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NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Energy Storage & Reliability

Engineering the Changing Grid

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Energy Storage Workshop for Southwest Public Utility Regulatory Commissions
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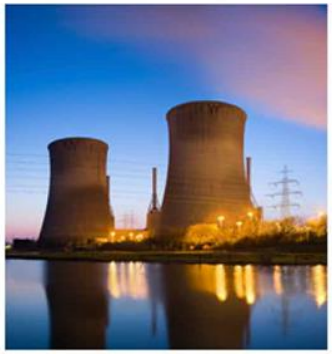
RELIABILITY | ACCOUNTABILITY

NERC Overview

FRCC	**Florida Reliability Coordinating Council**
MRO	Midwest Reliability Organization
NPCC	Northeast Power Coordinating Council
RF	ReliabilityFirst
SERC	SERC Reliability Corporation
SPP-RE	Southwest Power Pool Regional Entity
TRE	Texas Reliability Entity
WECC	Western Electricity Coordinating Council

Overview

- Change is Coming
  - Changing Load Characteristics
  - Changing Resources
- Essential Reliability Services
  - Demand/Resource Balance
  - Frequency Control
  - Voltage and reactive power support
- Roles for Energy Storage
  - Primary Frequency Response
  - Frequency control services
  - Ramping
- Engineering the change
  - Need for strategy of cohesive action

Change is Coming

- Characteristics and behavior of the system are changing
  - Rapid penetration of new types of loads
  - Rapid penetration of new types of electronically-coupled resources
  - Retirement/displacement of conventional generation
  - Reduced inertia
  - Variable resources
- Paradigm of system control is changing

- We ***MUST engineer*** the changes to maintain reliability

Changing Load

- Load composition changing
  - Electric vehicle charging
  - LED lighting
  - Variable speed drive motors
- Distributed Energy Resources
  - Inverter-based resources
    - Roof-top solar panels
    - Micro turbines
    - Small wind turbines
- Load becoming schizophrenic
  - Load models no longer adequate for simulations

Changing Resources

Changing Dispatch Mix

- High penetration of renewables – variable resources
- Minimum generation levels on conventional units
- Ramping needs increase for load following

Retirement of large fossil-fired generation plants

- Loss of dynamic reactive support for voltage control
- Possible reduced system inertia
- Lower levels of synchronizing torque

Changing System Inertia

- Trade-offs between inertia and Primary Frequency Response

Cautionary Tales

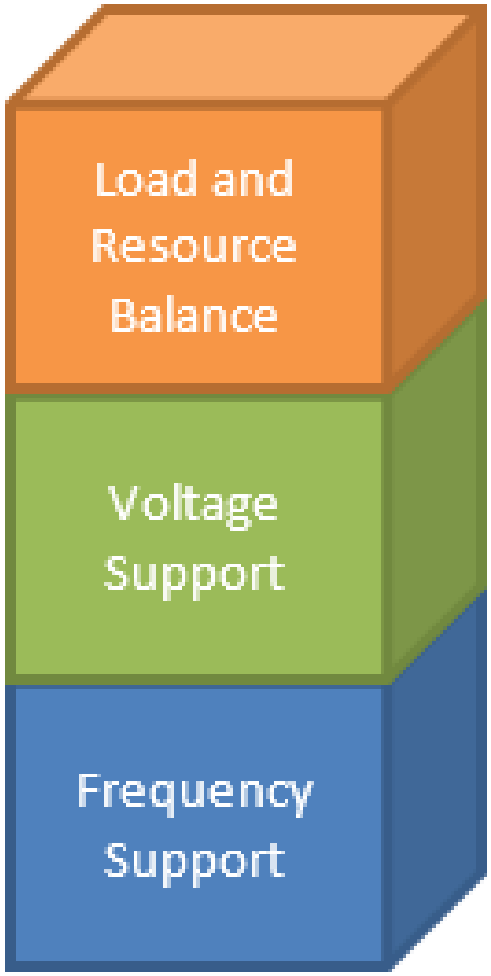
Inadvertent creation of new reliability hazards

- Very large DC transmission projects
  - New largest single hazards

Series-compensated transmission lines

- Sub-synchronous resonance
- Sub-synchronous controls interaction
  - Inverter-based resources
  - Digital controls on conventional generation
  - System controls – SVCs, Statcoms, DC converter stations,

ERS Fundamentals



- "Building blocks" of physical capabilities
- Accentuated by resource changes
- Not all MWs are equal
- Some partly covered through ancillary services
- Accommodate local/regional needs

Essential Reliability Measures

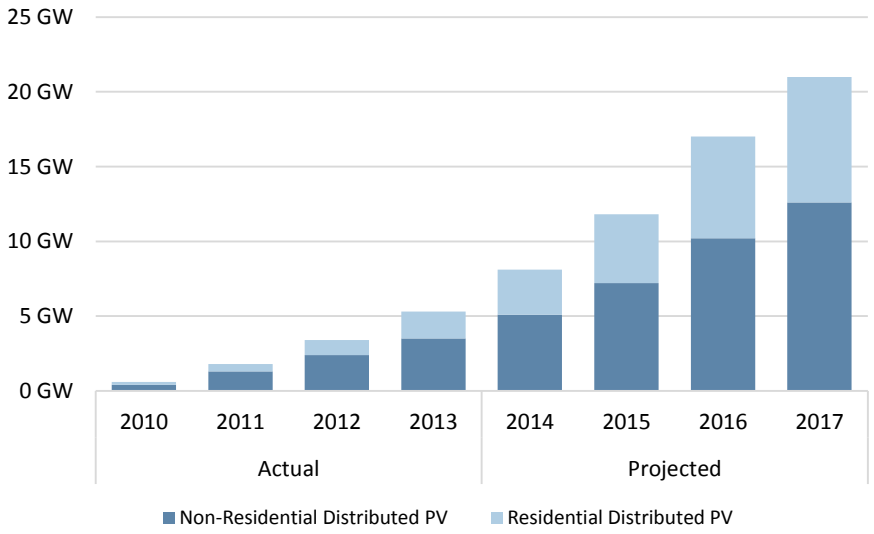
- Synchronous Inertial Response – Interconnection level
- Initial Frequency deviation following largest contingency
- Synchronous Inertial Response – Balancing Authority level
- Ramping capability
- Voltage performance
- Overall system reactive performance

2015 Long-Term Reliability Assessment
#3: Reliability Trends and Emerging Issues

System operators and planners face uncertainty with increased levels of distributed energy resources and new technologies

- Distributed energy resources (DERs) are contributing to changing characteristics and control strategies in grid operations.
- NERC has established a Task Force focused on examination of reliability impacts of large amounts of DER on the Bulk Power System.

