



# Unit Commitment at the CAISO

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# New Market – April 1, 2010

- New Day-Ahead and Real-Time nodal energy market started April 1, 2010
- Mixed Integer Program (MIP)
- Number of generators and integer variables
  - ~ 1000 units /
  - ~ 35,000 variables
- Number of bids:

Market (Horizon)	Number of Energy Bids (Approx.)			Number of Ancillary Service Bids (Approx.)		
	Generation	Interchange	Demand	Generation	Interchange	Demand
Day-Ahead Market (per 24 hours)	14,000	7,000	2,000	9,000	100	10
Real-Time Pre Dispatch (per 2 hours)	1,000	700	50	500	20	10
Real-Time Dispatch (per 2 hours)	1,000	14 Dynamic	50	N/A	N/A	N/A

- Full Network Model:
  - 4000 nodes,
  - 2100 Loads,
  - 7000 lines, 200 XFMRs
- AC modeling of active power losses (Newton-Raphson Powerflow)

# Facts about the Solution

- 1 Security Constrained Unit Commitment (SCUC) pass:
  - 3-4 MIP-PF/CA iterations
  - Each MIP iteration with two passes i.e. 1 scheduling and 1 pricing run
- 1 Security Constrained Dynamic Dispatch (SCDD) pass:
  - 1 MIP iteration with two passes i.e. 1 scheduling and 1 pricing run
  - Multiple interval ramping and forbidden operating region constraint enforced
- DAM 24 hour simultaneous intervals run ~ 1 hour computing time for 4 SCUC passes
  - 2 SCUC passes, 1 – Market Power Mitigation / Reliability Requirements (LMPM)
  - 1 SCUC pass – Integrated Forward Market (Energy and A/S)
  - 1 SCUC pass – Residual Unit Commitment
- RT Unit Commitment executed every 15' up to 18-15' intervals ahead ~ 12' computing time for 3 SCUC passes
  - 2 SCUC passes, 1 – Market Power Mitigation / Reliability Requirements
  - 1 SCUC pass, Real-Time Unit Commitment and A/S procurement
- RT Dispatch executed every 5' up to 13 - 5' intervals ~ 2.5' computing time
  - 1 SCDD pass, Security Constrained Dynamic Dispatch
- MIP Gap ~ 0.1% for 24 hour DA-Integrated Forward Market runs in about 10-20 min
- Observed more constraints enforced sometimes results in faster solution within MIP Gap

# Constraints

- Large number of transmission constraints from AC Powerflow / Contingency Analysis
  - Up to 2000 binding constraint for 24 intervals,
  - Up to 150 AC contingencies simulated every market time interval
  - Corridor Constraints
- Nomogram Constraints
  - Simultaneous interface vs. interface limits or interface vs. gen output limits,
  - Minimum On-line Commitment Constraints
- Intertie Constraints
  - Scheduling Limits
  - Wheeling Constraints
  - Multi-hour block
- Resource Constraints
  - Dynamic ramp rates: Different ramp-rates at different operating levels
  - Minimum up time, minimum down time, maximum starts/day
  - Resource Startup costs and startup times as functions of off time
  - Forbidden Region of Operation
  - Energy Limitation Constraints: Maximum amount of energy or hours of availability
- Pump/Storage Modeling
  - Decision regarding pumping or generation operational mode

# Other Features

- Fully integrated multi-interval Ancillary Service and Energy Co-optimization in DAM and RTPD
  - Decision to procure A/S based on resources constraints and energy/AS bid prices
  - Competition of energy and AS on inter-ties
  - Ancillary Services (Spin, Non-Spin, Regulation-up and Regulation-down)
  - Cascading Services (Higher Quality service can substitute for Lower Quality)
  - Nested regional requirements
- Integrated bilateral and spot market with priorities for self-schedules curtailment controlled by uneconomic adjustments i.e. separate scheduling and pricing runs
- Compensating injections to handle loop flows in real-time
- Constrained Output Generator (COG) ( $P_{min} = P_{max}$ ) Dispatch and Pricing
- Scarcity Pricing
- Metered-Sub System Load Following
- Proxy Demand Response

