A MODEL BASED MARKET POWER ANALYSIS OF THE GERMAN MARKET FOR FREQUENCY CONTAINMENT RESERVE

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Overview

When transforming the electricity system it is important to ensure a high level of security of supply. To maintain the frequency of the electricity system at a certain level, supply and demand need to be equal at all times. To balance short-term deviations the activation of balancing reserves is needed, which is controlled by transmission system operators (TSOs). Currently mostly conventional power plants (CPPs) provide balancing power. Due to the raising share of renewable energy resources, the market share of CPPs is constantly shrinking. Hence it is unclear, how and by whom the future balancing power demand is met. Less supply could raise the already high market concentration especially for Frequency Containment Reserve (FCR), which would raise the potential for strategic behavior of suppliers (Dena, 2014). As the markets for balancing power could suffer from the abuse of market power, an efficient market design for the allocation of FCR is crucial. The evaluation of gaming incentives in respect to different auction designs needs to be undertaken, since various mechanisms are suggested (Heim und Götz, 2013). Because the bids for balancing power are strongly dependent on the expectations of future spot-market prices, long contract durations lead to inefficient allocation. Concurrently shorter contract durations tend to lead to higher market concentrations (Knaut et al., 2017). Yet it is unclear, if the higher market concentration leads to higher market prices. Therefore we conduct a quantitative evaluation of different market designs with respect to the strategic behavior of suppliers for FCR.

Methods

To analyze the individual bidding behavior and to determine their change under different market designs bi-level optimization and equilibrium models can be used. These models account for the fact, that suppliers anticipate the market equilibrium on a first (upper) level, while the market clearing takes place on a second (lower) level (Barroso et al., 2006). Nevertheless, the application of such bi-level models in real electricity markets is yet rarely conducted due to their methodological problems (Koschker and Möst, 2015). The meaningfulness of the results of such models depend mainly on the used solution approach. Bi-level models can have no or multiple solutions and the solution approach of real world analysis is mostly heuristic (Ralph und Smeers, 2006*).* According to this problem, we propose a complementarity bi-level market model for FCR procurement in Germany to be solved by each generator, whose objective is to maximize his own profit. This model is constrained by the CPP's capacity as well as the market-clearing problem of the TSO. In order to examine the effects of strategic behavior of individual providers on the market result, the model results of a linearized mathematical program with equilibrium constraints (MPEC) are analyzed. Strategic suppliers optimize their profits with the help of non-competitive price offers, while competitors act as price takers and offer capacity at marginal costs, whereby marginal cost for FCR are expressed as the opportunity costs for selling the generation capacity at the spot market. As the coordination of strategic behavior could lead to a simultaneous increase of profits for all providers, an equilibrium problem with equilibrium constraints (EPEC) is used to identify such market equilibria. We solve the model via various approaches to identify the best solution method for real world applications. Therefore we linearize the MPEC and the EPEC by mixed-integer linear programming (MILP) techniques. Furthermore, we solve the EPEC via diagonalization in order to compare the different solution approaches. Eventually, a quantitative analysis of current and future market outcome is conducted under various auction designs.

Results

Current market outcomes are beyond competitive levels. However, the historic market outcomes of 2015 converge with the competitive benchmark model. In particular the expansion of the grid control cooperation seems to be decisive. Sole strategic behavior results only in specific market situations in higher prices. Nevertheless, joint strategic behavior can increase prices for FCR at around 6.5 %. A shortening of the product duration can be essential for reducing the system costs, as a more efficient use of power plants, which is linked to specific hourly opportunity cost, is realized. At the same time, suppliers are able to act more strategically, due to a steeper merit order, which increases the Lerner index significantly with daily and hourly product durations. As a result, daily product durations yield to Lerner indices up to 70 %. Hourly contracts ultimately lead, in spite of increased market power potential, to lower system costs, which is why this market design should be preferred to the current auctioning. Future market development of FCR is mainly driven by investments in battery storage capacities. Additional battery storage capacity not only has a positive effect on the price development, but rather reduces the effects of strategic behavior, assuming decentralized ownership structures. At the same time, it can be seen that new technology-specific concentration rates hold considerable market power potential. Accordingly, a regulatory incentive for battery storage investments should be chosen wisely to ensure a sustainable positive price development. In addition to the efficiency-critical evaluation of the market for FCR, methodological knowledge could be gained. The application of linearized equilibrium models seems to be problematic even on moderate problem size. In particular, the advantages in terms of computational effort cannot be utilized, due to the necessary parameterization. Possible configurations and extensions of the linearization methodology result in no reduction of effort regarding the application to real problems. Furthermore, there can be no transferability of the findings of Siddiqui and Gabriel (2013) on reduction of the computational effort by applying SOS1 variables to EPECs.

