



Optimizing Wind Generation in ERCOT Nodal Market

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Efficiency through Improved Software - June 23-25, 2014

Agenda

- **Overview of ERCOT**
 - Wind in ERCOT
 - Operational Challenges
- **Wind Scheduling in ERCOT Nodal Market**
 - Day-Ahead Market (DAM)
 - Reliability Unit Commitment (RUC)
 - Real Time Market (RTM)
- **Improvements due to better handling of wind**
- **Summary**

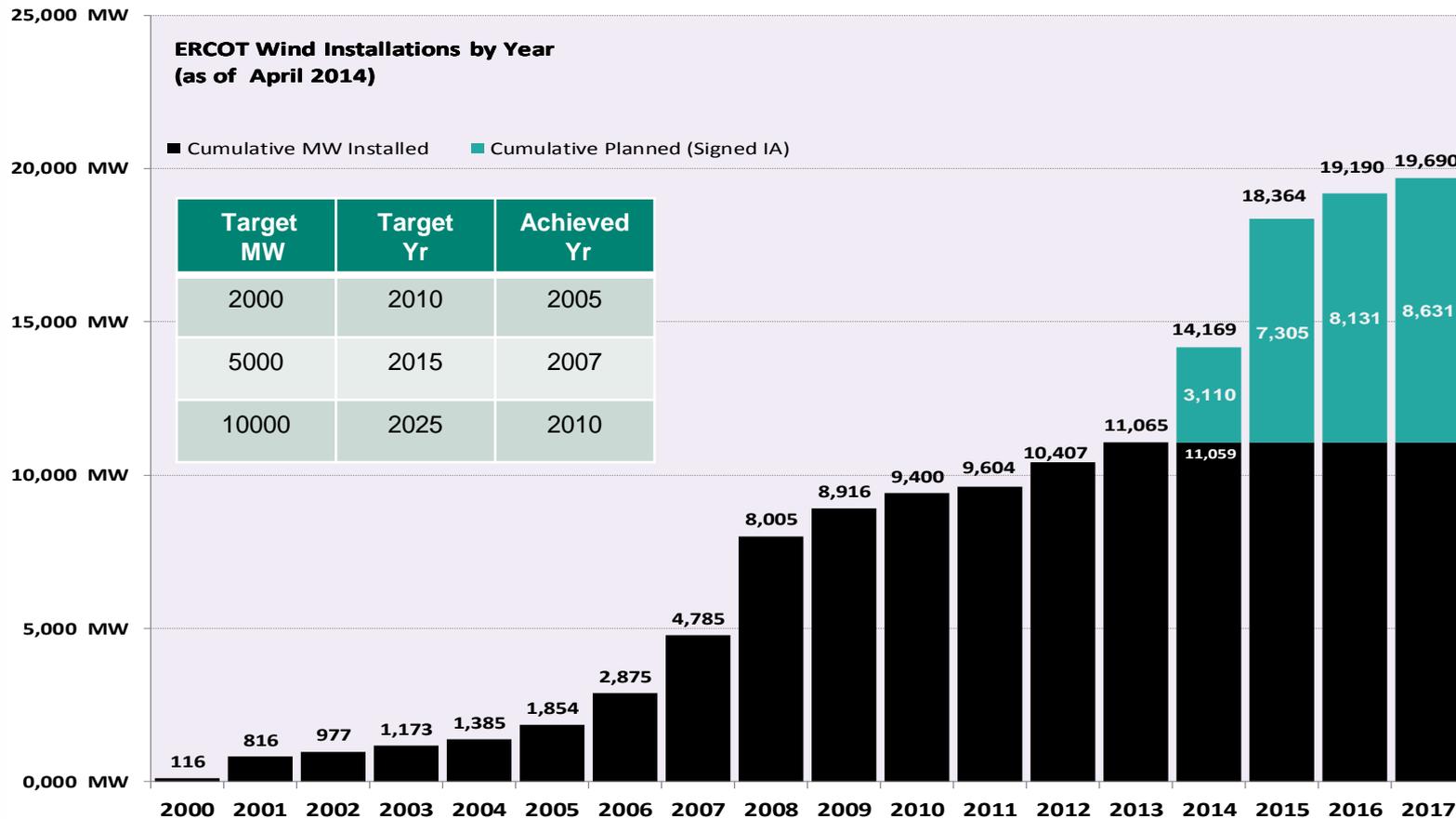


ERCOT

- 85% of Texas load
 - 24 million consumers
- 40,530 circuit miles of high-voltage transmission
- 74,000 megawatts (MW) capacity for peak demand
 - From 550 generation resources
 - With 8.7 % Wind capacity included
 - 11,059 MW Wind Capacity
- 68,305 MW peak demand (Aug.3, 2011)
 - Peak Wind 10,296 MW (March 26 , 2014)
- \$33 billion Market
 - ~1,100 active Market entities
- 73% of load are competitive-choice customers
 - 179 competitive retailers
- Nodal market completed three year of operation on Dec. 1, 2013
- Extensively working on ensuring Resource Adequacy



ERCOT Wind Generation



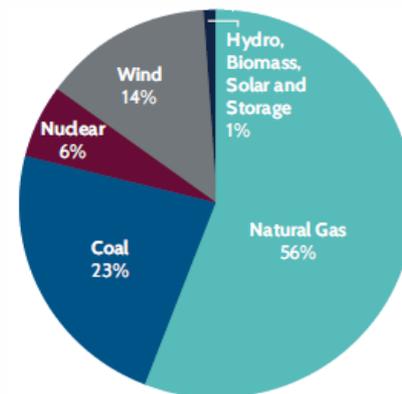
The data presented here is based upon the latest registration data provided to ERCOT by the resource owners and can change without notice. Any capacity changes will be reflected in current and subsequent years' totals. Scheduling delays will also be reflected in the planned projects as that information is received.

This chart reflects planned units in the calendar year of submission rather than installations by peak of year shown.

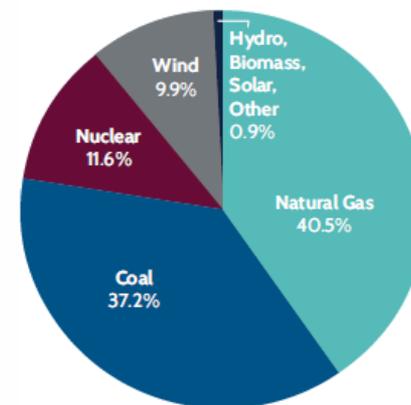


ERCOT Wind Generation

- 11,059+ MW of installed wind capacity
 - Significant amount of additional MW being reviewed
- Wind generation record of Peak Wind 10,296 MW (March 26 , 2014)
 - 29% of system load
- Improved transmission, market rules and operator tools allowed more energy from wind to be generated

