# Monitoring Voltage Stability using Real Time Dynamics Monitoring System®

## iPCGRID Meeting

## Voltage Stability Panel Session

San Francisco

March 26, 2013

Bharat Bhargava

**Electric Power Group**

# Monitoring Voltage Stability with RTDMS

**RTDMS has the capability to display:**

- **Summary Dashboard**

- **Voltage magnitude contour Plot**

- **Voltage magnitude plots**

- **Voltage magnitude trend plots**

- **Voltage angle contour Plot**

- **Voltage phasor plot (polar display)**

- **Voltage sensitivity – change in voltage (kV) for every 100 MW change in flow**
  - Voltage Sensitivity Trends
  - Voltage Sensitivity Plot

**RTDMS can alert operators when the monitored quantities exceed the thresholds**
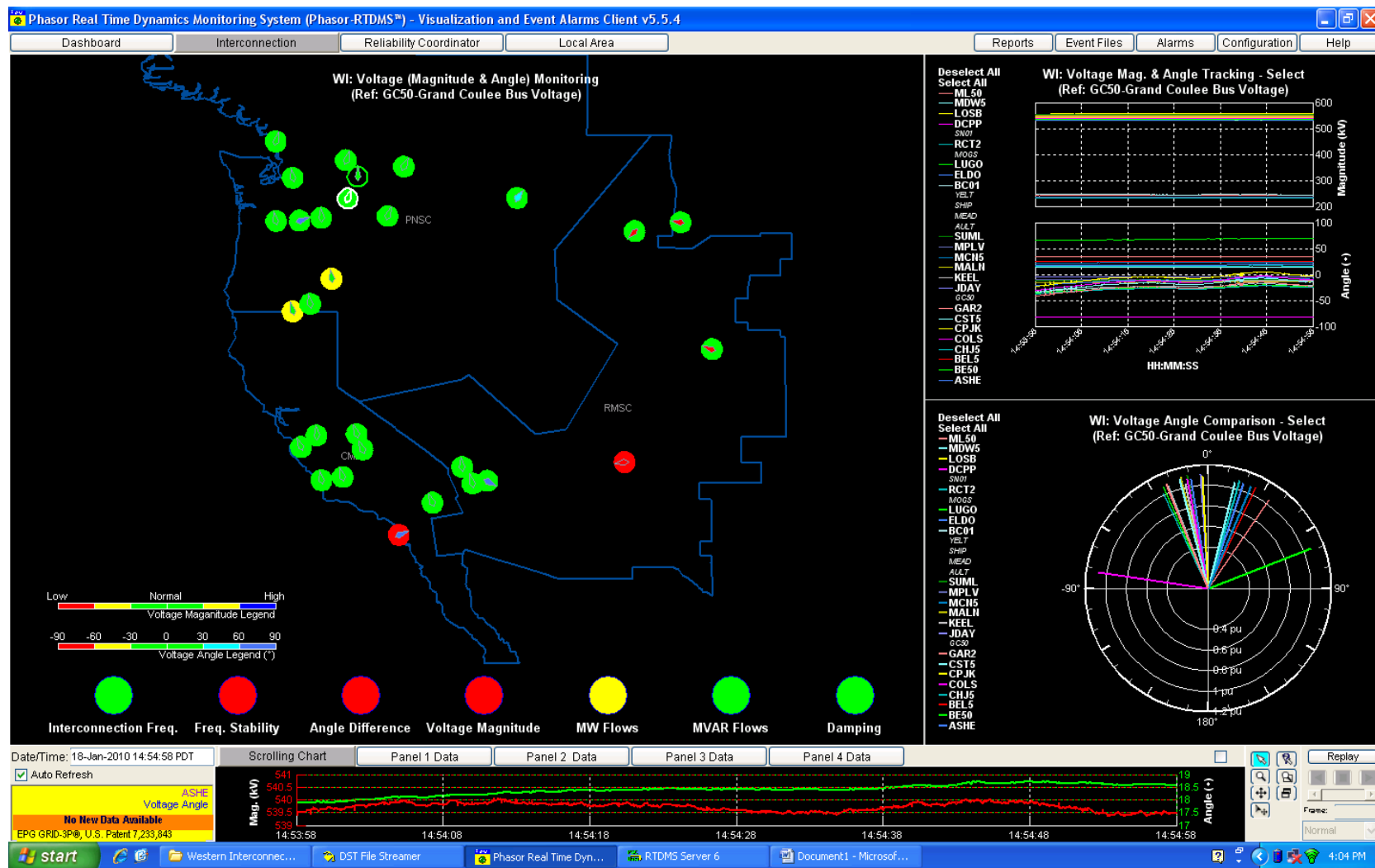
Electric Power Group

