Phasor Grid Dynamics Analyzer™

PHASOR RTDMS®

# Real Time Dynamics Monitoring System (RTDMS®) and Phasor Grid Dynamics Analyzer (PGDA)

## User Training for ERCOT

### September 16-17, 2014

Electric Power Group

# The ERCOT PMU Project

Bill Blevins

ERCOT Operations

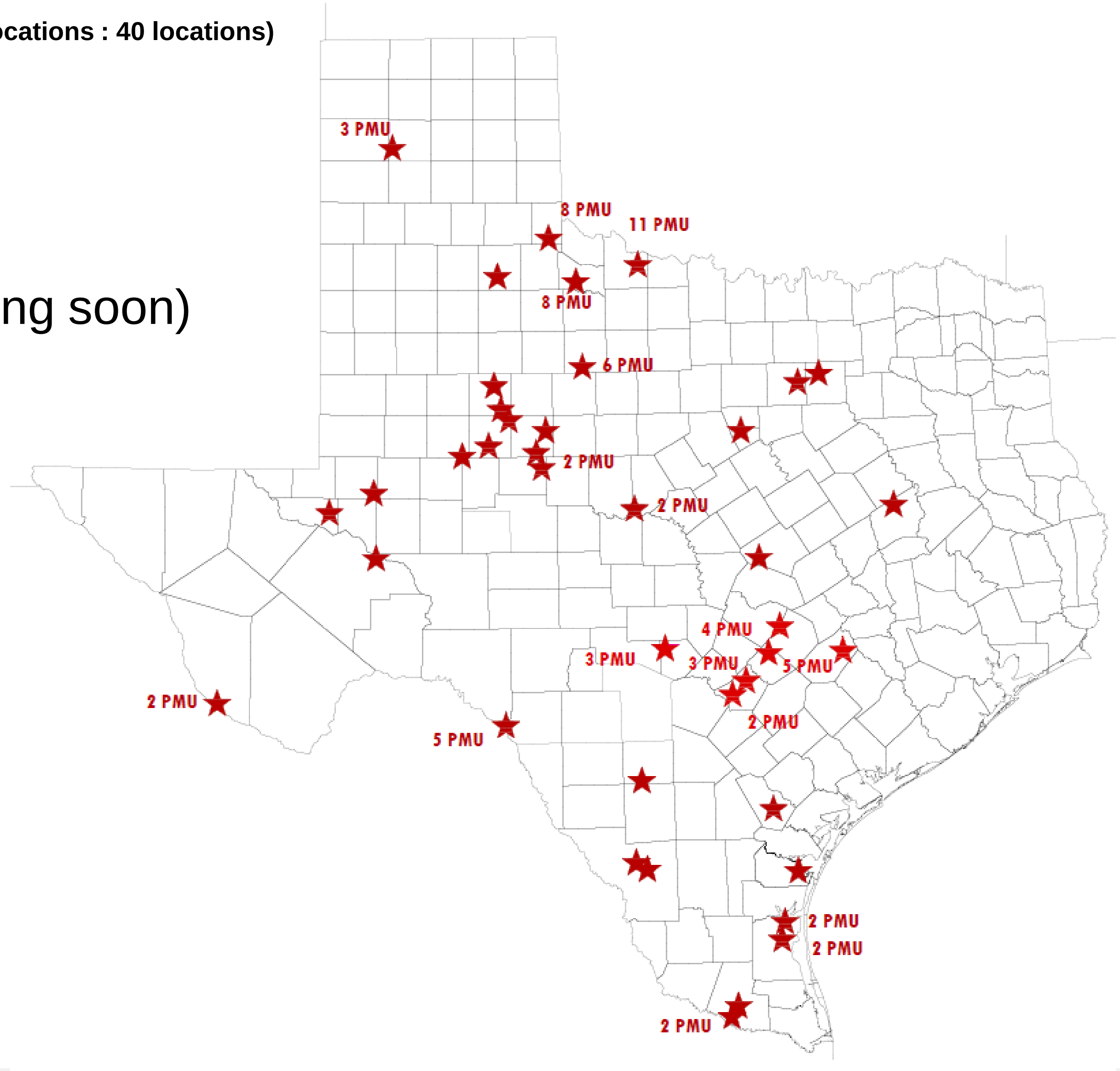
Sept 2014

# THE ERCOT SYNCHROPHASOR (PMU) PROJECT

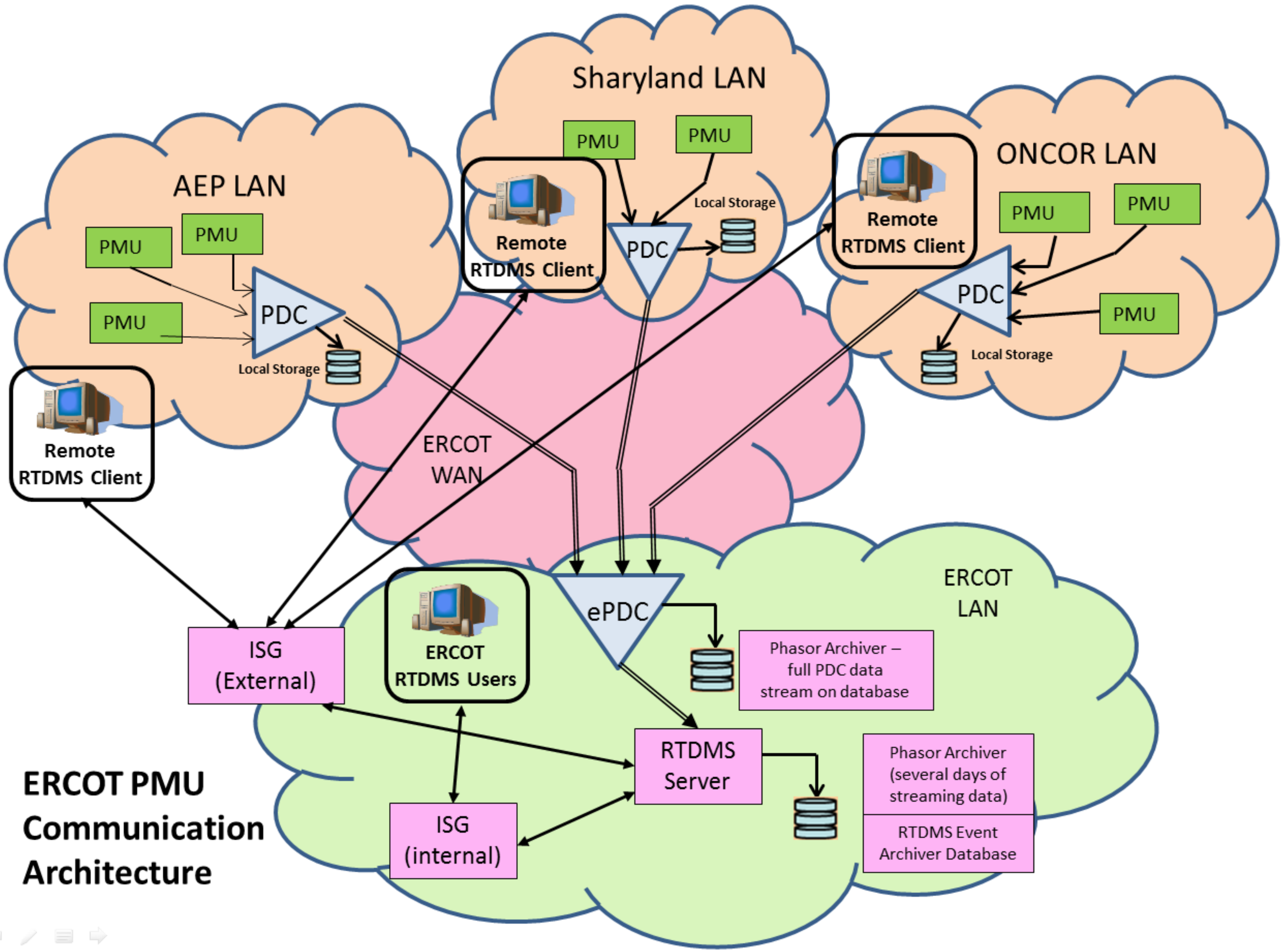
- **Awarded to CCET** - Texas 501(c)6 non-profit formed in 2005
- **CCET Members and Mission**: 21 corporate members and 5 university cooperators. Mission - enhance the safety, reliability, security, and efficiency of the Texas electric transmission and distribution system through research, development and commercialization of emerging technologies (http://www.electrictechnologycenter.com)
- **Awarded Jan 4, 2010**: DE-OE-0000194; Value $27 million (DOE 50%); 17 participants; 3 Components – Synchrophasors, Smart Meter Texas Portal, and Smart Grid Community of the Future; 3 phases – Planning, Design, Demonstration
- **Title**: *Discovery Across Texas: Technology Solutions for Wind Integration in ERCOT*
- **Goal**: Demonstrate a synergistic approach to managing fluctuations in wind power (currently 8 GW increasing to 18 GW) in the ERCOT transmission grid through better system monitoring capabilities, enhanced operator visualization, and improved load management
- **Synchrophasor Project Participants:** ERCOT, TOs, Electric Power Group – Lead for Synchrophasor portion of the project

# CURRENT STATUS OF THE SYNCHROPHASOR NETWORK

- **Total 94 PMUs** **(Locations : 40 locations)**
  - AEP: 54
  - ONCOR: 17
  - Sharyland: 5
  - LCRA:18 (Coming soon)



# THE SYNCHROPHASOR DATA COMMUNICATION NETWORK




ERCOT PMU
Communication
Architecture

# ERCOT ROS SYNCHROPHASOR TASK FORCE

Search >

News | Careers | Feeds | FAQ | Contact Us

About ERCOT | Services | Committees and Groups | Market Rules | Market Information | Grid Information

Home > Committees and Groups > ROS > PMTF

- Meeting Calendar
- Board of Directors
- TAC
- COPS
- PRS
- RMS
- ROS
  - BSWG
  - CIPWG
  - DWG
  - NDSWG
  - NRWG
  - OWG
  - PDCWG
  - PLWG
  - PMTF
  - RDWG
  - SPWG
  - SSWG
  - VRTF
- WMS
- Other Groups
- Inactive Groups
- Market Participants

## PHASOR MEASUREMENT TASK FORCE

The purpose of the PMTF is to formalize a framework of requirements and criteria associated with the provision of phasor measurement data to ERCOT through the initiation of appropriate Protocol and Guide changes after consideration of the capabilities of the technology, the expected and required uses of the data, and the relevant policy considerations.

### Contact Information

Chair: Kristian Koellner
Vice Chair: Bill Blevins

Send an email to this group: pmtf@lists.ercot.com
(Subscribe to this email list.)

### Scheduled Meetings and Meeting Details

| | | |
|---|---|---|
| January 08, 2014 | February 05, 2014 | March 07, 2014 |
| April 09, 2014 | May 14, 2014 | June 04, 2014 |
| June 11, 2014 | July 09, 2014 | August 06, 2014 |
| September 03, 2014 | October 01, 2014 | October 29, 2014 |
| December 03, 2014 | | |

(Subscribe to calendar and receive meeting updates. Get help with calendar subscription.)

### Key Documents

**ERCOT PMTF 2014 Roster**
(03/18/2014, xls, 45 KB)

**Phasor Measurement Task Force Scope ROS Approved March 6 2014**
(03/06/2014, doc, 46 KB)

**PMTF Issues List 030714**
(03/18/2014, doc, 52 KB)

All information is posted as Public in accordance with the ERCOT Websites Content Management Corporate Standard.

### Archives

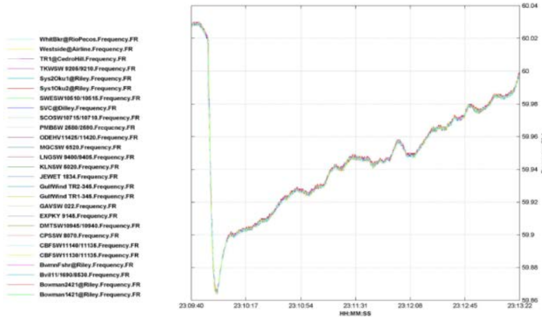
2013 Archives



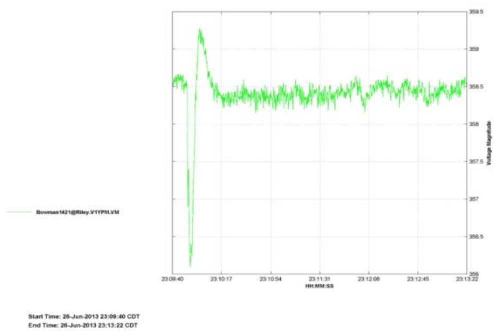
Feedback | Site Map | Glossary | Terms of Use | Privacy

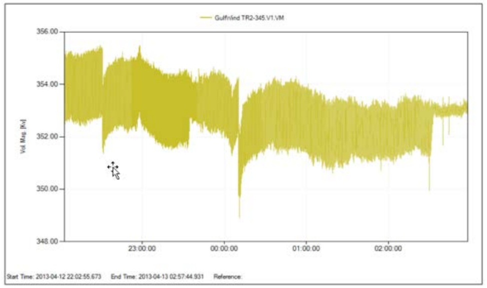
# HOW SYNCHROPHASOR DATA IS BEING USED IN ERCOT

- **Post-Event analysis**
  - Frequency analysis



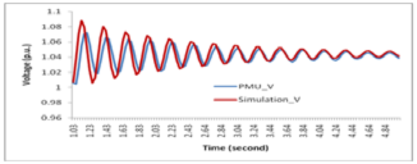
  - System Oscillations





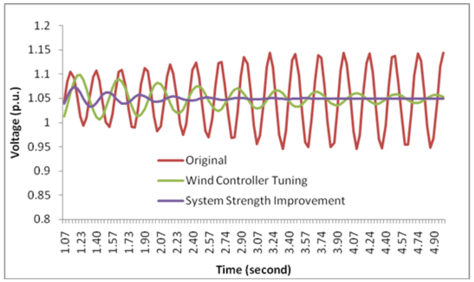
  - Generator model validation/tuning

- **Post Event Analysis**
  - Re-create the oscillations as captured by the PMU
  - Identify the cause and solutions to mitigate the oscillations
- Benchmark study using PMU data




