PHASOR RTDMS®

Phasor Grid Dynamics Analyzer™

REAL TIME DYNAMICS MONITORING SYSTEM (RTDMS®) AND PHASOR GRID DYNAMICS ANALYZER (PGDA)

USER TRAINING FOR ERCOT

SEPTEMBER 16-17, 2014

Electric Power Group

RTDMS and PGDA User Training

Training Agenda – Day 2

RTDMS Alarms, Events, Configuration	Kevin Chen
RTDMS Advanced Monitoring and Metrics	Kevin Chen
Hands-on Guided Training Exercises	Wayne Schmus / Prashant Palayam
Lunch Break	
PGDA Training • Overview of PGDA • Case Studies	Wayne Schmus / Prashant Palayam
Q&A, Proficiency Evaluation	

RTDMS Alarms, Events and Configuration

- **What will be covered:**
  - Monitor alarms in RTDMS Visualization Client
  - Retrieve historical alarms
  - User marked events

RTDMS Server Alarm/Event

- **Value violates threshold – Alarm**
  - Individual **threshold** for different PMUs and levels/severity
  - Individual **time window** for different PMUs and levels/severity
- **Rate of change violates threshold – Event**
  - Individual **rate of change threshold** for different PMU
  - Individual **time window** for different PMUs
- **Event also Known as Transient Event**

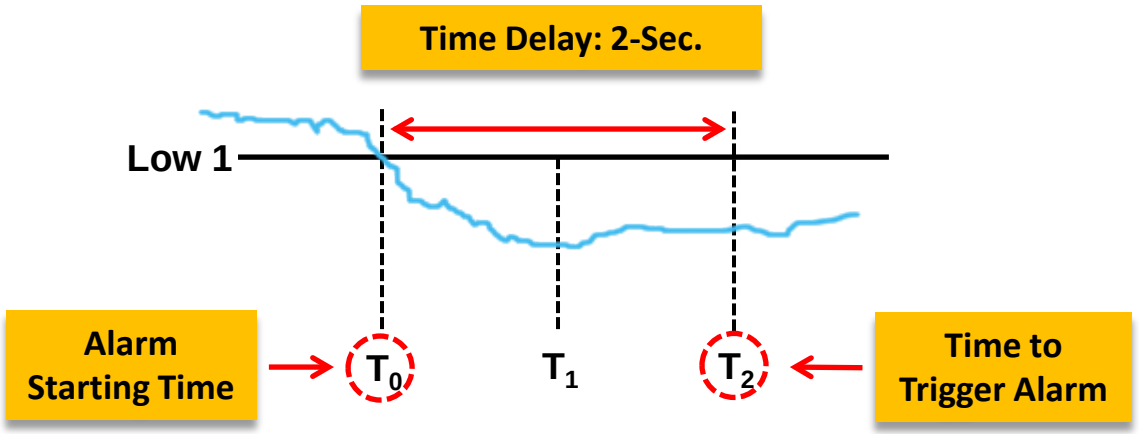
Alarm/Event Matrices and Severity Types

	Metric	Low 4	Low 1	High 1	High 4	Time window
Threshold Violation Alarms	Frequency	√	√	√	√	√
	Voltage (Magnitude)	√	√	√	√	√
	Current (Magnitude)	√	√	√	√	√
	Angle Difference	√	√	√	√	√
	Active Power	√	√	√	√	√
	Reactive Power	√	√	√	√	√
	Damping	√	√			
	Voltage Sensitivity (Magnitude and Angle)	√	√	√	√	√

	Metric	Rate of change threshold	Time window
Transient "Event" Alarms	Frequency	√	√
	Voltage (Magnitude)	√	√
	Angle Difference	√	√

Alarm Implementation in RTDMS

- **Alarms Trigger:**
  - Threshold (59.95 Hz)
  - Rate of Change (40 MHz/S)
  - Time delay (2 Seconds):



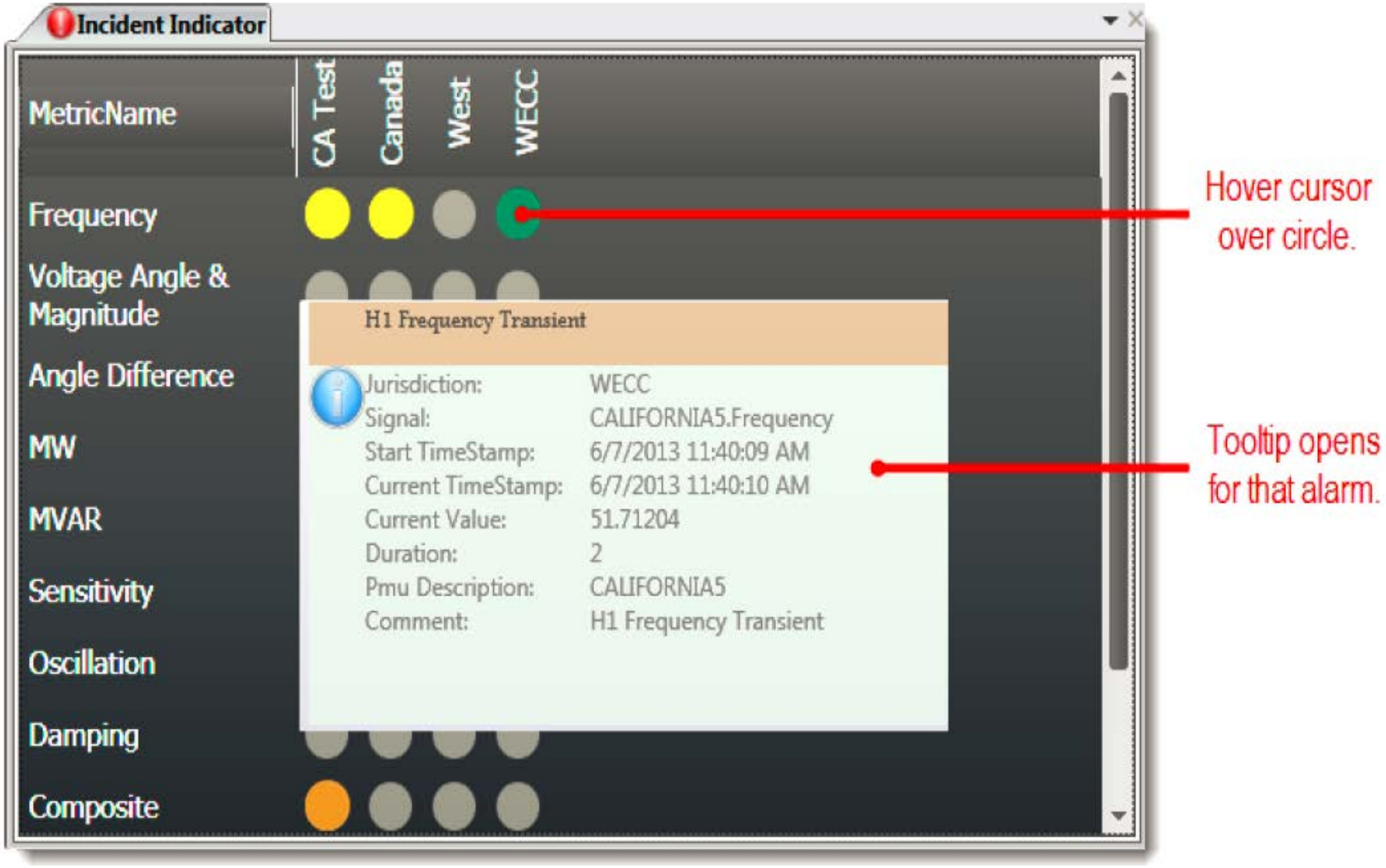
Alarm level: 2 levels, 4 levels and 8 levels

Alarm Implementation in RTDMS

Example: 4-Level Threshold Frequency Alarm

Threshold	Frequency	Alarm Color
Low 2	59.90 Hz	
Low 1	59.95 Hz	
Normal	60.00 Hz	
High 1	60.05 Hz	
High 2	60.10 Hz	

How to use Incident Indicator



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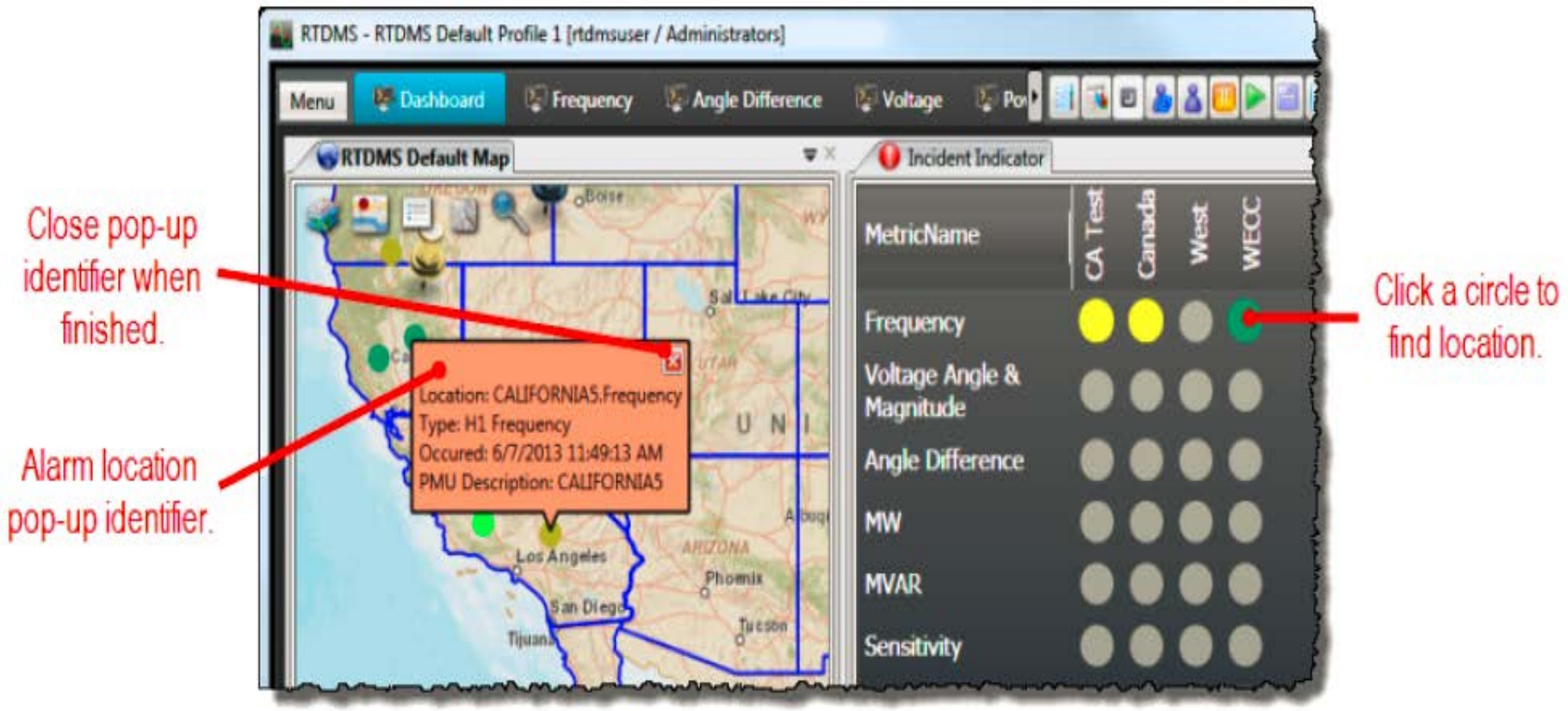
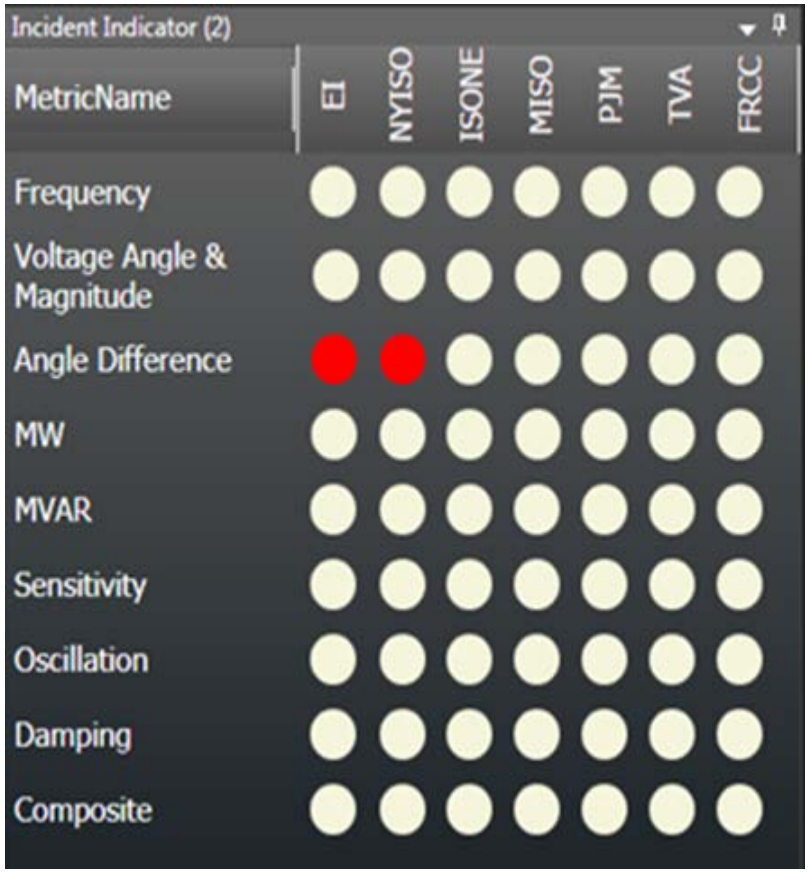
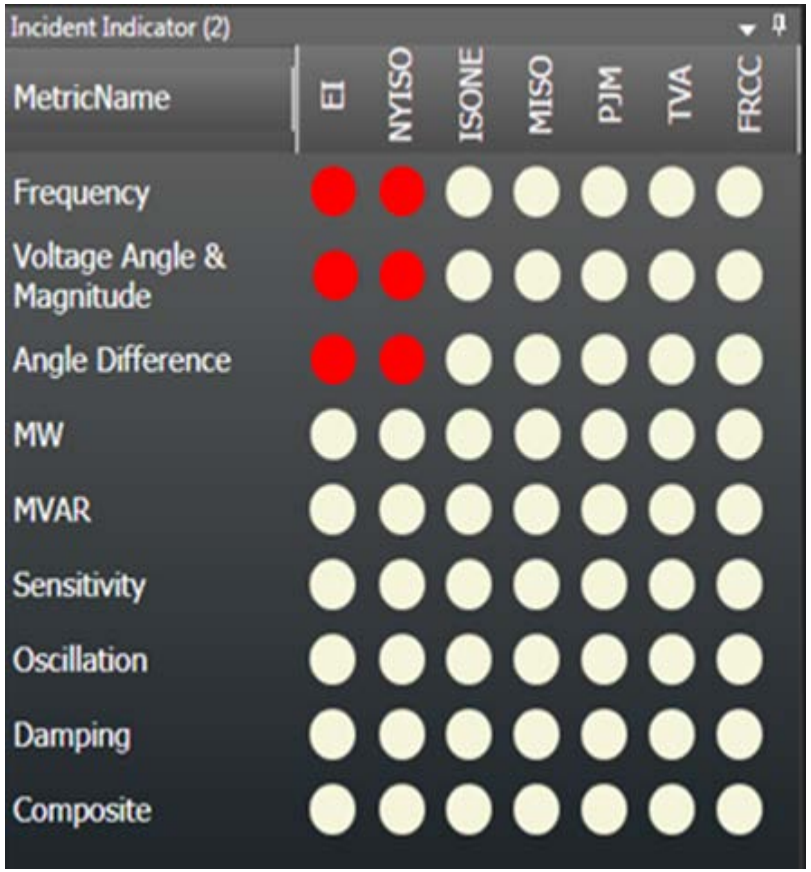


Use of Alarms in Real-Time Operations



- **Early Warning of Grid Stress (Increasing Phase Angle differences)**
- **Pinpoint Incident Location (First Mover PMU - frequency, voltage etc.)**
- Assess Incident Severity (3 Metrics alarm)
- Assess Vulnerability to Cascade (Multiple Alarms in Large or Multiple Footprints)

Use of Alarms in Real-Time Operations



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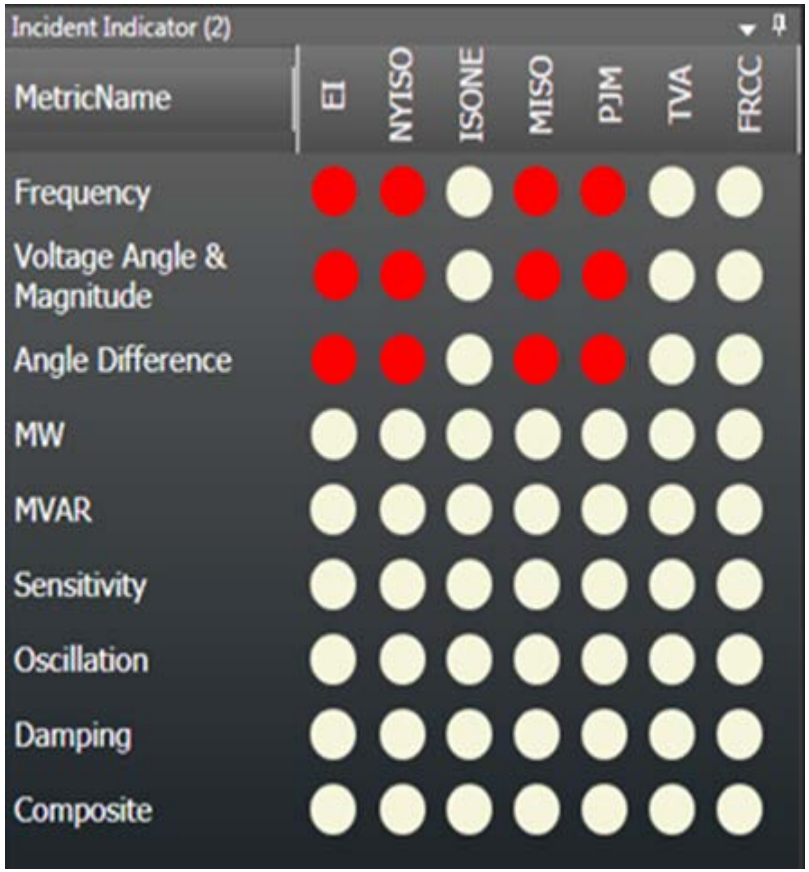

