Overview

- Interconnection Differences
- Measurement of PGFR
- Confirm EI Declining PGFR
- Excursion / Disturbance Precursors
- Significance of PGFR Risk
- Sensitivity Analysis
- Eastern I Risk Trends
- Future Work
Frequency Response Plot

Frequency Response

Frequency

Time (Seconds)

A = 60.003
B = 59.945
C = 59.925
Western Plot

Typical Frequency Event WECC
(Average of 5 events, T-5 to T+60)
Eastern Plot

Typical EI Excursion
(Average of 6 Events, T-5 to T+60)
Measurement of PGFR

- Values of Interest
  - Minimum Frequency
  - Settling Frequency

- Minimum - High Resolution Data

- Settling Frequency – Step Function

- Use Two Step Measurement?
  - High Resolution Minimum Frequency
  - Step Function Settling Frequency
Basic Frequency Data

- 2-Second Frequency Error
- 1-Minute Frequency Error
- 2-Second 1\textsuperscript{st} Differences
- 1-Minute 1\textsuperscript{st} Differences
- Sampling Limit Change
2-Second Frequency Error

Frequency Error Trend - 2-Second Data

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1-Minute Frequency Error

Frequency Error Trend - 1-Minute Data

Year

Frequency Error

2002 2003 2004 2005 2006

1m Error 1m Trend
2-Second 1st Difference

1st Difference Trend - 2-Second Data

Year:
- 2002
- 2003
- 2004
- 2005
- 2006

Frequency Error:
- 0.00000
- 0.00020
- 0.00040
- 0.00060
- 0.00080
- 0.00100
- 0.00120
- 0.00140
- 0.00160
1-Minute 1st Difference

1st Difference Trend - 1-Minute Data

Year

Frequency Error

2002 2003 2004 2005 2006

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2-Adjacent 1-Minute Limits

Sampling Limits Trend - Two-Adjacent-Minute Data

- Frequency Error
- Year

- 1m Limit
- 1m Trend
3-Adjacent 1-Minute Limits

Sampling Limits Trend - Three-Adjacent-Minute Data

Frequency Error

Year

1m Limit
1m Trend
Confirming Declining PGFR

- 2-Second Frequency Error Stable
- 1-Minute Frequency Error Stable
  - Control Actions Stable
- 2-Second 1\textsuperscript{st} Difference Stable
  - Interconnection Inertia Stable
- 1-Minute 1\textsuperscript{st} Difference Increasing
- 1-Minute Sampling Limits Increasing
  - Frequency Response Declining
## Table I – Correlating Excursions and Disturbances

<table>
<thead>
<tr>
<th>Interconnection (Events)</th>
<th>Eastern</th>
<th>Western</th>
<th>Texas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial (50)</td>
<td>11 %</td>
<td>51 %</td>
<td>59 %</td>
</tr>
<tr>
<td>Secondary (10)</td>
<td>17 %</td>
<td>70 %</td>
<td>64 %</td>
</tr>
<tr>
<td>Final (1)</td>
<td>60 %</td>
<td>67 %</td>
<td>100 %</td>
</tr>
<tr>
<td>Change (mHz)</td>
<td>&lt;10 mHz</td>
<td>&lt;10 mHz</td>
<td>&lt;40 mHz</td>
</tr>
</tbody>
</table>
Significance of PGFR

- **Frequency Error Drivers**
  - Normal Control Errors
  - Disturbance Errors
  - Disturbance Recovery Errors
  - Scheduled Time Error Corrections

- **Sensitivity Variables**
  - Epsilon 1
  - Generation and Transmission Inventory
  - DCS Limits: Size and Recovery Limits
  - Time Error Correction Procedures
Disturbance Probability

A-C Cumulative Disturbance Probability - > 0.026
2-Second Data - 2002

Frequency Error

-0.25 -0.20 -0.15 -0.10 -0.05 0.00 0.05 0.10 0.15 0.20 0.25
Disturbance Density

A-C Disturbance Density
2-Second Data - 2002

Frequency Error

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Disturbance Recovery

- The Disturbance versus Excursion comparison demonstrated that the disturbance events did not move the frequency outside of the normal distribution. Therefore, any change in disturbance recovery would be offset by a opposing change in normal control action.
Time Error Corrections were evaluated with sensitivity analysis on the final risk trends due to large changes in time error correction requirements from year to year.
Folded Error Density

Folded Frequency Error Density

-Probability vs Frequency Error (Hz)

2006 - Eastern I

Max Combined Folded
Tail Probability - Eastern A-C

Cumulative Tail Probability

2006 - Eastern I

Probability

Frequency Error (Hz)

Max Folded Cumulative

Relay Limit - 1 / 50 Y Limit - 1 / 10 Y Limit -
Tail Probability - Texas A-B

Cumulative Tail Probability

Frequency Error (Hz)

Probability

2006+ - Texas I - A-B Risk

Relay Limit - 1 / 50 Y Limit - 1 / 10 Y Limit - Max Folded Cumulative
### Table II – Sensitivity Ratios

<table>
<thead>
<tr>
<th>Interconnection</th>
<th>Eastern</th>
<th>Western</th>
<th>Texas</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary/Secondary Control for A-C</strong></td>
<td>1.4 / 1</td>
<td>30 / 1</td>
<td>30 / 1</td>
</tr>
<tr>
<td><strong>Primary/Secondary Control for A-B</strong></td>
<td>NA</td>
<td>15 / 1</td>
<td>30 / 1</td>
</tr>
</tbody>
</table>
Reliability Risk Limit Trends

- Maximum Distribution 1/50Y Limit
- Maximum Distribution 1/50Y Trend
- Maximum Distribution 1/10Y Limit
- Maximum Distribution 1/10Y Trend
- Max with ½ Response 1/50Y Limit
- Max with ½ Response 1/50Y Trend
- Max with ½ Response 1/10Y Limit
- Max with ½ Response 1/10Y Trend
- Limit 182 mHz
Conclusions & Future Work

- Interconnections Currently Reliable
- Risk more sensitive to Primary Control than to Secondary Control
- Eastern I Risk Trend Problematical
- Develop a workable Frequency Response Standard
- Review Reserve Definitions
- Review precursor effect on Disturbance Control Standard