Reliability Issues
How Frequency Control Affects Reliability
Frequency Performance Metrics

- Pre-disturbance Frequency: Frequency_{point A}
- Settling Frequency: Frequency_{point B}
- Frequency Nadir: Frequency_{point C}

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

Nadir-Based Frequency Response = \frac{\text{Generation Lost (MW)}}{\text{Frequency}_{point A} - \text{Frequency}_{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
Illustration of the frequency propagation from the Southwest to the Northwest

The slope of the green line illustrates the system inertia (generation and load). The slope of the green line is defined as $\Delta P / [D + (2H)]$

The settling frequency is determined by the Primary Frequency Control reserves deployed and Secondary Plant Controls.

The nadir is determined by the deployment of Primary Frequency Control Reserves and load response.
How Frequency Control Affects Reliability
Under-frequency Load Shedding is a Safety Net!
### Study Conditions Assumed for 2012 Frequency Response Simulation Analysis

<table>
<thead>
<tr>
<th>Interconnection</th>
<th>2012 Minimum or Light System Load (GW)</th>
<th>Highest Level of Wind Generation Examined (GW)</th>
<th>Size of Loss of Generation Event Studied (GW)</th>
<th>Highest Under-Frequency Load Shedding Set Point (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western Interconnection</td>
<td>80</td>
<td>9</td>
<td>2,800</td>
<td>59.5</td>
</tr>
<tr>
<td>Texas Interconnection</td>
<td>34</td>
<td>14.4</td>
<td>2,450</td>
<td>59.3</td>
</tr>
<tr>
<td>Eastern Interconnection</td>
<td>309</td>
<td>10.5</td>
<td>4,500</td>
<td>59.7</td>
</tr>
</tbody>
</table>
Simulated Western Interconnection System Frequency Over the First 19 Seconds Following the Sudden Loss of 2,800 MW of Generation
The Power Delivered by Primary Frequency Control Actions via Generator Governors in the Low and High Reserves Cases for the Western Interconnection

22 GW of spinning capacity

6 GW of spinning capacity
Dynamic Simulation Results
ERCOT
Frequency of the Eastern Interconnection following the Loss of 4,500 MW of generation – Comparison Recorded Data with Results from a Simulation of the Event
Governor / Demand Response to a Contingency in WECC
Governor / Demand Response to a Contingency in ERCOT
The Recorded Frequency Response of Three U.S. Interconnections, 2002-2008
Thank you!