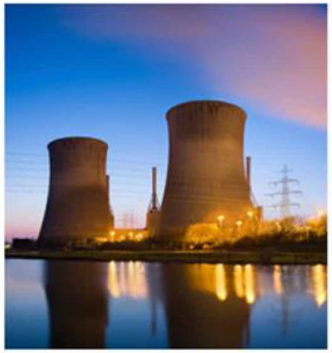
NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Efforts to Maintain Adequate Frequency Response

NERC Frequency Response Initiative

NAGF Annual Meeting
October 5, 2016

RELIABILITY | ACCOUNTABILITY

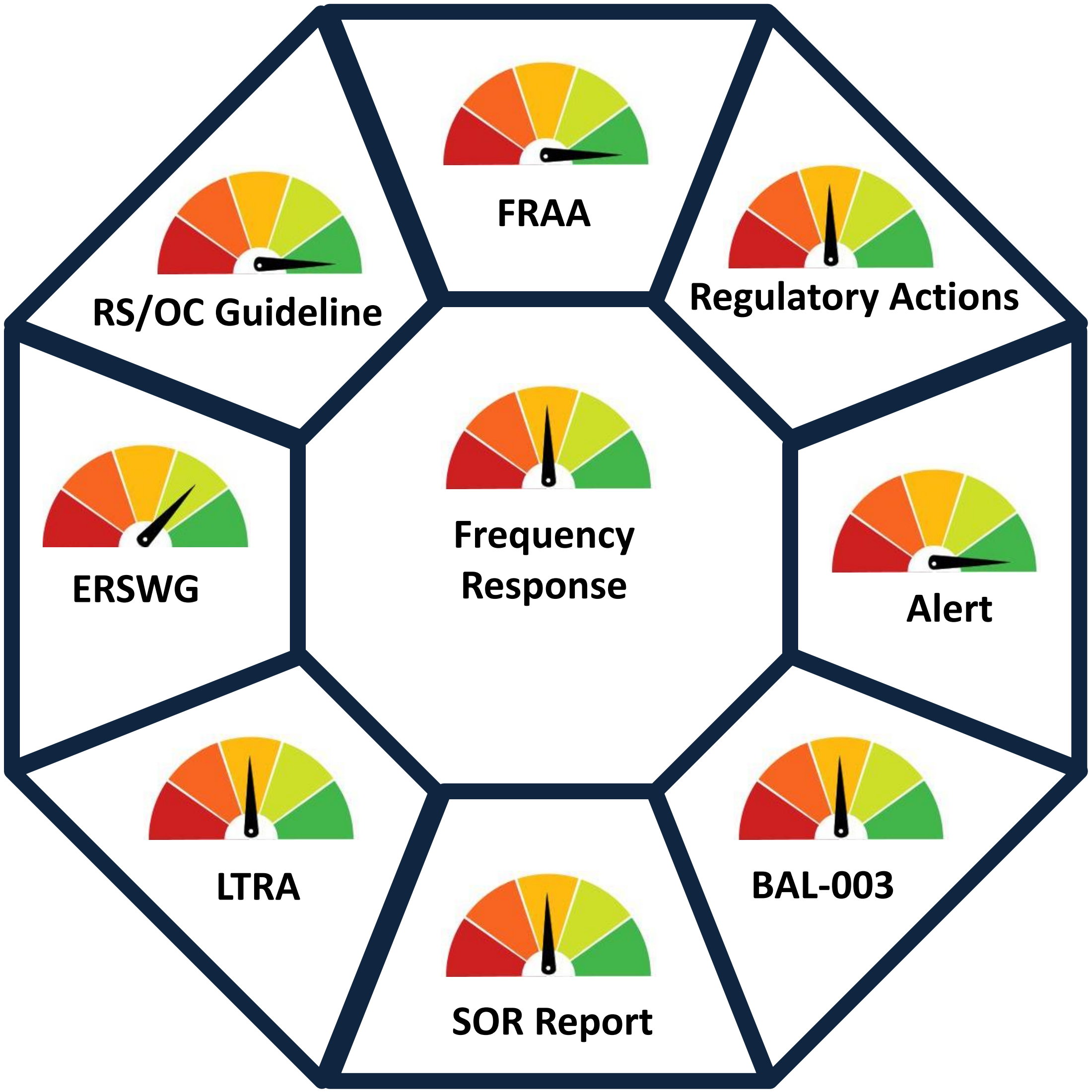
What is the Frequency Response Initiative?

- Started in 2009
- Technical studies to support development of BAL-003-1
- 2012 Frequency Response Initiative Report – The Reliability Role of Frequency Response
  - Explained Frequency Response
  - Analyzed resource loss contingencies
  - Method to calculate Interconnection Frequency Response Obligations (IFROs)
  - Method to measure Frequency Response performance
  - Examined state of generation fleet governors
  - Called for NERC Frequency Response Resource Guideline to define the performance characteristics expected for supporting reliability
- Frequency Response Annual Analysis reports
- Ongoing analysis of frequency and frequency response

Current Efforts

- Monitoring of ERS Measures
  - Long-Term Reliability Assessment
  - State of Reliability Report
- NERC-ERAG Assessment on Frequency Response in Eastern Interconnection – More discussions tomorrow
- ERSWG Development of Sufficiency Guidelines
- Expansion of NERC Reliability Guideline on Primary Frequency Control to include electronically-coupled resources
- Coordinating with IEEE on the frequency response requirements in their Standard 1547 for Distributed Energy Resources

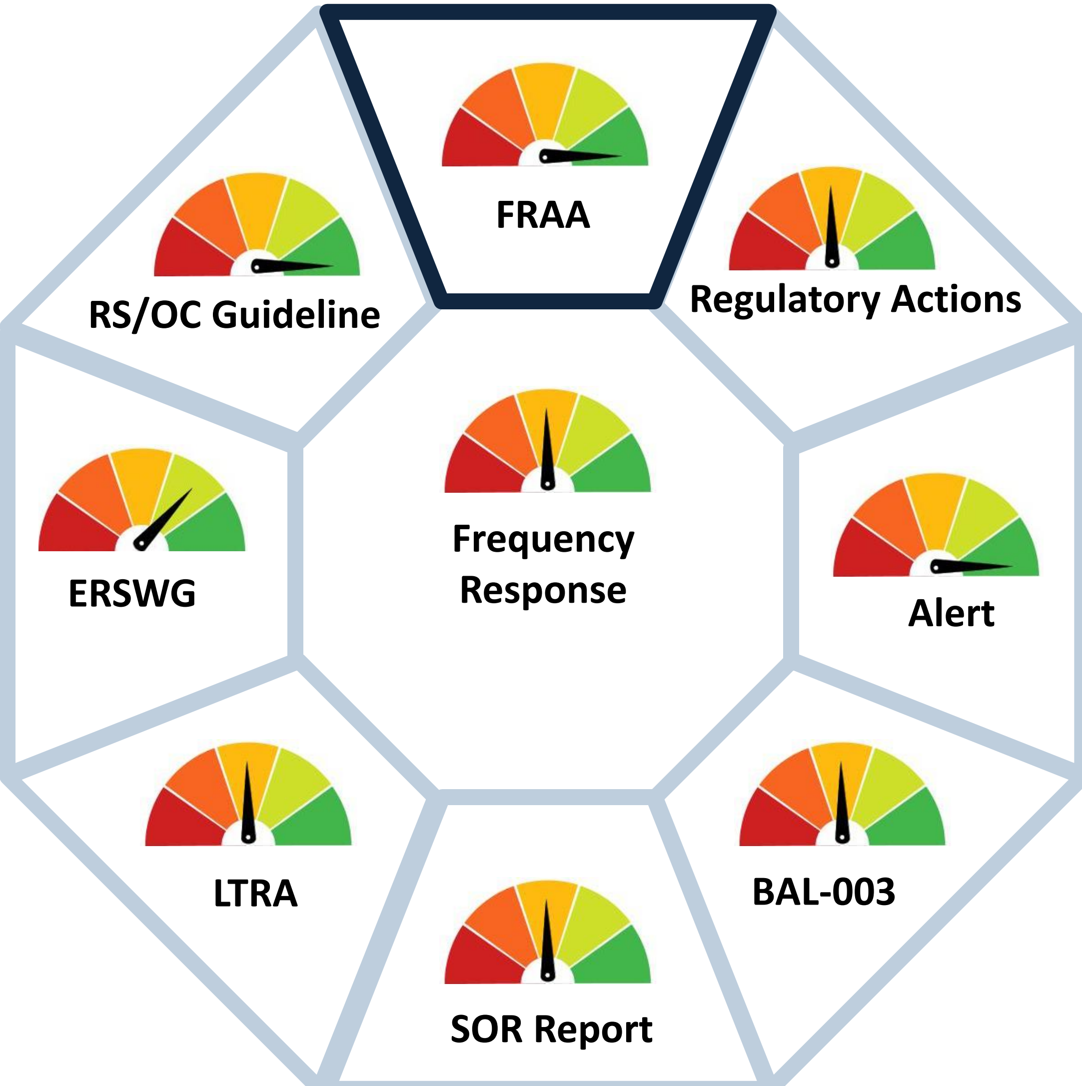
Many Moving Parts



- Providing desired effect (green)
- Providing some desired effect (yellow-green)
- Currently inconclusive (yellow)
- Potentially negative effect (orange)
- Not providing desired effect (red)

