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VOLUME I

Session 1 - Systems Engineering and Intelligent Systems

Session 2 - Advances in Control Theory and Control Engineering

Session 3 - Optimisation and Management of Complex Systems and Networked Systems

Session 4 - Intelligent Vehicles and Mobile Systems

Session 5 - Robotics and Motion Systems

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Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.
I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.

Professor Peter Scharff
Rector, TU Ilmenau

Professor Christoph Ament
Head of Organisation

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V. Krugljak, M. Heit, D. Westermann

Approaches for modelling of power market. A comparison.

MOTIVATION

The electricity market is moving towards greater reliance on competition. Changing technology, new players in the generation market and a legislative mandate to provide access to the essential transmission facility have accelerated the process of competition that requires major changes in the institutions and operations of the electricity market. Nowadays, electricity markets are an evolving system of complex interactions between nature, physical structures, market rules and participants. They face risk and volatility as they pursue their goals, and make decisions based on limited information and their mental models of how they believe the system operates.

These crucial changes and challenges need to be analysed in order to make competent decisions. The necessity of modelling of power markets results from a number of economic, technical and educational reasons. Power market models enable the examination of new market design rules and restrictions. Furthermore they can serve as a platform for makinf reasonable investment decisions. The most challenging parts in power market modelling are the uniqueness of power markets and their products, as well as the complex interactions between market players and market institutions. Some more reasons refer to the necessity of generation pattern to be analysed, the input information for the physical network model to be provided, and model of the whole power system for power supply reliability to be established. Furthermore such a model could provide a powerful tool for training of future market operators and other market players.

For above mentioned reasons short-term models are needed to be investigated. Models for a long-term analysis are not considered here and can be found in [1], [2], [3], [5]. This paper concentrates the attention on modelling of imperefect competition and strategic bidding in short time horizons (spot-market), with special attention to investigation of market players' interactions within the framework of unified-pricing mechanism. The study is aimed at definition of main advantages and limitations of elelctricity market models.

From a structural viewpoint, the approaches to electricity market modelling reported in the technical literature can be classified as showed in Figure 1:

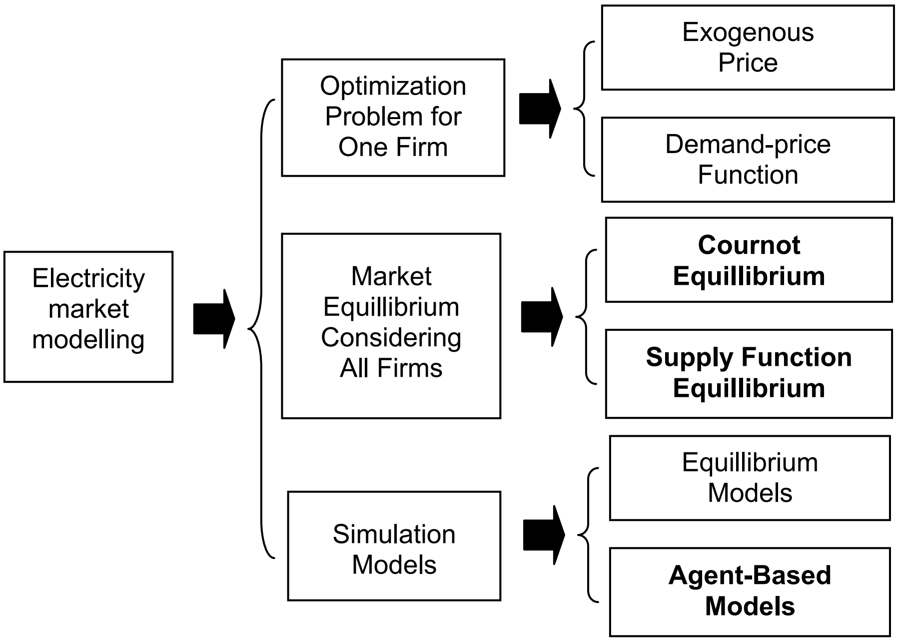

Figure 1: Main electricity market modelling trends [1]

COMPARISON OF POWER MARKET MODELS

Since the purpose of this paper is to analyse the competitive circumstances concerning an "all firms approach", market equilibrium models are most suitable to be considered here. As an alternative approach the agent-based models are also included into analysis.

