



Massachusetts Institute of Technology

Transmission and Renewables

November 4, 2011

Morning Session



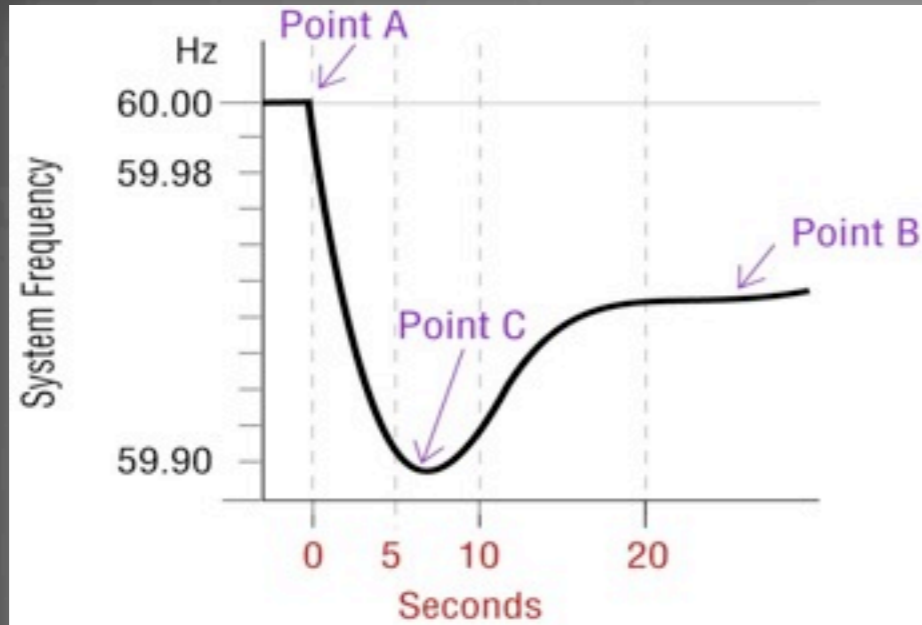
— ≥ 230 kV Transmission



Reliability

How Frequency Control Affects Reliability

Frequency Performance Metric



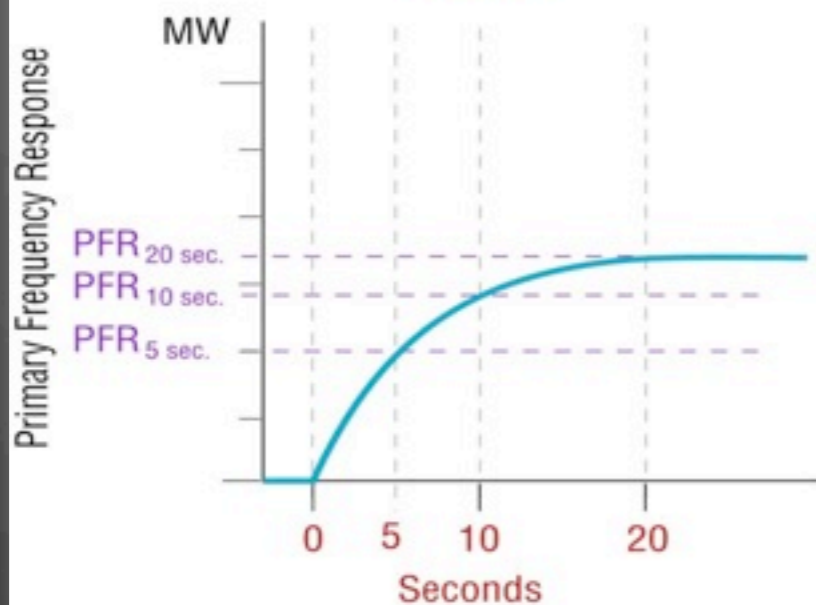
Pre-disturbance Frequency: Frequency_{point A}

Settling Frequency: Frequency_{point B}

Frequency Nadir: Frequency_{point C}

$$\text{Frequency Response (current practice)} = \frac{\text{Generation Lost (MW)}}{\text{Frequency}_{\text{point A}} - \text{Frequency}_{\text{point B}}}$$

$$\text{Nadir-Based Frequency Response} = \frac{\text{Generation Lost (MW)}}{\text{Frequency}_{\text{point A}} - \text{Frequency}_{\text{point C}}}$$