Actual and Projected Cumulative Distributed PV Installed Capacity in U.S. Since 2010



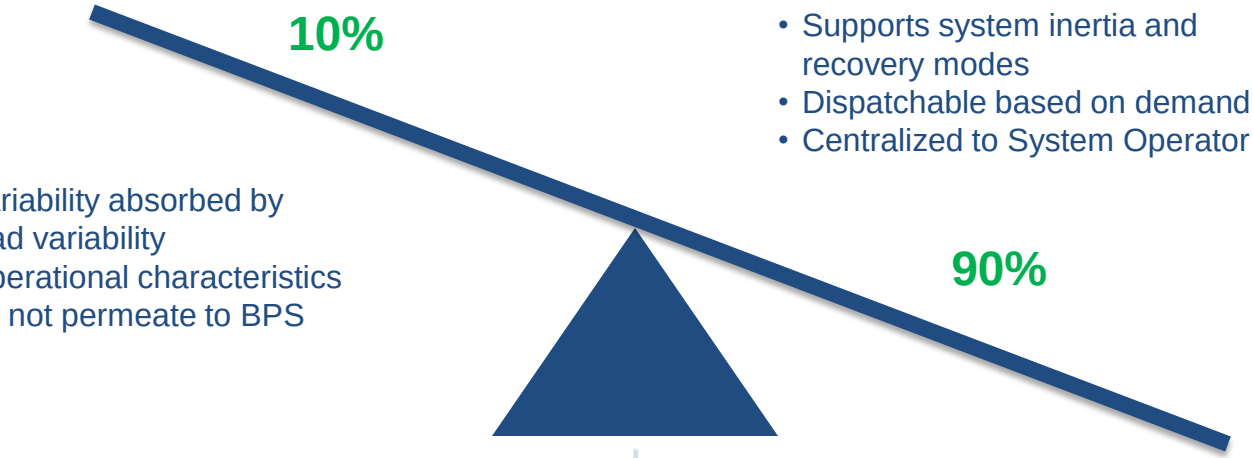
The Control Shift

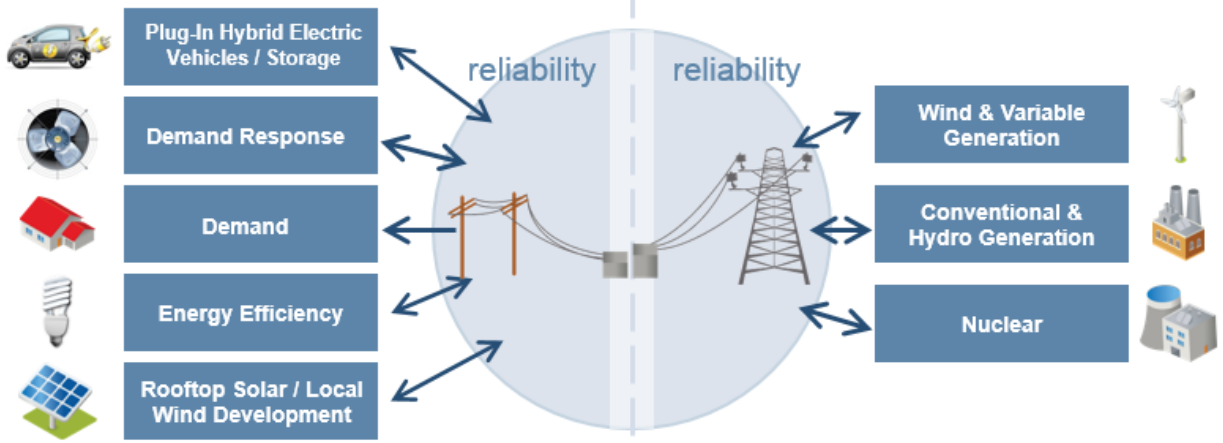
Distribution

- Variability absorbed by load variability
- Operational characteristics do not permeate to BPS

Bulk-Power System

- Supports system inertia and recovery modes
- Dispatchable based on demand
- Centralized to System Operator





The Control Shift

Distribution

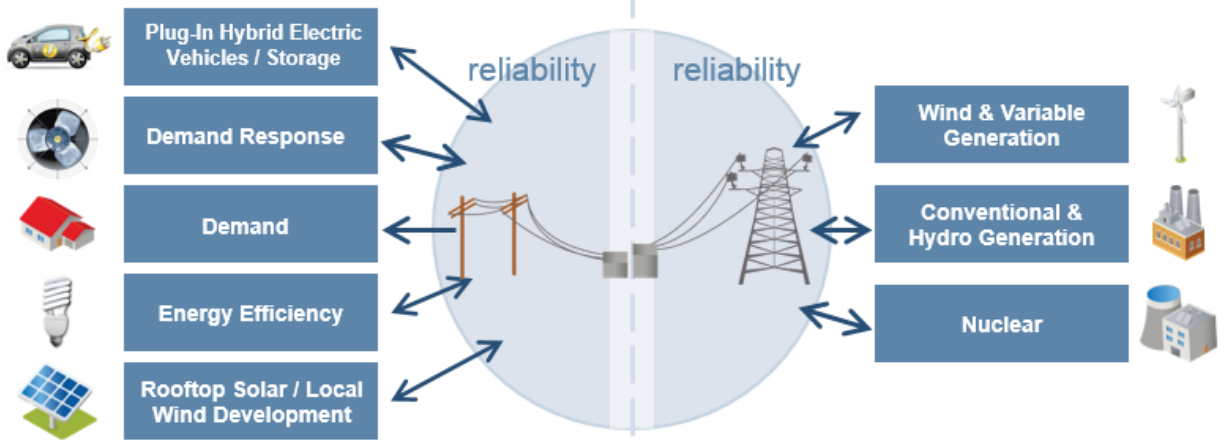
30%

- Disturbances permeate to BPS (common-mode)
- Dynamic and fast demand response
- Potential for over-generation

Bulk-Power System

70%

- More rigorous generator control and dispatchability
- Increased reliance on BPS generation
- Additional equipment to control local voltages



The Control Shift

Distribution

Bulk-Power System

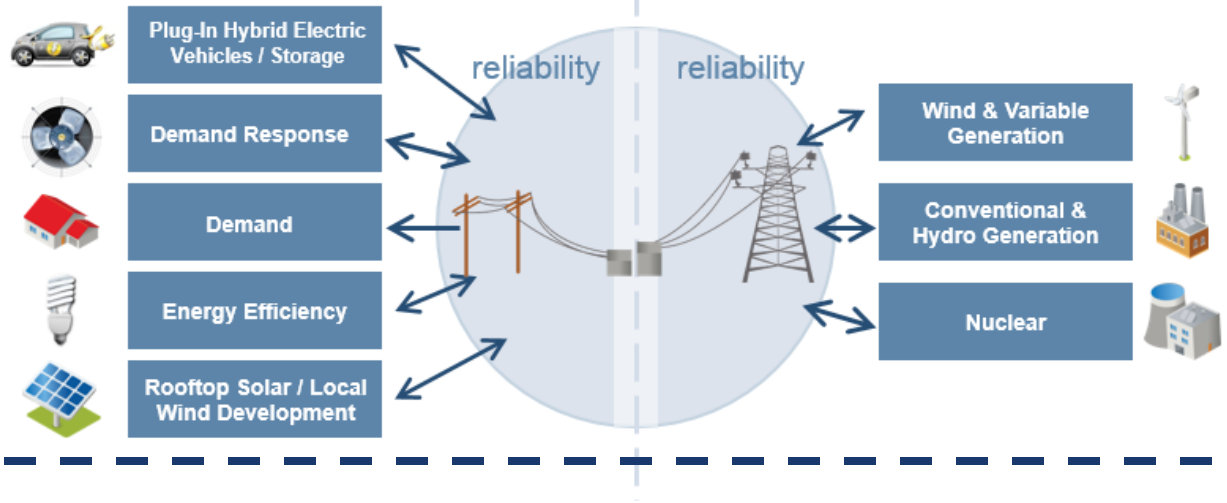
Integrated Power System

- Supports electricity services
- Provider of long-haul power transfers
- Reliability backbone

50%

- DERs must act as a system resource
- Storage, curtailment, coordination, grid support, and control
- Operator or aggregator function may be needed

50%



ERSTF Report Recommendations

1	2	3
All new resources should have the capability to support voltage and frequency.	Monitoring of the ERS measures, investigation of trends, and use of recommended industry practices will serve as an early warning indicator to reliability concerns if issues are not addressed with suitable planning and engineering practices.	Further examination by NERC of the forecasting, visibility, and participation of DERs as an active part of the electric grid is needed.