Cournot Equilibrium

In the Cournot model, each firm chooses an output quantity to maximize profit. Firms are assumed to produce homogeneous goods that are nonstorable. So all quantities produced are immediately sold. Market price in the model is determined through an auction process that equates industry supply with aggregate demand. The model also assumes that all firms in the industry can be identified at the start of the "game", and that decision-making by firms occurs simultaneously.

According to this model each generation company uses its output decision as its decision variable, trying to define its volume targeting at maximizing its profit. However the individual profit maximization problem of each firm depends not merely on its own decision, but is strong dependent on the decisions of other market players.

Assuming the linearity of demand function and a qudratic form of the cost curve of each producer, each Generation Company (GENCO) now tries to determine its best response function, given the outputs decisions of other players. Solving the set of best response functions of all the market players present an equilibrium point, i.e. that point where no individual can unilaterally increase its output (1) [4].

$$q_i = \frac{P_{\max} - b_i - K\sum_{\substack{j=1 \\ J\neq i}}^{n} \frac{b_i - b_j}{K + 2c_j}}{2(K + c_i) + K\sum_{\substack{j=1 \\ J\neq i}}^{n} \frac{K + 2c_i}{K + 2c_j}}, \quad \text{where} \qquad (1)$$

q_i - profit maximizing output decision of i-th GENCO (MWh);

b_i, c_i bzw. b_j, c_j - coefficients of cost curves of i-th bzw j-th GENCOs ($i \neq j$) (€/MWh);

$P_{\max}$ - maximum price (€/MWh);

$K = \frac{P\max}{Q\max}$ - the slope of the demand curve.

SFE (Supply Function Equilibrium)

In the SFE model, participants endowed with a cost curve find the equilibrium bid curve. I.e., a price-quantity offer that maximizes profit. An equilibrium is calculated on the basis of an interactive noncooperative game among the suppliers, where the supply function of each individual supplier is a function of production costs, capacity, the price elasticity of demand, and the extent to which the other suppliers will adjust their output to changes in market prices. This model is conceptually superior to the Cournot model in the electricity markets. This superiority consists in the “strategy space”—i.e., the range of choices over which suppliers can offer electricity products—which in the SFE modelling approach includes both price and quantity. In order to determine the optimal supply function (bid function) each GENCO, tries to find the profit maximizing point at each specified price level.

Among other papers [6] gives a good overview on a modelling approach. The persuasive convinience of its algorithm and its applicability to asymmetric environments allow to analyse the main features of this type of equilibrium simulation. Taking into consideration the lemmas for achieving the existence and uniqueness of SFE, capacity and price constraints the modelling algorithm can be sketched as follows.

Starting with capacity constraints of GENCOs, their supply functions are calculated using the alteration of the SF’s slope:

$$q_i'(p) = \frac{1}{n-1}\sum_{j\in N_p} \frac{q_j(p)}{p - c_j(q_j(p))} - \frac{q_i(p)}{p - c_i(q_i(p))}, \quad \text{where} \qquad (2)$$

$q_i'(p)$ - slope of supply function of the i-th producer;

p - market clearing price;

$c_j(q_j(p))$ - marginal costs;

N_p - subset of contrary bidders.

This algorithm is constructed downwards using the equilibrium system of differential equations targeted to individual profit maximization and is continued until the point $c_i(0)$ (marginal costs for zero output) is achieved.