Conclusions

Currently, the German market for FCR has a weekly tender frequency. Yet another auction design is needed to prevent the excessive abuse of market power. Hence the shortening of product durations for FCR is discussed. Since it is known from the literature that shorter tender frequencies come along with higher market concentration it needs to be investigated, if an altering market design really leads to efficiency gains. The analysis at hand focuses on (1) the evaluation of the efficiency of present market outcomes for FCR in Germany, (2) market results with different product duration under consideration of strategic behavior, and (3) a projection of future market outcomes with respect to various scenarios. The authors conclude, that current market outcomes are beyond competitive levels, but sole strategic behavior only has moderate market power potential. The costs for FCR procurement can be reduced by shorter contract durations, while an increase of strategic behavior must be tolerated. Thereby, daily contract durations could lead to higher system costs due to the abuse of market power. Hence strategic behavior should be considered when altering the market design. Prospectively, the investments in stationary battery systems for balancing power provision play an important role, as they cannot only decrease costs, but also have the potential of mitigating market power. Further research should focus on the economic interpretation of the dual variable of the strong duality theorem of MPECs, which specifies the parameterization space and thus leads to a reduction of the computational effort. In addition, the integration of uncertainties with regard to opportunity costs is an important approach to extend in determining the two-stage profit maximization problem of FCR providers. This could be used to assess the effects of uncertainties and alternative tendering periods even more precisely. However, the solution of such a model should be implemented as a linearized MPEC since a significant increase in the required computational effort is expected. Furthermore the MPEC representation could incorporate uncertainties with regard to the competitive behavior, so that a model for biding optimization can be derived. Incentive for battery storage investments, should be analyzed and quantified, in order to ensure a sustainable positive price development of the German FCR. In doing so, the analysis should also include in particular the effects of a European enlargement of the grid control cooperation.

References

Barroso, L.A., Carneiro, R.D., Granville, S., Pereira, M.V. und Fampa, M. (2006): Nash Equilibrium in Strategic Bidding. A Binary Expansion Approach. In: IEEE Trans. Power Syst., 21 (2), S. 629–638.

Dena (Hrsg.) (2014): Systemdienstleistungen 2030.

Heim, S. und Götz, G. (2013): Do Pay-as-Bid Auctions Favor Collusion? Evidence from Germany's Market for Reserve Power. Centre for European Economic Research, Discussion Paper (13-035).

Knaut, A., Obermüller, F., Weiser, F. (2017): Tender Frequency and Market Concentration in Balancing Power Markets, EWI Working Paper, Nr. 17/04, University of Cologne.

Koschker, S. und Möst, D. (2015): Perfect competition vs. strategic behaviour models to derive electricity prices and the influence of renewables on market power. In: OR Spectrum, 38 (3), S. 661–686.

Ralph, D. und Smeers, Y. (2006): EPECs as models for electricity markets. IEEE PES Power Systems Conference and Exposition. S. 74–80.

Siddiqui, S. und Gabriel, S.A. (2013): An SOS1-Based Approach for Solving MPECs with a Natural Gas Market Application. In: Networks and Spatial Economics, 13 (2), S. 205–227.