
	Losses in electric power transmission between network nodes and the cost of such transmission
The structure of demand for electric energy	The total number of guaranteeing suppliers
	The number of guaranteeing suppliers in the host k
	The electrical load of guaranteeing suppliers in each hour of the day
Structure of supply	The total number of generations
	The number of generators located at node k
	The cost function and the allowable range of the production capacity of competitors

- Market price of electric energy in the node connected generation using market power
- Amount of electrical energy implemented by generating, applying market power
- Revenue generating, applying market power
- Profit generating, applying market power

It is obvious that the possibility of using market forces generating companies primarily depends on the ratio between supply and demand on the day-ahead market in each hour of the day. Therefore, to determine the influence of other factors in the experiment set to a fixed value of demand for every day and every hour of the day.

Consider the formation models of games on the market of electrical energy. The initial conditions assume that electricity demand is inelastic and therefore, the price bids of the buyers in the formation of a quotation can be neglected. Under the "game" will understand the order of price bids Administrator Trading System (ATS). The Russian electricity market applies node model in which computational model determines the price indicator hub. Indices of average prices in the nodal model cannot provide the full hedge closing positions. Lack of regulated contracts and free bilateral contracts.

Generating companies as suppliers of electricity are forced to make decisions in the face of opposition the other side which may pursue the opposite or other purposes. At the same time countering the opposite side can be passive or active. In the case of the Wholesale Electricity Market (WECM) cannot assert that generating companies pursuing their own goals, consciously counteract the objectives of each other. The other hand, against the generating company may act uncertain environmental factors which in game theory called "nature" a non-active side which obviously does not oppose the attainment of the objectives of the generating company. In this case, the generating company makes the decision and "nature" does not render it conscious, aggressive reaction but its actual behavior is unknown. On the WECM for the game to the pair since all participants (in this case the generating companies and wholesale customers) can be divided into two groups: Generation A (Group generating companies) and buyers (wholesale customers). In this case, the following WECM model games (Fig. 1).

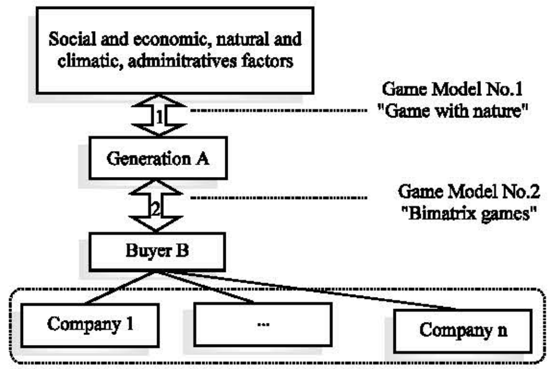

Fig. 1: Models games generating companies WECM

A situation where the parties lack the "antagonism" can be represented as a game with "nature". On the WECM as "nature" which does not have an aggressive reaction, may be: fluctuations in demand; uncertainty of weather conditions; repair modes stations; seasonality; regulation by the government, the system operator, commercial operator, the Federal Antimonopoly Service (FAS); competitive environment, etc.

Dependence winning generation A the extent of regulation possible to represented as a matrix whose elements will act wins generation A corresponding to the i strategy at the j state of "nature". As a "nature" can also be considered the actions of competitors, taking the assumption that choosing a strategy, they do not think about the behavior of other players.

Choice of optimum strategy game with "nature" can be made using the following the classical criteria: criterion extreme pessimism wald orients player (generation company) on the worst conditions for him "nature" and consequently, the cautious behavior when choosing a strategy.

Maximum criterion acting opposite in meaning Wald test is a measure of extreme optimism as orients Player (generation company) at the best conditions "nature".

