

Frequency Deviation Reliability Risk Evaluation and Mitigation

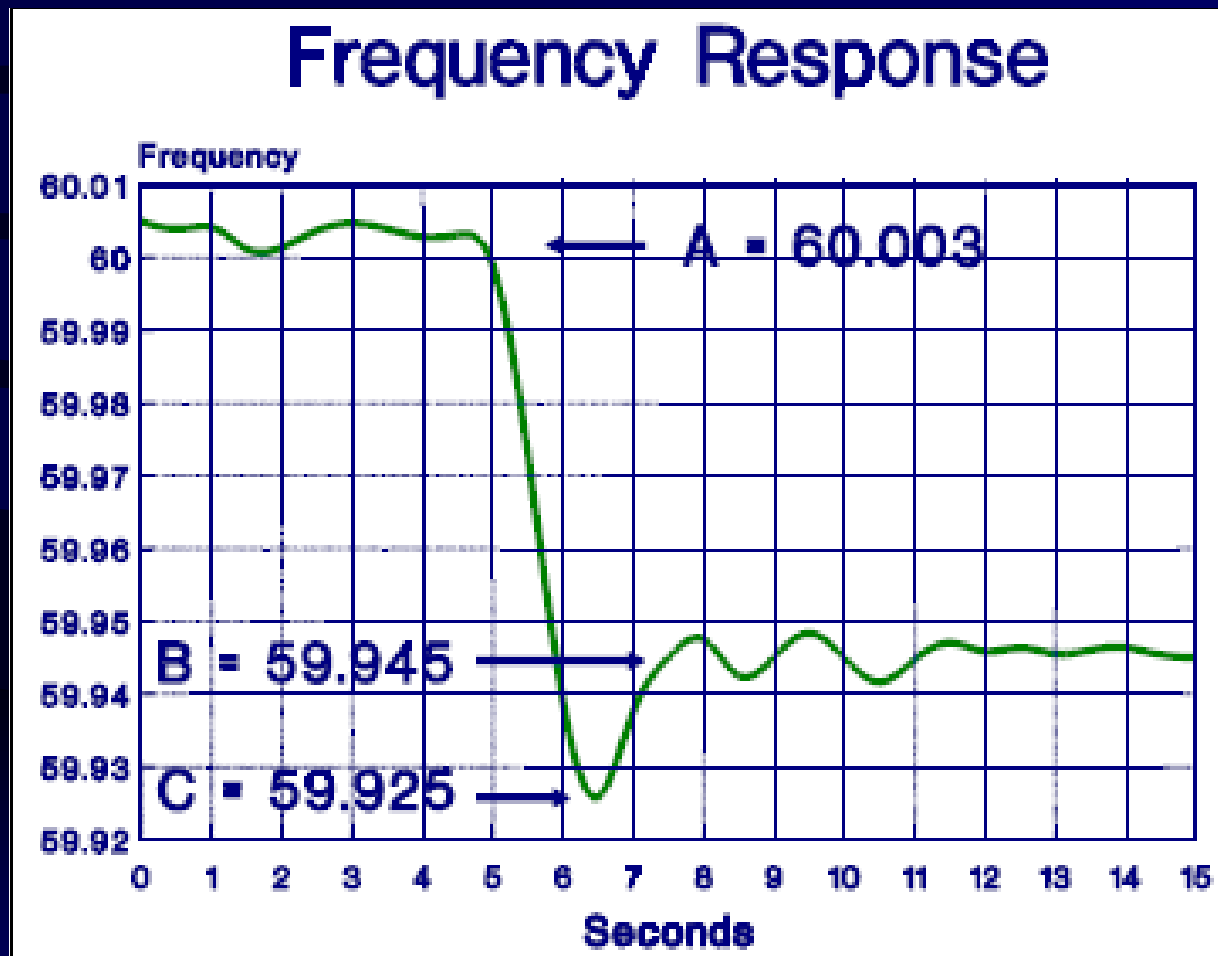
Howard F. Illian, President
Energy Mark, Inc.
March 11, 2008