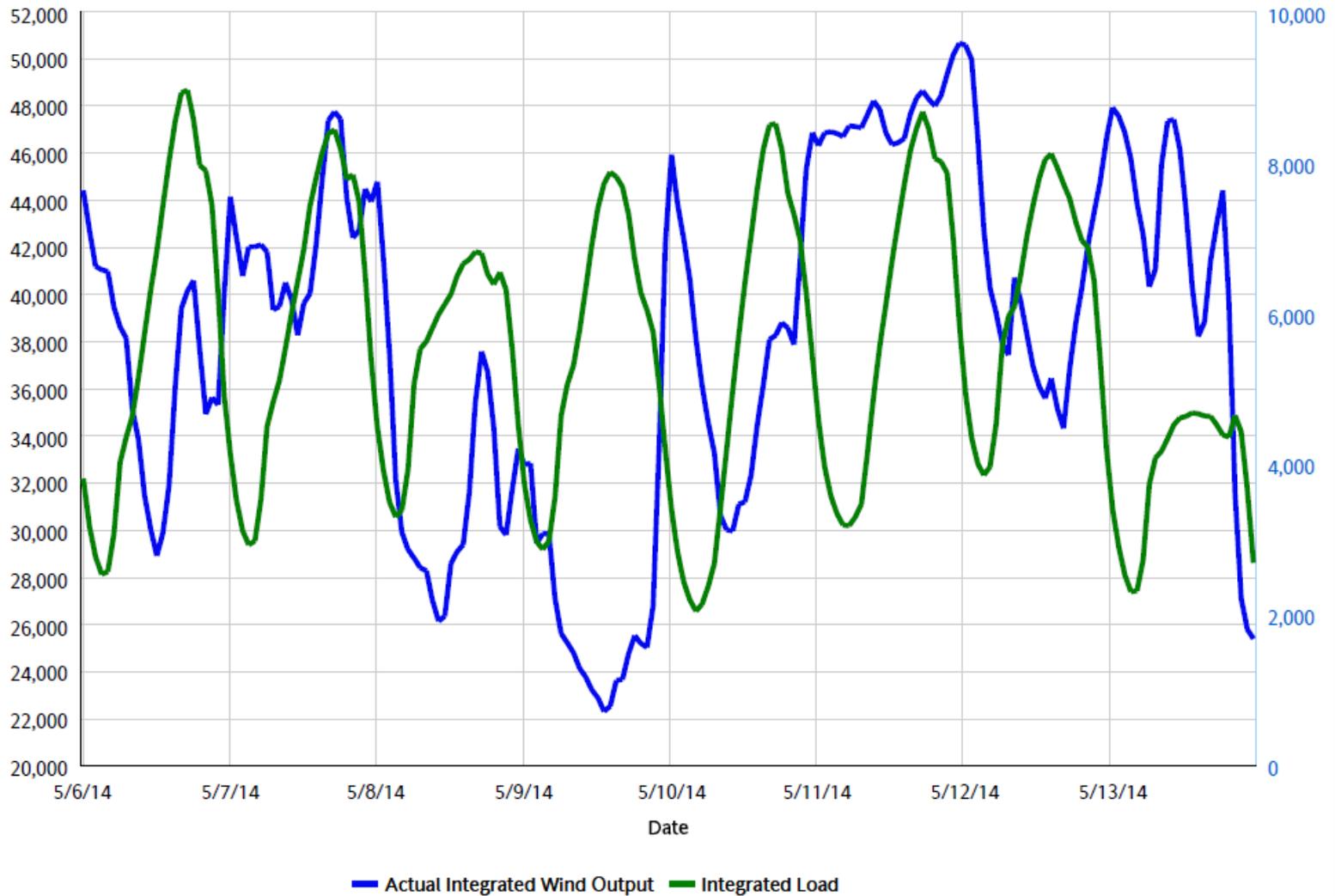


2014 Generation Capacity
effective January 2014

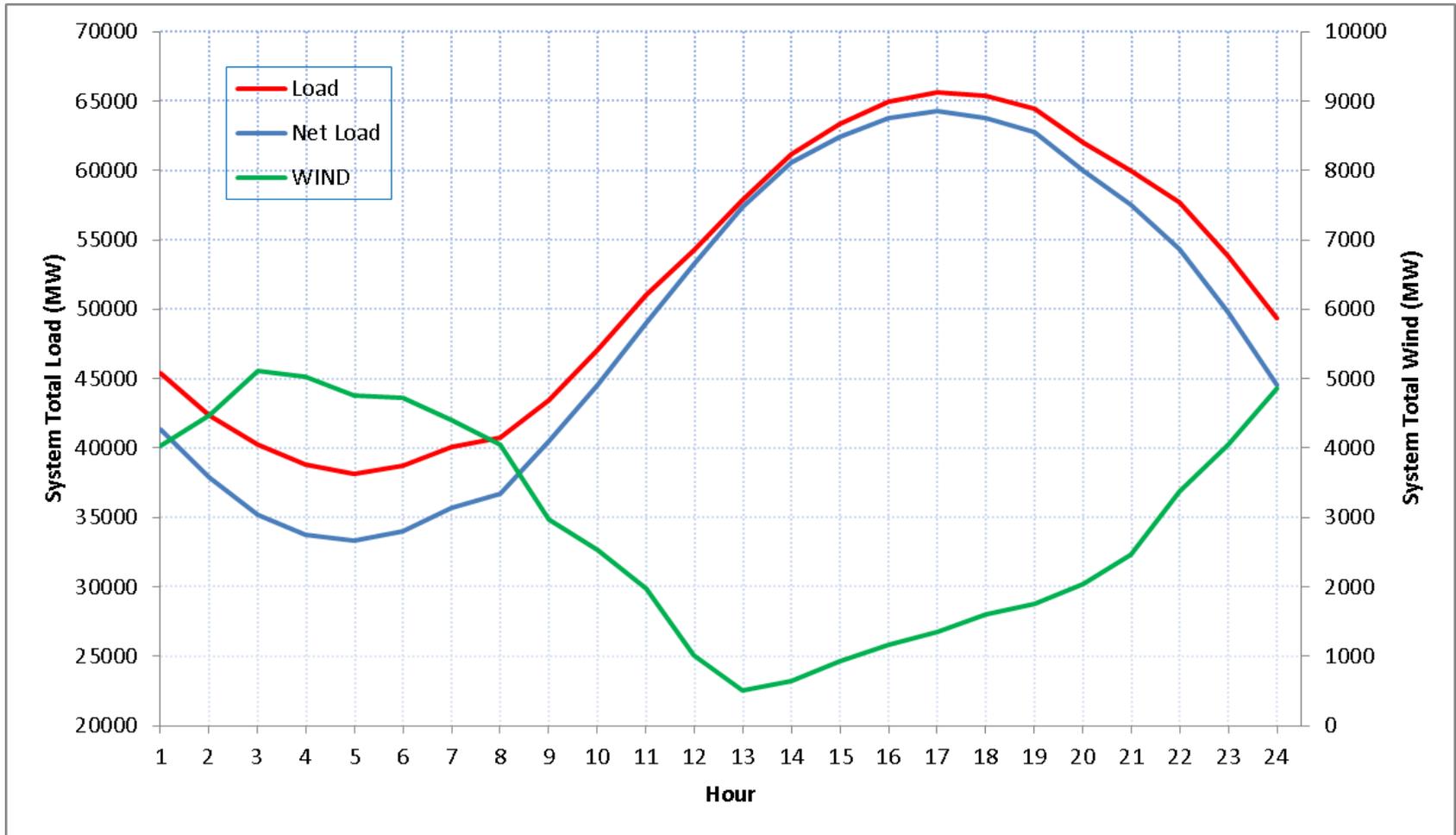


Energy Use 2013*
*Totals >100% due to rounding

Wind Pattern in ERCOT



Wind Pattern in ERCOT



ERCOT Wind Generation vs. System Load on a typical peak day

Operational Challenges due to High Wind

- Inadequate transmission for projected wind growth
- Constraint management under high and low wind
- Higher frequency deviations due to large system excursions
- Difficulty in managing transient stability due to reduced inertial response
- Increased variability of net load
- Higher Ancillary Service Requirement
 - Increased Non-Spin for forecast error of net load
 - Increased Regulation due to increased net load variability
- Increased volatility in prices
 - Lower average system wide energy prices
 - Lower average Real Time prices in West Zone
 - Higher Day-Ahead premium in West Zone