****Dial positions are for discussion purposes****

Many Moving Parts

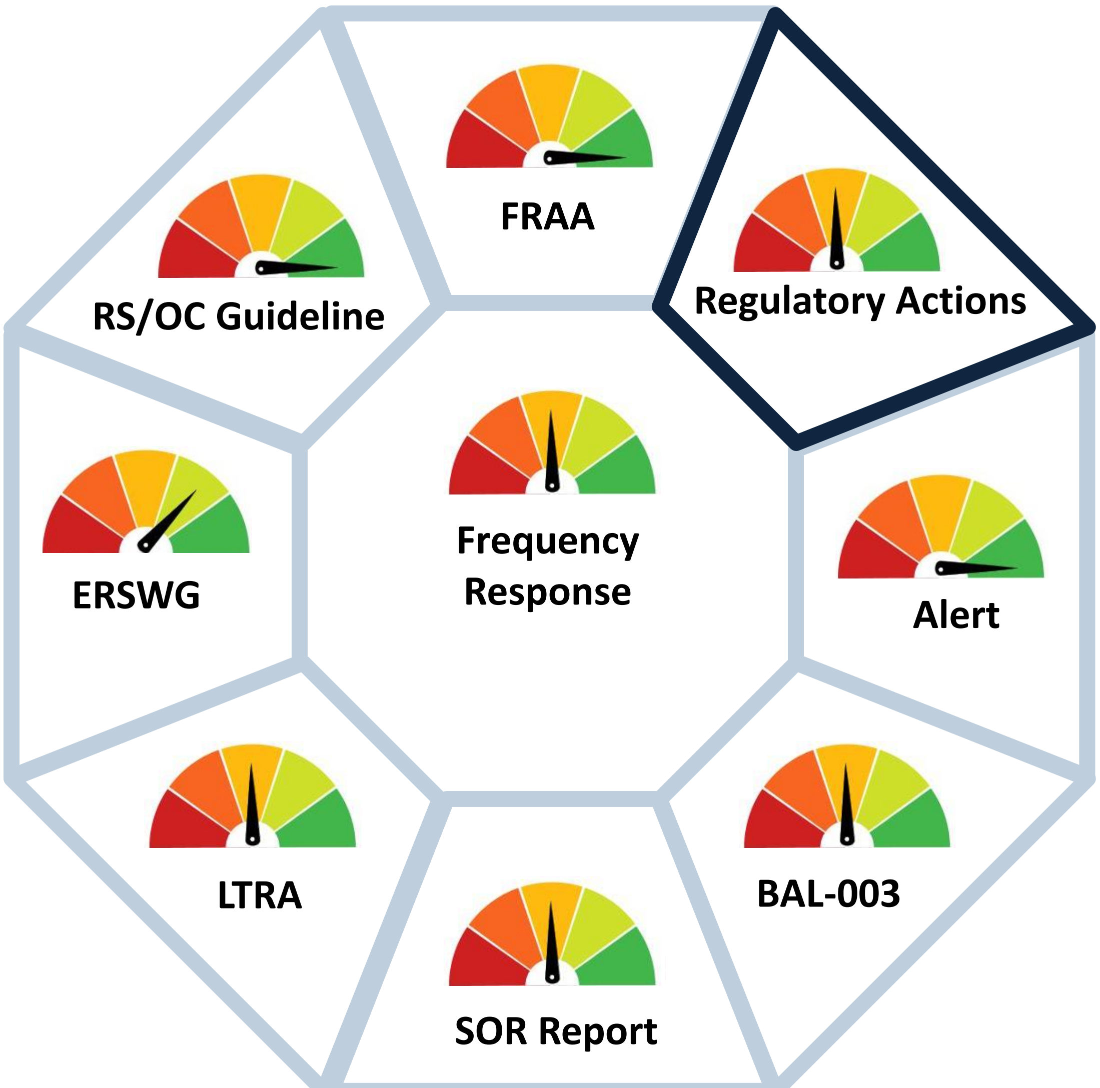


Frequency Response Annual Analysis (FRAA)

Complete and Ongoing

- NERC System Analysis group develops an annual frequency response report for all interconnections.
- FRAA establishes the Interconnection Frequency Response Obligation (IFRO) and Balancing Authority Frequency Response Obligations (BA FRO).
- 2016 FRAA was approved by the Operating Committee in September 2016
- IFROs not changing for Operating Year 2017.

Many Moving Parts

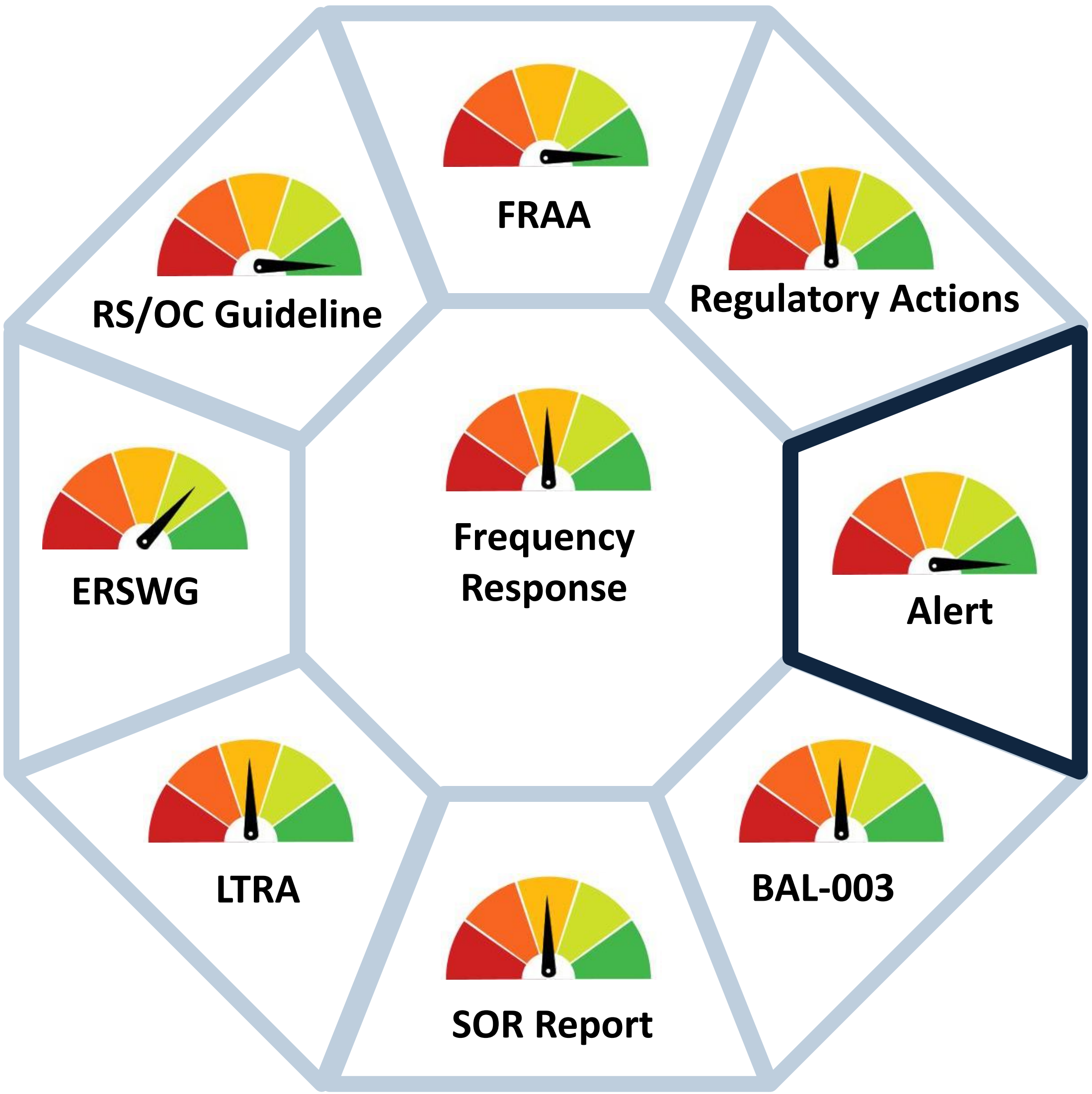


Regulatory Actions

Work in Progress

- Industry stakeholder group worked with NERC staff to develop comments for FERC NOI,
- Changes made to SGIA
- Possible changes to LGIA

Many Moving Parts

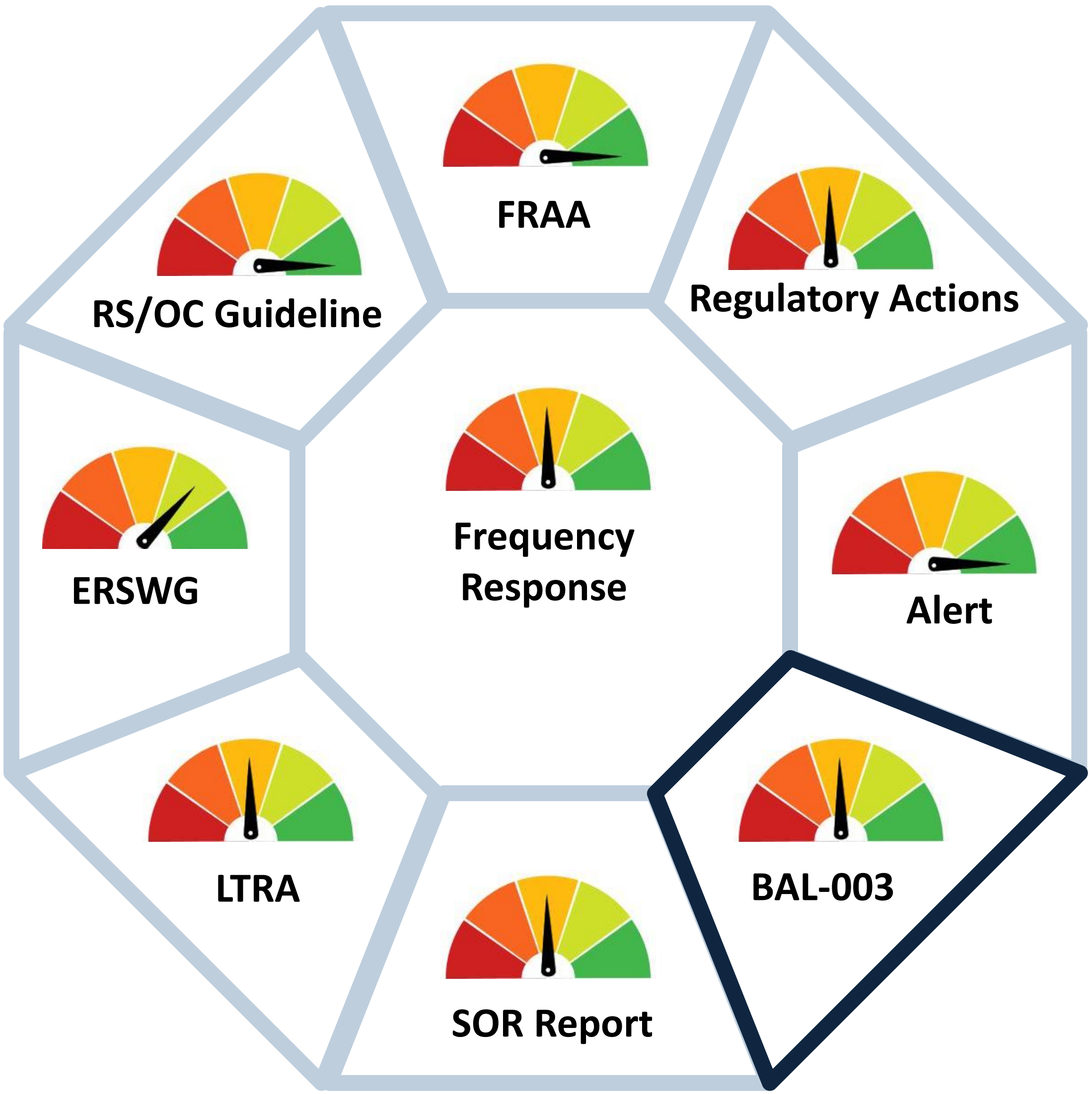


Alert

Complete

- RS and FWG developed a NERC Advisory Alert on governor response.
- The advisory alert was published in January 2015 and addressed governor response and control coordination for synchronous generation.
- Webinars and industry outreach conducted
- Improvements should be measurable for each generator as well as the interconnection as a whole.