# RTDMS Dashboard Display at California ISO
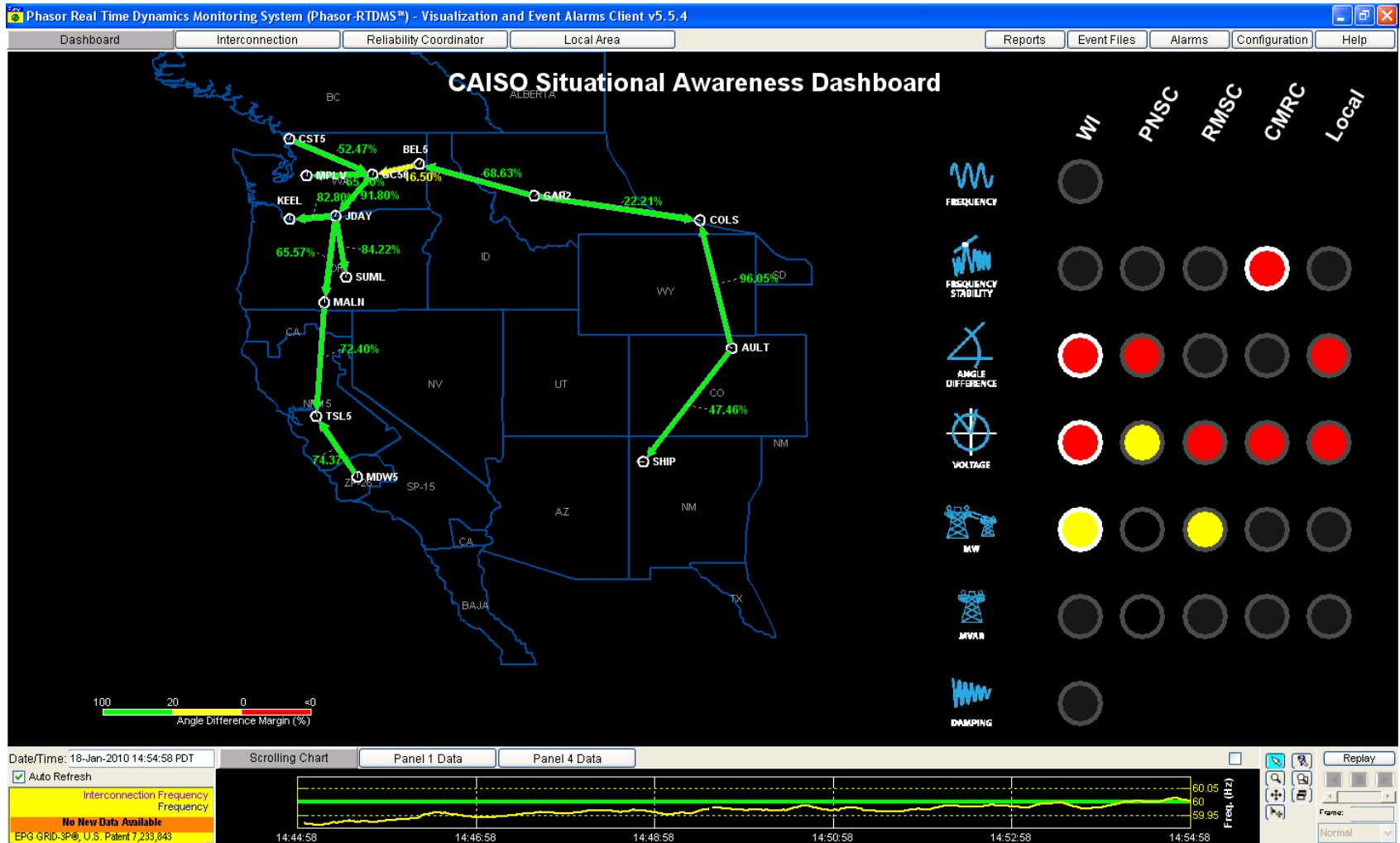
# RTDMS Plot Showing
