Using Phasor System Data in RTDMS & PGDA to Validate System Response and Dynamic Models

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Model Validation Case Studies Using RTDMS and PGDA

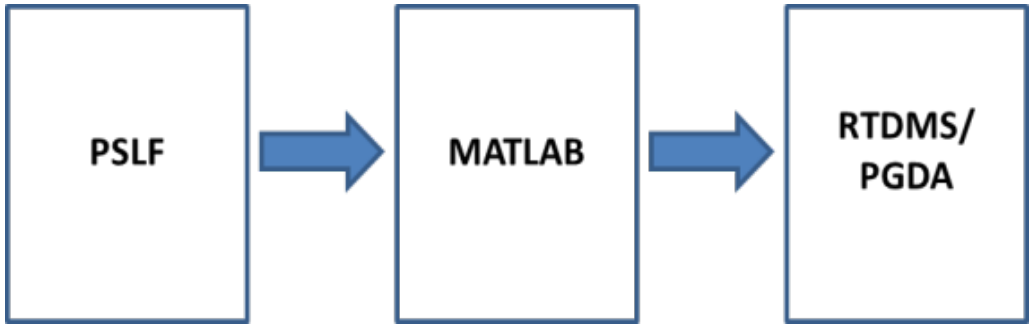
- September 8, 2011 Pacific Southwest Blackout Simulation
  - Event simulated and compared with NERC/FERC report
- January 26, 2008 (HVDC Oscillations)
  - Compared with actual event files, simulation compares fairly well
  - Do see high frequency oscillations (2.3 Hz) in simulation, instead of 3.8-4.3 Hz observed in the real event
- Pacific Intertie (COI) Simulations
  - Loading COI to 4860, 5680 and 6370 MW (Static stress) and subjecting it to dynamic stress
  - Monitoring voltage and angle sensitivity at Malin substation

RTDMS and PGDA Overview for Simulations

- Real Time Dynamic Monitoring System (RTDMS) is used for visualization and Phasor Grid Dynamics Analyzer (PGDA) is used for detailed off-line analysis
- RTDMS typically takes C37.118 / 61850 high-speed synchro-phasor system data and can display multiple parameters important for operation of the power system
- PGDA takes multiple formats such as dst, comtrade, csv, synchro-phasor system data and supports detailed analysis of the system event
- For simulations, EPG developed capability to import csv file formats in both these programs
- These programs can now be used to visualize and analyze PSLF simulations by converting PSLF output data in to CSV files
- Simulated data can be compared with actual events and can be used for system model validation
- Extreme events can be simulated and run using RTDMS to train operators

Overview of Methodology to Validate System Response and Dynamic Models Using RTDMS and PGDA

- Perform simulations using PSLF – dynamic simulations typically 10 to 15 minutes
- Convert PSLF simulation data to CSV format using MATLAB
- PMU Simulator to stream CSV file data to RTDMS for visualization and validation
- Perform detailed offline analysis of simulated event using PGDA



Methodology – Parameters Used in Visualization

- **Basic**
  - Voltage Magnitude
  - Voltage Angle
  - Frequency, df/dt
  - Power
  - Reactive Power
- **Advanced**
  - Modes of Oscillations and their Damping
  - Voltage sensitivity (dV/dP100 – kV change per 100 MW)
  - Angle sensitivity (dA/dP100- degrees change per 100 MW)

Methodology – Parameters Used in Off-Line Analysis

- **Basic**
  - Voltage Magnitude
  - Voltage Angle
  - Frequency Transients
  - Frequency Response
  - Real Power
  - Reactive Power
- **Advanced**
  - Oscillation and Damping
  - Mode Meter – Ambient Oscillation Analysis
  - Ring Down Analysis
  - Spectral Analysis

Methodology Use Cases

PSLF Simulation capability is used to:

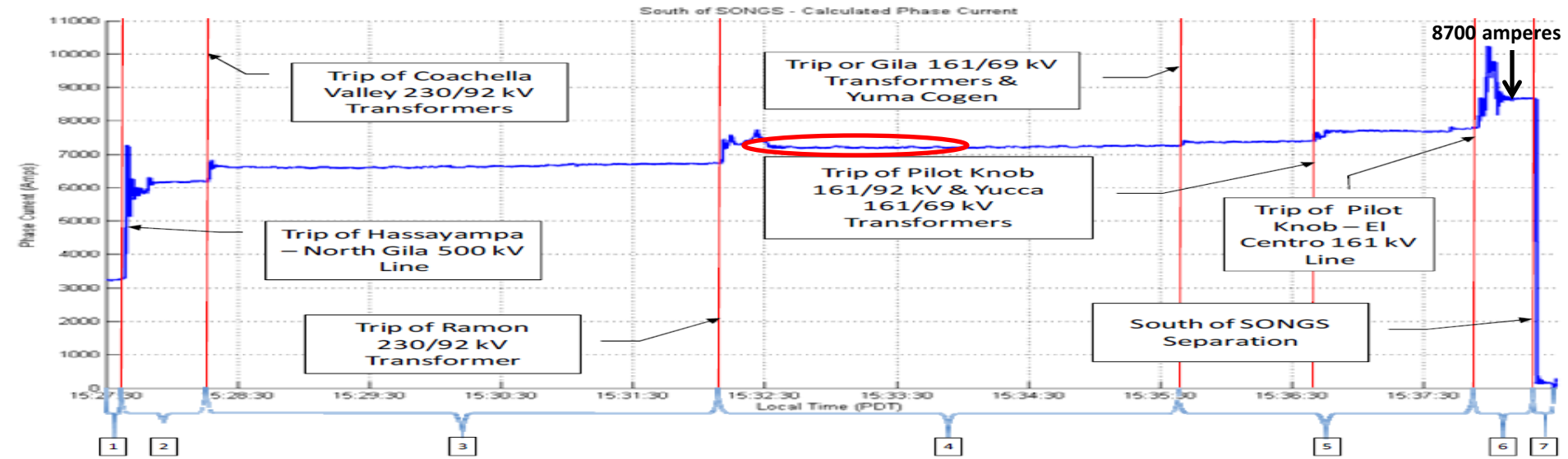
- Compare a real event with the simulated event to validate simulation and models
  - Once a good match is obtained, the case can be used to examine event details
- RTDMS is used for wide-area visualization of the simulation results
  - Wide-area view can be used to identify stress points and locations
- Visualization and Off-Line Analysis can be used for:
  - Training operators by simulating extreme system events
  - Setting and Validating Alarm/Alert levels for use in real-time monitoring
  - Conducting contingency analysis and testing established thresholds for Alert/Alarm

