AN AGENT-BASED SIMULATION MODEL FOR WHOLESALE ELECTRICITY MARKETS

Andreas BUBLITZ*[1], Philipp RINGLER*[1], Massimo GENOESE[1], Wolf FICHTNER[1]

Motivation

Today's liberalized wholesale electricity markets are generally considered to be highly complex systems. This is due to, among other things, the specific characteristics of the commodity electricity (e.g. instantaneous balancing of supply and demand, limited storability) and the fact that electricity can only be transported by a transmission grid with limited capacities. Other factors that increase the complexity are the various interrelated markets where electricity or related products can be traded (e.g. day-ahead market, future market) and the influence of other volatile markets such as the market for carbon emission allowances.

Given the electricity system's complexity the relevant actors rely on different types of models for decision support. For instance, models are used by regulatory entities to analyse questions related to market design which is necessary to guarantee system reliability on different levels. Similarly, generation companies rely on electricity market models, for example, in order to examine investment cases.

An important development in the electricity market is that the current borders of the national markets are subject to change; there are ongoing efforts to achieve a single European market. One aspect thereof is the implementation of market-based mechanisms to allocate limited cross-border capacities between European countries. The Central Western Europe (CWE) Market Coupling between Germany, France, Belgium, the Netherlands and Luxemburg serves as one of the most prominent examples. Market coupling maximizes social welfare, leads to price convergence and helps to balance different supply and demand situation in the interconnected market areas (EPEX Spot, 2010). The integration of markets is a matter-of-fact, thus influencing market prices and profitability of power plants in Europe.

Naturally, market changes need to be reflected appropriately in modelling techniques. The aims of this paper are to present a comprehensive overview of the PowerACE modelling framework for electricity markets and how it can be applied to different research questions. Finally, exemplary results for two coupled day-ahead electricity markets are presented.

Methodology

The models used for electricity markets can be classified into several categories. Ventosa et al. (2005) identify three major categories in electricity market modelling: optimization models, equilibrium models and simulation models. Distinguishing features include the mathematical structure, market representation, computational tractability and main applications.

While in Europe the liberalization of electricity markets started in 1996, electricity market models developed beforehand had been mostly optimizing models incorporating the perspective of a single planner, i.e. the government. Through the liberalization, the integration of a market perspective in models has gained importance, which brought forth the development of alternative models such as agent-based models. In general, agent-based models can provide a flexible environment which allows considering inter alia learning effects, imperfect competition including strategic behaviour and asymmetric information among market participants (Tesfatsion, 2006). Nowadays, there exists a large number of different agent-based electricity market models (Guerci, 2010).

---

[1] Chair of Energy Economics, Institute for Industrial Production (IIP), Karlsruhe Institute of Technology (KIT), Hertzstraße 16, 76137 Karlsruhe, Germany, {andreas.bublitz, philipp.ringler, massimo.genoese, wolf.fichtner}@kit.edu

Originally, PowerACE was designed for the German market area. However, Europe's electricity markets are all liberalized and set up according to the same fundamental principles. That is why PowerACE can be used to simulate other European market areas as well. One of the key features of the model is the integration of both short-term market developments and long-term capacity expansion planning. Thereby, interactions and feedback loops between short-term and long-term output decisions are considered. Decisions regarding the expansion of capacity, i.e. whether to install a new power plant are influenced by current and future developments in the daily electricity trading as the main source of income and vice versa.

The key modules of the model are markets, electricity supply, electricity demand and regulatory aspects. The main players participating in the wholesale electricity market are modelled individually; small companies are represented in an aggregated form. Different types of market participants are modelled as different types of agents. Each agent takes over certain roles, makes decisions based on specified functions and either takes part in or sets rules for a respective market. In accordance with the CWE Market Coupling architecture, market coupling is implemented within PowerACE for the day-ahead market and market participants submit their bid curves to the local power exchanges.

Exemplary results

Exemplary, PowerACE is used in this paper to simulate the coupling of two interconnected day-ahead electricity markets, namely Germany and France. Compared to the simulation without market coupling, average electricity prices are lower in both markets when they are cleared together increasing social welfare. The more pronounced effect for France can be explained, to some extent, by the shape of the merit order curves in the two market areas.

Bibliography

EPEX Spot (ed.) (2010): Project Document – A report for the regulators of the Central West European (CWE) region on the final design of the market coupling solution in the region, by the CWE MC Project. Retrieved from http://static.epexspot.com/document/7 616/01_CWE_ATC_MC_project_documentation.pdf.

Guerci, E.; Rastegar, M. A.; Cincotti, S. (2010): Agent-based Modeling and Simulation of Competitive Wholesale Electricity Markets. In: Handbook of Power Systems II. Berlin, Springer, S. 241–286.

Tesfatsion, L. (2006): Agent-Based Computational Economics: A Constructive Approach to Economic Theory. In: Judd, K. J.; Tesfatsion, L. (eds.).

Ventosa, M.; Baíllo, Á.; Ramos, A.; Rivier, M. (2005): Electricity market modeling trends. In: Energy Policy 33 (7), pp. 897–913.