Wind Input to ERCOT Markets

- **Wind Forecasts**

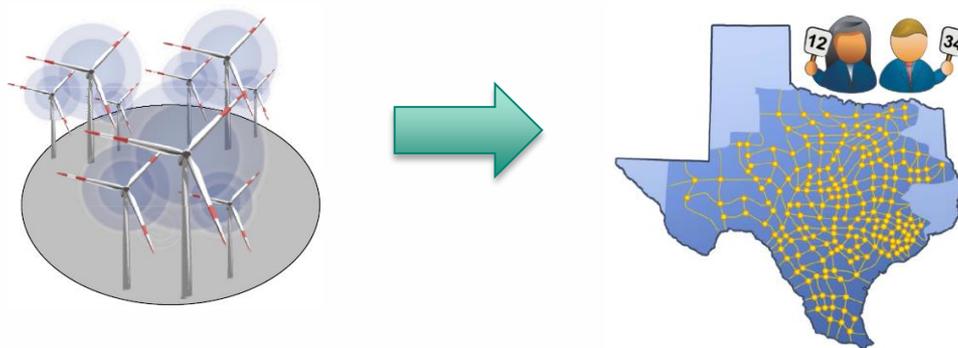
- Hourly forecasts for a rolling 48-hour in both system level and individual Wind-Powered Generation Resource (WGR) level
- Total ERCOT Wind Power Forecast (TEWPF):
 - probability distribution of the hourly production potential from all wind-power in ERCOT for each of the next 48 hours
- Short-Term Wind Power Forecast (STWPF):
 - 50% probability of exceedance forecast
- Wind-powered Generation Resource Production Potential (WGRPP):
 - 80% probability of exceedance of the TEWPF

- **Current Operating Plan (COP)**

- Anticipated operating conditions for next seven Operating Days
- WGRs are required to keep High Sustained Limit(HSL) in COP updated to less than or equal to the most recent STWPF for the first 48hrs

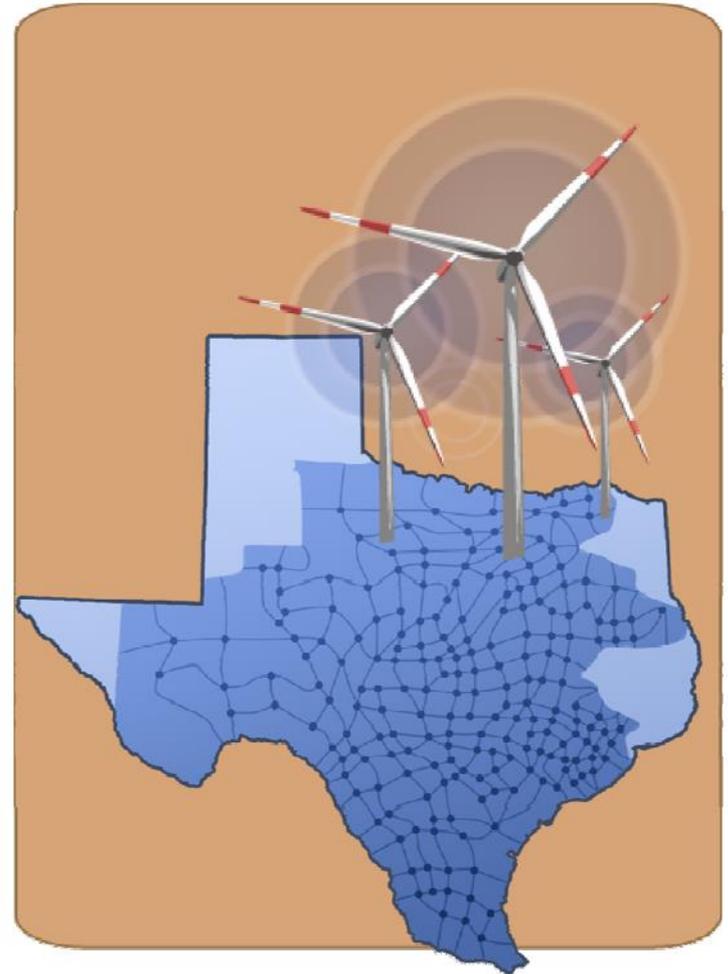
Wind in Day-Ahead Market

- The QSE representing WGRs may participate in DAM for wind scheduling by submitting one of the following offers or bids in DAM:
 - Three-Part Supply Offer to sell energy for the physical WGR
 - Virtual Energy Only Offers to sell or Bids to buy at the WGR Settlement Point
 - CRR Point to Point (PTP) Obligation Bids with source or sink at the WGR Settlement Point
- Physical offers are cleared based on HSL from COP