# Voltage Contour Plot for WECC System
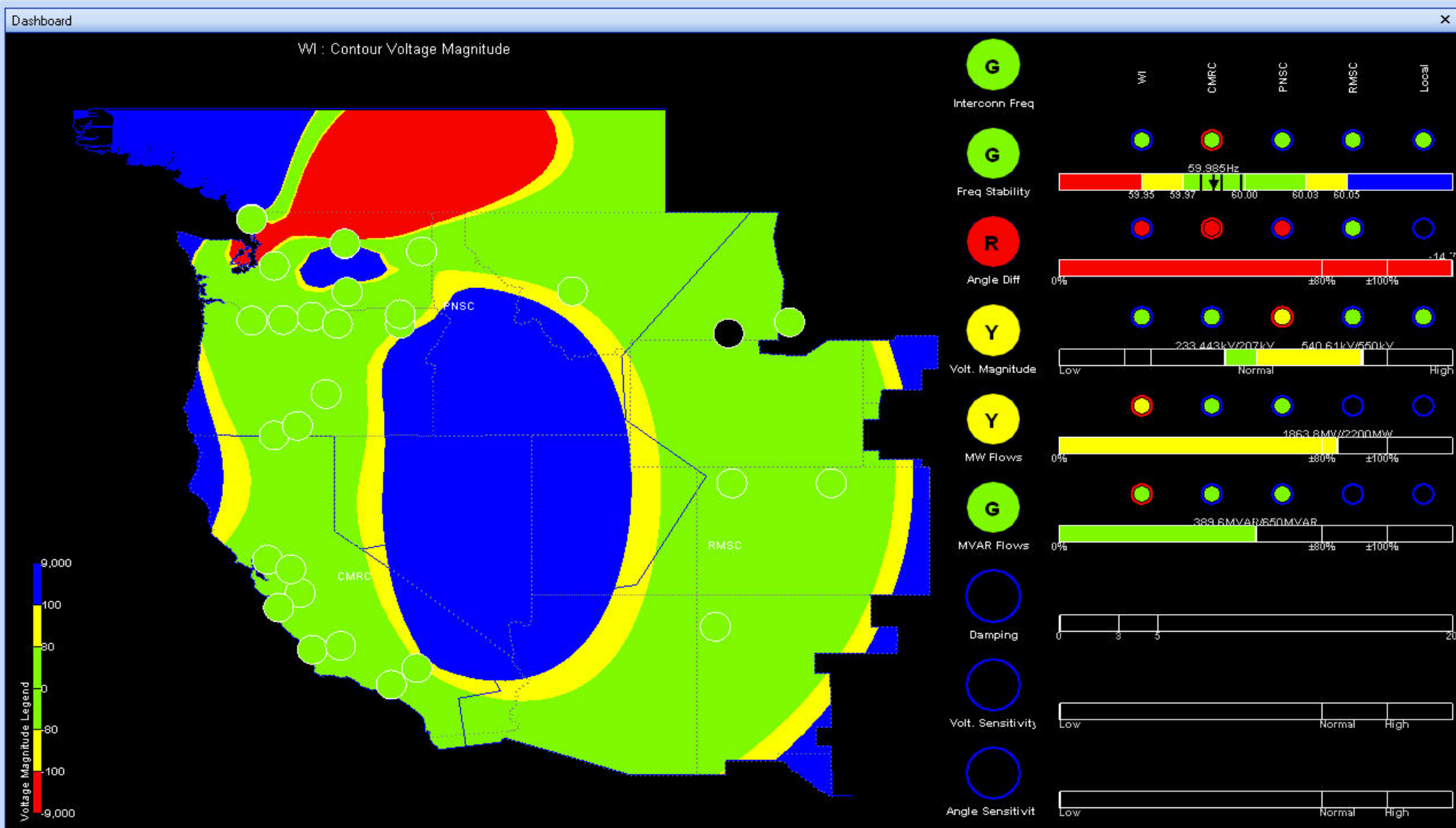