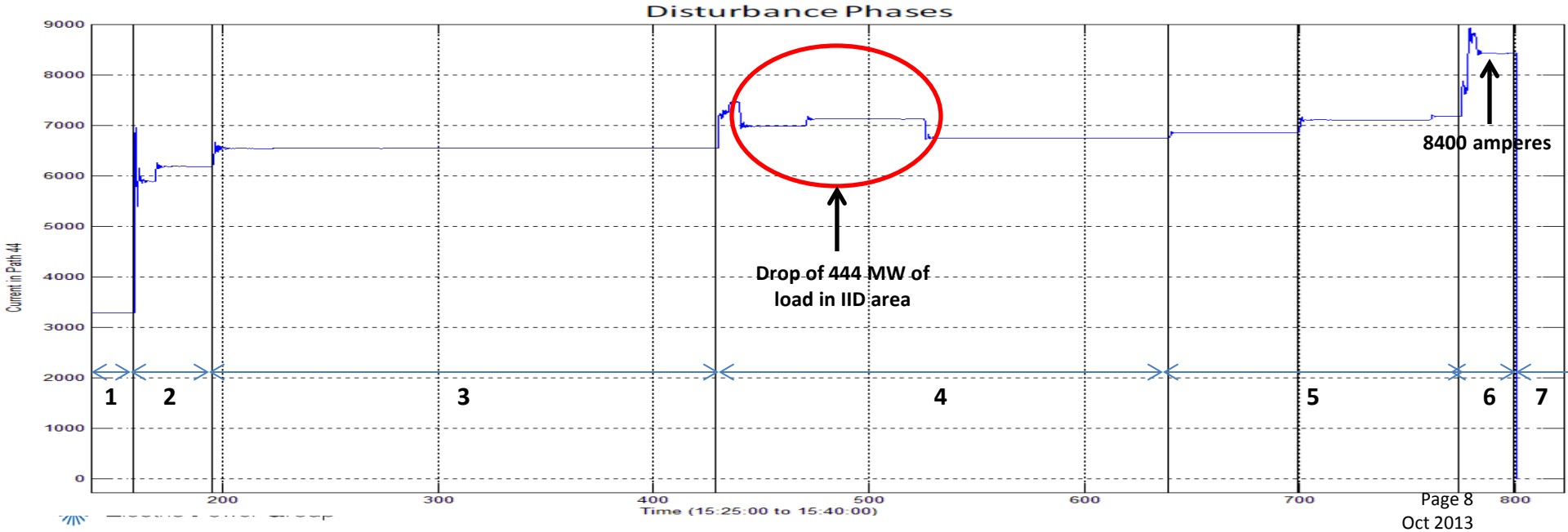
September 8, 2011 Pacific Southwest Blackout Event Simulation

Event Description:

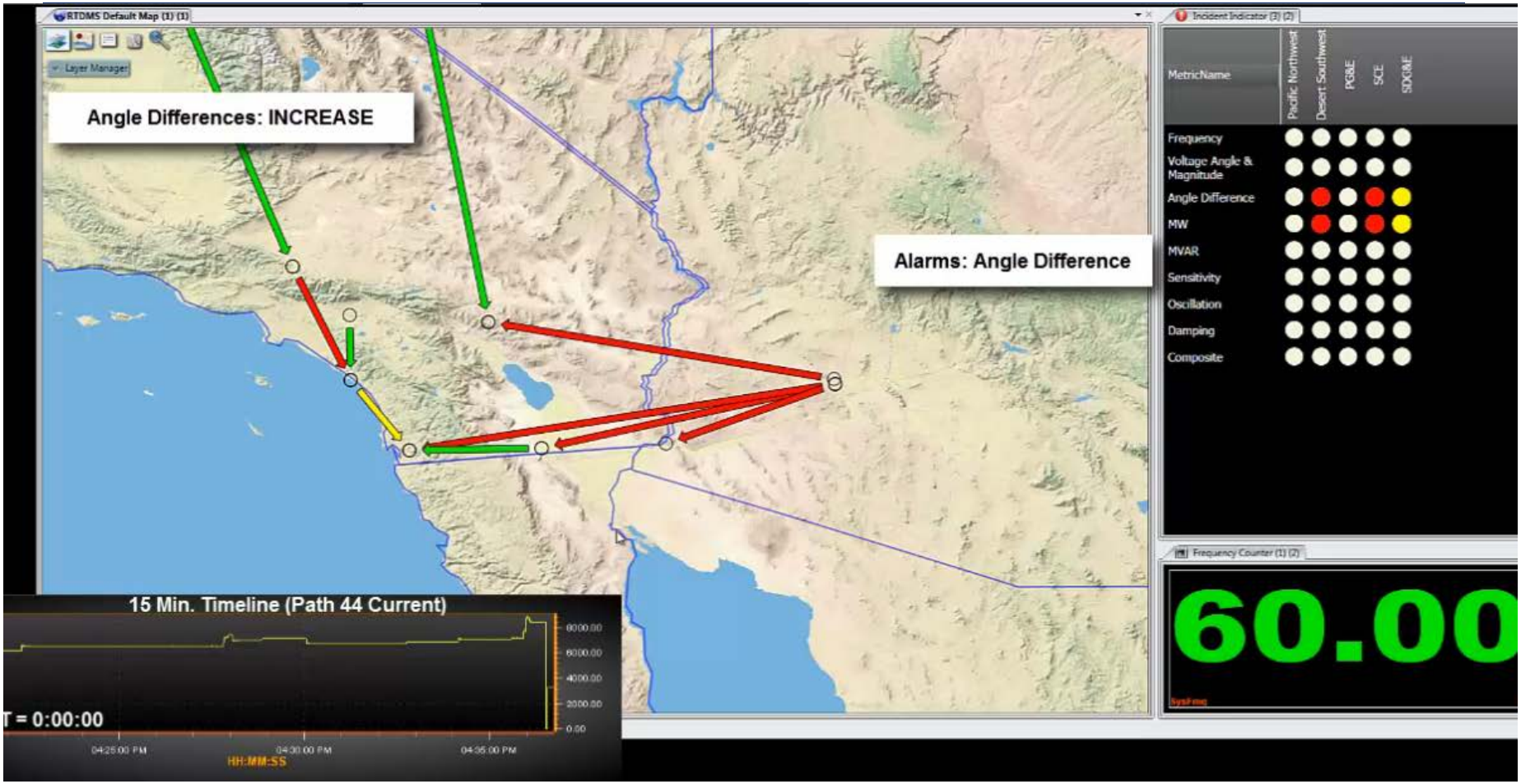
- Event took about 12-minutes
- Complete event simulated using PSLF
- Compared with the NERC/FERC report
- Simulation matches very closely
- Simulation replayed in RTDMS and analyzed using PGDA for validation
- EPG is working with SCE to simulate the event using their Real Time Digital Simulator (RTDS)
- Sequence of events in simulation includes:
  - Outage of North Gila-Hassayampa line
  - Outage of IID transformers
  - Load drop in IID and CFE
  - Loss of CFE and IID generation
  - Separation of SDGE at San Onofre Power Plant