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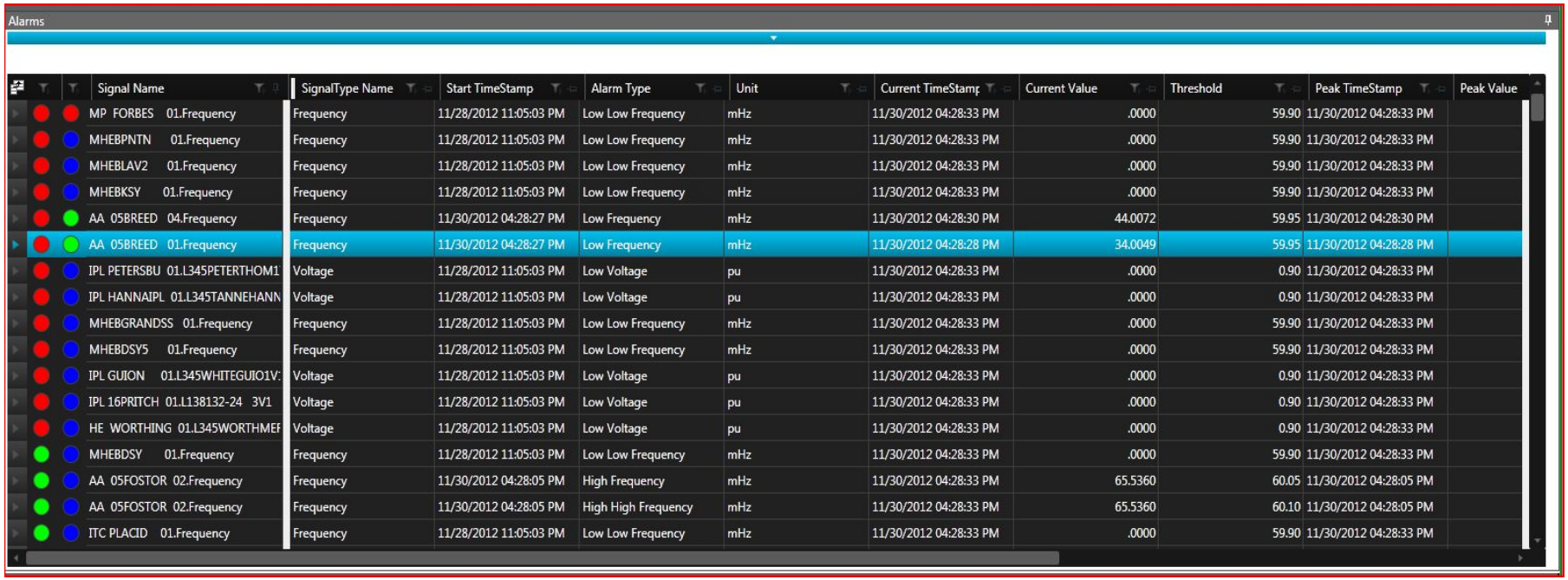
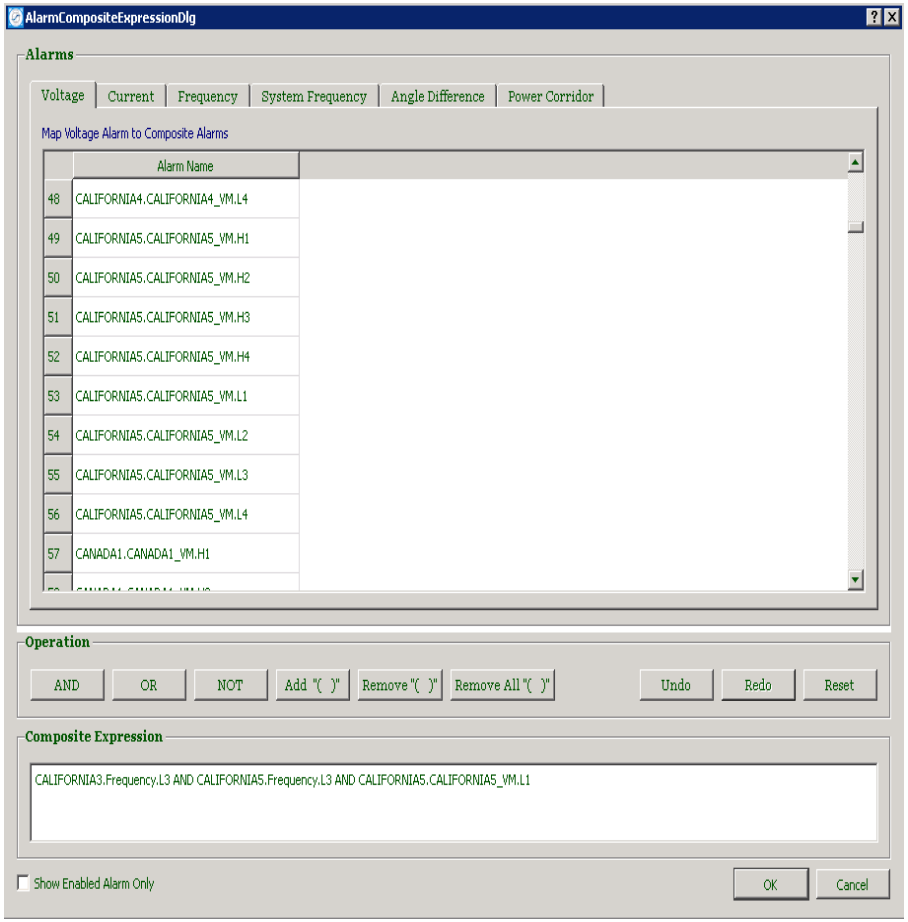
RTDMS Client Alarm Grid View



Signal Name	SignalType Name	Start TimeStamp	Alarm Type	Unit	Current TimeStamp	Current Value	Threshold	Peak TimeStamp	Peak Value
MP FORBES 01.Frequency	Frequency	11/28/2012 11:05:03 PM	Low Low Frequency	mHz	11/30/2012 04:28:33 PM	.0000	59.90	11/30/2012 04:28:33 PM	
MHEBPNTN 01.Frequency	Frequency	11/28/2012 11:05:03 PM	Low Low Frequency	mHz	11/30/2012 04:28:33 PM	.0000	59.90	11/30/2012 04:28:33 PM	
MHEBLAV2 01.Frequency	Frequency	11/28/2012 11:05:03 PM	Low Low Frequency	mHz	11/30/2012 04:28:33 PM	.0000	59.90	11/30/2012 04:28:33 PM	
MHEBKSY 01.Frequency	Frequency	11/28/2012 11:05:03 PM	Low Low Frequency	mHz	11/30/2012 04:28:33 PM	.0000	59.90	11/30/2012 04:28:33 PM	
AA 05BREED 04.Frequency	Frequency	11/30/2012 04:28:27 PM	Low Frequency	mHz	11/30/2012 04:28:30 PM	44.0072	59.95	11/30/2012 04:28:30 PM	
AA 05BREED 01.Frequency	Frequency	11/30/2012 04:28:27 PM	Low Frequency	mHz	11/30/2012 04:28:28 PM	34.0049	59.95	11/30/2012 04:28:28 PM	
IPL PETERSBU 01.L345PETERTHOM1	Voltage	11/28/2012 11:05:03 PM	Low Voltage	pu	11/30/2012 04:28:33 PM	.0000	0.90	11/30/2012 04:28:33 PM	
IPL HANNAIPL 01.L345TANNEHANN	Voltage	11/28/2012 11:05:03 PM	Low Voltage	pu	11/30/2012 04:28:33 PM	.0000	0.90	11/30/2012 04:28:33 PM	
MHEBGRANDSS 01.Frequency	Frequency	11/28/2012 11:05:03 PM	Low Low Frequency	mHz	11/30/2012 04:28:33 PM	.0000	59.90	11/30/2012 04:28:33 PM	
MHEBDSY5 01.Frequency	Frequency	11/28/2012 11:05:03 PM	Low Low Frequency	mHz	11/30/2012 04:28:33 PM	.0000	59.90	11/30/2012 04:28:33 PM	
IPL GUION 01.L345WHITEGUIO1V:	Voltage	11/28/2012 11:05:03 PM	Low Voltage	pu	11/30/2012 04:28:33 PM	.0000	0.90	11/30/2012 04:28:33 PM	
IPL 16PRITCH 01.L138132-24 3V1	Voltage	11/28/2012 11:05:03 PM	Low Voltage	pu	11/30/2012 04:28:33 PM	.0000	0.90	11/30/2012 04:28:33 PM	
HE WORTHING 01.L345WORTHMEF	Voltage	11/28/2012 11:05:03 PM	Low Voltage	pu	11/30/2012 04:28:33 PM	.0000	0.90	11/30/2012 04:28:33 PM	
MHEBDSY 01.Frequency	Frequency	11/28/2012 11:05:03 PM	Low Low Frequency	mHz	11/30/2012 04:28:33 PM	.0000	59.90	11/30/2012 04:28:33 PM	
AA 05FOSTOR 02.Frequency	Frequency	11/30/2012 04:28:05 PM	High Frequency	mHz	11/30/2012 04:28:33 PM	65.5360	60.05	11/30/2012 04:28:05 PM	
AA 05FOSTOR 02.Frequency	Frequency	11/30/2012 04:28:05 PM	High High Frequency	mHz	11/30/2012 04:28:33 PM	65.5360	60.10	11/30/2012 04:28:05 PM	
ITC PLACID 01.Frequency	Frequency	11/28/2012 11:05:03 PM	Low Low Frequency	mHz	11/30/2012 04:28:33 PM	.0000	59.90	11/30/2012 04:28:33 PM	

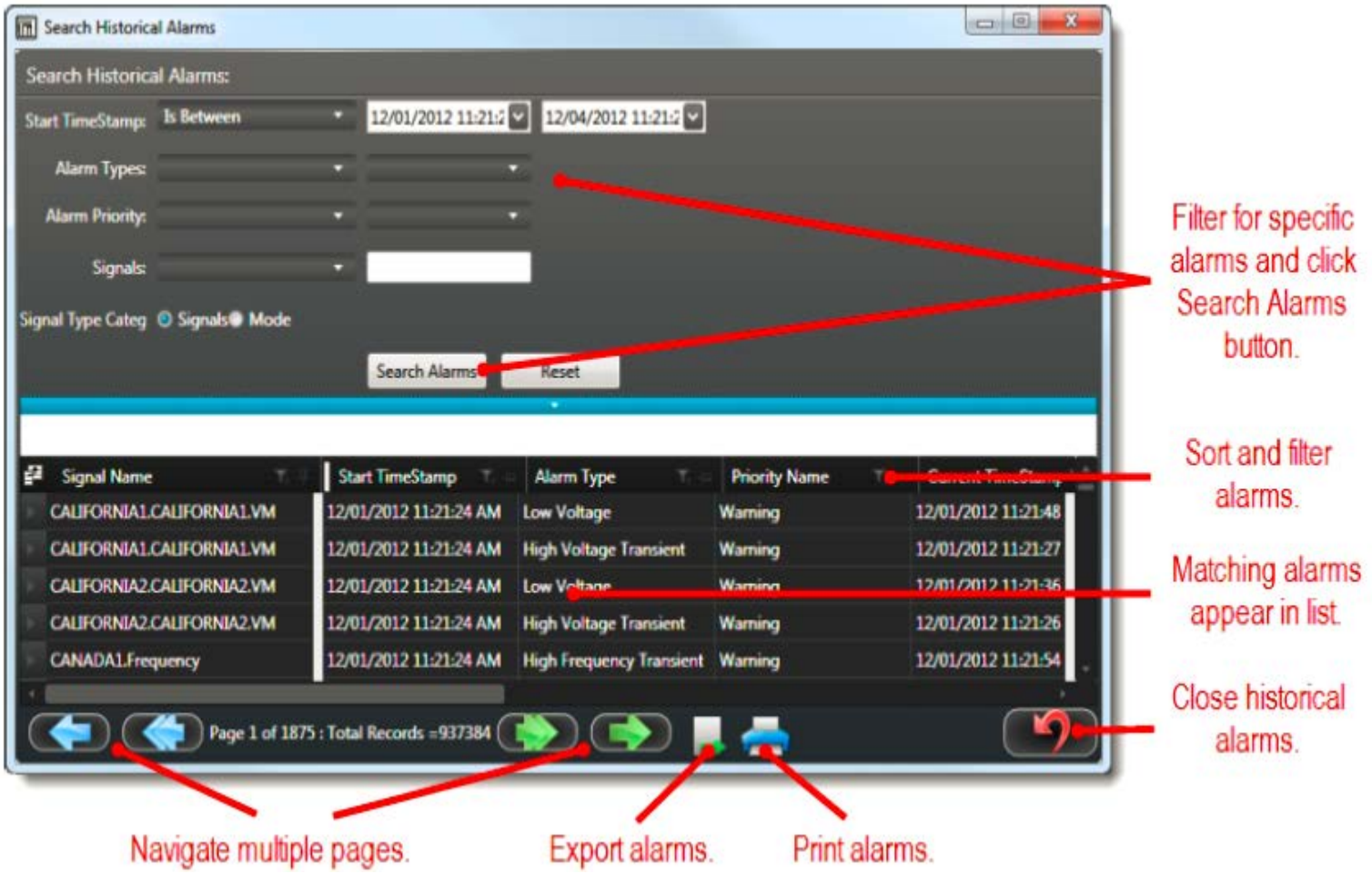
- Alarm View records and alerts abnormal situations in the system
- Alarms can be grouped or filtered w.r.t. alarm type, priority, etc.
- Alarms can be acknowledged by authorized users

Composite Alarms



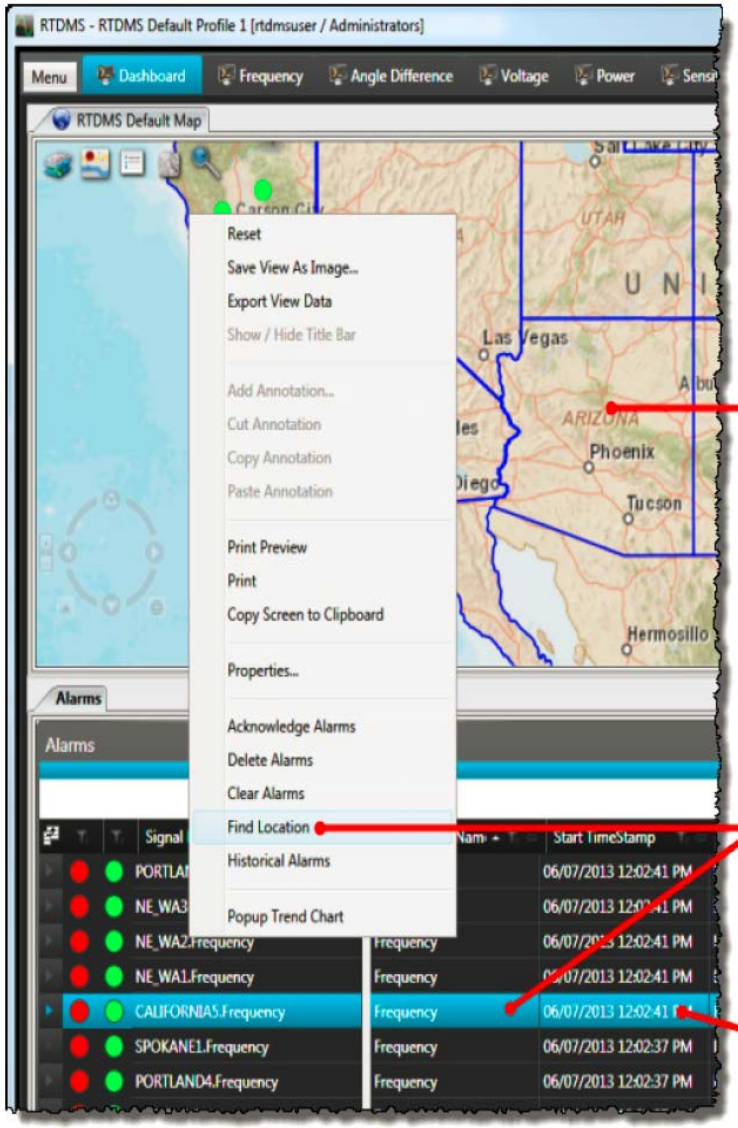
- User-defined logical combination of multiple conditions (AND, OR, NOT)
- Example: Voltage Sensitivity at KilleenSwitch AND Airline to KilleenSwitch Phase Angle Difference

Retrieve Historical Alarms



- Search historical alarm records
- Sort, filter and export alarm records

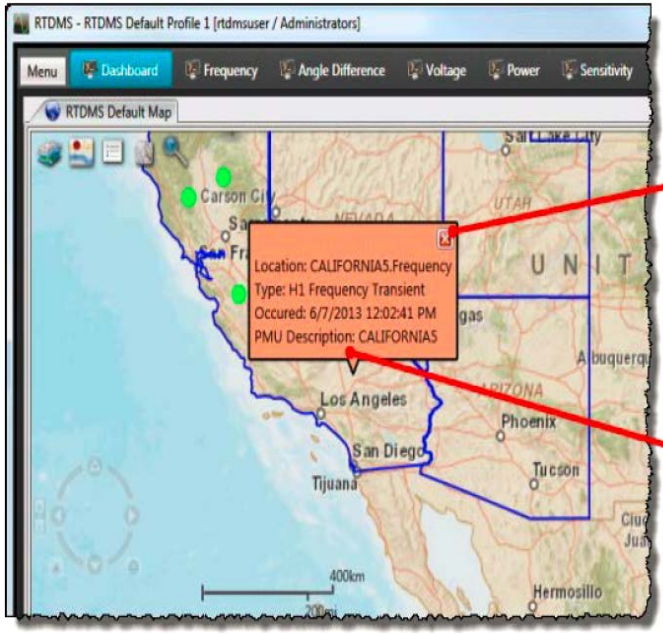
Locate alarm on maps



The same parent display contains a map view.

Double-click alarm to find location on map, or right-click alarm and select Find Location on pop-up menu.