Voltage responses at WPP's POI

- Proposed solution based on simulation studies



# Introduction to RTDMS

## INTRODUCTION TO RTDMS

- DASHBOARD
- ALARM PANEL
- HIGH RESOLUTION FREQUENCY DISPLAY
- MULTIPLE LAYERS
    - Geographical Map
    - Transmission Lines
    - Weather
    - Angle Differences
    - Frequency
- CLUTTER MANAGEMENT
- AUTOMATIC EVENT ANALYZER

# RTDMS and PGDA User Training

## Training Agenda – Day 1

| | |
|---|---|
| Training Kickoff and ERCOT Project Overview | Bill Blevins |
| EPG Team Introductions | Wayne Schmus |
| Using Synchrophasor Technology<br>• Fundamentals<br>• Metrics<br>• Real-Time Operation Use Cases | Wayne Schmus |
| RTDMS Platform Overview | Kevin Chen |
| Navigating RTDMS | Iknoor Singh |
| Hands-on Guided Training Exercises | Wayne Schmus /<br>Kevin Chen |

# The Electric Power Group Team

**Wayne Schmus, P.E.**
**Sr. Principal Engineer**

**Kevin Chen, P.E.**
**Sr. Engineer**
**RTDMS Product Manager**

**Prashant Palayam**
**Sr. Engineer**
**PGDA Product Manager**

**Iknoor Singh**
**Engineer**

**Pankaj Mishra**
**Training Coordinator**

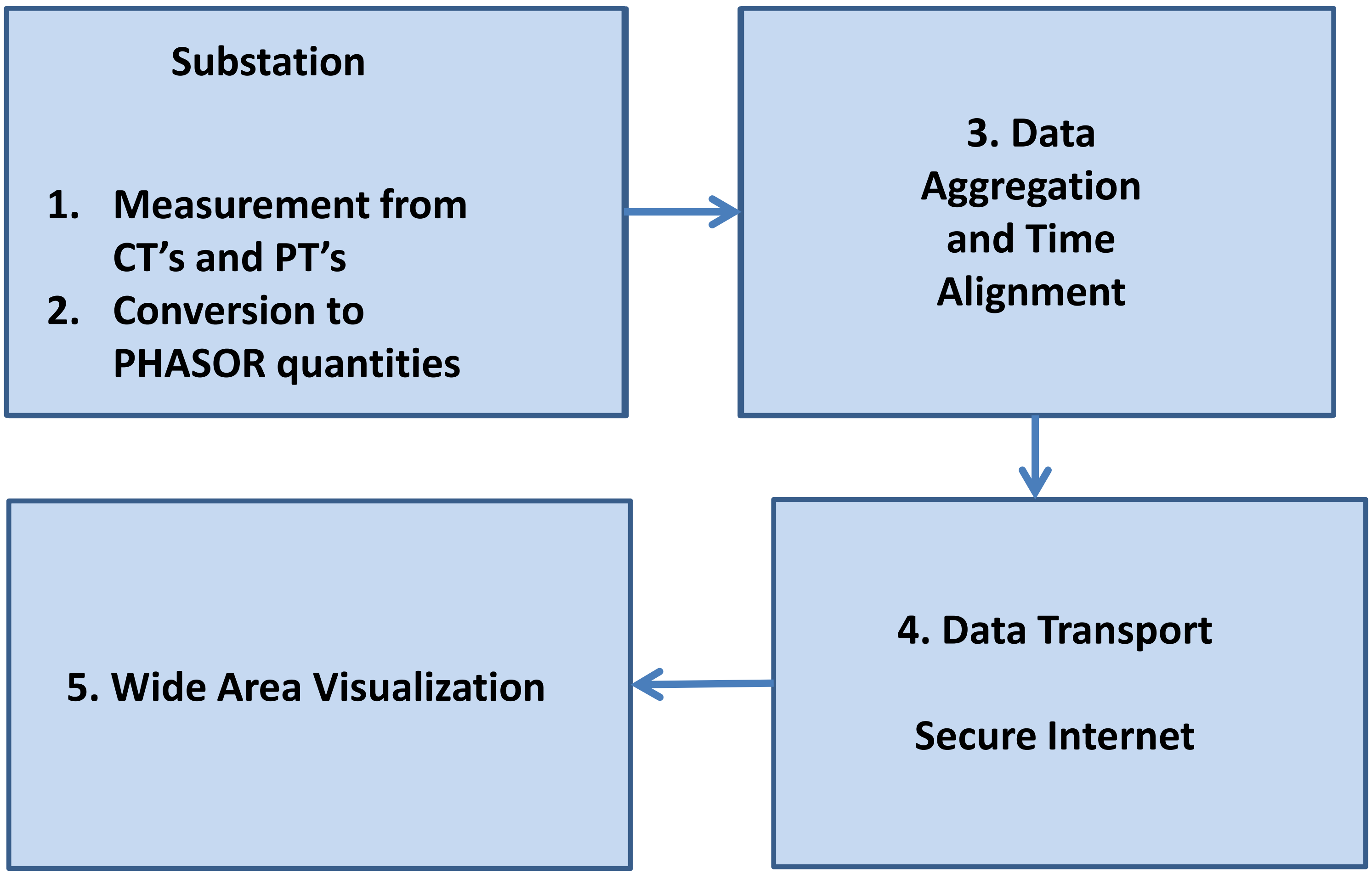
# Using Synchrophasor Technology in Real-Time Operations

# Using Synchrophasor Technology in Real-Time Operations

- **What will be covered:**
  - Synchrophasor Technology Infrastructure
  - Using Synchrophasor Technology in Control Rooms - Monitor, Diagnose and Act
  - Major Blackout Events - Lessons Learned
  - How Synchrophasor Technology can Help Operators in Real-Time

# Synchrophasor Technology Infrastructure

## Flow of Information

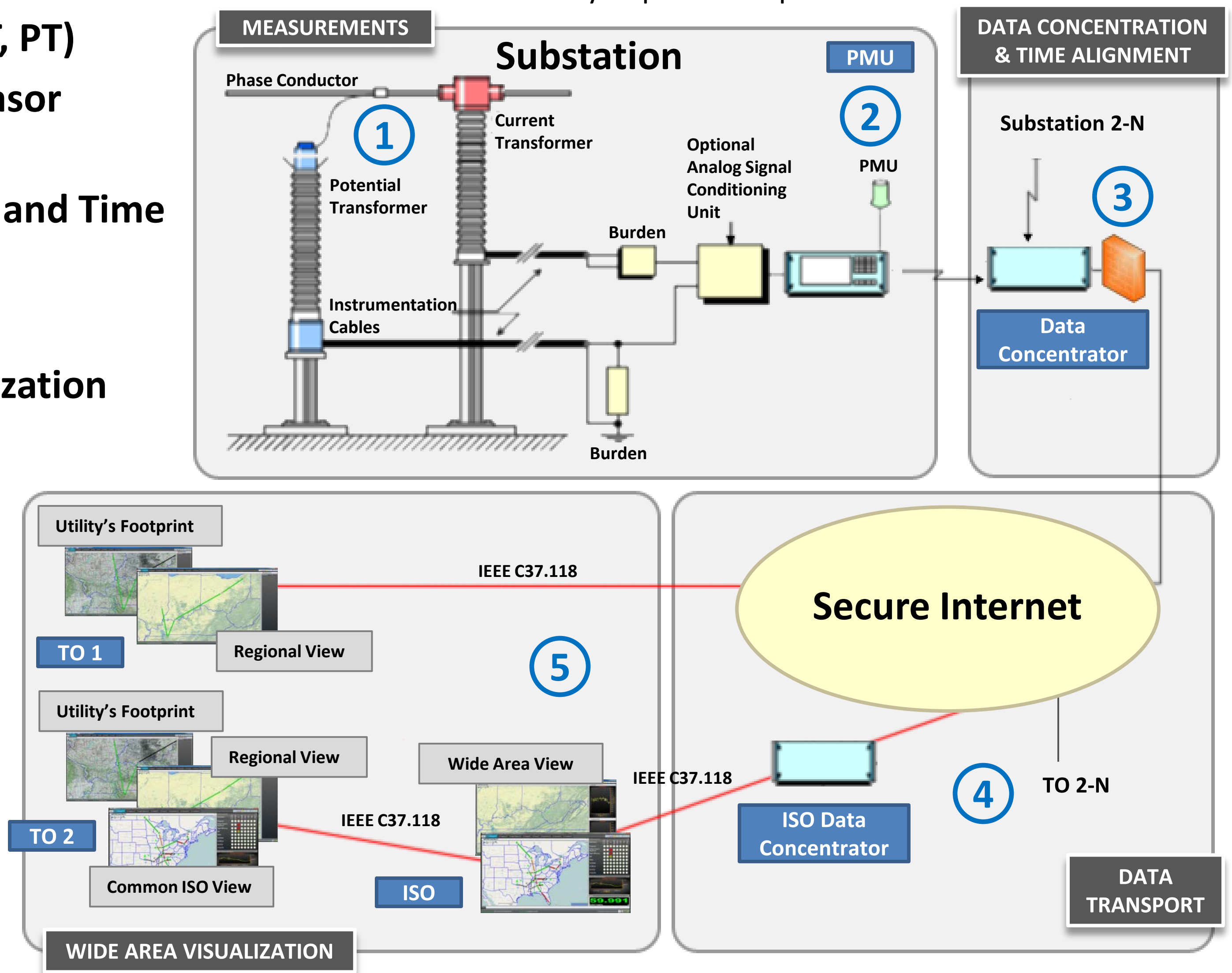


# Synchrophasor Technology Infrastructure

## Time Synchronized High Resolution Measurements and Wide Area Visualization

1. Measurement (CT, PT)
2. Conversion to phasor quantities - PMU
3. Data Aggregation and Time Alignment
4. Data Transport
5. Wide Area Visualization

Courtesy: Adapted from EIPP presentation



# Key Attributes of Synchrophasors

1. High Resolution – 30-60 measurements/second
   - ✓ Dynamics (Modes, Sensitivities etc.); Improved Observability (MRI Vs. X-Ray)
   - ✓ Event Signatures
2. Time Synchronized– GPS based UTC time stamped
   - ✓ Wide Area View in Real Time
   - ✓ Phase Angle Differences
   - ✓ Inter Area Dynamics
3. Vector (Angle + Magnitude)
   - ✓ Phase Angle measurements

# Phasor vs. SCADA Measurements

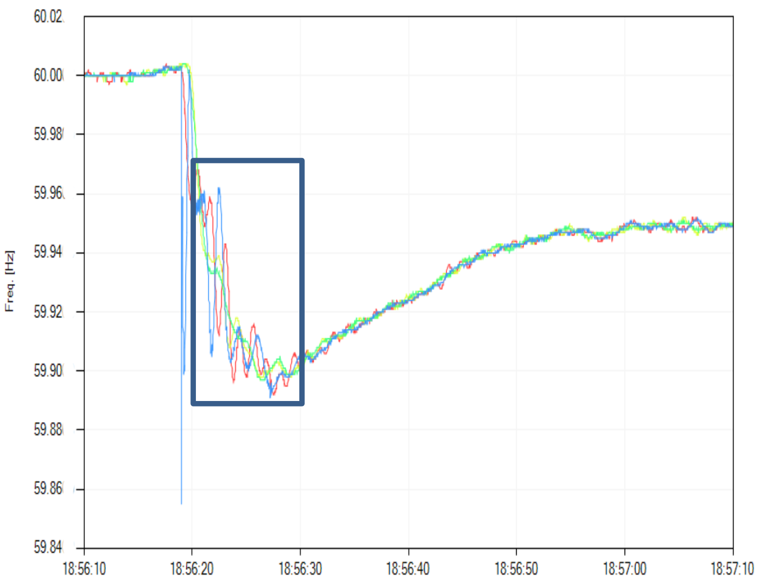
**Phasor technology is NOT a replacement for SCADA.**
**Rather, it complements existing SCADA systems.**

| ATTRIBUTE | SCADA | PMU |
|---|---|---|
| Resolution | 1 sample every 2-4 seconds (Steady State Observability) | 10-60 samples per second (Dynamic/Transient Observability) |
| Measured Quantities | Magnitude Only | Magnitude & Phase Angle |
| Time Synchronization | No | Yes |
| Focus | Local utility monitoring & control | Wide area monitoring & control |

# Observability – SCADA vs. PMUs

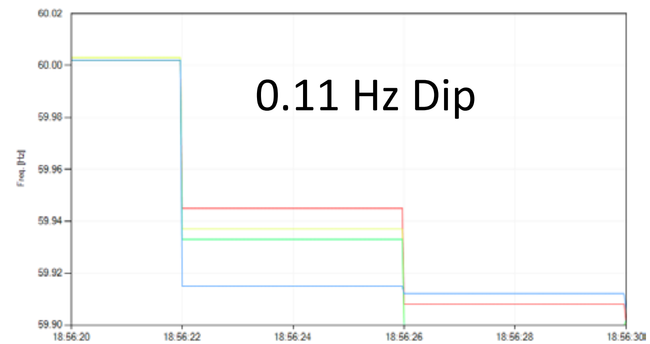
**QUESTION: Detection of Frequency Differences Across the Interconnection**