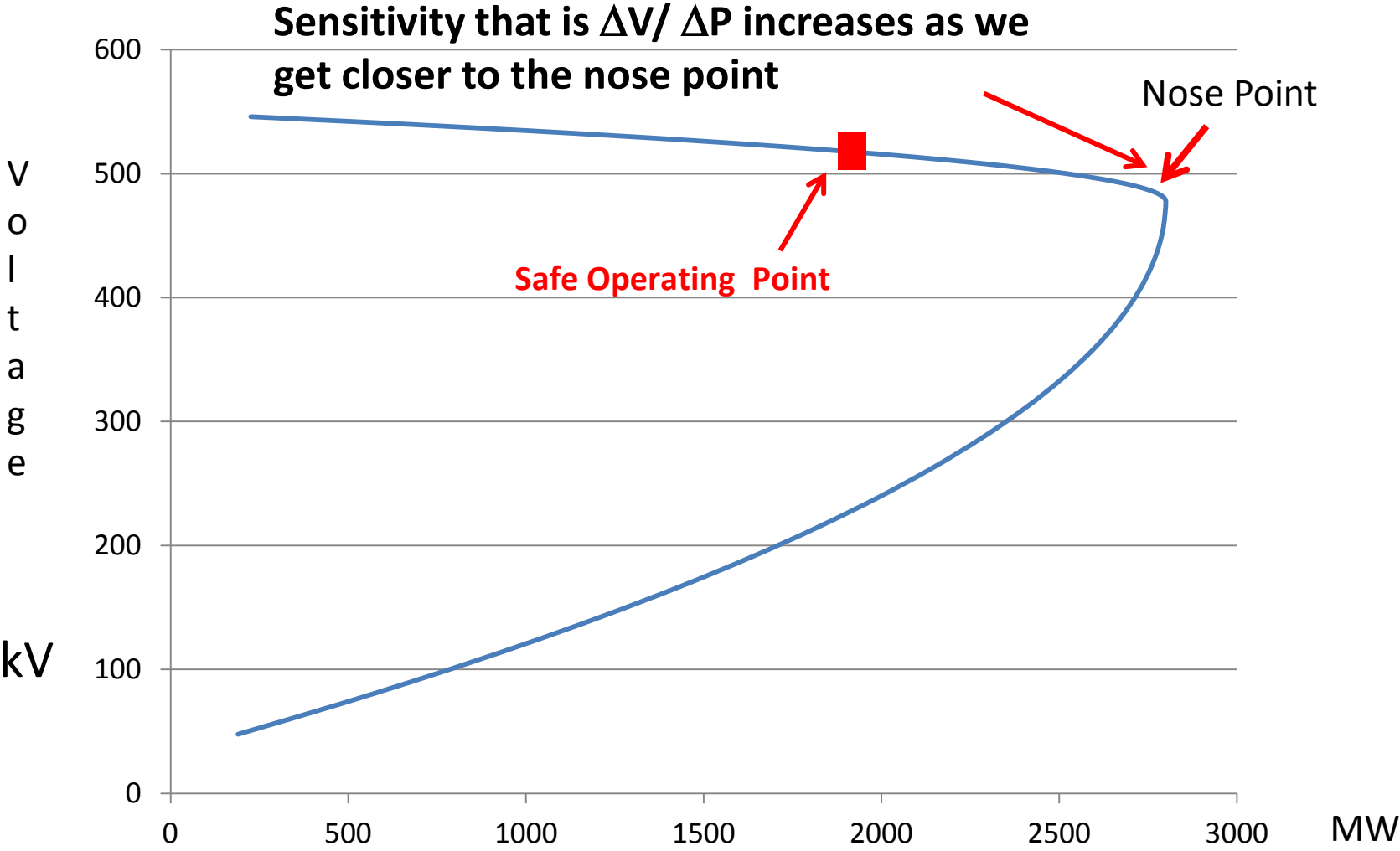# RTDMS Screen Showing PMU Locations and Monitored Voltage Magnitude and Angles