Criterion taken into account when the front of the player with a dilemma either get the most benefit or become bankrupt. The payoff function of Generation A can be represented as follows:

$$L=\sum_{i=1}^{g}\sum_{j=0}^{23}(P_{mj}-P_{ij})V_{ij},\forall(P_{mj}-C_{ij})\geq 0 \qquad (1)$$

Where:

- L = Daily profit
- P_{mj} = Equilibrium price of the j hour of the day
- P_{ij}, V_{ij} = Corresponding values of price and volume pricing application in respect of the generating equipment i considered the generating company for the corresponding j hour of the day
- g = Pieces of equipment of the company

For bimatrix games on the basis matrix of players possible to construct a general matrix of size 4×4, elements of which will be a pair of numbers: the first player to win a prize and the second player. Wins both players meet their applicable strategies. The payoff function of buyer B can be written in the following:

$$L=\sum_{k}^{r}\sum_{i=1}^{g}\sum_{j=0}^{23}(P_{mj}-P_{ijk})V_{ijk},\forall(P_{mj}-C_{ijk})\geq 0 \qquad (2)$$

Where:

- P_{ijk} = Price value application in respect of the generating equipment generating i company k corresponding to the j hour of the day
- V_{ijk} = The values in relation to the volume of applications generating i equipment generating company k corresponding to the j hour of the day
- g = Pieces of equipment to the player
- r = Amount of generation companies as a part Generation B

The model is designed so that a change in one factor, other conditions are not changed. For clarity, the selected low, medium and high values of these indices, the procedure is comparable with real data of energy companies.

Simulated modeling allows to get the following results: a limitation of increasing market prices through financial withdrawal is the elasticity of demand at a price, the next price tier higher application or system restriction to the possibility of applying market forces (limit price if another proposal with a higher price does not exist).

From the perspective of the behavioral approach, the most expensive generation has the greatest motivation to use market forces to compensate for the high costs it has the greatest impact on price, revenues and profit in the absence of volume changes. The smallest effect of the use of market forces receives the generation with the average costs, the exception is the case of the average value of fixed costs, ceteris paribus where this generation gets the maximum profit of three generations. At the same time, the generation with minimal costs being the price leader is committed to use its advantages.

The value of constant costs to a greater extent the tendency to overestimate the generating company in the application of the market price of the financial strategy of impressments.

Restriction network capacity can create a competitive advantage for a number of energy companies, leading to increased effect from the application of financial exemptions due to the smaller volume decrease.

The change affects the height of a step of strategic applications: the greater the difference between the price in the strategic application and the equilibrium price in the absence of market forces the greater the change entails the use of strategy of withdrawal.

If the price strategic bid pricing is lower than in the application without the use of market forces, the supply of such application will not lead to changes in the market prices.

The change of volume accepted by the market depends on the correlation length (i.e., the quantity) of the strategic applications and the total length of the steps located to the right of the equilibrium point under conditions without the use of market forces and below the equilibrium point subject to the application of market forces.

Generation, the application of which does not pass competitive selection for margin pricing strategy may not effectively apply the strategies of market power market day ahead.

Strategy physical impressments allows you to increase the market price only moving to the next price level. Pricing between the closest price levels through physical impressments is impossible.

The decrease in revenue as a result of applying the strategy of market forces does not speak clearly about its ineffectiveness.

The use of market forces effectively while increasing the revenue of the company in case if a new market price relative to the competitive value exceeds the amount of electrical energy taken by the market without using market forces to his new volume.

Under other equal conditions, the company using financial exemption that is loaded to a lesser extent than its competitors.

The use of market power by the i generation of node k has an effect on equilibrium price at all nodes and loading of each generator individually and consequently, the profit of the competitors.

In all cases, the generation i receives a higher profit when you apply market forces to a competitor compared with the result from the application of market power by the i generation. Rationale: the withdrawal strategy involves the reduction of download i generation, i.e., part of the claimed amount is not accepted by the market.

In some cases, i generate using a strategy for financial withdrawals is loaded to full capacity. Background: the offer price above this generation the true meaning of its costs and below the prices of competitors ($MC_i^{true} < MC_i^R < MC_{\neq i}^R$).