Comparison of Actual (NERC/FERC Report) and Simulated September 8, 2011 Event

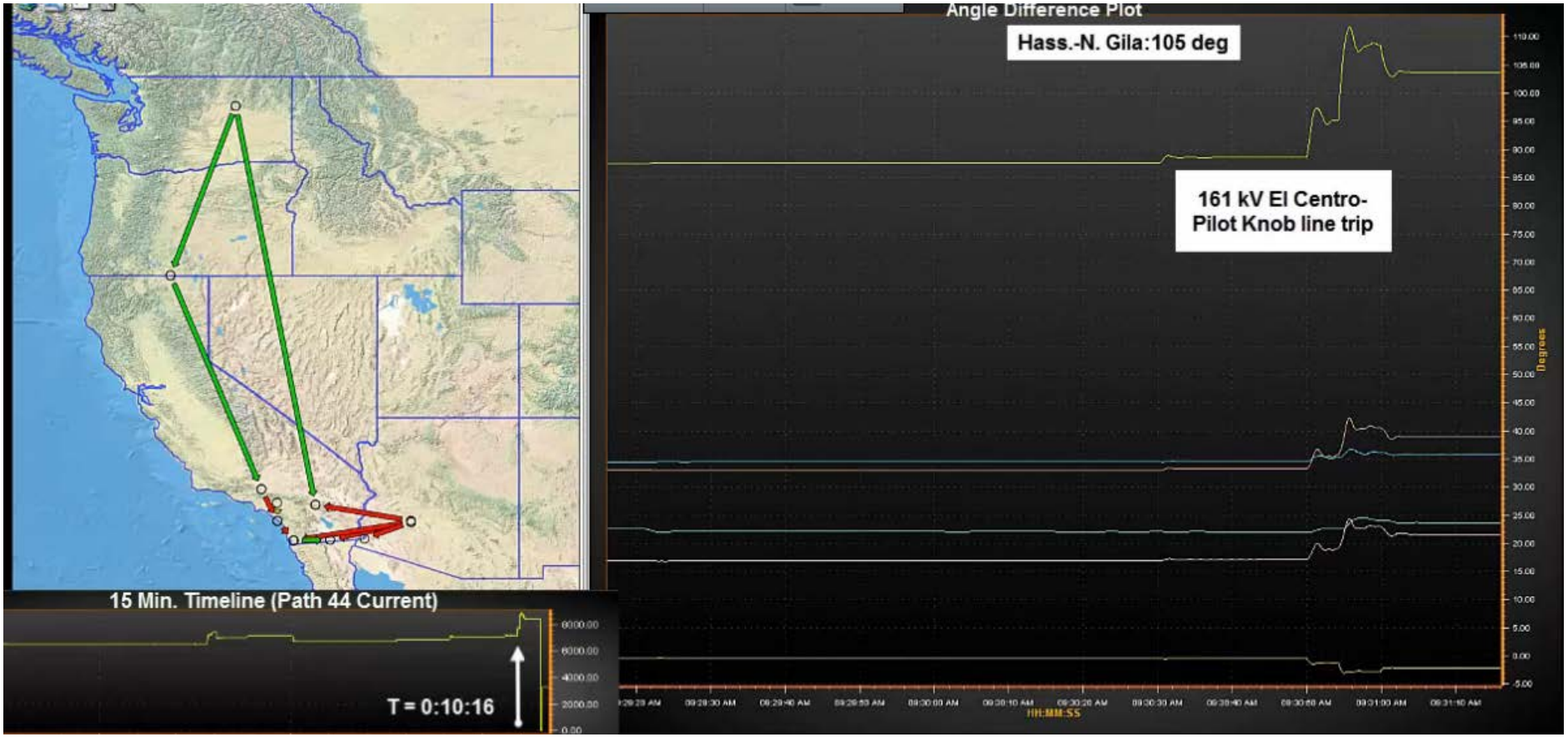




Visualization of San Diego Blackout Simulation (After Hassayampa-N.Gila Line Trip) - Replay



Simulation File Replay Showing Angle Differences Just Before Separation - Phase V of Blackout

