Agent-Based Simulation of an Automatic Mitigation Procedure

Robert Entriken and Steve Wan
EPRI
rentrike@epri.com, swan@epri.com

Abstract

This paper describes experiments using computer-based agents to simulate the impact of the California ISO's proposed Automatic Mitigation Procedure on market behavior. The agents play the role of market participants by formulating bids to maximize their profits. They exercise their skills under a number of scenarios with and without AMP being present and for various levels of demand and transfer capability over a simple, two-node market. The results of these experiments indicate that AMP is effective in reducing market clearing prices under situations when they would otherwise reach the price cap. In congested networks, congestion rents can be fleeting when suppliers are able to equalize prices across zones through strategic bidding. The analysis of significant issues such as the long-term effect of the AMP on investment incentives or its potential to help coordinate out-of-market activities lies beyond the capabilities of this type of simulation.

1. Introduction

An experimental application of agent-based simulation has recently been made using this new technology to study the effects of specific rules on the operation of a large-scale power market. As summarized here, this application demonstrates that agent-based simulation can be a useful tool for analyzing key design features of actual electricity markets. Within the limits imposed by simplifying assumptions, the results of the STEMS simulations show how well designed rules can help solve some long-standing problems in power markets, such as stimulating investment and mitigating market power. The results also provide valuable insights into market behavior, which can be used to improve future designs and facilitate dialogue between regulators and market participants.

This application investigates the impact of market design features proposed and implemented by the California Independent system Operator (CA-ISO):

- *Automatic Mitigation Procedure (AMP)* is a methodology for altering certain supplier bids, after they have been submitted, by reducing their offer prices. The purpose of this procedure (as imposed by the Federal Energy Regulatory Commission – FERC) is to "limit the exercise of market power, not to suppress prices during scarcity conditions." In other words, the AMP mechanism must be able to "differentiate between the exercise of [local] market power and true scarcity prices when demand is high."

The STEMS simulations allow decision makers to explore the effectiveness of existing and proposed market rules under a variety of conditions – specifically, whether AMP can help reduce the incidence of non-competitive behavior. In addition, these applications contribute to a better fundamental understanding of electricity market characteristics and offer a valuable opportunity for market designers to test the impact of new rules before implementing them.

2. AMP experiment

Based on FERC's requirement that AMP should limit the exercise of market power but not suppress prices during scarcity conditions, the experimental design attempts to simulate market behavior under tight system conditions to see what limits it places on prices and how these limits allow prices to rise under conditions of scarcity. In particular, the CA-ISO cites two examples of the types of bidding behavior that AMP is attempting to dissuade:

1. Bids into the ISO markets that vary with unit output in a way that is unrelated to the known performance characteristics of the unit (also known as "hockey stick" bidding);
2. Bids into the ISO markets that vary over time in a manner that appears unrelated to change in the unit's performance or to changes in the supply environment that would induce additional risk or other adverse shifts in the cost basis.

The first citation refers to the practice of exploiting supply shortages by bidding one or more high-cost units at or near the price cap. The second citation refers to bidding practices that vary according to the environmental circumstances of the market that are not related necessarily to a supplier's own operations but to events affecting other aspects of the power system, such as demand levels and network characteristics.

In their ruling to the CA-ISO, FERC ordered that AMP be applied to the Real-Time Market for electric power during the predispatch process occurring 45-minutes before the operating hour. FERC also instructed the ISO to utilize three screening processes to govern the activation of bid mitigation:

- For the conduct screen, the threshold will be whether the individual bid would result in a 200 percent or a $100/MWh increase, whichever is less, above the reference price established for the unit;
- For the impact screen, the threshold will be whether the aggregated bids that fail the price screen would result in a 200 percent or a $50/MWh increase, whichever is less, in the market clearing price;
- For the price screen, if the market-clearing price for all zones is $91.87/MWh or below, AMP will not be applied.

FERC ordered that reference prices for each generation unit apply to all hours of the day. Exemptions apply for small portfolios once the full network model is in effect. All bids below $25/MWh are exempt from mitigation.

2.1. Scenarios

A stylized model of the California market is used, having two nodes (North and South) and eight suppliers (three in the North and five in the South). The demand side is always bid at a fixed price (250 $/MWh) for both nodes. The supply bidders are free to choose the price at which they offer each block, but the maximum willingness to pay on the demand side effectively acts as a bid cap on suppliers. Suppliers must also bid 100% of their capacity into the market at or below the bid cap.