CONCLUSION

The result of the integration of electricity markets is that generating companies appear more and more opportunities to apply market power that allows them to influence the offer price and conditions of sale of electricity on the market without a reaction from competitors.

The roadmap will allow consumer members to meet the growing electricity demand and suppliers to implement excess reserves and to ensure the capacity of generating companies and distribution lines.

With the help of simulation methods, the researchers have developed a model of the market "day ahead" which allows to investigate the strategic behaviors of generating companies.

The study presents the main factors that influence the effectiveness of market power generating companies. On the basis of model experiments the proposed parameters for the evaluation of the application of market strategies of generating companies on the wholesale electricity market the conditions under which the use of strategies of withdrawal (financial and physical) leads to an increase in profit and/or revenue of the company. The results of the study allow for the generating companies to assess the possible effect of strategies for financial and physical withdrawal subject to market and a number of the physical capabilities of the Energy roadmap.

REFERENCES

Ajupov, A. and T. Polteva, 2014. Handling depositary receipts for global financial markets. Life Sci. J., 11: 464-468.

Ajupov, A.A., A.A. Kurilova and D.U. Ivanov, 2015. Hedging as an important component of the financial mechanism of enterprise management in the automotive cycles. Mediterr. J. Soc. Sci., 6: 45-49.

Ajupov, A.A., A.A. Kurilova and I.A. Anisimova, 2015. Energy roadmap: Techno-economic content and implementation issues. Mediterr. J. Soc. Sci., 6: 30-34.

Alexeev, M. and W. Pyle, 2003. A note on measuring the unofficial economy in the former Soviet republics. Econ. Transition., 11: 153-175.

Borenstein, S., 2002. The trouble with electricity markets: Understanding California's restructuring disaster. J. Econ. Perspect., 16: 191-211.

Capros, P. and R. Weijermars, 2012. Introduction to energy strategy reviews theme issue European energy system models. Energy Strategy Rev., 1: 71-72.

Groenveld, P., 2007. Road mapping integrates business and technology. Res. Technol. Manage., 50: 49-58.

Iliadis, N.A. and E. Gnansounou, 2016. Development of the methodology for the evaluation of a hydro-pumped storage power plant: Swiss case study. Energy Strategy Rev., 9: 8-17.

Kahneman, D. and A. Tversky, 2000. Choices, Values and Frames. Cambridge University Press, New York, USA., Pages: 791.

North, M., G. Conzelmann, V. Koritarov and C. Macal, 2002. E-laboratories: Agent-based modeling of electricity markets. Proceedings of the Conference on American Power, April 15-17, 2002, Argonne National Laboratory, Chicago, Illinois, USA., pp: 1-19.

Phaal, R., L. Simonse and E.V. Ouden, 2008. Next generation road mapping for innovation planning. Intl. J. Technol. Intell. Plann., 4: 135-152.

Roth, A. and I. Erev, 1995. Learning in extensive-form games: Experimental data and simple dynamic models in the intermediate term. Games Econ. Behav., 8: 164-212.

Schneider, F., 2012. The shadow economy and work in the shadow: What do we not know?. Master Thesis, Johannes Kepler University Linz, Linz, Austria.

Stoft, S., 2002. Power System Economics: Designing Markets for Electricity. Wiley, Hoboken, New Jersey, USA., ISBN:9780471150404, Pages: 496.

Tesfatsion, L. and L.K. Judd, 2006. Handbook of Computational Economics. Vol. 2, Elsevier, North-Holland,Amsterdam,ISBN:978-0-444-51253-6,

Tesfatsion, L., 2007. The AMES market package (Java): A free open-source test bed for the agent-based modeling of electricity systems. Electric Power Research Institute, Charlotte, North Carolina.

Weijermars, R. and H.V. Dorssen, 2012. Energy strategy reviews: Perspective and ambition. Energy Strategy Rev., 1: 1-2.

Weijermars, R., 2014. Introduction to energy strategy reviews themed issue sustainable energy system changes. Energy Strategy Rev., 2: 205-208.