Electric Power Group

# Monitoring Voltage Sensitivity in RTDMS

- **Voltage Sensitivity Definition - change in voltage as a function of power flow on a line (slope of PV curve)**

- **Metric - kV/100 MW change**

- **Recommended safe level – below 4 kV/100 MW for 500 kV system**

- **Benefit – Early warning of deteriorating voltage conditions**

- **Metric Value  - Increases as system approaches the collapse region identified  as the Nose Point**

- **Metric Value - Will increase if a nearby adjacent line trips**

- **Indicates – how far we are from the voltage collapse region**

# A Typical Power / Voltage Curve

**Sensitivity that is $\Delta V / \Delta P$ increases as we get closer to the nose point**

Nose Point

**Safe Operating Point**

V
o
l
t
a
g
e

kV

MW

Electric Power Group

# RTDMS Displays for Monitoring Voltage Sensitivity

- **Voltage Sensitivity Units in RTDMS – change in voltage (kV) for every 100 MW change in power flow**

- **RTDMS Display Shows**

  - **Monitored voltage busses  - panel 1**

  - **Voltage Sensitivity Trends – panel 2**

  - **Voltage sensitivity current (red) and historical data window**

- **Event Example – Eastern Interconnection – Fraser and Hatch-Duvall busses**

Electric Power Group
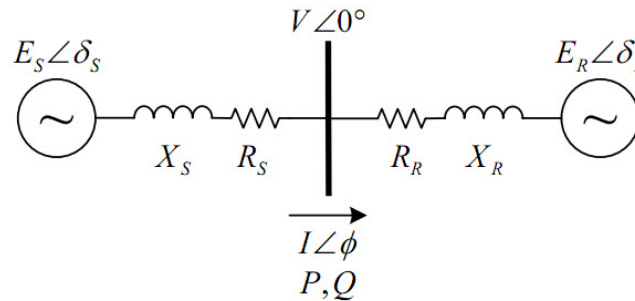
# RTDMS Voltage Sensitivity Panel
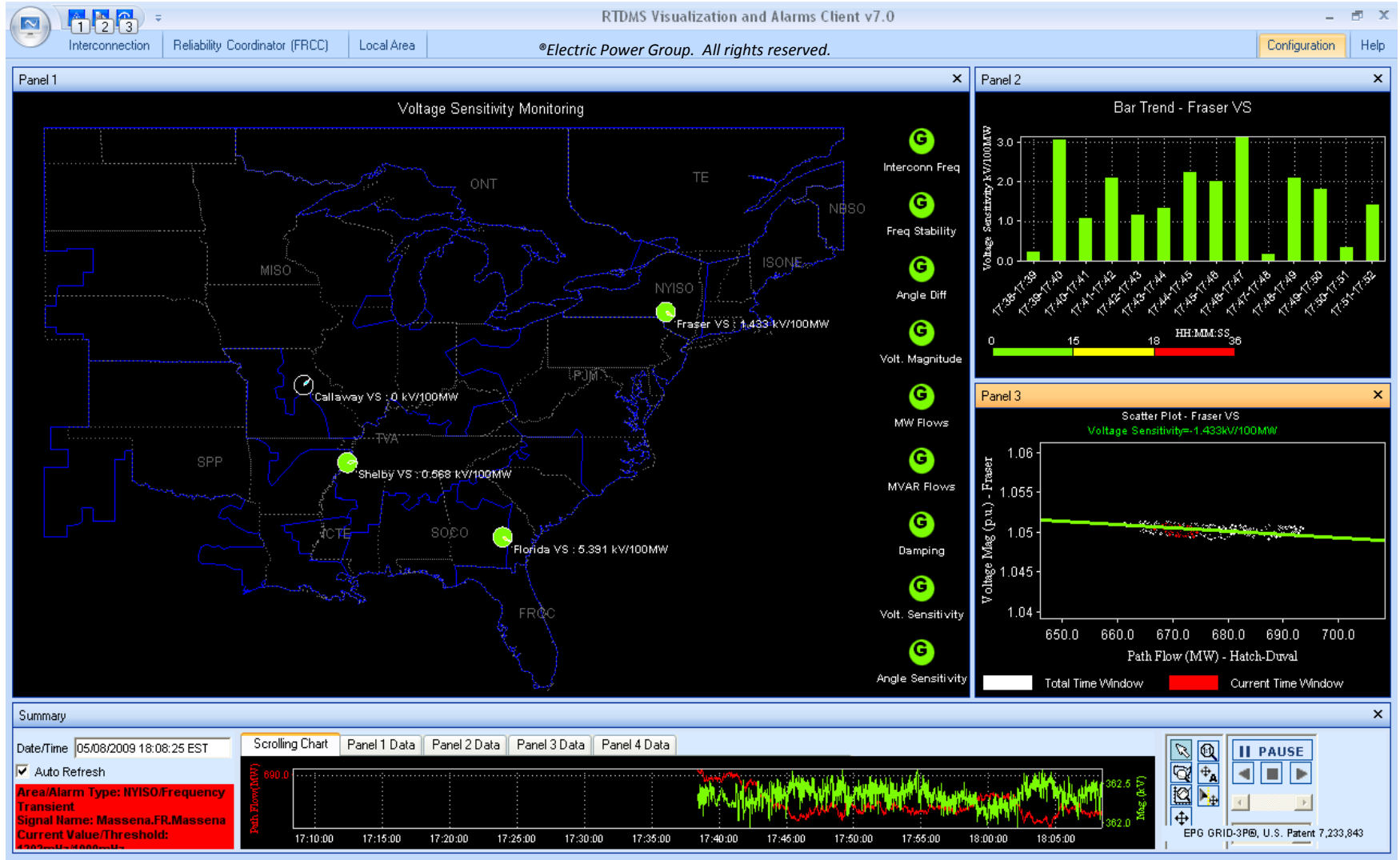
# Voltage Sensitivity at a Stressed Bus With No Voltage Support
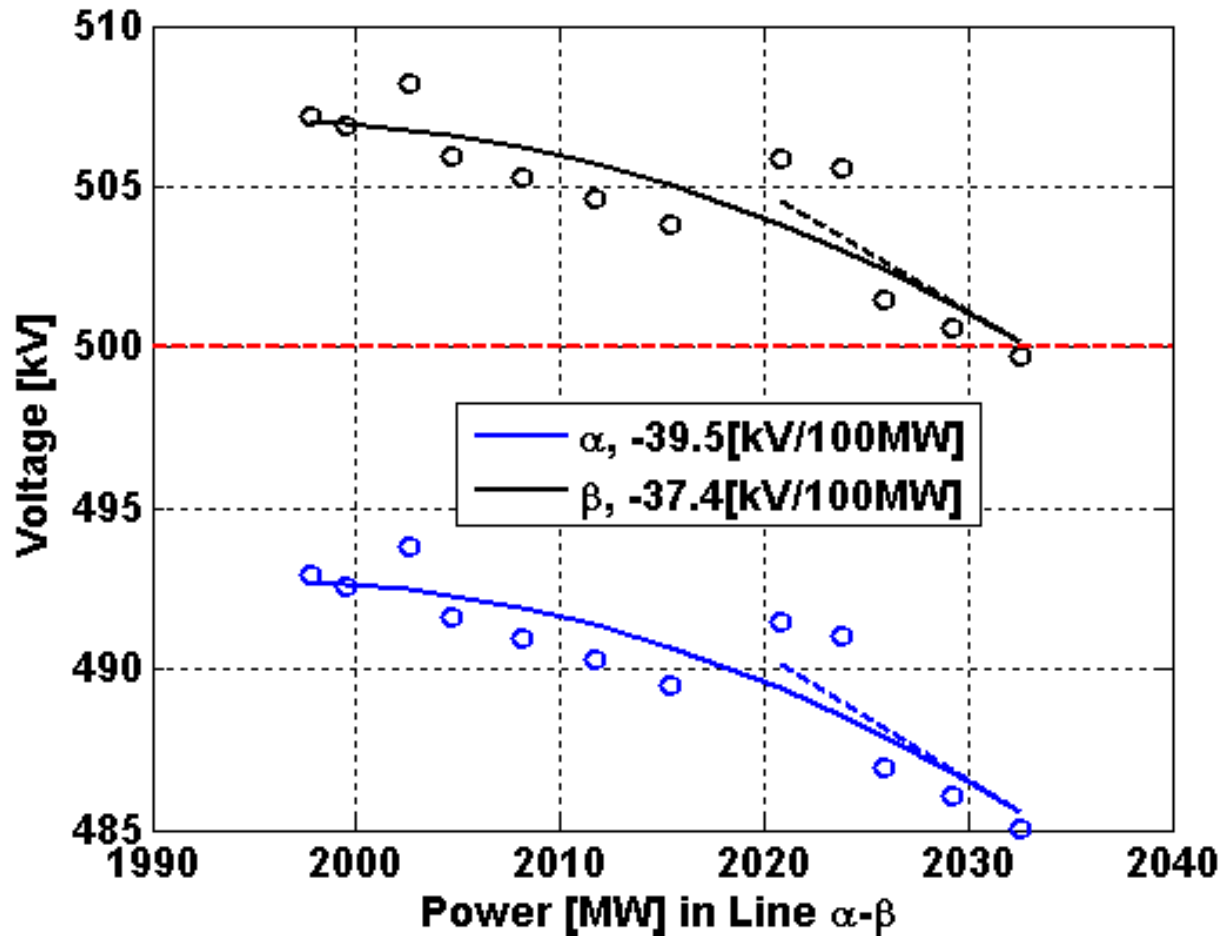
# CEC/CAISO
# Voltage Stability Monitoring Project