Many Moving Parts

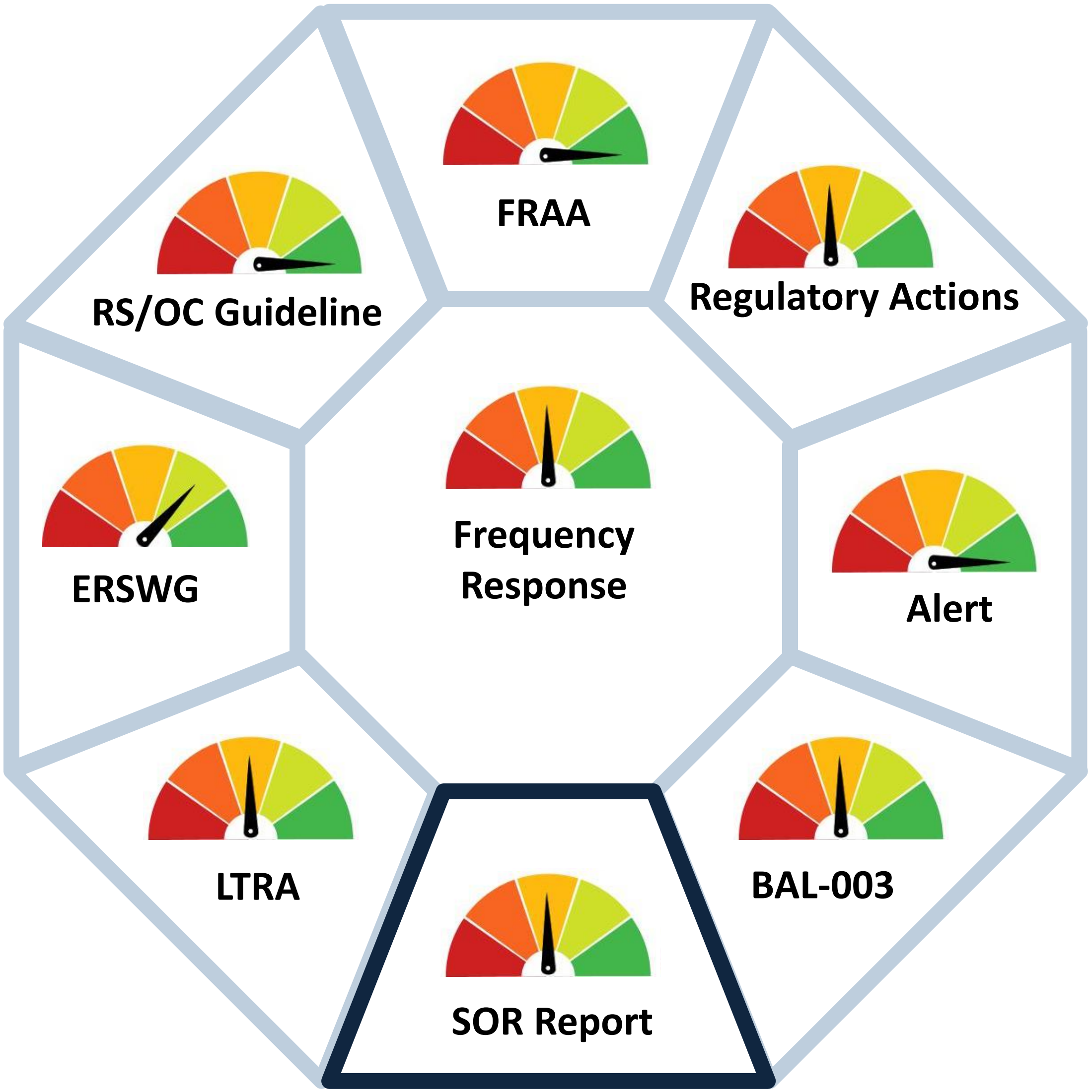


BAL-003

Work in Progress

- NERC Reliability Standard BAL-003 defines an Interconnection Frequency Response Obligation (IFRO) and subsequent Balancing Authority obligations to preserve reliability and ensure the frequency nadir for the largest credible event stays above UFLS.
- R2, R3, and R4 on Frequency Bias Settings in effect April 2016
- R1 on Frequency Response goes into effect December 2016 (Operating Year 2017)
- Refinements to BAL-003 may be needed in the future.

Many Moving Parts

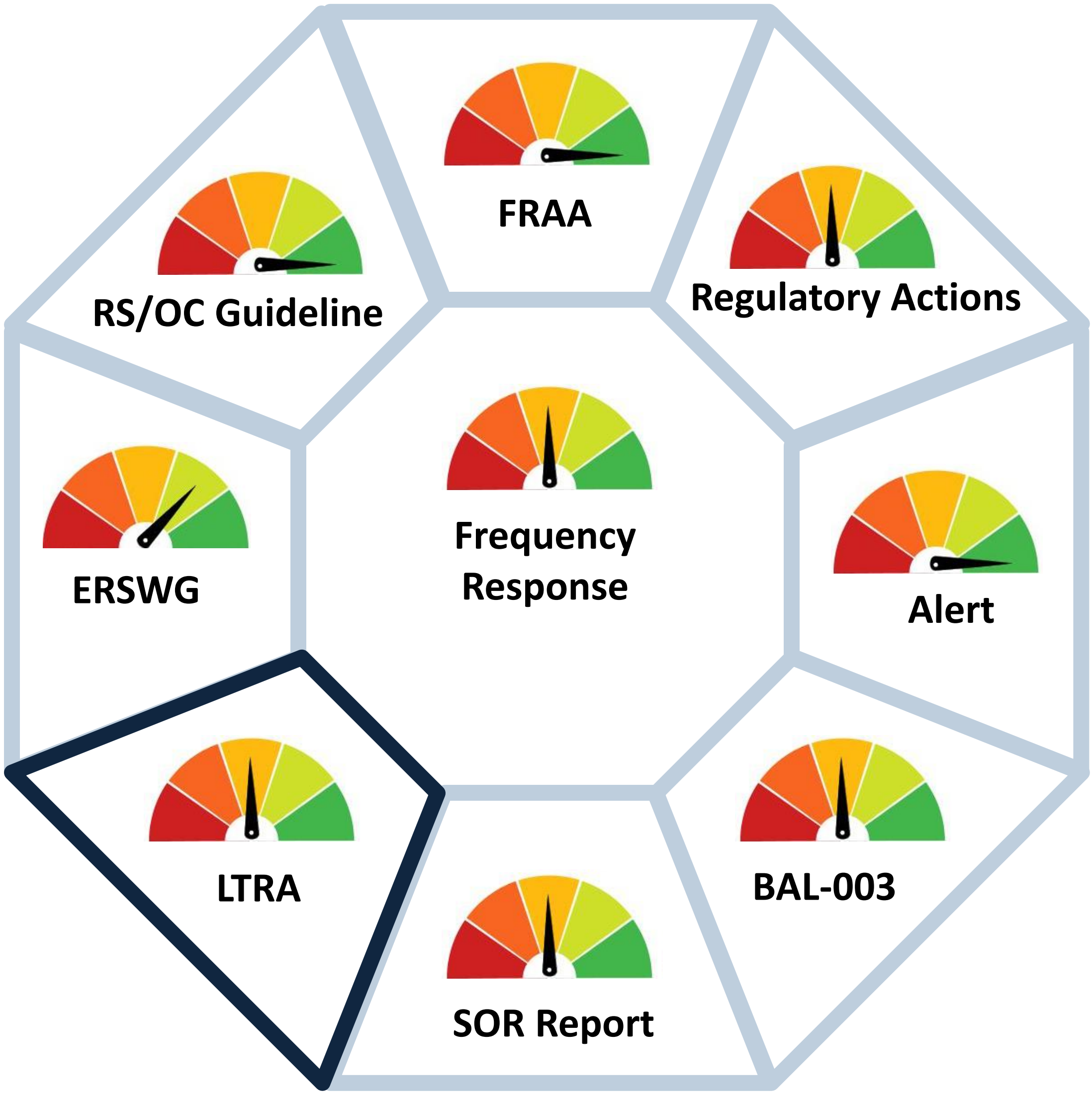


State of Reliability Report (SOR)

Inconclusive

- New measures to be included and considered for the 2016 report.
- 2016 report published in May
- The report addresses ERS and other ALR Metrics and the *FRM for each event (ALR 1-12 events)*
- Currently has not found supporting data that firmly identifies a decline in frequency response
- PAS will continue to analyze and support as necessary.

Many Moving Parts

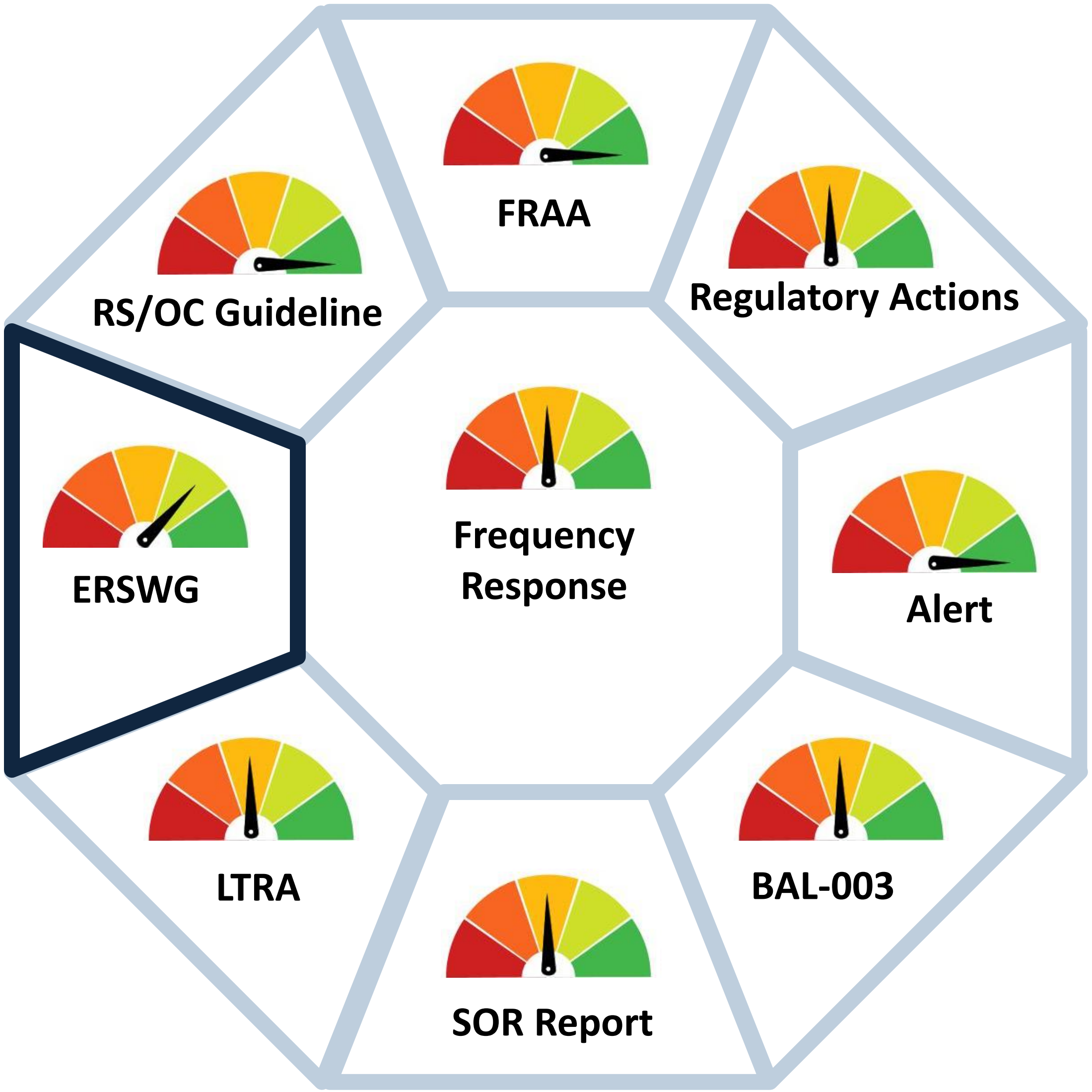


Long-Term Reliability Assessment (LTRA)

Work in Progress

- Key findings from past assessments indicated a trend of more asynchronous resources and retirements of conventional generation, potential decreasing the overall inertia and frequency response capability of the BPS.
- In 2016, the LTRA includes an evaluation of ERS measures.
- The 2016 LTRA will be published in December.
- Special Assessment to be conducted on frequency response and the changing resource mix in Eastern Interconnection.