## Observability

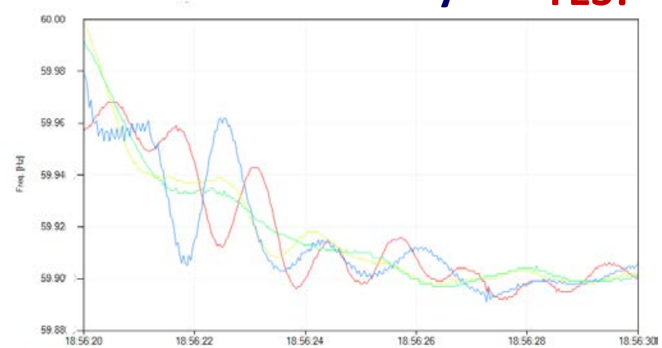



**Zoom-in**

## SCADA Observability




## PMU Observability **YES!**

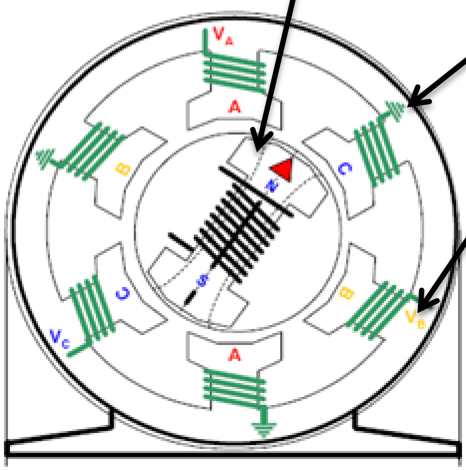


**ANSWER:** SCADA - Frequency appears to be similar at all locations – no oscillation PMU's Frequency measurements from different locations show variations – indicates inter-area dynamics or oscillations

# Synchrophasor Fundamental – Voltage Phasor

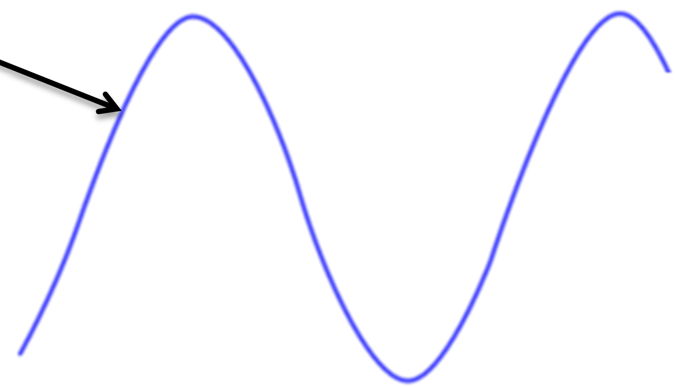
In a simple AC generator, this two-pole rotor is an electro-magnet, creating a magnetic field in the surrounding stator

It rotates at 3600 rpm, or 60 cycles per second



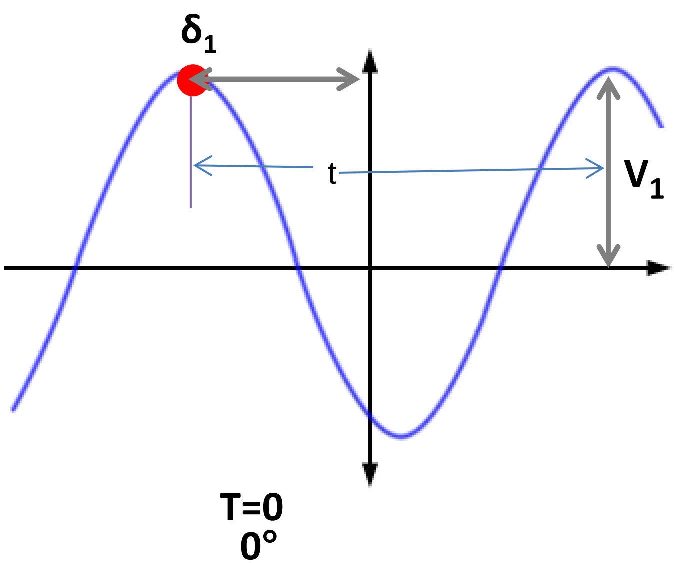
In the stator, the moving magnetic field creates an alternating voltage in the windings

In a time graph, the voltage looks like this



# What Is A Voltage Phasor?

Adding the axes and labels, we have a time graph of a voltage phasor. A sinusoidal function whose magnitude $V_1$, frequency (ω), and phase ($\delta_1$) are fixed at a given time.

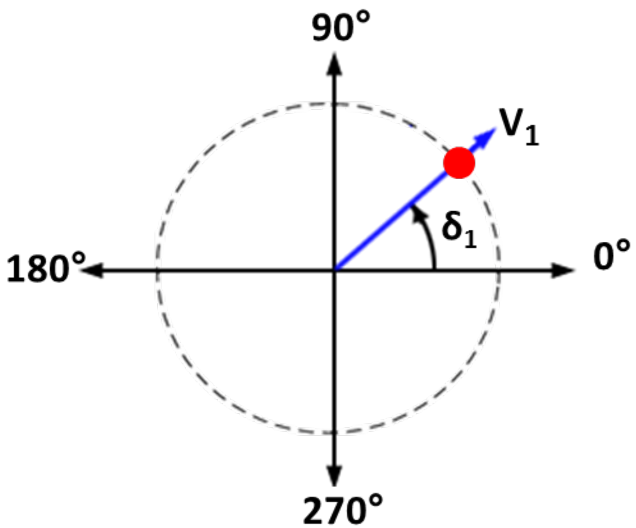



Sinusoidal Waveform

$V_1$ Voltage Magnitude
$\delta_1$ Voltage Angle
$\omega = \frac{1}{2\pi t}$ Frequency

# Voltage Phasor in Polar Format

This is the same voltage phasor, but shown in polar coordinates. It is typically rotating counter-clockwise at 60 cycles per second.



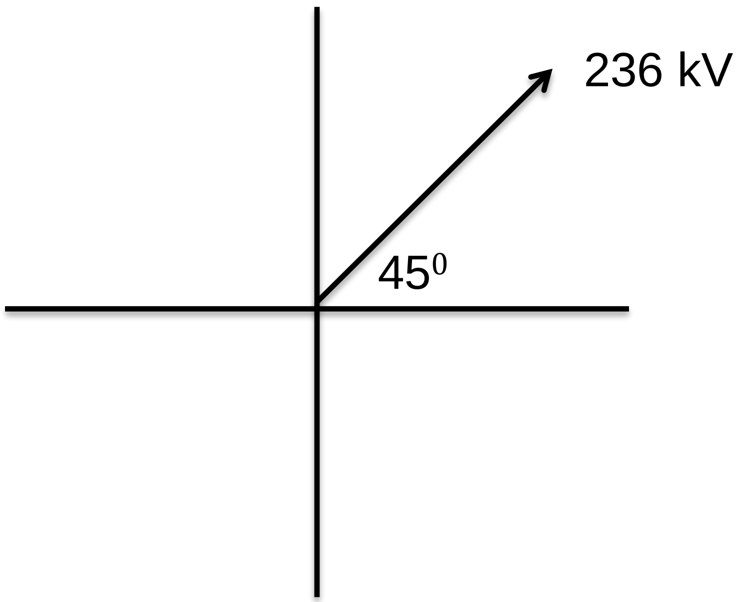

**Phasor Representation**

It has magnitude $V_1$, a time reference T=0 at 0°, and a voltage phase angle $\delta_1$

# Voltage Phasor Example

*Example*

This voltage phasor has a magnitude of 236 kV, at an angle of 45$^o$ referenced to 0$^o$.



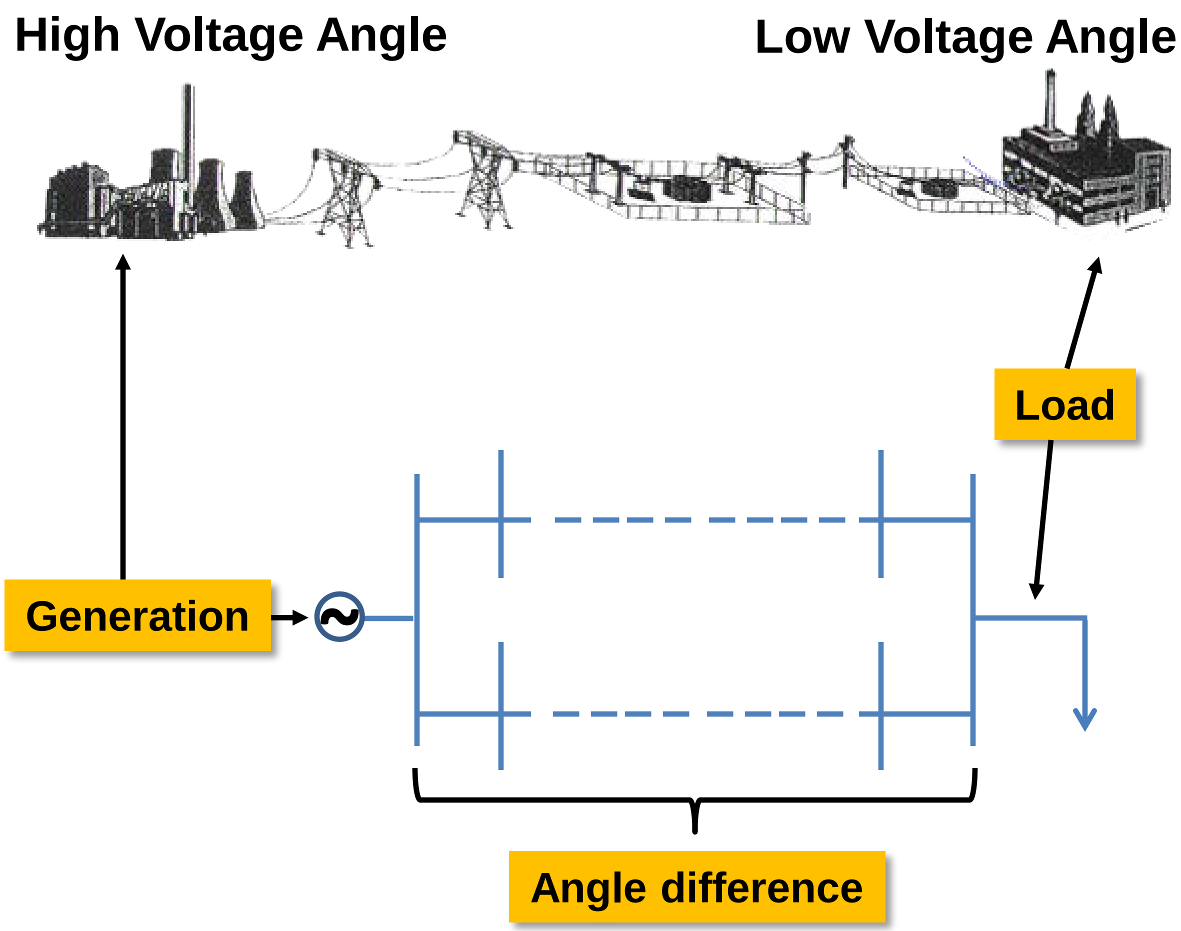
# Voltage Phasor Recap

**The following are properties of a voltage phasor:**

A. **Magnitude**
B. **Phase Angle**
C. **Time Reference**
D. **Frequency**
E. **Location of the Measurement**

**Voltage angle cannot be measured by SCADA in real-time.**

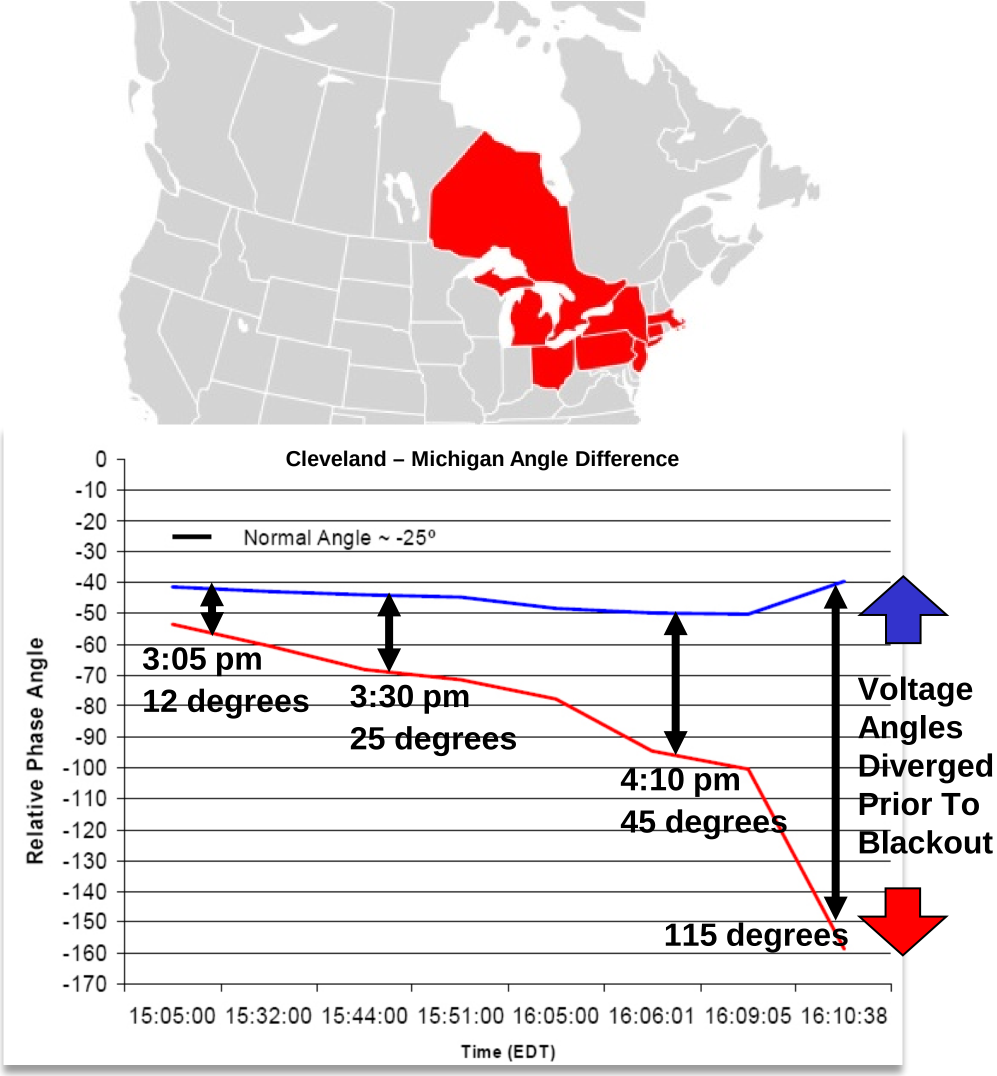
# Voltage Angles Determine Power Flow Direction




