Financial Arbitrage and Efficient Dispatch in Wholesale Electricity Markets

John Parsons, Cathleen Colbert, Jeremy Larrieu,
Taylor Martin and Erin Mastrangelo

MIT Sloan School of Management & Center for Energy and Environmental Policy Research
and the Federal Energy Regulatory Commission

CEEPR-EPRG Seminar, July 9-10, 2015

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.

Zone	Avg. Diff % (DA - RT)			Avg. Absolute Diff %		
	2011	2012	2013	2011	2012	2013
West	1.4%	0.0%	-1.9%	24.0%	26.4%	36.3%
Central	1.1%	0.6%	1.3%	25.7%	25.5%	29.5%
Capital	2.6%	2.9%	4.5%	28.1%	27.0%	33.1%
Hudson Valley	0.9%	0.9%	-0.8%	30.0%	29.9%	33.9%
New York City	1.8%	0.8%	-1.4%	32.4%	31.4%	35.0%
Long Island	0.9%	1.7%	-6.5%	35.5%	42.1%	46.5%

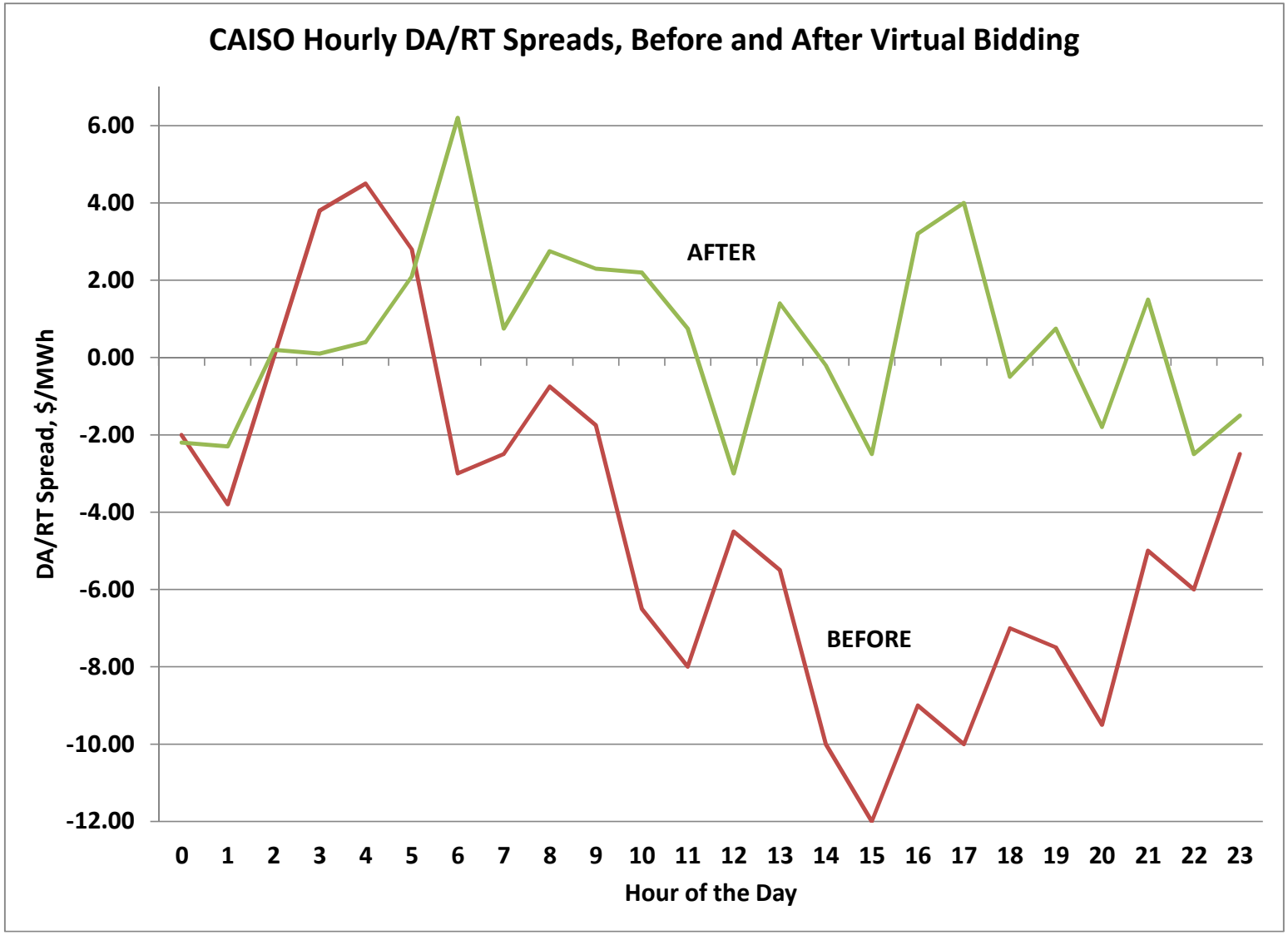
Virtual Bidding

- 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.

$$\pi_{VD,i,t} = (RT_{i,t} - DA_{i,t}) \tag{1}$$

- Other charges can materially affect the net payoff.
- Directly impacts unit commitment and dispatch schedule in the Day-Ahead market.

Improved Convergence in California



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.

Reality: Approximate Solutions, Articulated

- 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."

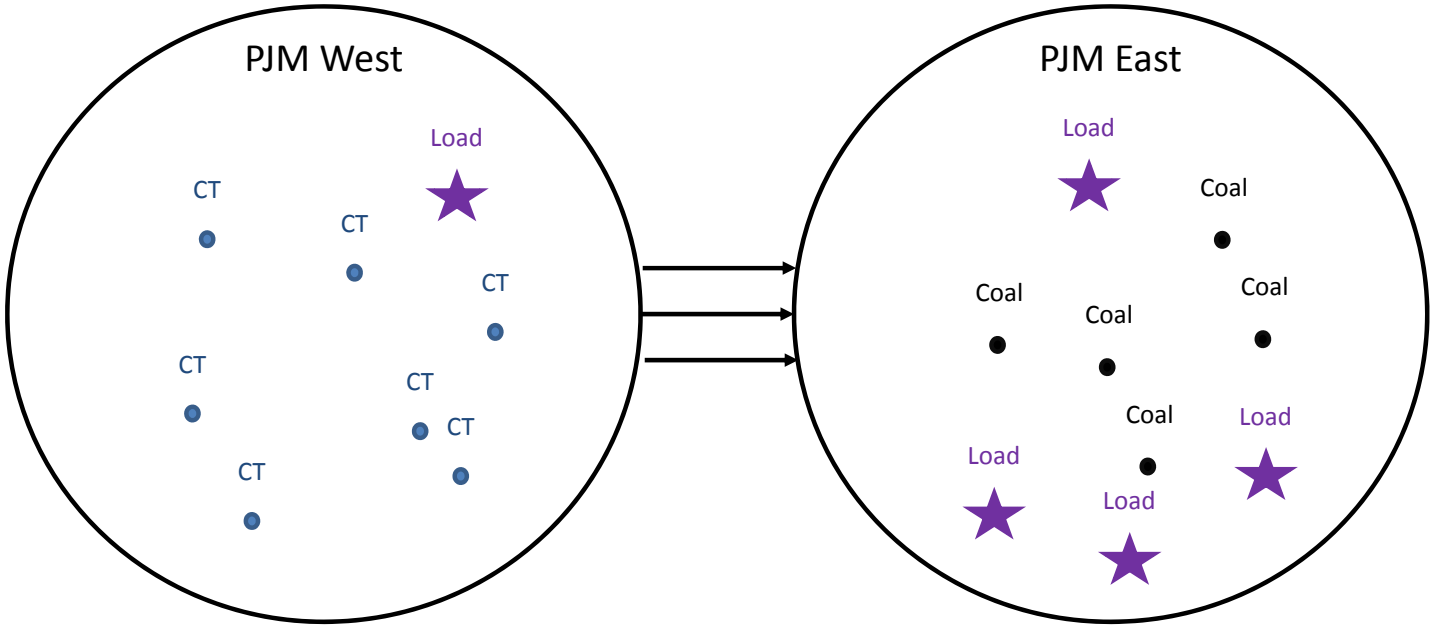
Reality: Approximate Solutions, Articulated (2)

