The Electricity Journal 29 (2016) 33–47

Contents lists available at ScienceDirect

The Electricity Journal

journal homepage: www.elsevier.com/locate/electr

Virtual bidding and electricity market design

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ARTICLE INFO

Article history:
Available online 25 June 2016

Keywords:
Electricity
Market
Design
Virtual
Bidding
PJM
Uplift
Equilibrium
Efficiency

ABSTRACT

Efficient electricity day-ahead market designs include virtual transactions. These are financial contracts awarded at day-ahead prices and settled at real-time prices. Under current PJM market rules, there is an asymmetry in the settlement treatment of different types of virtual transactions, but a recent recommendation by PJM to eliminate this asymmetry is problematical.

1. Introduction

Efficient electricity day-ahead market designs include virtual transactions. In particular, in markets with a multi-settlement system including a day-ahead and a real-time market, day-ahead transactions can clear bids and offers that are strictly financial and are not intended for physical fulfillment in real time. These day-ahead financial transactions are settled against real-time prices in the same manner as other day-ahead market transactions. A recent PJM study reviewed the operation of its energy market, discussed the role of virtual transactions, and offered recommendations on proposed rule changes that would affect the scope and treatment of virtual transaction participation in their day-ahead market (PJM, 2015). The purpose of the present article is to comment on this PJM analysis and set of recommendations.

A full analysis of the impacts of virtual bids must immediately consider and model outcomes in an electricity market with uncertainty. Assessing the costs and benefits of virtual transaction on electricity market outcomes with even an approximation of the complications induced by realistic unit commitment and dispatch, e.g., taking into account uncertainty about the level of real-time load and resource availability, would be difficult. The PJM report does not attempt such an analysis, but argues primarily from examples that pertain to a context without uncertainty. There are important features of the implicit assumptions in the PJM analysis that affect the conclusions about the costs and benefits of virtual bidding, and the introduction of reasonable and realistic changes to these assumptions would lead in a different direction than PJM in specifying recommendations.

2. PJM analysis overview

The PJM analysis presents background context and provides discussion and analysis of many of the issues surrounding virtual bidding. The context can be alarming, as in the consideration of possibilities of market manipulation, where PJM raises the specter of " . . . perhaps going so far as to eliminate outright virtual trading in RTO markets" (PJM, 2015, p. 9). However, although PJM notes the concerns about market manipulation, the PJM analysis neither takes a position on this matter nor pursues explicitly the how and the where of possible market manipulation. Essentially, market manipulation is treated as a separate topic and while presented as context is not afforded material discussion or analysis.

The focus of the PJM analysis is narrower and addresses the efficiency effects and benefits of virtual trading assuming that market participants are simply responding to market signals without an attempt to manipulate those signals. This aspect of the PJM analysis is generally supportive of the impacts of virtual bidding. The discussion and examples in the analysis illuminate the issues and are instructive in expanding our understanding of the many dimensions of the benefits, and costs, of virtual bidding.

Broadening the discussion of virtual bidding requires more background about the context of electricity market design. The review below summarizes the critical and relevant engineering-economic elements of efficient electricity market design, short-

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http://dx.doi.org/10.1016/j.tej.2016.05.009
1040-6190/

term electricity system operations, and long-term contracts, and their relationship to the use of virtual transactions in electricity markets.[1] The interconnections among these topics have implications for the evaluation of recommended changes in the treatment of virtual transactions. The main conclusions are that the PJM recommendations are in certain cases inconsistent with the broader principles of efficient market design, and in other cases there is no direct connection between the PJM analysis and its recommendations. Both the scope of PJM's analysis and the breadth of its recommendations should be expanded.

3. Electricity market design

The special characteristics of the electrical transmission network create strong instantaneous interactions in how power flows between and among generators injecting energy into the grid and loads withdrawing energy. Dealing with these interactions induces related interactions in the elements of electricity market design. Although the structure and interconnections may be familiar, it is often helpful to go back to the basics to understand how the pieces fit together. Forgetting the details of the larger context linking the market design economics to engineering principles can result in analyses and recommendations that can neglect the requirements of efficient electricity market design and recreate problems already solved. A relevant case in point appears in recommendations for undoing financial transmission rights in PJM (see Monitoring Analytics, 2016), therein ignoring the long history of the fundamental transmission problem they were intended to solve (Hogan, 1992, 2002a; Pope, 2016).