Risk 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
- Trade-offs between inertia and Primary Frequency Response

Conservative approach

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

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

Frequency Response

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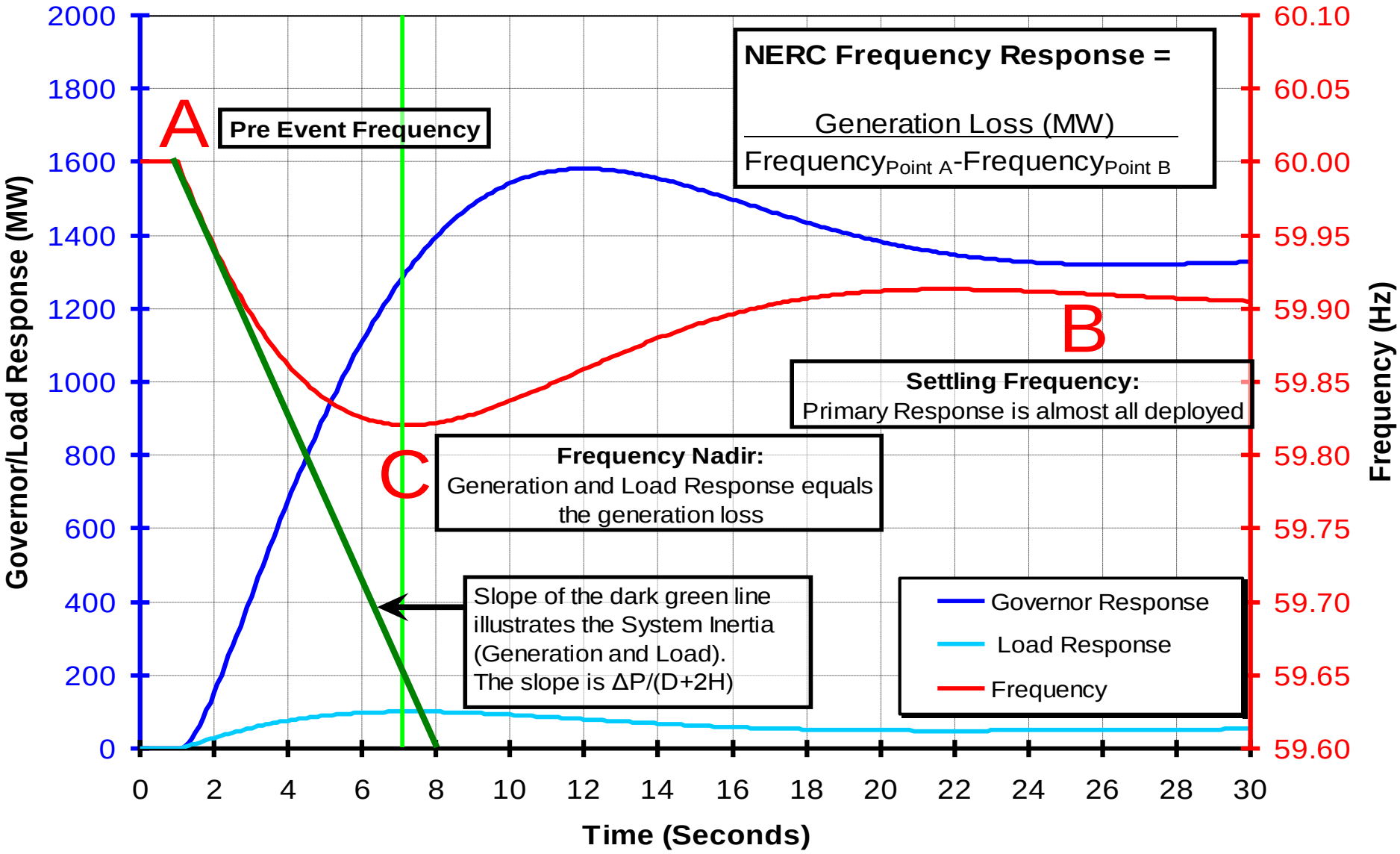
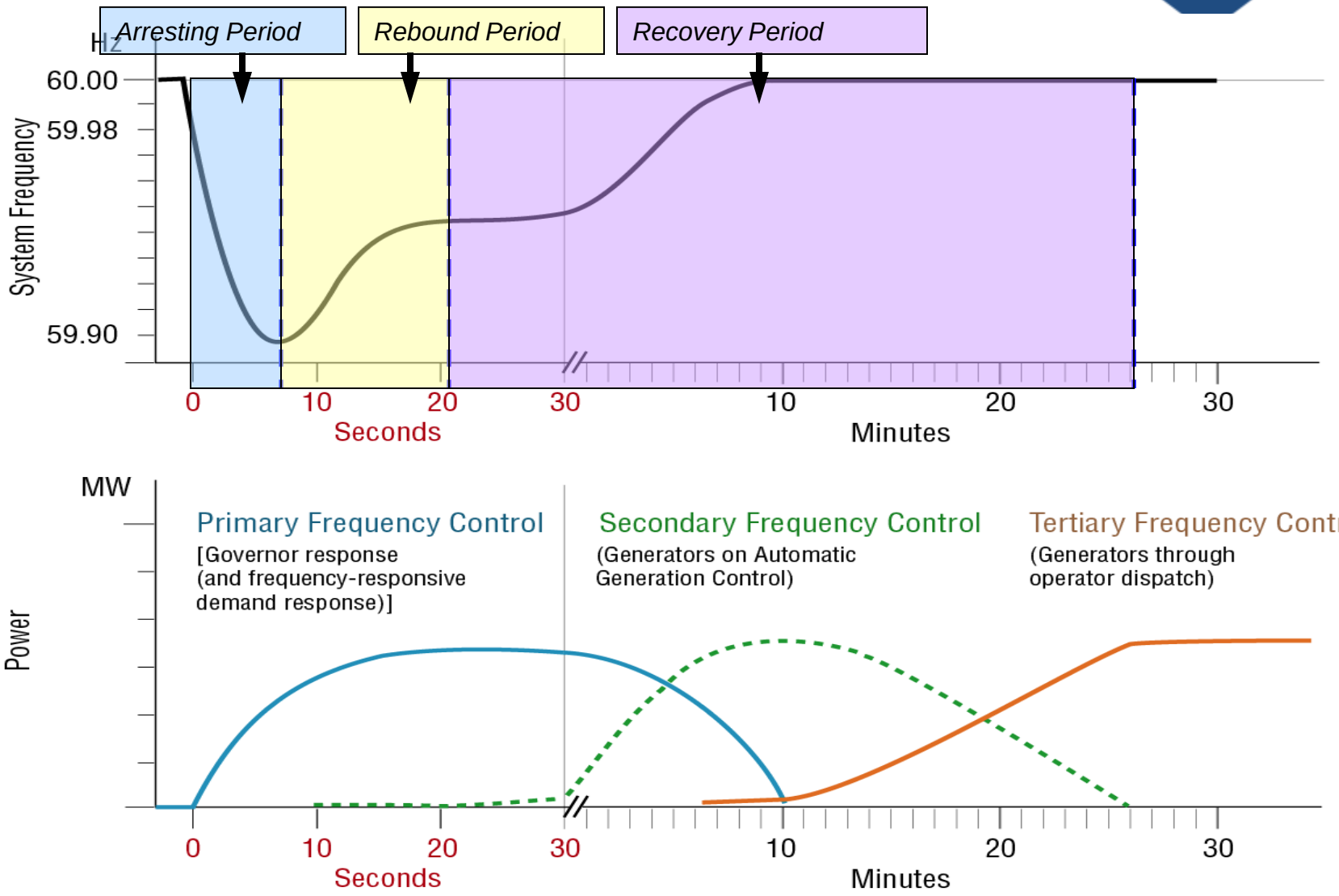
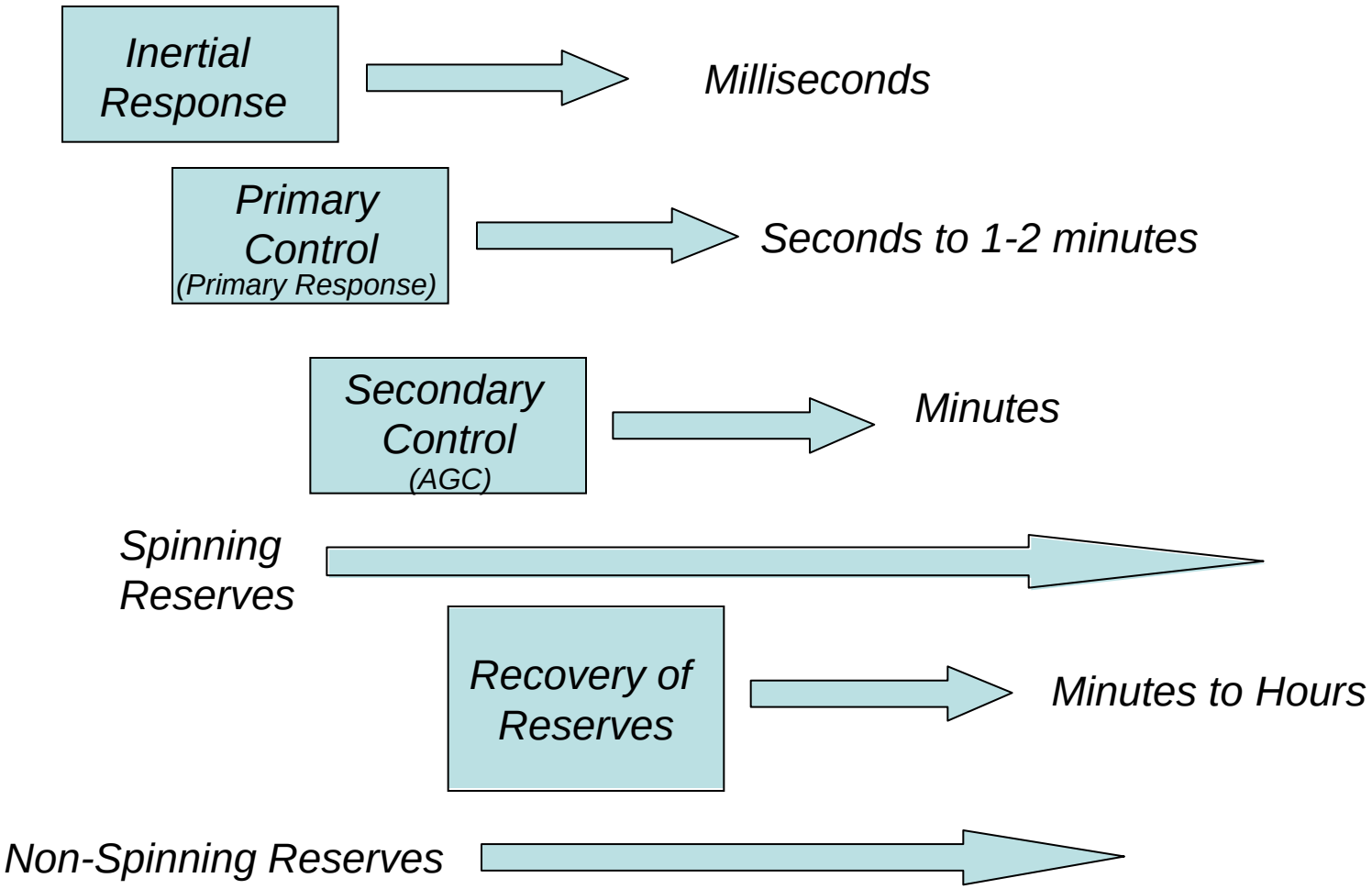
Frequency Response Basics