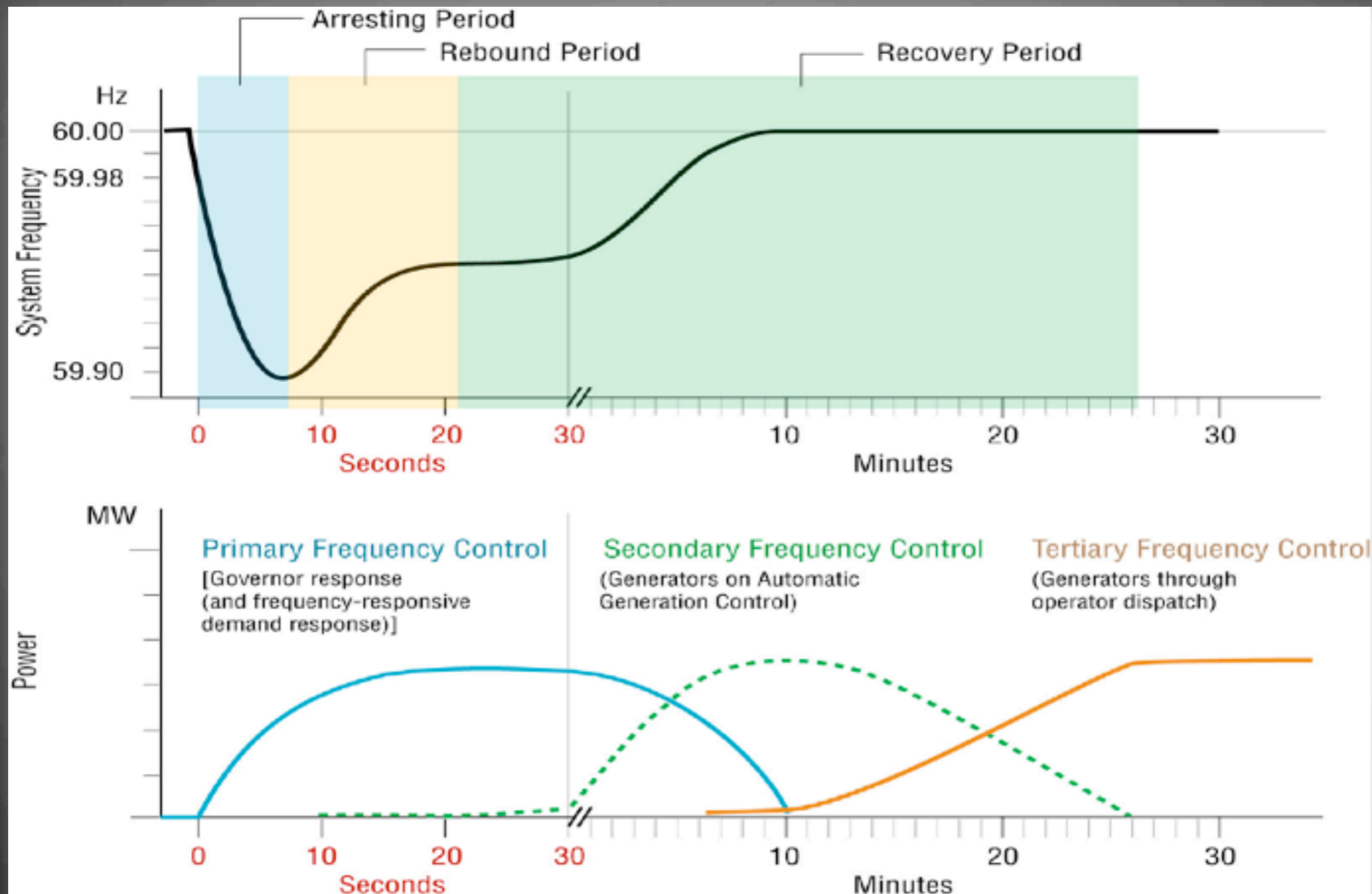


← Primary frequency response (PFR) delivered at 20 seconds

← Primary frequency response (PFR) delivered at 10 seconds

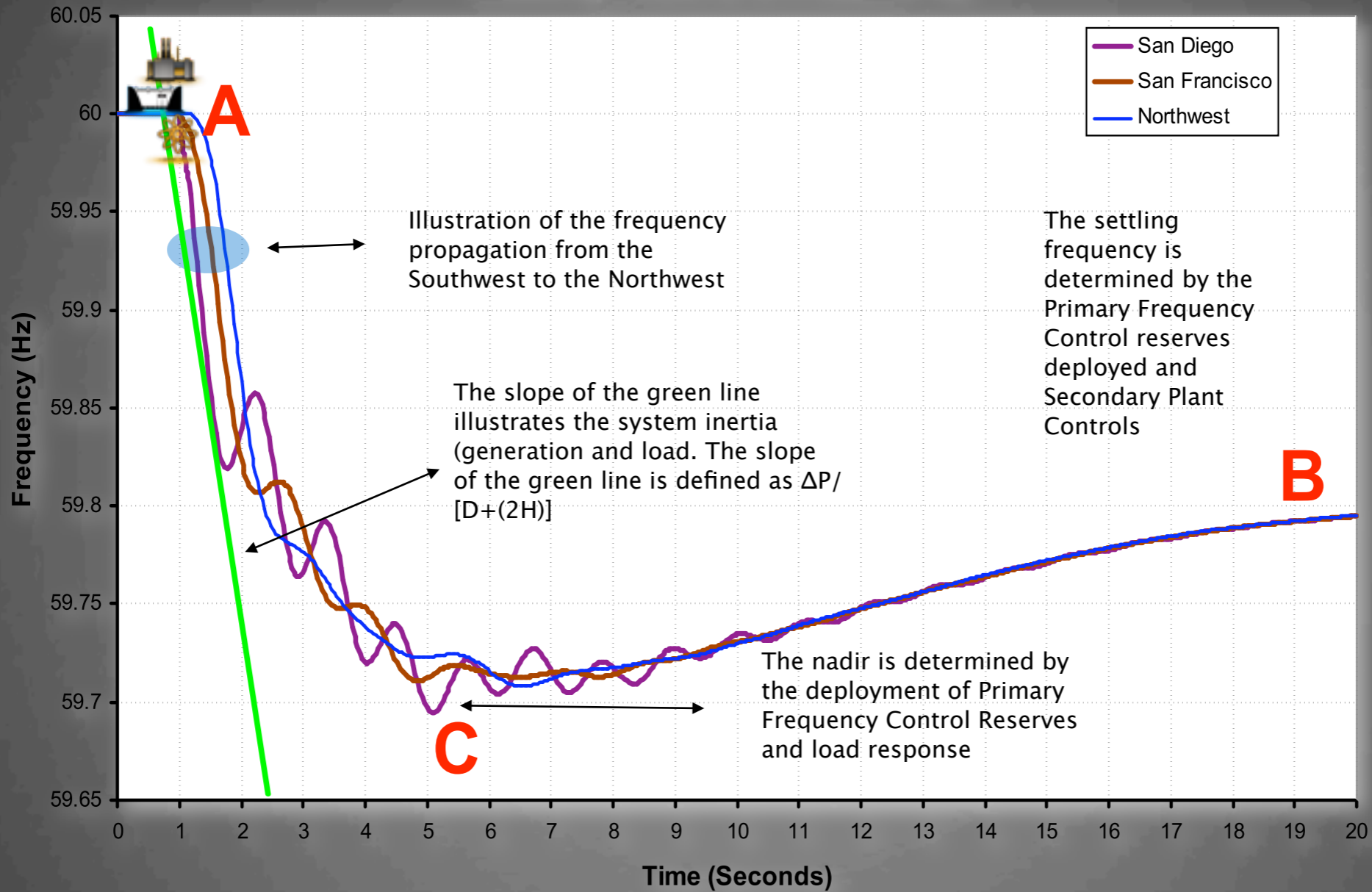
← Primary frequency response (PFR) delivered at 5 seconds

Background



Secondary Preserves Primary

Frequency Propagation in the Western Interconnection Initiating event is in Phoenix AZ