- 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)

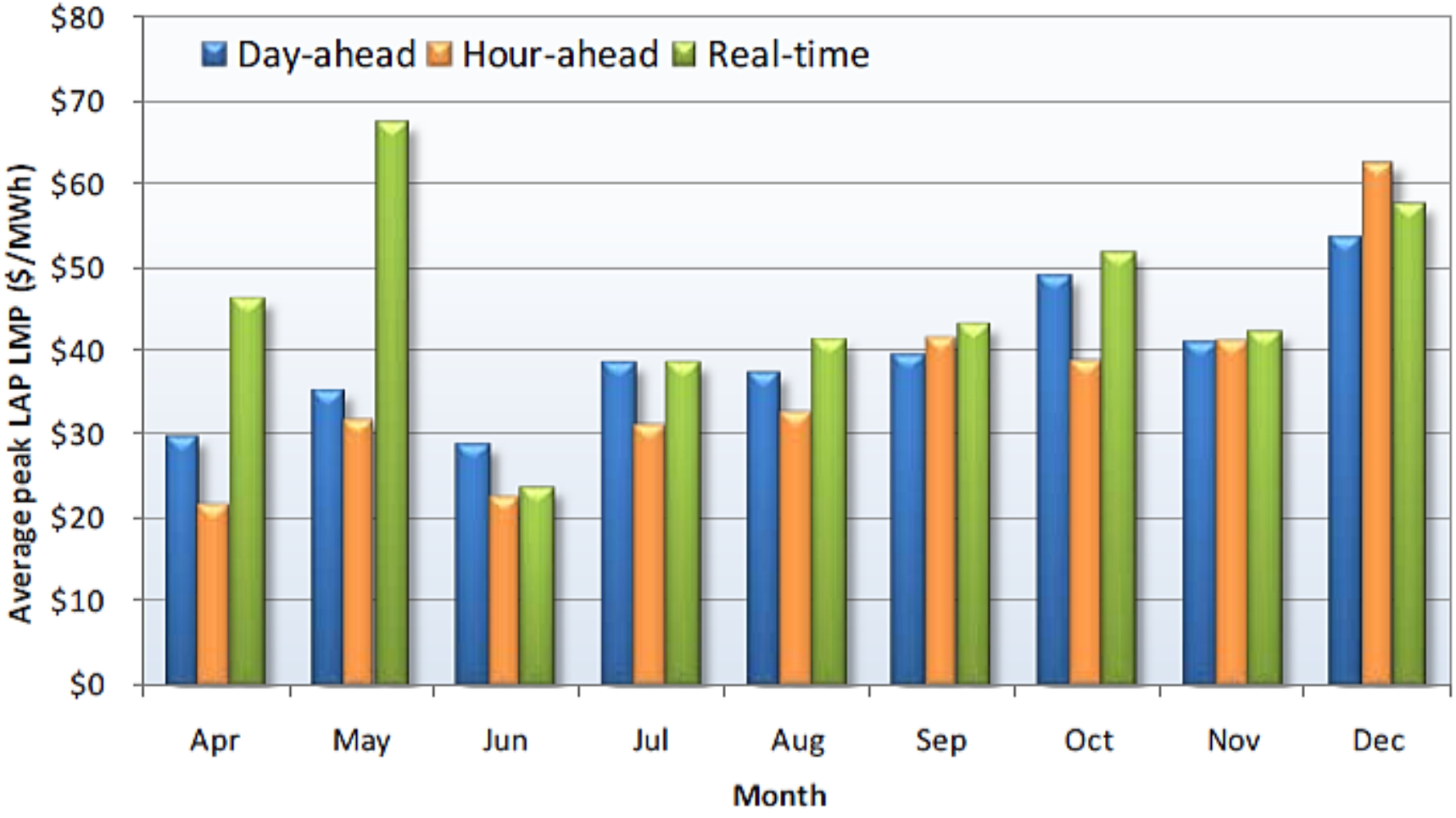
- Works reasonably well.
- Until it doesn't.
  - Over time, system parameters change—investments in new generation, new technologies, new transmission—and context changes, too—prices of fuel, emissions penalties and constraints, etc.
- Recalibration.
  - Requiring adaptation in the approximations, decompositions, 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

