Simulation and Evaluation of Zonal Electricity Market Designs

EPRG Working Paper 1813

Cambridge Working Paper in Economics 1829

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Over the last two decades, a number of countries have deregulated their electricity industry in order to create competitive electricity markets. These markets use different methods for handling transmission congestions. The US uses nodal pricing while Europe and Australia have favoured zonal pricing. Nodal pricing explicitly considers the transmission constraints and all accepted bids are paid with the local price in the node where the participant is located. Zonal pricing is a simplification of the nodal pricing design. In Europe, the zonal market is settled in two stages. The first stage is the day-ahead market where transmission constraints inside zones are neglected, only transmission constraints between zones are considered. The second stage is the real-time market, where all transmission constraints are represented in the economic dispatch problem. Zonal pricing is often favoured by market participants and politicians, and it also simplifies hedging and intra-day trading.

A problem with zonal pricing is that different representations of the transmission constraints in the two stages yield different prices. This gives producers an arbitrage opportunity. A producer located in an export constrained node can increase its profit by overselling in the day-ahead market and then repurchasing power at a lower price in the real-time market. This type of arbitrage strategy is referred to as the increase-decrease (inc-dec) game.

In practice, the inc-dec game is said to result in large payments to Scottish producers in the UK. The game was a major concern during the California electricity crisis and in the original design of the PJM (Pennsylvania - New Jersey – Maryland) market. Partly due to these problems, more or less all markets in the US have now adopted nodal pricing.

In this paper, we use simulations to quantify inefficiencies and other problems related with the inc-dec game. We also show how these problems can be mitigated by a change in the design of the real-time market. We consider three different methods to set prices in the real-time market: (1) pay-as-bid pricing as in Britain, (2) optimal zonal pricing, and (3) a hybrid approach that resembles the Nordic market design. Optimal zonal pricing means that all transmission constraints are considered and that prices within a zone are constrained to be the same. This is related to flow-based market coupling, which the European Union advocates for day-ahead markets. One of our contributions is that we evaluate optimal zonal pricing when it is implemented in the real-time market. This introduces extra constraints in the real-time market (nodal prices must be equal within a zone). Normally this makes the design inefficient. On the other hand, the extra constraint means that prices in the day-ahead and real-time market are set in a more unison way. This reduces the arbitrage opportunities and mitigates the inc-dec game.

We use nodal pricing as a benchmark. In comparison to this benchmark, our numerical results illustrate that the inc-dec game can lead to large production inefficiencies and large profits for producers in the zonal electricity markets designs that are used in the UK and the Nordic countries. Our results also illustrate that optimal zonal pricing in the real-time market mitigates the inc-dec game problems and the excess profits associated with this game. Overall, the market efficiency improves substantially in our examples, compared to standard zonal designs. In one of our examples, optimal zonal pricing is approximately as efficient as nodal pricing.

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Publication May 2018
Financial Support SweGRIDS, Swedish Energy Agency, Torsten Söderberg Foundation, Jan Wallander and Tom Hedelius Foundation