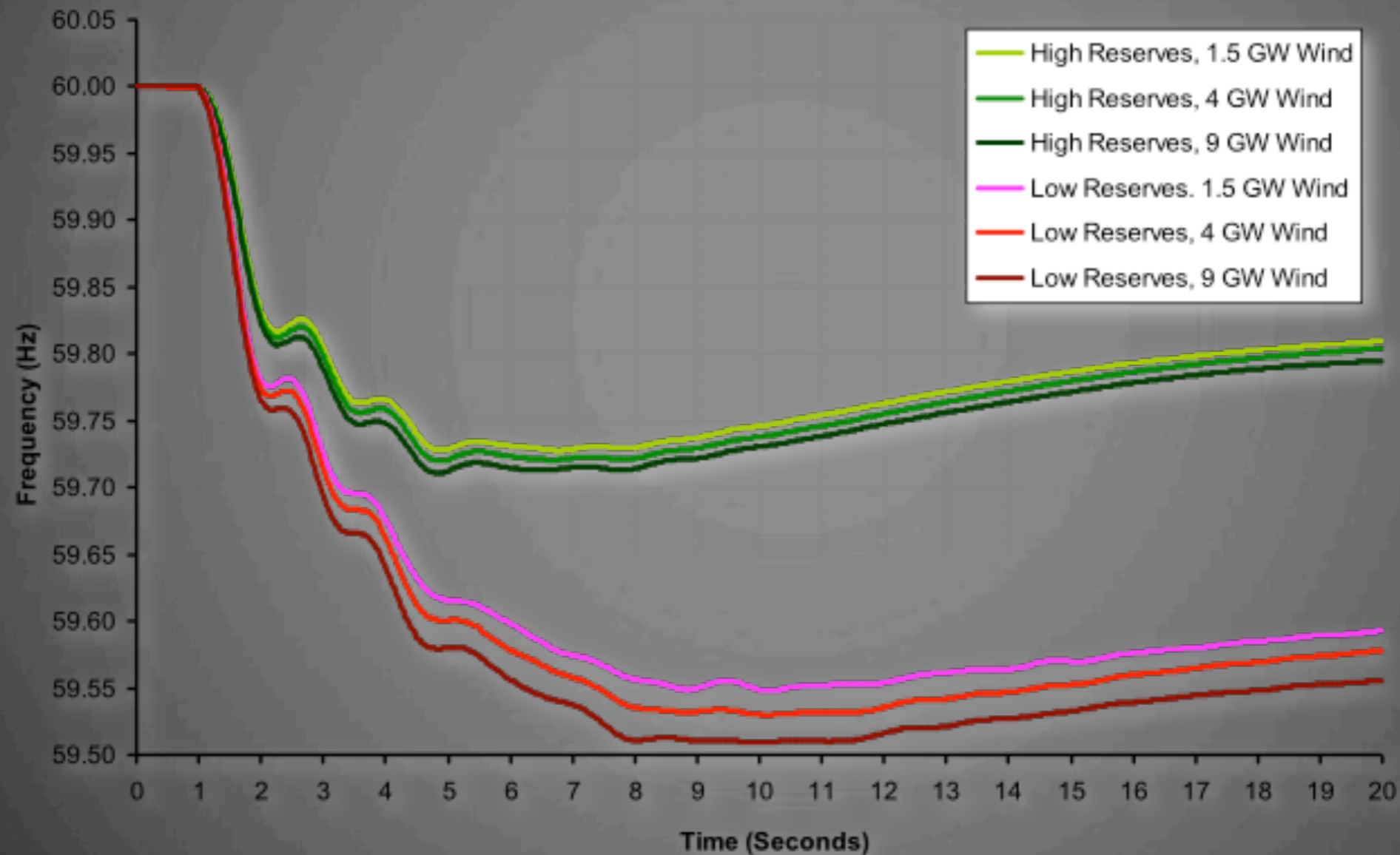
How Frequency Control Affects Reliability

**Under-frequency Load
Shedding is a Safety Net!**