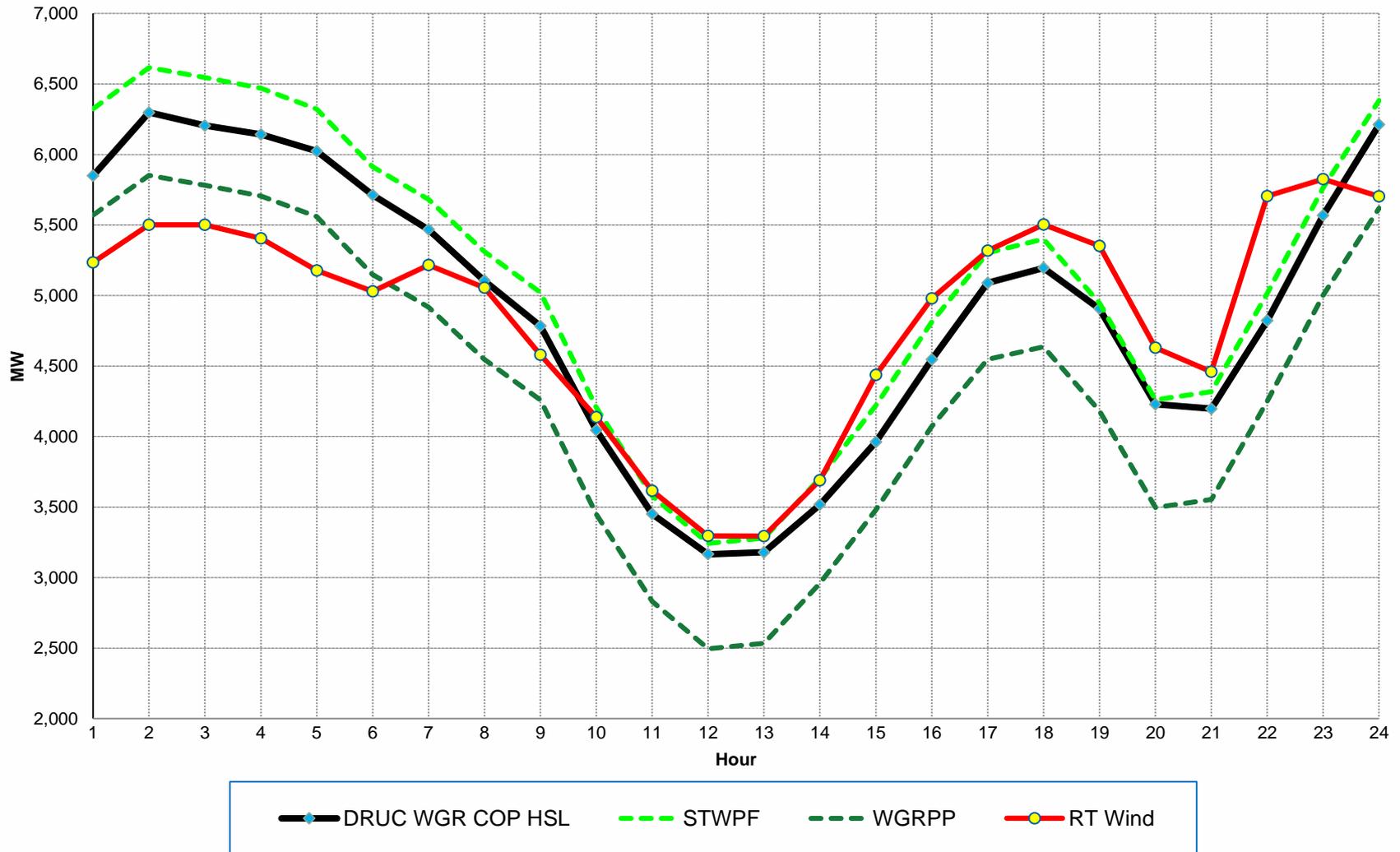


Wind in Reliability Unit Commitment

- WGRs are required to participate in RUC by submitting a valid COP
- The full capacity up to HSL of WGR is considered available to be dispatched in RUC
- WGRPP value used in the RUC for each WGRs is considered the available capacity of the WGR when determining capacity-short RUC charges, regardless of the real-time output of the WGR



Wind Scheduling in DRUC

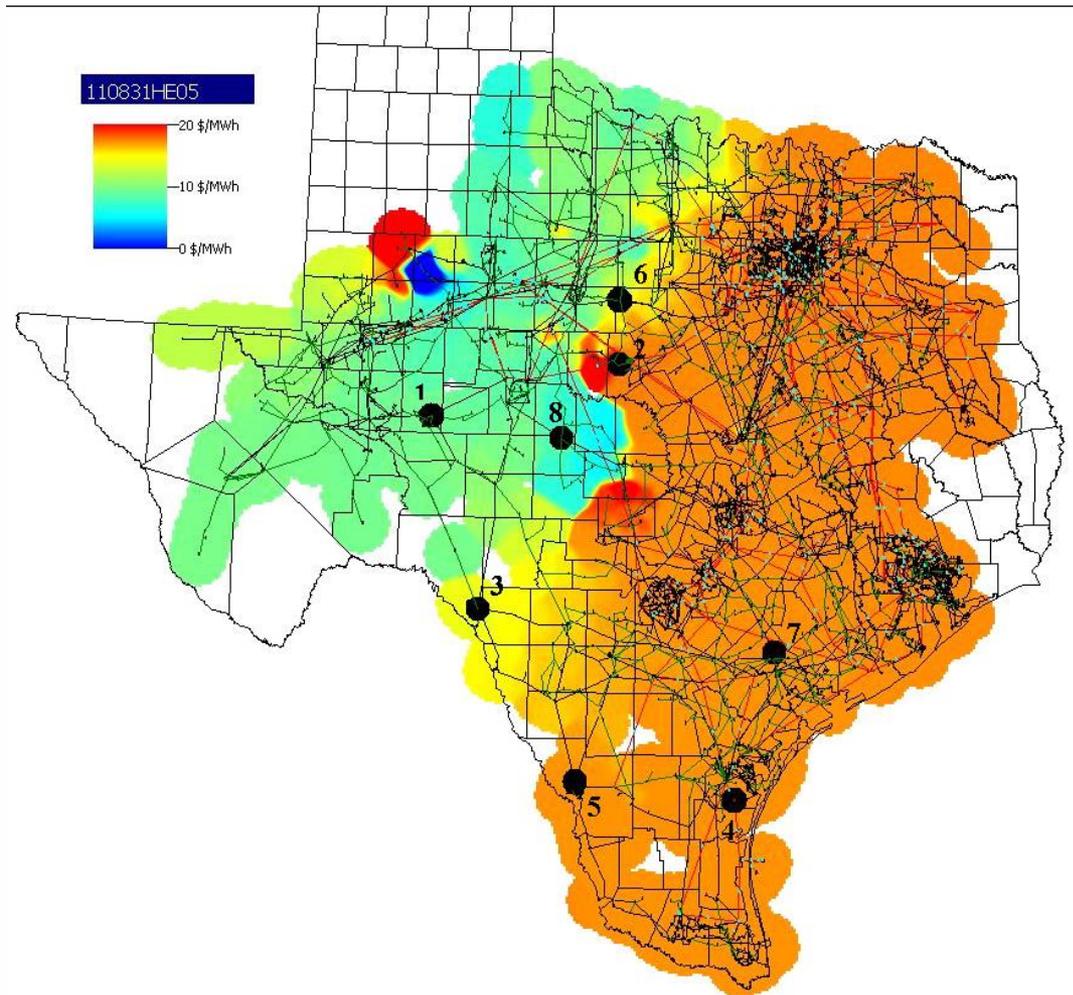


Improvements in DAM/RUC for Wind

- Optimize the Phase Shifter tap in DAM/RUC
 - Initially used fixed tap position for each hour for each Phase Shifter based on the WGR forecast and system load condition 2 days ahead of operating day
- Hourly absolute phase shifter tap positions are modeled as control variables in the optimization engine of Security Security Constrained Unit Commitment (SCUC)
- Shift factor of phase shifters with respect to the transmission constraint is defined as MW/tap
 - i.e. the MW flow change on the constraint with respect to each tap position change
- Cost function of phase shifter tap position is modeled as a cost of tap position changes to the initial position