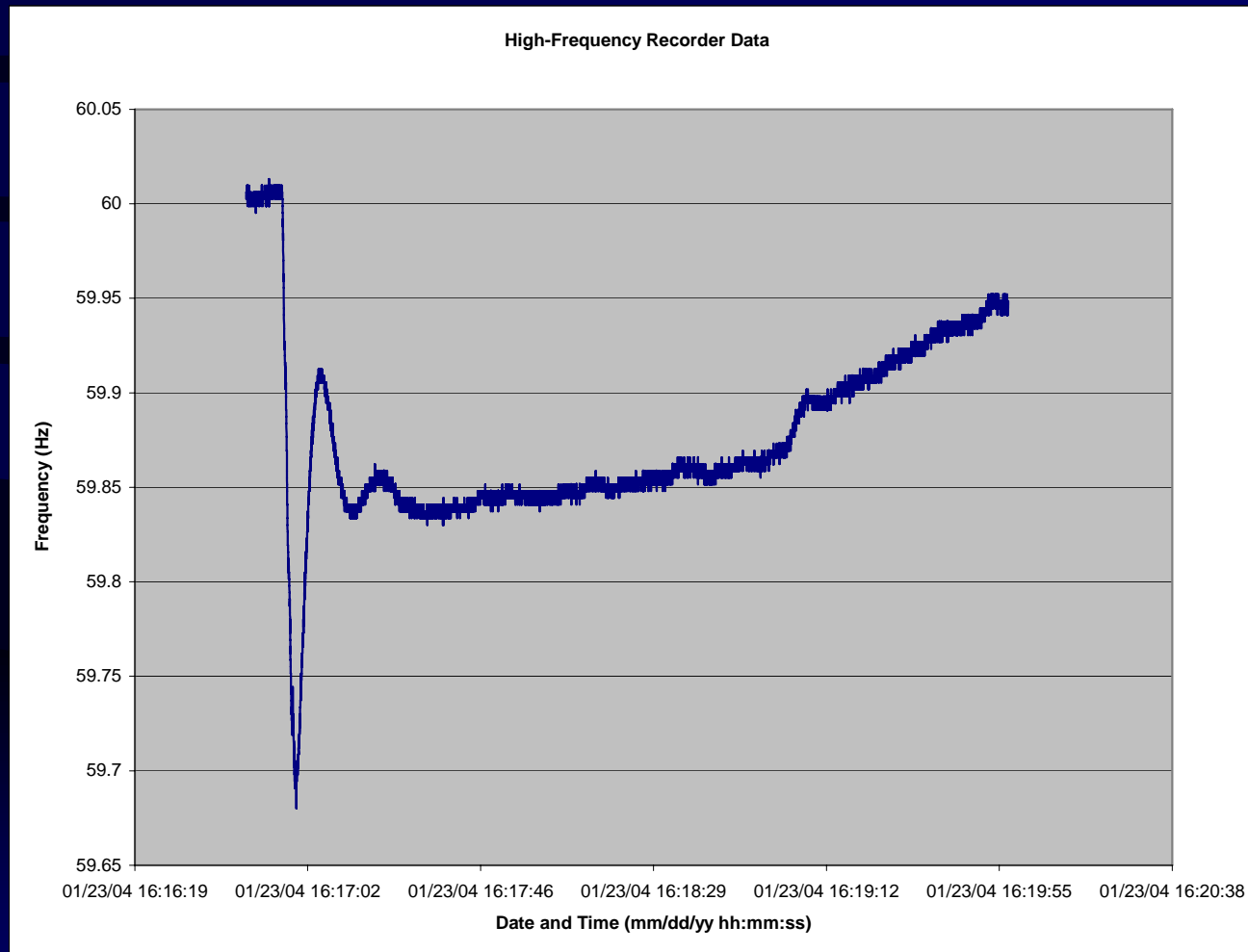
Overview

- **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

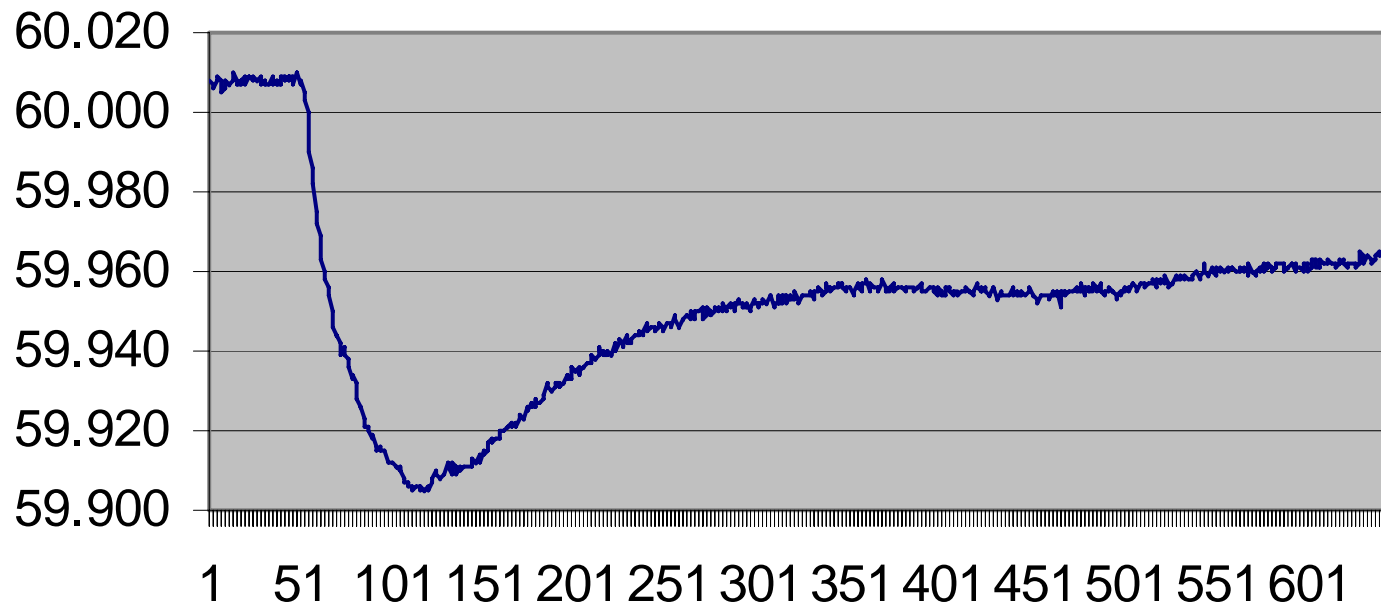


Texas Plot



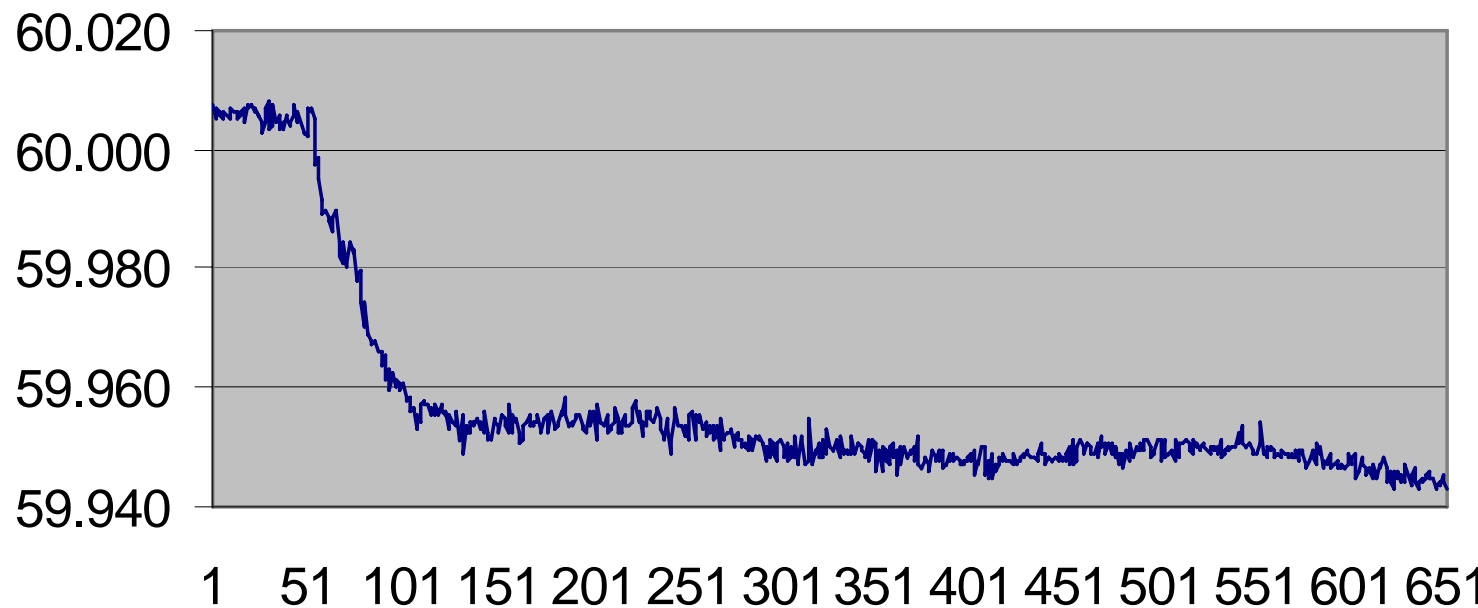
Western Plot

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

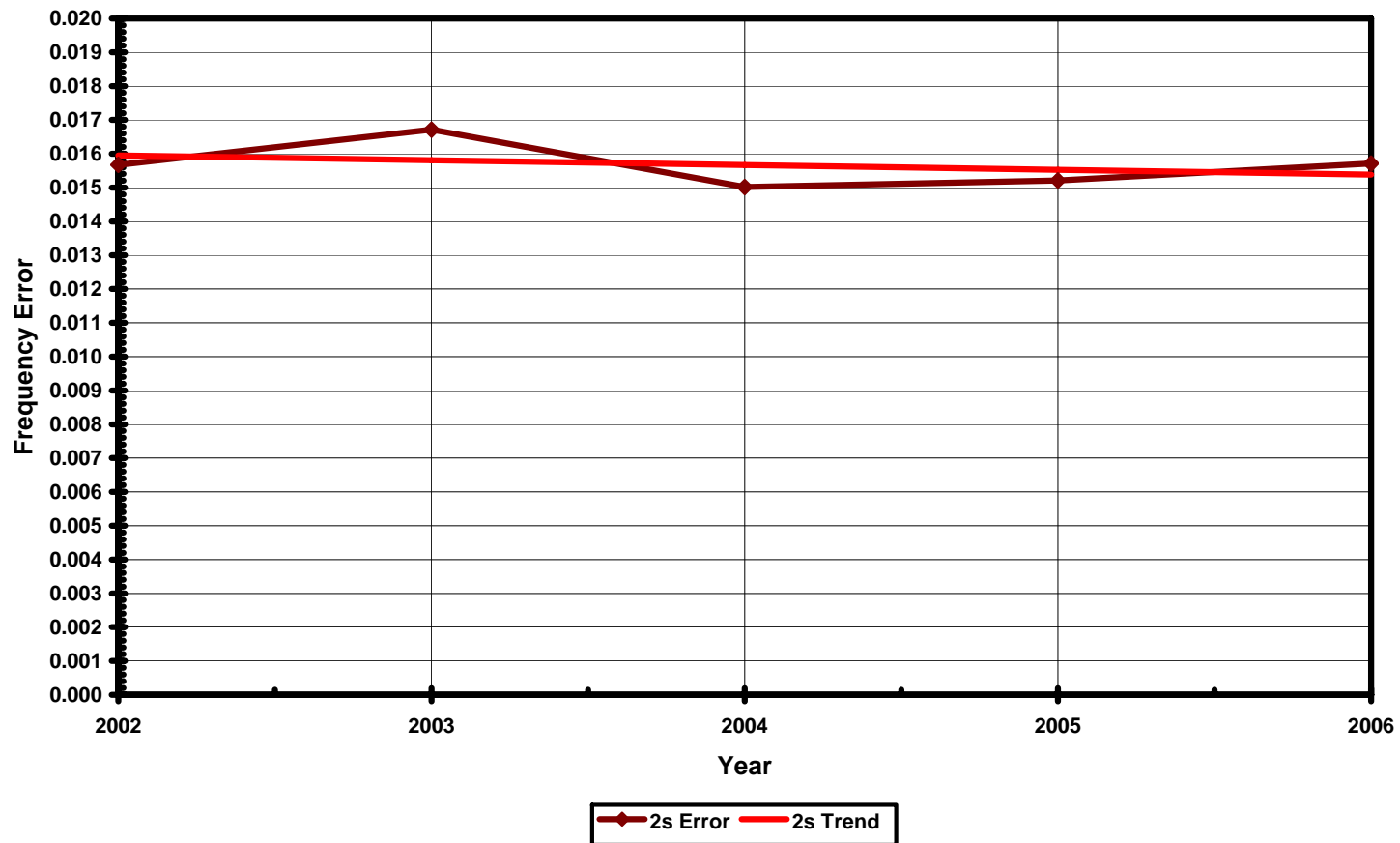
- **Values of Interest**
 - Minimum Frequency
 - Settling Frequency
- **Minimum - High Resolution Data**
- **Settling Frequency – Step Function**
- **Use Two Step Measurement ?**
 - High Resolution Minimum Frequency
 - Step Function Settling Frequency

Basic Frequency Data

- 2-Second Frequency Error
- 1-Minute Frequency Error
- 2-Second 1st Differences
- 1-Minute 1st Differences
- Sampling Limit Change