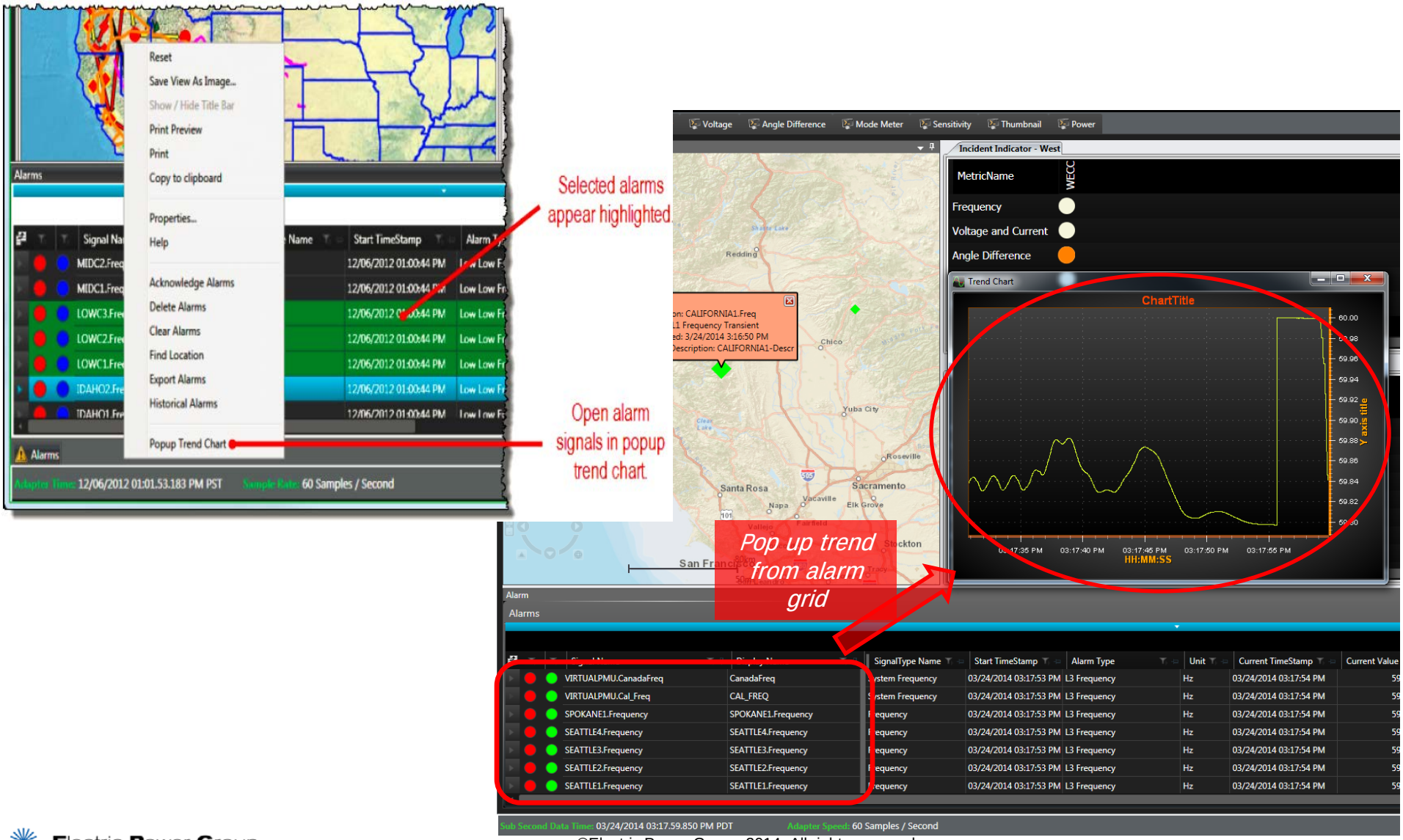
Selected alarm appears highlighted.



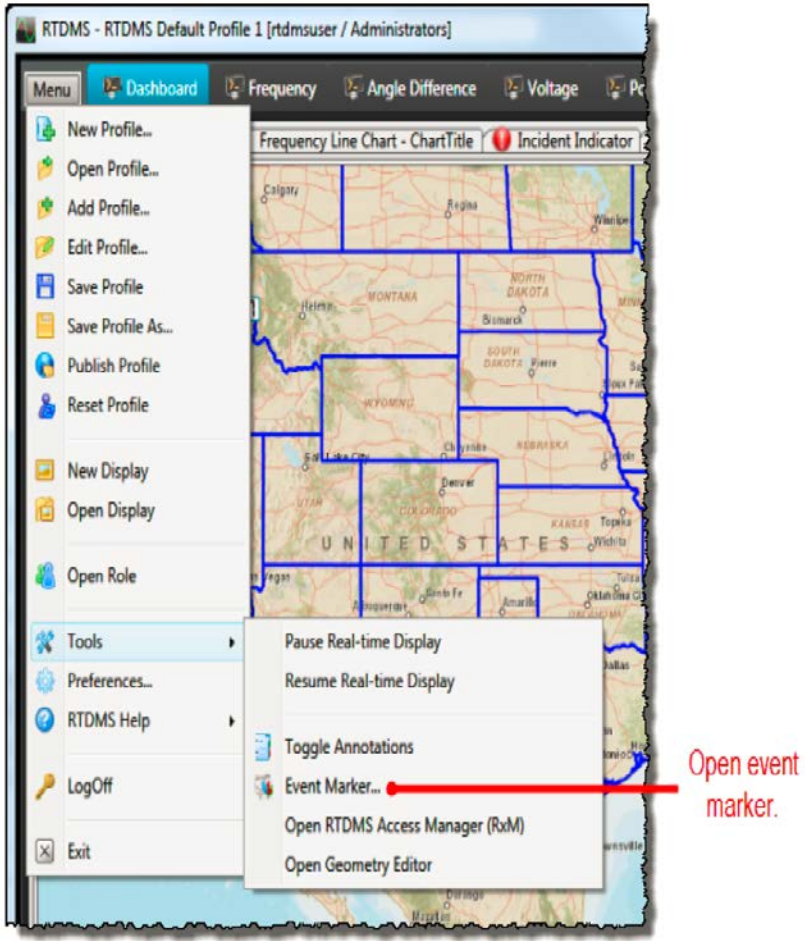
Close location pop-up when finished.

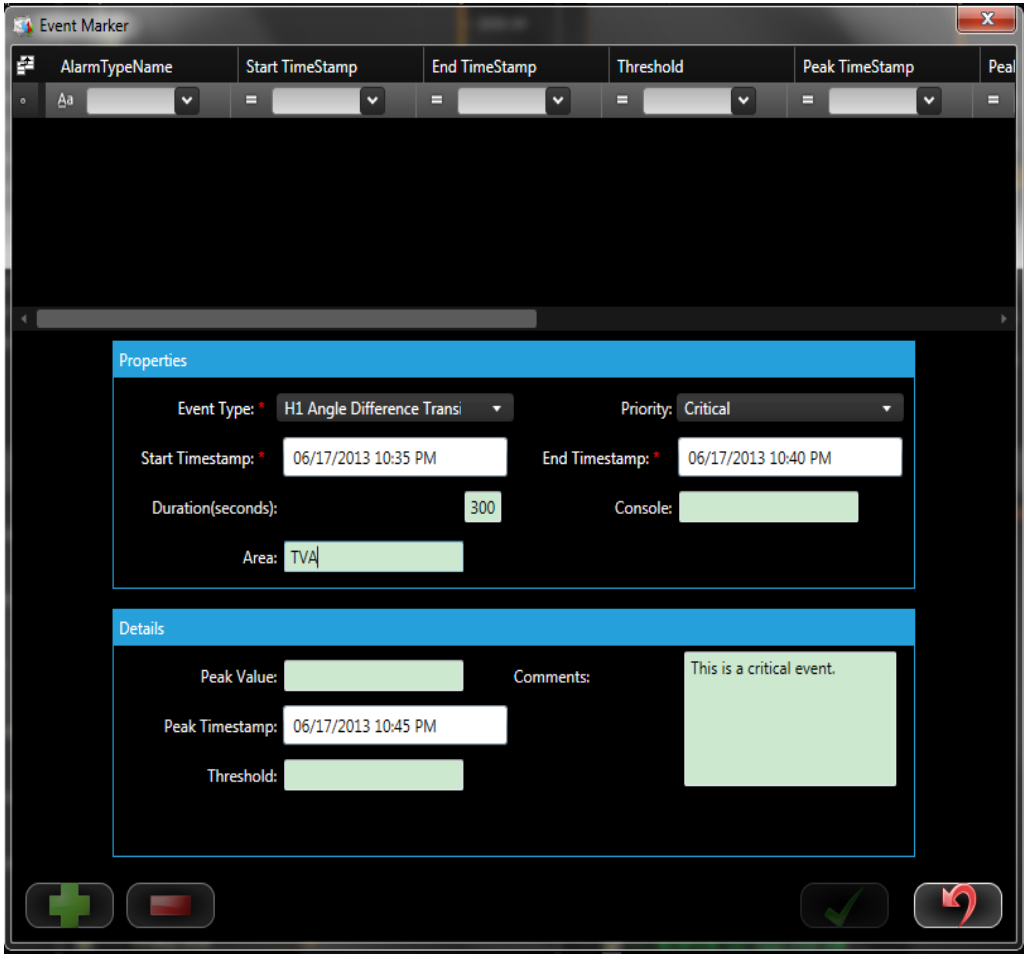
Alarm location.

On-the-fly alarm trending from Alarm Grid



How to Mark Events From RTDMS Client





- User to select time range to mark as event
- Ability to retrieve marked event and replay

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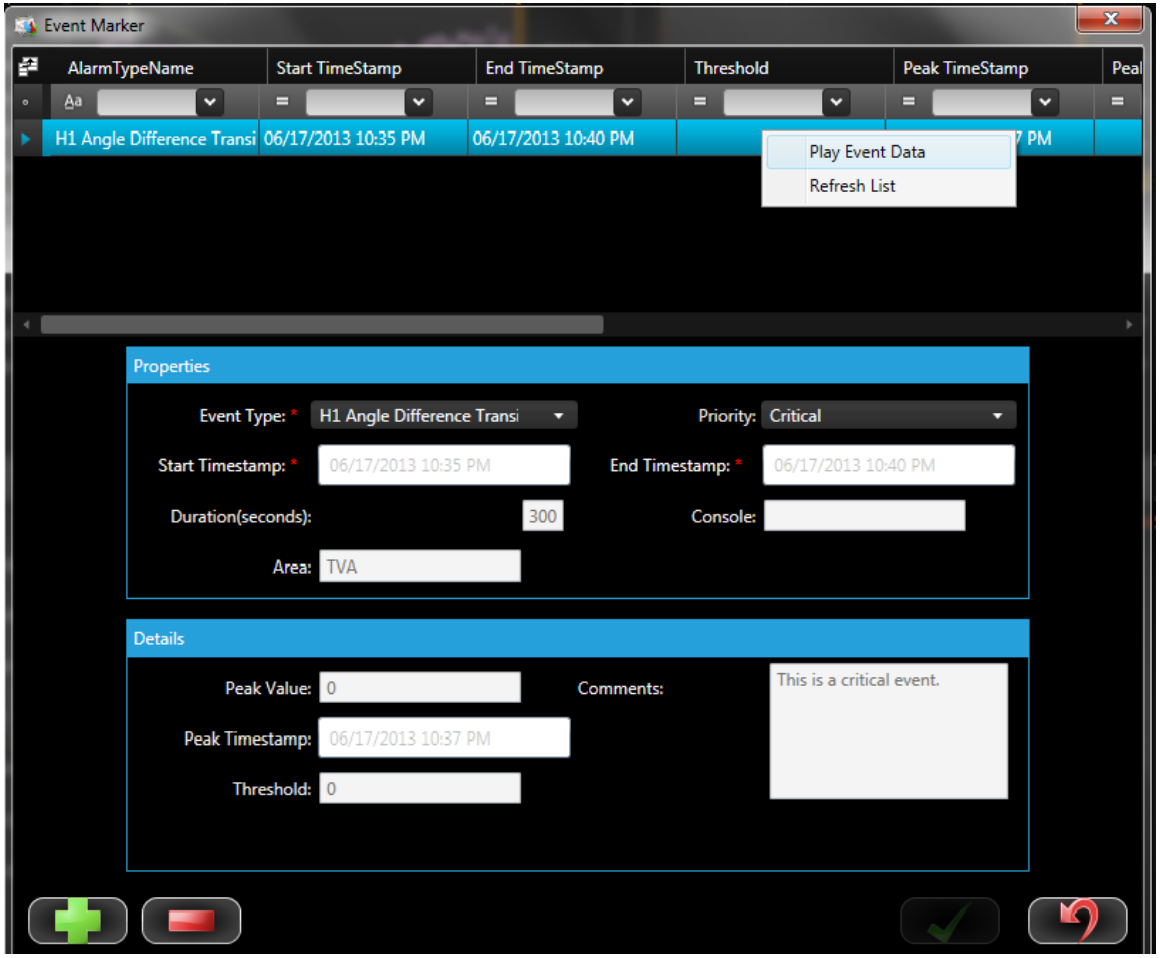

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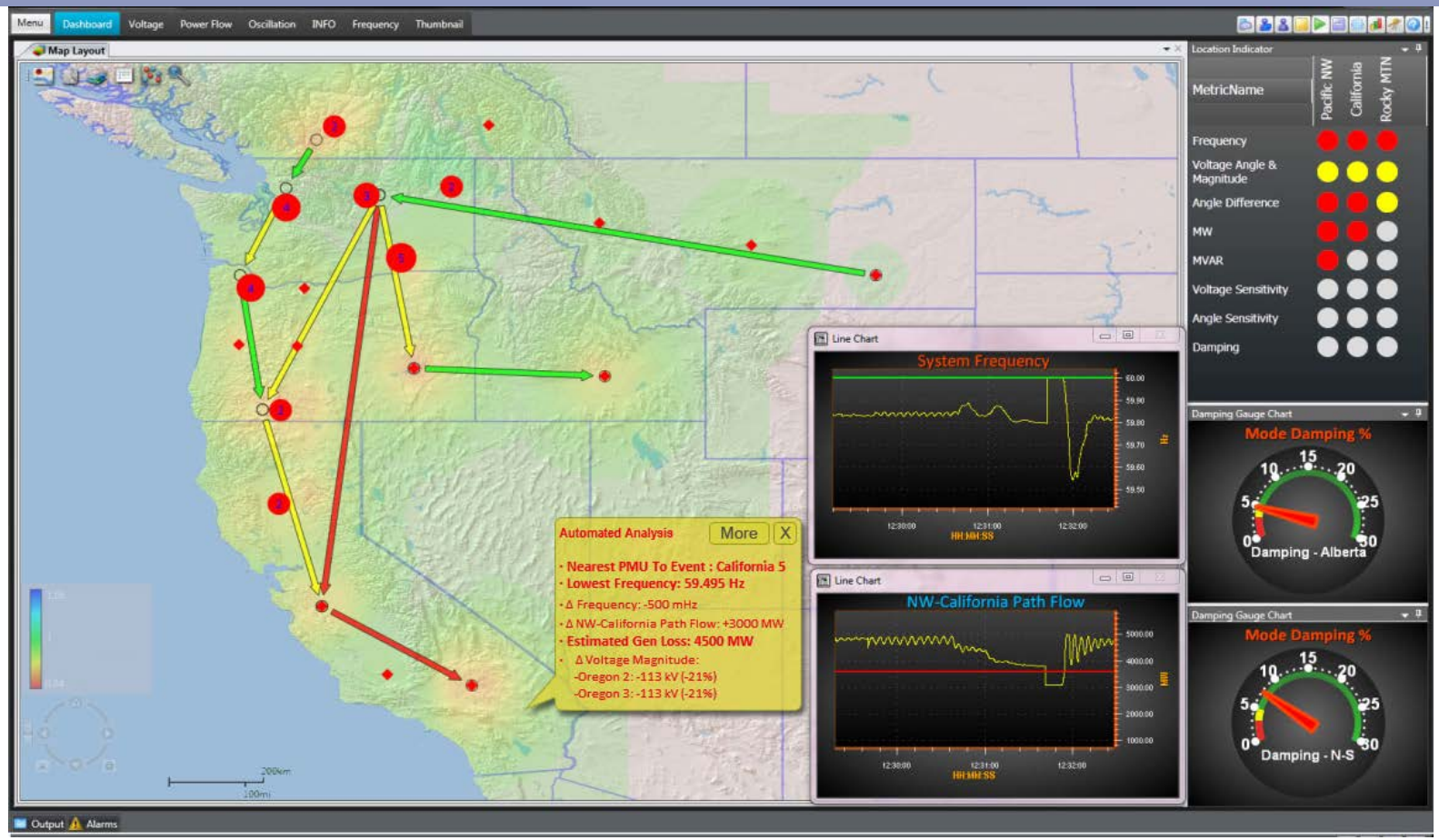
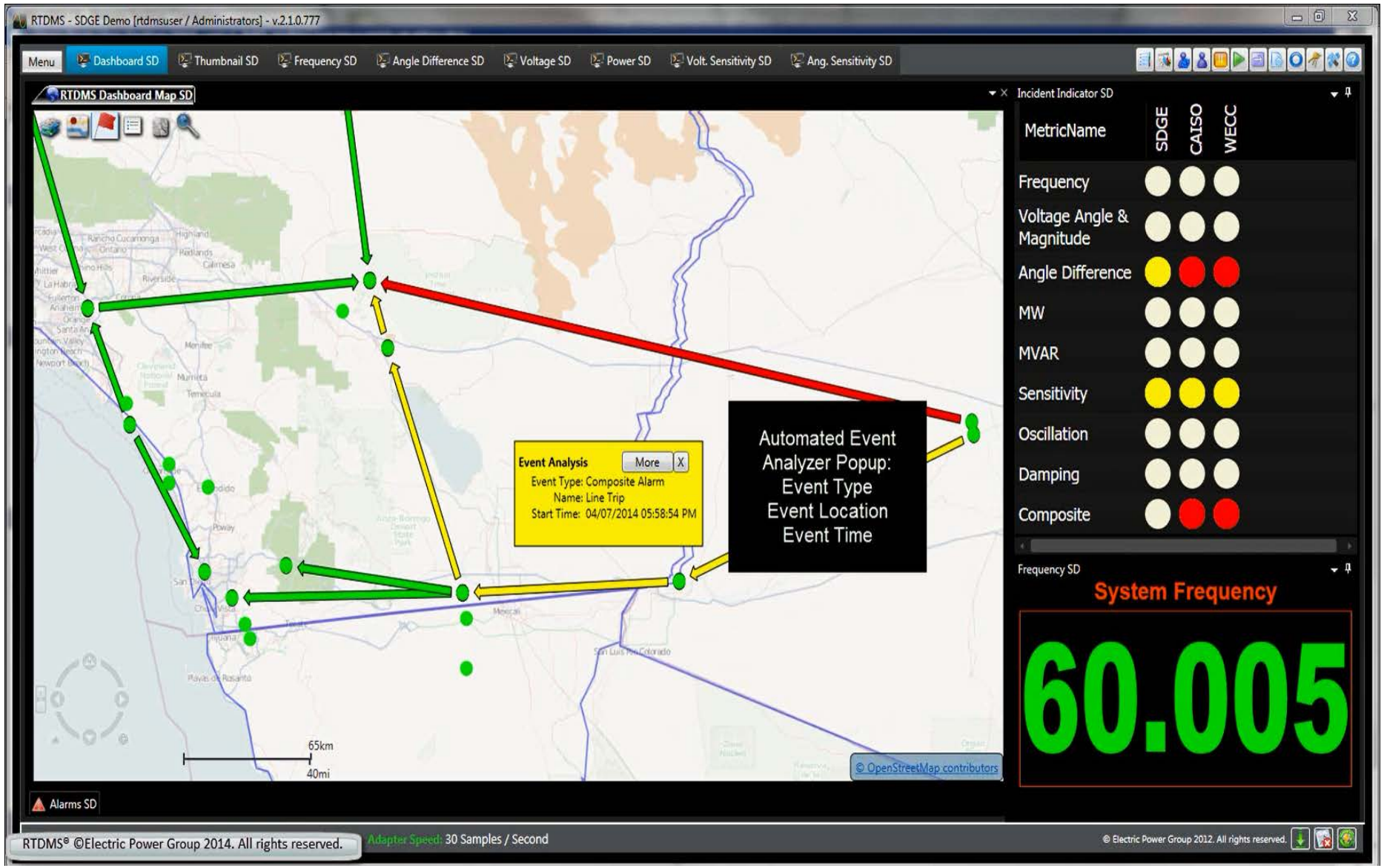
Automated Event Analyzer



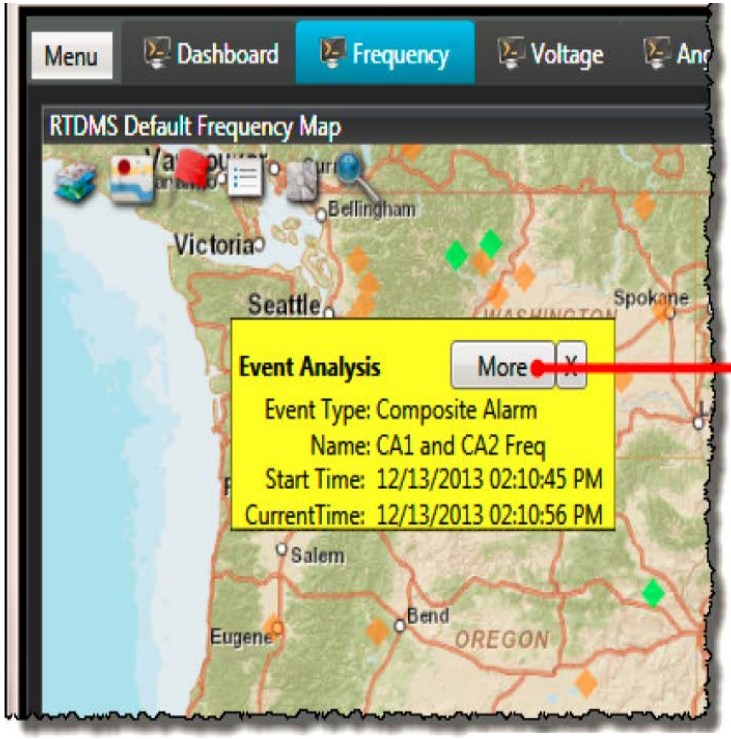
- Performs incident detection, incident classification, and incident location estimation
- Including oscillation, islanding, generation trip, load shedding events
- Summary of event facts to operators via ‘Yellow pop ups’
- Ability to bring up detailed diagnostics and the relevant metrics to operators at a glance

Example – Line Trip Detection



Example – Line Trip Detection

How to use event analyzer



Click More button to explore signal data from event.