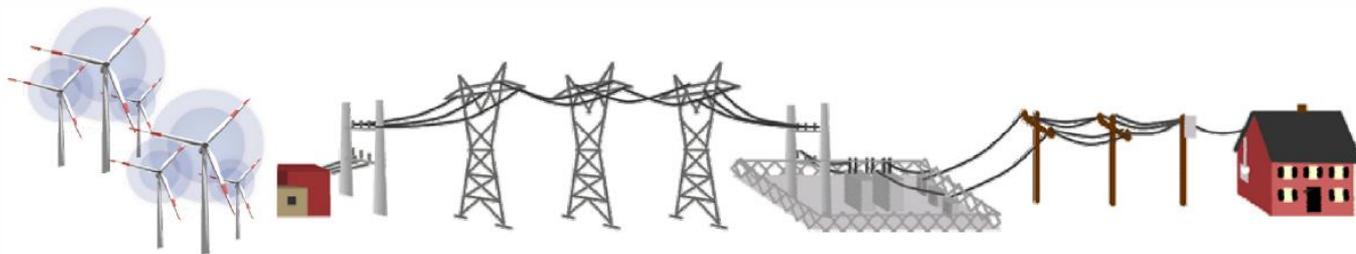
Phase Shifters in ERCOT

- Majority of the Phase Shifter in ERCOT relieves transmission overloads caused by variations in wind generation
- The maximum degree change for each of the phase shifters is $\pm 1.875 * 16 = \pm 30$ degree
- Optimization of these phase shifter tap positions helped remove unrealistic congestion in DAM and RUC



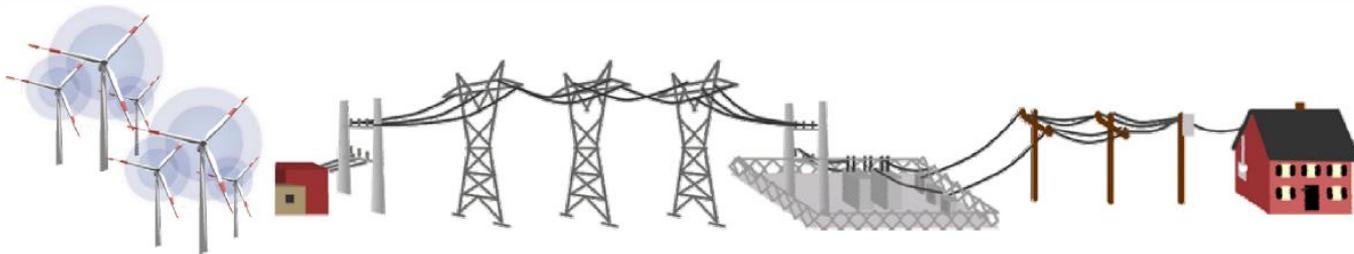
Wind in Real-Time Market

- RTM re-dispatch generation every 5 minutes based on current WGR output to take care of net load variability
- RTM issues WGR specific curtailment instruction for managing congestion
- WGRs are required to
 - follow Base Points if the curtailment flag is set and
 - automatically release from curtailment under low frequency
- WGRs are charged a fine if they generate more than 10% of their Base Point when they are curtailed unless it is aiding frequency



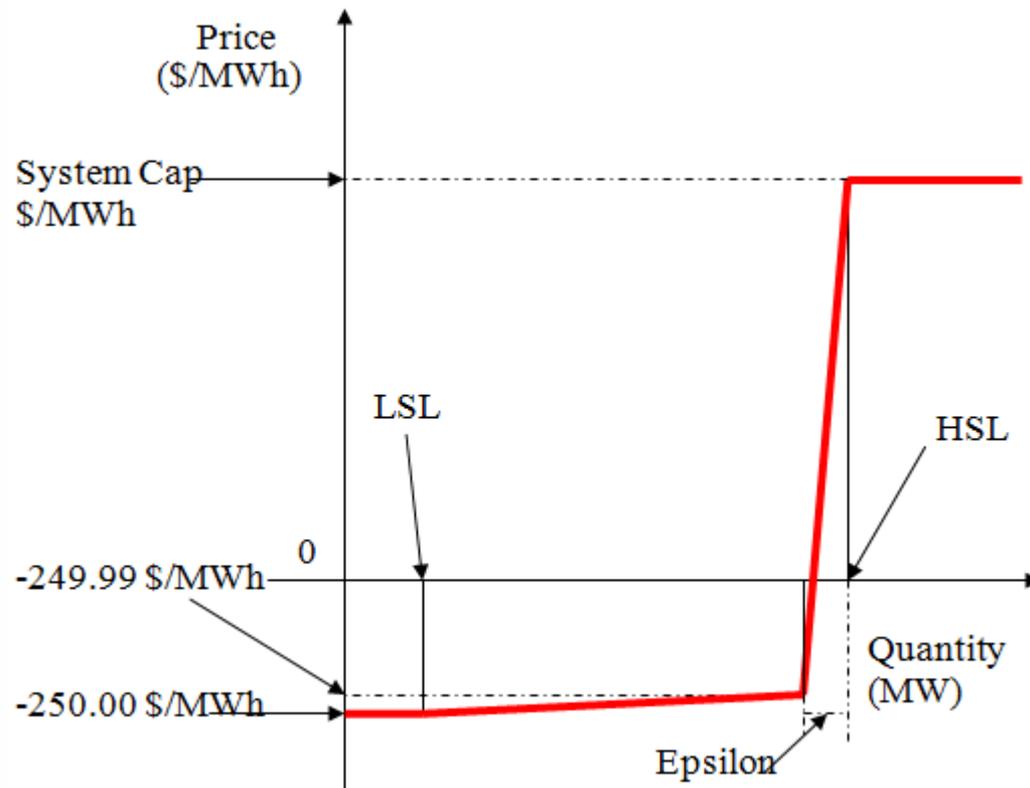
Wind in Real-Time Market

- In Real-Time, WGRs are required to
 - offer in their full capacity
 - telemeter HSL equal to current net output of the facility
 - limit its ramp rate to 20% per minute of its nameplate rating as registered with ERCOT when responding to or released from an ERCOT deployment
 - limit its ramp rate to 25% per minute of its nameplate rating as registered with ERCOT anytime