Average Prices 2009, Pre-Virtuals



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

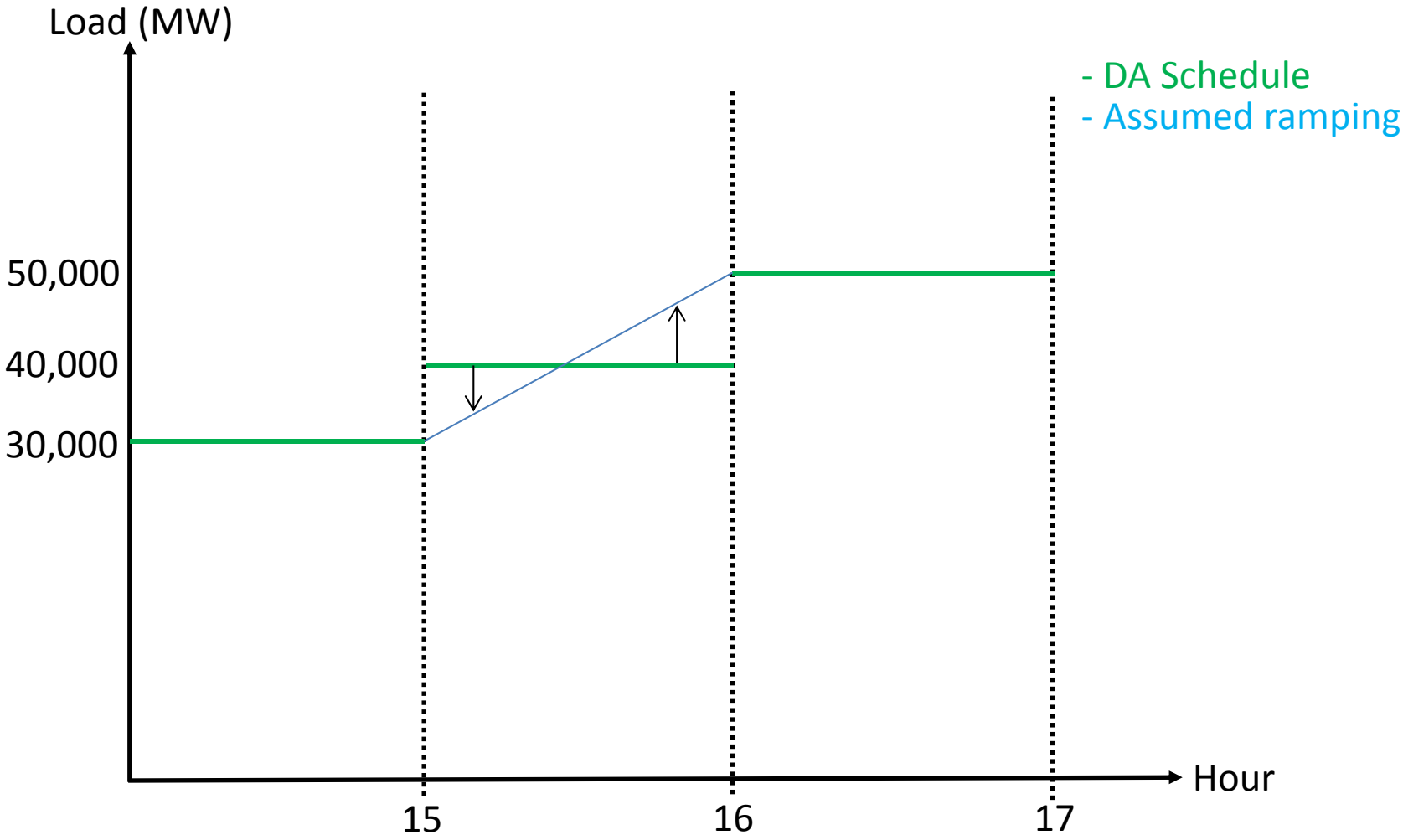


Fig 3. Real-Time Intra-Hour Load Ramp