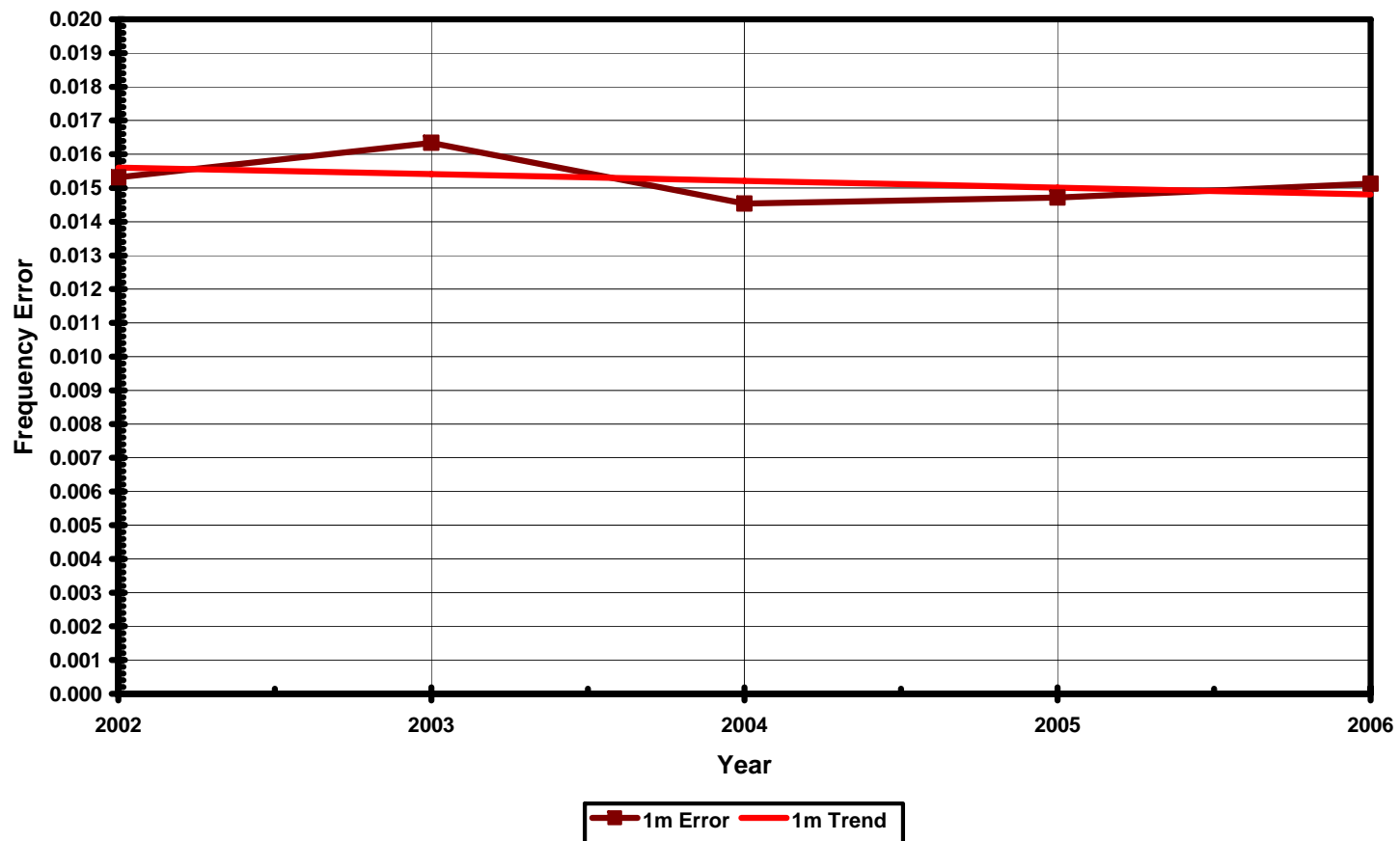
2-Second Frequency Error

Frequency Error Trend - 2-Second Data



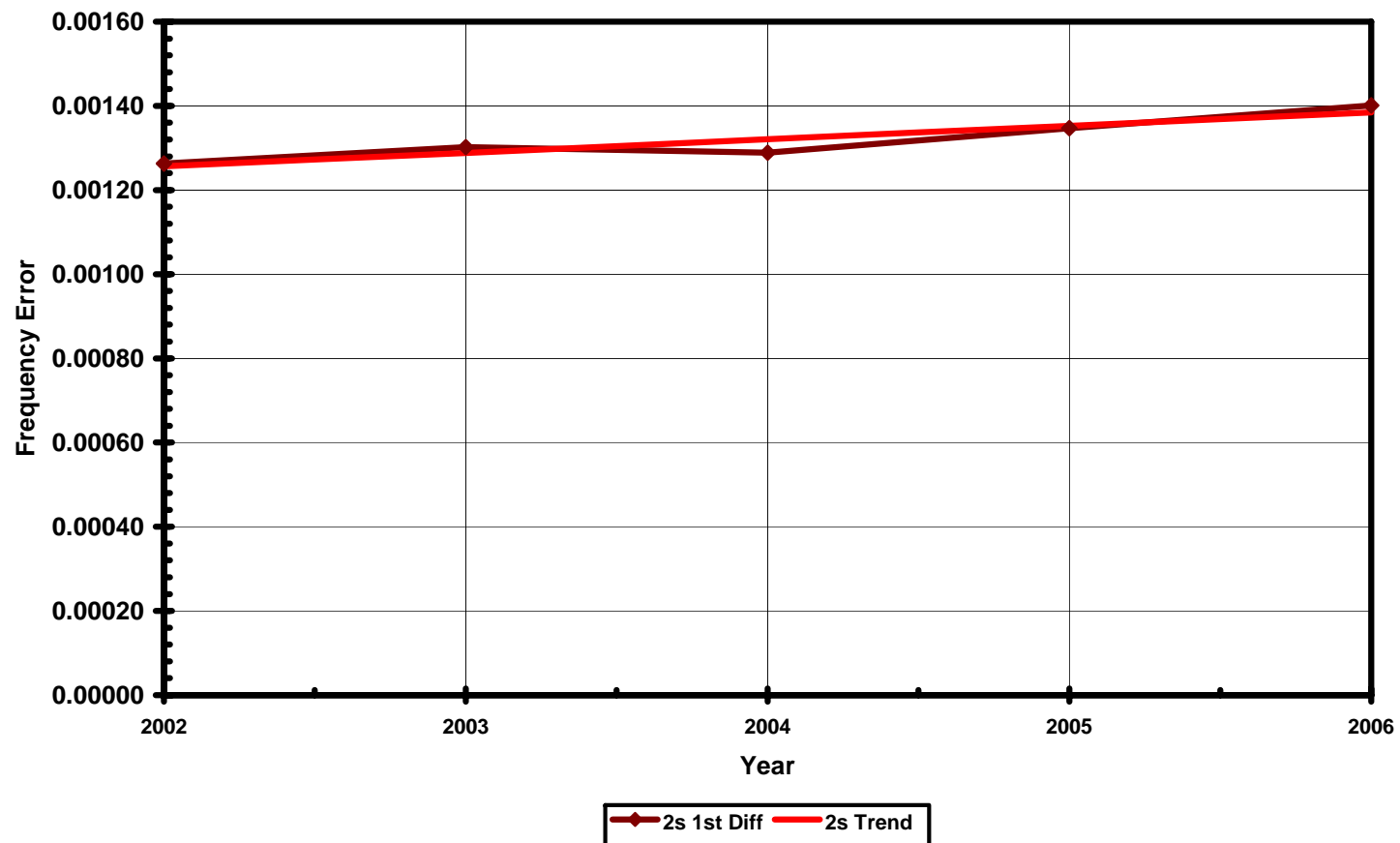
1-Minute Frequency Error

Frequency Error Trend - 1-Minute Data



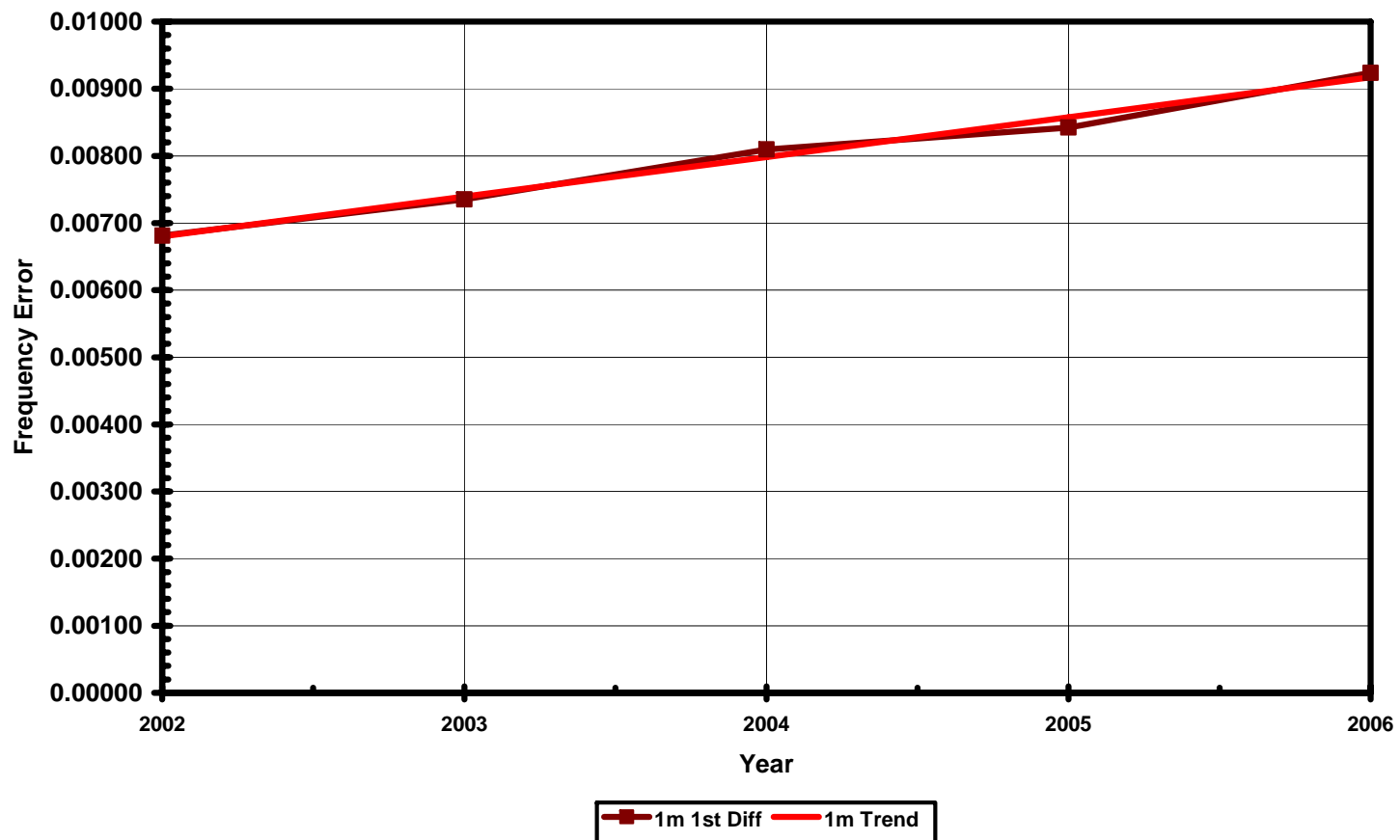
2-Second 1st Difference

1st Difference Trend - 2-Second Data

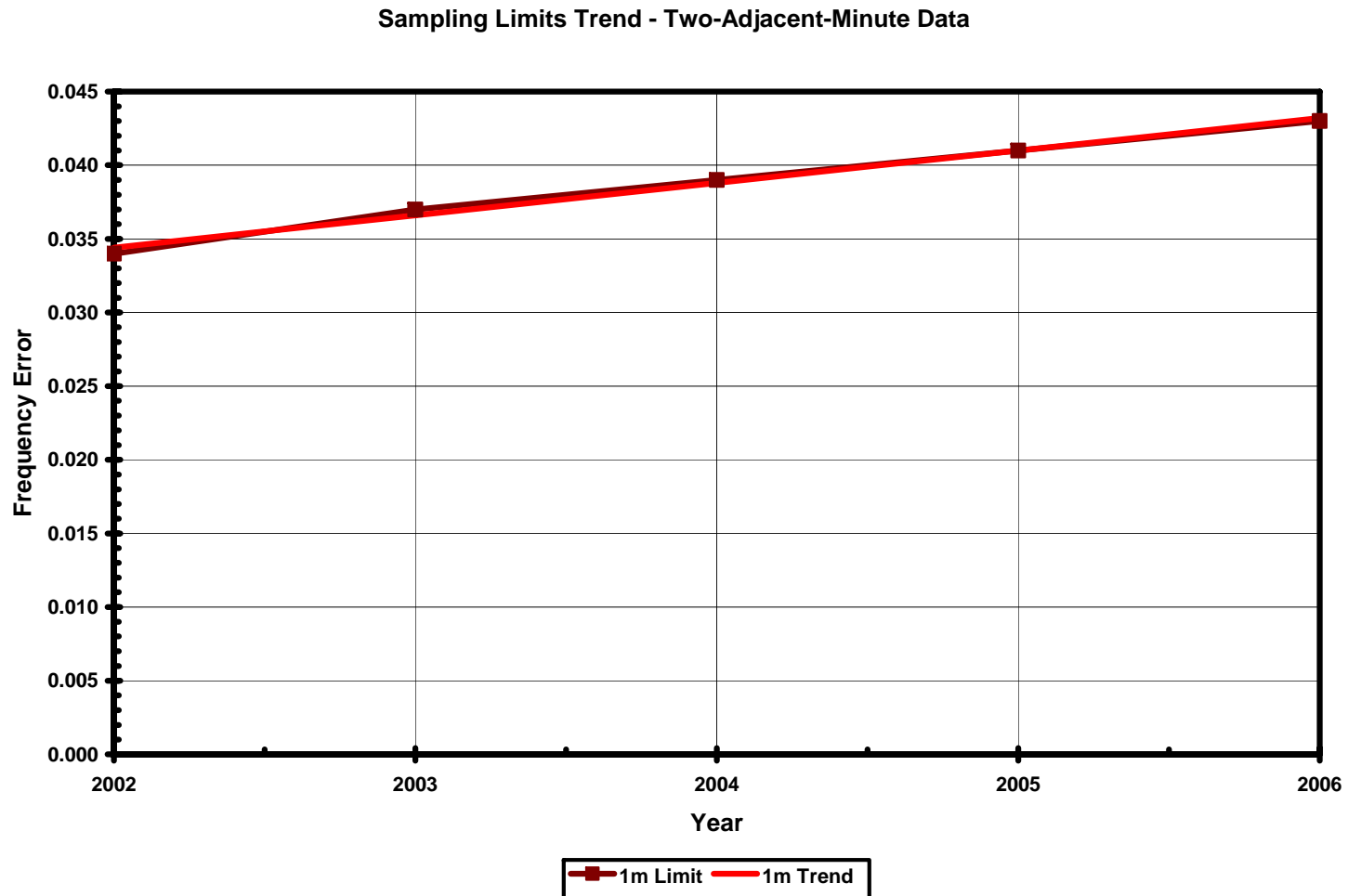


1-Minute 1st Difference

1st Difference Trend - 1-Minute Data

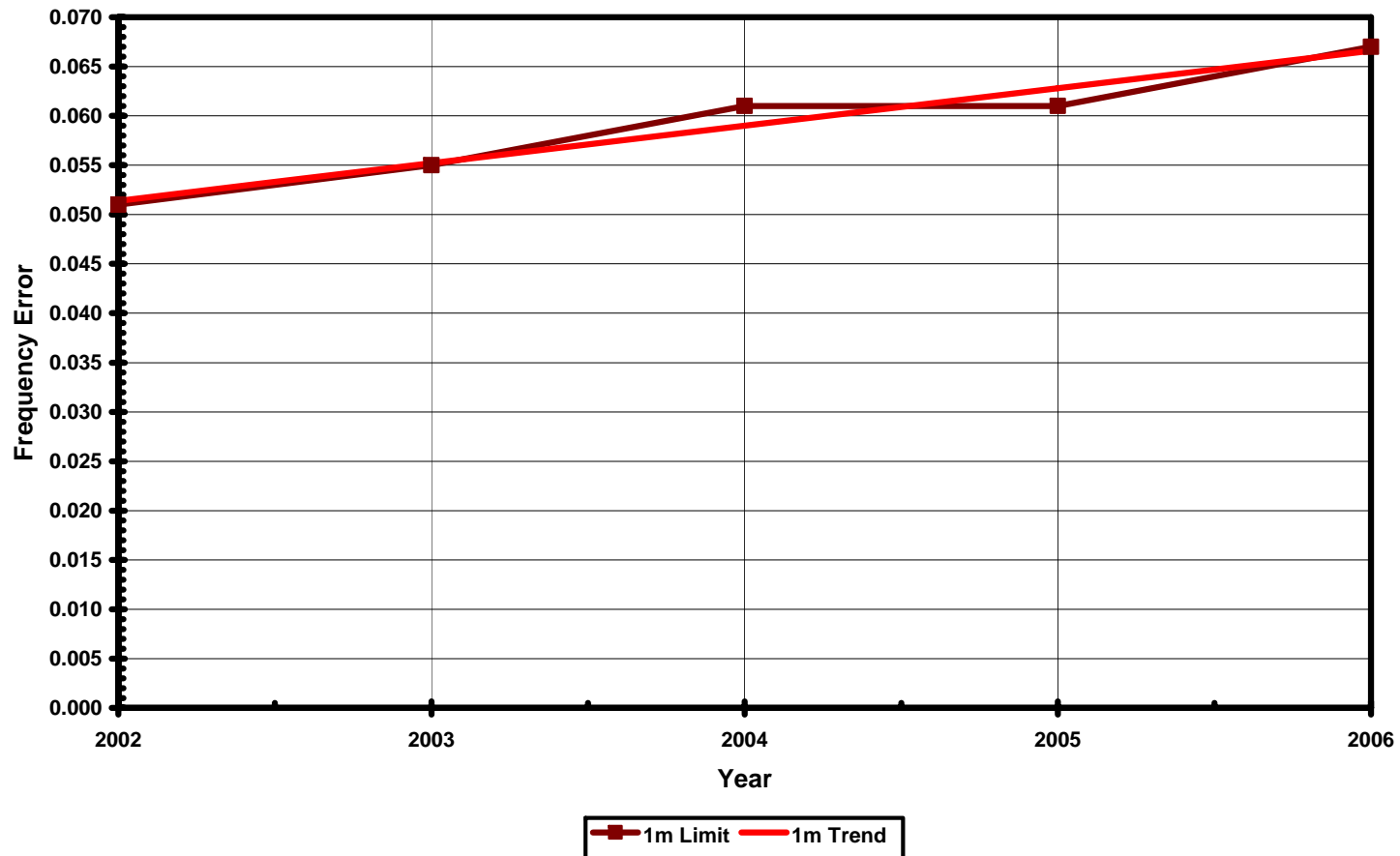


2-Adjacent 1-Minute Limits



3-Adjacent 1-Minute Limits

Sampling Limits Trend - Three-Adjacent-Minute Data



Confirming Declining PGFR

- **2-Second Frequency Error Stable**
- **1-Minute Frequency Error Stable**
 - **Control Actions Stable**
- **2-Second 1st Difference Stable**
 - **Interconnection Inertia Stable**
- **1-Minute 1st Difference Increasing**
- **1-Minute Sampling Limits Increasing**
 - **Frequency Response Declining**

Excursions / Disturbances

Table I – Correlating Excursions and Disturbances

Interconnection (Events)	Eastern	Western	Texas
Initial (50)	11 %	51 %	59 %
Secondary (10)	17 %	70 %	64 %
Final (1)	60 %	67 %	100 %
Change (mHz)	<10 mHz	<10 mHz	<40 mHz

Significance of PGFR

➤ Frequency Error Drivers

- Normal Control Errors
- Disturbance Errors
- Disturbance Recovery Errors
- Scheduled Time Error Corrections