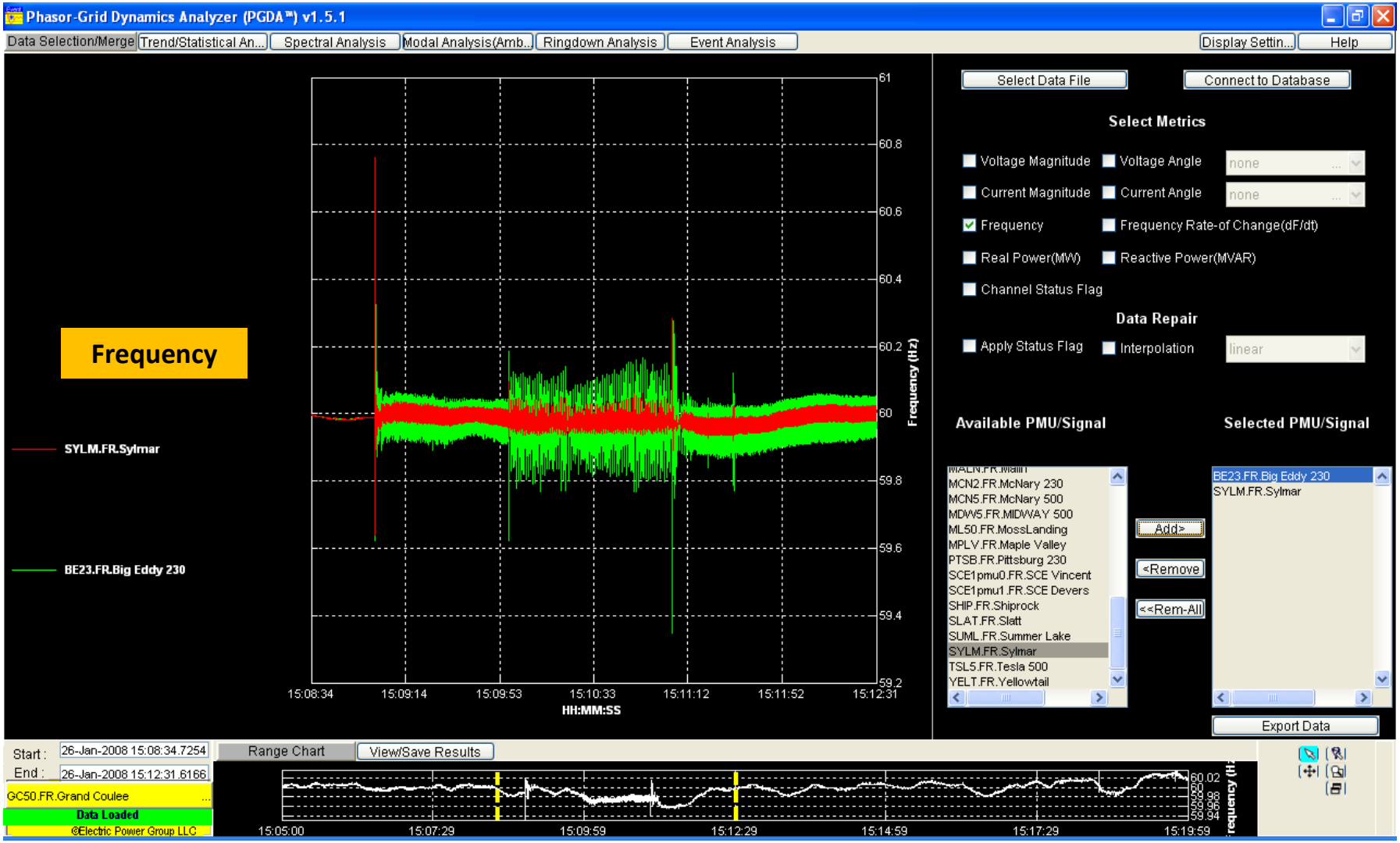


Oscillations Caused by PDCI Controls on January 26, 2008

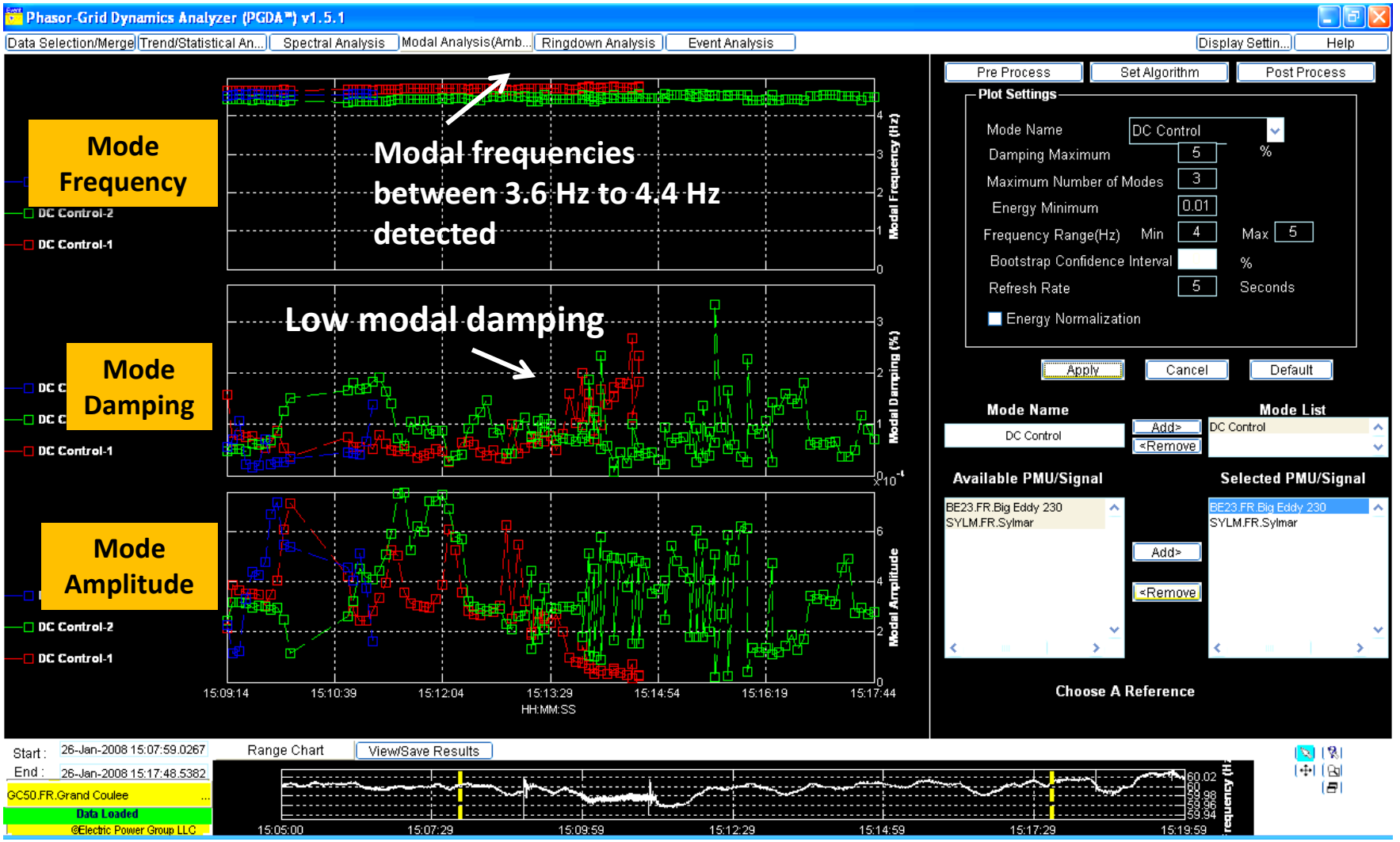
Event Description:

- Oscillations caused by the DC system control at Celilo substation when the three 525/230 kV transformers at Big Eddy – near Celilo tripped
- High frequency oscillations occurred at HVDC 230 kV bus at Celilo and Sylmar – the two ends of the PDCI line.
- Oscillation frequency varied between 3.6 to 4.4 Hz.
- Damping dropped to 1-2 %
- Simulation shows high frequency oscillations occurring on Power, voltage and frequency at Big Eddy and Sylmar
- Oscillation frequency in simulations is lower (About 2.3 Hz)
- PGDA shows oscillation frequency (2.3 Hz) and damping (1-2 %)