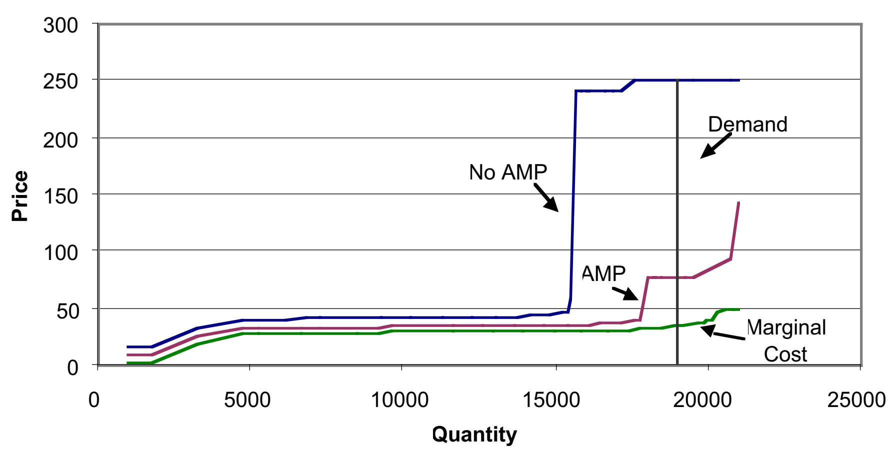
Since prices should reflect scarcity, simulations are conducted for scenarios of varying loads and levels of transfer capability between the two nodes. The following tables show the values for seven demand and seven transfer capability scenarios (labeled zero for the base case), creating 49 combined scenarios.

Demand Scenarios	0	1	2	3	4	5	6
North Demand (MW)	6,800	6,476	6,152	5,829	5,505	5,181	4,857
South Demand (MW)	14,200	13,524	12,848	12,171	11,495	10,819	10,143
Total Demand	21,000	20,000	19,000	18,000	17,000	16,000	15,000

Transfer Cap. Scenarios	0	1	2	3	4	5	6
Transfer Capability (MW)	2,000	1,700	1,400	1,100	800	500	200

2.2. Agent behavior

Computerized agents representing suppliers exercise all of the strategy in these simulations, and each one uses an identical strategy of aggressive profit maximization when they submit bids to the market. Their bids take the form of price-quantity pairs, where the quantities are constant and the prices can vary. Thus, withholding is exercised economically, not physically.



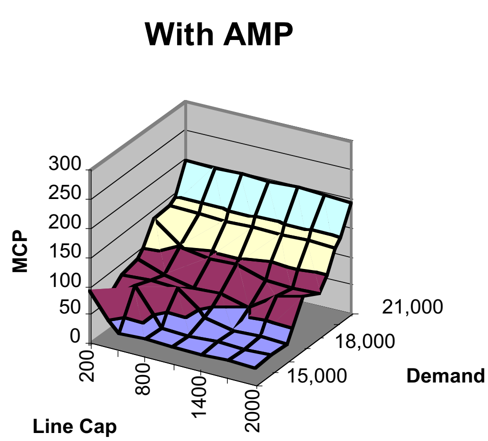
Agents have the opportunity to bid and learn the market-clearing price and their own schedules over thirty rounds of bidding and market clearing. During these thirty rounds, they learn whether the market is more or less competitive and respond accordingly by switching between heuristic strategies to raise either their sale prices or quantity sold, in an effort to increase profits.

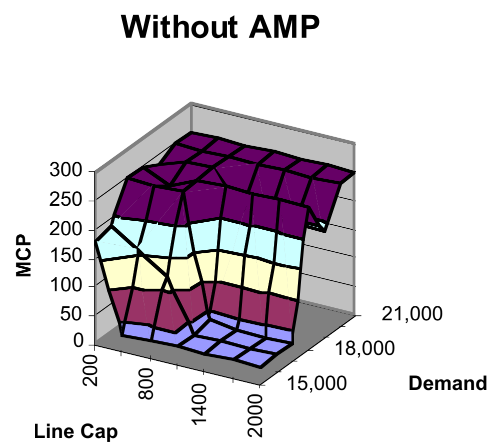
Agents have no specific information about their competitors and do not interact directly. They know their own costs, the rules of AMP, and each is informed whether it is a pivotal player and will first attempt to bid at the price cap if it will increase profits. This strategy can dominate all others when enough profit is available.

As a secondary strategy, they utilize public information to detect whether they are marginal suppliers by comparing their bid prices with the market-clearing price. Players that are neither pivotal nor marginal utilize a price taking strategy. Marginal players utilize a very simple "greedy algorithm" for rent capture. The rule is that, when they are marginal, they test the margin by raising their bid prices. This is coupled with rules for AMP to know how high to bid.