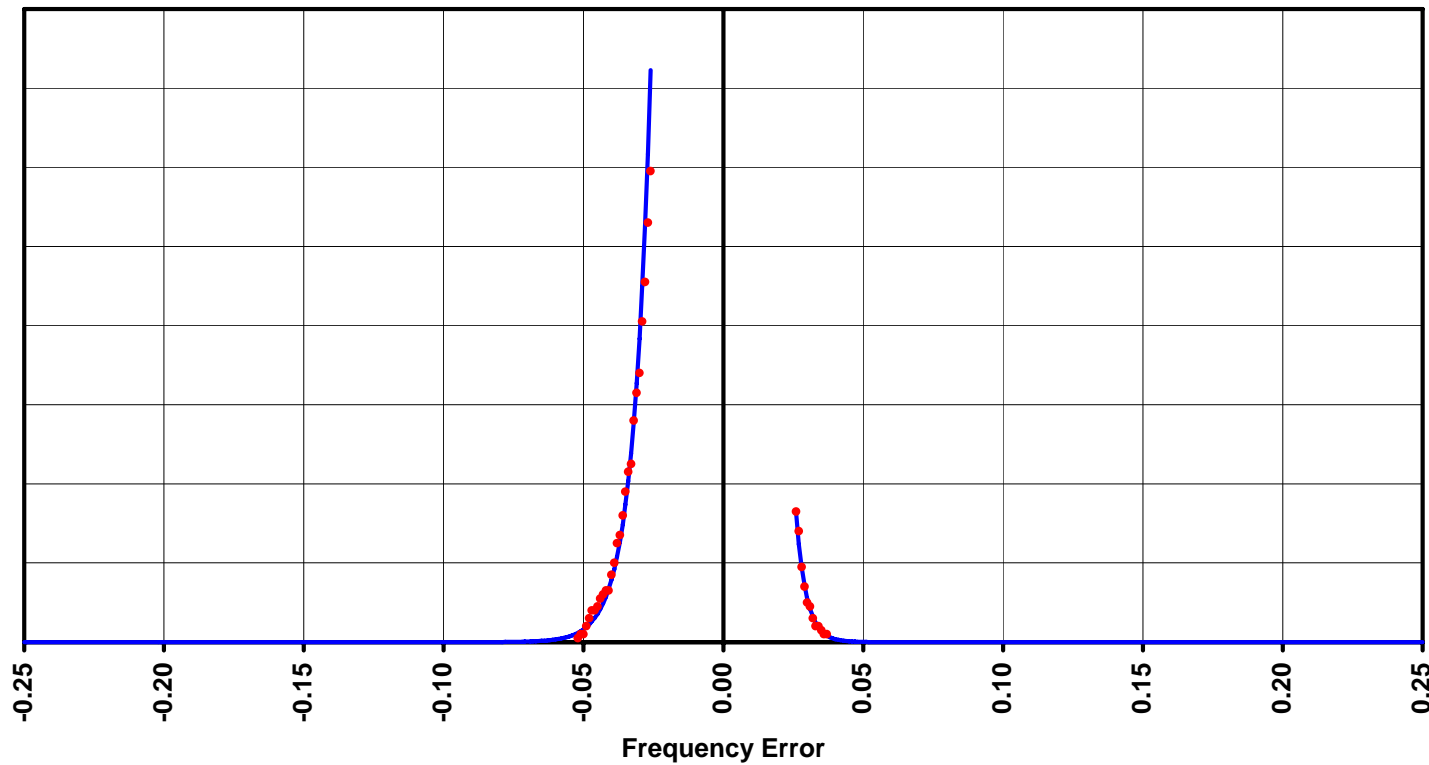
➤ Sensitivity Variables

- 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

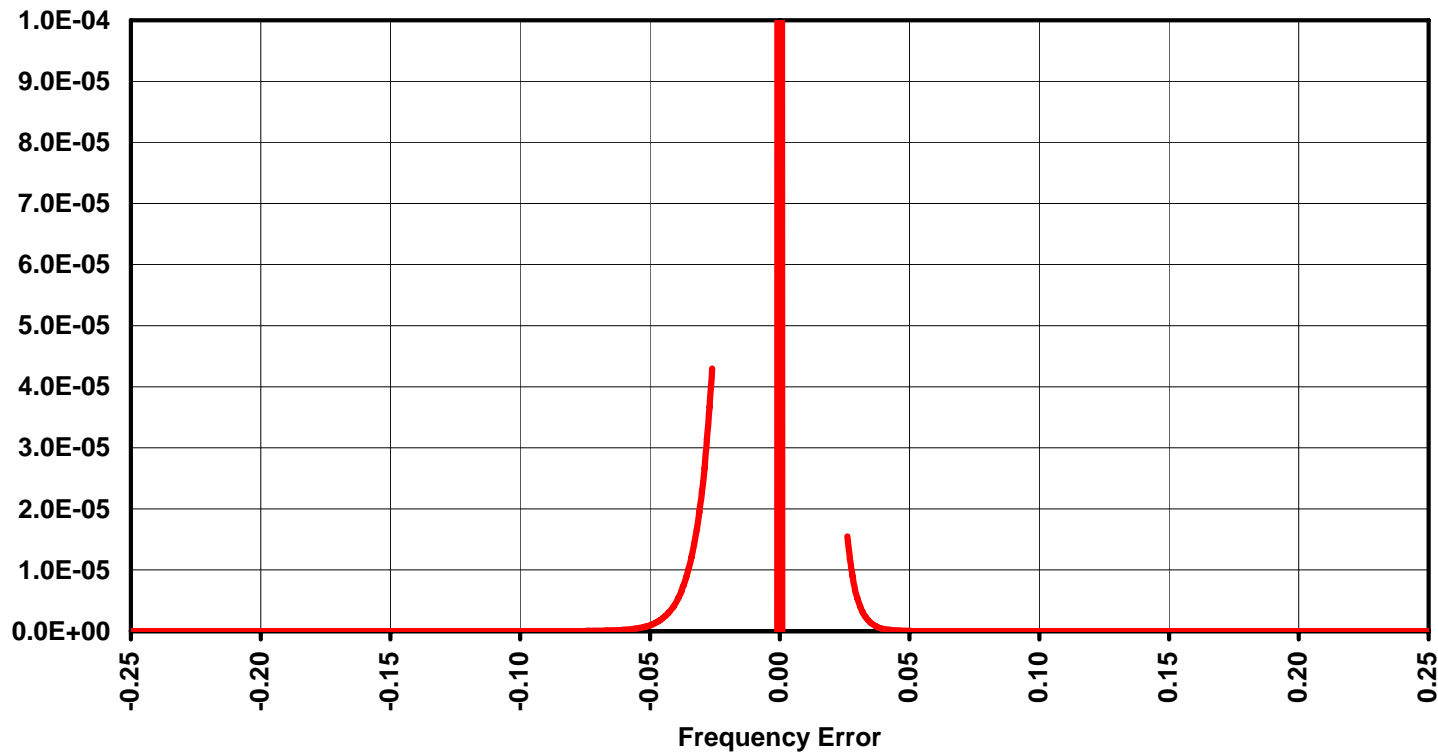
2-Second Data - 2002



Disturbance Density

A-C Disturbance Density

2-Second Data - 2002



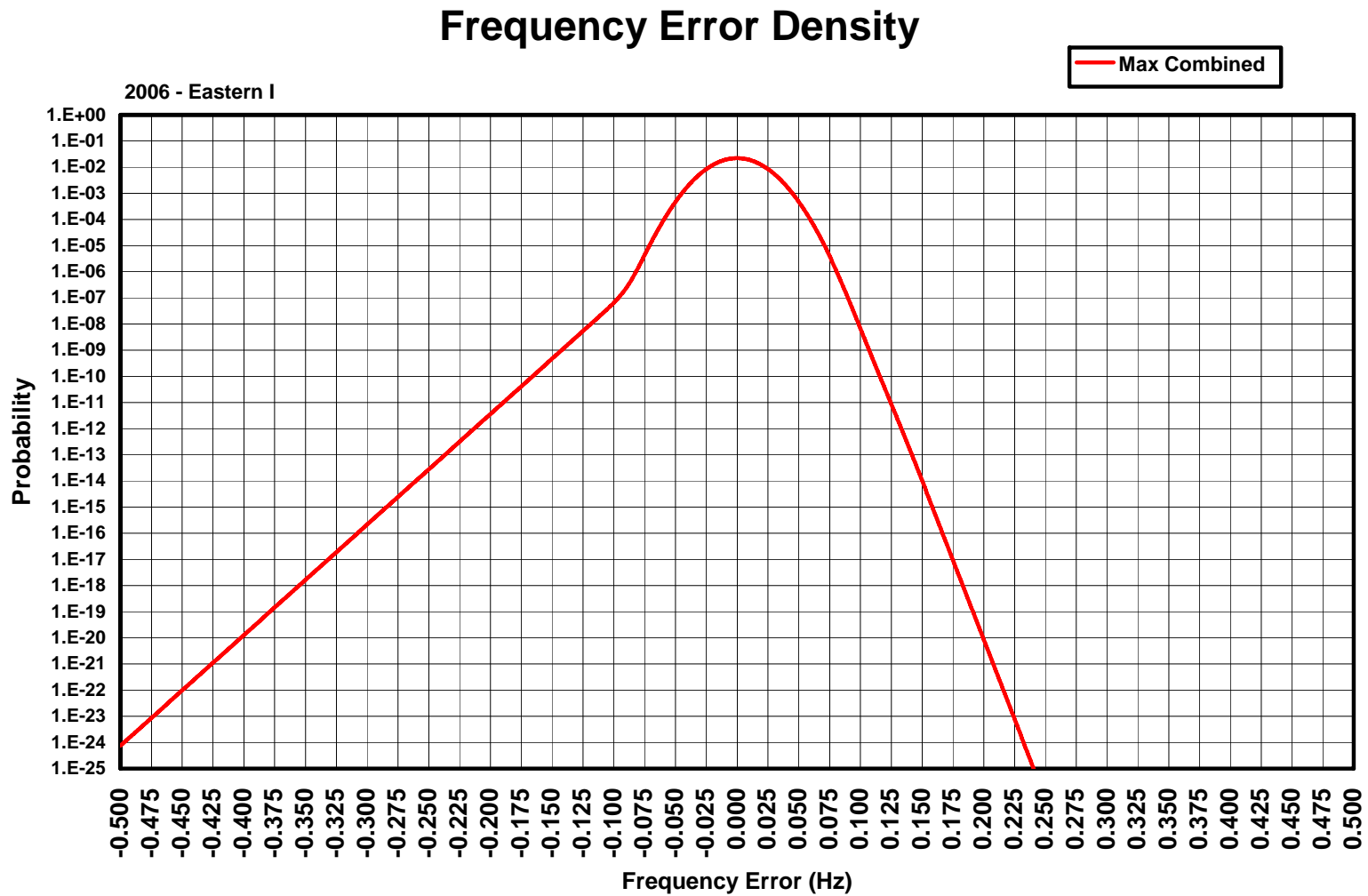