Click to go to beginning of time frame.

Shows start time of the event.

Click arrow buttons or drag scroll bar to view data at different times during event.

Shows end time of the event.

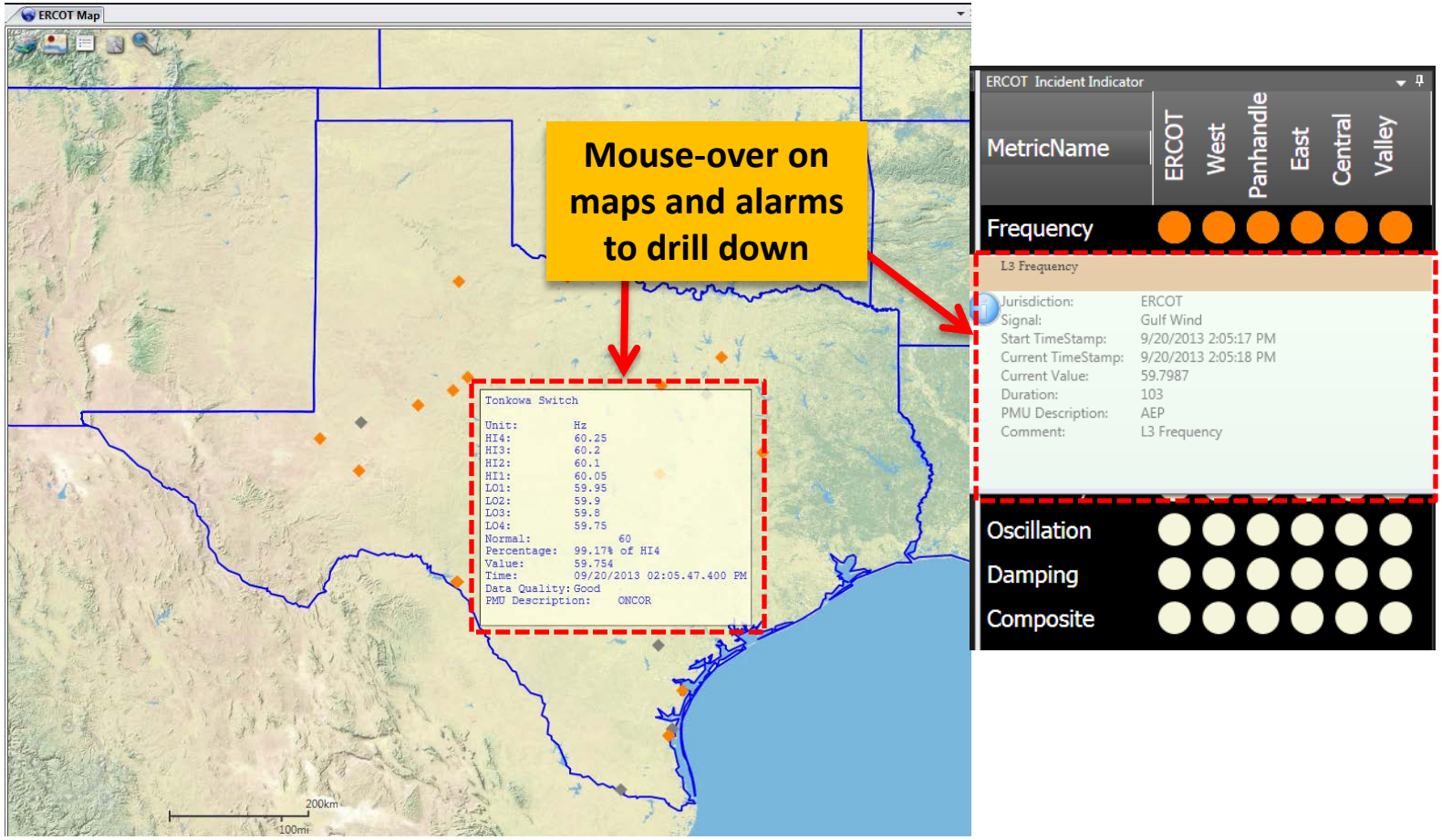
Click to go to end of time frame.

Alarms and Event: Hands-on Tutorial

- **Monitor alarms in RTDMS Visualization Client**
  - Incident Indicator: monitor, mouse-over function, double click function
  - Alarm Grid: monitor, ad hoc trending, filter, group

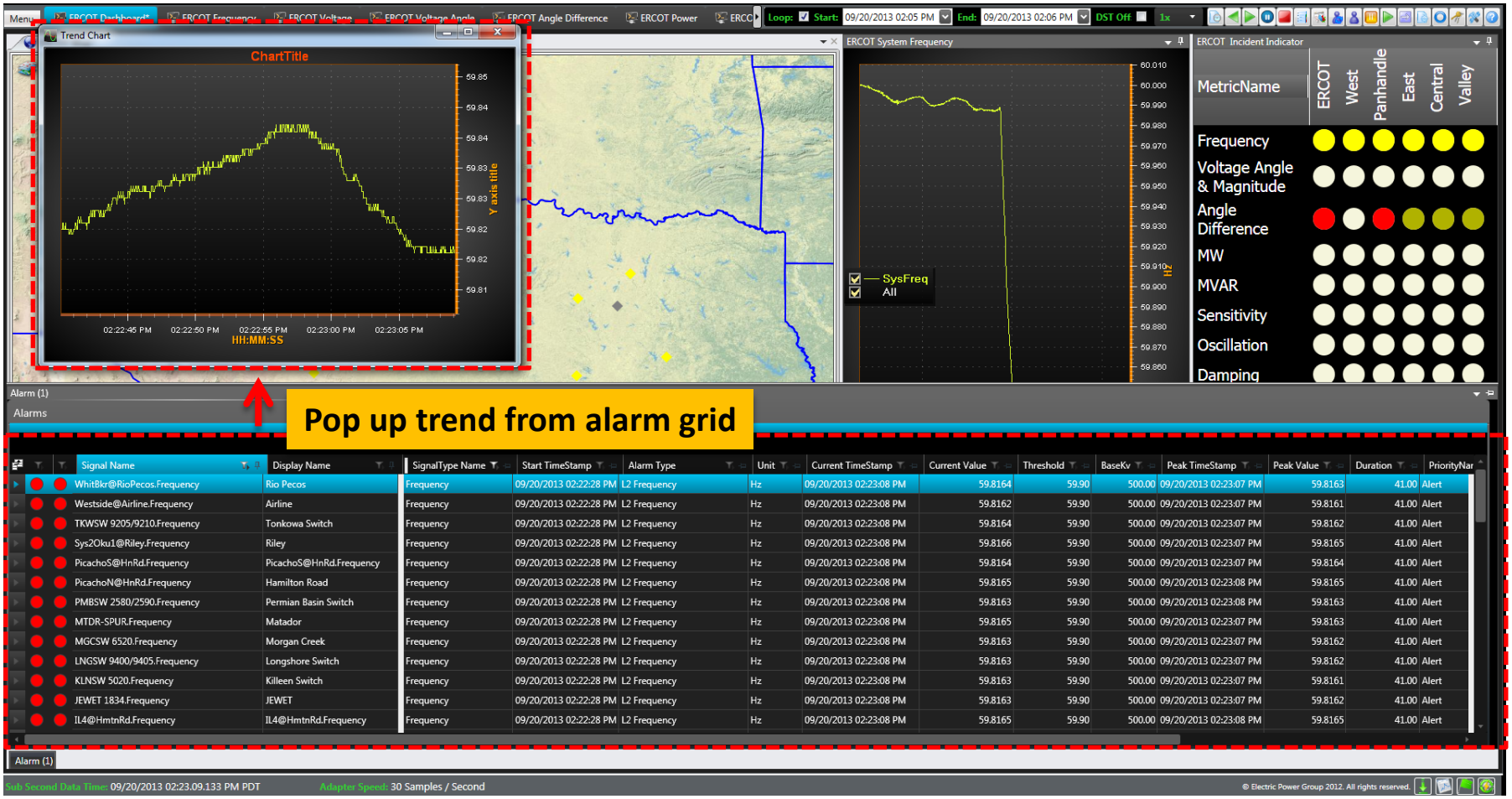
- **Event marker**
  - Mark an event; replay marked event

Recap – Monitor Alarms



- Pinpoint location of problem
- Drill down to detailed information

Recap – Pop Up Trend Chart from Alarm Grid



RTDMS Advanced Monitoring

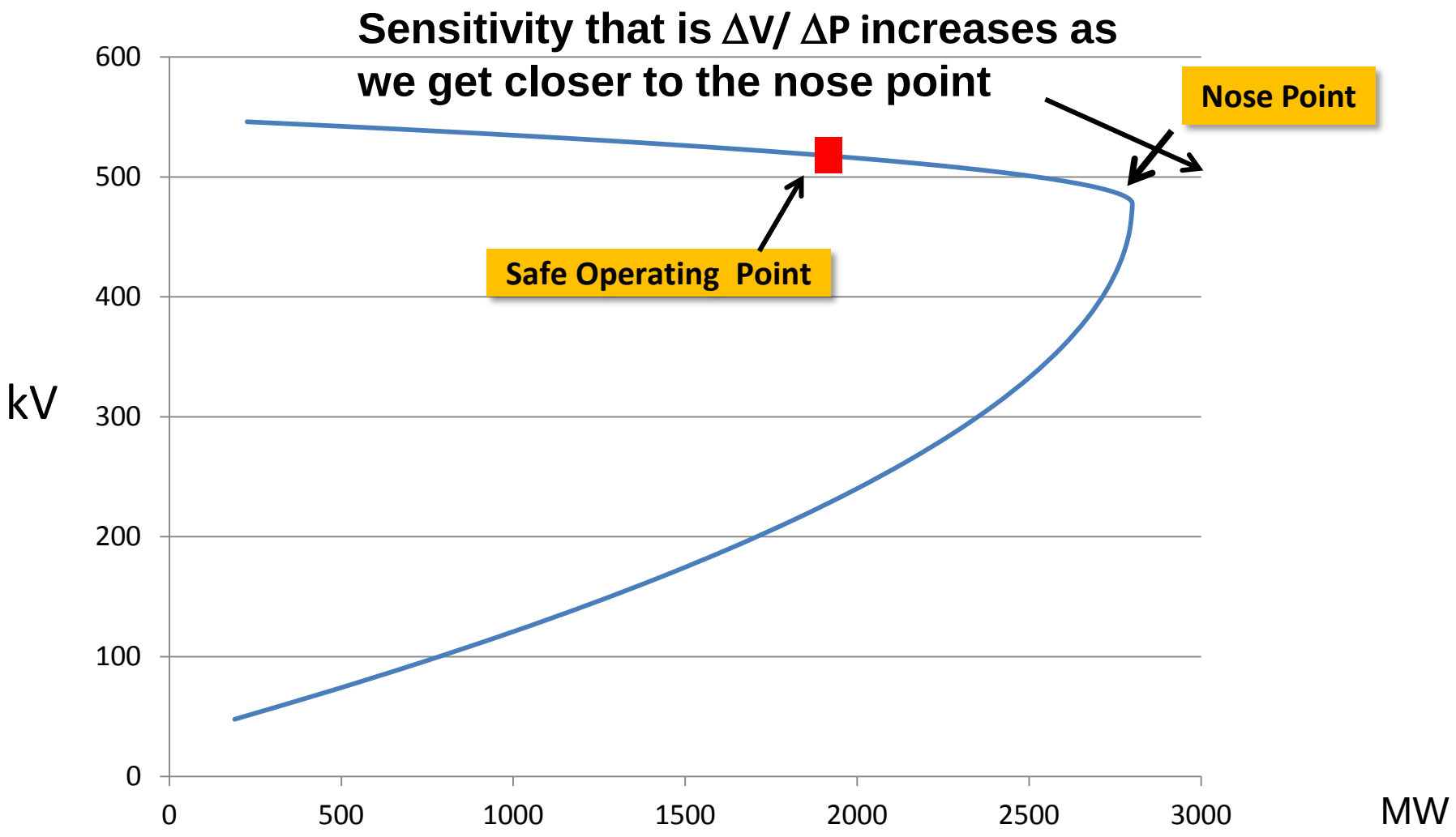
Advanced monitoring

- **What will be covered:**
  - Voltage sensitivity and angle sensitivity
  - Mode meter oscillation monitoring
  - Composite alarms
  - Automated event analyzer

Voltage Sensitivity in RTDMS

Definition	Change in voltage as a function of power flow on a line / path
Metric	kV/100 MW change Suggested Limit – 4kV/100 MW for 500kV system
Benefit	Early warning of deteriorating voltage condition
Metric Value	Sensitivity increases as system approaches the Nose Point
	Sensitivity increases if an adjacent line/path trips