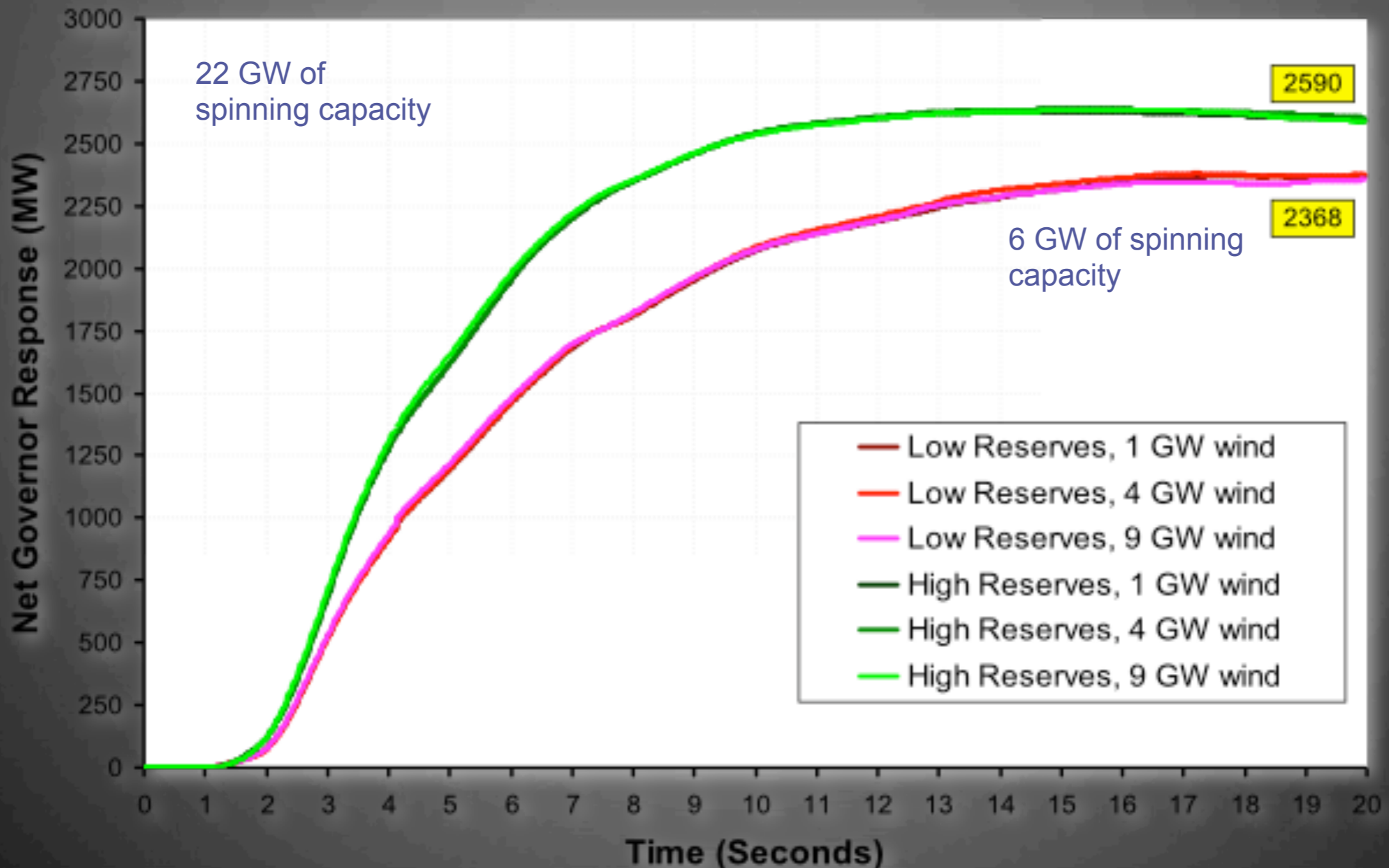
Study Conditions Assumed for 2012 Frequency Response Simulation Analysis