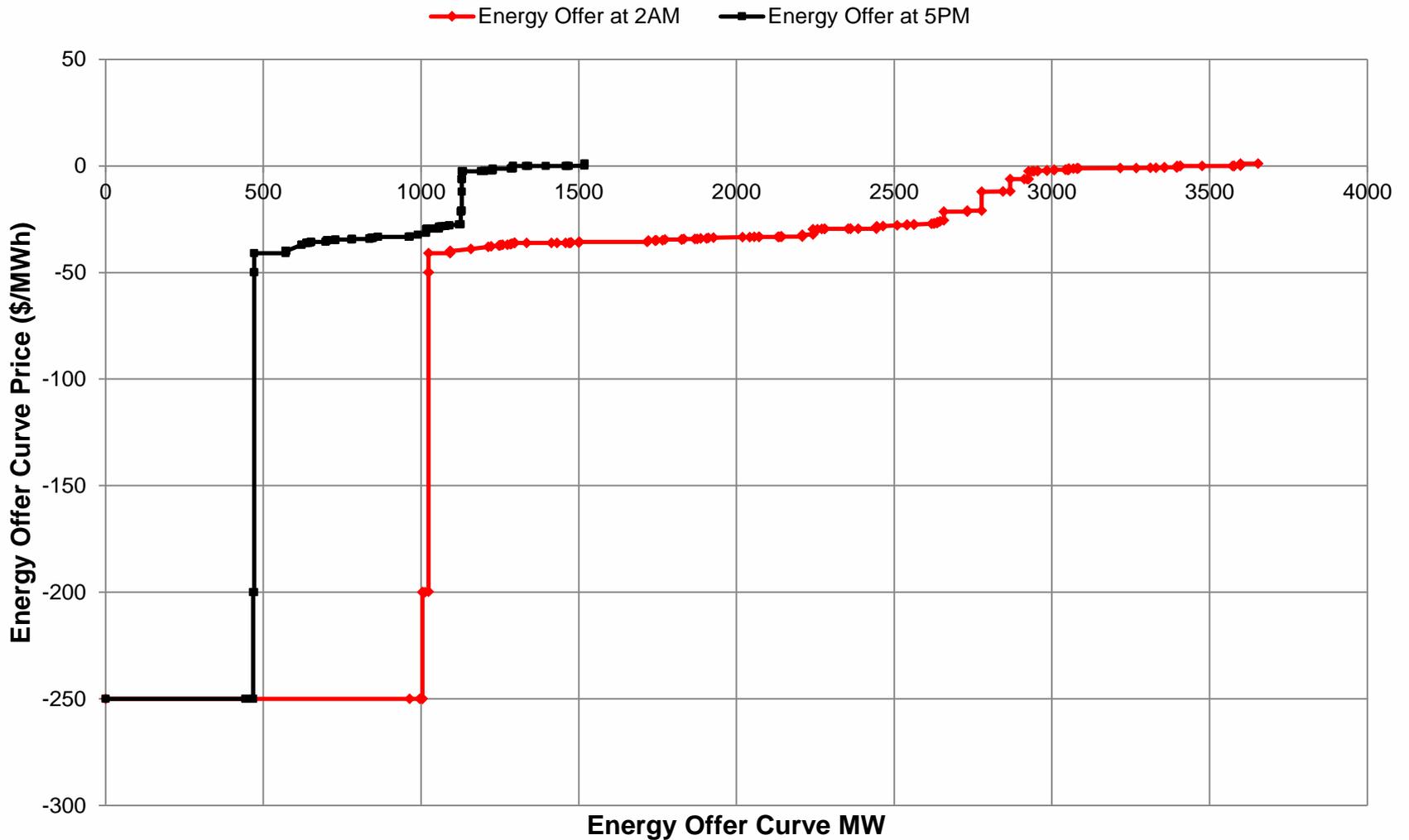


Real Time Proxy Offer Curve for Wind Resources

- If a Wind Generation Resource did not submit Energy Offer Curves in Real-Time Market, SCED market clearing engine will create a Proxy Offer Curve for it



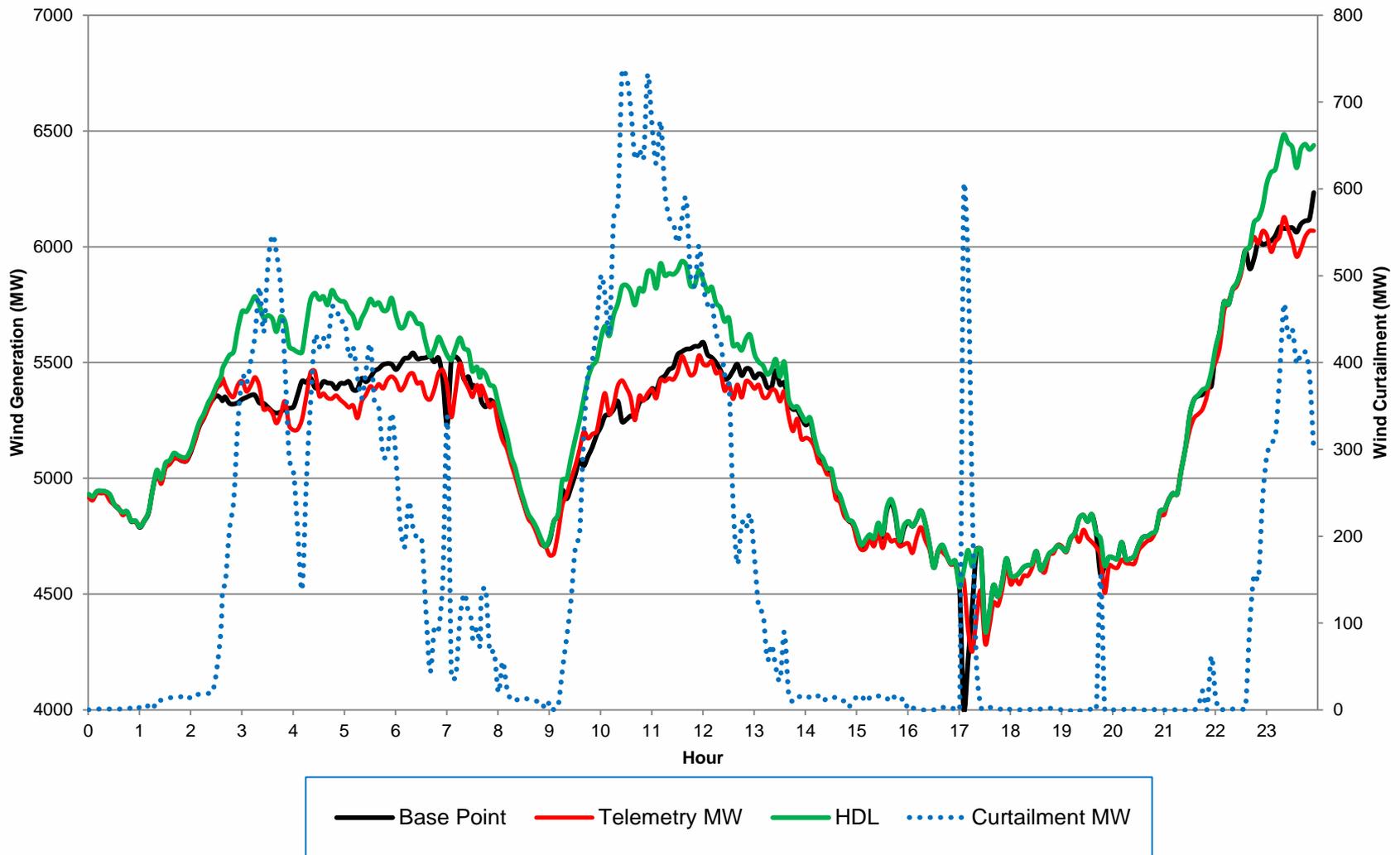
Typical Wind Aggregated Energy Offer Curve