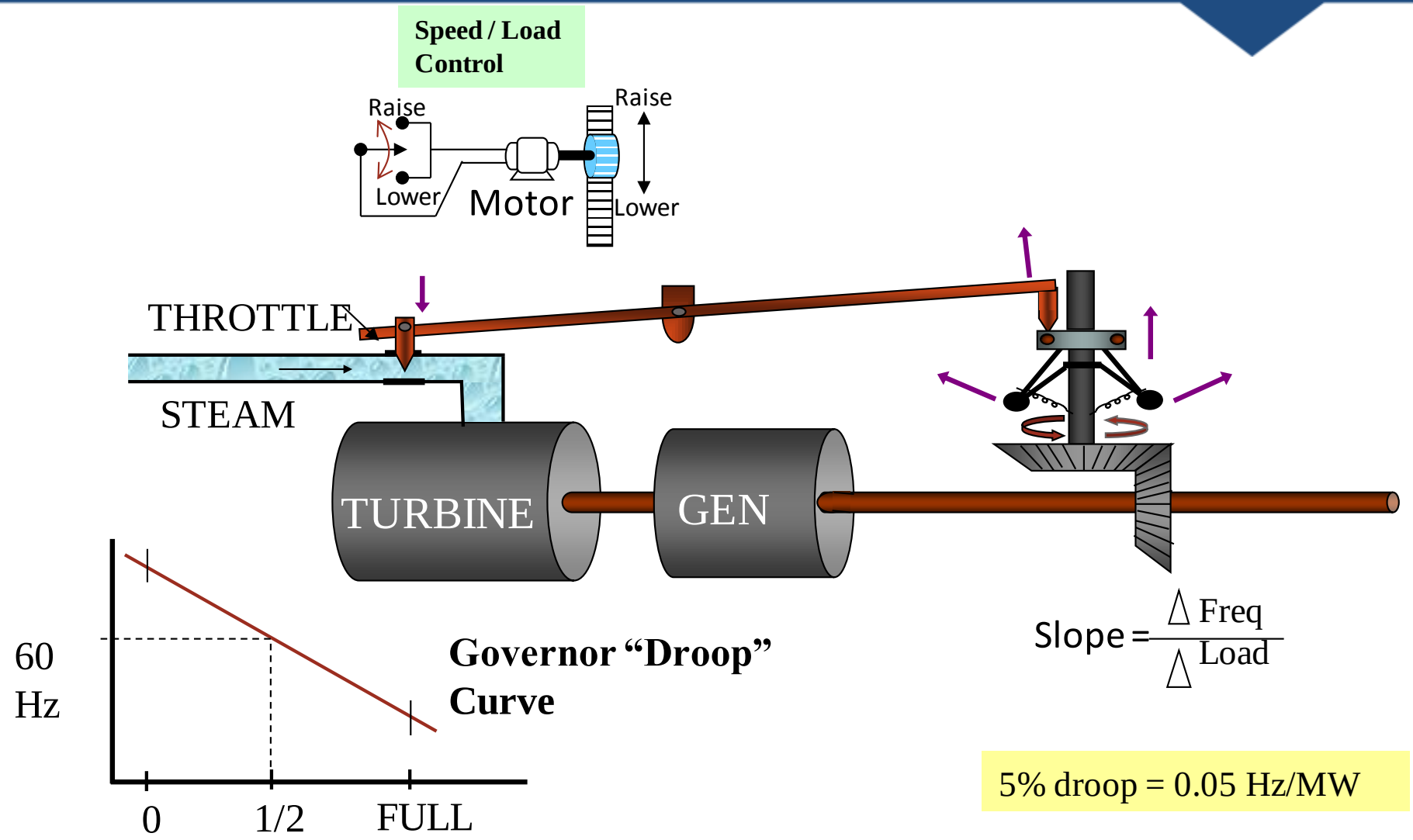
Frequency Response Breakdown



Frequency Response Control Continuum



Response from Governors



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