A mathematical model of electricity markets including mitigating measures to inc-dec gaming

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Abstract:

The increased participation of renewable energy sources, while key to the green shift towards a future with lower carbon emissions, is adding more uncertainty to the electricity markets, due to source intermittency. The distributed aspect of new energy sources builds up the complexity and may stress the current balancing system. A market-based redispatch is a design intended to efficiently reward providers of flexibility in electricity markets. However, this design may present shortcomings, such as opening up for strategies where market power can be abused to obtain disproportionately high profits. One such strategy happens when power suppliers increase their output in the day-ahead market and decrease it in the real-time market, and this is known as inc-dec gaming. In this paper, we analyse to what degree producers can benefit from engaging in inc-dec gaming, and calculate the impact of measures that aim to prevent or mitigate the harmful effects of inc-dec gaming, and whether implementing these measures entails adverse side effects. An equilibrium problem with equilibrium constraints (EPEC) framework was developed to analyse these issues in a reduced market model with a day-ahead market and a real-time redispatch market. Results indicate that suppliers can abuse market power in order to obtain significant profits through inc-dec gaming. We find that there are effective measures to prevent and mitigate the adverse effects attributable to inc-dec gaming. However, the implementation of these measures brings a trade-off between the suppliers' profits, the system operator's costs, and the consumers' costs, and will not always increase general welfare.

Keywords:

Two-stage game, inc-dec gaming, real-time electricity market, day-ahead electricity market, zonal pricing, market-based redispatch

Stage of the work:

This paper is based on a Master’s thesis that is currently ongoing, by authors Audun Systad and Jens Eilertsen and supervised by authors Felipe Araujo and Ruud Egging-Bratseth. The project of the thesis was delivered last semester and has a complete structure, with introduction, literature review, methodology, results and conclusion. In the project the authors employed bi-matrix games implemented in python code. This paper will extend the work done in the project, by applying it in an EPEC formulation. The presentation in ROC conference will include results already obtained in the project, and new results from the thesis and the paper itself.

Project Introduction:

Designing electricity markets to make optimal use of the transmission lines and handle congestion better could potentially remedy some of the congestion problems that often exist in transmission networks and save considerable sums in the process. In contrast, a flawed market design may result in significant inefficiencies in the power market (e.g., as seen in Harvey and Hogan (2001)). As such, determining market designs that are both efficient and reliable is an important task.

Many ways of organizing energy markets to handle congestion better have been proposed, one of which is market-based redispatch. The EU prefers this congestion management method over other alternatives. (EU Regulation 2019/943 2019). In this design, transmission constraints (within zones) are disregarded in the regular day-ahead market before the market is cleared a second time by a voluntary auction to reconcile any transmission constraint violations. This auction is held close to the actual dispatch, and in this second clearing, the constraints are rectified. Supporters of market-based redispatch point to several strengths of this way to organize redispatch over cost-based redispatch. The two most important arguments are that the flexibility providers are remunerated fairly for their contribution and that more sources of flexibility can be accessed, unlocking new potential in the market.

Flexibility here refers to the ability to adjust consumption or generation by market participants on short notice. However, critics believe that market-based redispatch is vulnerable to strategic bidding, largely in the form of increase-decrease gaming. Increase-decrease gaming (inc-dec gaming) is a bidding strategy in which participants submit strategic bids in the day-ahead market, which exacerbate congestion in order to either price themselves in or out of the day-ahead market. Participants gaming the system would then potentially abuse market power, taking extraordinary profits from self-created arbitrage opportunities, thereby making the market less efficient and less profitable for other players. Therefore, it is important to assess the viability of inc-dec gaming, the extent of its negative effects and if modifications to the market design can prevent it.

This research aims primarily to study inc-dec gaming and explore options to prevent or reduce the effectiveness of inc-dec gaming within a market with market-based redispatch. This aim is summarised in the following research questions:

- RQ1: To what degree can suppliers exploit market power by participating in inc-dec gaming?
- RQ2: What are effective measures to prevent or mitigate the adverse effects of inc-dec gaming?
- RQ3: Does the implementation of these measures entail adverse side effects?

While, according to some authors, market power is not necessary for inc-dec gaming (Sarfati and Holmberg 2020), it facilitates the strategy as the market is dependent on your supply, and the risk of failing in the gaming strategies becomes much smaller. For this reason, the focus of this project is on inc-dec gaming as a result of market power exploitation and its relevant mitigating measures.

To address the research questions, we examine potential measures to prevent inc-dec gaming (or reduce its impact) and assess their effectiveness. These measures include long-term contracts, the Norwegian solution (a strategy to override strategic bids), randomised bid selection and an adapted randomised bid selection (to mitigate higher prices in the day-ahead market). These measures were proposed qualitatively in DNV-GI (2020). Our contribution is an adaptation of these into numerical models, where the mitigating measures are tested in a game-theoretic framework to gain insight into how market participants would act in such an environment. In this way, we analyse how effective the measures are at mitigating inc-dec gaming and its corresponding adverse effects.

The results show some promise, as the mitigating efforts could drastically reduce the occurrence of inc-dec gaming in the models. At the same time, while they hampered gaming and, to some degree, reduced the suppliers' profits to a reasonable level, the solutions occasionally resulted in other non-desirable outcomes. An example is that the mitigating measures in some situations led to the base price for consumers in the day-ahead market to rise. We conclude that, in our setup, there is a trade-off between mitigating inc-dec gaming and lowering prices for the consumers, which must be carefully considered. Our results indicate that the different mitigating measures that were analysed lead to differing balances of this trade-off. Long-term contracts were found to be the most effective at preventing inc-dec gaming and reducing its extra costs while also resulting in relatively low prices for the consumers. This measure is, therefore, deemed to be especially interesting for further research. The findings also call for these measures to be further elaborated on and studied closer in further and more complex models, which is a goal for our further research.

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