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Pricing in Day-Ahead Electricity Markets with Near-Optimal Unit Commitment

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In the US, wholesale electricity markets are run by Independent System Operators (ISOs). The ISO coordinates the market by accepting bids and offers from market participants then solving a unit commitment problem that determines the most cost-efficient production schedule. Wholesale electricity prices are based on the bids and offers that the ISO receives as well as the production schedule that it determines. A well-known drawback to this approach is that prices can change substantially based on which production schedule is selected. That is, the ISO must choose among production schedules that might raise or lower prices significantly despite almost no difference in cost.

This raises an issue of the ISO's impartiality because the choice of one production schedule over another creates a wealth transfer between market participants. It is commonly believed that these wealth transfers are an unavoidable due to the complexity of the underlying unit commitment problem, a non-convex mixed integer program.

A separate pricing issue has received more attention in recent years. One property of the unit comment problem is that uniform prices are not guaranteed to clear the market. Because of this, ISOs offer make-whole payments to generators that would otherwise suffer financial losses by following the ISO's production schedule. Such side payments are non-transparent and discriminatory, which limits the ability of prices to incent efficient participation in the market. A perfect solution to this problem is impossible due to the nonconvexities in the underlying market, but locational marginal pricing (LMP) is the most commonly used pricing framework in ISO markets in the US. Among

the proposed alternatives to LMP, so-called convex hull pricing has received the most attention. Somewhat controversially, the proposal expands side payments to a definition based on participant lost opportunity costs and minimizes the payments based on this definition. We show that a previously unappreciated property of convex hull pricing is that it nearly eliminates the wealth transfers that result from the ISO's choice of production schedule, even if side payments are only paid in the manner of make-whole payments.

This property of convex hull pricing is important for a multitude of reasons. First, it prevents the ISO's arbitrary scheduling decision from affecting prices, which ensures that market participants trust that the market outcome is not biased against them. Second, unscheduled participants are less likely to see that they would have been profitable given the current prices, if only they had been scheduled. This property translates to better market efficiency by reducing incentives for participants to self-schedule, for which we provide a numerical example. Finally, we show that the profits of individual generators are essentially independent of the unit commitment solution, regardless of the size and cost of the generator. Thus, the convex hull pricing mechanism reduces inequities to resources that only provide small or negligible improvements to the unit commitment solution.

This paper is the first to our knowledge to recognize connections between near-optimal unit commitment and convex hull pricing. A simple example in the appendix shows how self-scheduling incentives can arise in the presence of multiple near-optimal solutions. These incentives are reduced when convex hull pricing is adopted, thus providing some theoretical support for the efficiency gains of convex hull pricing. It would be difficult to estimate potential efficiency gains in a realistic test case, but improved computational approaches to do so may be a valuable area for future work.

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