	2012 Minimum or Light System Load (GW)	Highest Level of Wind Generatio n Examined (GW)	Size of Loss of Generation Event Studied (GW)	Highest Under- Frequency Load Shedding Set Point (Hz)
Western Interconnection	80	9	2,800	59.5
Texas Interconnection	34	14.4	2,450	59.3
Eastern Interconnection	309	10.5	4,500	59.7

Simulated Western Interconnection System Frequency Over the First 19 Seconds Following the Sudden Loss of the 2,800 MW Generation

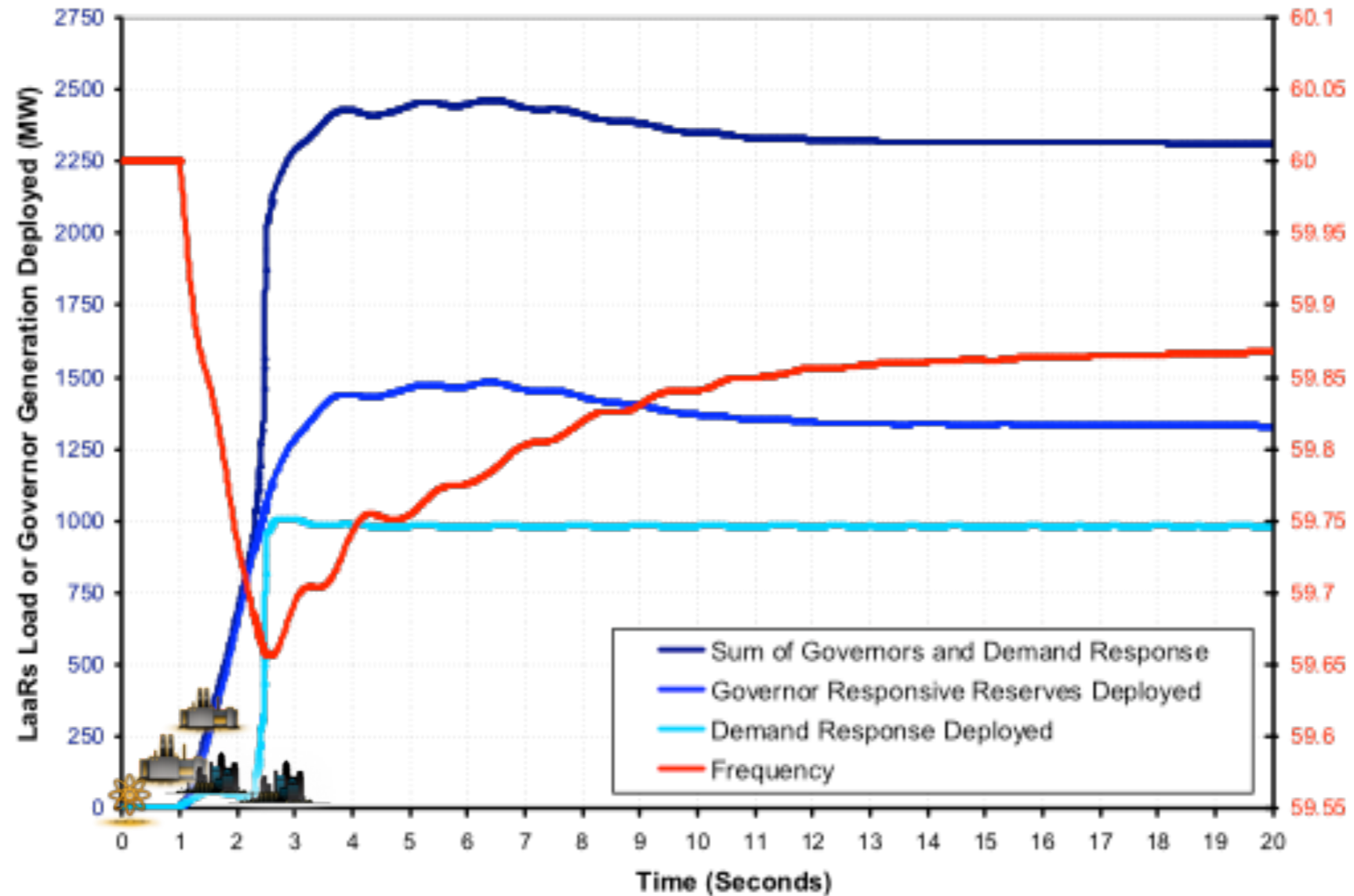


The Power Delivered by Primary Frequency Control Actions via Generator Governors in the Low and High Reserves Cases for the Western Interconnection