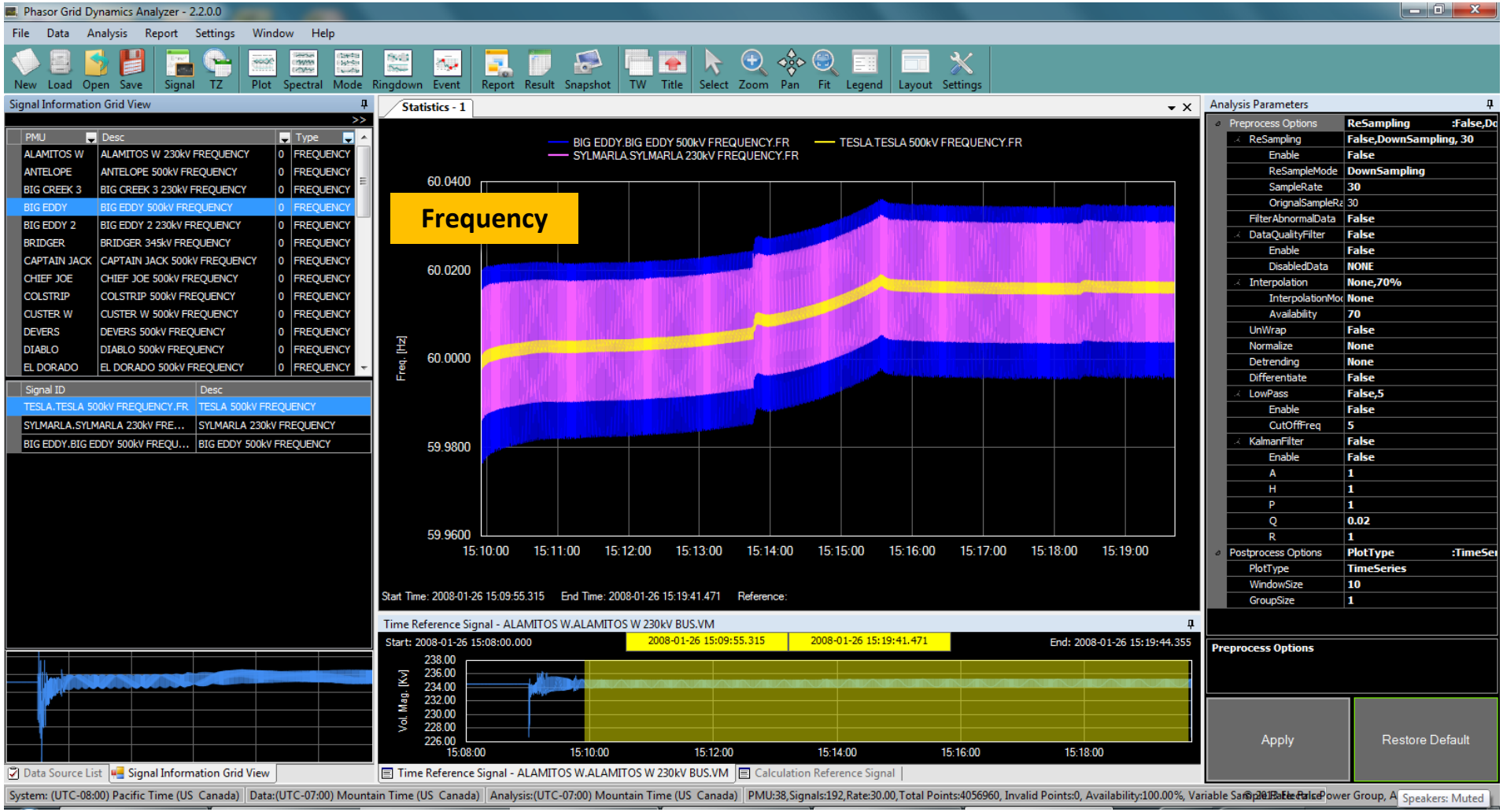
Large Sustained Frequency Oscillations Occurring at Celilo and Sylmar (Actual Event)



Large Sustained Frequency Oscillations Occurring in the System (Actual Event)



Large Sustained Frequency Oscillations at Big Eddy, Sylmar and Tesla Substation (Simulations)



Mode Meter Analysis of DC System Oscillations Using PGDA (Simulations)

Simulation – Stressing Pacific Intertie (COI) to 6370 MW

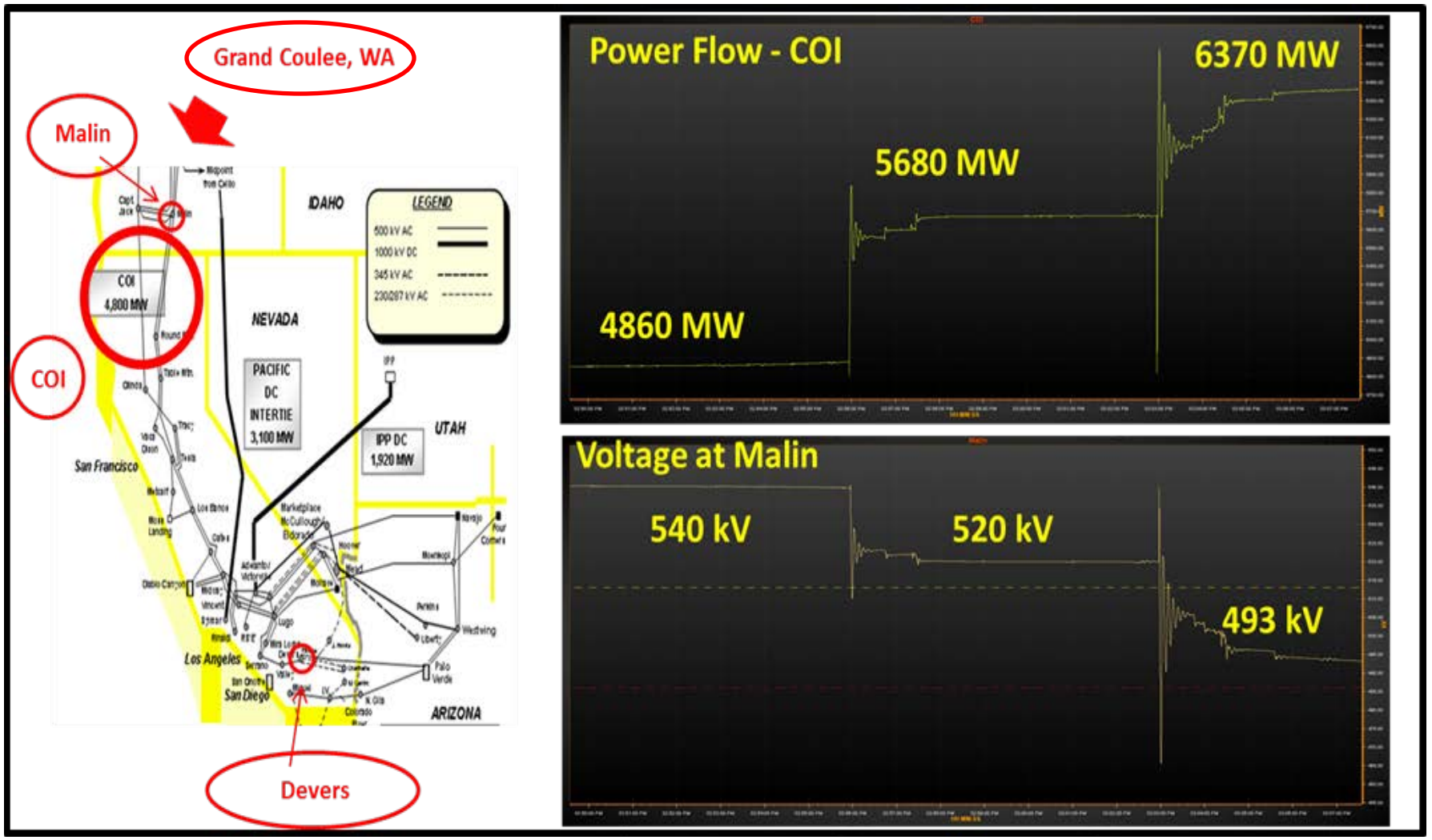
Simulation Description:

- Highly stressed 2011 Heavy Summer Base case
- System stressed (Static- in power flow case)
  - COI at 4860 MW
  - COI at 5680 MW
  - COI 6370 MW
- Angle difference between Grand Coulee – Devers
- Wide Area visualization shows Malin voltage is very sensitive to COI loading

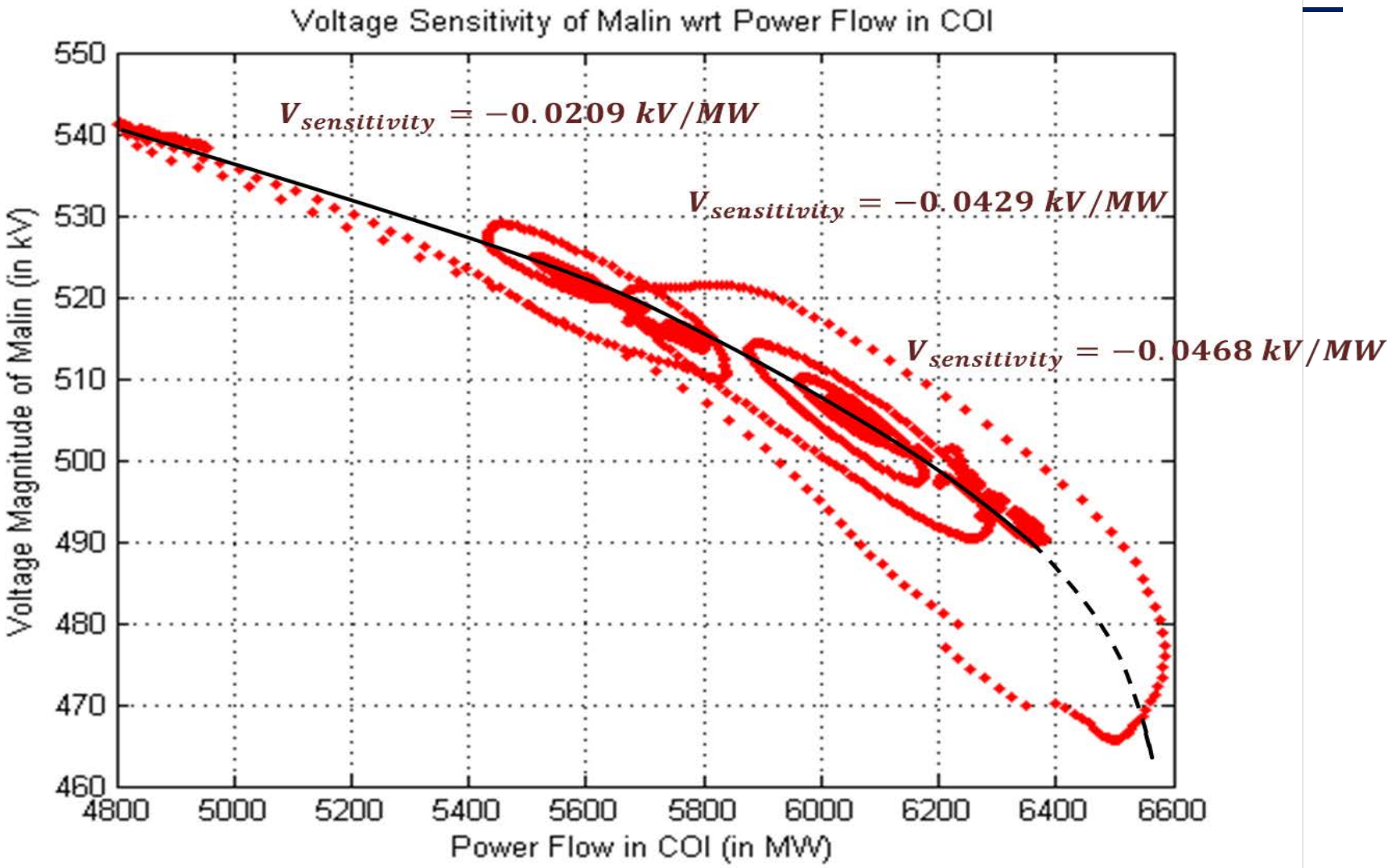
COI Loading	Grand Coulee – Devers Angle	Malin Bus Voltage
4860 MW	88 Degrees	540 kV
5680 MW	108 degrees	520 kV
6370 MW	129 degrees	493 kV

As seen in the above table, the Voltage at Malin substation sags as the COI is loaded and Angle difference between Grand Coulee and Devers increases

Power and Voltage Plot at Malin Substation

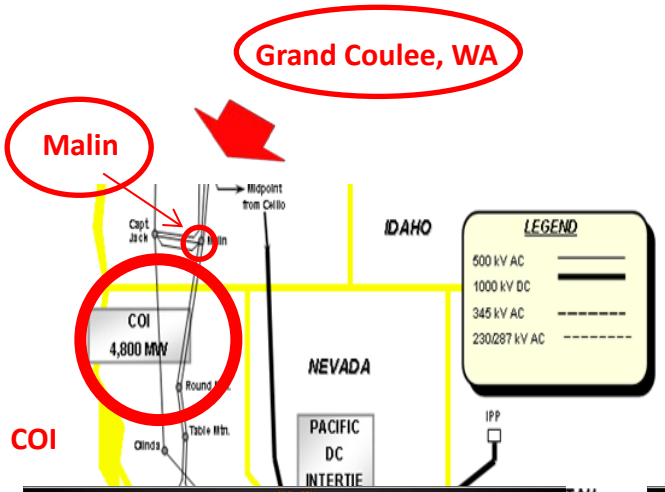


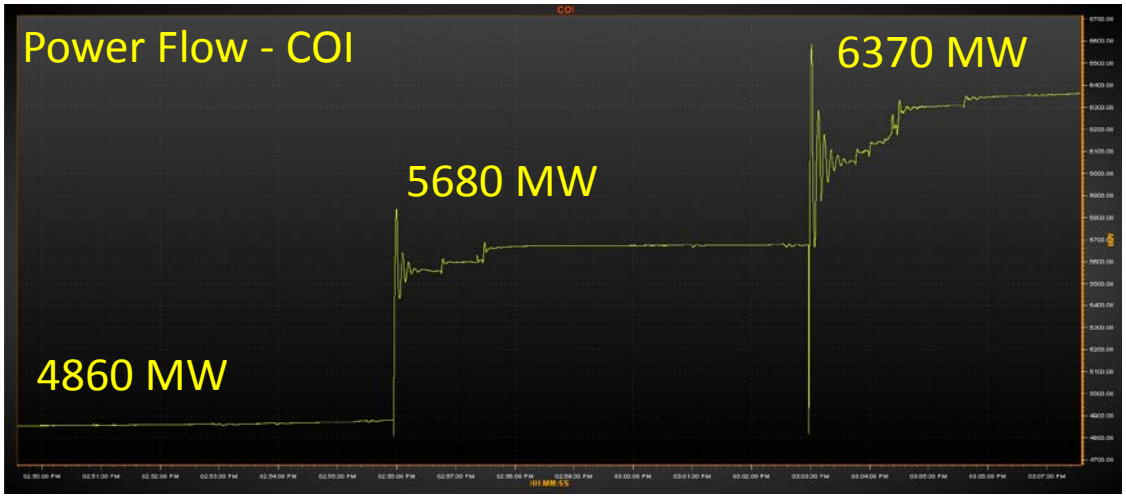
PV Curve for the COI Stressed Case Simulation