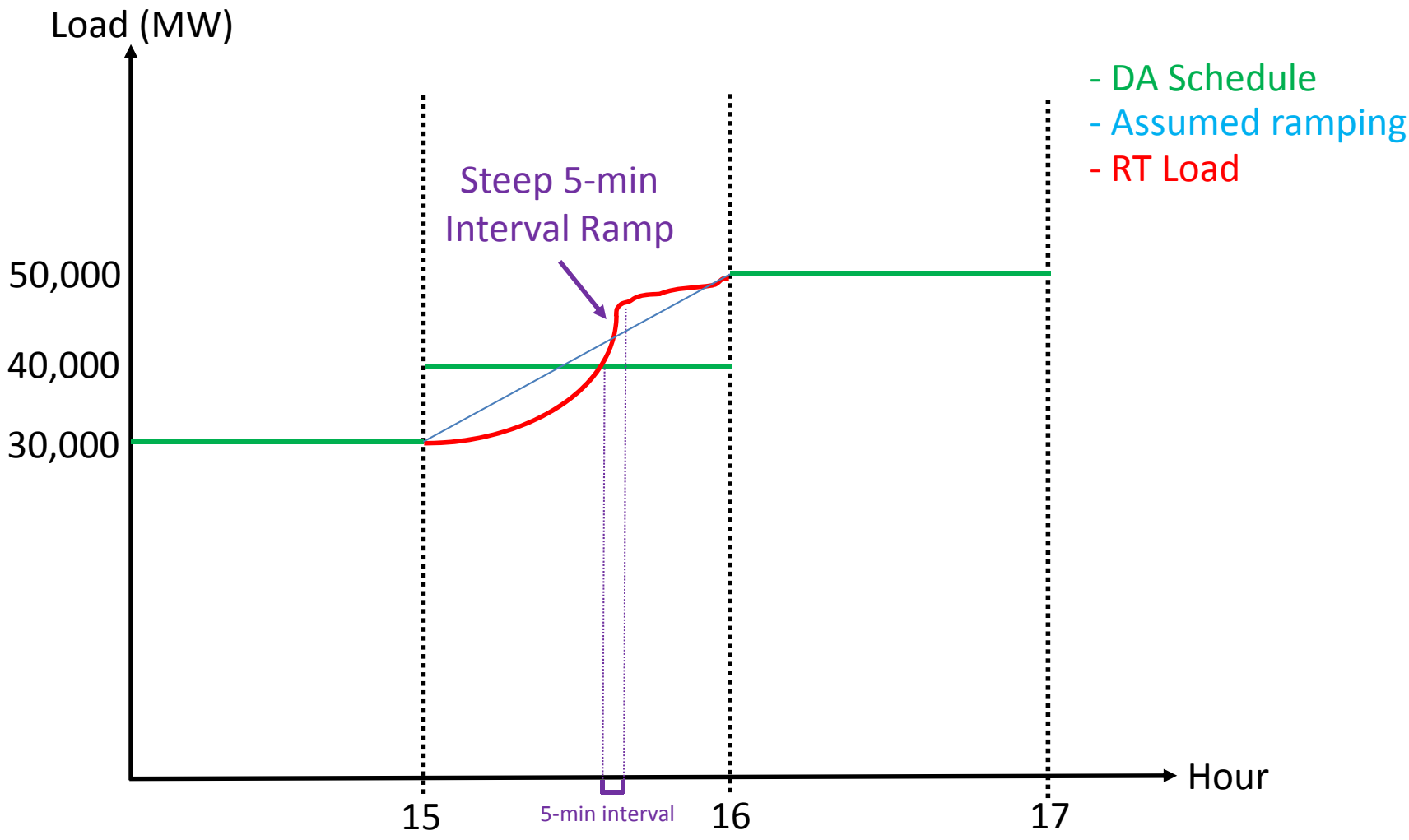
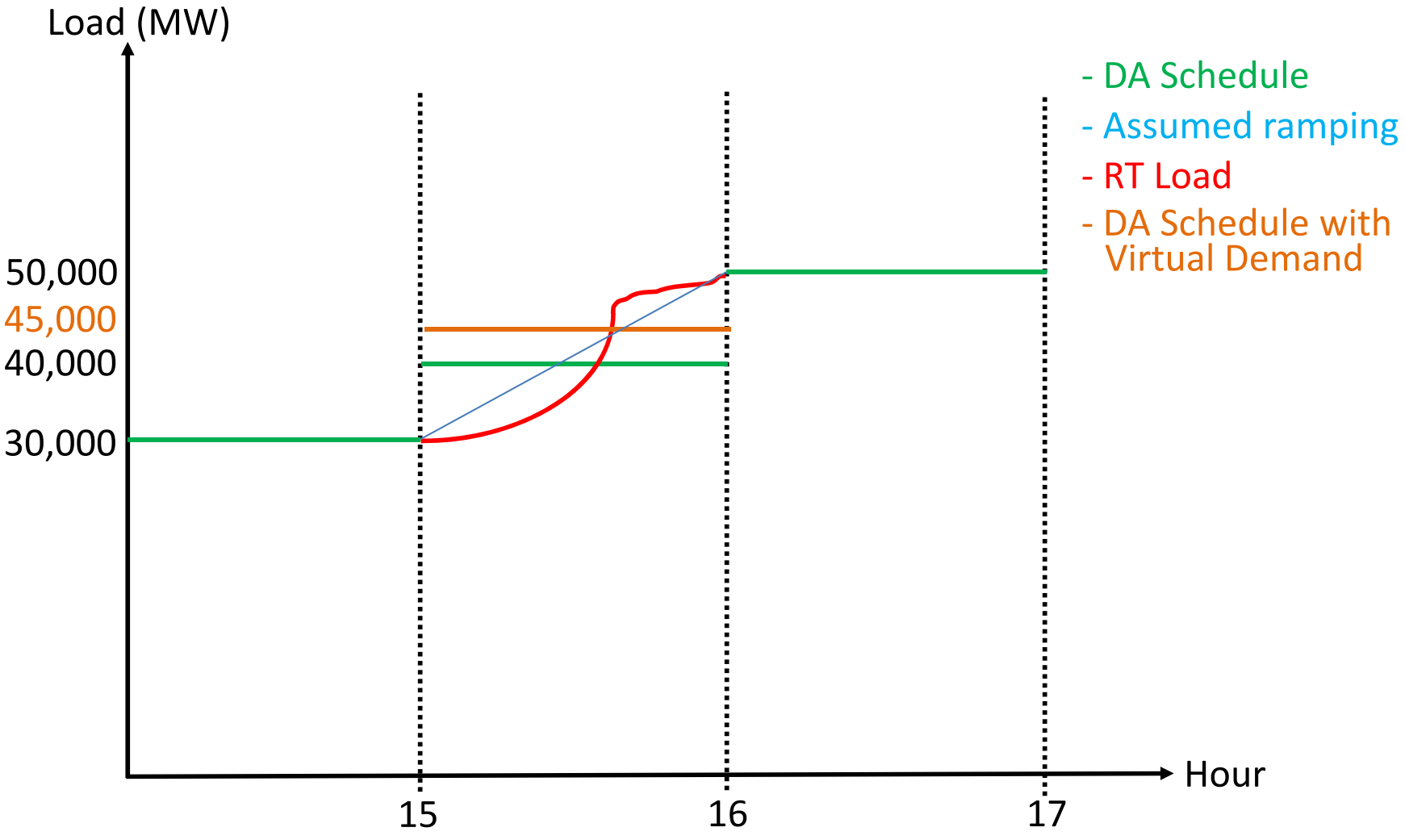