Many Moving Parts

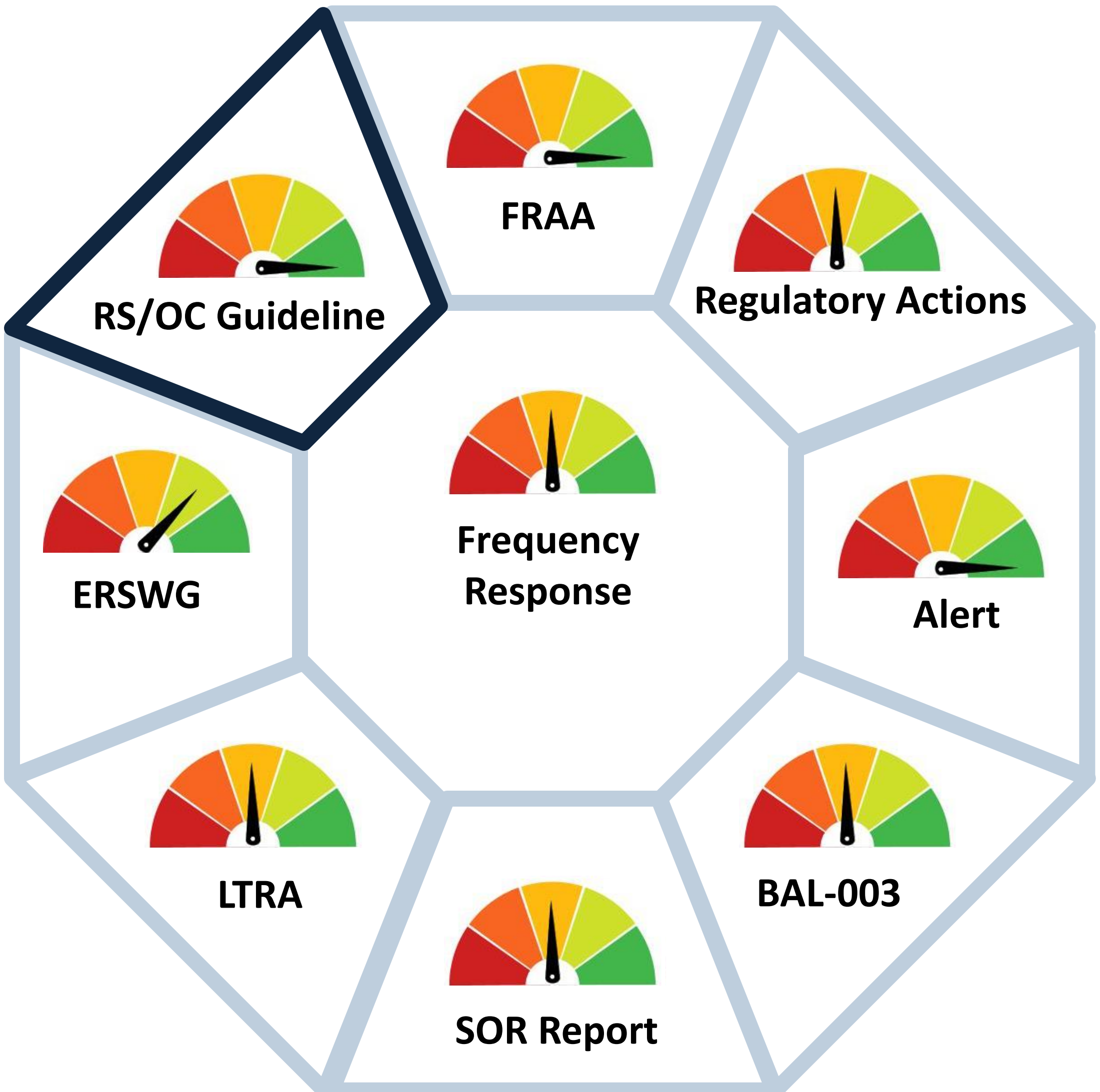


Essential Reliability Services WG

Work in Progress

- The ERSWG has four measures relative to frequency for BA's and interconnections.
- These measures also include revised ALR 1-12 metric (now metric M4).
- The WG will monitor activities of the working groups related to ERS measures
- The ERSWG working on initial strategy on quantifying the sufficiency guidelines for the ERS measures.
- Whitepaper to be competed by December 2016.

Many Moving Parts



RS/OC Guideline

Phase I Completed

- The RS and OC developed a guideline for generator owners on governor response and DCS control strategies for thermal plants.
- The guideline includes industry recommended governor deadband and droop settings that will potentially enable resources to provide better frequency response to the BPS
- The OC approved the guideline in December 2015
- Being revised to add asynchronous resources (per Recommendation 1 of 2012 Frequency Response Initiative report)

Proposed changes to Reliability Guideline Primary Frequency Control

Add Inverter-based resources

- Inverter-based resources can be very fast (too fast?)
  - Inverter-base resource speed is based on the time constants and speed of the resource behind the inverter
  - Extremely fast action can cause instability of the plant or the system
  - Interaction of multiple inverters at high speed can cause problems

Address non-traditional FR resources

- Storage (stationary) charging device behavior
- Storage can operate in several modes
- Demand response used as for Frequency Response
- “Modulated Load”

Frequency Response Requirements: Different Approaches and Considerations

Not Required in Interconnection Agreement	Required for All Resources
Relies on third-party/market mechanisms to meet requirements - Requirement would apply to BAs; no requirement for GOs to have ***capability*** - No measurable performance for GOs; only Interconnection and BA FRMs - No requirements on deadbands – GOs can set however they like - Wider frequency variability – status quo - No requirements on droop – GOs can set however they like - Tendency to depend on "select few" resources to meet BA FRO – what if offline? - May drive stability risks for unbalanced response – heavy transfers on interties - BA approach is unique to North America	*Interconnection Requirement/Rule/Reliability Standard for frequency responsive resources* - Requirement would apply to all applicable GOs – "fair and equitable" ***capability*** - Measurable performance for GOs - Requirement for reasonable deadbands in support of frequency stability - Projected (seen in ERCOT) tighter control - Requirement for reasonable droop controls in support of frequency stability - Wholesome reliance on all resources – units always online - Operator flexibility - Uniform response alleviates intertie pickups - Similar to most modern systems' Grid Codes

Essential Reliability Service Task Force Report

- Primary Frequency response (as part of overall frequency support) is an Essential Reliability Service (ERS).
- Essential for interconnection stability, prevention of equipment damage, coordination of droop response, and system restoration (cranking path).
- The ERSTF final report recommended that *all* resources have the *capability* to provide frequency response.

Potential Risks to Reliability

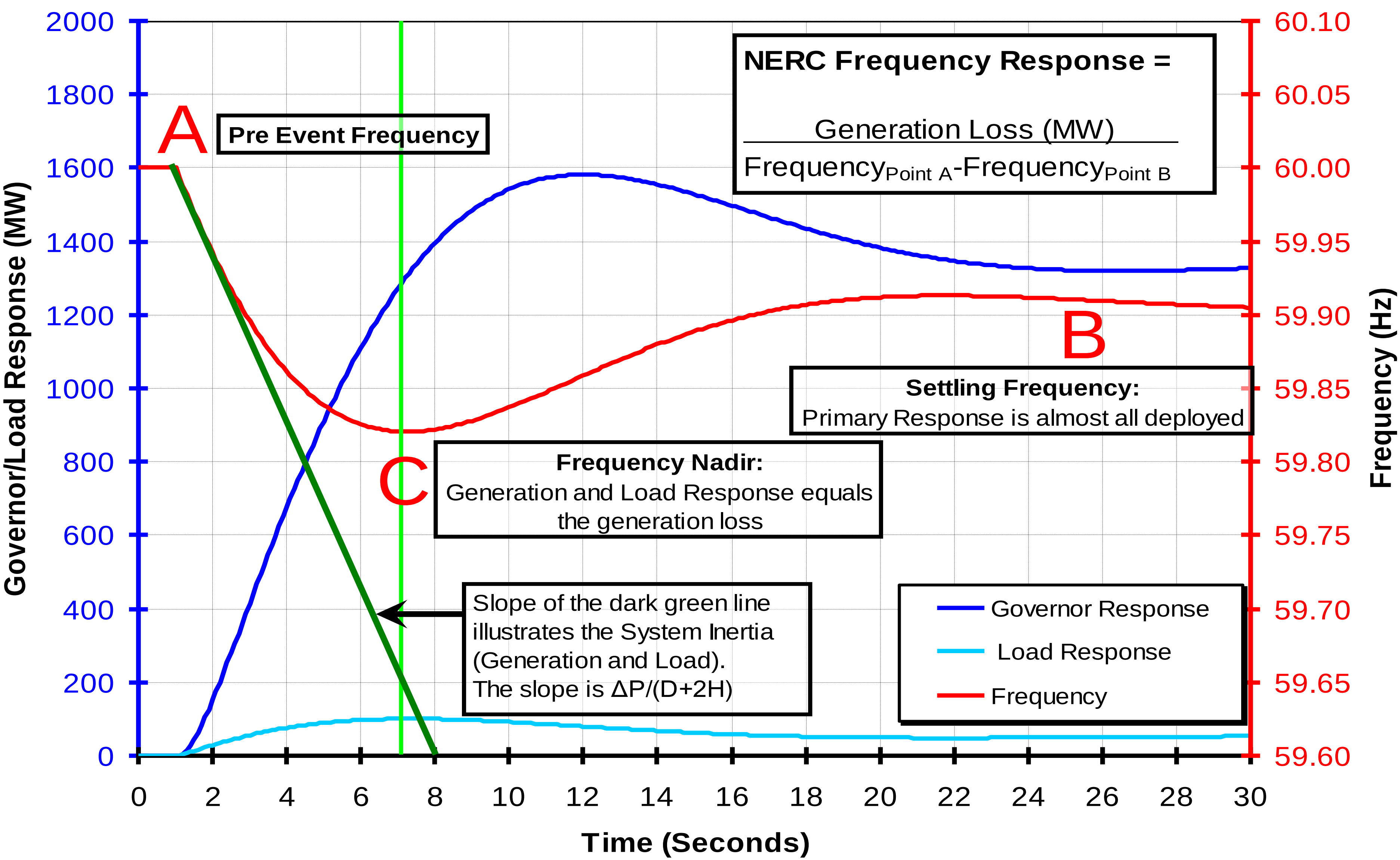
Changing Resource Mix

- Potential for lower inertia with retirement of coal and oil-fired synchronous generators
- Higher penetration of renewables with potentially lower frequency response
- No assurance of adequate inertia or frequency response capability for some resource dispatch scenarios

