CHANGING WHAT'S POSSIBLE

Improved Power Systems Operations Using Advanced Stochastic Optimization AKA *Stochastic Unit Commitment at Scale*

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Project Objectives

- ***Technical objectives – to mitigate the following (valid) criticism of stochastic approaches to unit commitment***
  - ***We can't create sufficiently accurate sets of scenarios to capture load and renewables uncertainty***
  - ***Even if we could create accurate sets of scenarios, the resulting models would be too difficult to solve***
  - ***Even if we could solve the resulting models, it would require significant HPC resources – which is a major impediment to industrial adoption***
- ***Given mitigation of these barriers, does stochastic unit commitment yield sufficient cost and/or reliability savings to warrant industrial adoption?***

Project Progress – CY 2014

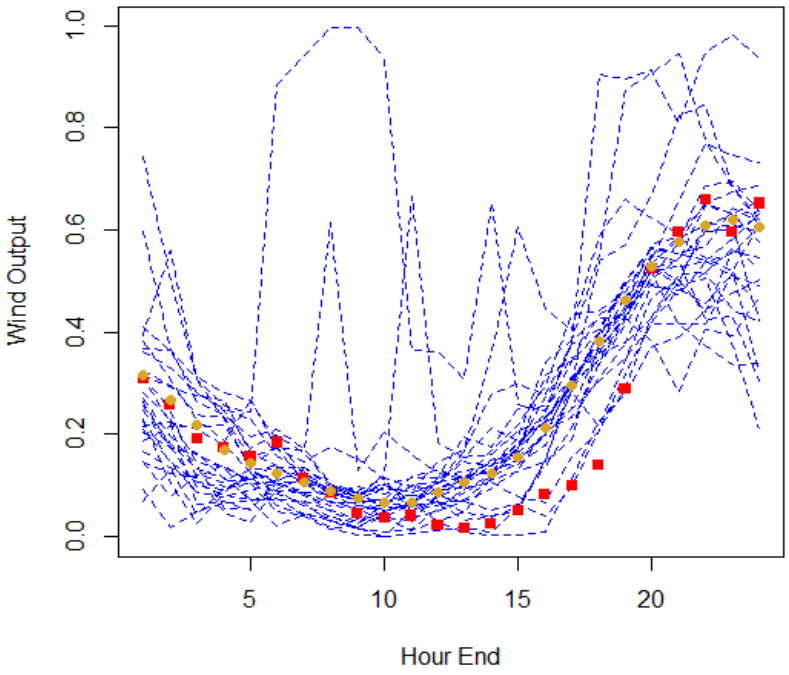
- Year 2 efforts focused primarily on the following:
  - Finalization of wind scenario generation methods
  - Further scaling of the Progressive Hedging (PH) scenario-based decomposition method
  - Extension of analysis from WECC-240 to ISO-NE
  - Computation of cost savings relative to deterministic

Our Scenario Generation Methodology

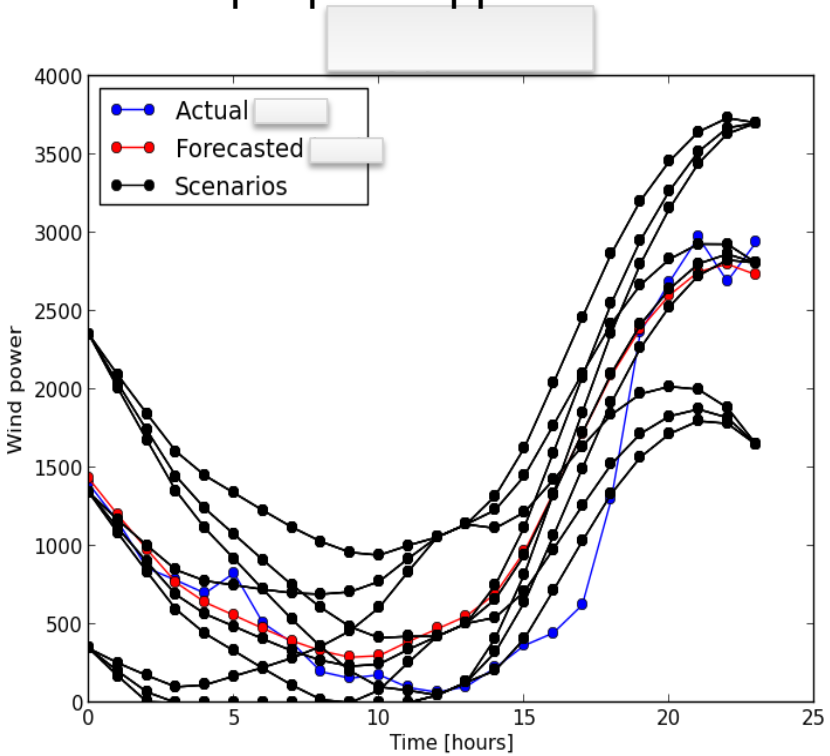
- We can and should leverage the significant volume of historical data concerning load and renewables forecast / actuals
  - Arguably do ***not*** need stochastic forecasts from vendors
  - We can build stochastic models from historical point forecasts
- Stochastic process model accuracy can approach that of state-of-the-art point forecasting techniques
  - But in addition represents variability
- Approximation of stochastic process models, rather than Monte Carlo sampling, can yield significant reductions in the number of scenario required for stochastic unit commitment
  - Enabled by *epi-spline-based* models of stochastic load / wind