When AMP is activated, the agents know that they can bid as high as their conduct prices without having their bid changed. When AMP is not activated, they attempt to bid higher than their conduct prices in search of the impact price, which could yield even higher profits. Further details of the software architecture, market structure, and bidding strategies are available online in [13].

The Price-Quantity chart depicts the resulting bid curves under one of our scenarios (19,000 MW demand, 2,000 MW transfer capability). In this case, five players know they are pivotal and enough of them bid at their perceived caps to make the supply curve horizontal around the demand level. The vertical line represents inelastic demand and, since there is no congestion, market-clearing prices (MCP in $/MWh) are: 250 without AMP, 76.5 with AMP, and 34.5 with competitive equilibrium (marginal cost).





3. Results

Results of the experiment are summarized in a series of three-dimensional diagrams, in which the vertical axis is MCP (average of last five rounds) and the two horizontal axes are line capacity and demand. When all scenarios of line capacity and demand are plotted, they produce a two-dimensional surface of prices, as shown in the sample charts below – representing the North market with and without AMP.

Clearly, prices are lower in the second chart due to the effect of the mitigation procedure. With AMP, when demand is above 19,000 MW, the last few production units are able to raise the market clearing price to somewhere between 150 and 200 $/MW. These values are a direct result of strategic bidding with the highest cost units. Without AMP, however, suppliers do not compete at higher levels of demand and prices rise close to the maximum of 250 $/MWh. In addition, AMP prices rise more gradually with demand than non-AMP prices – meaning that more scenarios are competitive.

4. Conclusions

The obvious conclusion of this study is that AMP has the effect of a price cap and is effective in the short term at lowering market-clearing prices when supply conditions are tight or line capacity is reduced. In the long-term, however, the lack of differentiation between scarcity and market power could lead to capacity shortages if the price reductions are too severe, because of the reduced incentive for new investment.

The presence of pivotal suppliers and the reference prices of the highest cost units are the determining factors for non-competitive prices. There was a significant reduction in the number of non-competitive scenarios attributable to AMP, but more-realistic simulations, coupled with load-duration statistics are needed to judge the true magnitude of this impact.

Beyond the obvious conclusions lie several more subtle insights:

1. Even simulation agents, acting without explicit collusion or super-sophisticated analytical tools, can (besides capturing congestion rents) manage to avoid triggering the impact screen and therefore drive prices considerably above the levels of the conduct screen.
2. As structured in our scenarios, AMP is effective in promoting more competition in the short term than would be the case without it. This is because it has the same effect as a price cap, and thus suffers the same liability of reducing long-term incentives for investment. In the long term, AMP may be responsible for inadequate capacity if not managed very carefully. A more realistic model and correlation to load-duration statistics is needed to better assess how much more competition results from AMP.
3. Suppliers in this simple two-node example are quite able to extract congestion rents. This is especially true when supplies are so tight that there are pivotal suppliers in both regions.
4. Bidding behavior very much depends on AMP. Not only are bids reduced in particular circumstances with AMP, it also changes the incentives to exercise market power and hence indirectly changes bids in situations where no bids are mitigated directly.
5. A careful design of AMP would account for its potential use as a facilitating mechanism. That is, certain market participants could trigger AMP or threaten to trigger AMP as a means of extracting benefits they would not otherwise obtain.

One of the main benefits of simulation derives from improving our understanding of how a particular AMP implementation reduces incentives to exercise market power. Detailed inspection of agent bidding practices showed that AMP increases the risks of bidding high, further confounds the decision-making process, and reduces the level of the maximum achievable price. All of these factors combine to make the market as modeled here more competitive under AMP.

The FERC statement that AMP should reduce market power while not suppressing prices under scarcity conditions is supported by the evidence that AMP introduces a level of uncertainty that manifests a large transition region between two phases of market behavior: a competitive phase and a non-competitive phase. In severe conditions of scarcity, the market behavior approaches that of a monopoly that is restricted by AMP. This supports FERC's statement that prices can rise under scarcity conditions. The evidence also shows that oligopoly rents are substantially reduced, on average, while scarcity rents are little affected.

Future simulation studies that include the use of more realistic market data will offer an opportunity to further test both the methodology and conclusions. In particular, valuable lessons can be learned from simulations related to the actual implementation of AMP, based on more detailed and realistic models and scenarios of the market.

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