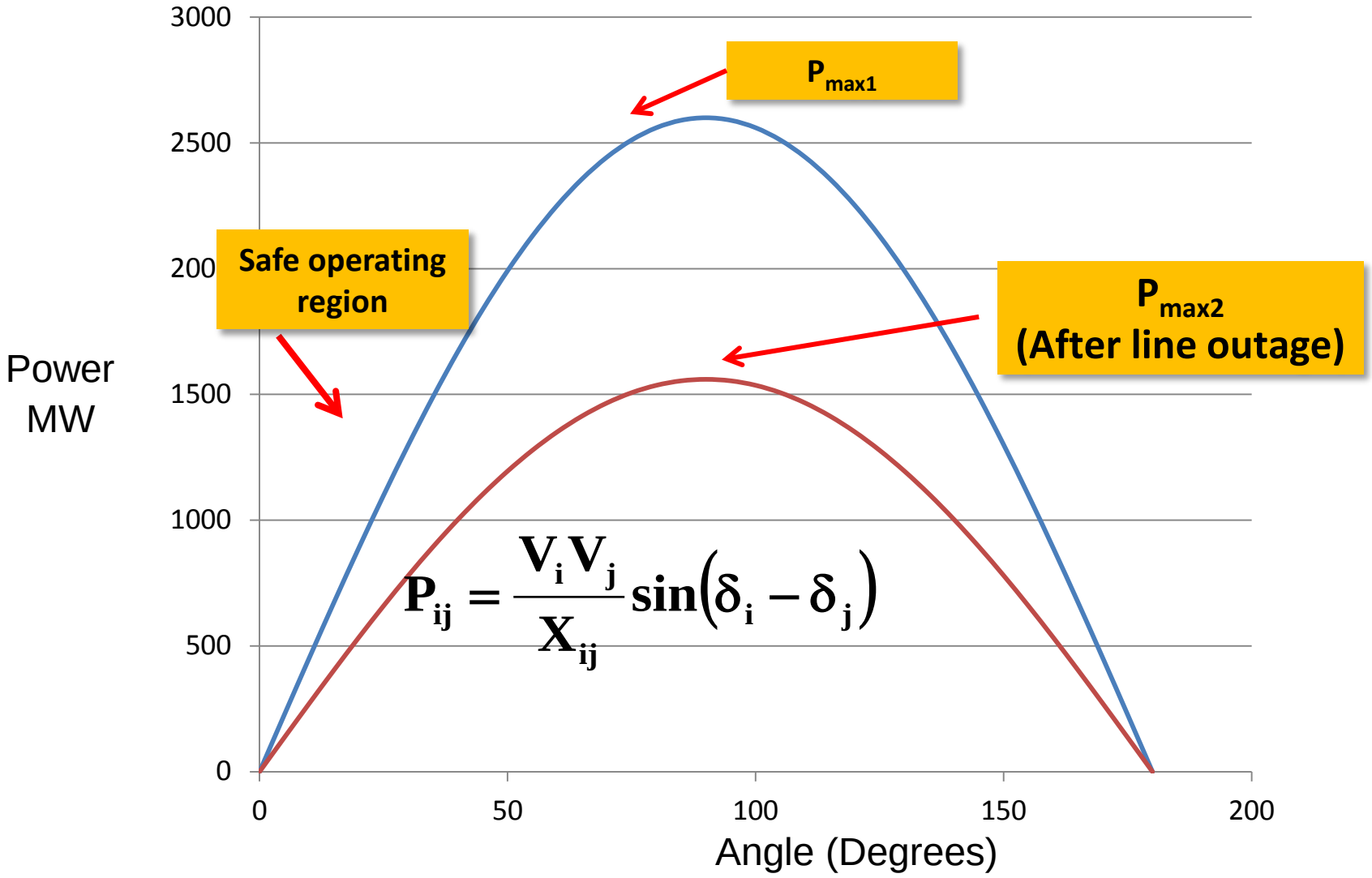
A Typical Power/Voltage Curve



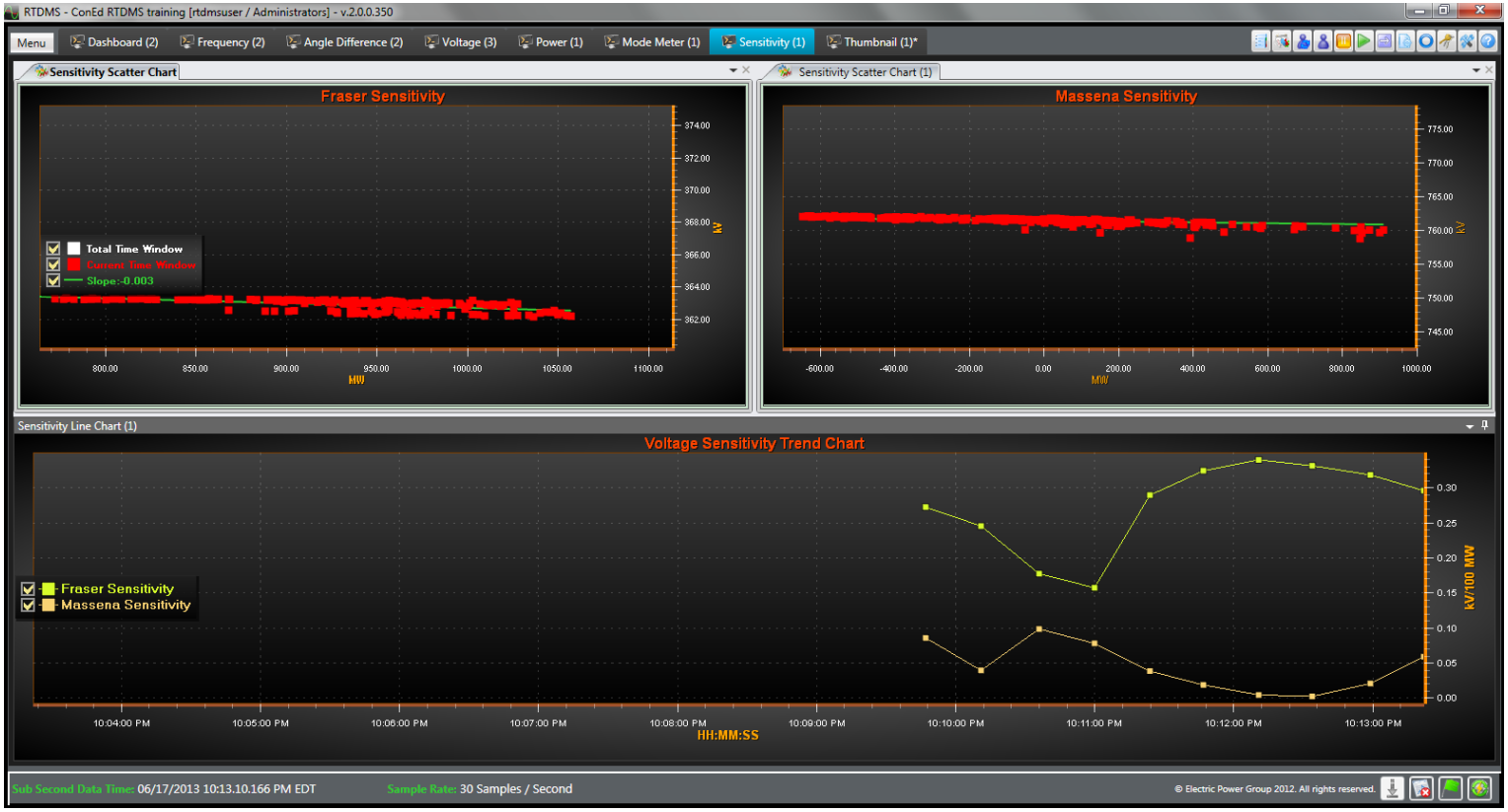
Angle Sensitivity in RTDMS

Definition	Change in angle as a function of power flow on a line / path
Metric	Degrees/100 MW change Suggested Limit – 2.5 Degrees/100 MW
Benefit	Early warning of deteriorating angle stability
Metric Value	Sensitivity increase as we approach the P MAX – maximum power that can be transmitted
	Sensitivity increases if an adjacent line / path trips

Power – Angle Curve & Sensitivity



Voltage Sensitivity Monitoring



- Monitor Voltage Stability at the desired PMU w.r.t changes in power flow on a Path
- Provide operators real-time assessment of the Power Voltage curve and a calculation of change in voltage per 100 MW in power flow
- Calculate linear fit to determine sensitivity value from slope

Monitoring Modal Oscillations in Power Systems

- What are system oscillations in power systems?
- Why is monitoring oscillations important?
- What is good damping, and why is it important to monitor?
- Ambient and disturbance induced transient oscillations
- What are the oscillation frequencies and what causes the oscillations to occur?
- What can happen if the damping reduces or becomes negative and oscillations start to increase?

Monitoring Modal Oscillations in Power Systems

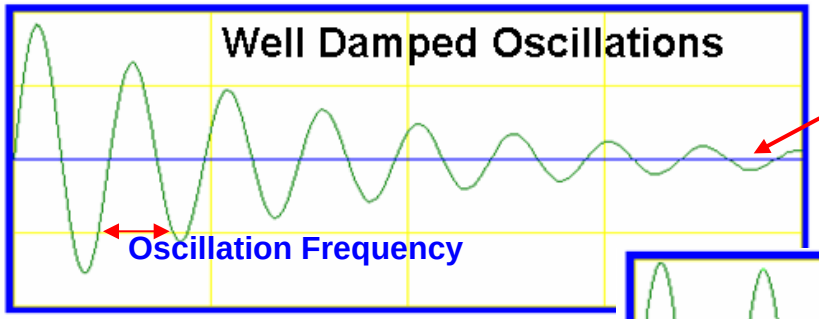
- The components of a complex power system are always oscillating with respect to each other
- Under normal conditions, the system oscillations are at low level, damped and controlled. These are known as ambient oscillations
- Oscillations can be induced by faults or other disturbances in the system. These have high power transfers and high energy, but generally damp fast
- Oscillations can be observed in power flows, frequencies or angles of the oscillating systems
- Oscillations, if not damped, lead to instability and system collapse , e.g., 1996 WECC break-up

Characterizing Oscillations
Frequency and Damping

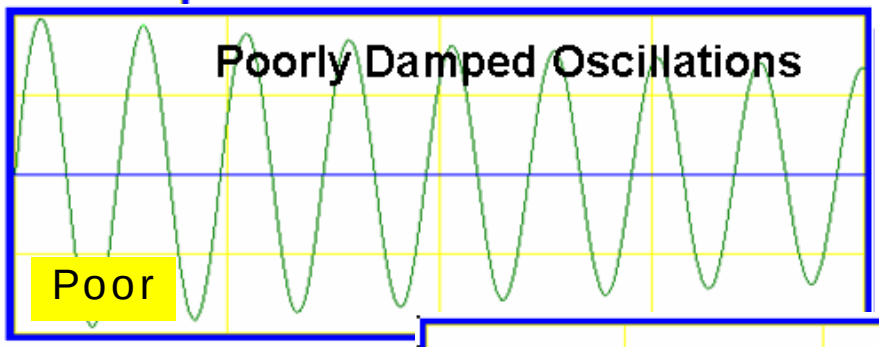
Oscillatory Frequency & Damping Interpretation

Desirable Condition

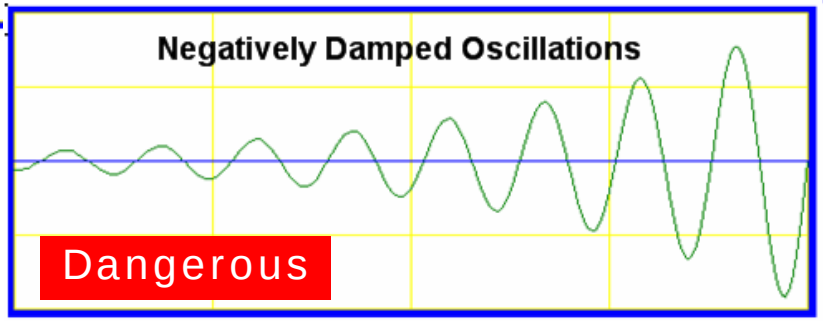
Desirable: 10% Damping ⇒ 30 sec decay time; 5% Damping ⇒ Decay in 60 sec



Poor: Less than 3%



Dangerous- Growing oscillations

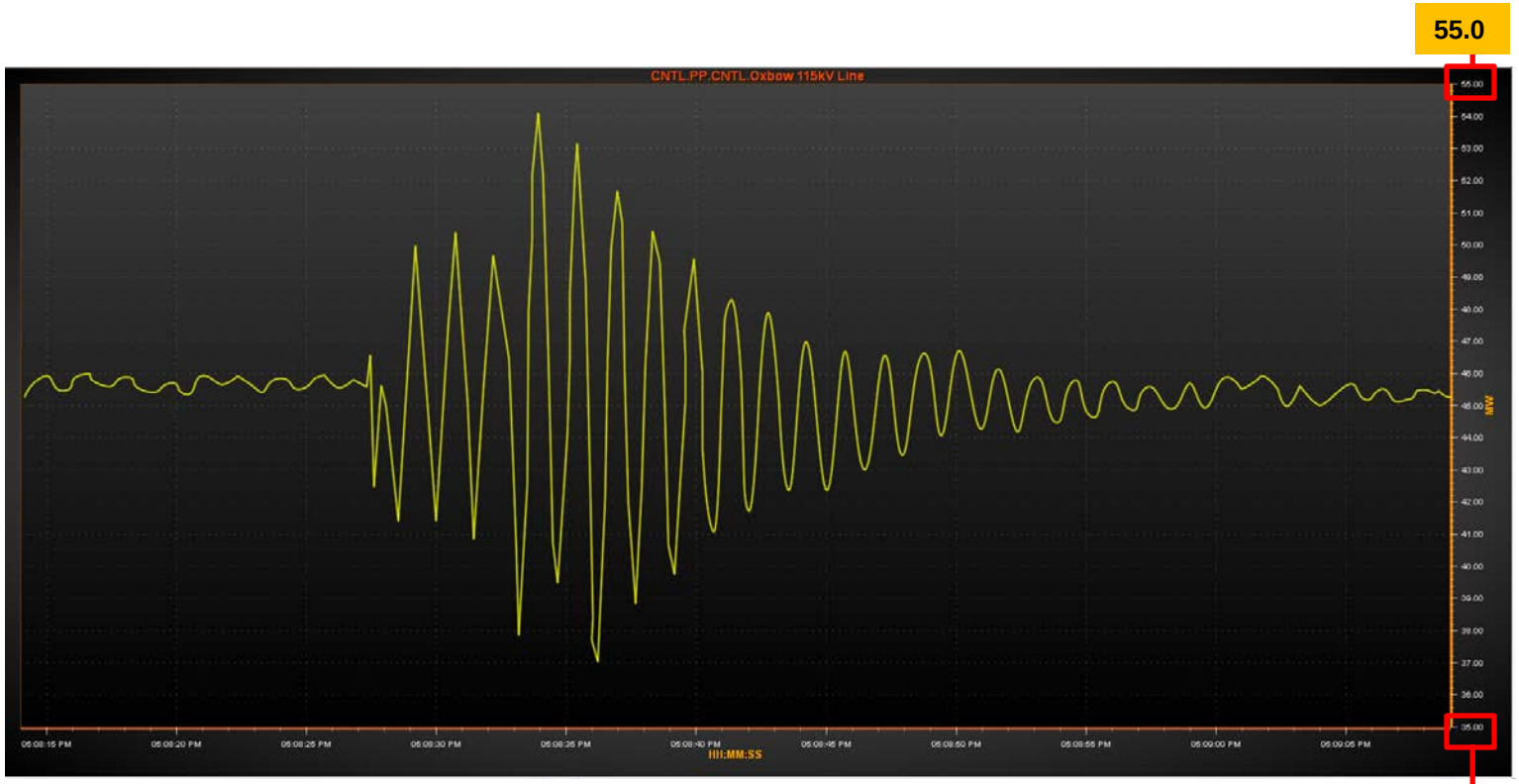


Higher Damping ⇔ Greater Dynamic Stability (i.e., Desirable Situation)

Oscillations Event Example:

CAISO Radially Connected Geothermal Generator Oscillation

Frequency	Diagnosis	Action
0.8 Hz	Poorly tuned generator governor controller	Advise generator owner to tune governor controller



Screenshot of RTDMS – Real Time Dynamics Monitoring System

Oscillations Event Example:

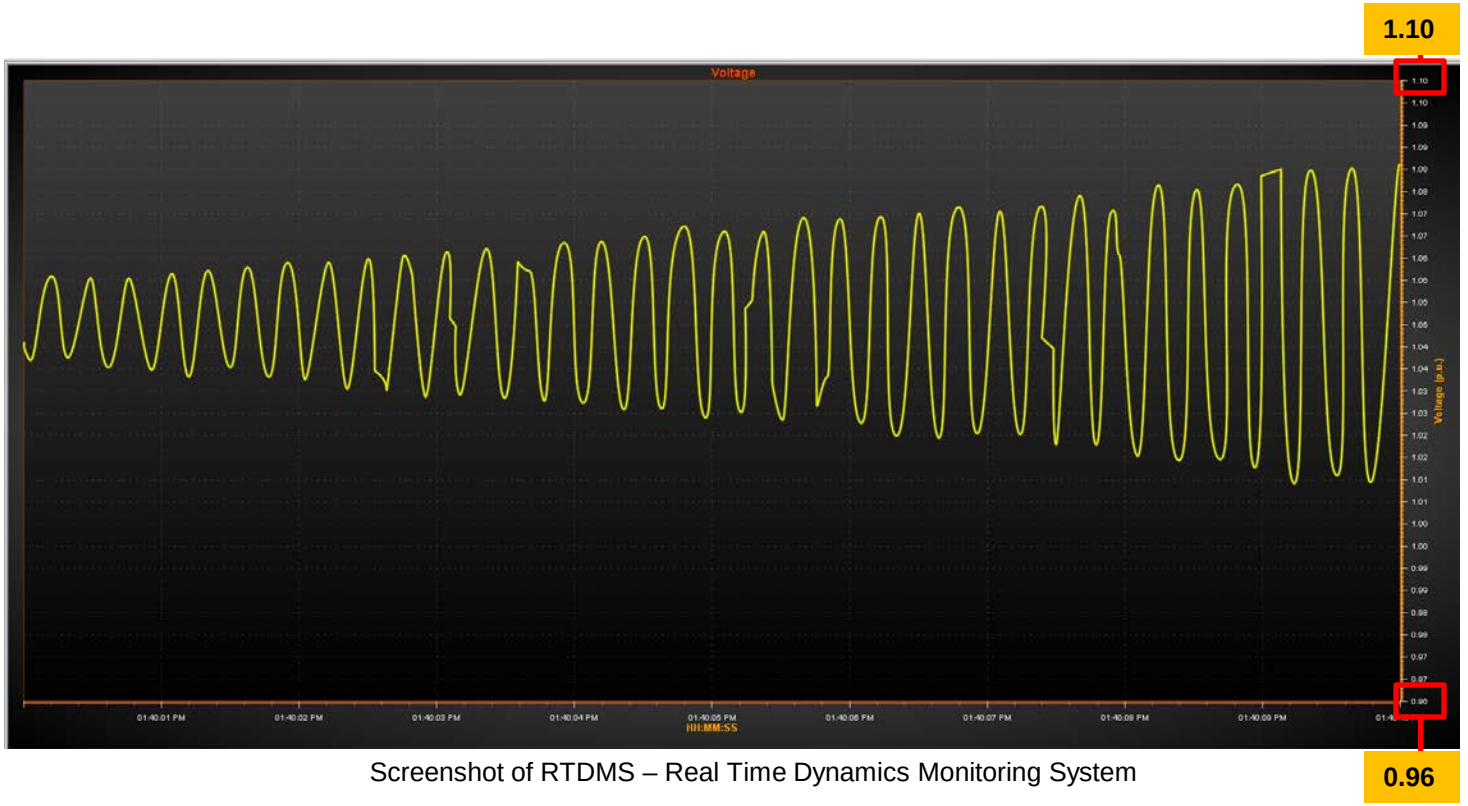
ERCOT Wind Generator Oscillation

Frequency	Diagnosis	Action
2.0 Hz	Improper voltage controller setting	Identify generation causing oscillations, advise to adjust regulator settings

Screenshot of RTDMS – Real Time Dynamics Monitoring System

Oscillations Event Example:
ERCOT Wind Generator Trip

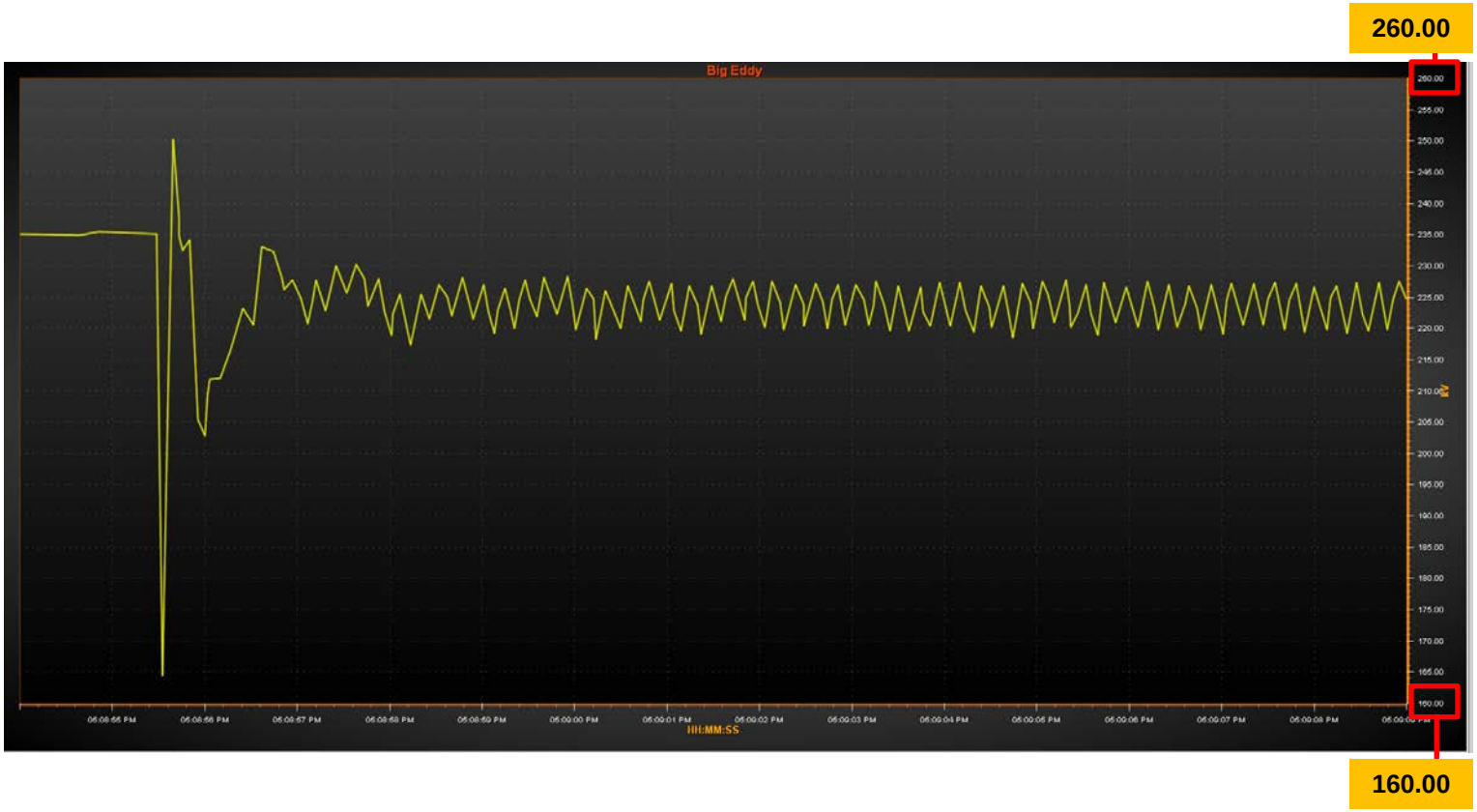
Frequency	Diagnosis	Action
3.7 Hz	Improper voltage controller setting caused undamped oscillations and generation tripping following parallel line maintenance outage	Identify generation causing oscillations, advise to adjust regulator settings