- **Algorithm used in EPG's prototype is based on Double Voltage Source method developed by Dr. Joe Chow, Rensselaer Polytechnic Institute**



- **Topology Independent**
- **Utilizes only PMU data**
- **Estimates Power-Voltage relationships from measured data**
- **Method uses system equivalency and is suited for local area measuring**
- **Prototypes Shortcoming - Lacks the ability to perform contingency analysis**
- **Research in process – Validated for Big Creek, Investigating application for Devers and Captain Jack Substations**

Electric Power Group

# Voltage and Angle Sensitivity Analysis in the WECC System

**Voltage Sensitivity Analysis conducted to compare results with EPG prototype Voltage Stability monitoring on WECC system at:**
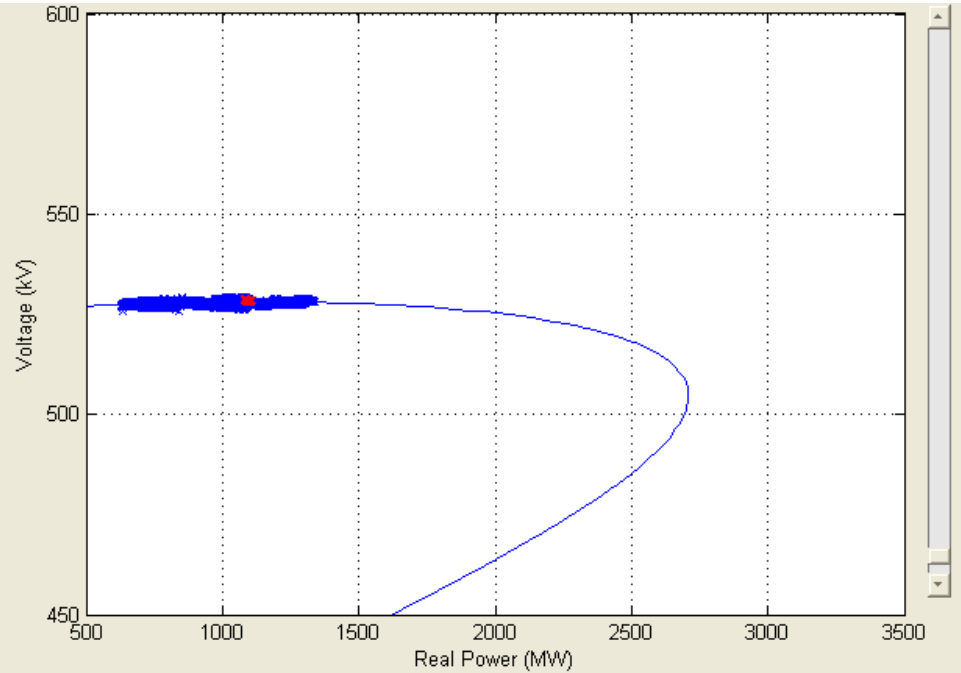
1. **Devers substation – Sensitivity analyzed for power flow on Palo Verde-Devers line and voltage at Devers**
   - **With and without Devers SVC**
   - **HD Wash-N.Gila in and out of service**