Some numerical calcultaions were made to represent this approach of power market modelling. Following parameter values for two power producers were considered:

$c_b = 0 \quad c_p = 20 \quad p^m = 100 \quad k_{1b} = 15 \quad k_{1p} = 15 \quad k_{2b} = 30 \quad k_{2p} = 30$

where k_{it} is installed capacity of firm i in technology t; c_t is the marginal cost of technology t; p^m is the price cap. Additionally is assumed that quantities demanded are uniformly distributed on [0,100]. Figure 2 shows the equilibrium supply functions (q_1^*, q_2^*).

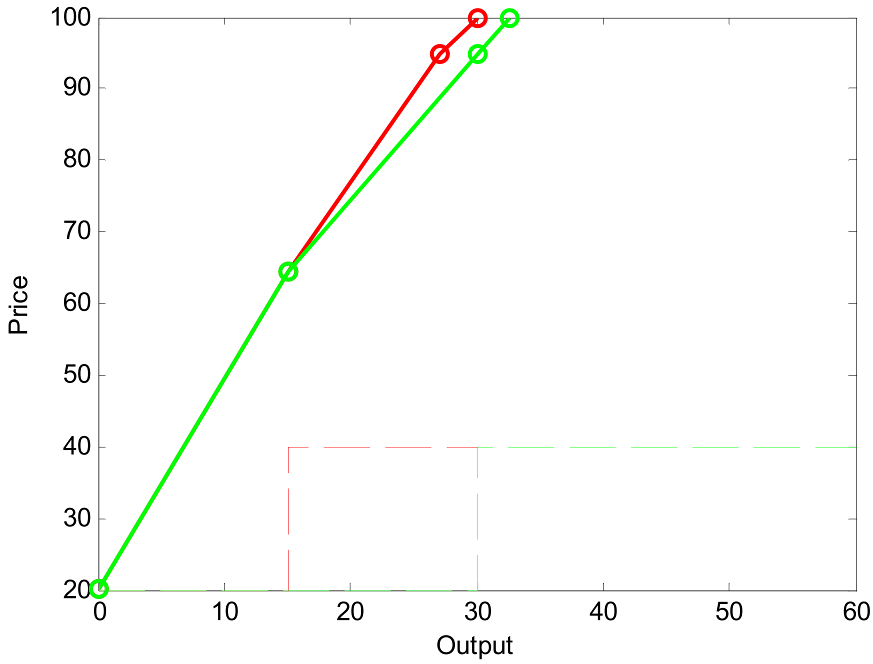

Figure 2 Equilibrium Supply Functions (q_1^* – red solid, q_2^* – green solid)

Both supply functions are identical up to $p = 64{,}5$. At that price the baseload capacity for firm 1 is binding; the slope of firm 1's supply function is larger than the slope of firm 2's supply function. At a price close to 94,7 firm 2 starts using peaker capacity. Starting at that price the gap in quantities offered decreases.

Agent-based models

Simulation provides a more flexible framework to explore the influence that the repetitive interaction of participants exerts on the evolution of wholesale electricity markets. Static models (e.g. equilibrium models) seem to neglect the fact that agents base their decisions on the historic information accumulated due to the daily operation of market mechanisms. In other words, agents learn from past experience, improve their decision-making and adapt to changes in the environment (e.g. competitors' moves, demand variations or uncertain wind power infeed). This suggests that adaptive agent-based simulation techniques can shed light on properties of electricity markets that static models ignore.

One of the possible variants of power market model is presented in Figure 3 [7].