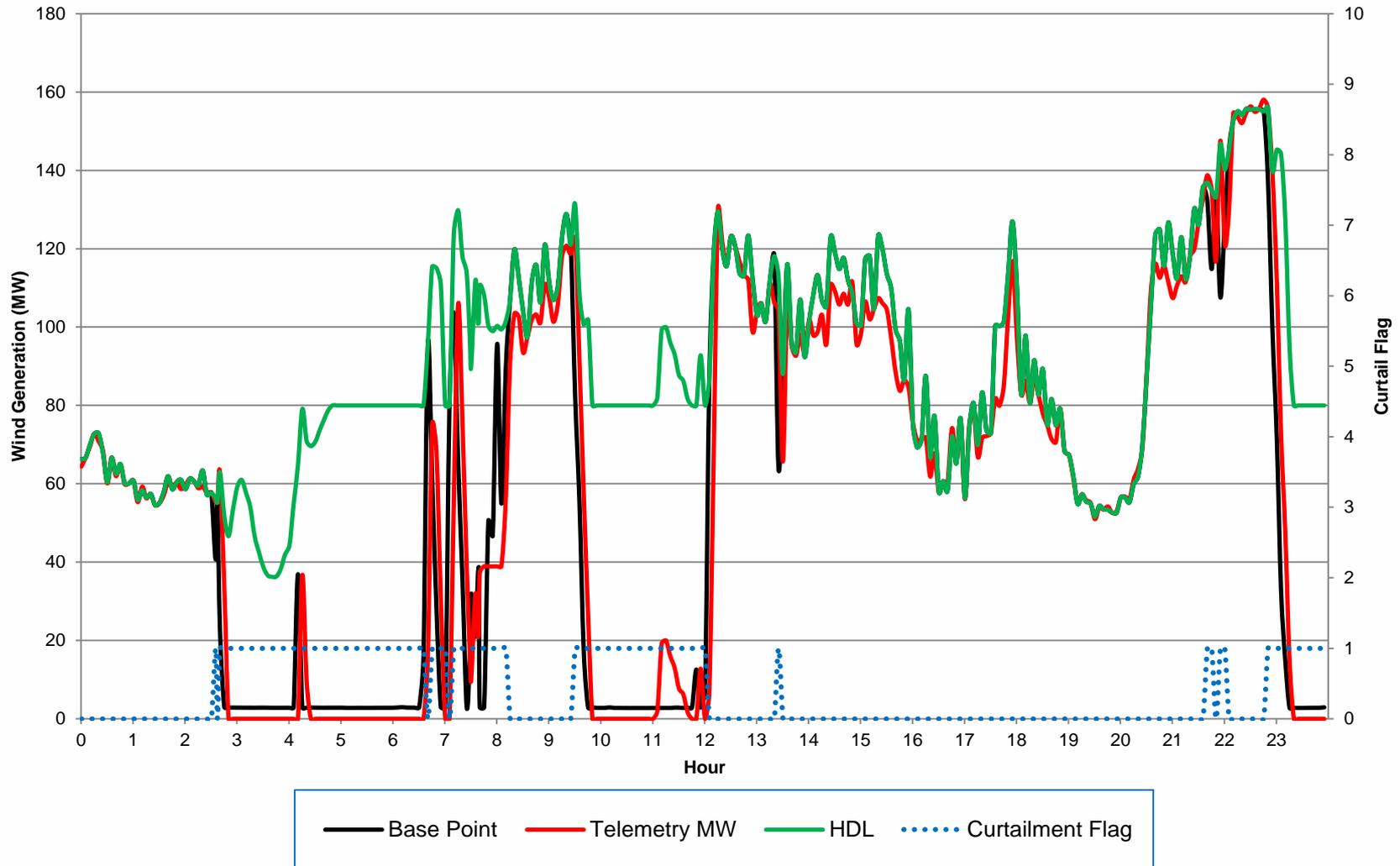
Improvements in RTM for Wind

- Implemented a flag to indicate when a WGR was curtailed
- Initially WGRs were required to
 - Set HSL to current net output capability after each RTM run and hold it constant until the next RTM run
 - consider the WGR as curtailed if the base point from RTM was less than HSL minus 2 and not curtailed if base point from RTM was greater than HSL minus 2
- Changed to
 - Telemeter HSL as current net output capability all the time
 - Consider as curtailed and follow Base Point if the curtailment flag is set

System Wide Wind Generation Curtailment



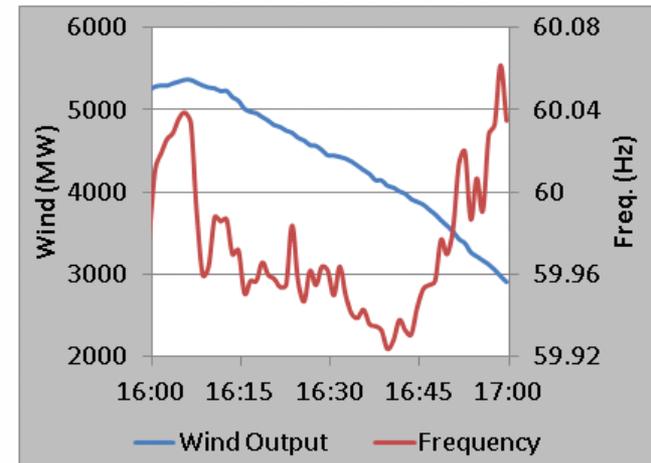
Real Time Curtailment of Single Wind Resource



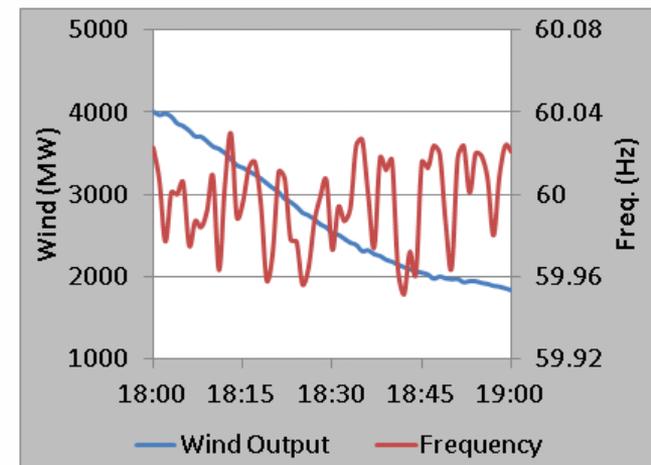
Enhanced Ability to Manage Volatility

- The Nodal Real-Time Market design has resulted in more stable frequency control
- The Graphs illustrate an observed 2000 MW drop in wind under both designs:
 - Under the Zonal design the frequency fluctuated ± 0.08 Hz
 - Under the Nodal design the frequency fluctuated ± 0.04 Hz