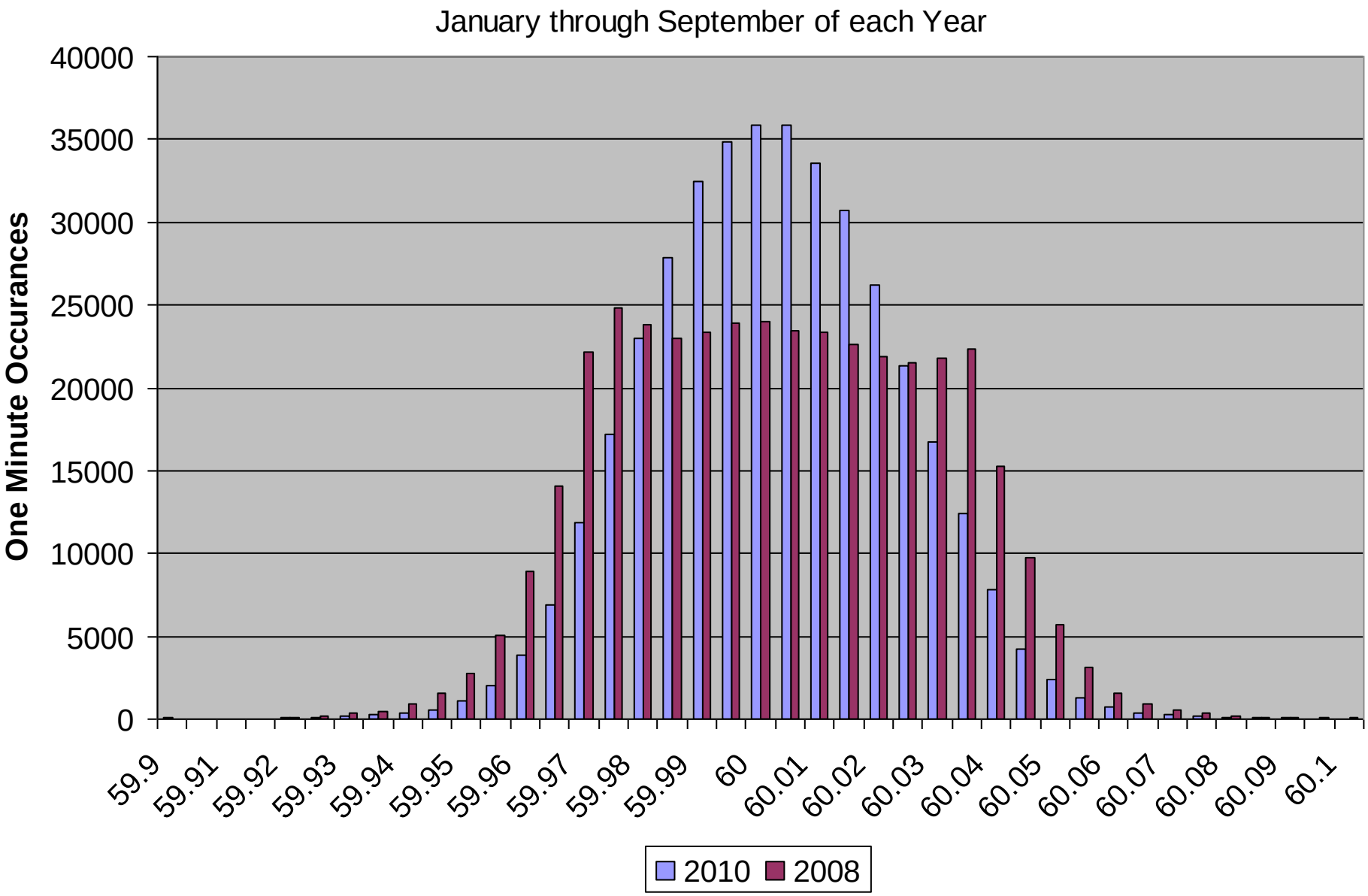
ERCOT Frequency Profile



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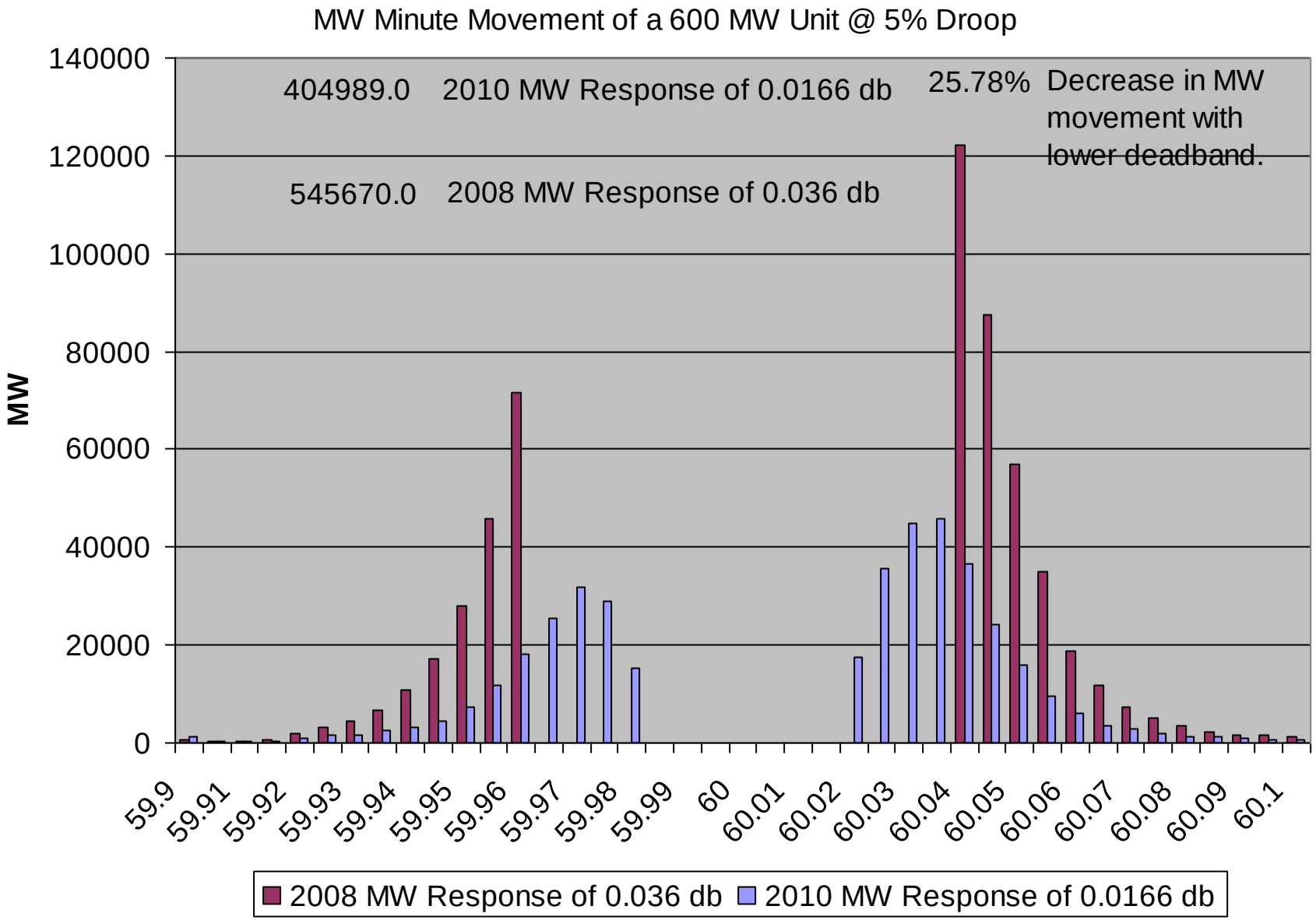
±0.036 Hz Vs ±0.016 Hz Deadband