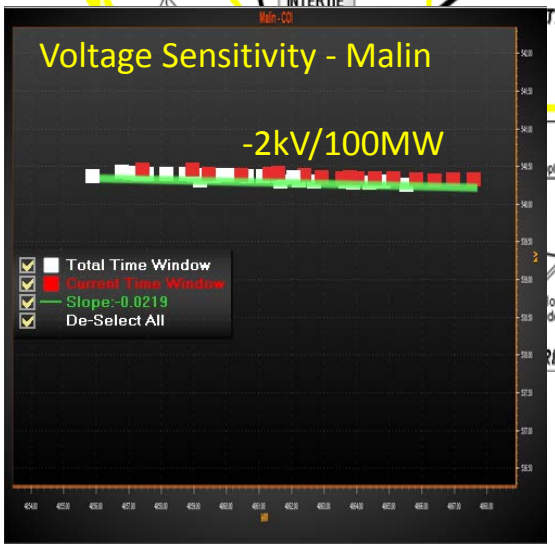


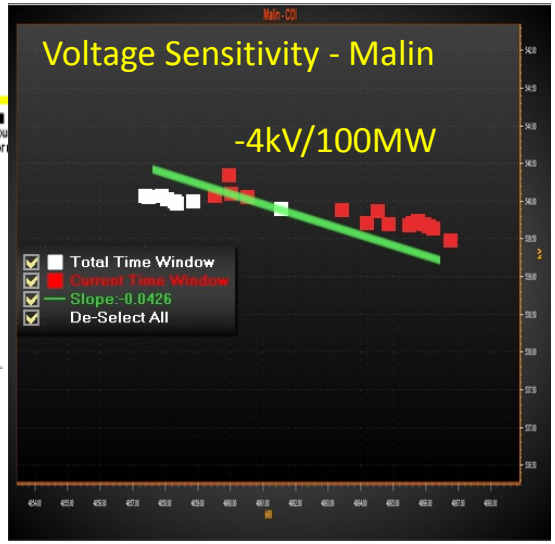
Monitoring Voltage Sensitivity Using RTDMS

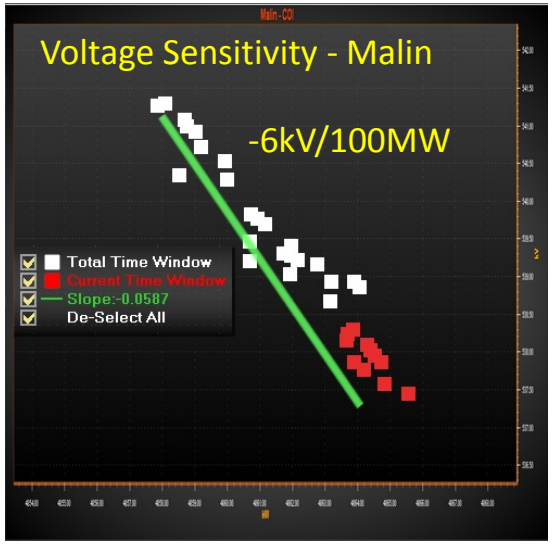
WECC Simulation Case: California - Oregon Intertie Stress Test