Wind Ramp in Zonal

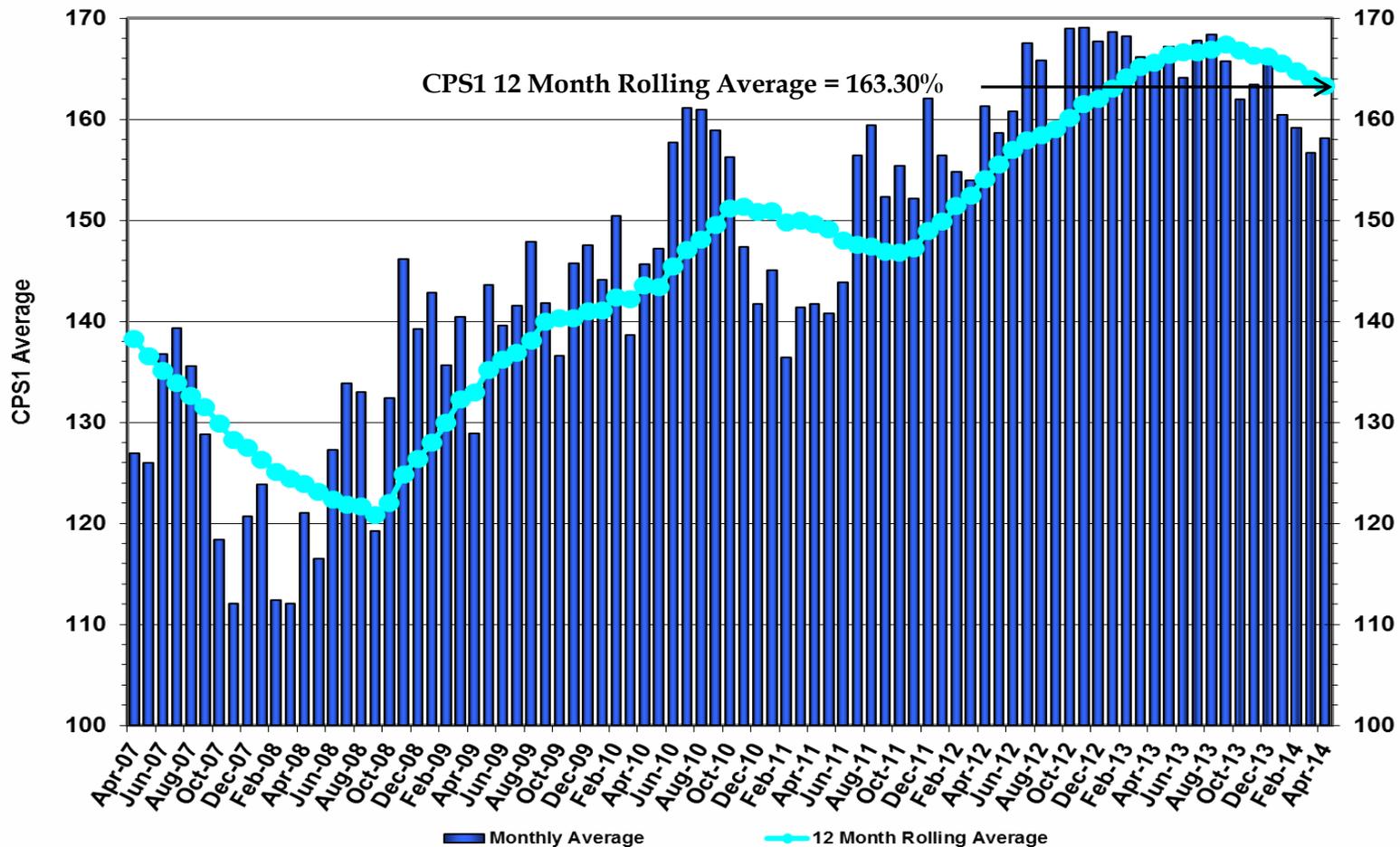


Wind Ramp in Nodal



Better Frequency Control Performance

ERCOT's recent NERC CPS1 scores shows control improvements



Summary

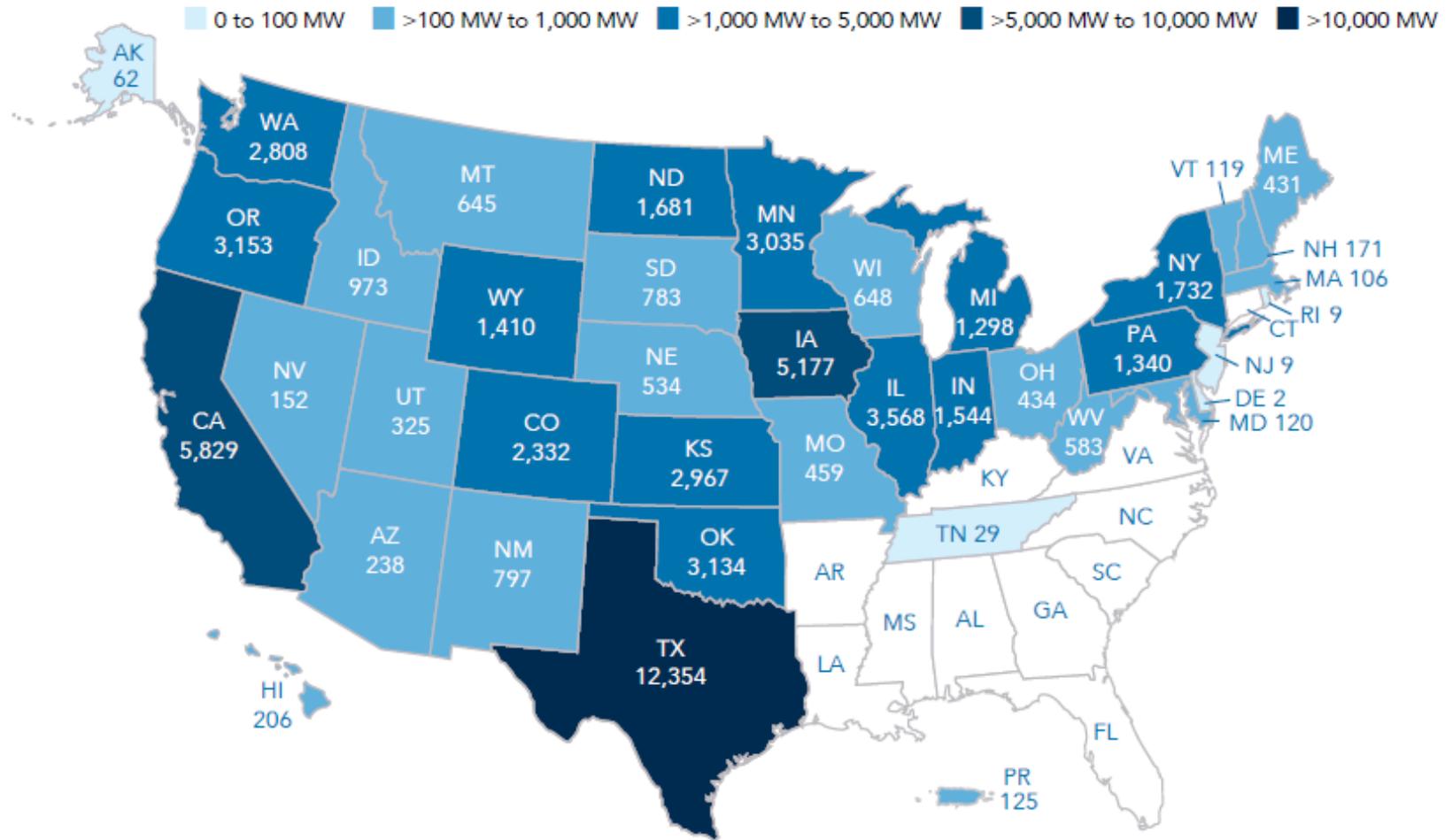
- Texas continues to explore more wind power capacity
 - more than 11,000 MW of commercial wind power capacity installed
 - nearly 8,000 MW of new projects in development
 - more than 26,700 MW under study.
- Special rules and system improvements made for wind generation resources resulted in better utilization of the available wind capacity while maintaining reliability
 - Running RTM every 5 min based on current Wind Resource production
 - Proxy offers at -\$250,
 - WGR specific curtailment signals,
 - Requiring WGRs to follow Base Point and implementing deviation charges
 - Putting ramp restrictions
 - Requiring WGRs to provide primary frequency response
 - Phase shifter tap optimization,



Appendix



Wind Generation in U.S.



Source: www.awea.org