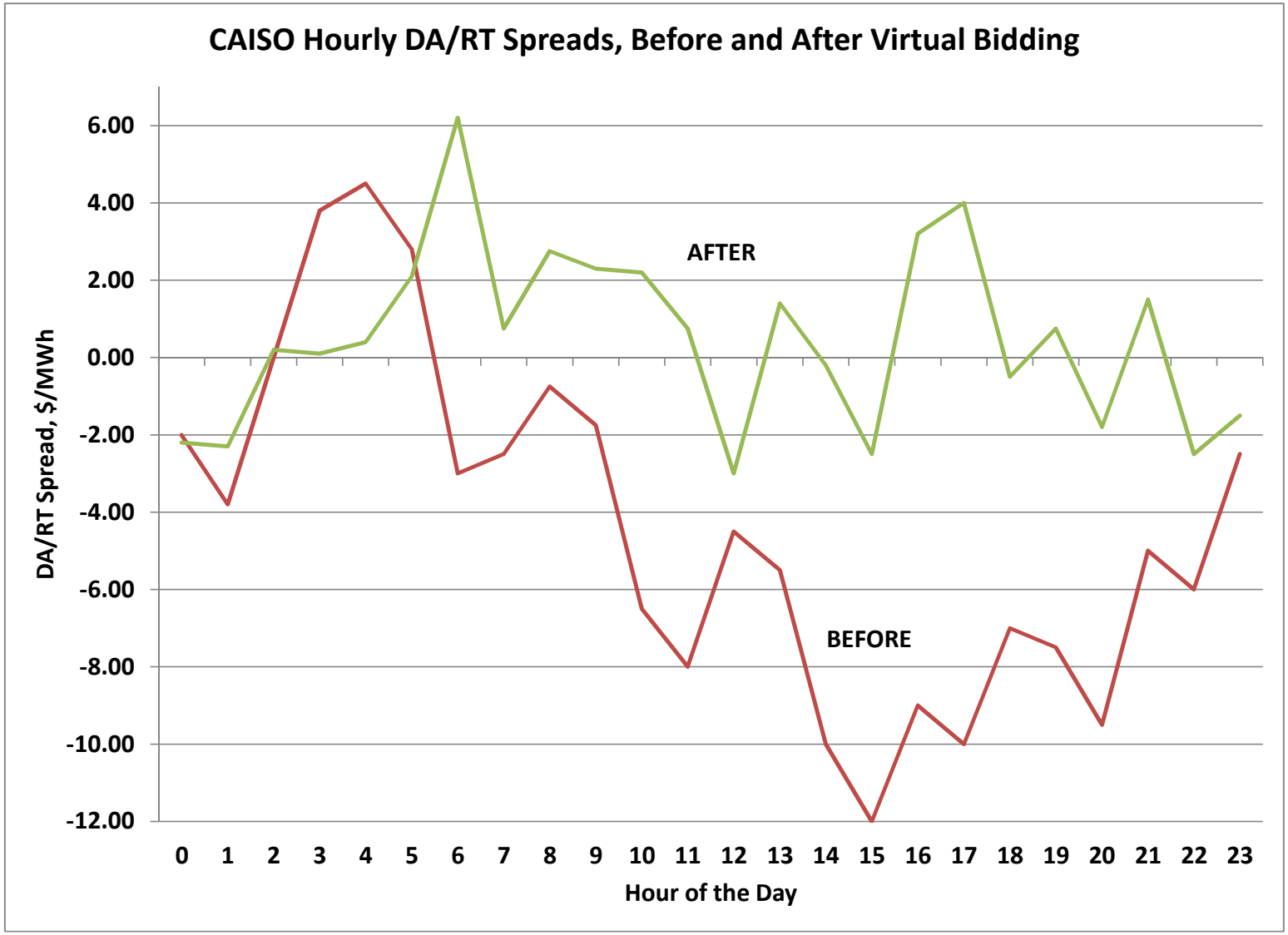
Fig 9. The Impotency of Virtual Bidding



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 supplly 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



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.