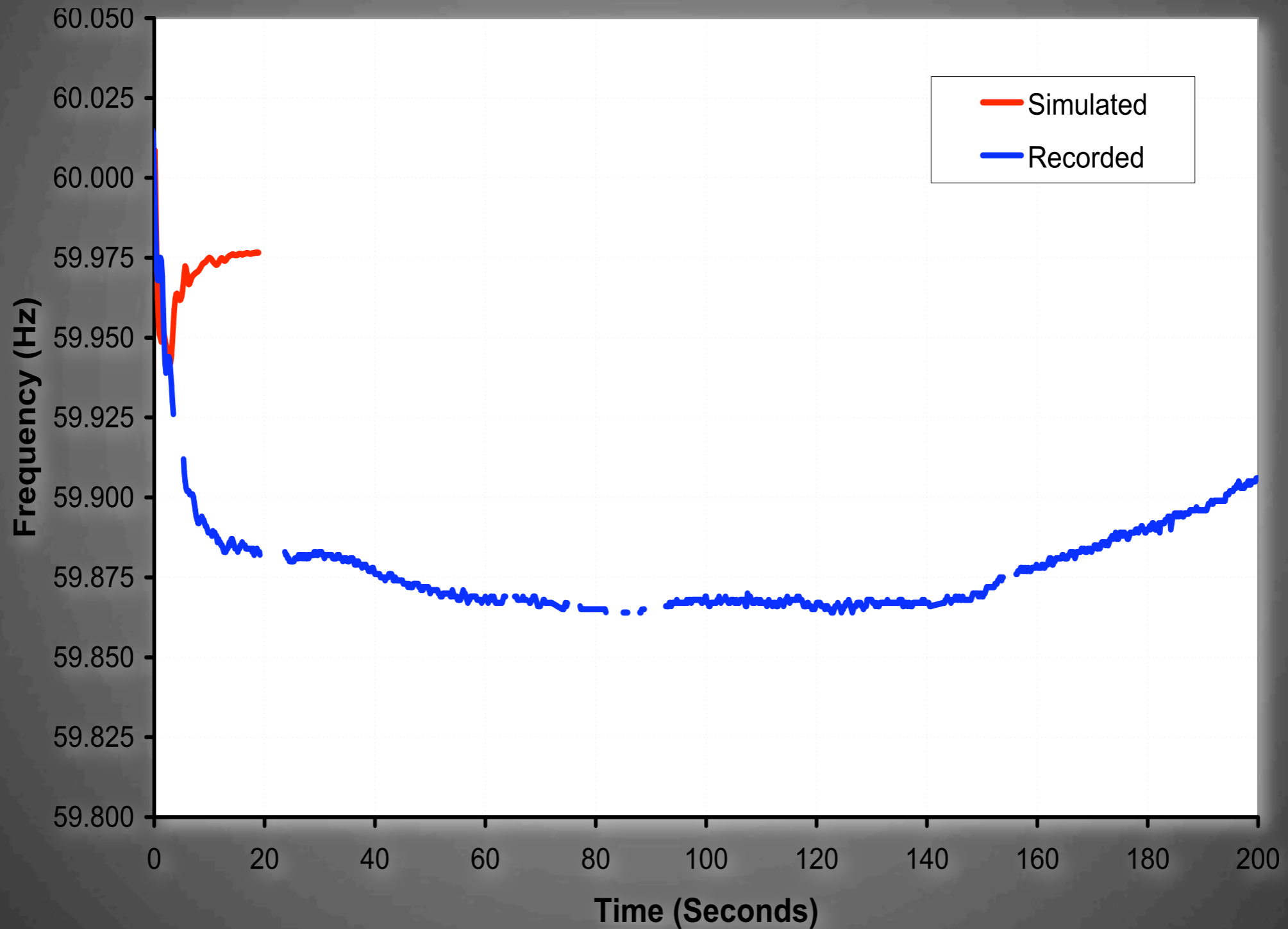


Dynamic Simulation Results ERCOT

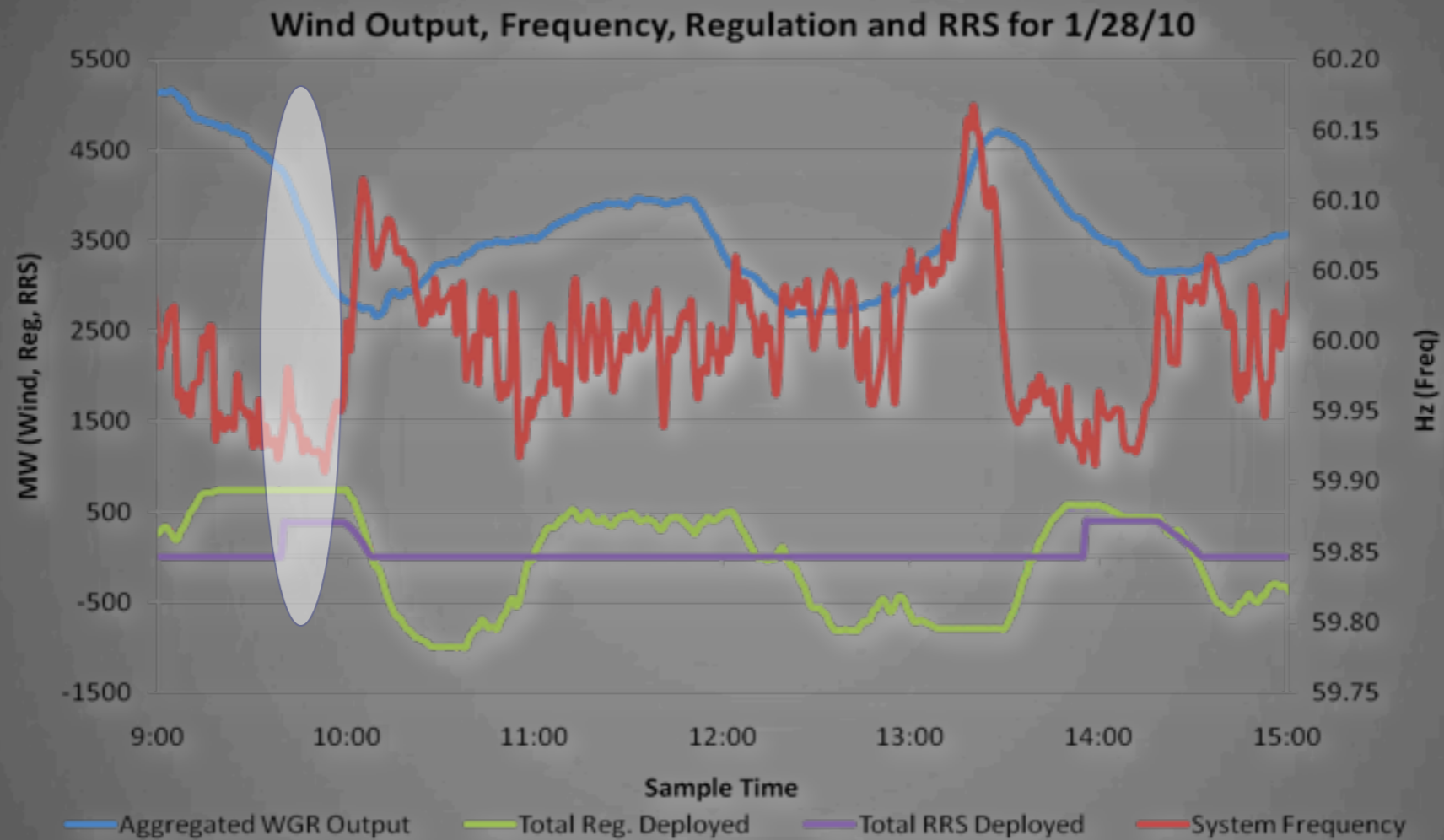
Governor and Demand response



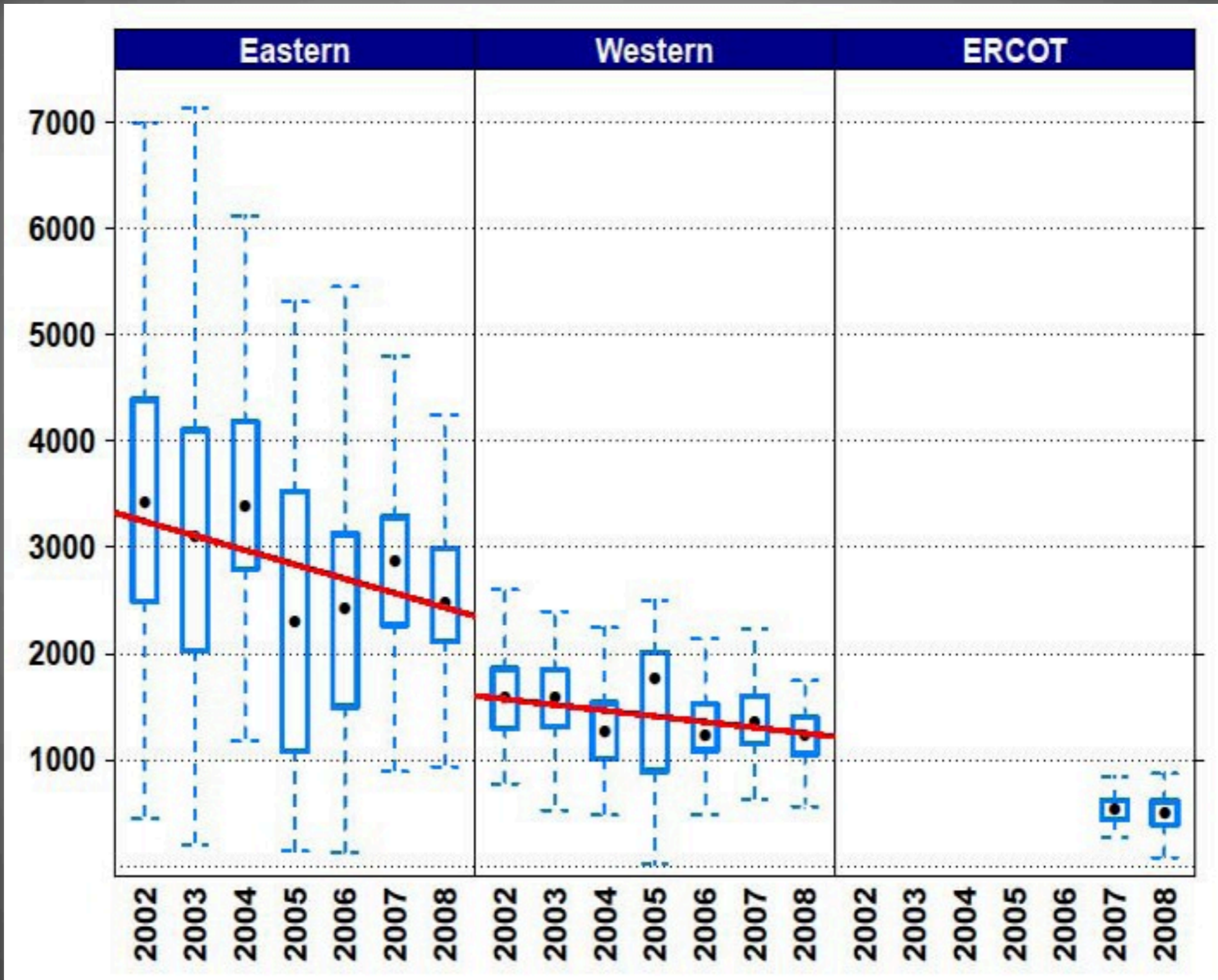
Frequency of the Eastern Interconnection following the Loss of 4,500 MW of Generation—Comparison of Recorded Data with Results from a Simulation of the Event



Findings: ERCOT (2010)



The Recorded Frequency Response of the Three U.S. Interconnections, 2002-2008





Thank you!