- **AC Power System:** **Power *flows* from a point of high voltage angle to a point of low voltage angle**
- **Voltage Angles across a network change when something happens (e.g. line outage, generation trip, or load change)**
- **Voltage Angle difference across a network is an indicator of stress**

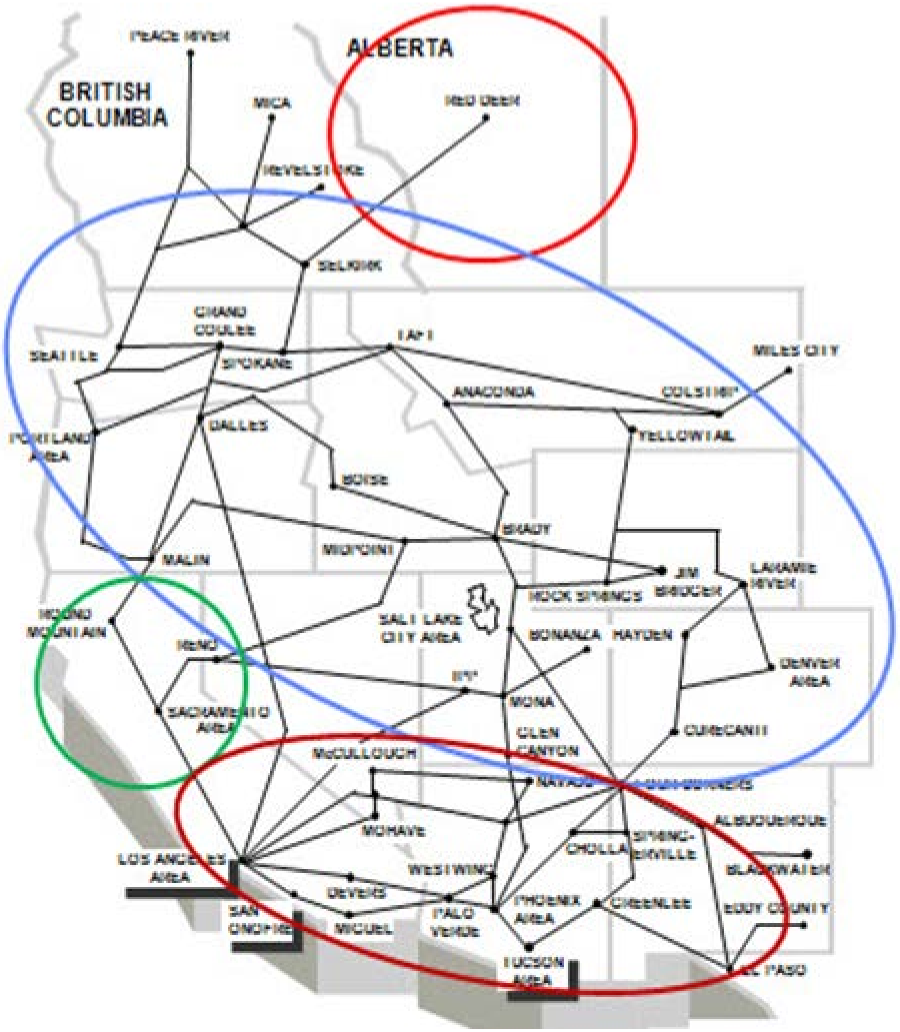
# Why Voltage Angles Are Important

## August 14, 2003: Eastern Interconnection Blackout



# Major Blackout Events - Lessons Learned

## August 10, 1996: WECC Blackout



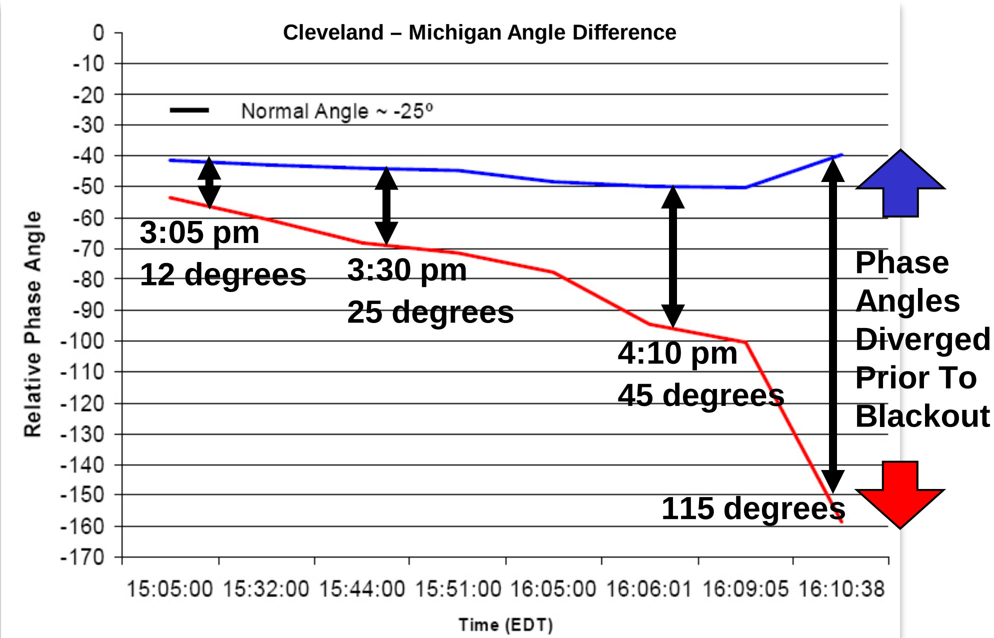

- **Hot Summer Day**
- **Problem started in Idaho, propagated to Oregon, and led to system collapse into four islands within <u>two hours</u>**

| TOTAL WECC IMPACTS | |
|---|---|
| Load Lost | 30,489 MW |
| Generation Lost | 27,269 MW |
| Customers Affected | 7.49 Million |
| Outage Time | Up to 9 Hours |

***Synchrophasor technology provides wide-area visibility to monitor diverging phase angles to enable operators to take timely action.***

# Major Blackout Events - Lessons Learned

## August 14, 2003: Eastern Interconnection Blackout




Note:
Angles are based on data from blackout investigation. Angle reference is Browns Ferry.

- **Problem started in Ohio, and over <u>several hours</u>, propagated into Canada and New York**

| OUTAGE IMPACTS | |
|---|---|
| Load Lost | 61,800 MW |
| Generation Lost | 55,000 MW (508 Units) |
| Customers Affected | 50 Million |
| Outage Time | Few hours up to 2 weeks |

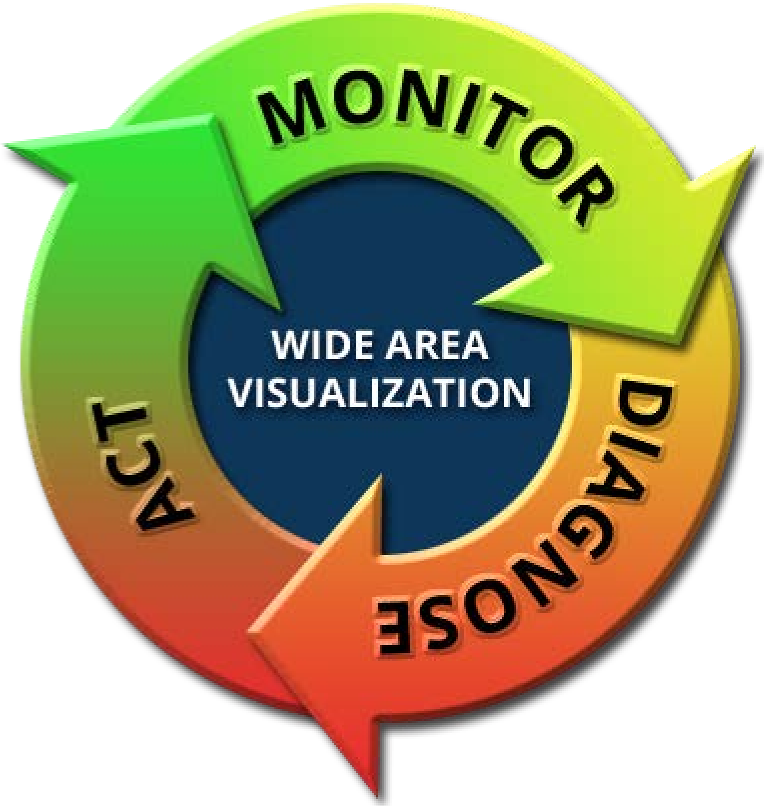
***Synchrophasor technology provides wide-area visibility to monitor diverging phase angles to enable operators to take timely action.***

- Multiple Issues leading up to the blackouts
- Lack of Wide Area Situational Awareness
- Lack of Time Synchronized data
- Lack of Unified Displays and monitoring tools
- Inability to monitor Grid Dynamics

# Using Synchrophasor Technology in Control Rooms

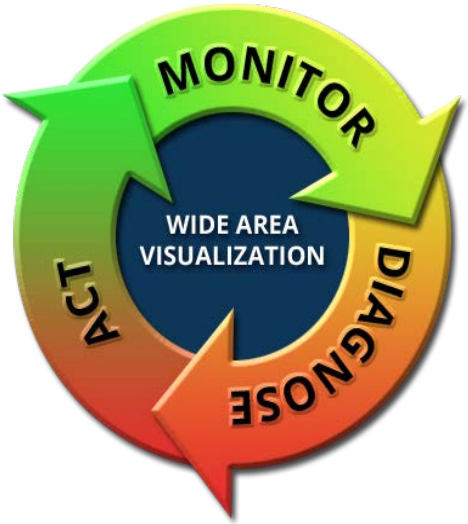
## Monitor, Diagnose and Act

**Operator's Mission: Keep the lights on!**



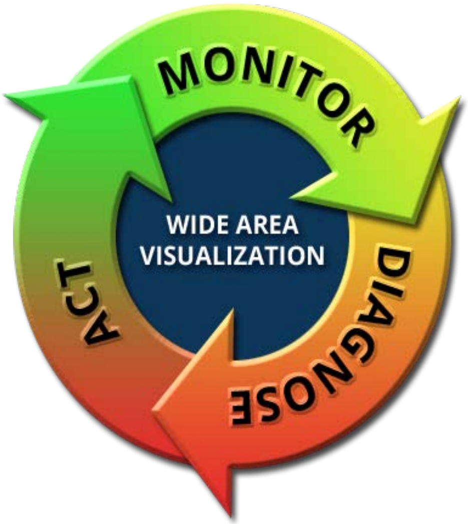
# How Synchrophasor Technology Can Help Operators in Real-Time Operations

- **Wide Area View – Situational Awareness**
- **Phase Angle Difference**
- **Voltage Sensitivities**
- **Damping and Oscillation**
- **Synchrophasor Technology Enables Operators to:**
  - Monitor Grid Dynamics
  - Integrate Renewables
  - Improve Asset Utilization
  - Prevent Blackouts
  - Enable Faster Recovery



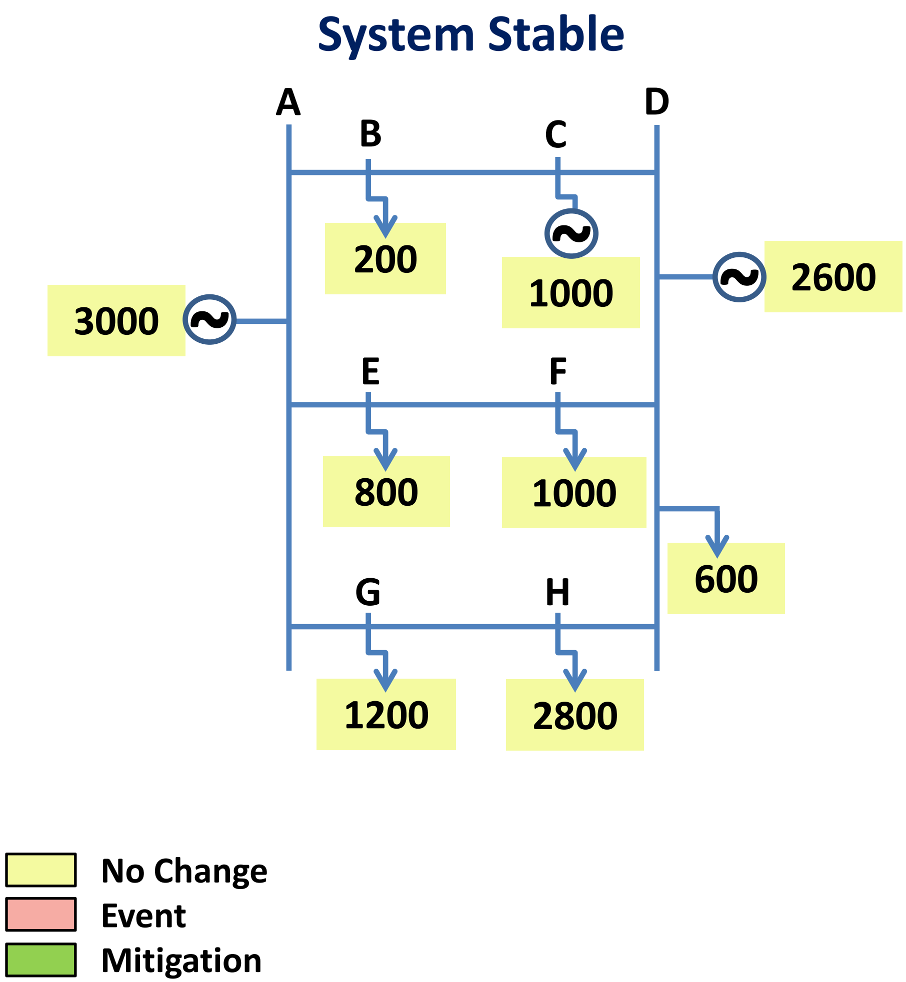
# How Synchrophasor Technology can Help Operators in Real-Time Operations

- **Wide Area View – Situational Awareness**
- **Phase Angle Difference**
- Voltage Sensitivities
- Damping and Oscillation
- Synchrophasor Technology Enables Operators to:
  - Monitor Grid Dynamics
  - Integrate Renewables
  - Improve Asset Utilization
  - Prevent Blackouts
  - Enable Faster Recovery