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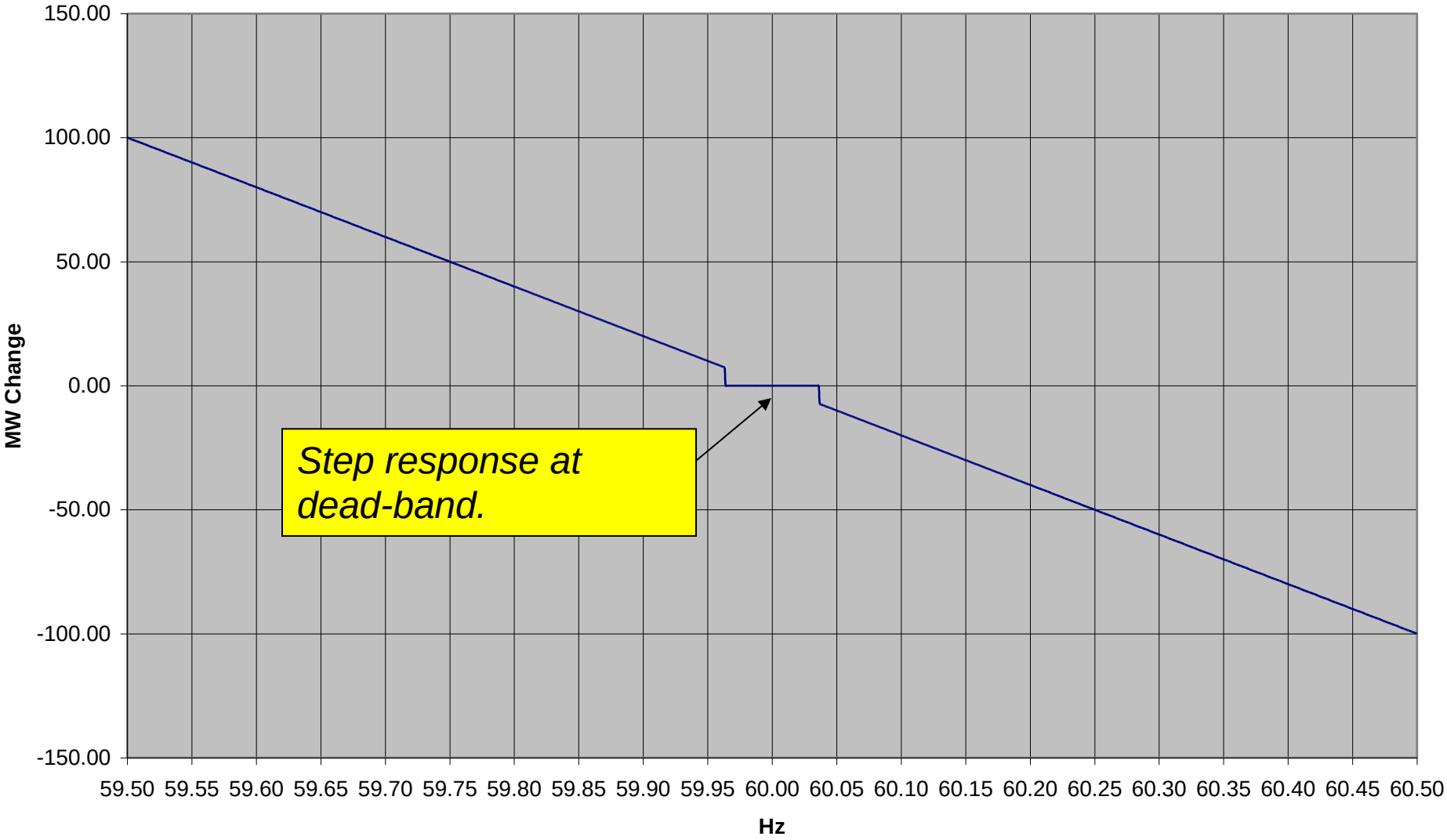
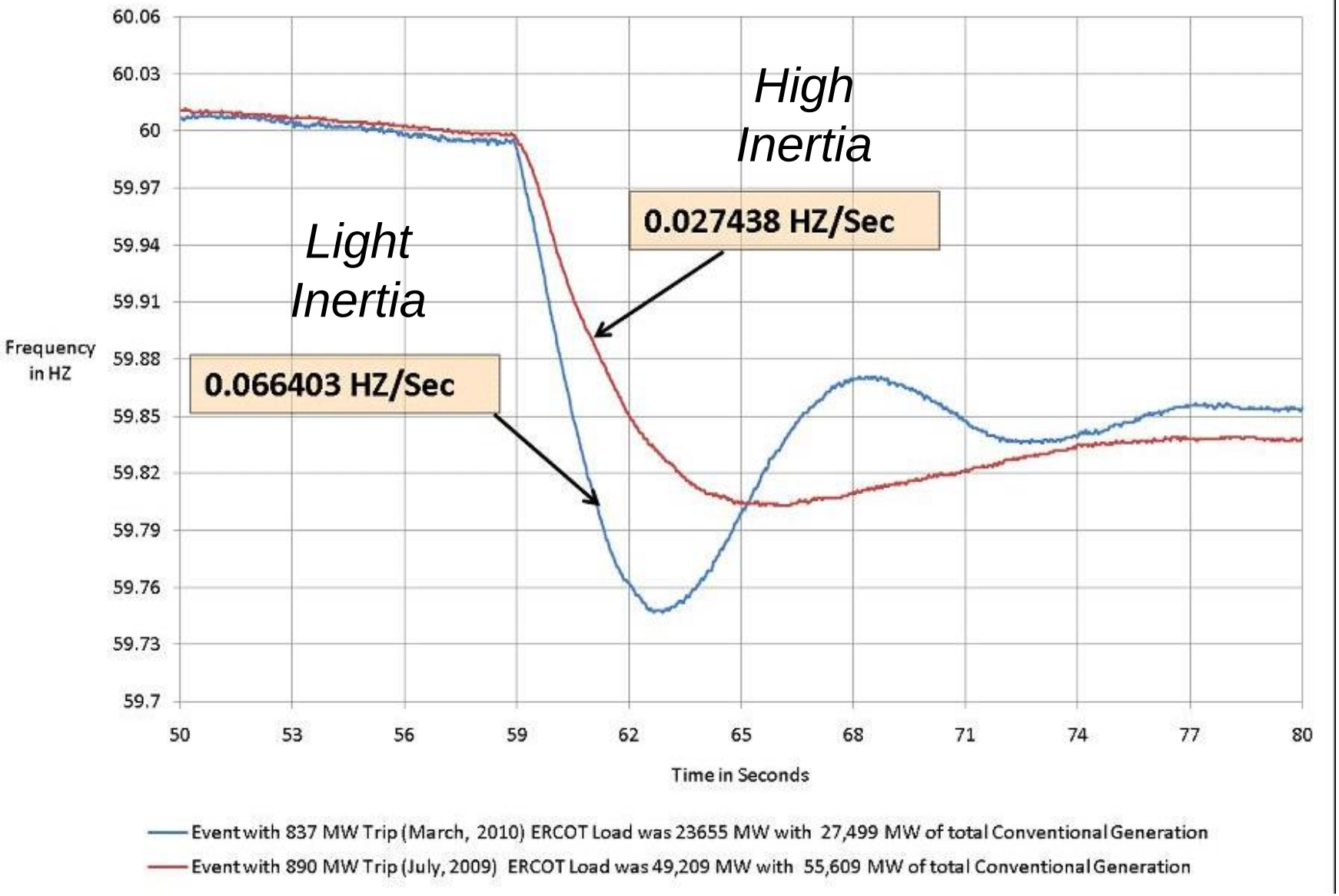
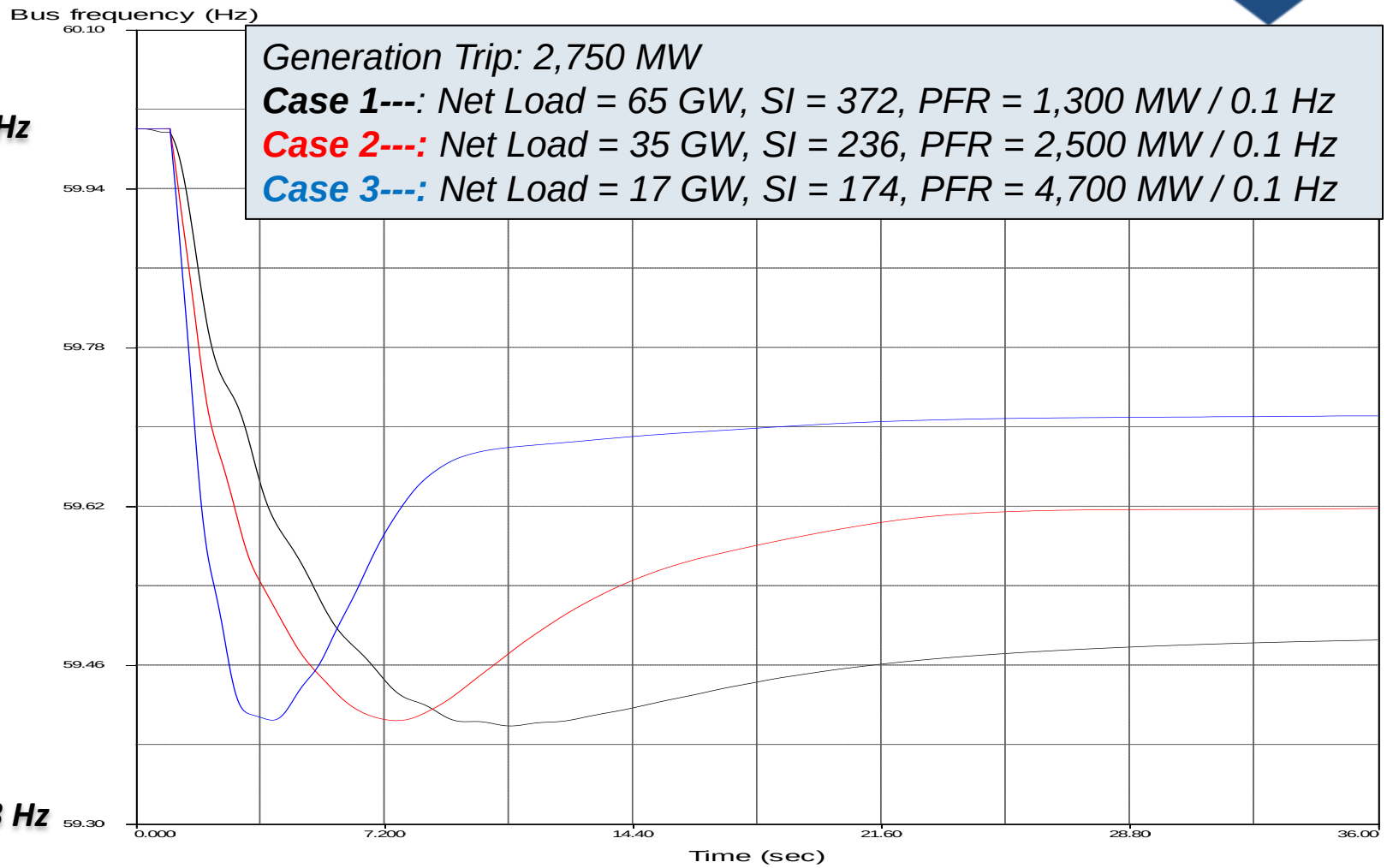
Step Implementation of ±36 mHz Dead Band