Screenshot of RTDMS – Real Time Dynamics Monitoring System

Oscillations Event Example:
WECC PDCI Oscillations 2008

Frequency	Diagnosis	Action
4.6 Hz	Inadequate voltage support for DC Line power order setting	Reduce DC Line power order setting

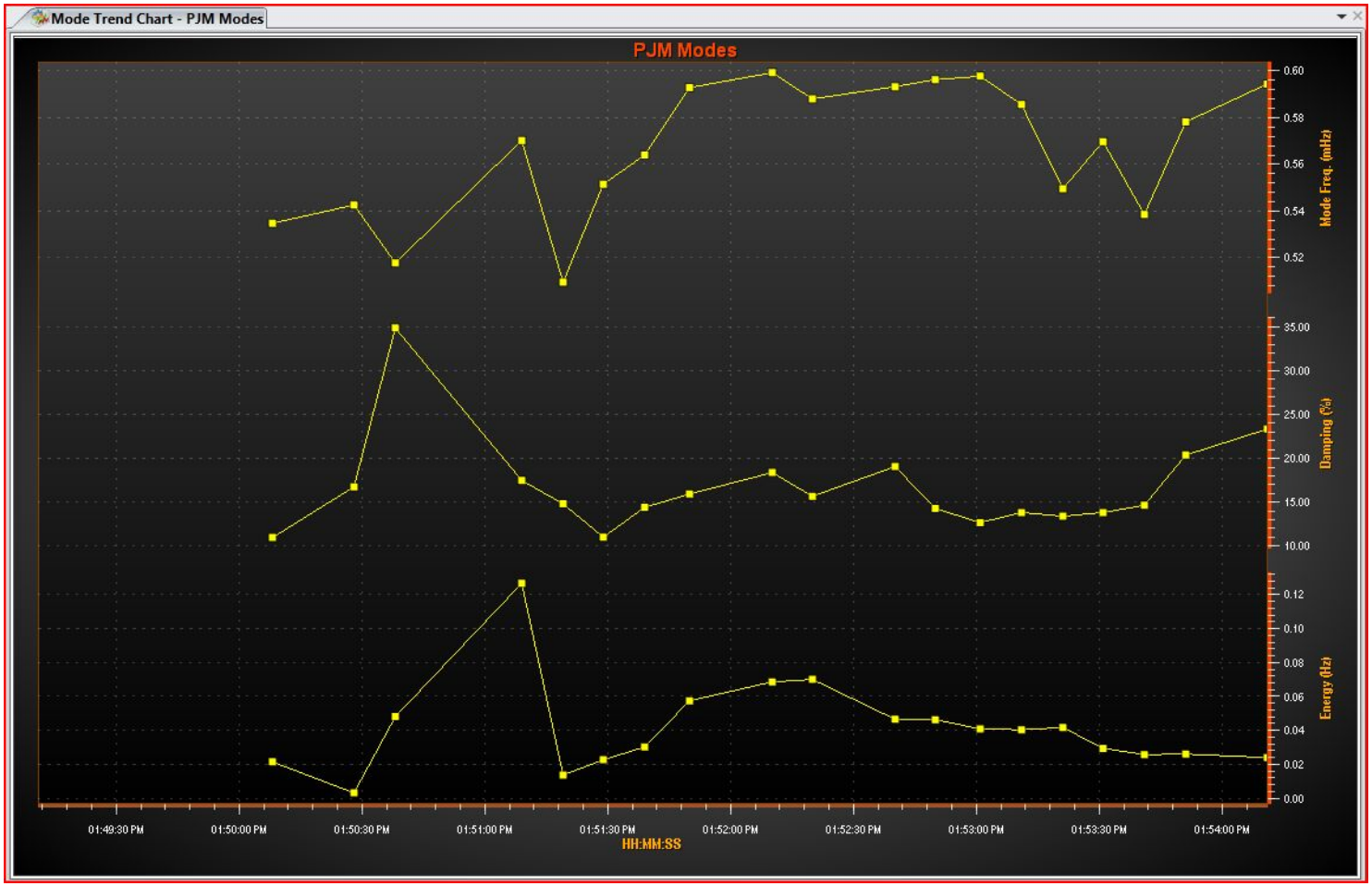


Screenshot of RTDMS – Real Time Dynamics Monitoring System

Oscillation Stability Analysis & Monitoring

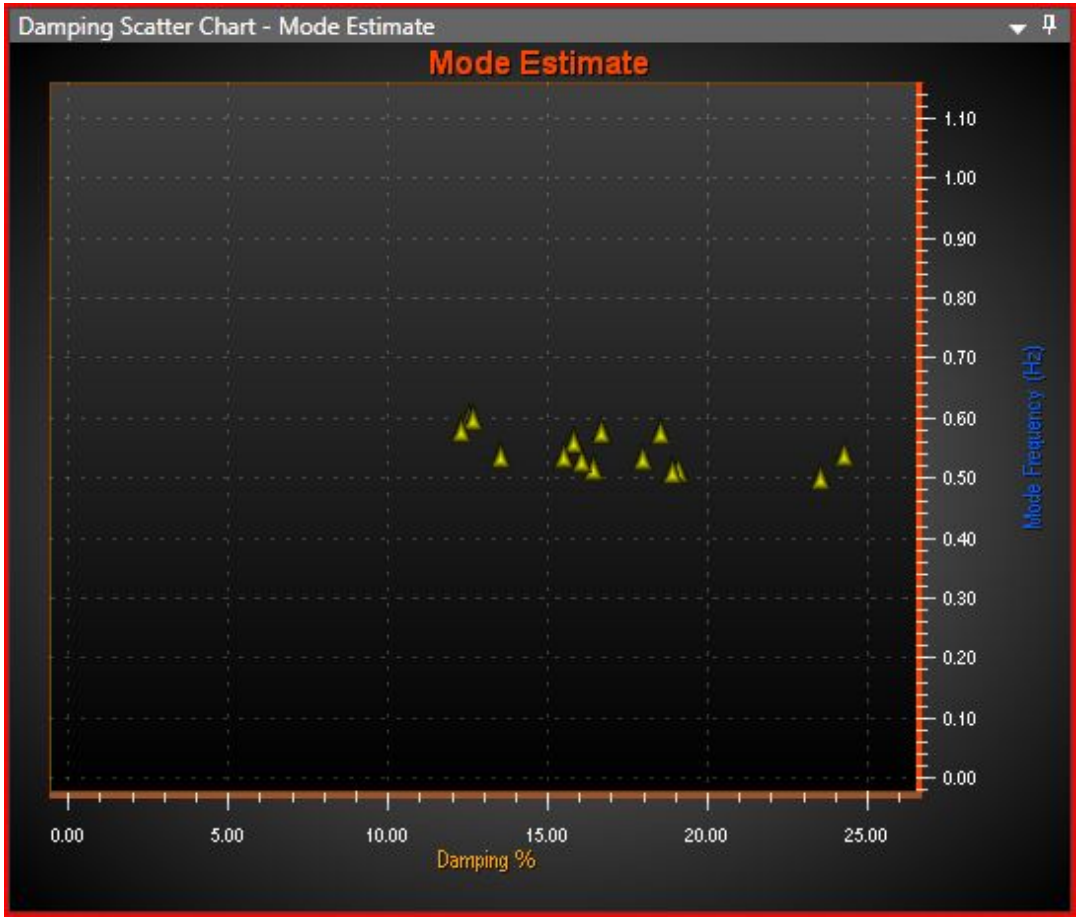
- Detects oscillations of interest based on event analysis and system characteristics in each interconnection
- Monitors modal frequency, energy, damping, mode shape in real-time

Mode Meter Trend Chart



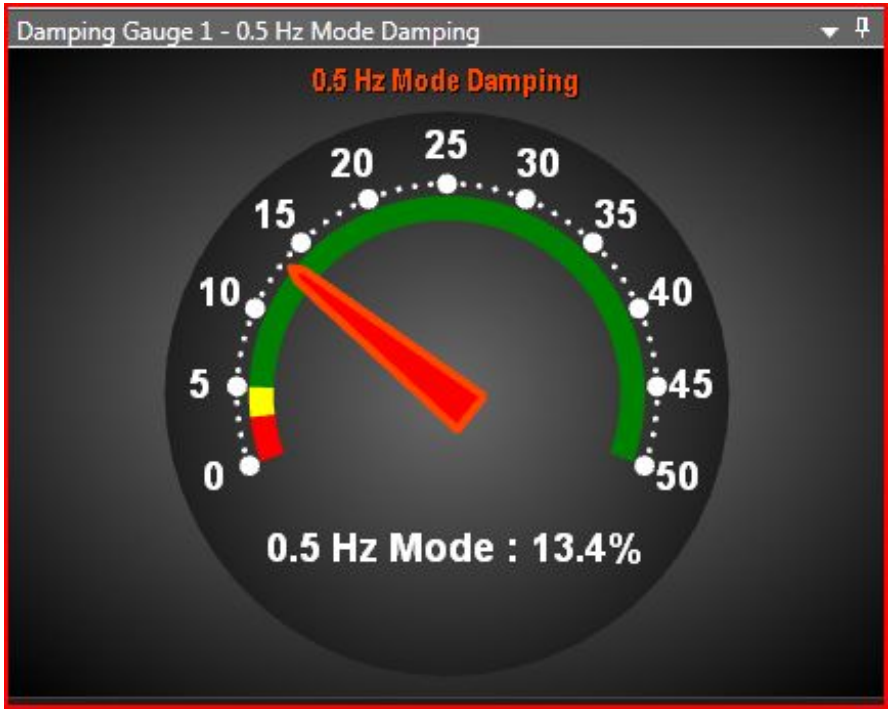
- Displays the oscillation frequency of the dominant mode in the system
- Displays damping of the obtained modal frequency
- Displays estimated energy in the modal frequency

Scatter Chart
Mode and Damping



- This chart tracks the value of modal frequency and damping for the most recent and historical data
- This chart enables to observe the trend of different modes over a period of time.

Gauge View
Mode and Damping

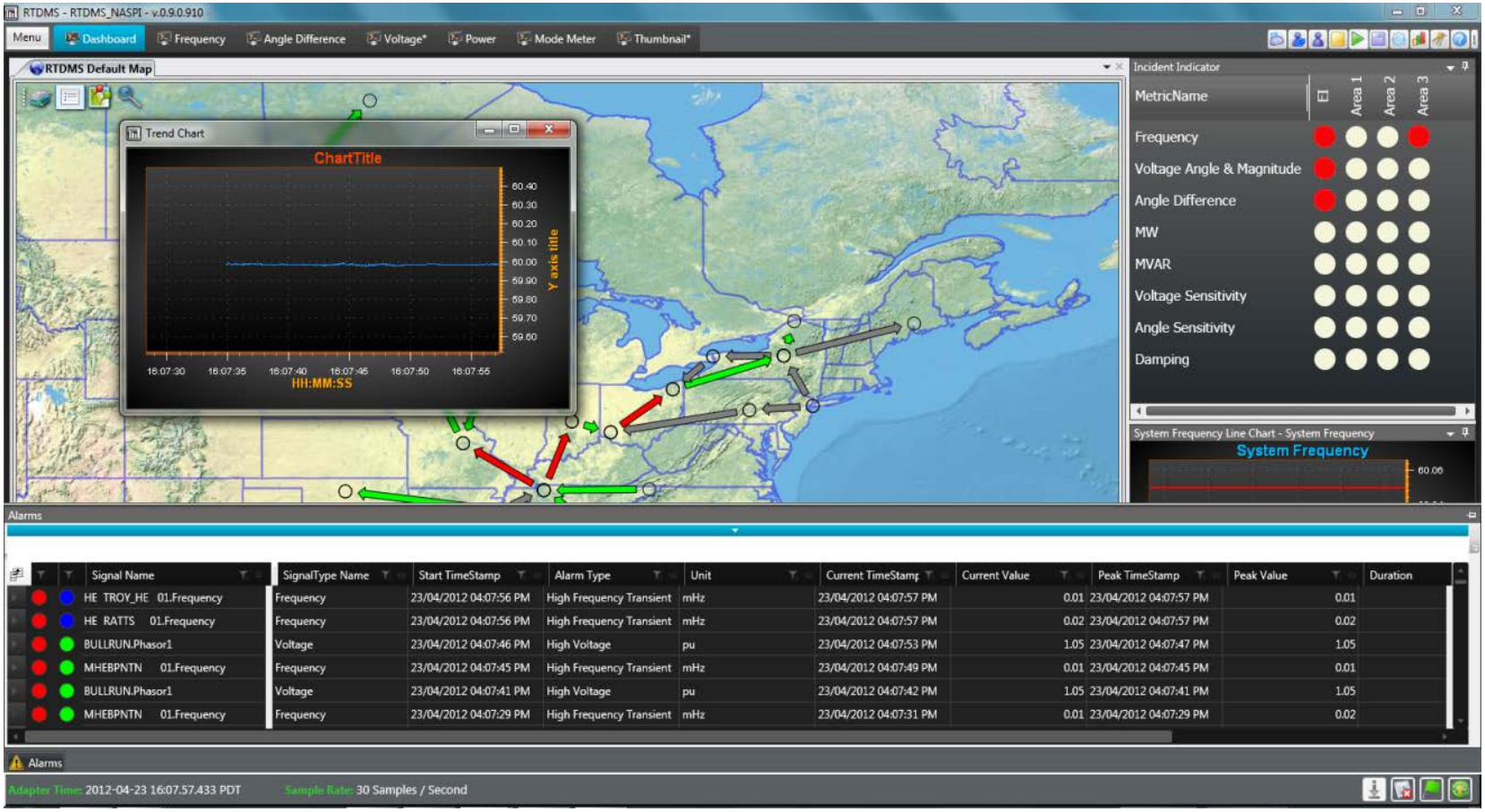


- **Damping Gauge View provides a real time gauge indication of damping percentage for user selected modes.**
- **A damping less than 3% is generally considered too low as indicated by the red band, while a damping in 3-5% range is considered moderately low as indicated by the yellow band**

Advanced Monitoring
Hands-on Tutorial

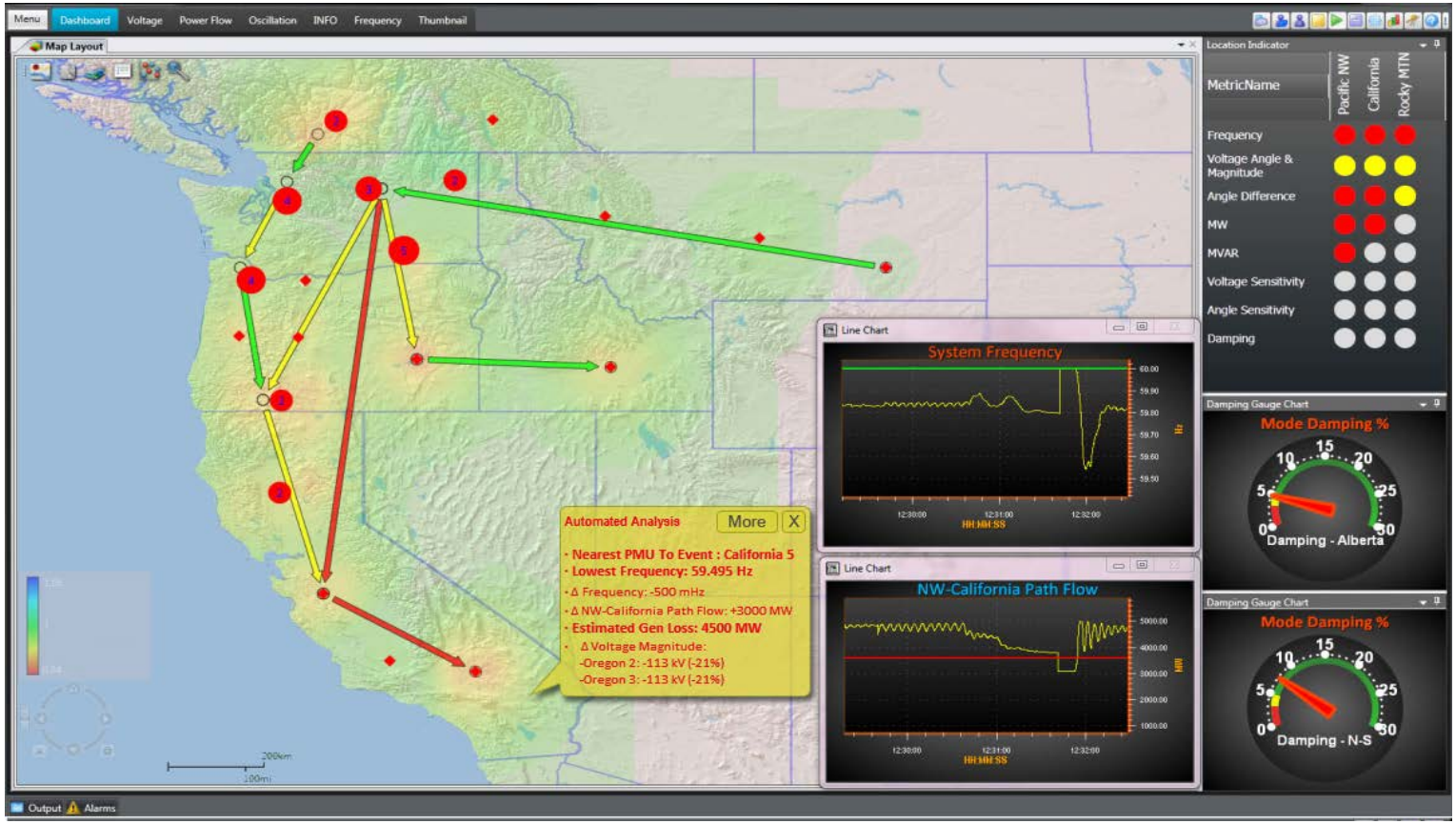
- Use Mode Meter Damping Trend Chart
- Use Mode Meter Damping Gauge