2. **Captain Jack substation – power flows on Grizzly and Klamath Falls line and voltage at Captain Jack substation**
   - **Malin-Round Mountain line I in and out of service**

# Voltage Sensitivity Analysis at Captain Jack Substation Using PMU Data & Prototype Voltage Stability Monitor

- **Analysis Conducted  Using 24-hour PMU Data**

- **Total Window Displayed  (Blue) – 24 hours**

- **Current Window (Red) – 10 minutes**

- **Power Flow Change**
  - **Whole window – 630 MW to 1337 MW  (( 707 MW)**
  - **Current window – 1095 to 1123 MW ( 28 MW) Angle difference changes from  19 deg. to 26.5 deg.**

- **Voltage Magnitude Change**
  - **Whole window 525.6 kV to 529.4 kV (3.8 kV)**
  - **Current window - 529.1 kV to 528.5 kV (0.6 kV)**

- **Voltage Sensitivity**
  - **Whole window - 0.56 kV/100 MW**
  - **Current window - 2.15 kV/100 MW**

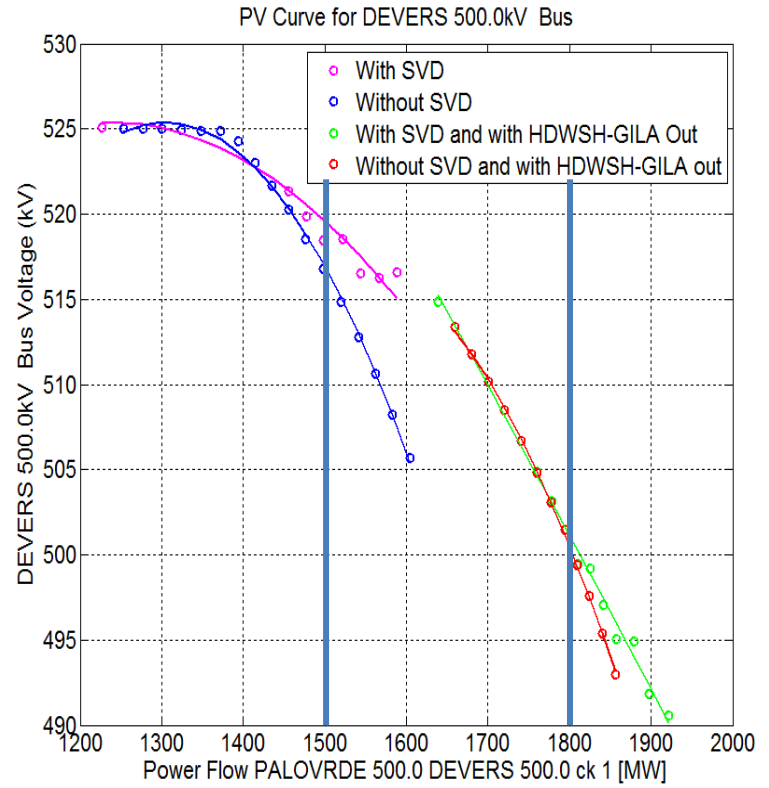# Voltage Sensitivity Analysis for Devers 500kV Bus



**Voltage Sensitivity at Devers Substation**

Whole window    – 0.56 kV/100 MW

Current window   - 2.15 kV/100 MW

# Conclusions / Summary

- **Monitoring voltage support and stability in large power systems is important when operating at large phase angle separations (stressed conditions)**

- **RTDMS has the ability to monitor voltage and voltage sensitivity in real-time**

- **Voltage sensitivity is a good indicator of voltage stability and can easily be monitored at a bus**

- **Voltage sensitivity deteriorates when the system is stressed or adjacent lines are taken out**