Disturbance Recovery

- 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

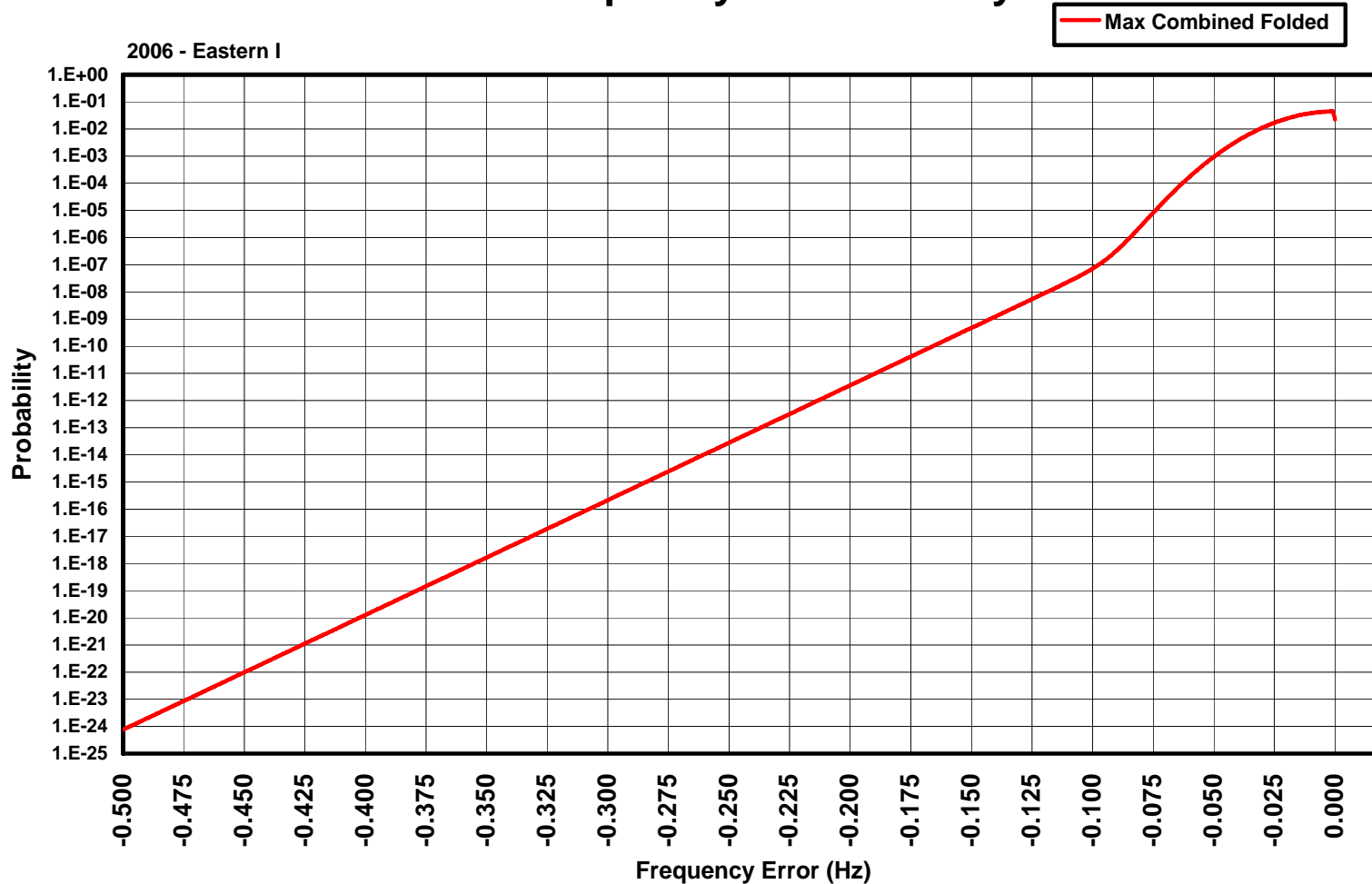
- Time Error Corrections were evaluated with sensitivity analysis on the final risk trends due to large changes in time error correction requirements from year to year.