# Market and Performance Initiatives

- Modeling of Combined Cycle Resources (Multi-Stage Modeling)
  - Multiple Start-up functions
  - Start-up decisions of different stages
- Startup MW profiles
- Enhance Forbidden Region with Hold-Time Constraints
  - Must stay above forbidden region for specified period of time
- Demand Response
  - Curtailment Decisions
  - Shut-down constraints
  - Linkages between different demand
- Convergence Bidding
- Multi-Day Optimization
  - Improve cross-day unit commitment decision making and avoid unnecessary cycling

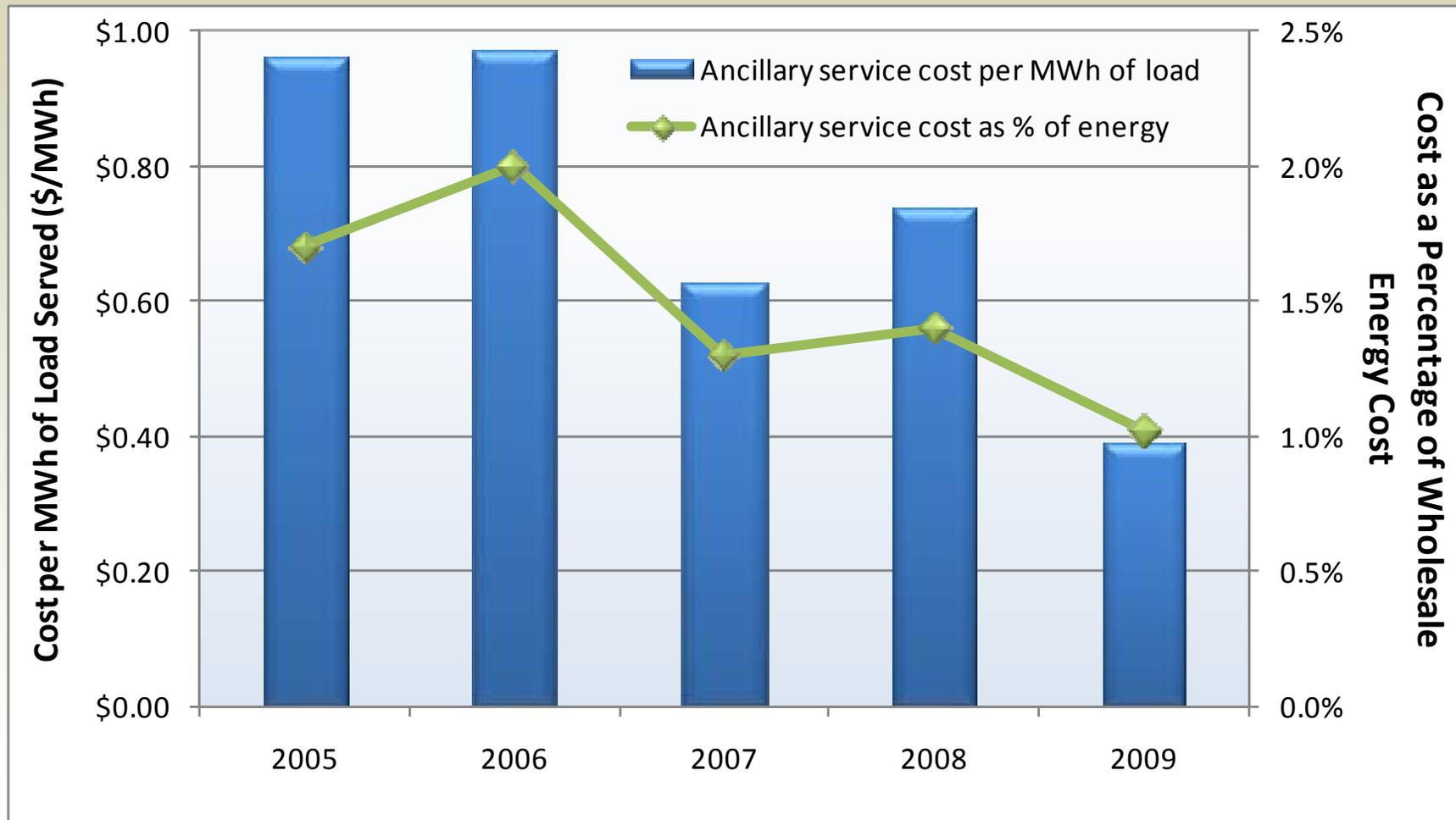
# Other Future Developments

- Integration with voltage and stability assessment tools
- Simultaneous market power mitigation, residual unit commitment and market solutions
- Renewable integration
  - Additional market products to accommodate ramping / load following needs
- Battery/Storage devices participation
- Integrated preventive/corrective control in handling contingency cases
- Co-optimization of energy, AS, and active power losses i.e. integrated active/reactive optimization
- Switching operations as controls
- Dynamic transmission limits as functions of equipment connectivity statuses
- Application of Priorities
  - Possible replacement of penalty functions to enforce scheduling priorities (i.e. ETC, RMR, TOR, Self-Schedules....)