Wind Scenario Generation

Scenarios generated using Pinson et al. method



Scenarios generated using our epi-spline approach



Note: Real wind profiles show significant ramps, but not as extreme as those obtained using (e.g.,) the Pinson et al. method

Progressive Hedging Scalability

Table 10 Solve time (in seconds) and solution quality statistics for PH executing on the *WECC-240-r1* instance, with $\alpha = 0.5$, $\mu = 3$, and the MTR deterministic UC model.

# Scenarios	Convergence Metric	Obj. Value	PH L.B.	# Vars Fx.	Time
		64-Core Workstation Results			
3	0.0 (in 36 iters)	64141.771	64109.021	4080	237
5	0.0 (in 23 iters)	62628.532	62499.212	4080	161
10	0.0 (in 26 iters)	61384.016	61327.734	4080	215
25	0.0 (in 41 iters)	60927.903	60850.717	4080	366
50	0.0 (in 11 iters)	60617.311	60470.956	4044	318

ISO-NE results are obtained on Red Sky on average in 10 minutes, 20 minutes in the worst case (with 100 scenarios)

Cost Savings Computation – ISO-NE (1)

- Computed in terms of relative cost increase of deterministic over stochastic (ISO-NE, 20% wind penetration)
  - Yes, this implies that stochastic does win (but)…
- Results in terms of percentages
  - Q1: 1.52%
  - Q2: 1.31%
  - Q3: 0.89%
  - Q4: 1.23%
- Not as significant as we would have anticipated, given the large wind penetration levels
  - Lots to say (but not here) about pricing reserves
  - Forecasts and actuals “too” correlated?

Cost Savings Computation – ISO-NE (2)

- Translating percentage savings into dollars…
  - Q1: ~$4M per month
  - Q2: ~3M per month
  - Q3: ~$12M per month
  - Q4: ~$2.5M per month

- Overall, the savings in 2011 “would have been” $64.5M

- That is real money
  - Compare to PJM projections for cost savings associated with adoption of MIP solver technologies

Natural Gas Prices Over Time…

Cost Computation: Observations

- Stating the obvious
  - The cheap price of natural gas in 2011 *significantly* impacts the overall cost savings numbers we observe
- Most of the stochastic unit commitment literature still assumes that natural gas / peaker units drive costs when making up for discrepancies between forecasts and actuals
  - Which would be true with 2000 through 2008 gas prices
  - Current prices are 25% lower (at least) relative to that period
  - It now costs very little to be wrong for deterministic UC
- Almost all of the cost savings are due to natural gas units
  - Would significantly impact absolute dollar savings
  - Would impact percentages; not sure to the degree
- We are partially a victim of bad timing
  - If we had used 2008 data…

Overall Project Accomplishments

- We have largely removed the *technical* barriers to industrial adoption of stochastic unit commitment methods
  - We can generate scenarios quickly and efficiently
    - Using data utilities already possess
  - We can solve the resulting optimization models in reasonable (max 20 minute) run times
    - Vendors could do *much* better
  - We can do this on commodity hardware

- We have established a baseline cost savings figures for stochastic versus deterministic unit commitment at scale

Technology-To-Market

- In-Progress
  - Funded follow-on projects leveraging advanced technologies developed under this project
    - DOE EERE / Sunshot
    - DOE OE / Storage
  - Studies with vertically integrated utilities
    - To mitigate market issues
    - Already have significant renewables penetration

- Strengthening the business case is a major challenge
  - Technical challenges have been largely overcome

Post ARPA-E Plans and Goals

- Enhance the business case for stochastic unit commitment
  - Actively working with APS on high-penetration solar study
  - Beginning engagement with CPS
- Execute public release of tool chains and data sets
  - Under EERE / Sunshot
    - Pending Copyright Assertion
- Continue methodological advances to support
  - Multi-stage scenario generation and optimization
  - Continual look-ahead commitment operation
- Focus on addressing the market versus VIU issue
  - Critical to realizing full cost savings potential

Conclusions

- We have developed rigorous techniques for addressing the key deployment barriers to stochastic unit commitment
  - We can generate very accurate load and wind scenarios
  - We can solve the models in tractable (minute) run times
  - We don't need high-performance computers to do so

- Initial cost savings results indicate savings in the 1-3% range, depending on system specifics
  - Work remains in the area of reserves integration and costing, and to improve the business case