Composite Alarms



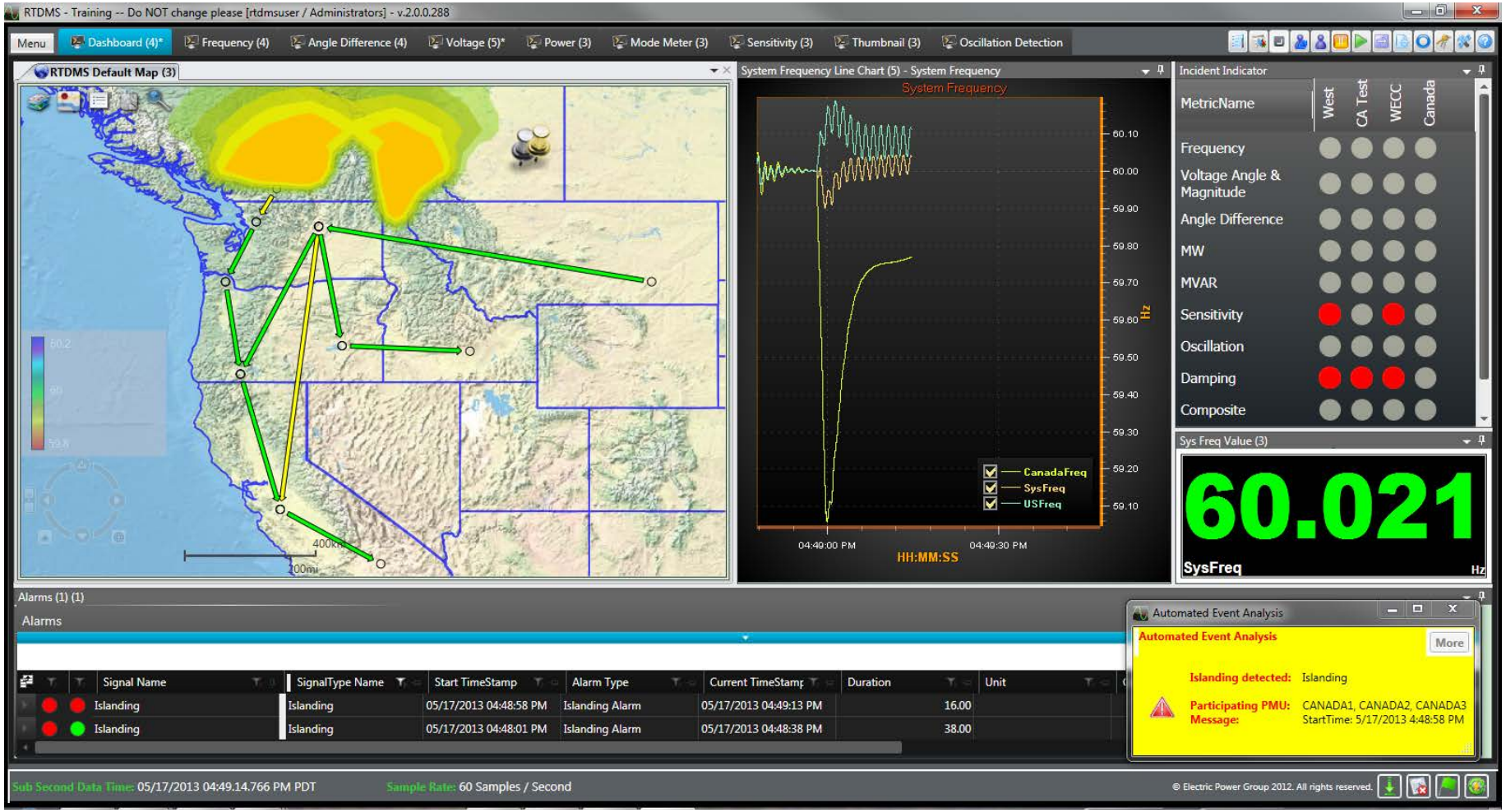
- **User-defined composite alarms (logical combination of multiple conditions)**
- **Integration of external alarms**
- **Alarm logs & events are recorded into event files for offline analysis**

Automated Event Analyzer

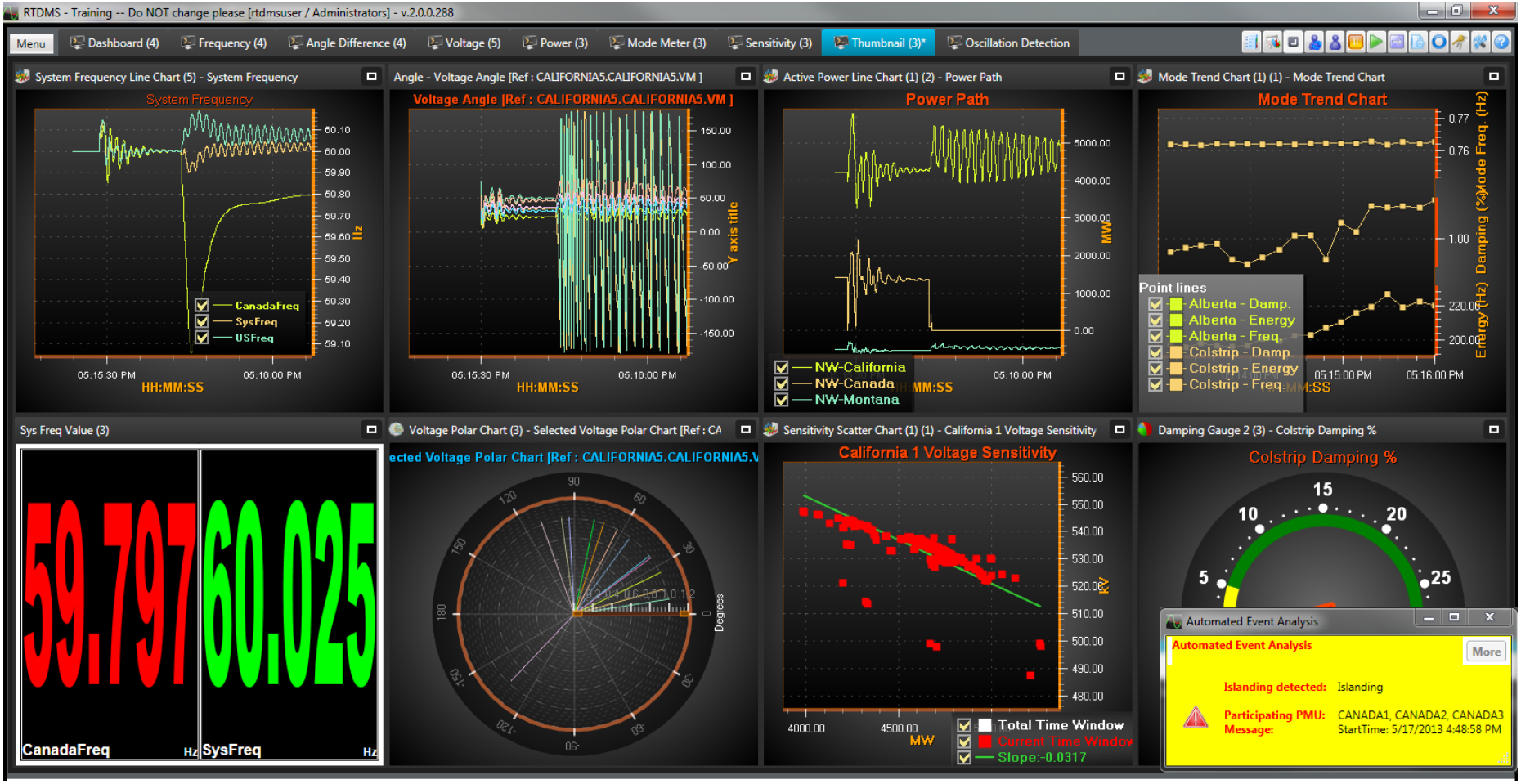


- Performs incident detection, incident classification, and incident location estimation in real-time
- Including islanding, generation trip, load shedding, and line outage events
- Summary of event facts to operators via 'Yellow pop ups'
- Ability to bring up detailed diagnostics and the relevant metrics to operators at a glance

Example: Islanding Detection



Example: Islanding Detection



Alarms and Events

RTDMS Server Alarm/Event

- **Value violates threshold – Alarm**
  - Individual **threshold** for different PMUs and levels/severity
  - Individual **time window** for different PMUs and levels/severity
  - General ignorable gap for all alarms

- **Rate of change violates threshold – Event**
  - Individual **rate of change threshold** for different PMU
  - Individual **time window** for different PMUs
  - General ignorable gap for all events

- **Event also Known as Transient Event**

Alarm/Event Matrices and Severity Types

	Metric	Low Low	Low	High	High High	Time window
Threshold Violation Alarms	Frequency	√	√	√	√	√
	Voltage (Magnitude)	√	√	√	√	√
	Current (Magnitude)	√	√	√	√	√
	Angle Difference	√	√	√	√	√
	Active Power	√	√	√	√	√
	Reactive Power	√	√	√	√	√
	Damping	√	√			
	Voltage Sensitivity (Magnitude and Angle)	√	√	√	√	√

	Metric	Rate of change threshold	Time window
Transient "Event" Alarms	Frequency	√	√
	Voltage (Magnitude)	√	√
	Angle Difference	√	√

Example: Frequency Alarm Configuration

- **Threshold Violation Alarm threshold**
  - Low 2 [59.90 Hz]
  - Low 1 [59.95 Hz]
  - Normal [60.00 Hz]
  - High 1 [60.05 Hz]
  - High 2 [60.10 Hz]
- **Threshold Alarm duration – Avoid too many alarms**
  - Default: 2 seconds
- **Ignorable Gaps – Avoid alarm fragmentation**
  - Default: 1 second

Frequency Event Configuration Example

- **Event Threshold**
  - Frequency rate of change: 40.00 mHz/sec
- **Event Duration (Time Window) – Avoid too many event**
  - Minimum: 2 seconds
- **Ignorable Gaps – Avoid event fragmentation**
  - Default: 1 second

RTDMS and PGDA User Training

Day 2

Hands-on Guided Training Exercises
Case Studies of ERCOT Interconnection

RTDMS and PGDA User Training

Day 2

Case Study # 5

Analysis of An Event

Presented By

Wayne Schmus

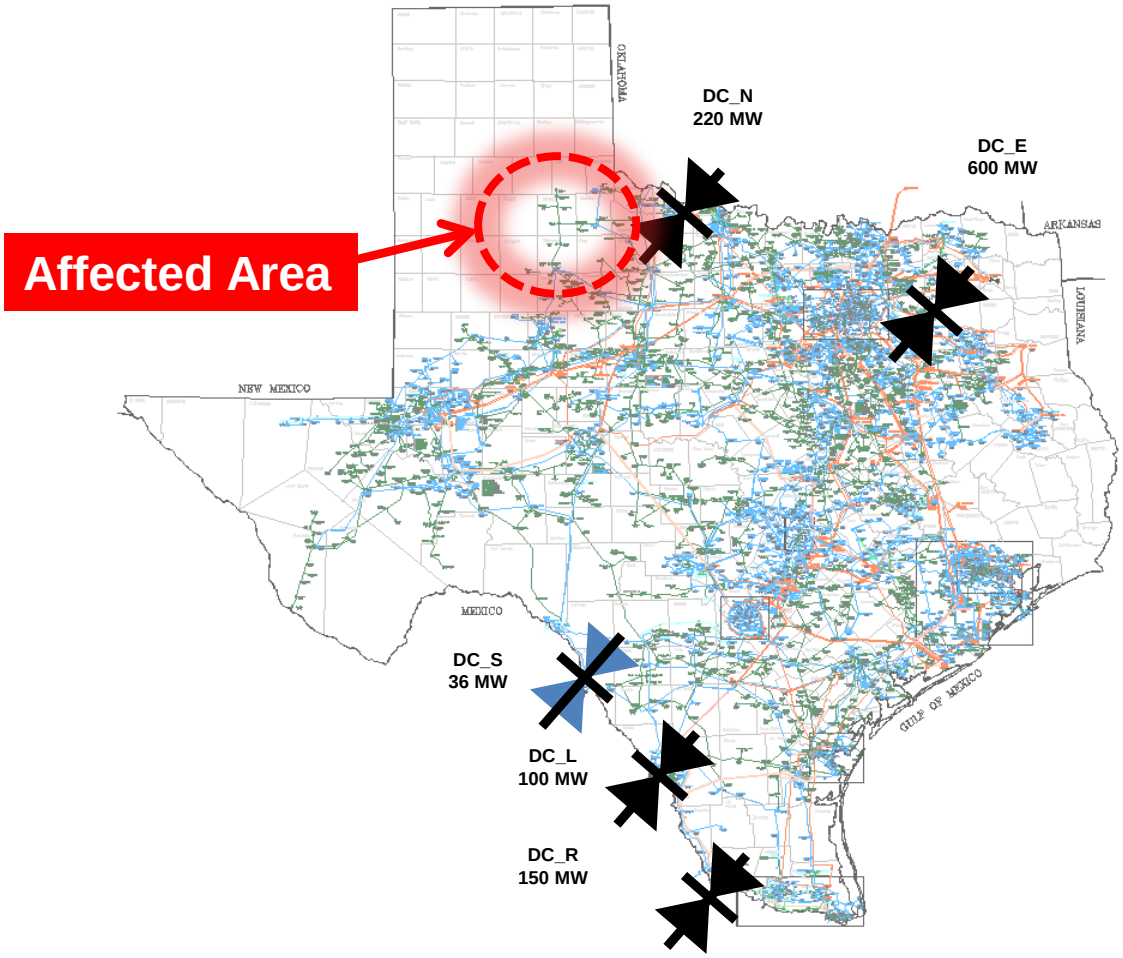
Prashant Palayam

Electric Power Group

Event Analysis

- **August 2013: Wind Farm oscillation**
  - Power Point Presentation Summary
  - RTDMS Demo

ERCOT Transmission Network

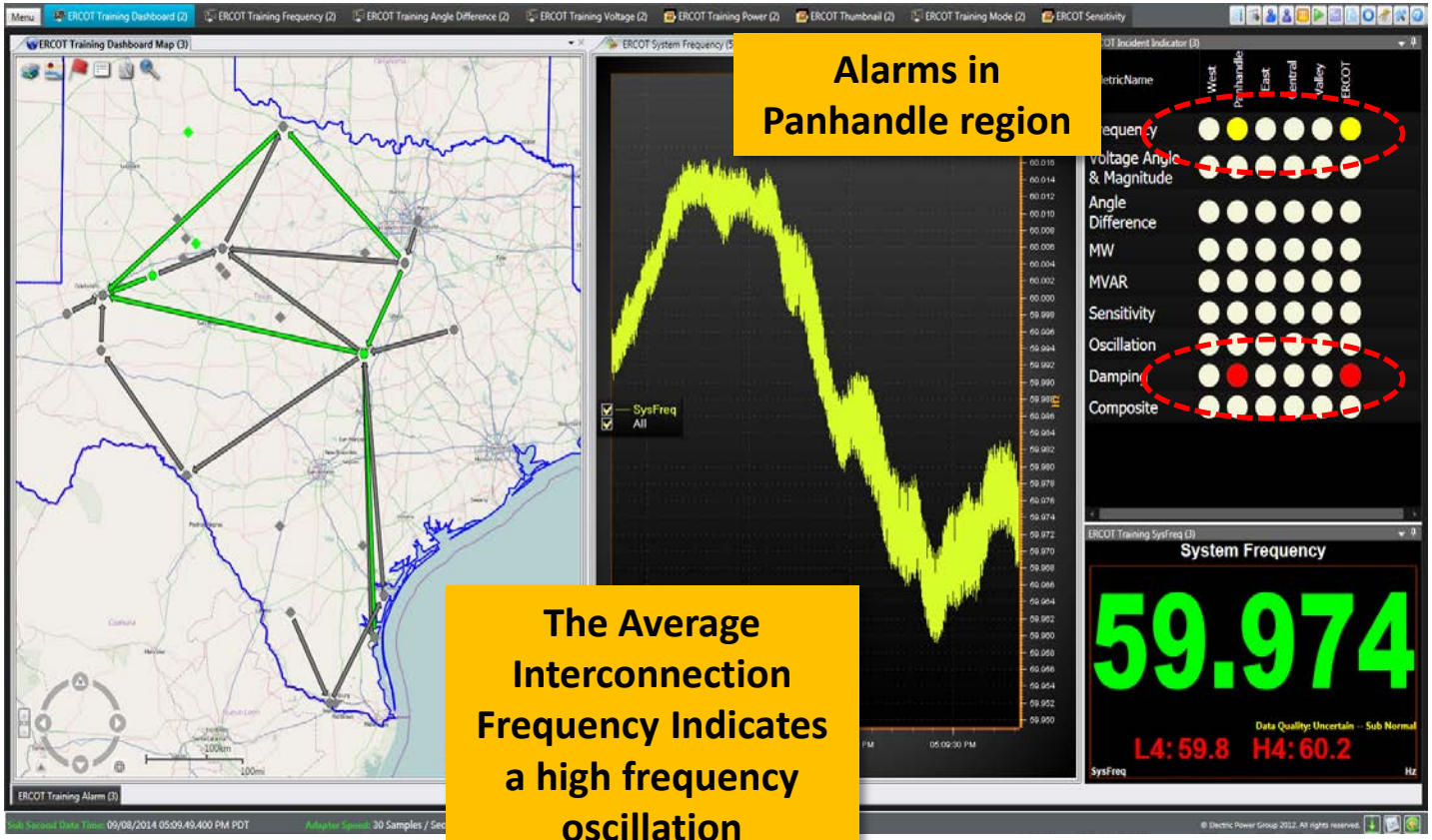


Monitoring, Event Detection and Diagnose with RTDMS

Monitoring, event detection and post event analysis with RTDMS are accomplished by carrying out the following process:

1. **Situational Awareness Dashboard (Real-Time Wide Area Monitoring)**
2. **Detect Emerging Problem**
3. **Diagnose the Situation**
4. **Assess System Vulnerability**
5. **Event Summary**