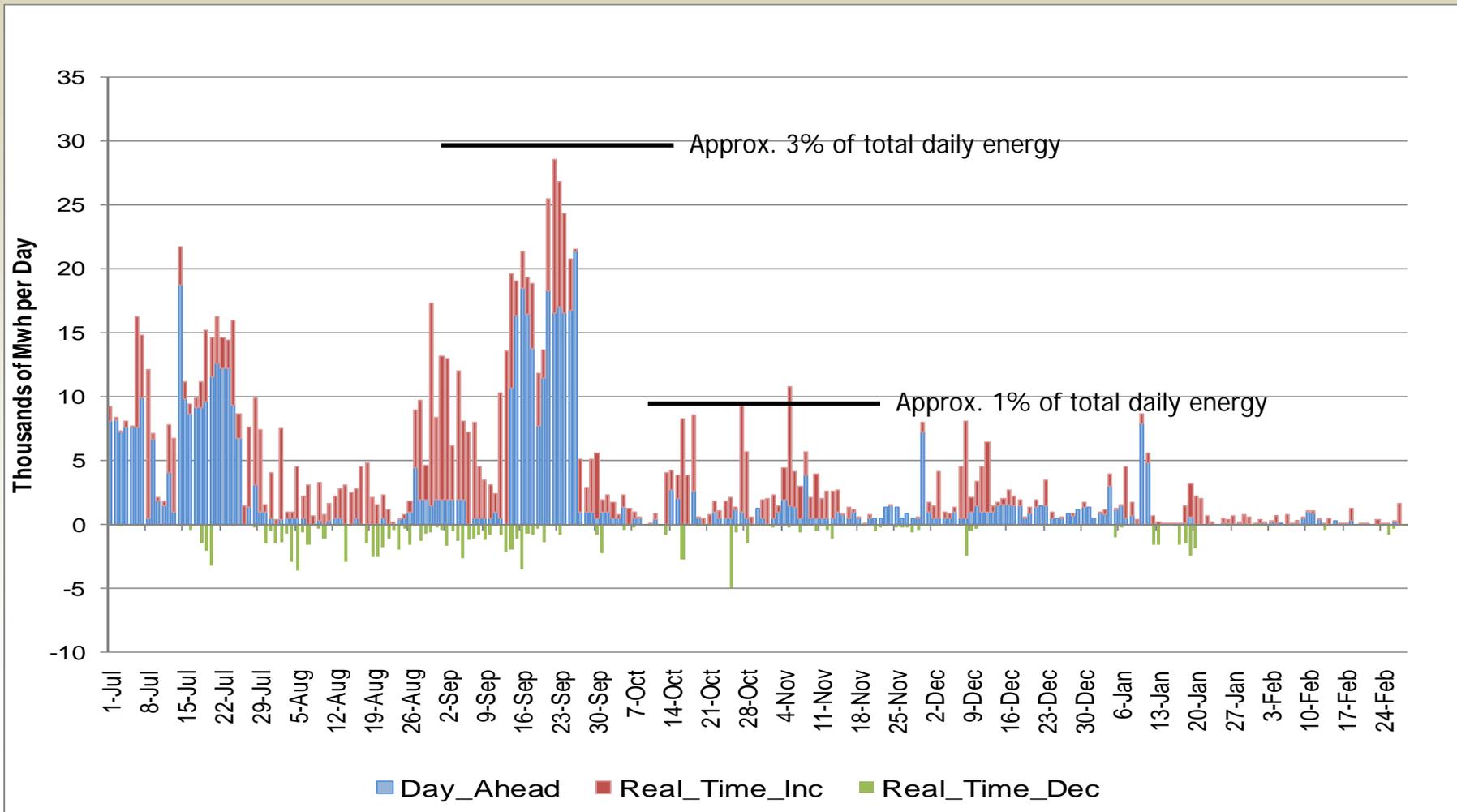
Day-ahead and real-time prices have been about equal to a perfectly competitive baseline.