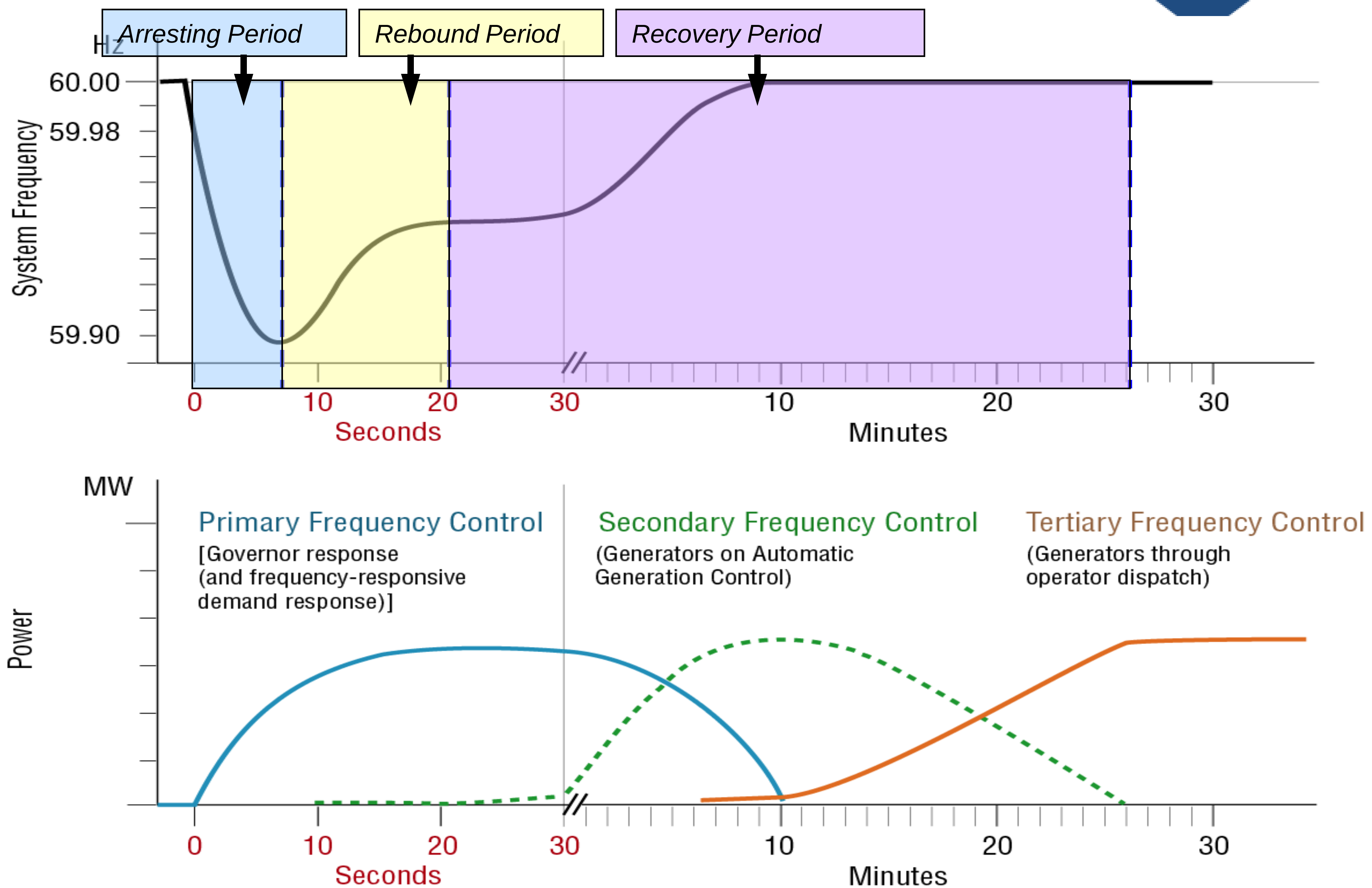
Conservative approach

- All resources should have frequency responsive capability to assure that frequency response is available for any resource dispatch.

Frequency Response Basics



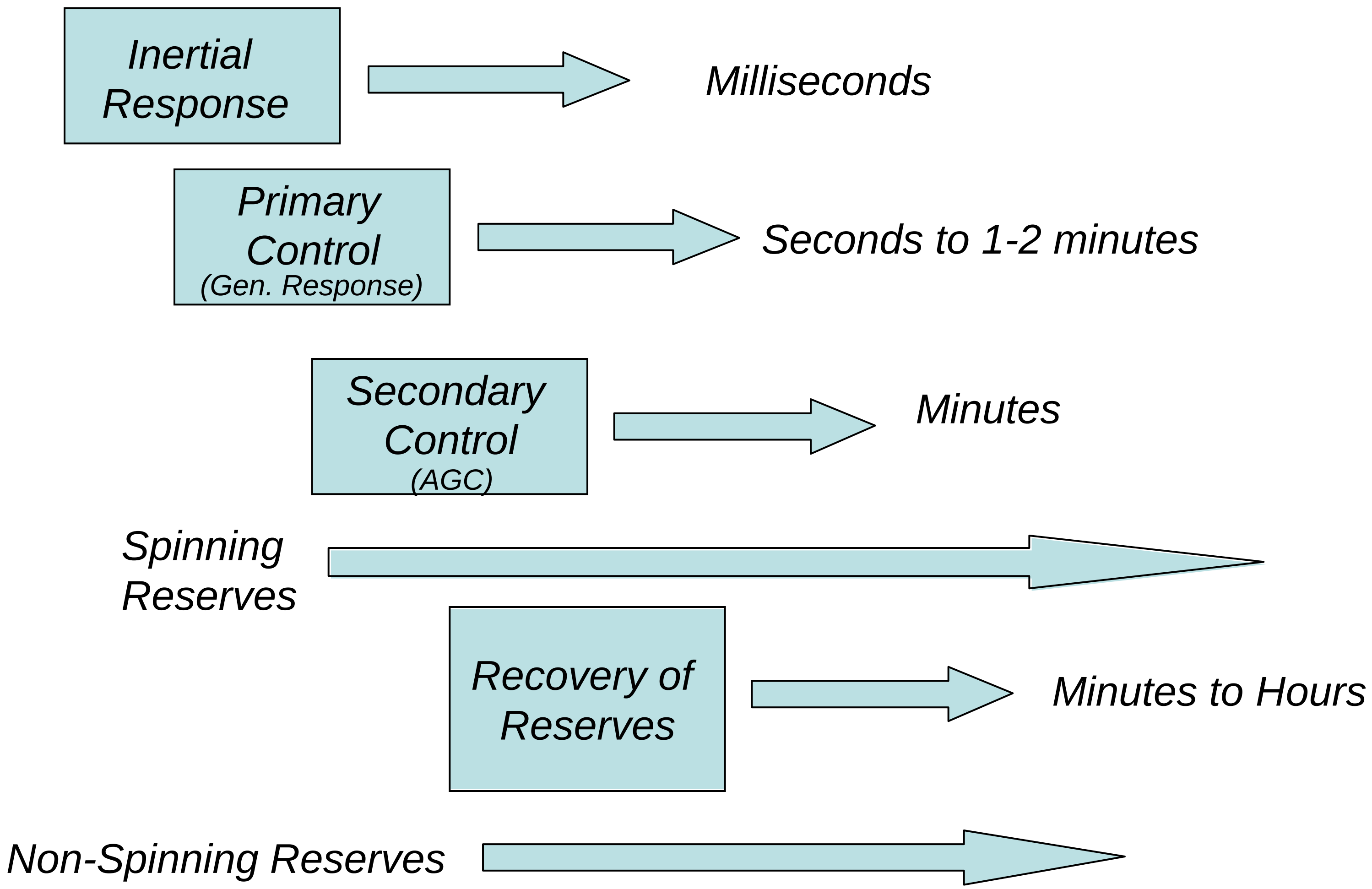
Frequency Response Breakdown



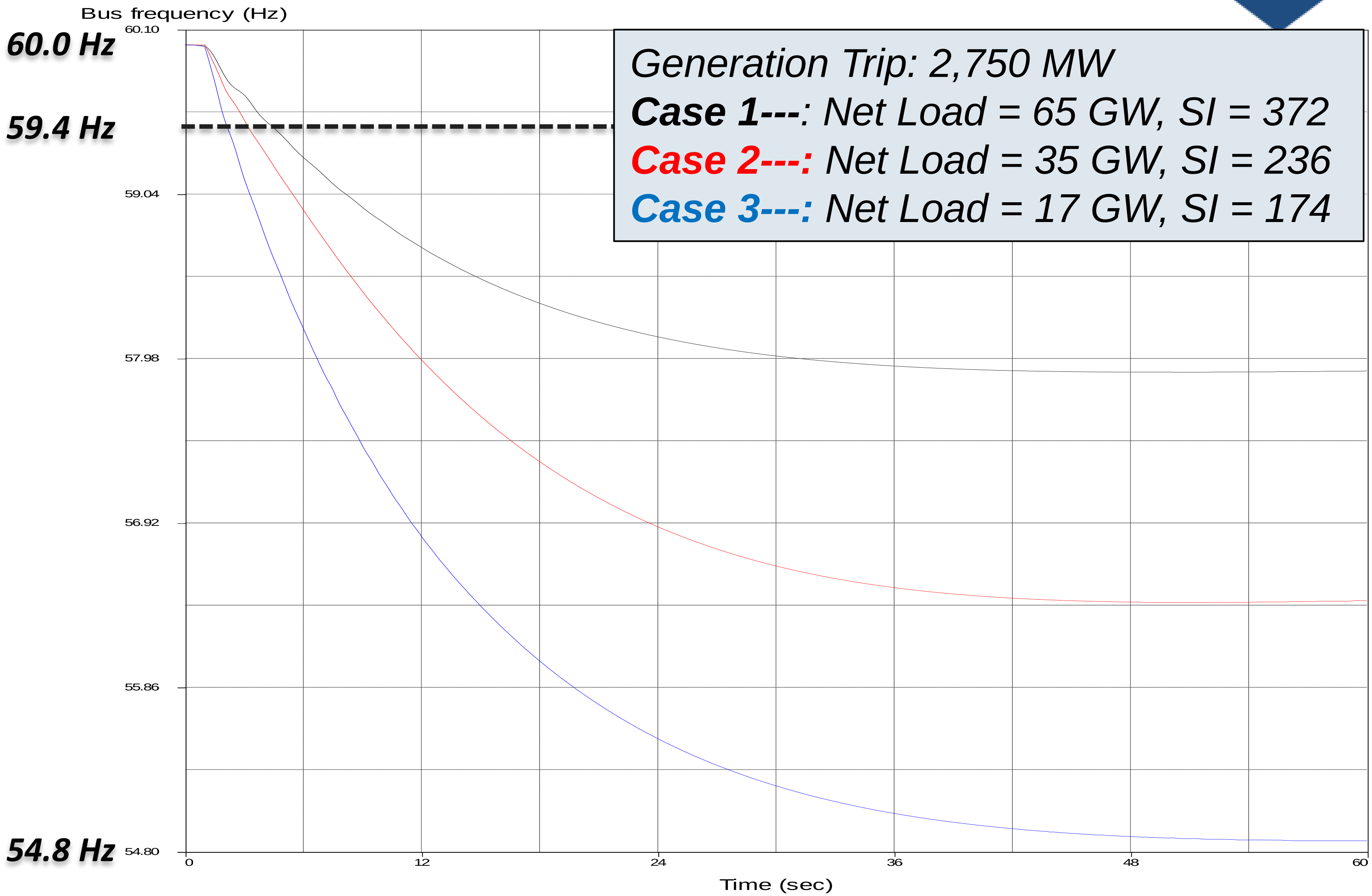
Potential Sources of Primary Frequency Response