Inertial Response Variability



Trade-off between Inertia and Primary Frequency Response



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

Asynchronous Resources

- Current resources are not required to have the capability to provide Frequency Response
  - Except ERCOT Interconnection
- FERC NOI on Generator Interconnection Agreement
- NERC is modifying its Reliability Guideline on Frequency Control to include desired operating characteristics for all frequency-responsive resources
- Coordinating with IEEE on Standard 1547 for voltage and frequency ride-through for DER

Components of Primary Frequency Response

Traditional

- Load Response
- Generator Governor Response

What's New

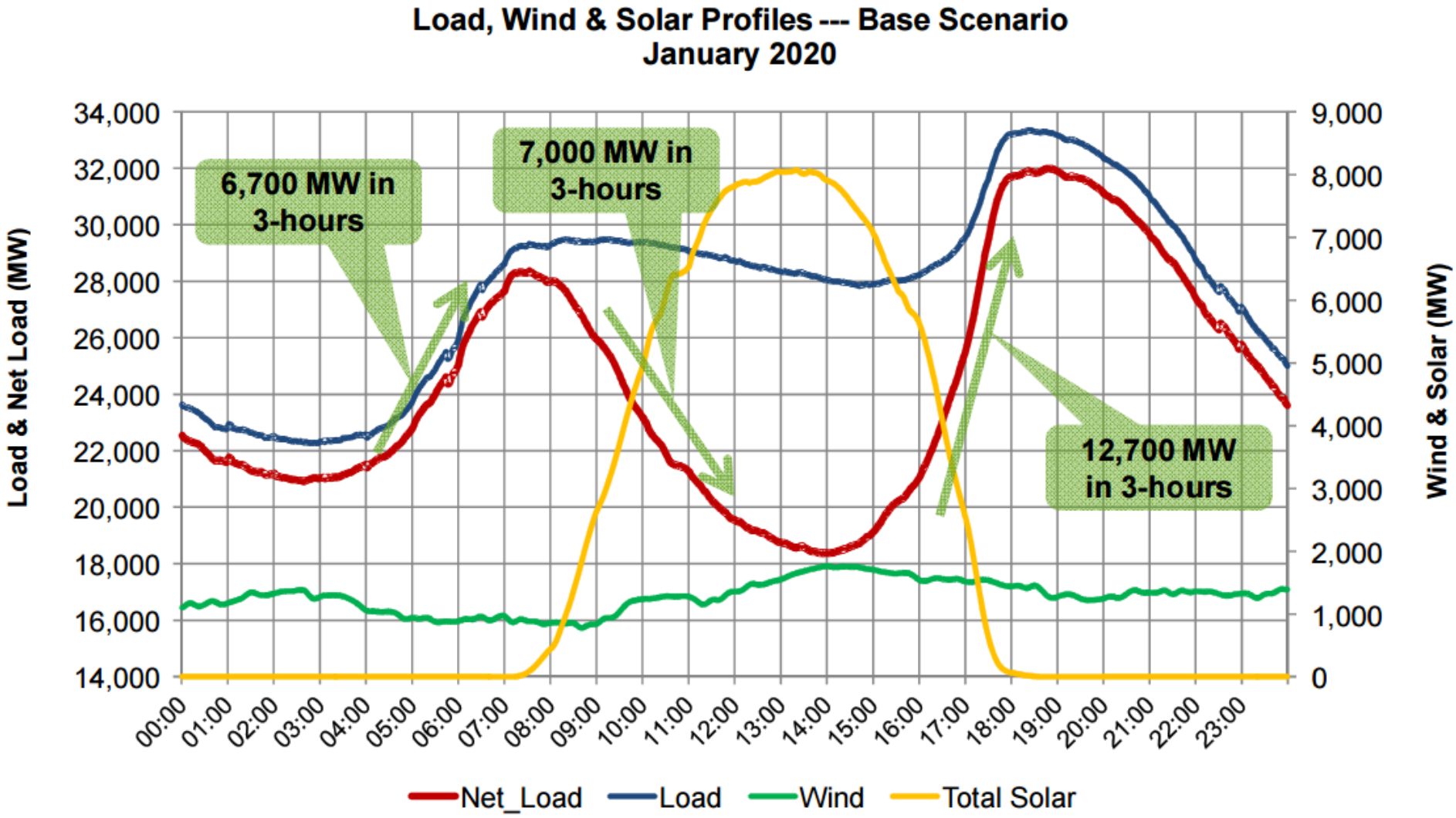
- "Feathered" wind
- "Synthetic inertia"
- Load acting as a Resource (LaaR)

What's coming

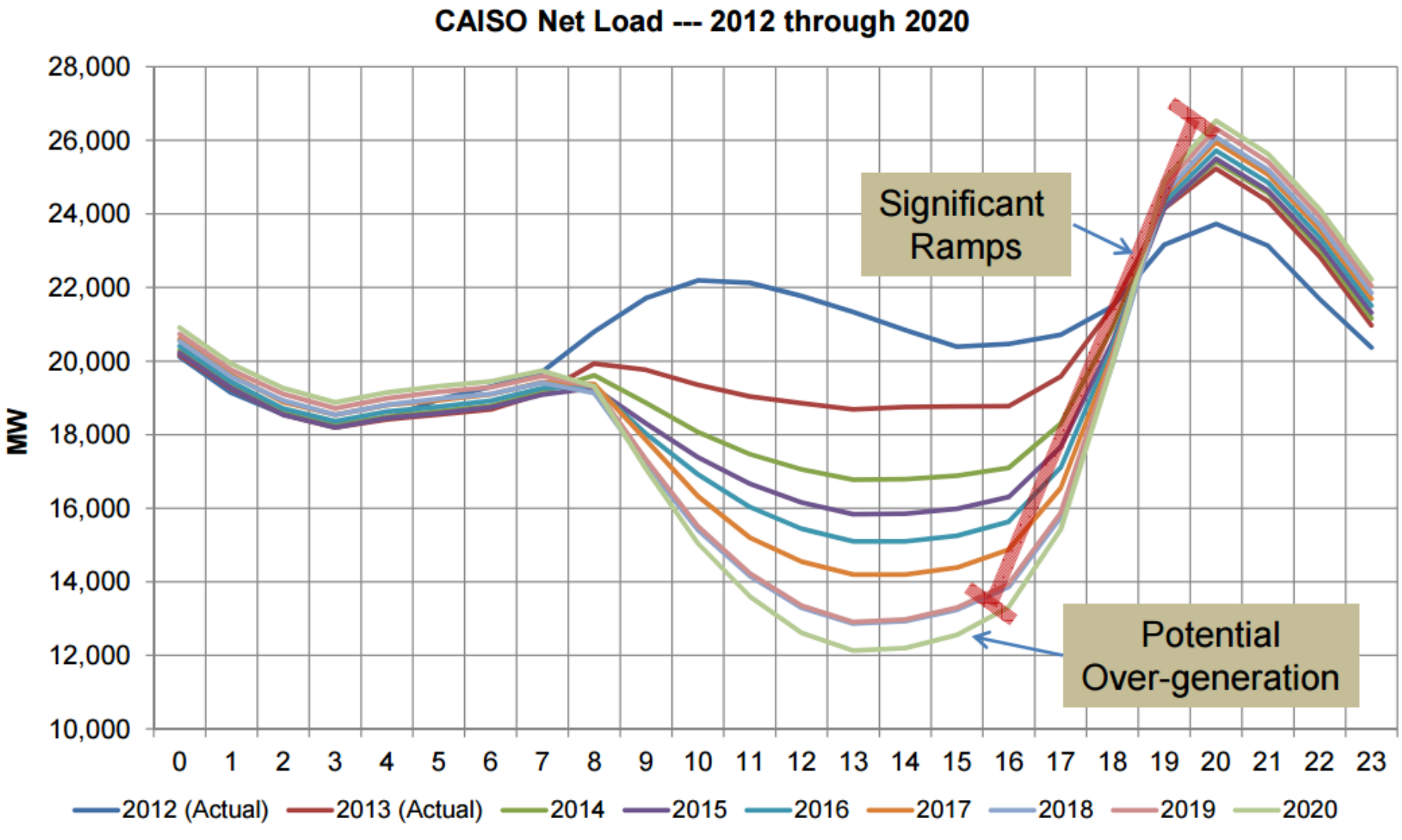
- High-speed energy injection
  - From storage
  - Modulated load

Ramping Services

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

Summary

- Characteristics and behavior of the system are changing
- Rapid penetration of new types of loads and new types of electronically-coupled, often variable, resources
- Current simulation tools are lacking necessary models for new technologies
- Controls interaction could cause instability
- Essential Reliability Services must be maintained
  - Frequency response
  - Voltage control and reactive support
  - Dispatchable resources for load following
- Storage has a tremendous role in the reliability of the future Bulk Power System
- We ***MUST engineer*** the change to maintain reliability

Questions and Answers