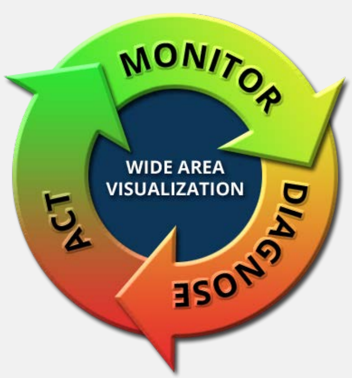
# Power Flow Model - 8 Bus System

## Base Case – Event – Mitigation




- Load: 6600 MW (Buses B, D, E, F, G and H)
- Generation: 6600 MW (Buses A, C and D)
- Key Phase Angle Paths:

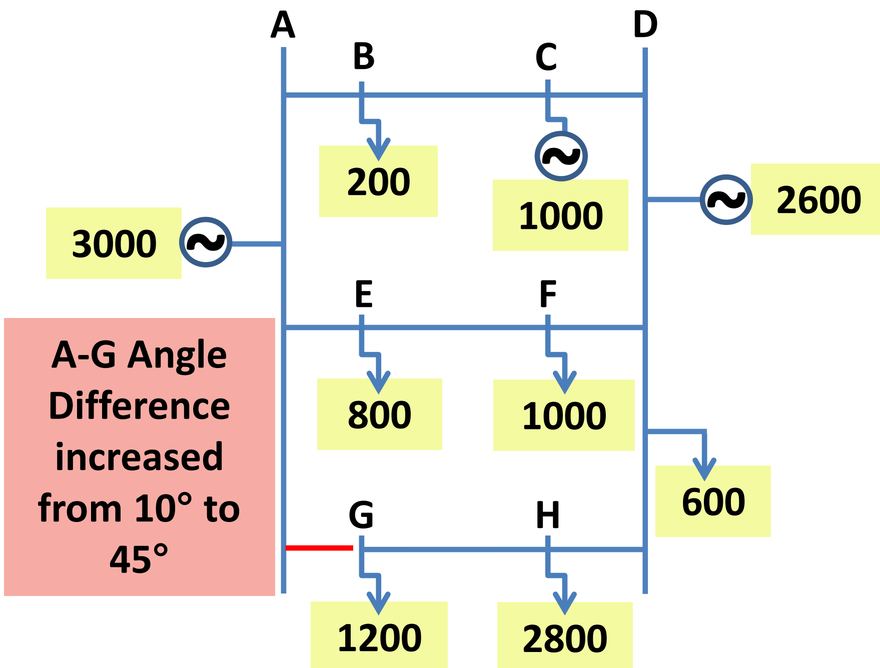
| PHASE ANGLE | BASE |
|---|---|
| A-G | 10° |
| A-E | 7° |
| A-D | 6° |



# Power Flow Model - 8 Bus System

## Base Case – Event – Mitigation

### Event: Line Trip (A-G)



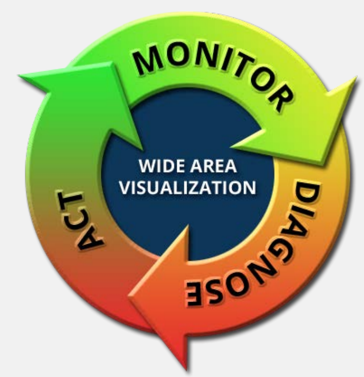

- No Change
- Event
- Mitigation

- Load: 6600 MW (Buses B, D, E, F, G and H)
- Generation: 6600 MW (Buses A, C and D)
- Key Phase Angle Path Changes:

| PHASE ANGLE | BASE | LINE TRIP |
|---|---|---|
| A-G | 10° | 45° |
| A-E | 7° | 16° |
| A-D | 6° | 24° |

A-G Phase Angle increases to 45°

**ACTION:** Redispatch

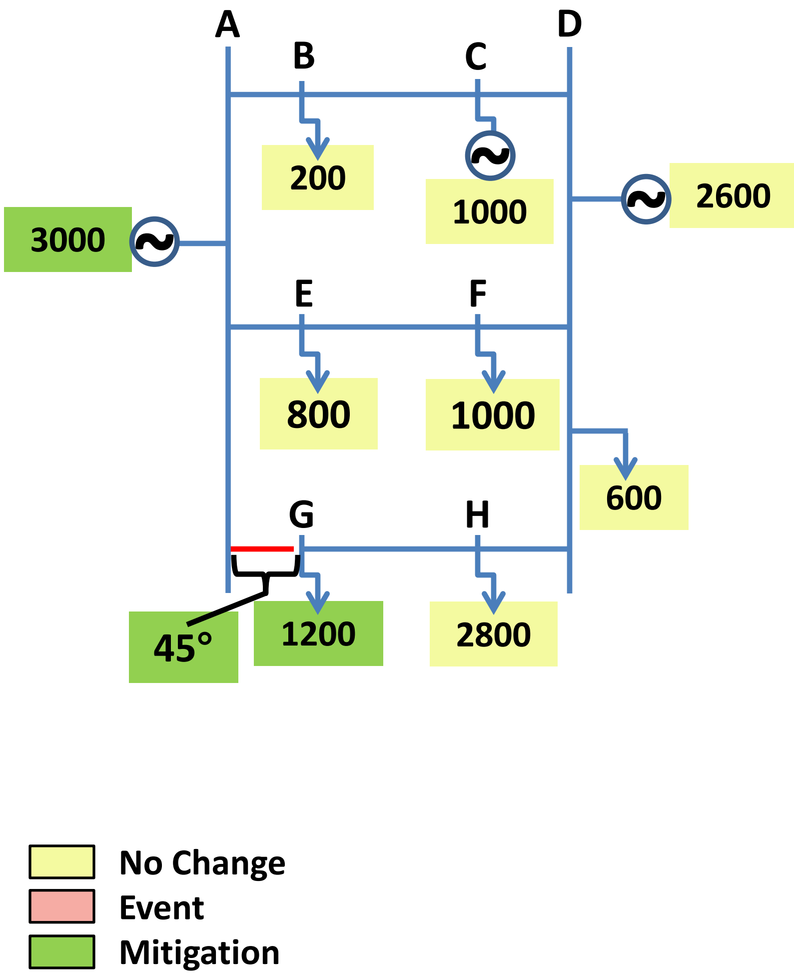



Line Trip

# Power Flow Model - 8 Bus System

## Base Case – Event – Mitigation

### Mitigation Options

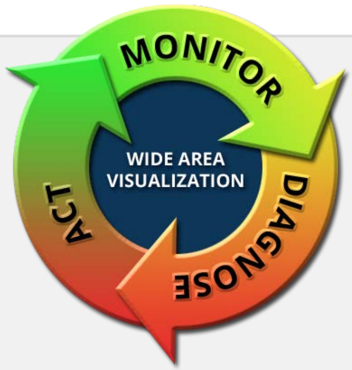



*Gen A adjusted to balance network load

- **Issues:**
  - A-G Angle at 45°
  - Assume 30° needed to close CB
- **Options for Redispatch:**

| ACTION | SENSITIVITY X°/100MW |
|---|---|
| Reduce G Load | 2.60° |
| Reduce H Load | 1.85° |
| Reduce D Load and/or Increase D Gen | 1.28° |
| Increase C Generation | 1.10° |

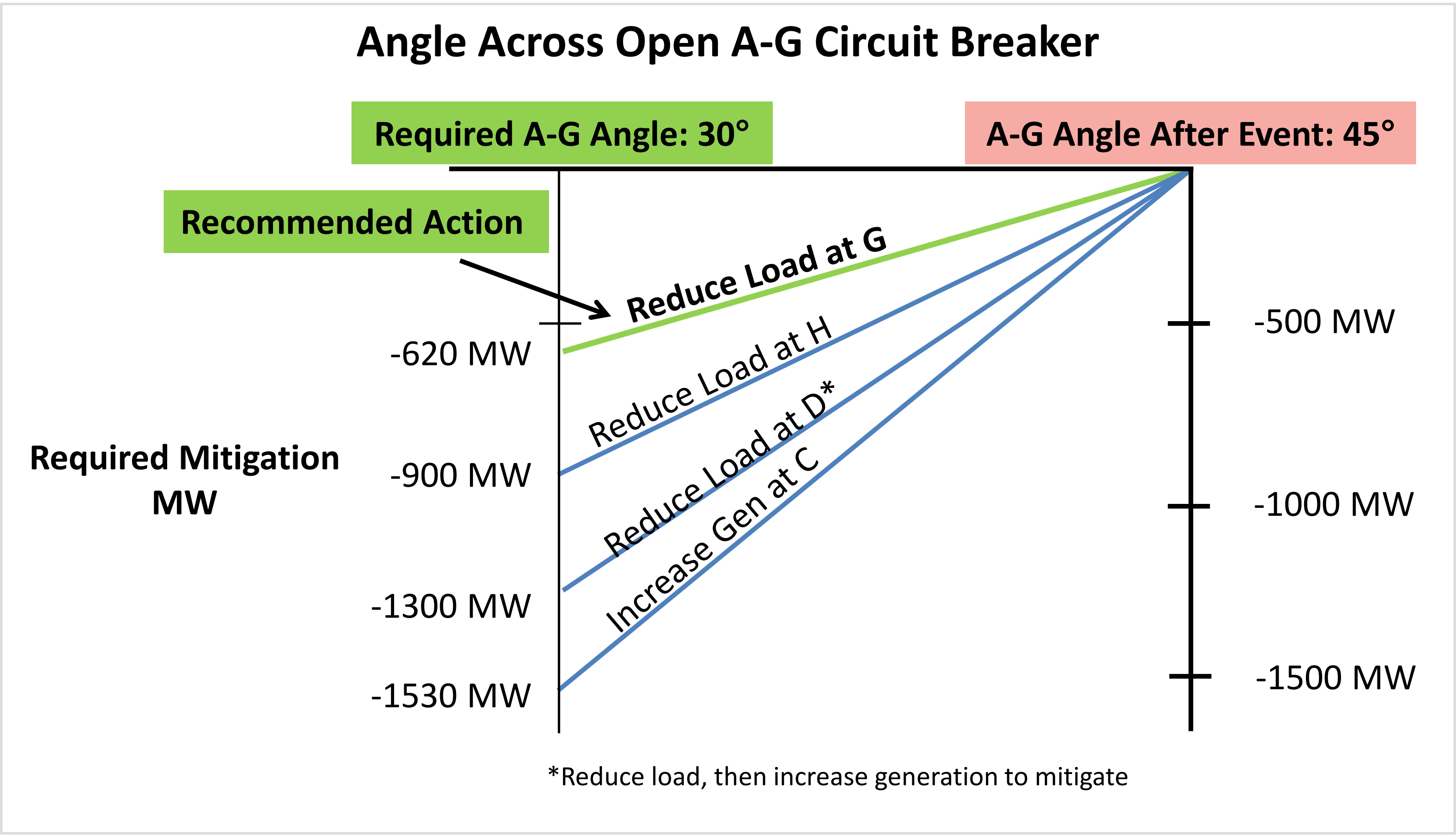
**REQUIRED ACTION:**
**Reduce angle across A-G to 30° to permit CB closing**



# Power Flow Model - 8 Bus System

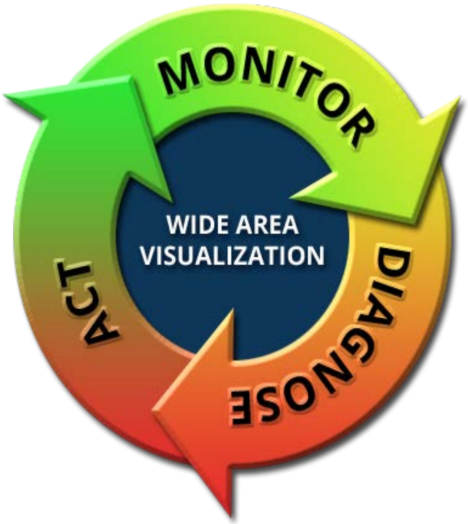
## Line Trip – Mitigation Options and Effectiveness

### Effectiveness of Mitigation Options In Reducing A-G Angle



# How Synchrophasor Technology can Help Operators in Real-Time Operations

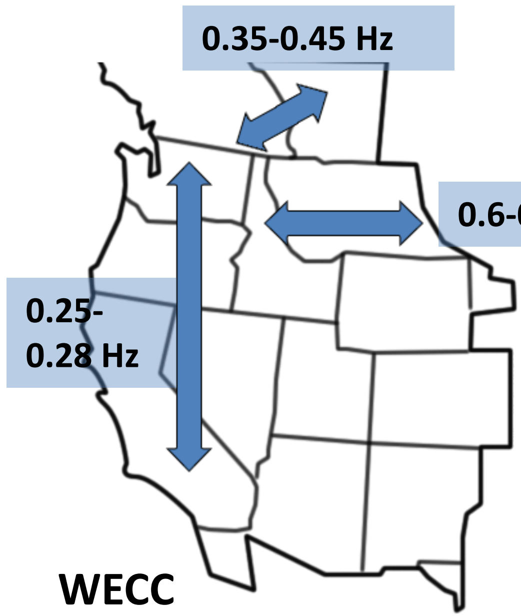
- Wide Area View – Situational Awareness
- Phase Angle Difference
- Voltage Sensitivities
- **Damping and Oscillation**
- Synchrophasor Technology Enables Operators to:
  - Monitor Grid Dynamics
  - Integrate Renewables
  - Improve Asset Utilization
  - Prevent Blackouts
  - Enable Faster Recovery