- Traditional generation
- Wind Turbines
  - "Synthetic Inertia"
  - Off-optimal blade attack angle – backing down from maximum
- Distributed Energy Resources
  - Solar
  - Micro turbines
  - Micro grid resources
- Load acting as a resource
  - Tripped by specialized under-frequency relays
  - Smart appliances – independent operation
  - Aggregated load – controlled by aggregator
  - "Modulated load"

Frequency Response Control Continuum

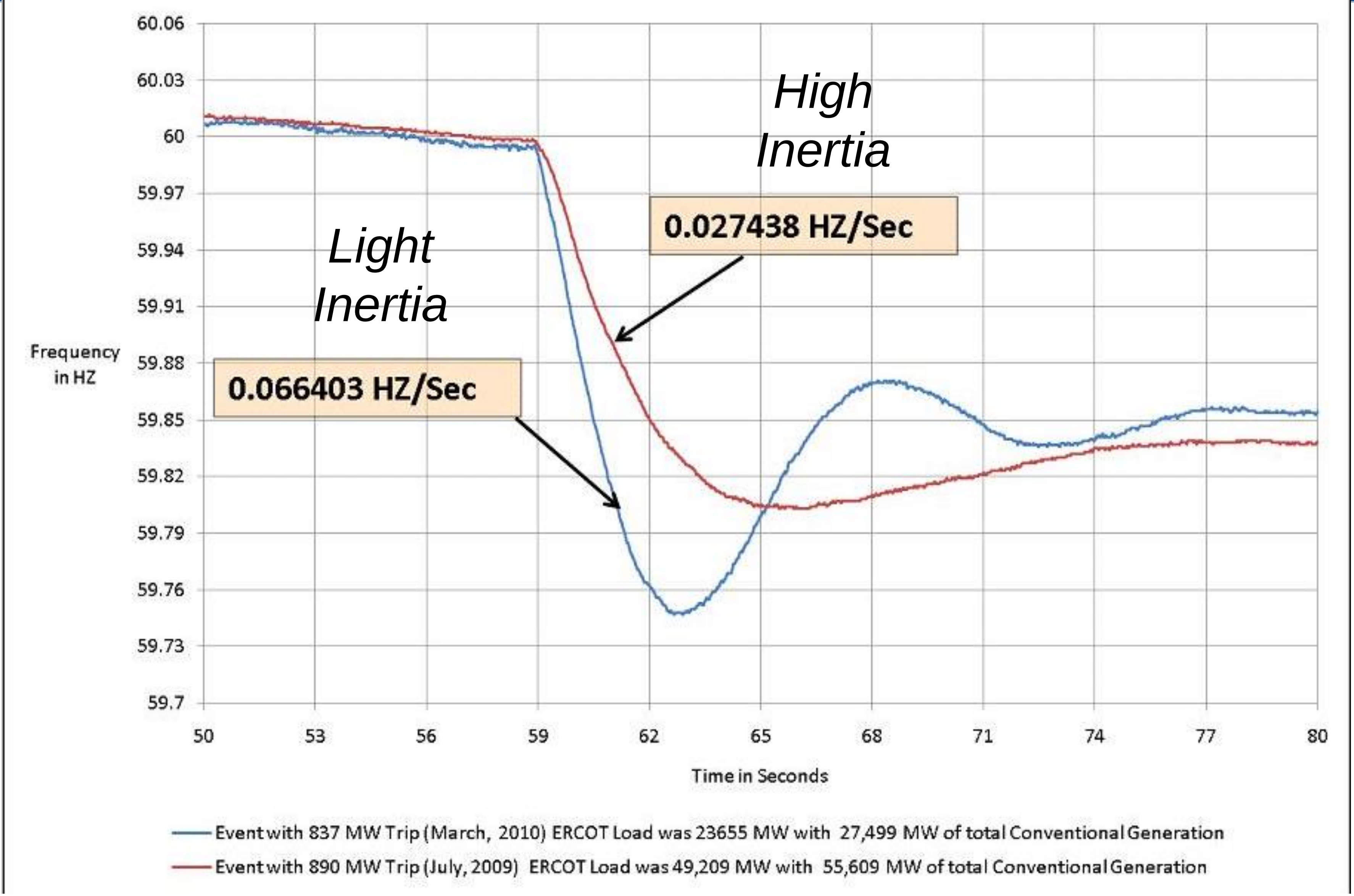


Importance of System Inertia in ERCOT

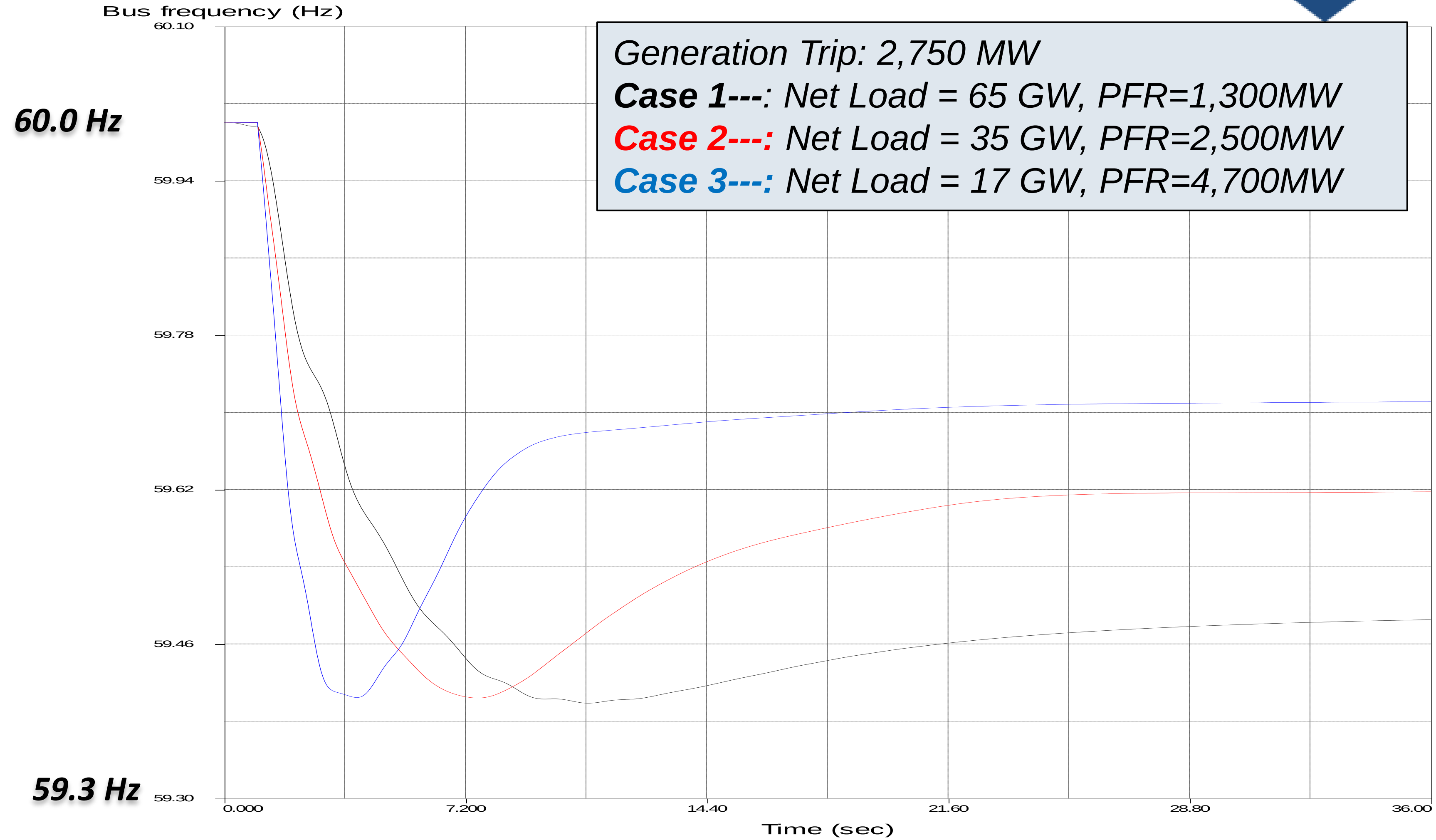


Inertia (GW-second): 1 > 2 > 3

Inertial Response Variability



Trade-off between Inertia and Primary Frequency Response

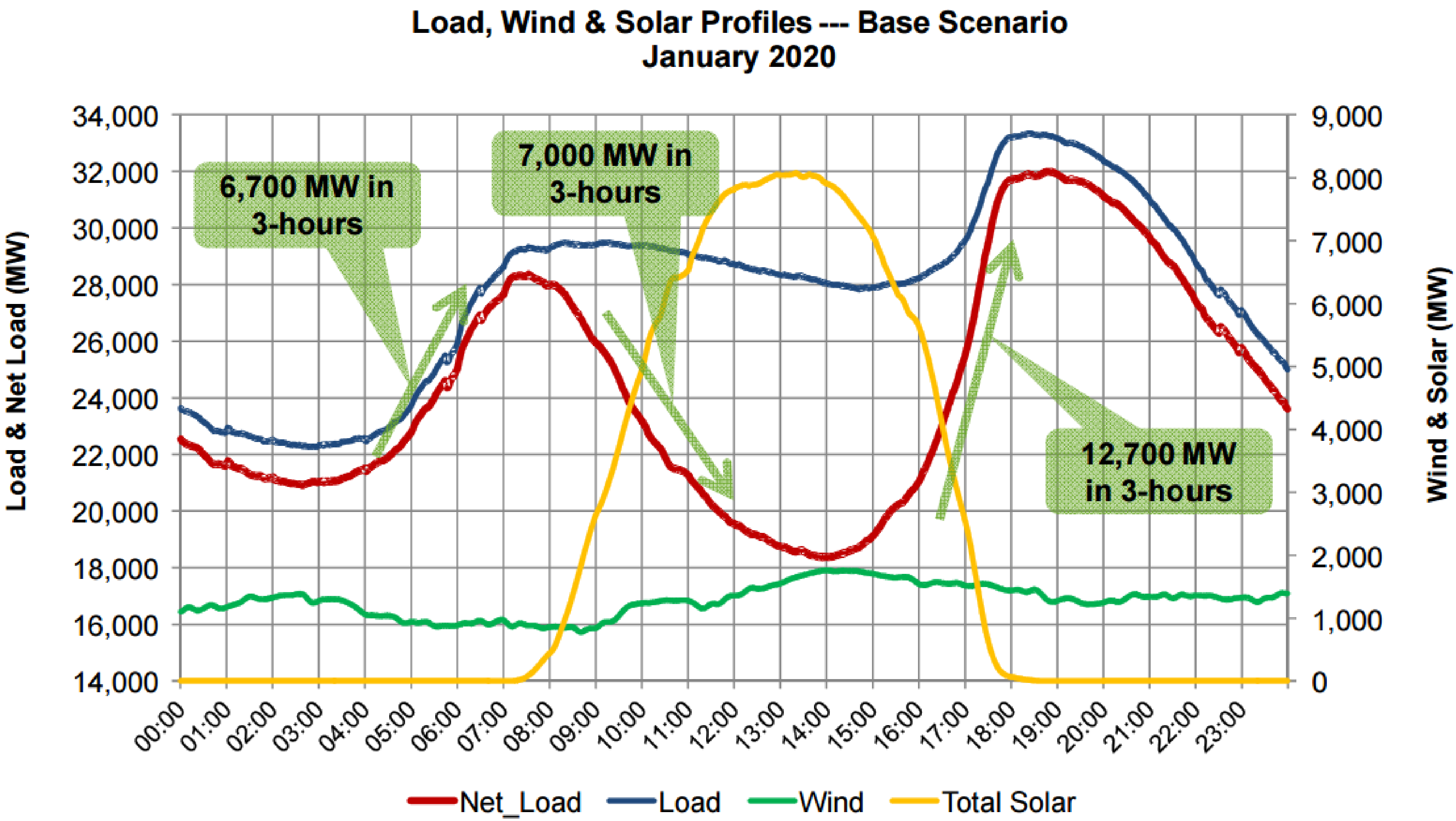


Primary Frequency Response (MW): 3 > 2 > 1