Frequency Error Density



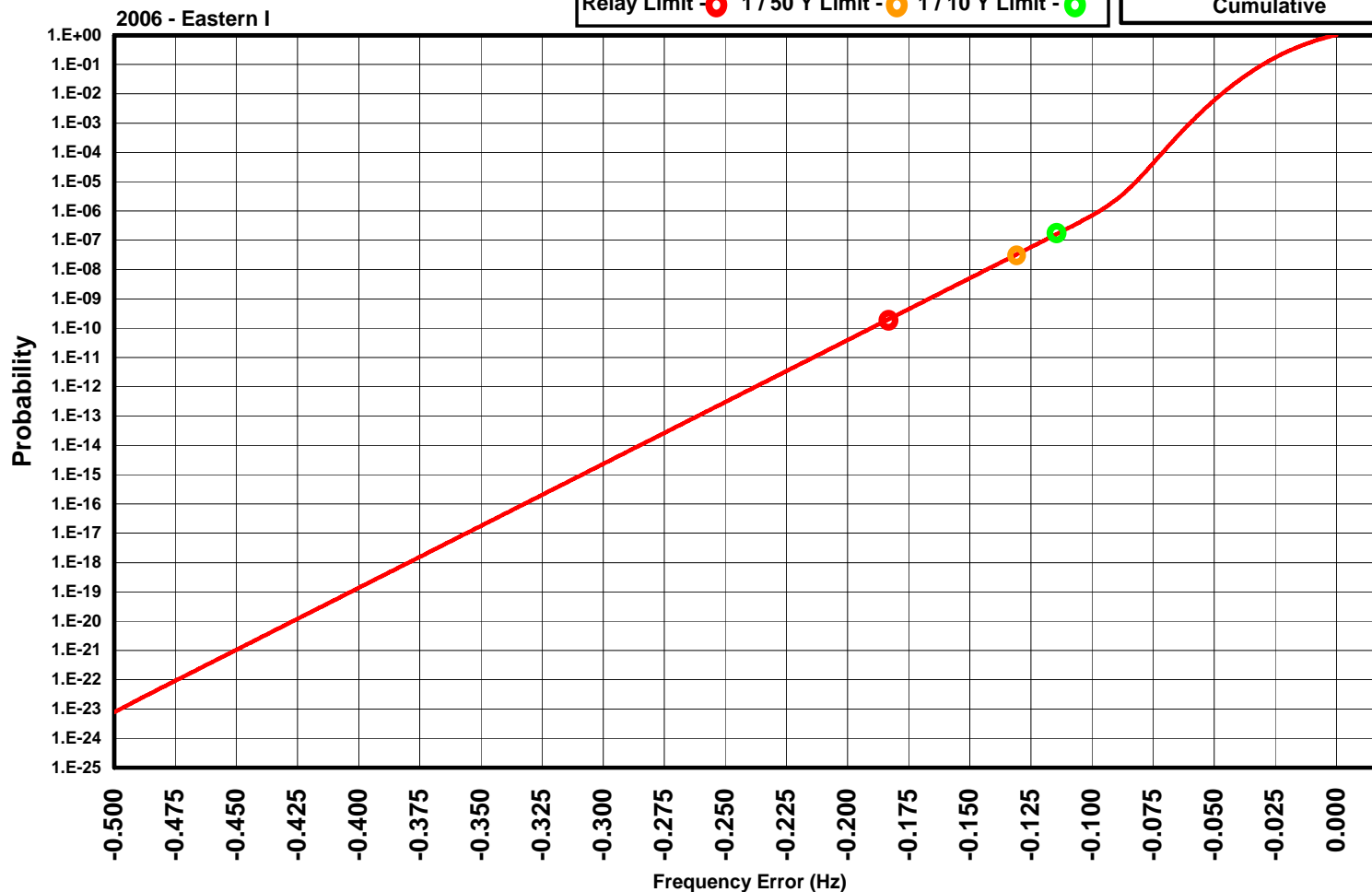
Folded Error Density

Folded Frequency Error Density



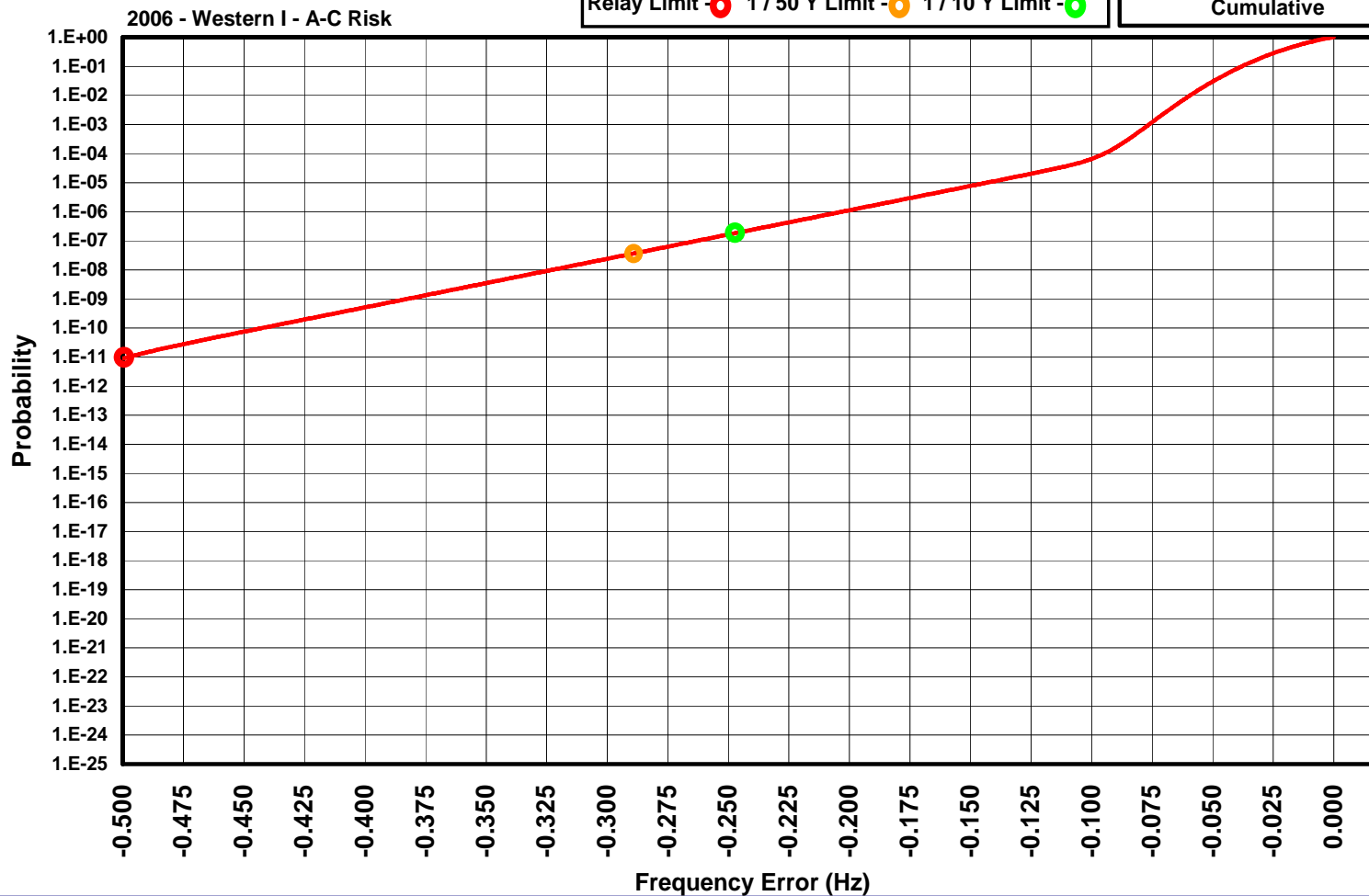
Tail Probability - Eastern A-C

Cumulative Tail Probability



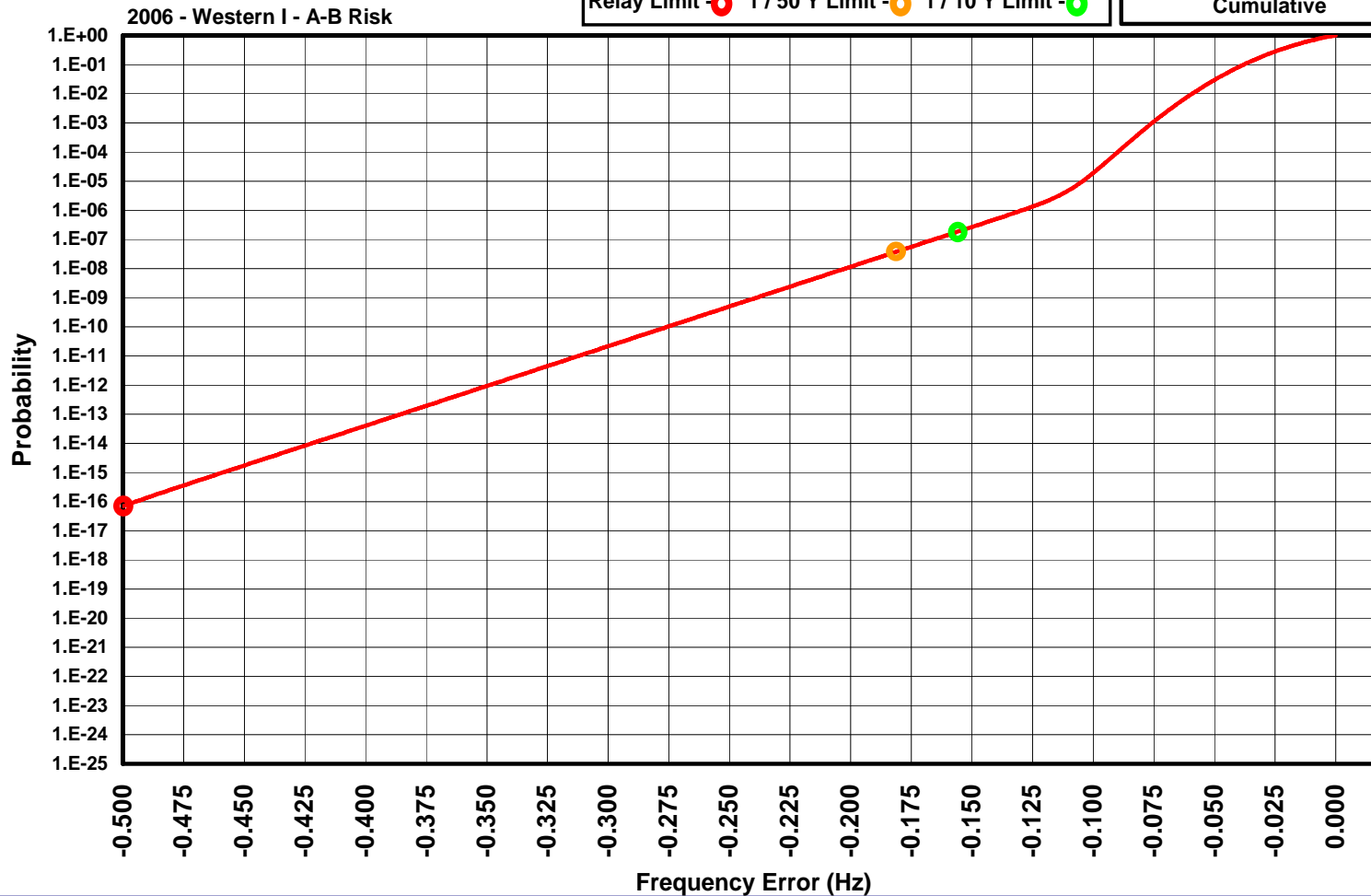
Tail Probability - Western A-C

Cumulative Tail Probability



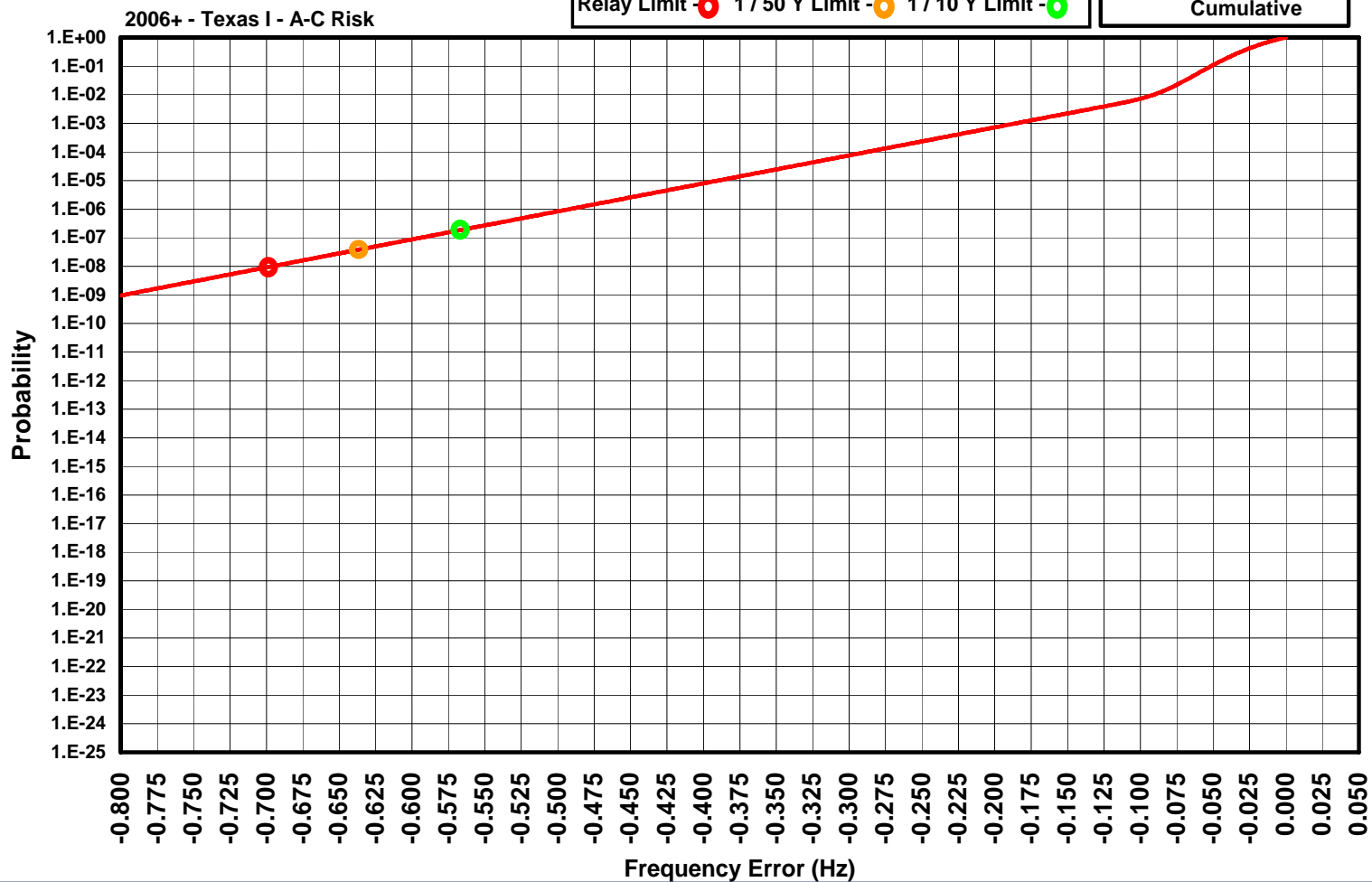
Tail Probability - Western A-B

Cumulative Tail Probability



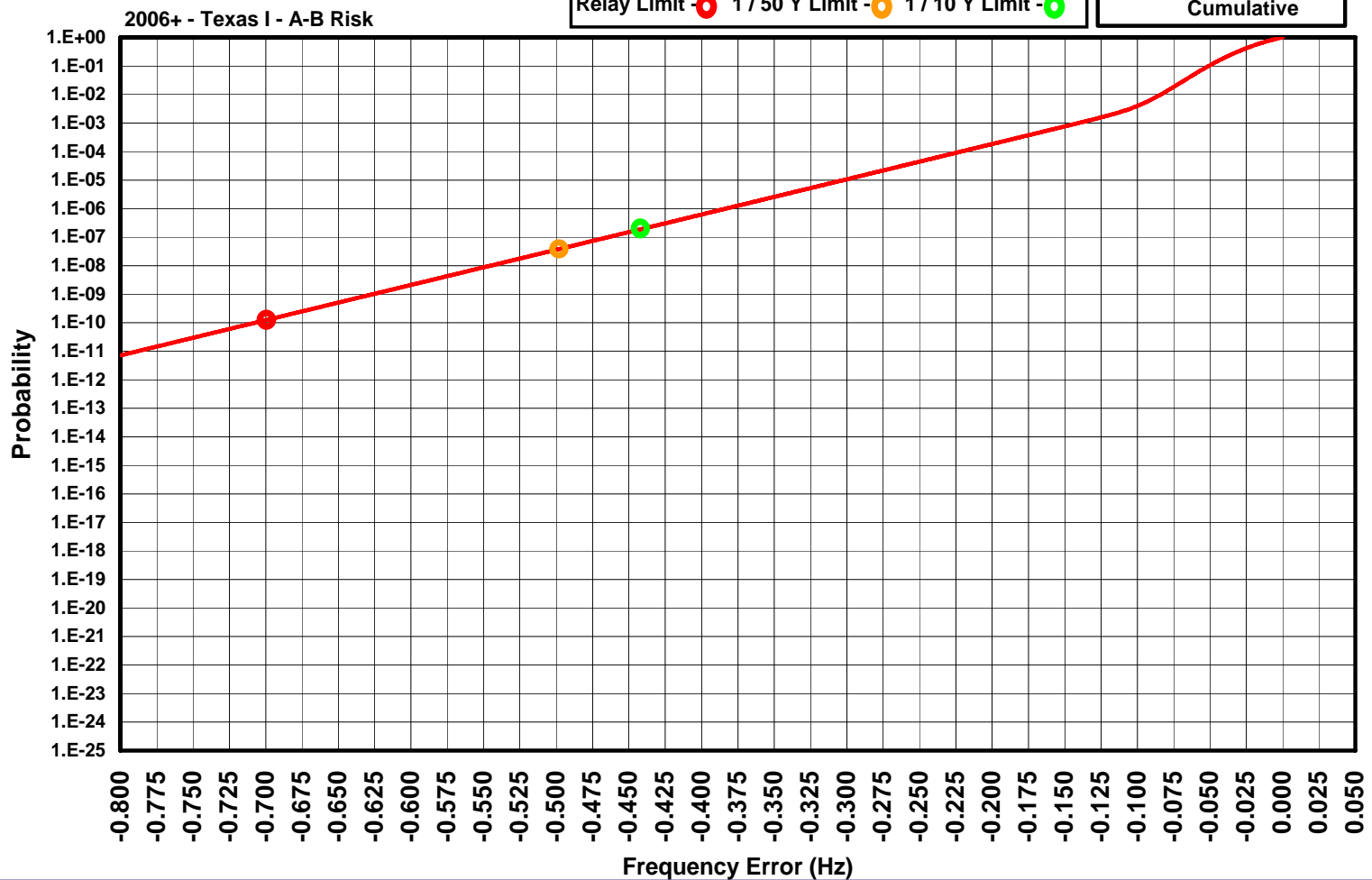