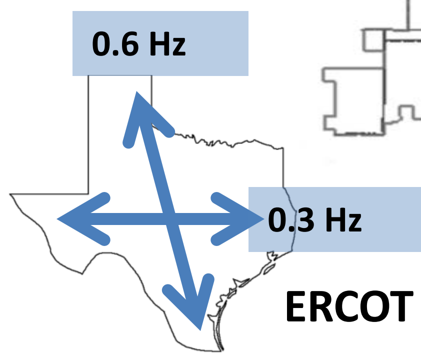


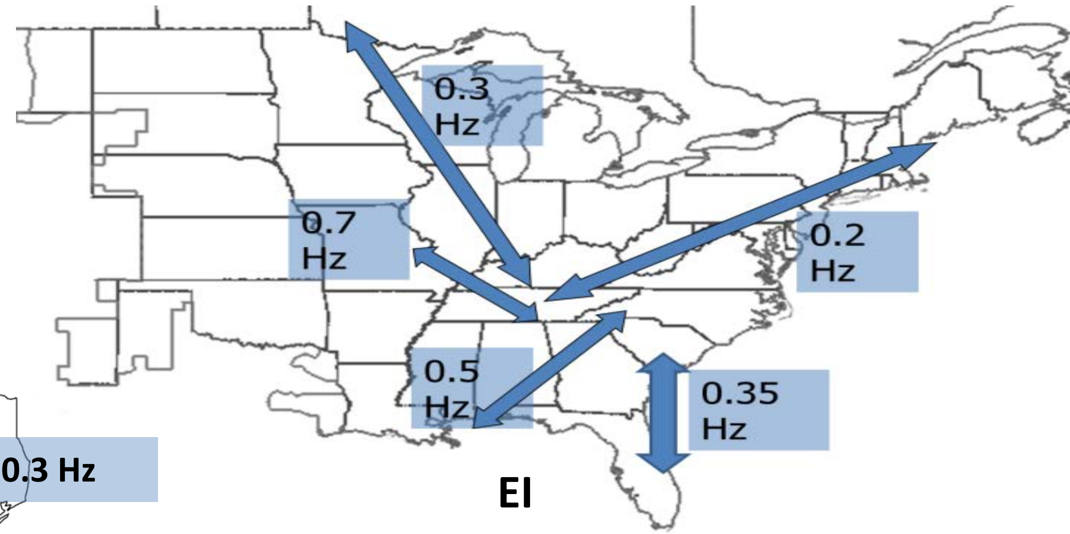
# Oscillation Frequencies

## What do they mean for operations?

### Typical Inter-Area Frequencies



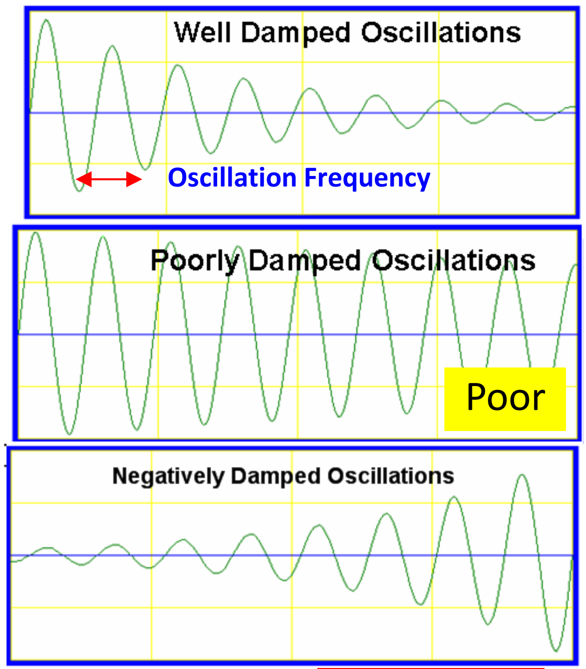




| Frequency | Footprint | Action |
|---|---|---|
| 0.01 Hz to 0.8 Hz | Wide Area | Check Damping |
| 0.8 Hz to 3.0 Hz | Local Area (BA) | Check Generator Controls |
| 3.0 Hz to 10Hz | Wide or Local Area | Check DC/FACTS Devices |

# Characterizing Oscillations
## Frequency and Damping

### Oscillatory Frequency & Damping Interpretation

Desirable Condition



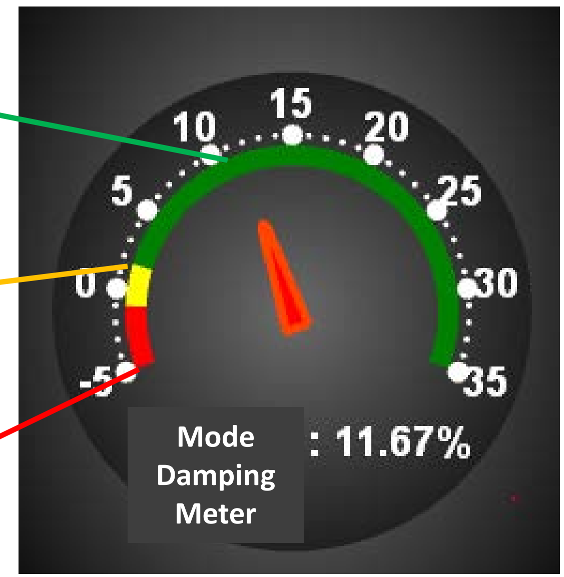

Dangerous

**Decay Rate (i.e., Damping)**

**Well Damped: 10% or Higher Damping**

**Poorly Damped: Less Than 3% Damping**

**Growing Oscillations- Negative Damping**



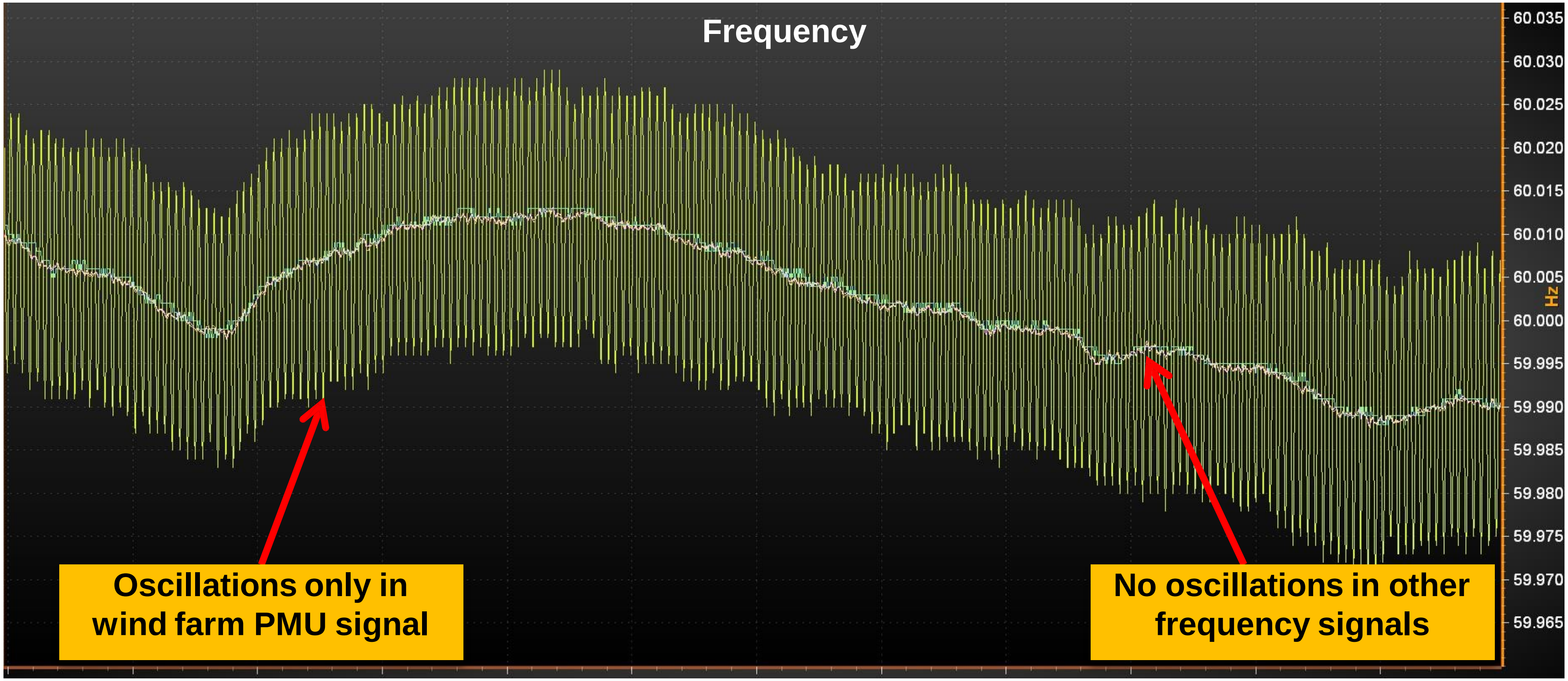

Screenshot of RTDMS – Real Time Dynamics Monitoring System

# Example - Wind Farm Oscillation

- Oscillation Detection
- Diagnostics
- Mitigation

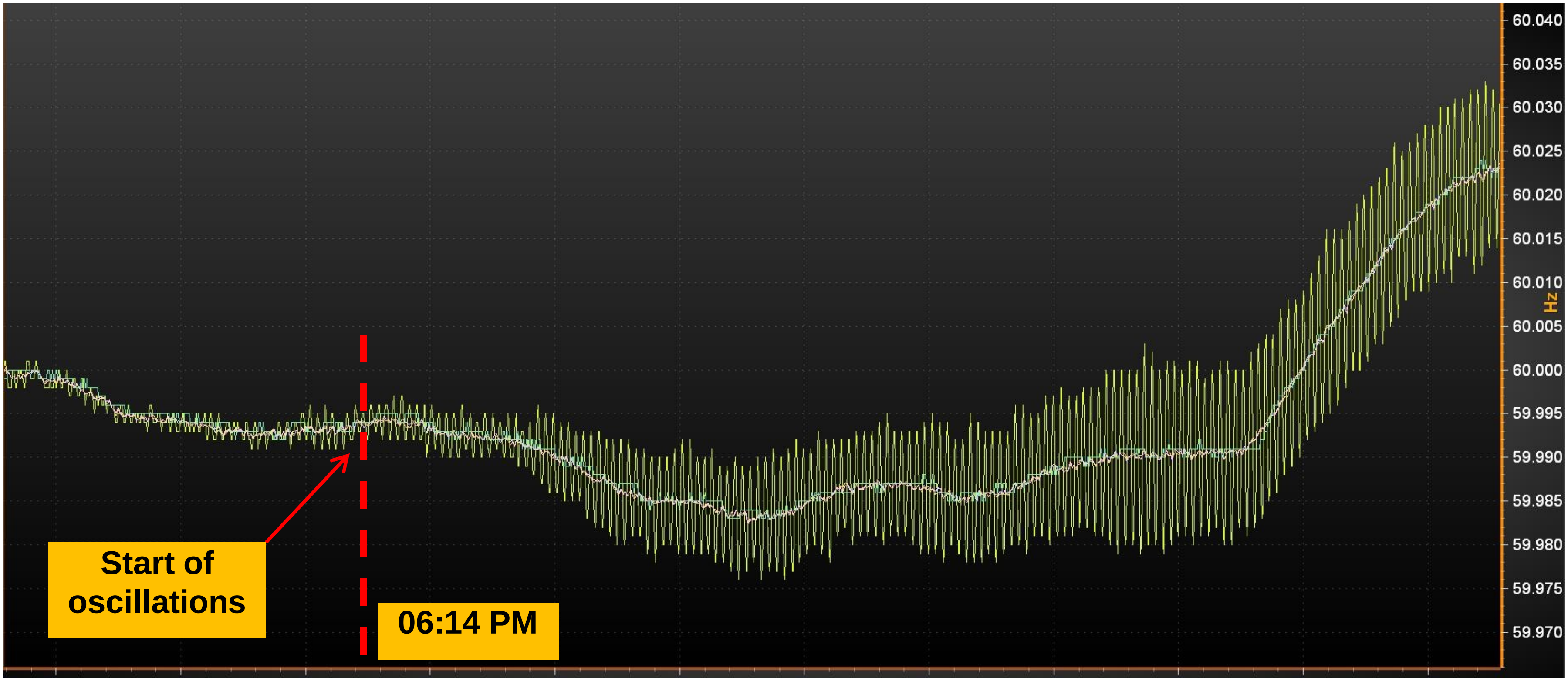
# Wind Farm Oscillation Detection & Mitigation

- Oscillations first observed on RTDMS when it was turned on by an analyst



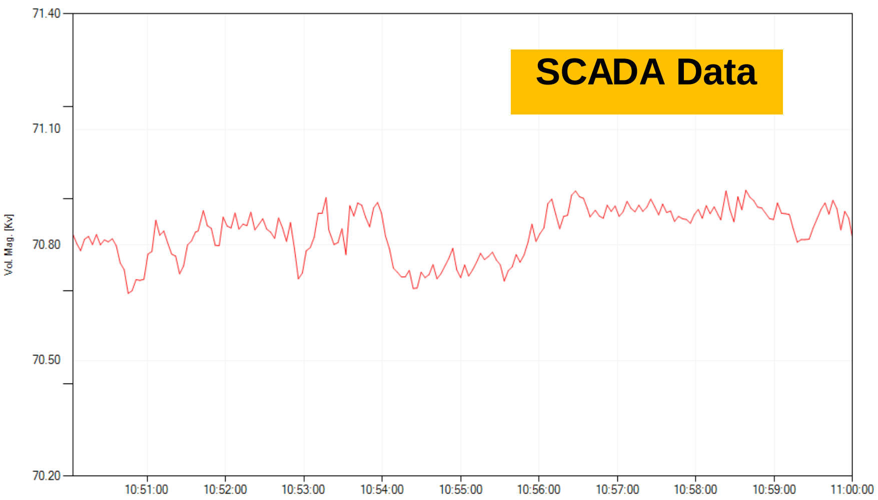

Oscillations observed by operators for first time

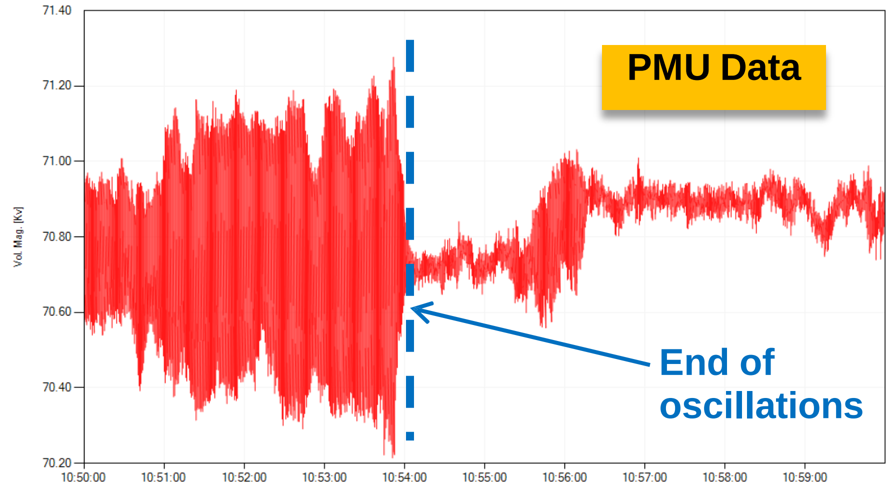
# Rewind/Replay to Determine the Start




- Oscillation started 6:14 p.m. the previous evening
- Not detected/observed on SCADA/EMS for over 14 hours

