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BIDDING IN INTERRELATED DAY-AHEAD ELECTRICITY MARKETS: INSIGHTS FROM AN AGENT-BASED SIMULATION MODEL

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Overview

In this paper we present results from an agent-based simulation model of two sequentially cleared electricity markets. Agents can bid on both a day-ahead market for physical delivery contracts and a day-ahead balancing power market and learn from their achieved results. Different scenarios of the order of market clearing and pricing rules are tested and their results are compared. We show that prices are lower in both markets when the day-ahead market is cleared first. We also show that pay-as-bid leads to lower resulting prices than a uniform price mechanism.

Methods

In a restructured electricity market where electricity transmission and generation are separated from each other, a transmission system operator (TSO) needs to procure balancing power from the market. In this environment, a generator that disposes of fast controllable generation units faces the problem of deciding whether to bid in a day-ahead market or to commit his units for balancing purposes. This increasing complexity of electricity trading and bidding decisions raises the necessity for methods and tools that allow modelling a variety of aspects.

The aspects that have to be addressed in a realistic electricity market model comprise strategic supplier behaviour, i.e. bidding above marginal cost strategies (e.g. Cramton [2004]), and the factor of daily repetition in trading (e.g. Rothkopf [1999]). A third important aspect in electricity market modelling is market interrelationships, as electricity is traded on different time scales, e.g. day-ahead, real-time, and also in form of different products, e.g. physical delivery, reserved (balance) capacity.

We apply agent-based simulation as a tool that has the potential to meet the aforementioned requirements and is a very promising approach for realistic electricity market modelling. It allows representing bidders as profit-maximising adaptive agents that can learn from their trading results in daily repeated auctions. And it can include several different markets that are linked together through the agents' trading decisions.

In our model generators are represented as adaptive agents that apply reinforcement learning. Within the tested scenarios, we differentiate between bidding strategies in a day-ahead market with physical settlement, and strategies in a day-ahead balancing power market. We shift the order of market execution and vary the pricing mechanism from pay-as-bid to uniform price.

Results

Resulting prices on the day-ahead market are depicted in Table 1. Prices attain a higher level if the day-ahead market is cleared after the balancing power market. The intuition behind this result is that competition is lower on the supply side in these cases, as some generators have already committed a part of their capacity on the balancing power market. When fewer agents compete on the day-ahead market, they can more successfully bid above marginal cost and thus achieve higher prices.

Scenario	Average $p^{dayAhead}$	Minimum $p^{dayAhead}$	Maximum $p^{dayAhead}$	SD $p^{dayAhead}$
DayAheadBalance_uniform	40.65	30.00	60.00	6.45
DayAheadBalance_payAsBid	37.01	20.00	65.00	7.32
BalanceDayAhead_uniform	66.14	35.00	100.00	15.56
BalanceDayAhead_payAsBid	64.03	35.00	100.00	16.28

Table 1: Simulated market clearing prices on the day-ahead market (SD = standard deviation)

Scenario	Average $p^{balance,cap}$ / $p^{balance,work}$		Minimum $p^{balance,cap}$ / $p^{balance,work}$		Maximum $p^{balance,cap}$ / $p^{balance,work}$		SD $p^{balance,cap}$ / $p^{balance,work}$	
DayAheadBalance_uniform	358.82	19.10	158.00	0.00	500.00	75.00	65.70	21.52
DayAheadBalance_payAsBid	273.80	17.54	60.23	0.00	431.25	75.00	76.42	20.26
BalanceDayAhead_uniform	393.79	17.51	225.00	0.00	475.00	99.75	45.83	20.53
BalanceDayAhead_payAsBid	354.29	17.21	206.25	0.00	457.88	75.00	55.04	21.24

Table 2: Simulated capacity/work prices on the balancing power market

Table 2 represents the resulting capacity and work prices on the balancing power market. Here, we observe that prices tend to be lower when the market is cleared second. This can be explained by the fact that agents mainly base their bid decision on their opportunity costs on the balancing power market. High prices on the day-ahead market mean high foregone profits for an agent that commits his capacity for minute reserve purposes. Thus, higher prices on the day-ahead market also causes prices to be higher on the balancing power market.

The question whether pay-as-bid or uniform price leads to lower market prices is controversially discussed in the literature (e.g. [Kahn et al. 2001], [Rassenti, Smith, Wilson 2003], [Bower, Bunn 2001]). Our simulation results suggest that pay-as-bid results in higher bid prices, but the bid price increase is not high enough to result in higher overall prices.

Conclusions

We find that prices on the day-ahead market are higher if this market is cleared after the balancing power market. We argue that this is due to the fact that competition is weaker in this case, as some agents have already committed (part of) their capacity on the balancing power market. The reduced supplier concentration enables agents to successfully bid higher mark-ups to their marginal costs. Results on the balancing power market give a different picture: prices are lower if this market is cleared second. Here, the effect of agents integrating their opportunity costs into their result evaluation leads to higher prices when day-ahead prices are high, and lower prices when day-ahead prices are low. As for the pricing rule on the balancing power market, we find the following result: average prices are higher under uniform price than under pay-as-bid although agents bid at higher prices under pay-as-bid. The increase in bid prices is outweighed by the effect of all infra-marginal bidders receiving the marginal, i.e. highest accepted bid under uniform pricing.

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