Tail Probability - Texas A-C

Cumulative Tail Probability



Tail Probability - Texas A-B

Cumulative Tail Probability



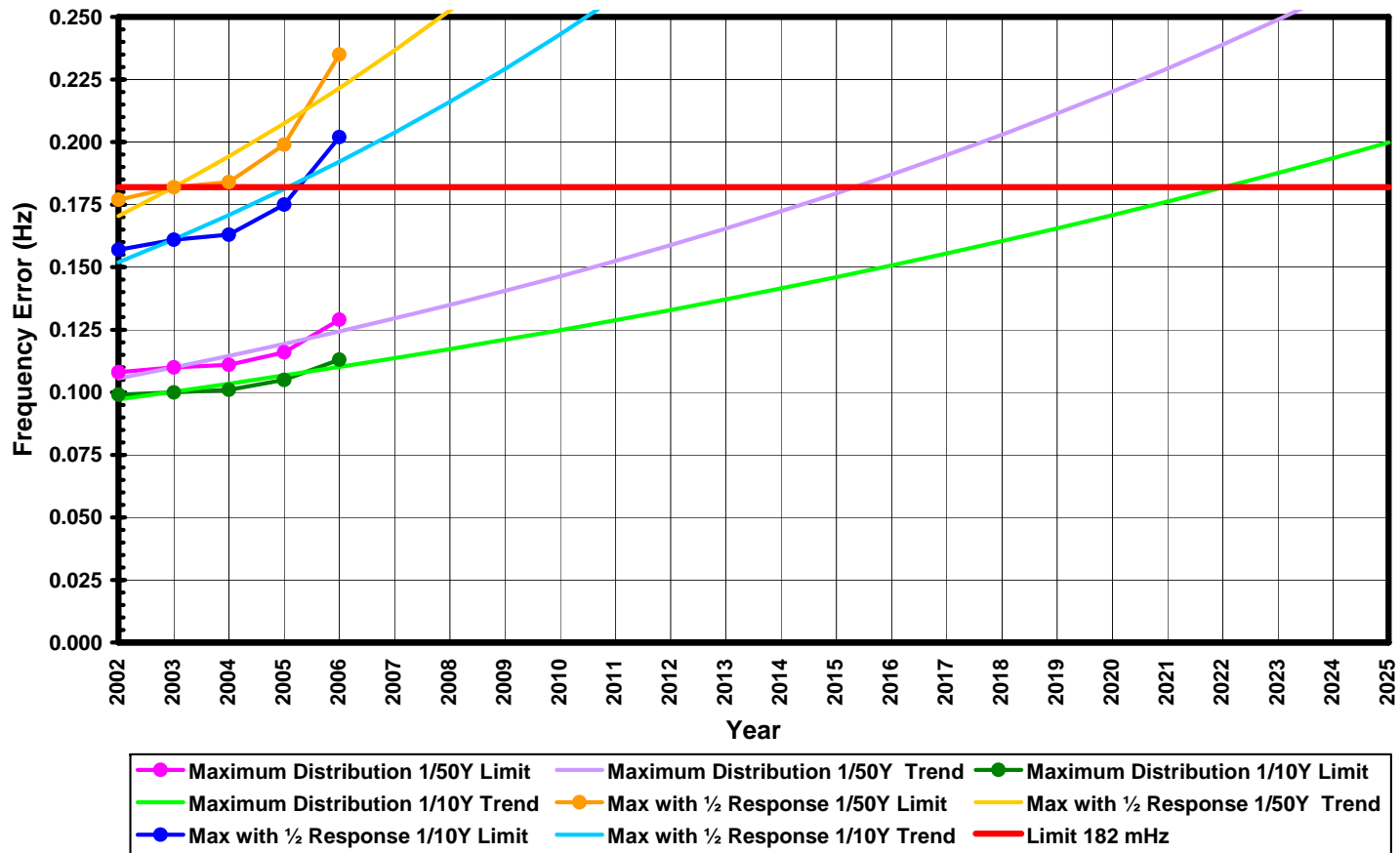
Sensitivity Ratios

Table II – Sensitivity Ratios

Interconnection	Eastern	Western	Texas
Primary/Secondary Control for A-C	1.4 / 1	30 / 1	30 / 1
Primary/Secondary Control for A-B	NA	15 / 1	30 / 1

Eastern I Risk Limit Trends

Reliability Risk Limit Trends



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

Questions