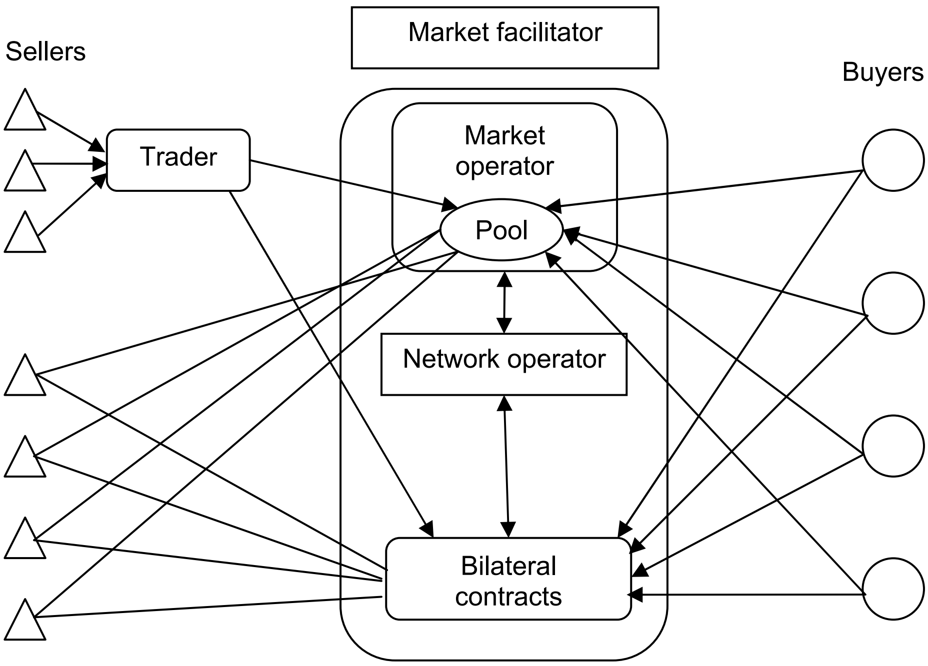

Figure 3 Multiple agents in power market modelling [7]

Superior to the equilibrium approaches, presented above, agent-based modelling avoid the restrictions to profit maximization in market players' behaviour. Other important behavioral characteristics (e.g. risk joy/aversion, individual knowledge related to price cap, preferred prices, and available capacity, their willingness to cooperation) stand now in foreground and can be defined within this framework of modelling. One more advantage of a agent-based simulations lies in the flexibility it provides to implement the mechanisms of autonomous learning, allowing agents to alter their decisions in accordance with their individual characteristics and results of other agents' actions. However, this freedom also requires that the assumptions embedded in the simulation be more carefully (and empirically) justified. That is why it refers to the future research tasks for authors of this paper to identify and implement the appropriate behavioral models could be used to model the power market properly.

CONCLUSION

Within the framework of this paper the existing approaches of modelling the power markets were analysed. Approaches for simulation electricity markets have been analysed; in particularly two main streams of research in this domain: equilibrium and simulation models. Equilibrium modelling approaches have some weaknesses compared to agent-based modelling. They do not include tools to represent other firm's intentions beside profit maximization and do not allow to test different players' characteristics. Nevertheless they could be embedded into agent-based simulation in form of certain behavioral modules. In this sense supply function equilibrium should be used as more feasible and realistic approach. Table 1 contains main criteria of comparison.

Table 1 Main criteria of comparison of power market modelling approaches

<table>
<tr><th colspan="2" rowspan="2">Modelling possibilities</th><th colspan="3">Modelling approaches</th></tr>
<tr><th>Cournot</th><th>SFE</th><th>Agent-based</th></tr>
<tr><td rowspan="2">Decisions are made on</td><td>price</td><td></td><td>+</td><td>+</td></tr>
<tr><td>quantity</td><td>+</td><td>+</td><td>+</td></tr>
<tr><td rowspan="5">Possibilty to represent</td><td>reactions to other players' actions</td><td>+</td><td>+</td><td>+</td></tr>
<tr><td>learning capabilities</td><td></td><td>+</td><td>+</td></tr>
<tr><td>attitude to risk</td><td></td><td></td><td>+</td></tr>
<tr><td>other goals beside profit maximization</td><td></td><td></td><td>+</td></tr>
<tr><td>different market designs</td><td></td><td></td><td>+</td></tr>
</table>

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