# Not Observable on SCADA

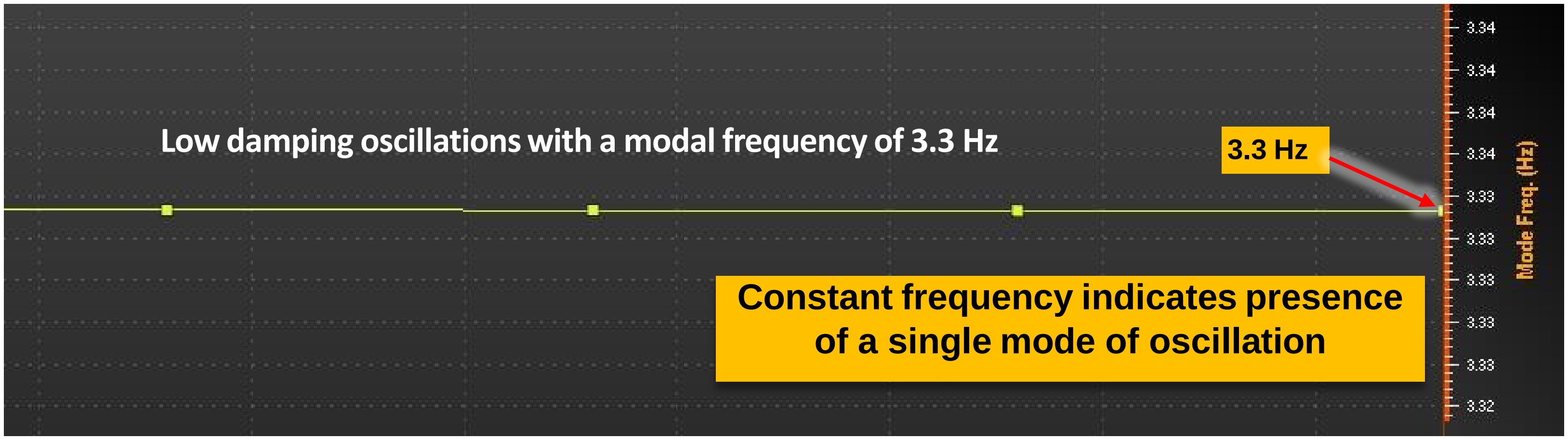


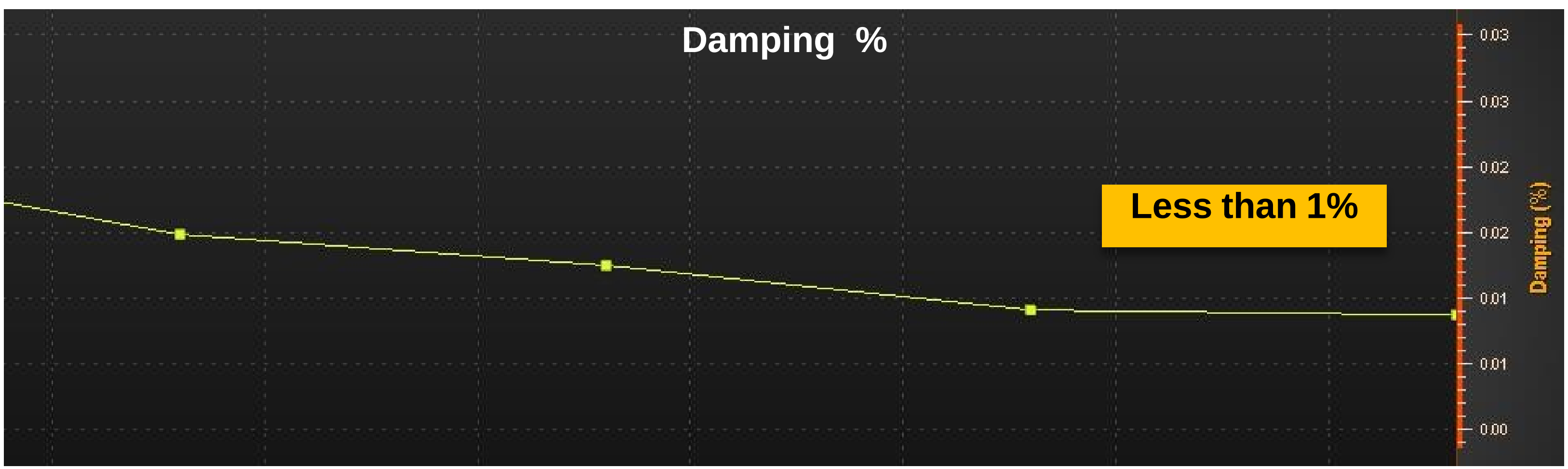




Comparison between voltage signal from the event as captured by SCADA vs. PMU data

- **Observability of oscillations in real-time**
- **Oscillation damping and frequency tracking in real-time**

# Determine Mode Characteristics in Real Time



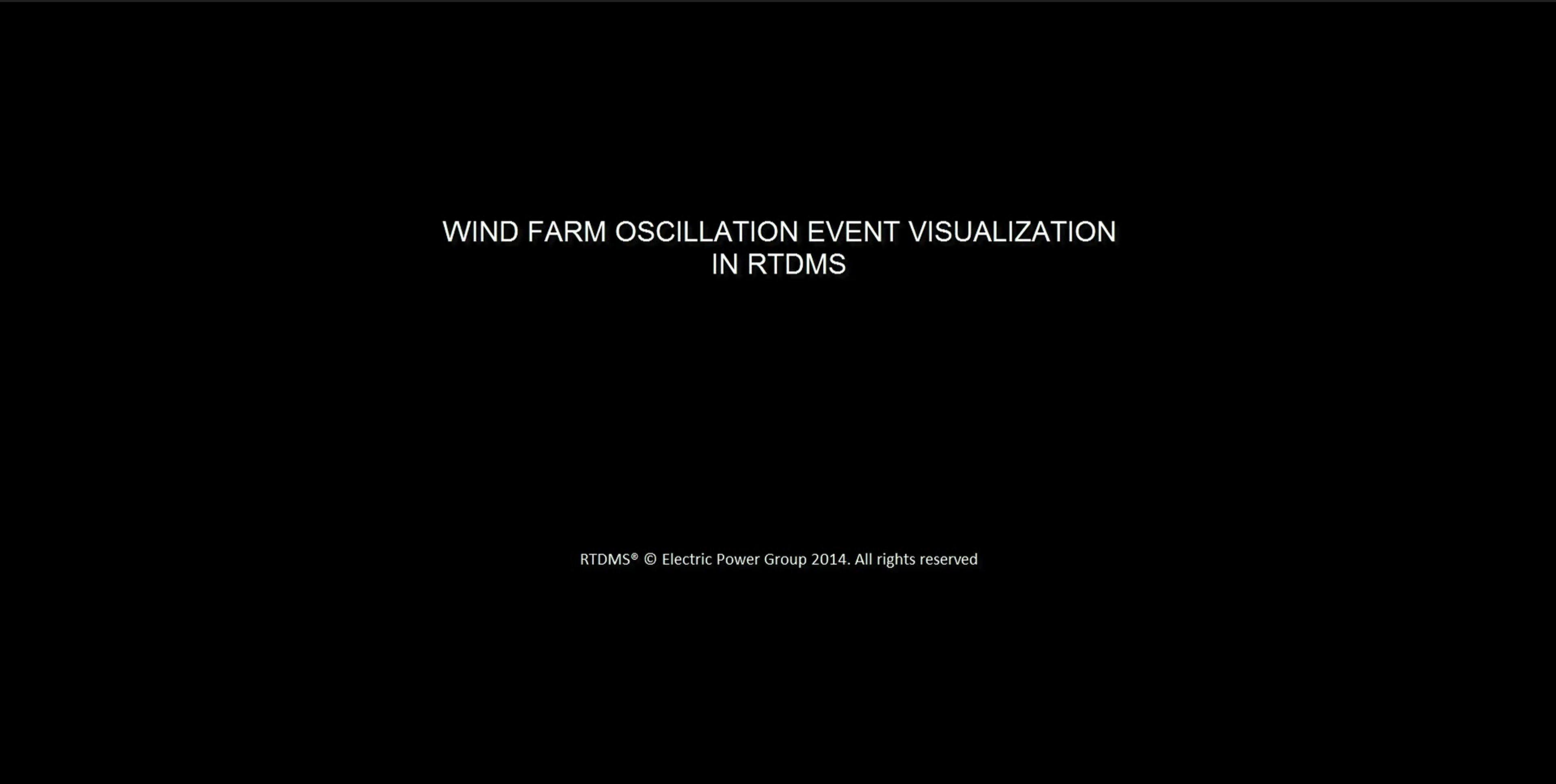
# Most Likely a Local Control Problem

| Oscillation Frequency | Typical Cause |
|---|---|
| 0.01 – 0.15 Hz | Speed Governor |
| 0.15 – 1.00 Hz | Inter - Area |
| **1.00 – 5.00 Hz** | **Local Control** |
| 5.00 – 14.0 Hz | **HDVC / FACTS* Controller** |

- **3.3 Hz oscillations fall under "local control" causes**
- **Indicated local wind farm near the PMU**
- **Helped identify the "root cause".**

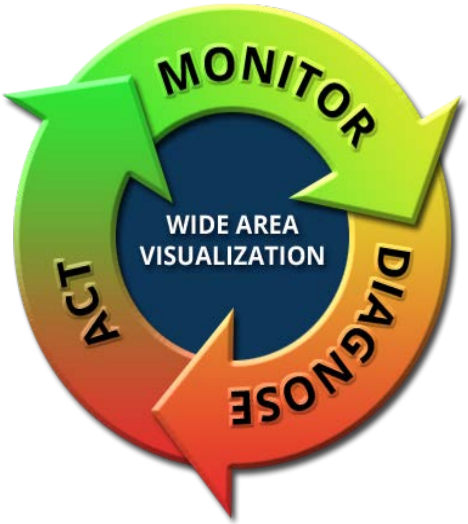
* FACTS: Flexible AC Transmission System

# Wind Farm Oscillation Event Visualization in RTDMS



# Recap - How Synchrophasor Technology can Help Operators in Real-Time Operations

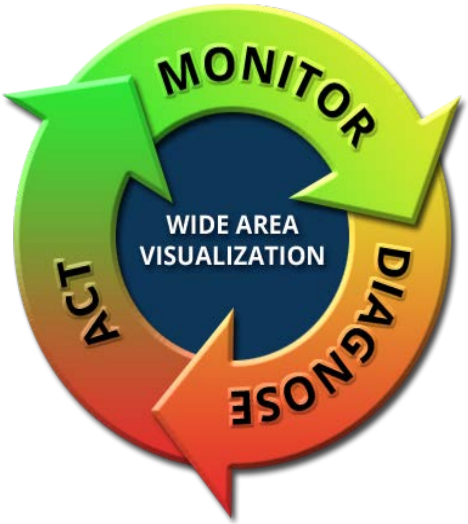
- **Wide Area View – Situational Awareness**
- **Phase Angle Difference**
- **Voltage Sensitivities**
- **Damping and Oscillation**
- **Synchrophasor Technology Enables Operators to:**
  - Monitor Grid Dynamics
  - Integrate Renewables
  - Improve Asset Utilization
  - Prevent Blackouts
  - Enable Faster Recovery