The central idea of efficient electricity market design is to recognize the critical engineering characteristics of the power system, operate that power system efficiently, and utilize prices and associated incentives that are consistent with and motivate efficient operation.

The distinctive critical characteristics of the power system are the lack of adequate storage, meaning that most power must be generated contemporaneously with its use, and limits on whether and how system operators can adjust which transmission lines power flows on as it moves through the grid (parallel flows). Due to the lack of adequate storage, the speed of power flows, and response of other engineering elements of the system, system operators need to maintain essentially instantaneous balance, i.e., equivalence, of generation and load. This balance between generation and load occurs as power flows on the grid along every parallel path between supply sources and load sinks in quantities determined by the engineering ratings of each specific transmission line, among other things, rather than through a system where the pattern of the flows can be controlled by valves and pipes. In effect, therefore, the use of the transmission grid, in terms of power flows on transmission lines, is determined by the distribution of load across the system and the dispatch of supply at different locations by the system operator. In every interconnected grid, a system operator is required to control the dispatch in order to control the flows on the grid within security limits.

These are not new challenges, and are familiar to power engineers who have well-developed techniques and tools for economic dispatch to coordinate and control flows on the transmission system to maintain reliability. In choosing the generation dispatch to supply load within the limits of power flow constraints, there is still a great deal of flexibility, so some criterion needs to be applied. The natural approach for choosing among alternative feasible dispatches is to minimize the costs or maximize the net benefits of the electricity system operation. The term of art is to choose the "economic dispatch" to meet the load at the least cost subject to the security (i.e., reliability) constraints of the electricity system.

An efficient design for real-time markets should address the special challenges of electricity system operation and support the intended economic outcomes by providing a spot market basis for development of and reliance on forward contracts. The essence of the successful electricity market design in PJM and elsewhere was to organize the real-time spot market around the principles of bid-based, security-constrained, economic dispatch with the associated locational prices (Hogan, 1992). Under this market system, market participants are able to buy, sell, and trade electricity through a non-discriminatory organized spot market. Settlement prices are the real-time locational prices. Charges for transmission service between locations are settled at the difference in the locational prices for the injection and withdrawal. The real-time locational prices can be volatile, but forward contracts allow market participants to hedge the real-time prices.

Applying security-constrained economic dispatch is a well-developed practice in power systems. It developed using engineering estimates of the operating costs of generation. The adaptation to markets was to replace the engineering cost estimates with the bids and offers of the market participants. With this change in the inputs, the form of the economic dispatch remained otherwise unchanged.

The second innovation of markets was to apply consistent prices to the purchases and sales determined in the economic dispatch. A by-product when determining the economic dispatch is the calculation of the marginal costs of incremental power at each location. Following the usual definition of competitive markets, these marginal costs define the market-clearing prices associated with the economic dispatch. Under reasonable simplifying assumptions about the nature of the dispatch, taking these prices as given the generators and loads would have no incentive to deviate from the dispatch.[2] These spot prices are known in the PJM system as locational marginal prices (LMP) (Schweppe et al., 1988).

Using any other materially different pricing system would by construction create a fundamental inconsistency with the market quantities determined in the economic dispatch. Because of this inconsistency, implementation of a pricing system other than LMP would require surrendering the benefits of efficient dispatch, restricting open access, or abandoning the principle of non-discrimination, or all of the above. There is no other pricing system that is compatible with economic dispatch, open access, and non-discrimination. Therefore, the centerpiece of successful market design is bid-based, security-constrained, economic dispatch with locational marginal prices.

4. Electricity market design and forward contracts

Electricity production is capital intensive. Furthermore, the cost structure implies that short-run system marginal costs and the associated prices will be volatile. This creates an interest in forward contracts to allocate the ubiquitous risks in the industry. Both customers and producers see forward contracts as inherently useful. Customers are interested in forward contracts of a variety of forms to manage the risks associated with future purchases of energy. Similarly, producers are interested in forward contracts to manage the complementary risks created by high investment in generating assets to be repaid through an otherwise uncertain stream of revenue.

[1] This is an updated and expanded version of (Hogan, 2012).

[2] The principal simplifying assumption employed is convexity of the cost function. More generally, the market clearing prices depend on the absence of a duality gap (Gribik et al., 2007).