Financial Arbitrage and Efficient Dispatch in Wholesale Electricity Markets

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Motivation

- Financial trading is always controversial.
  - Does speculation disrupt the market in the physical good?
  - ...or does it improve the market's functioning?
- Recently, FERC has actively prosecuted ‘name’ financial companies for manipulation. This has created some controversy.
- The U.S. standard design for electricity wholesale markets has always included a specialized form of financial trading known as ‘virtual bidding.’ Despite its resilience, it is constantly being reformed.
The What and Why of Virtual Bidding
DA/RT Spreads

DA/RT spread = Day-Ahead LMP – Real-Time LMP

Table 1. DA/RT Spreads in Select Zones of the NYISO, 2011-2013.

<table>
<thead>
<tr>
<th>Zone</th>
<th>Avg. Diff % (DA - RT)</th>
<th>Avg. Absolute Diff %</th>
</tr>
</thead>
<tbody>
<tr>
<td>West</td>
<td>1.4%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Central</td>
<td>1.1%</td>
<td>0.6%</td>
</tr>
<tr>
<td>Capital</td>
<td>2.6%</td>
<td>2.9%</td>
</tr>
<tr>
<td>Hudson Valley</td>
<td>0.9%</td>
<td>0.9%</td>
</tr>
<tr>
<td>New York City</td>
<td>1.8%</td>
<td>0.8%</td>
</tr>
<tr>
<td>Long Island</td>
<td>0.9%</td>
<td>1.7%</td>
</tr>
</tbody>
</table>

Conclusion:

As measured by the average difference in day-ahead and real-time prices, energy price convergence was fair in most areas in 2013. Convergence in 2013 was worse than in 2012. Inconsistencies between day-ahead and real-time prices were increased by higher real-time price volatility in 2013, particularly:
Virtual Bidding

- Day-Ahead market.
- Like any other bid, a (p,q) pair for any hour and for some node/zone, but flagged as virtual.
- Bids clear like all other bids.
- Gross payoff to cleared bid equal to the DA/RT spread.
  \[ \pi_{VD,i,t} = (RT_{i,t} - DA_{i,t}) \] (1)
- Other charges can materially affect the net payoff.
- Directly impacts unit commitment and dispatch schedule in the Day-Ahead market.
Improved Convergence in California

CAISO Hourly DA/RT Spreads, Before and After Virtual Bidding

AFTER

BEFORE
The Fault with Virtual Bidding
Received Theory:
Complete Markets, Run Successively

• Each market is a complete solution.
• Successive runs of the same market design. The only difference is information.
  • Given the same supply and demand, they will produce the same dispatch and prices.
• Day-Ahead is a often described as a cash settled forward market.
  • Equilibrium forward price must be the expected spot price, with a minor risk adjustment.
The combined unit commitment and optimal power flow problems are too complex to solve as needed.

- Sensible unit commitment requires looking far forward in time, which requires many hours of computing time.
- Transmission constraints are highly non-linear.
- Dynamic stochastic optimization is far too large a problem.

"Even 50 years after the problem was first formulated, we still lack a fast and robust solution technique for the full alternating current optimal power flow problem. We use approximations, decompositions and engineering judgment to obtain reasonably acceptable solutions to this problem."
Reality: Approximate Solutions, Articulated (2)

- Multi-settlement market design is a strategic solution—break the problem into two articulated steps.
  - Day-Ahead market does unit commitment and a granular dispatch schedule, but with a simplified representation of the transmission system and various other constraints.
  - Real-Time market is better resolved, but takes the unit commitment and granular dispatch schedule as the starting point.
  - A miscellany of other constraints are imposed to satisfice on the optimal stochastic solution.
- Day-Ahead is not ‘just’ a cash settled forward market.
  - Results of the Day-Ahead market are passed to the Real-Time market and shape that outcome.
Reality: Approximate Solutions, Articulated (3)

- Works reasonably well.
- Until it doesn’t.
  - Over time, system parameters change—investments in new generation, new technologies, new transmission—and context changes, too—prices of fuel, emissions penalties and constraints, etc.
- Recalibration.
  - Requiring adaptation in the approximations, decompositions, and engineering judgments employed in order to approximate the optimal solution.
- Convergence should be understood as a practical diagnostic.
  - DA/RT spreads are a product of the approximations and articulated design.
Example: Black Start & Voltage Support in PJM
Case Study of Virtual Bidding in California
Two problems:

1. Price spikes in RT, causing negative average DA/RT spreads.
2. Low Hour-Ahead prices, causing positive average DA/HA spreads.
Fig 2. The Hourly Granularity of Day-Ahead Markets

Load (MW)

- DA Schedule
- Assumed ramping
Fig 3. Real-Time Intra-Hour Load Ramp

Load (MW)

- DA Schedule
- Assumed ramping
- RT Load

Steep 5-min Interval Ramp

30,000
40,000
50,000
50,000
40,000
30,000

Hour

15 16 17
Fig 9. The Impotency of Virtual Bidding

Load (MW)

- DA Schedule
- Assumed ramping
- RT Load
- DA Schedule with Virtual Demand

Hour

15 16 17

Load (MW)

30,000 40,000 50,000

30,000 40,000 45,000 50,000
The Loss from Virtual Bidding into RT Spikes

- Results in increased scheduling of generation Day-Ahead.
- Increases the DA price, which means improved convergence, on average. An apparent improvement.
- However, this turns out not to be welfare improving:
  - 99% of the time this is a mistake: DA is already above RT, and extra supply scheduled increases DA cost.
  - 1% of the time this is also a mistake because it is the wrong capacity. Price still spikes in the Real-Time market.
  - More is not always better.
Empirical Literature Overlooks This Problem

CAISO Hourly DA/RT Spreads, Before and After Virtual Bidding

Hour of the Day
A General Problem

Episodic. Disparate. Transient. ...Inherent.
Conclusion

- Spreads between the Day-Ahead and the Real-Time price will often arise due to the many necessary approximations differently employed in the Day-Ahead and Real-Time algorithms;
- While virtual bidders can profit off of these spreads, oftentimes they cannot help resolve the underlying problem;
- In these cases, profits earned by virtual bidders can be a purely parasitic drain on the system, adding to the costs paid by load;
- In addition, virtual bidders may add to system costs;
- Convergence—a narrowing DA/RT spread—is an imperfect metric for evaluating system performance and the contribution of virtual bidders; virtuals may cause the average DA/RT spread to move closer to zero, and nevertheless all virtual profits are a purely parasitic drain, and, in addition, virtual trading has increased system costs.