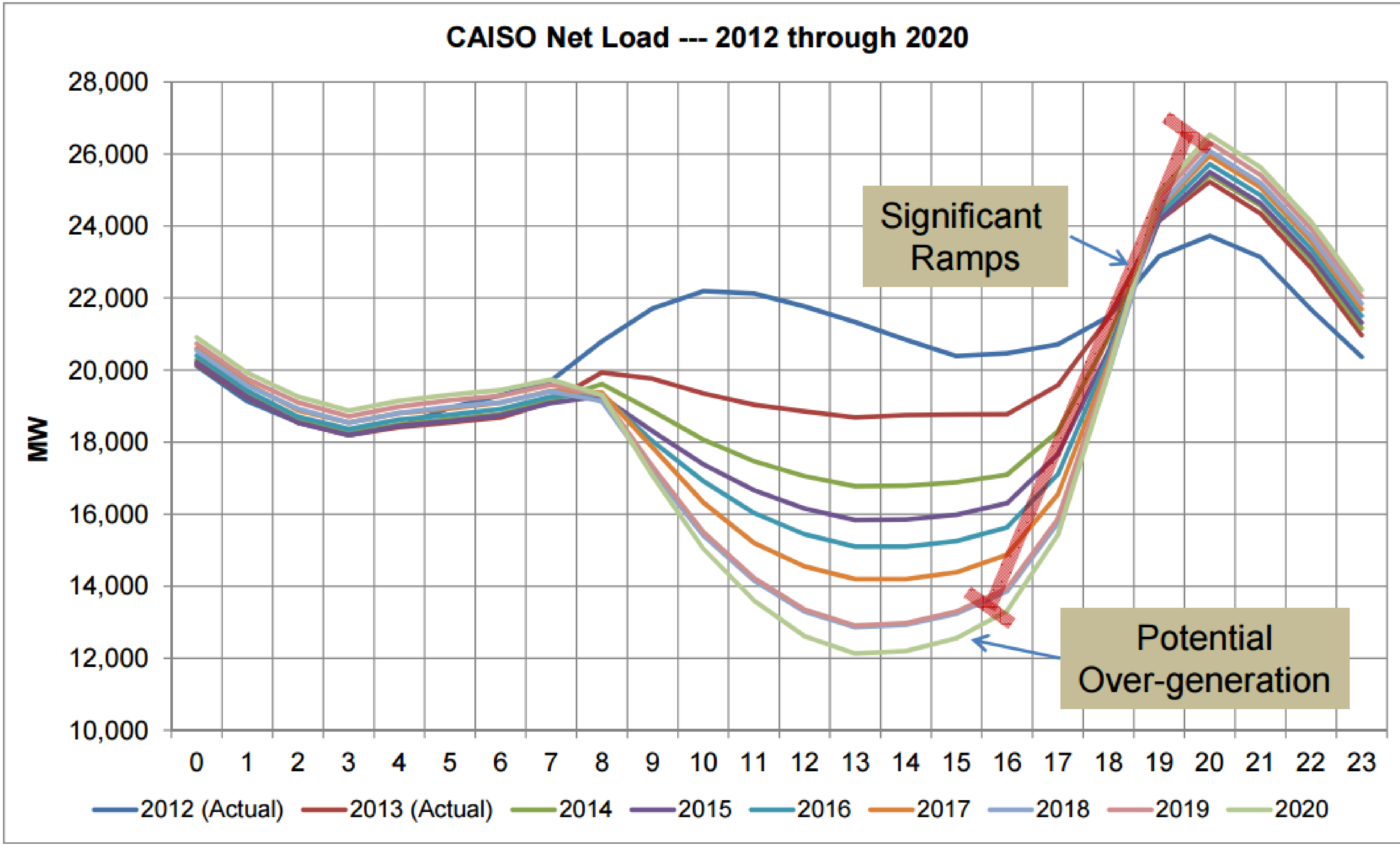
Multiple Roles for Energy Storage in Maintaining Reliability

- High-speed energy injection following loss of resources
  - High-speed response during Arresting Phase of a Frequency Event
    - Response proportional to the change in frequency and rate of change in frequency
    - Help to offset loss of system inertia due to displacement or retirement of generation
- Continuous proportional response to frequency deviations
  - Frequency control services
- Energy injection to perform ramping services
  - Reduce severity of solar-based resource drop-off in evening

CAISO Load Balancing Concerns

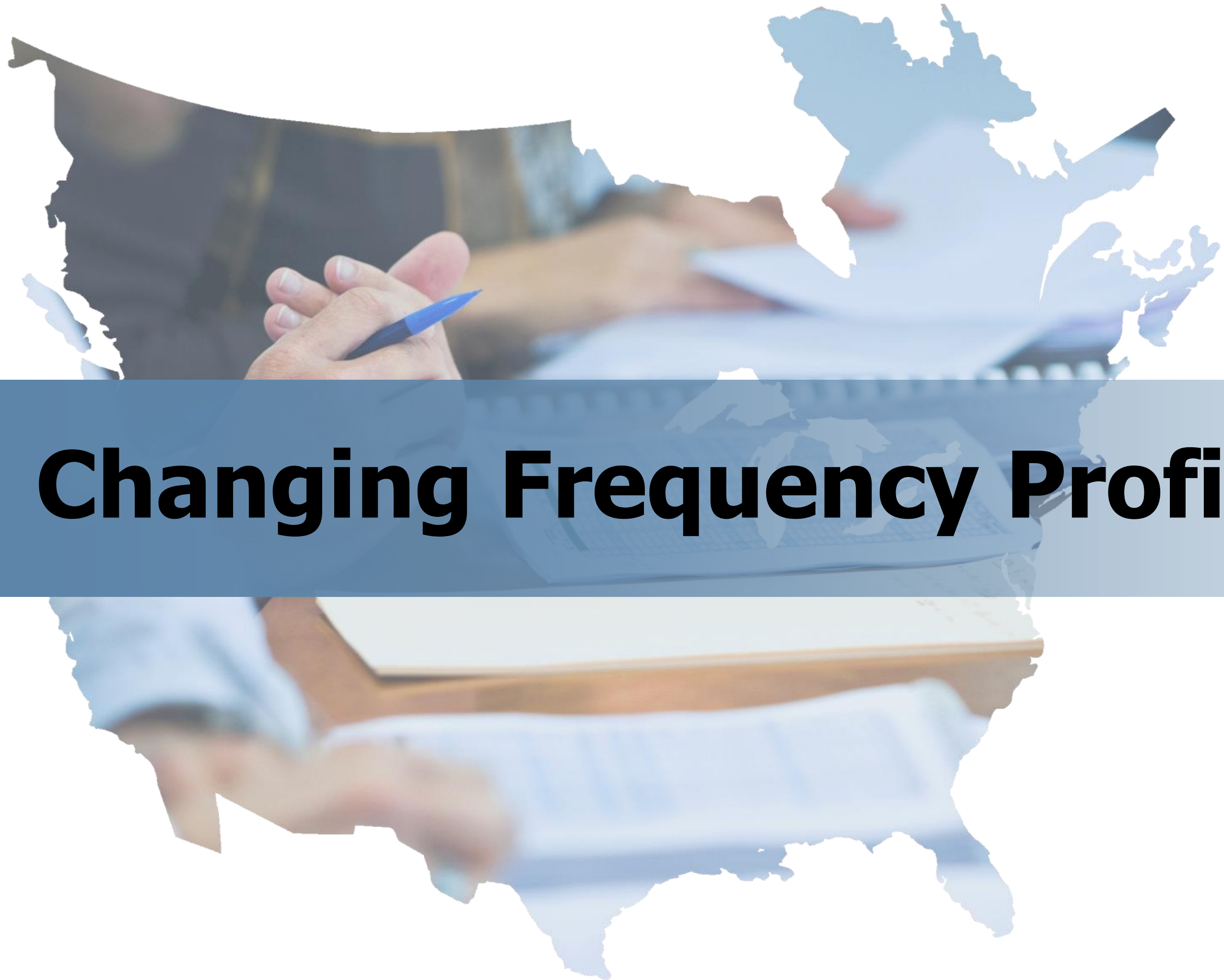


CAISO Net Load Pattern Changes



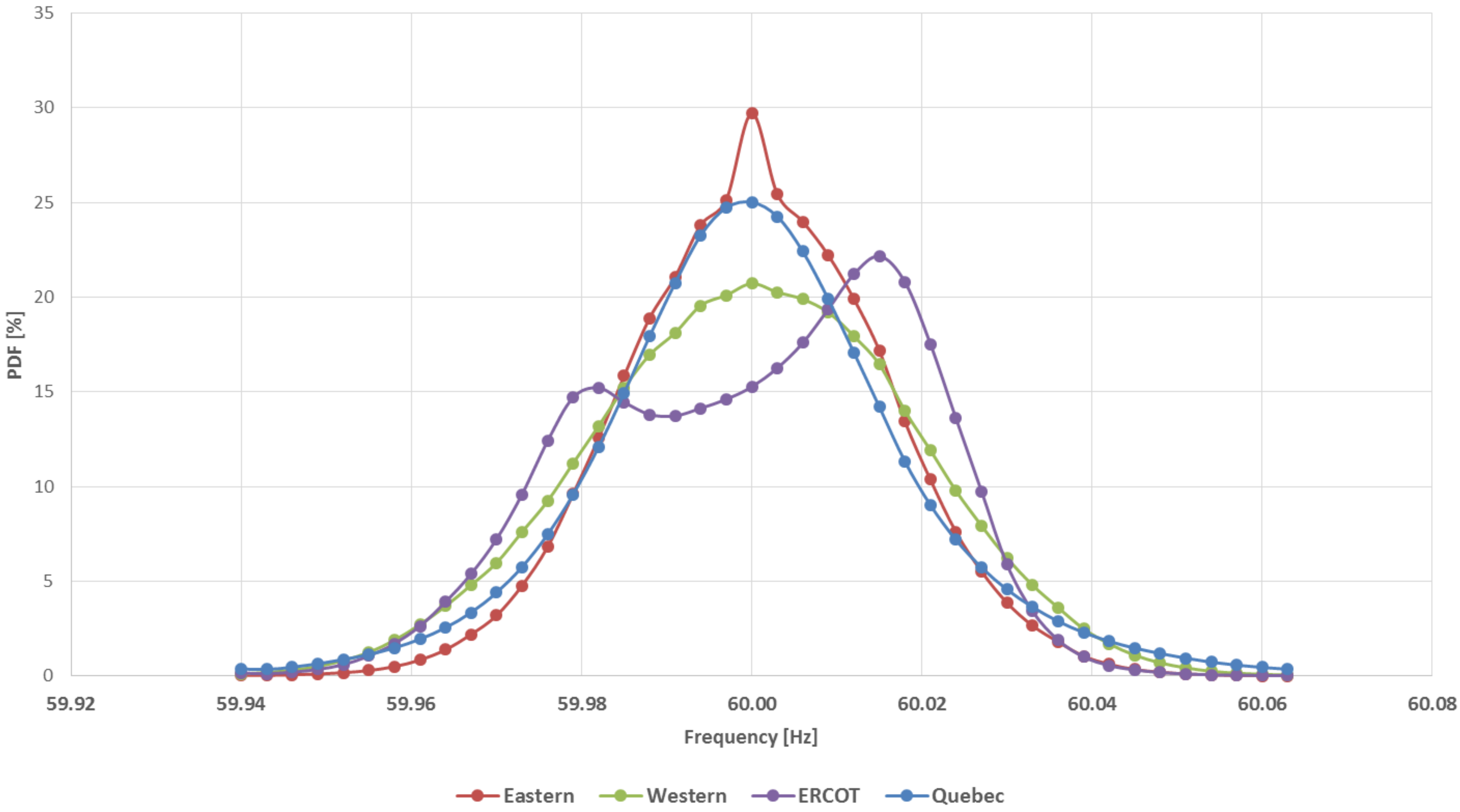
Ramping / Load-Following Services Role for Storage