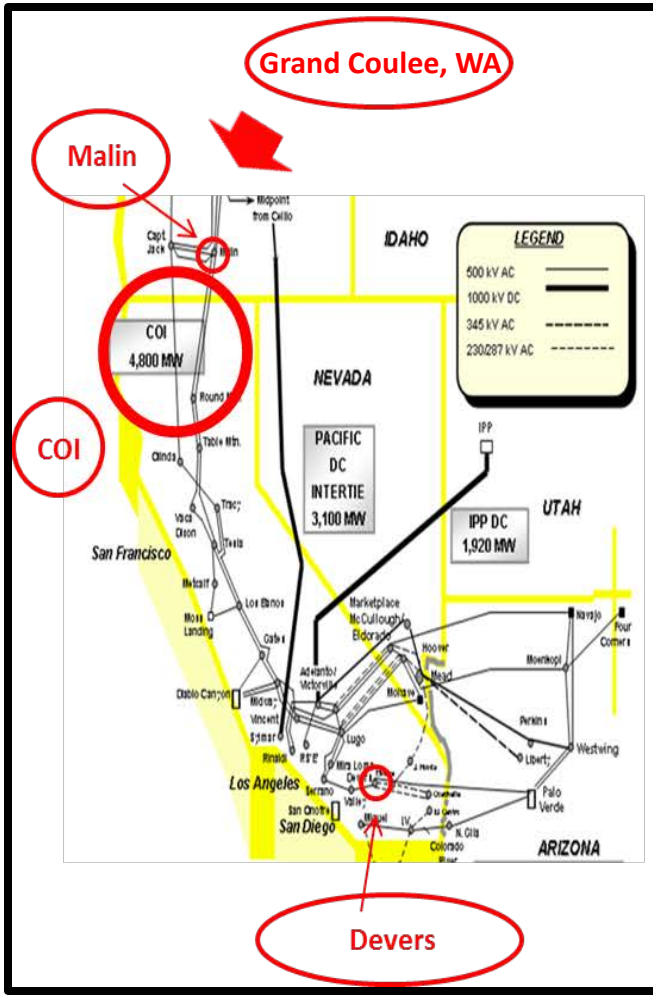


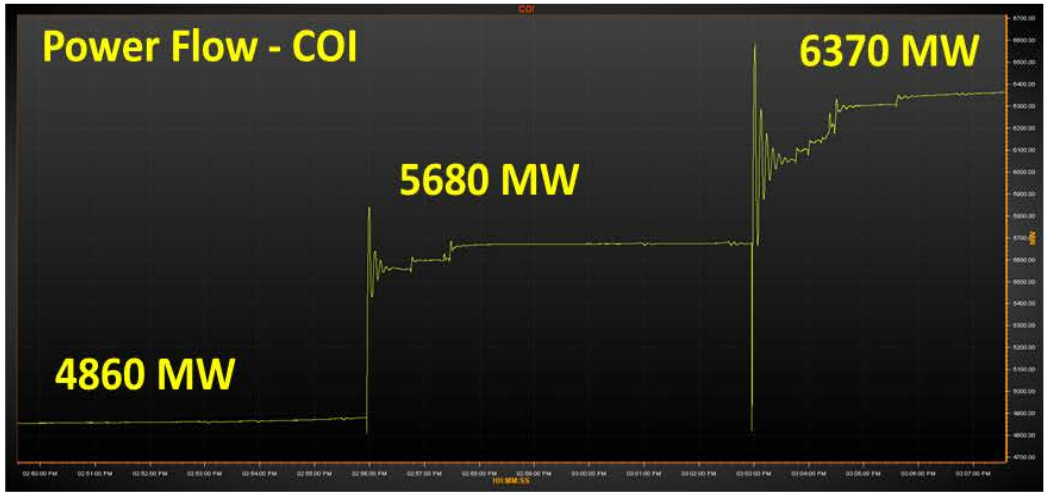


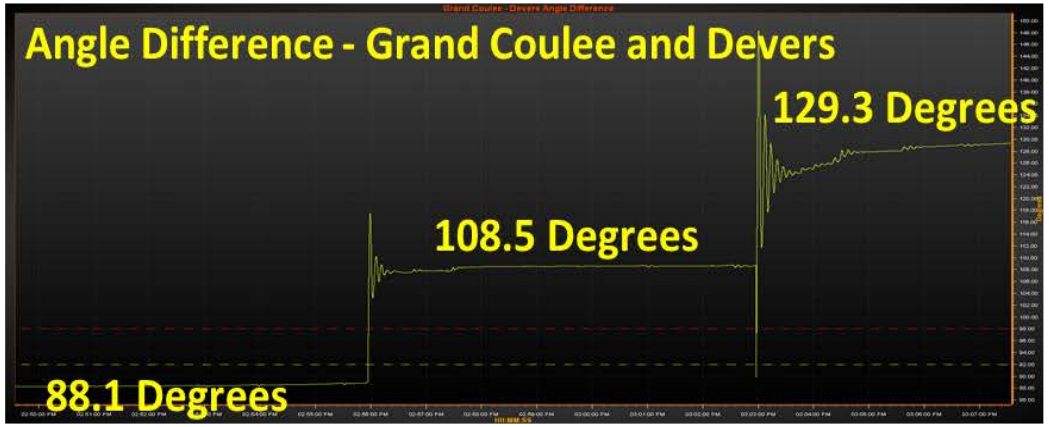




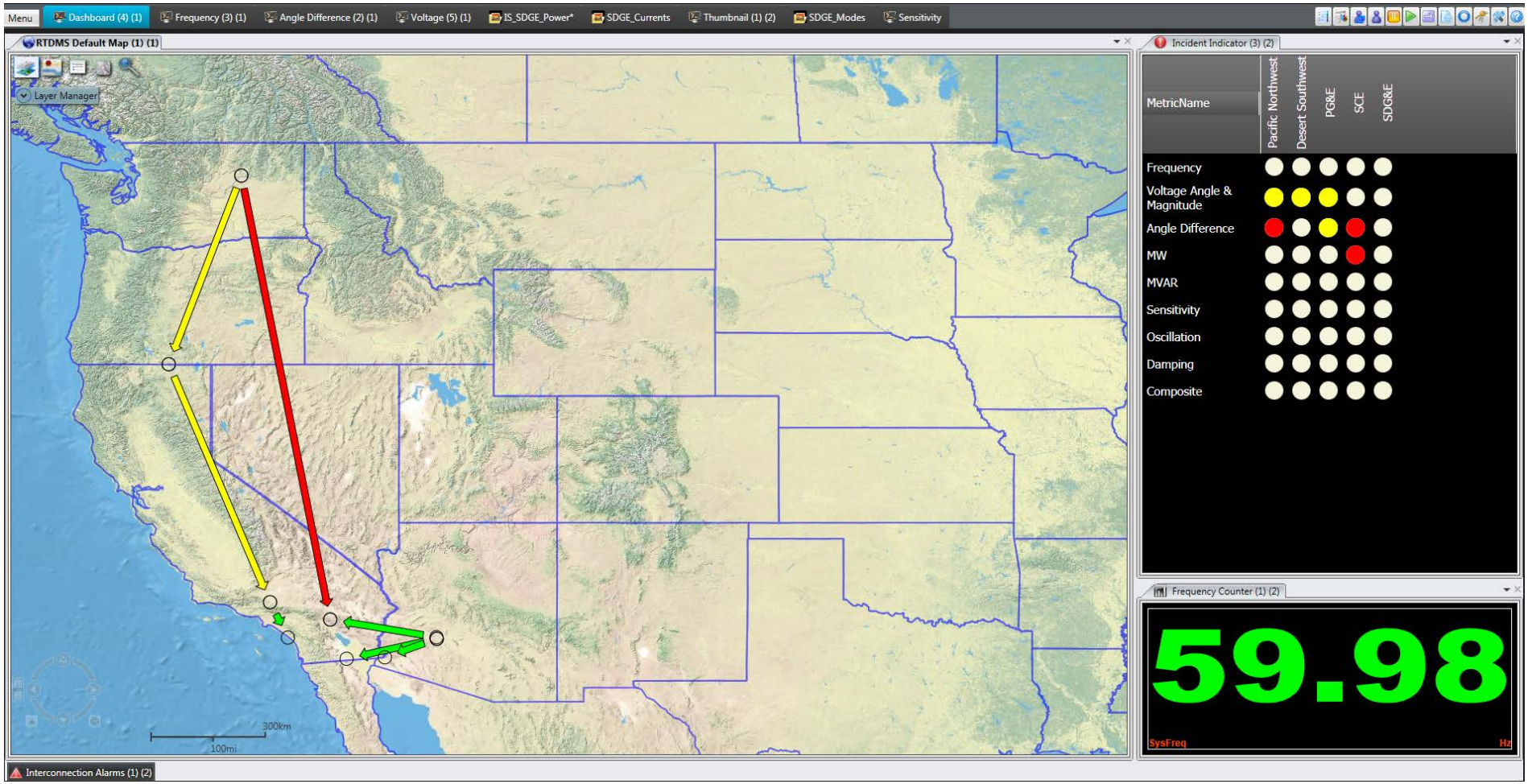
Power Flow at Malin and Angle Difference Between Grand Coulee and Devers







Monitored Angle Differences & Alarms for the Stressed COI Case



Conclusions / Summary

- Simulations were used for several different events
- Simulations can be conducted for actual disturbances/extreme events to compare and validate models
- RTDMS and PGDA were used to visualize PSLF simulated files and perform off line analysis
- Simulations can be used for model validation and operator training
- Simulated event replay - 2-minute video

Thank You!

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