THE EFFECT OF VOLUNTARY BIDS ON BALANCING MARKET EFFICIENCY: SIMULATION-BASED ANALYSIS

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Overview

In order to maintain system frequency, most European transmission system operators (TSOs) procure balancing services in a market-based way, through a two-stage process by first reserving the necessary balancing capacity and then activating balancing energy when actual system deviations occur. As system imbalances are likely to become more pronounced as a result of the integration of variable renewables, the efficient procurement of balancing services is gaining importance. Yet, the efficiency of balancing markets is hampered by high market concentration and complex market design.

The EU regulation establishing a guideline on electricity balancing (GL EB) introduced a number of measures to increase the integration and efficiency of balancing markets, including the authorization of so-called voluntary bids to compete for the provision of balancing energy [1]. Commonly, only those actors that committed their capacity for balancing can then submit energy bids for activation in the balancing energy market. Pursuant to the GL EB, bidders with short-term flexibility that did not reserve their capacity in advance may still submit their bids on a voluntary basis to the balancing energy market. This study focuses so-called voluntary bids authorized by the GL EB and answers the questions of whether and to which extent they can help increase market efficiency.

In order to analyze the behavior of market players, we simulate the balancing energy market with an agent-based model (ABM). We compare the bidding strategies of two types of actors, i) price-takers who bid their marginal costs and ii) agents with reinforcement learning that emulate strategic bidding behaviour. For the latter, a fitted Q-iteration algorithm was applied to identify their optimal bids. We investigate the potential efficiency gains from the introduction of a BE market as compared to a joint market for balancing capacity and energy. We analyse how the bidding behaviour, profits of BSPs, and market outcome change in the face of this regulatory transformation.

This paper presents the first study, to the authors' knowledge, that uses an agent-based model with learning agents to analyse the effect of voluntary bids in a balancing market.

Methods

ABM has proven to be a useful tool for addressing market design questions that otherwise cannot be solved by other approaches such as optimization or game theory(e.g. [2]). It is not bound by the assumptions of perfect competition and foresight, can flexibly integrate multiple heterogeneous and makes it possible to replicate the repeated nature of balancing auctions in which agents learn from their experience.

For our study, as a first step, the main mechanisms of the balancing energy market are implemented in a simulation framework with a limited number of participants bidding their portfolios in the market. The key characteristics of the BE market are modeled in a way to approximate the actual balancing market design implemented in multiple European countries. As a second step, we compare the bidding strategies of learning and simplified "naïve" agents under the same market design as well as their effect on the market outcome. The actors decide on the bid prices individually based on their marginal costs or prior experience (see types of agents below). Finally, we introduce a single voluntary bidder in a concentrated balancing energy market with strategic bidders and trace its effect on the bidding strategies of the other participants and overall market efficiency based on market prices and system costs.

To simulate the bidding behaviour of BSPs, we consider two types of agents:

1) Price-taker agents that bid their true marginal costs as it would be expected under the assumption of perfect competition;

2) Intelligent agents that, using a reinforcement learning (RL) algorithm called fitted Q-iteration [3], learn the optimal behavior when submitting market bids to maximize their profit. In detail, as any RL algorithm, the method considers that the agent and the BE market can be modeled via a Markov decision process, i.e. the agent modeled by a state x is controlled with a discrete set of actions $A = \{a1, ..., aN\}$, and transitions from one state to the other based on a probabilistic distribution. During the training, the RL agent learns an

optimal policy that outputs, for each state x, the optimal action a^* so that it maximizes the expected value of the cumulative sum rewards. After each round, the agents update their information about respective profits.

Results

Upward and downward regulation are procured in separate auctions. Since the cost structures of the bidders in the two markets are different due to the nature of these balancing products, their bidding strategies will also be different. We also investigate the effects of different pricing rules. The price for balancing services is either a uniform marginal price or pay-as-bid.

Results show that in scenarios with strategic bidders, weighted average prices exceed the competitive outcome by factor of 4 to 7, depending on the pricing rule. If voluntary bids are introduced, the effect on market efficiency is significant: even in an oligopolistic setting, the balancing prices approximate the result of a perfectly competitive scenario (Figure 1). Importantly, we did not assume that a voluntary bidder would necessarily bid low. The efficiency gains stem from the fact that learning agents are forced to lower their bids due to the competition from the voluntary bidder. Pay-as-bid pricing leads to the highest awarded bids reach 250€/MWh at times of high imbalances, yet the overall price reduction as compared to the oligopolistic scenarios, as illustrated in Figure 1 It further shows that marginal pricing leads to the highest efficiency gains: prices do not exceed 80€/MWh even when imbalances are high. Simulations for the balancing market for downward regulation produce similar positive results.

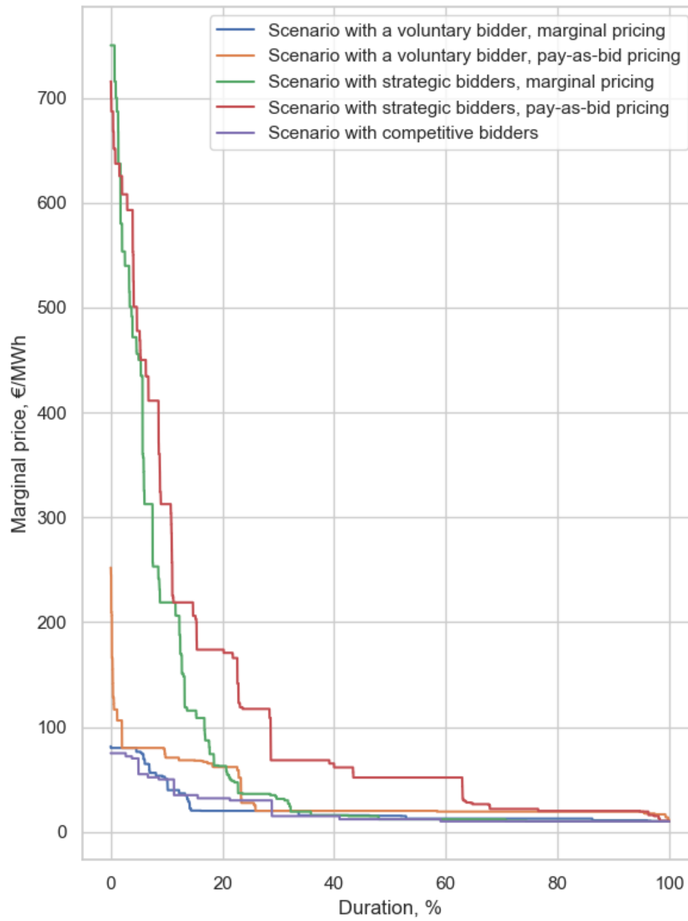

Figure 1. Price duration curves in the simulated scenarios show that even in an oligopolistic setting with strategic bidders, the presence of a voluntary bidder induces a much more competitive behavior, in particular if marginal pricing rule is applied.

Conclusions

The design of an efficient balancing markets has gained importance both due to the ongoing market harmonization efforts and due to the increasing shares of volatile renewables in European power systems. The results from this study are intended to inform policymakers about the impact of balancing market design on bidding strategies in the balancing market and, consequently, their economic efficiency. We show that the authorization of voluntary bids in the balancing energy market reduces the cost of balancing and improves the economic efficiency significantly.

This analysis estimates the effects of planned changes in the market design. It further demonstrates the importance of making the most of short-term flexibility and allowing all types of participants and technologies contribute to system balancing. Finally, our research shows the value of using agent-based modelling with reinforcement learning for testing the effects of strategic behaviour in complex markets.

References

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