- Supplement generation during severe upward ramps
  - Morning load pick-up before solar reaches full output
  - Evening load pick-up when solar output is dropping off
- Absorb energy during downward ramps
  - When solar and wind output ramps up to full output and morning load stabilizes
- Absorb energy to prevent over-generation
  - Charge storage when solar and wind output exceeds energy demand
- Load-following to provide balance for variable resources
  - Wind and solar variability due to changes in weather



Changing Frequency Profile

Frequency Probability Density Function by Interconnection

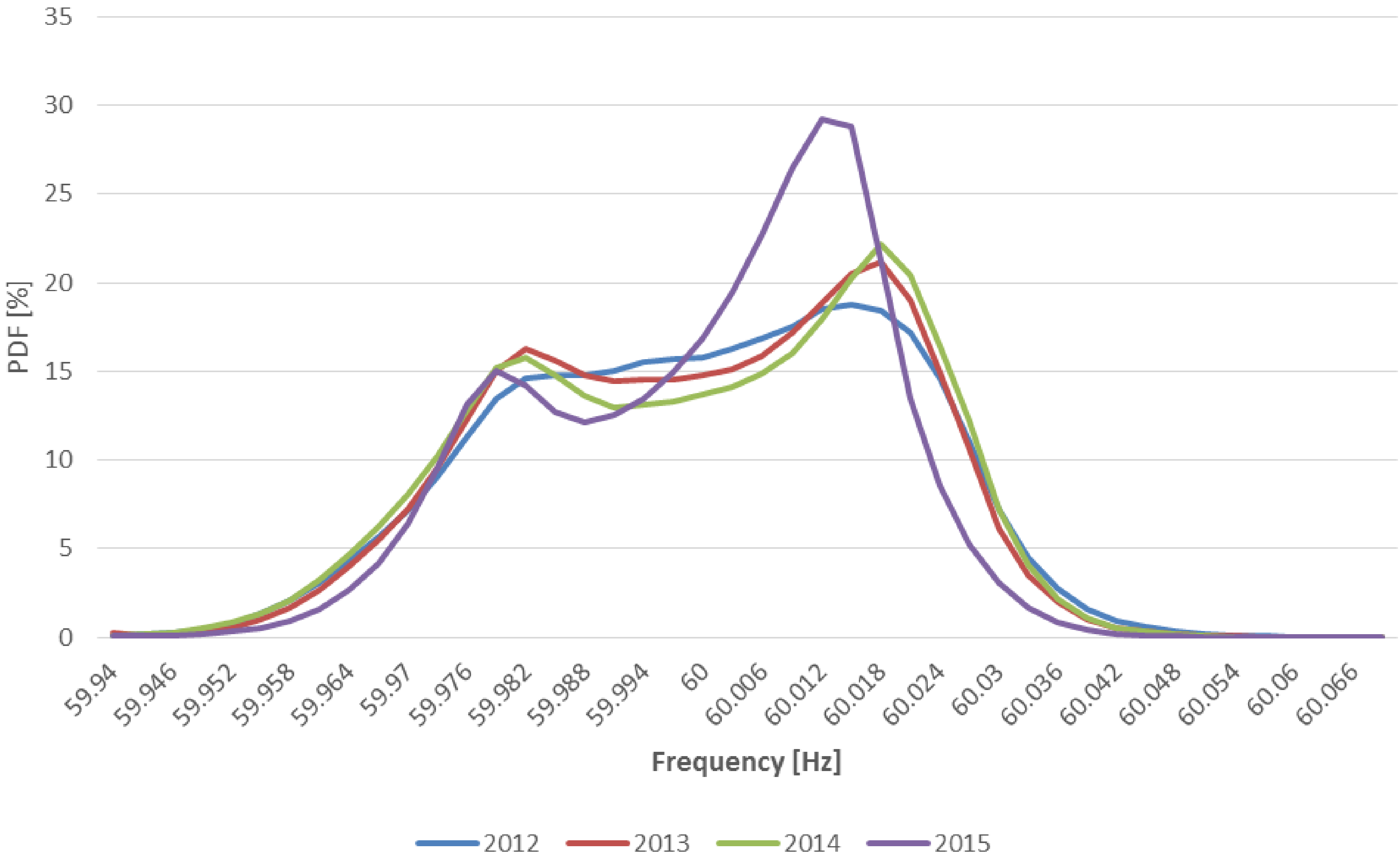


Reasons for Differences in Interconnection Frequency Profile

- Only ERCOT has a frequency response performance requirement –BAL-001-TRE-1
  - Also requires 17 (16.67) mHz deadband*, 4 to 5% droop, and proportional, non-step response
- Québec system requirements
  - No deadband allowed
  - 5% droop on all units
- Eastern and Western – NERC Reliability Guideline on Primary Frequency Control (December 2015) calls for:
  - ±36 mHz deadband
  - 3 to 5% droop

* Except for steam and hydro turbines with mechanical governors – ±34 mHz

ERCOT Frequency Probability Density Function Changes



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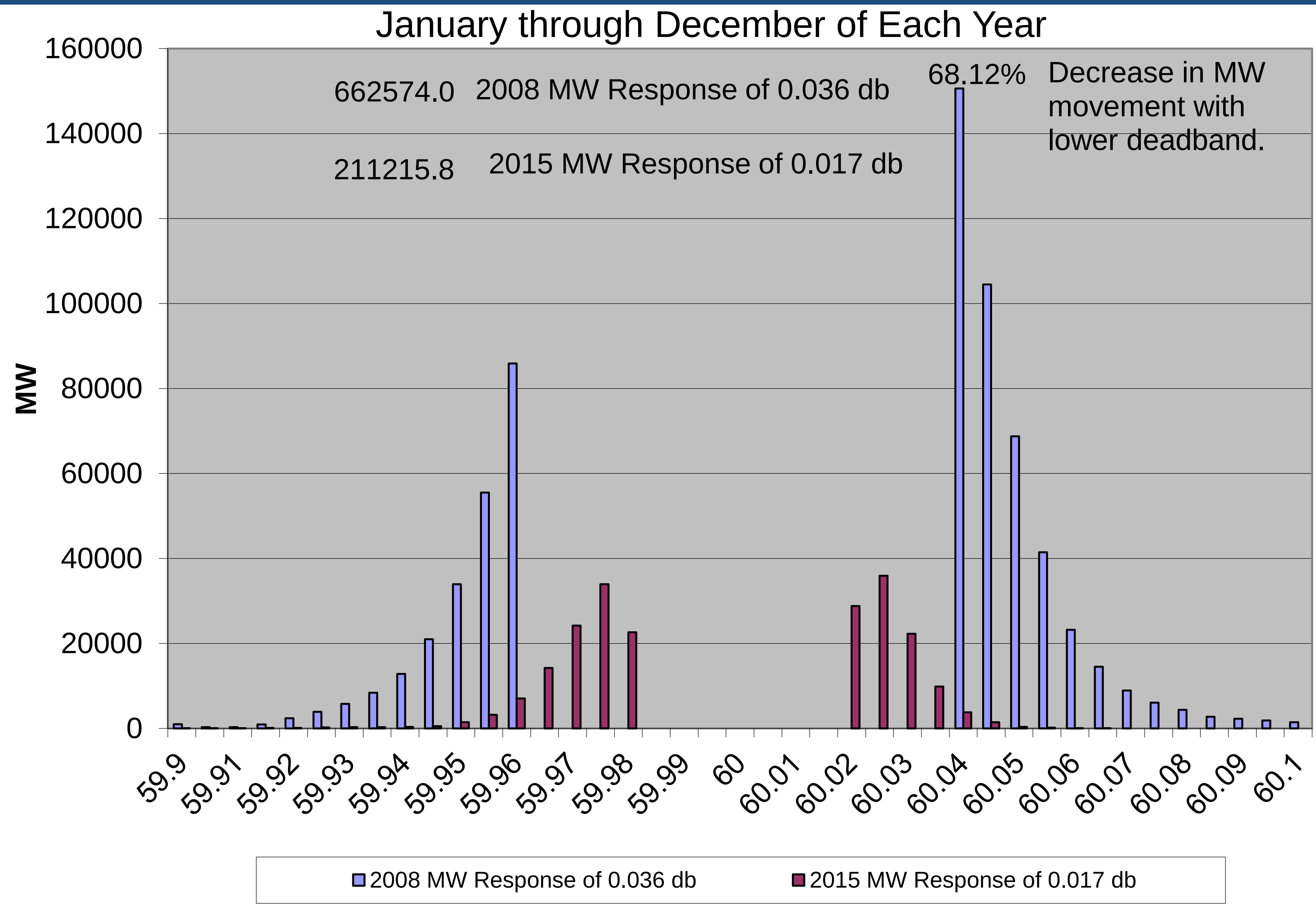
Affect on a Single Generator

Exposing a single 600 MW generator to ERCOT 2008 and 2015 frequency profiles with typical settings:

- 2008 – 5% Droop, ±36 mHz deadband, “Step” response
  - 622,574 MW-minutes of Primary Frequency Control.
- 2015 – 5% Droop, ±17 mHz deadband, “Proportional” response
  - 211,215.8 MW-minutes of Primary Frequency Control.
- 68.12% (451,358.2 MW-minute) *DECREASE* in generator control action by the governor in 2015 compared to 2008 even with the lower dead-band setting.

600 MW Unit Response – 2008 36 mHz Deadband versus 2015 17 mHz Deadband



Questions and Answers