Problem Detected: Interconnection Frequency



1. Situational Awareness Dashboard (Real-Time Wide Area Monitoring)
2. Detect Emerging Problem
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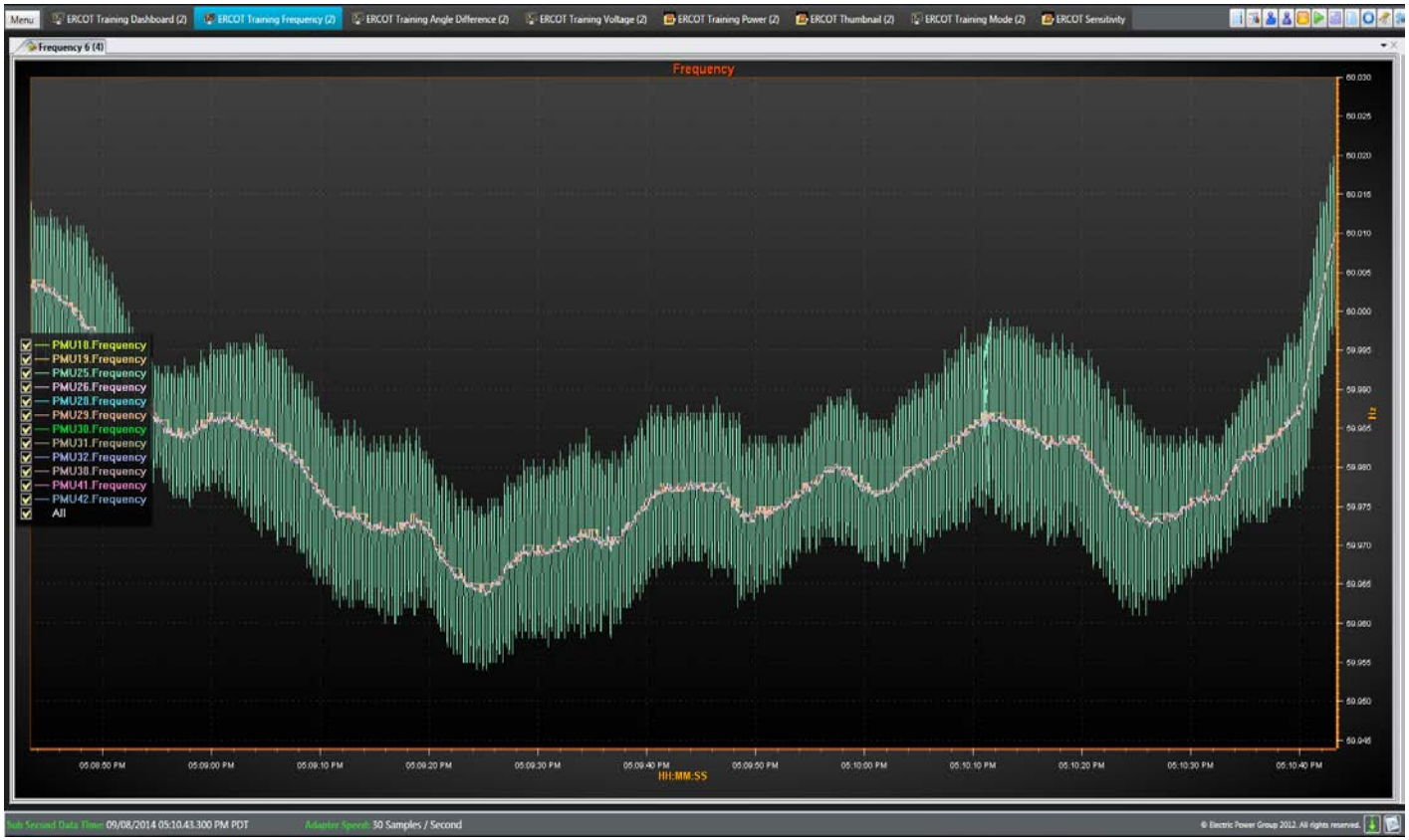
4. Assess System Vulnerability
5. Event Summary

Observation: Interconnection Frequency signal shows oscillations, with low damping alarms.

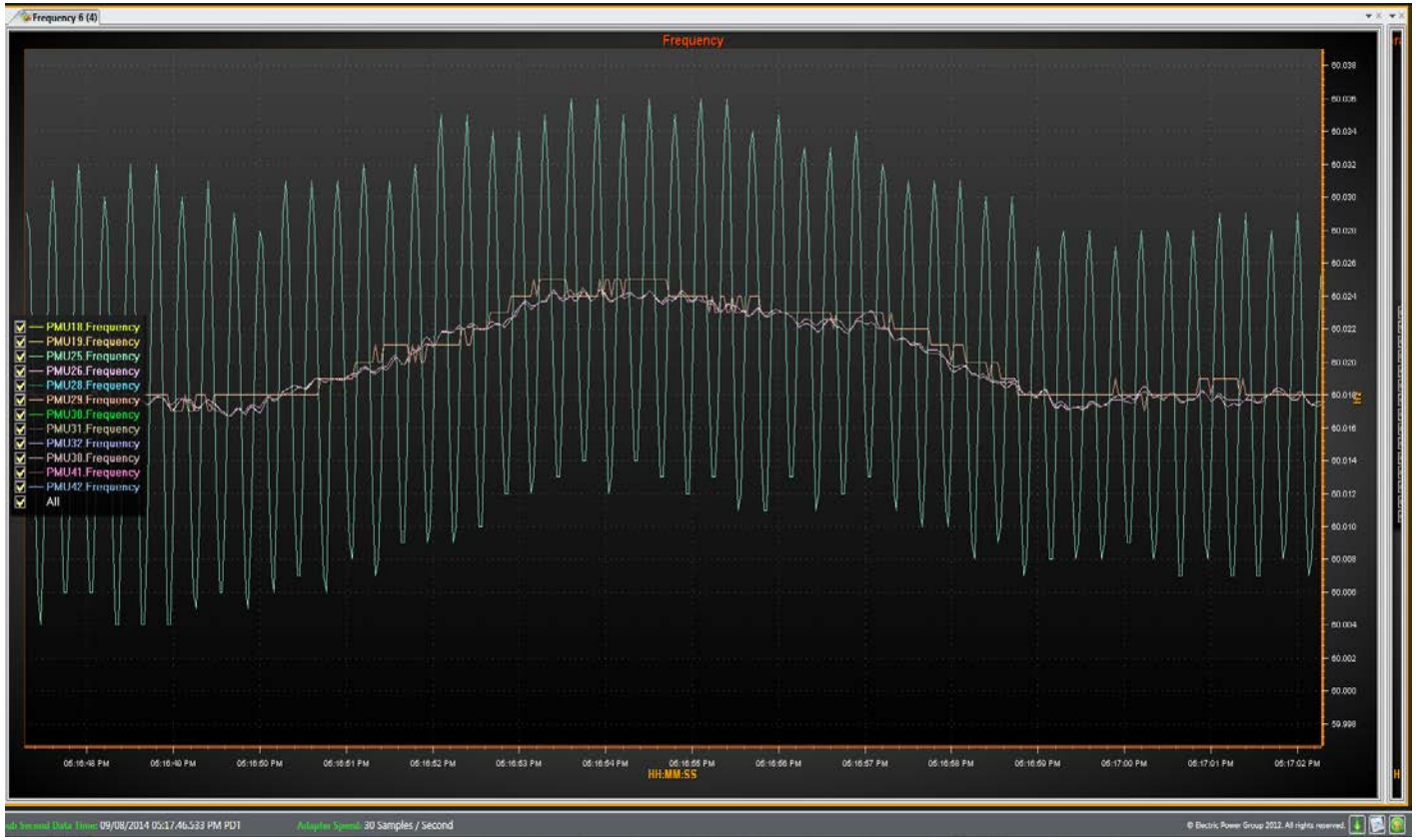
Event Diagnosis:
Frequency Metric



1. Situational Awareness Dashboard (Real-Time Wide Area Monitoring)
2. Detect Emerging Problem
3. Diagnose the Situation
4. Assess System Vulnerability
5. Event Summary

Observation: **Large Frequency oscillation can be identified closed to Hamilton PMU.**

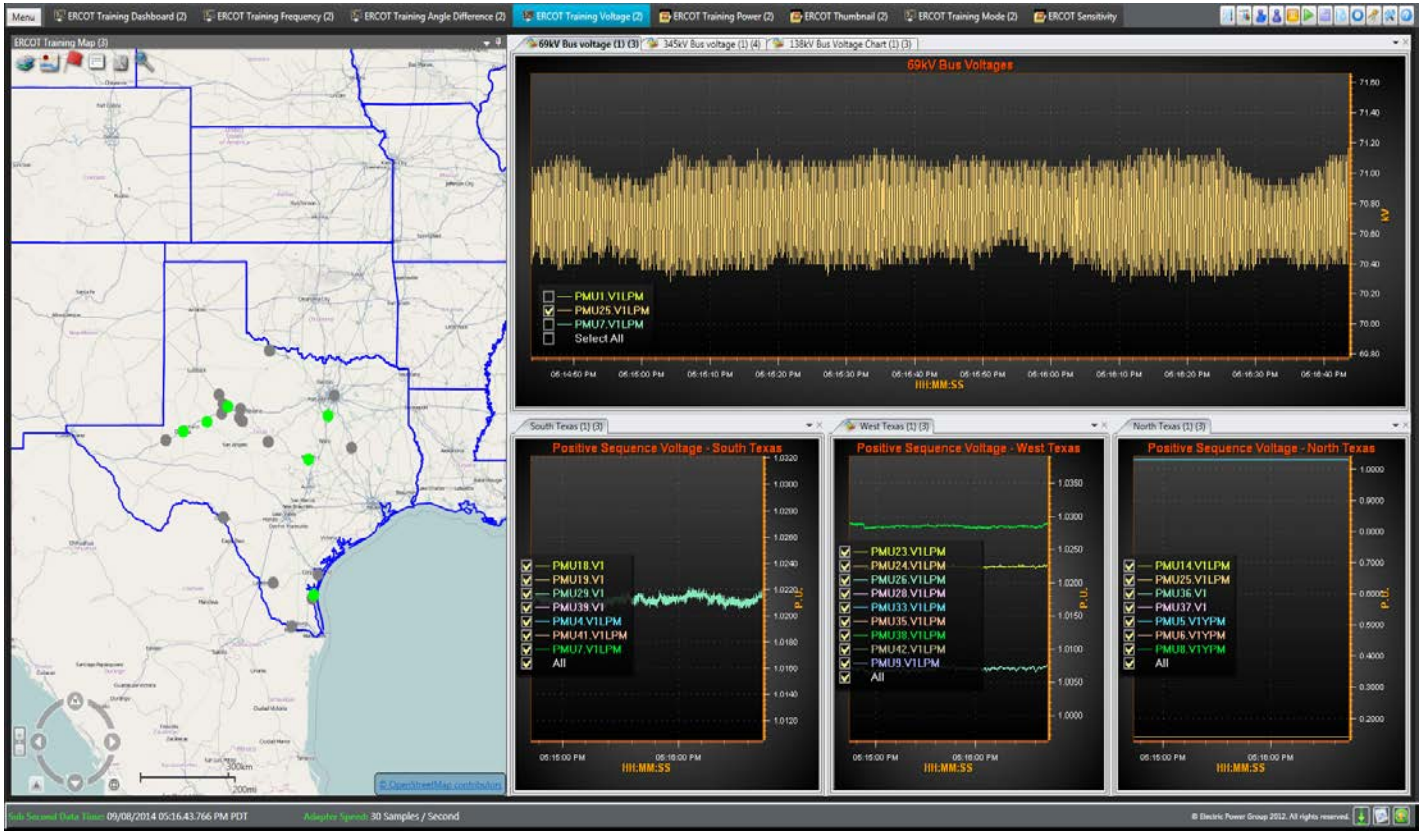
Event Diagnosis:
Frequency Metric



1. Situational Awareness Dashboard (Real-Time Wide Area Monitoring)
2. Detect Emerging Problem
3. Diagnose the Situation
4. Assess System Vulnerability
5. Event Summary

Observation: Zoom in frequency signal on PMU 25.

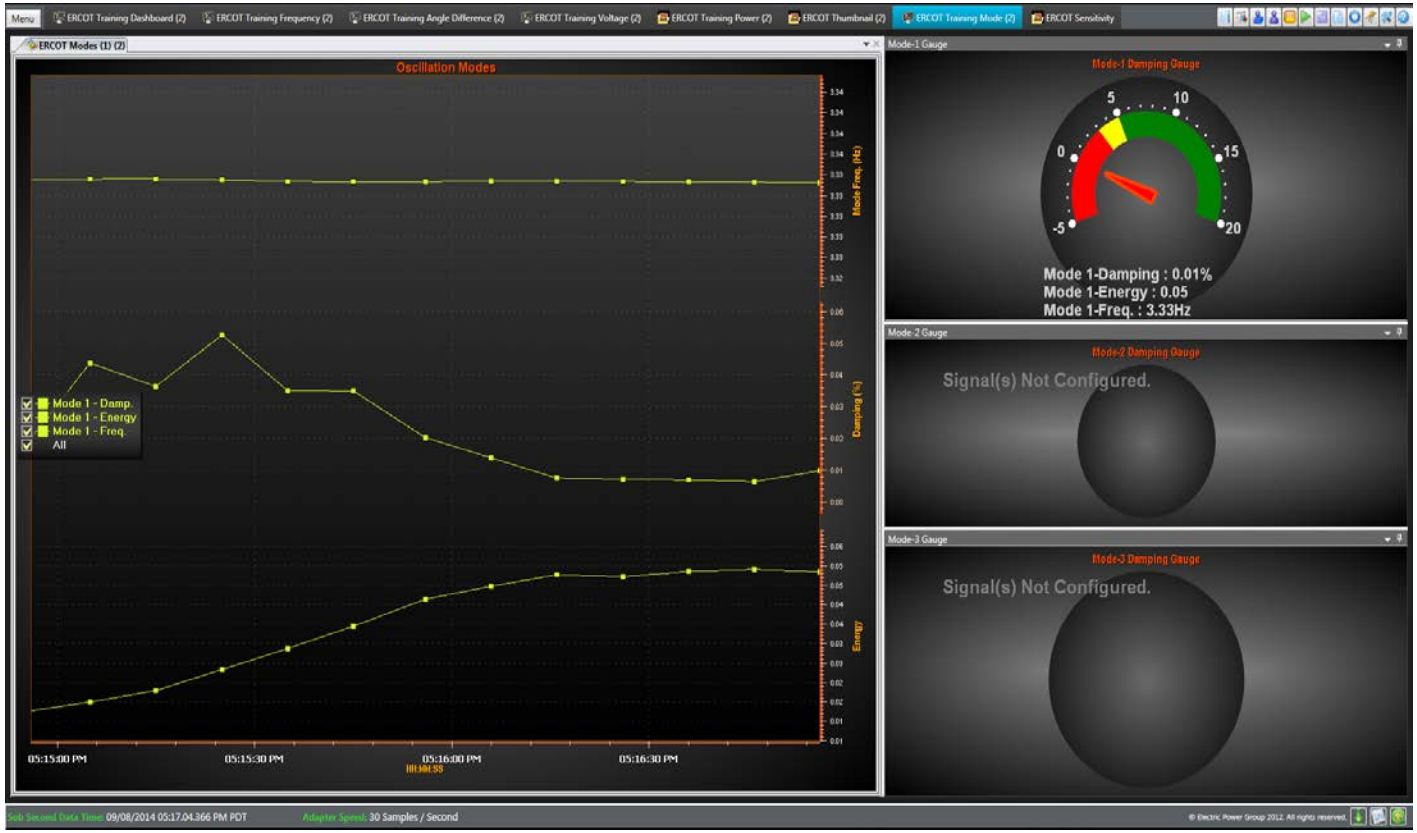
Assessing Vulnerability:
Voltage Metric



1. Situational Awareness Dashboard (Real-Time Wide Area Monitoring)
2. Detect Emerging Problem
3. Diagnose the Situation
4. Assess System Vulnerability
5. Event Summary

Observation：**High frequency voltage oscillation can be identified at PMU 25.**

Assessing Vulnerability:
Mode



1. Situational Awareness Dashboard (Real-Time Wide Area Monitoring)
2. Detect Emerging Problem
3. Diagnose the Situation
4. Assess System Vulnerability
5. Event Summary

Observation : **Low damping observed for mode 1 @ 5.5Hz.**

Assessing Vulnerability:
Thumbnail Display

1. Situational Awareness Dashboard (Real-Time Wide Area Monitoring)
2. Detect Emerging Problem
3. Diagnose the Situation
4. Assess System Vulnerability
5. Event Summary

Analysis Summary

- **What happened?**
  - High frequency oscillation around 3.3Hz
  - The oscillation exist for 3.5 Minutes
  - PMU 25 is the source of oscillations
- **Where did it happen?**
  - Panhandle region
- **Is the system at risk after the event?**
  - Initial damping was low
  - But oscillations damped out eventually

1. **Situational Awareness Dashboard (Real-Time Wide Area Monitoring)**
2. **Detect Emerging Problem**
3. **Diagnose the Situation**
4. **Assess System Vulnerability**
5. **Event Summary**

RTDMS and PGDA User Training

Day 2

Case Study # 6 - 8

Analysis of An Event – Student Hands-on Exercise

Presented By

Wayne Schmus

Prashant Palayam

Electric Power Group

Monitoring, Event Detection and Diagnose with RTDMS

Monitoring, event detection and post event analysis with RTDMS are accomplished by carrying out the following process:

1. **Situational Awareness Dashboard (Real-Time Wide Area Monitoring)**
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5. **Event Summary**

Customizing RTDMS Displays

Customizing RTDMS Displays

- **What will be covered:**
  - Using Profiles, Displays, and Views
  - Understanding Map Views and Layers
  - Other Views available in RTDMS:
    - Trend Views
    - Bar Chart Views
    - Numerical Views
    - Scatter Plot Views
    - Polar Chart Views

Using RTDMS – Hands-on Tutorial

- **Create/Edit New Profile**
- **Create/Edit New Display**
- **Create/Edit Basic View**
  - **Map View**
    - Base map layer
    - Phase angle difference layer
    - Voltage magnitude layer
    - Frequency layer
    - How to use Layer manager
  - **Trend Chart View**
    - Frequency
    - How to use trend chart
  - **Bar Chart View**
    - Voltage Magnitude
    - How to use bar chat
  - **Numerical View**
    - System Frequency
    - How to use numerical view

Using RTDMS – Hands-on Tutorial

- **Create, edit and navigate displays with multiple views**
  - Map View
  - Voltage Trend
  - Voltage Magnitude Bar Chart

- **Change Display Layout**
  - Dock/Undock Views
  - Using the “Float” feature
  - Reposition Views within a Display

Quiz

- Angle line chart view in your display
- Voltage angle signals:
- Angle reference:
- Dock it to the right of your display
- Chart title: Selected Voltage Angle (in green)
- Y-axis: Degree
- Manual scale to: [-180, +180]

PGDA Training

Thank You!

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