# Ancillary service costs have decreased due to co-optimization.

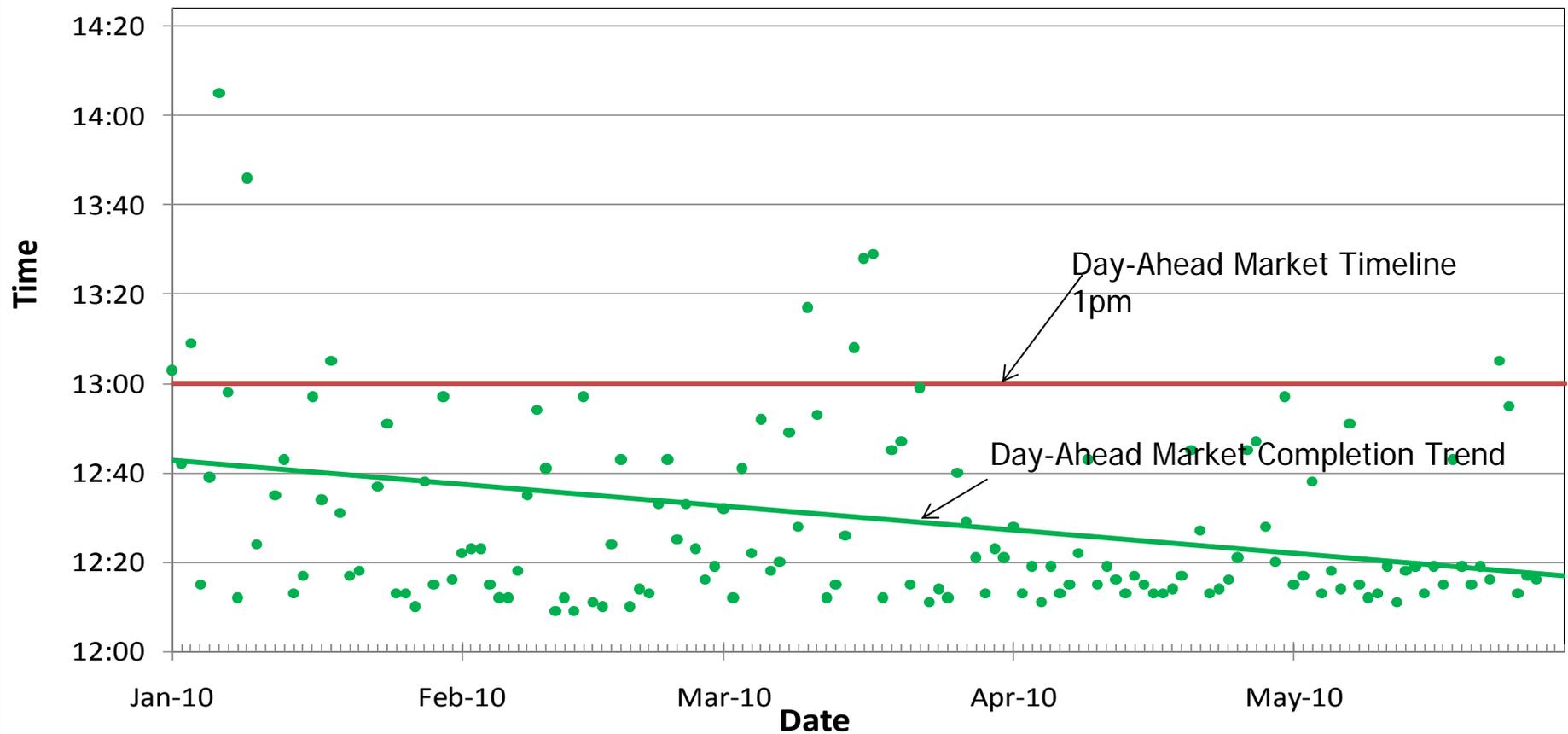


# Exceptional Dispatch volumes continue to decrease as effort to incorporate constraint into the market continues.



# Day-Ahead Market Publish Beats Timelines By an Average of 30 minutes

2010 DA Publish Time



# Real-time market completions have been near 100%.