# RTDMS in ERCOT Control Center Overview

# RTDMS Use at ERCOT for Real-Time Operations

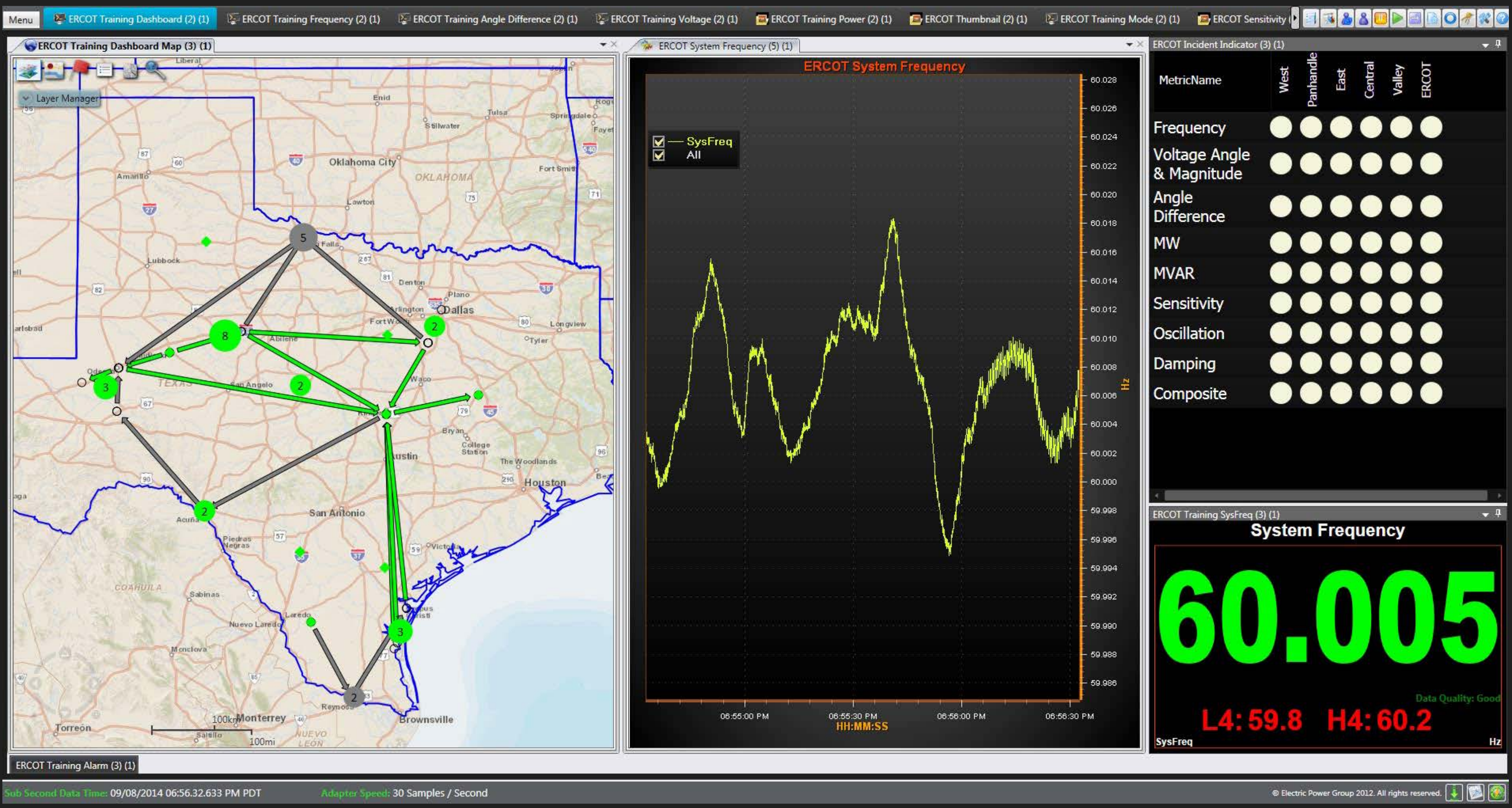
- **Wide Area View – Situational Awareness**
- **Phase Angle Difference**
- **Voltage Sensitivities**
- **Damping and Oscillation**
- **RTDMS Uses:**
  - Monitor Grid Dynamics
  - Integrate Renewables
  - Improve Asset Utilization
  - Prevent Blackouts
  - Enable Faster Recovery



# Operator Use of RTDMS

- Wide area monitoring – normal state
- Event detection – alarms
- Diagnose event situation
- Assess system vulnerability

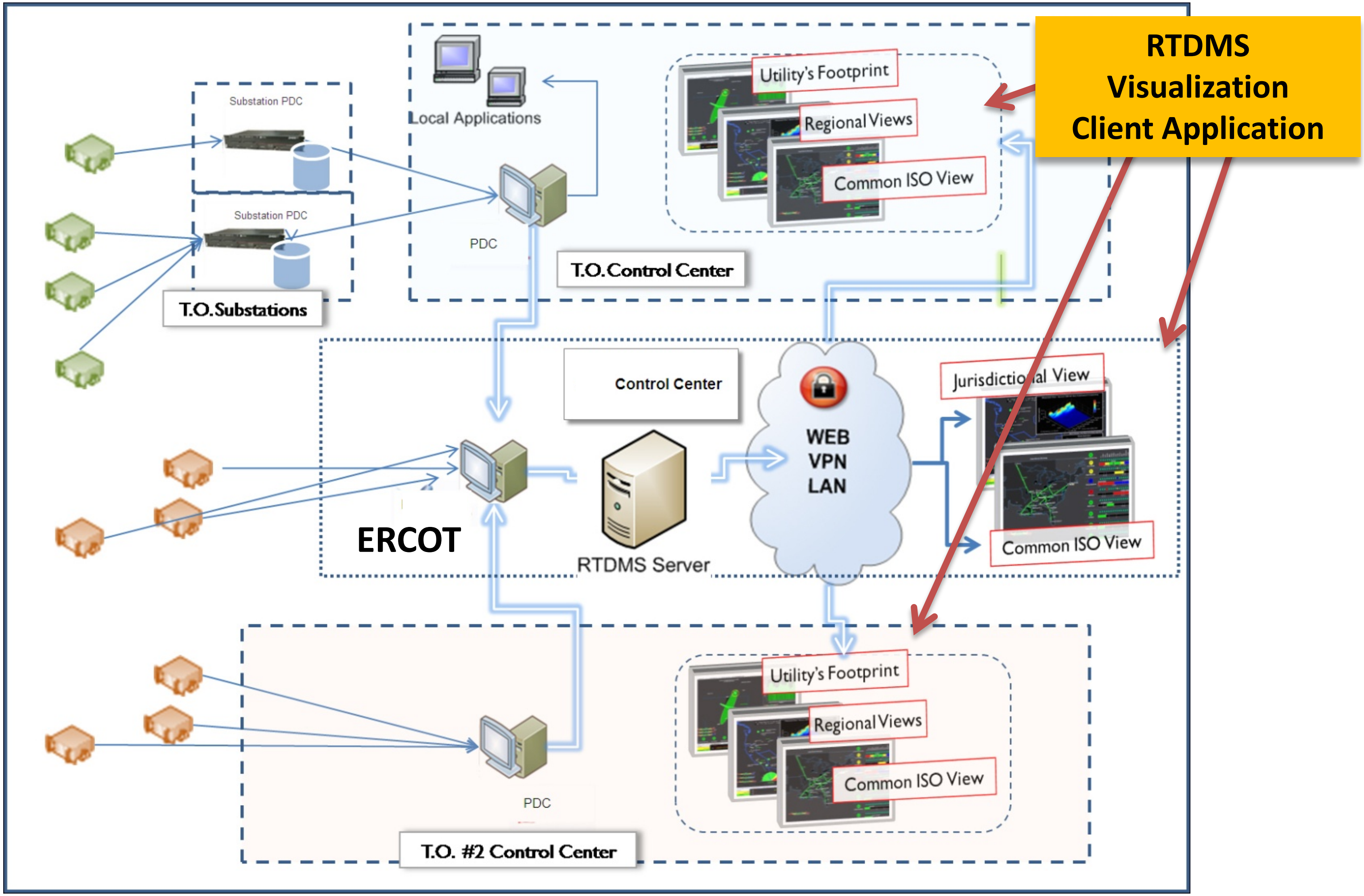
# How to Use RTDMS during Event in Real-Time Operations



# RTDMS Key Applications

1. Wide Area Situational Awareness (Dashboard)
2. Automated Event Analyzer
3. Phase Angle and Grid Stress Monitoring
4. Voltage Stability Monitoring
5. Angular Stability Analysis & Monitoring
6. Flow Gate and Inter-area Power Transfer
7. Frequency Stability Monitoring
8. Oscillation Stability Analysis & Monitoring
9. Oscillation Detection
10. Intelligent Alarms
11. RTDMS Daily Reports / Summary Reports/ Online Reports

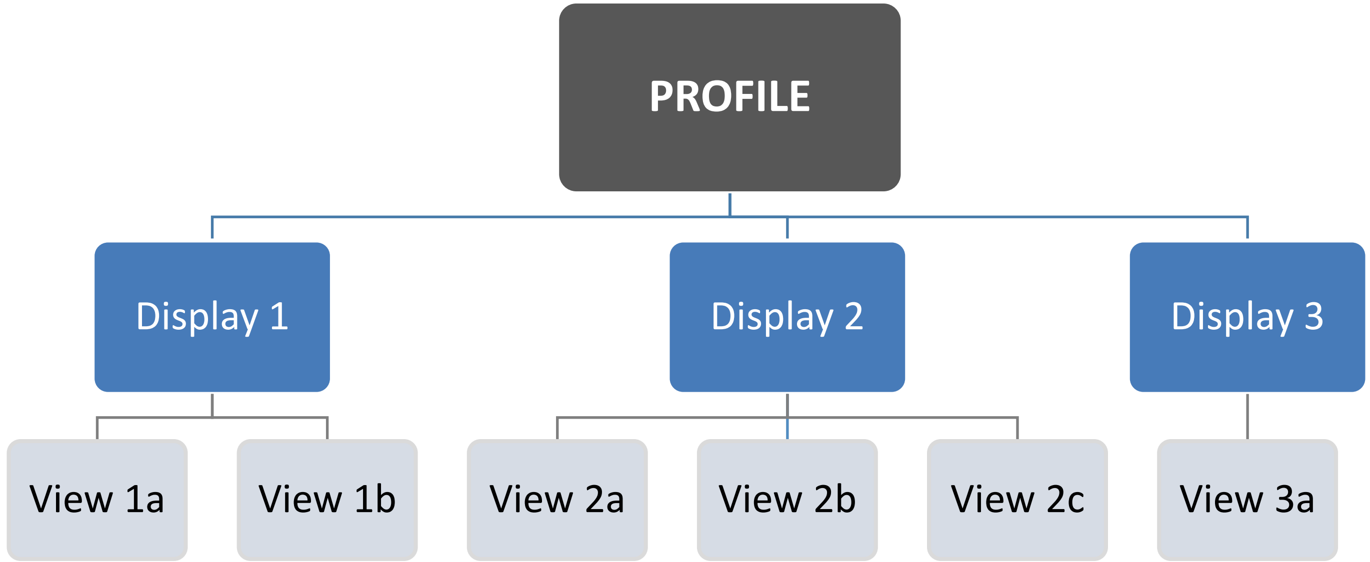
# ERCOT Synchrophasor System Architecture and RTDMS Visualization



# Training on RTDMS Visualization

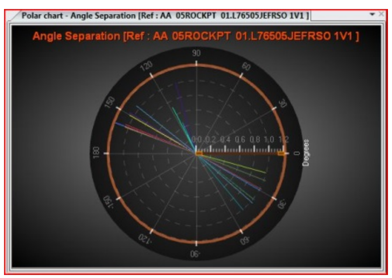
- **Dashboard:** Unified displays and metrics
- **Navigation:** Drill down and root cause assessment
- **Visualization:** Maps, charts, tables of key metrics
- **Alarm:** System conditions, query and acknowledgment
- **Playback:** Event replay for diagnostics and training

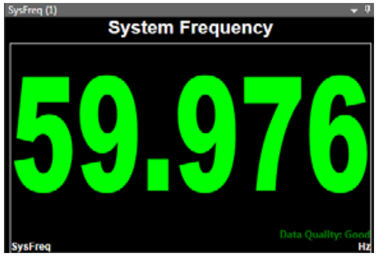
# RTDMS Client Visualization Hierarchy

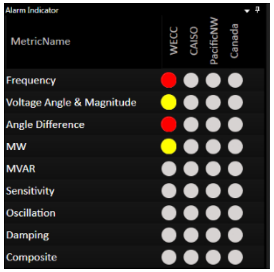


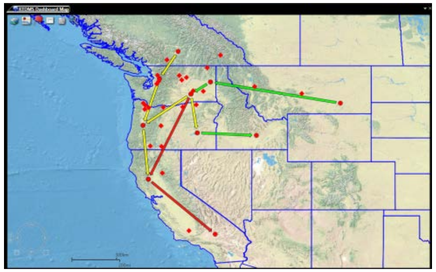
# What is a View?

- A view is a single frame or chart of visual representation
- Examples of views
  - Polar chart, Bar chart, Trend chart, Alarm panel, Map,etc.



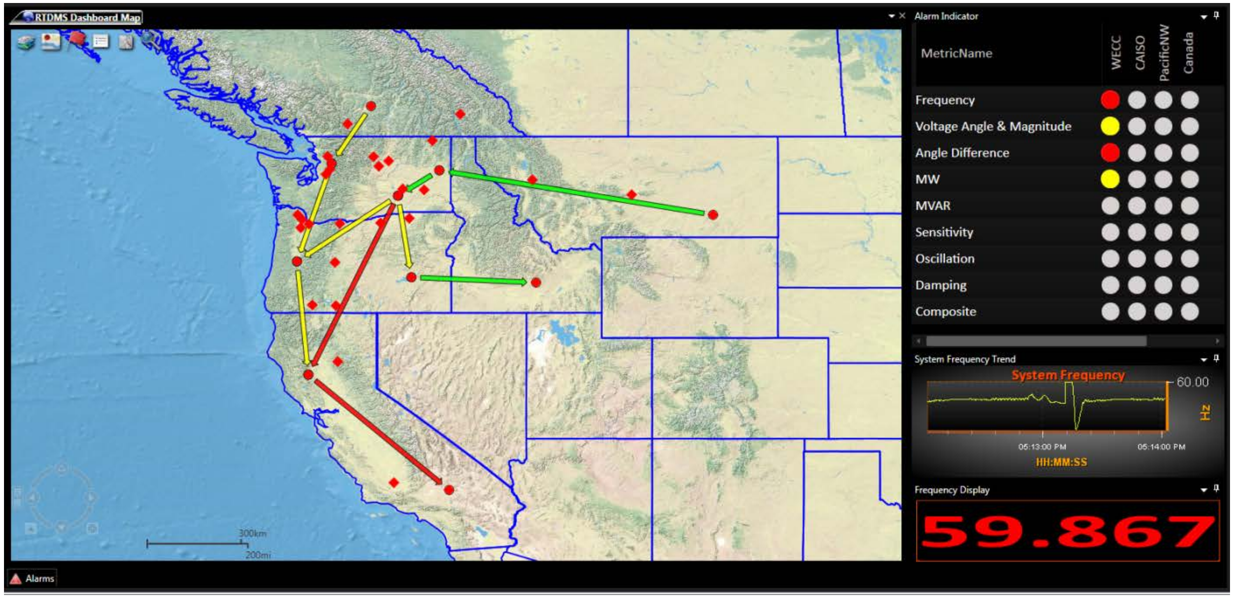



# What is a Display?

- A display is a combination of views that together,  in a meaningful way to provide related information

- Displays may be variety of different types of “views” including charts, maps, incident indicators, alarm grid, etc.

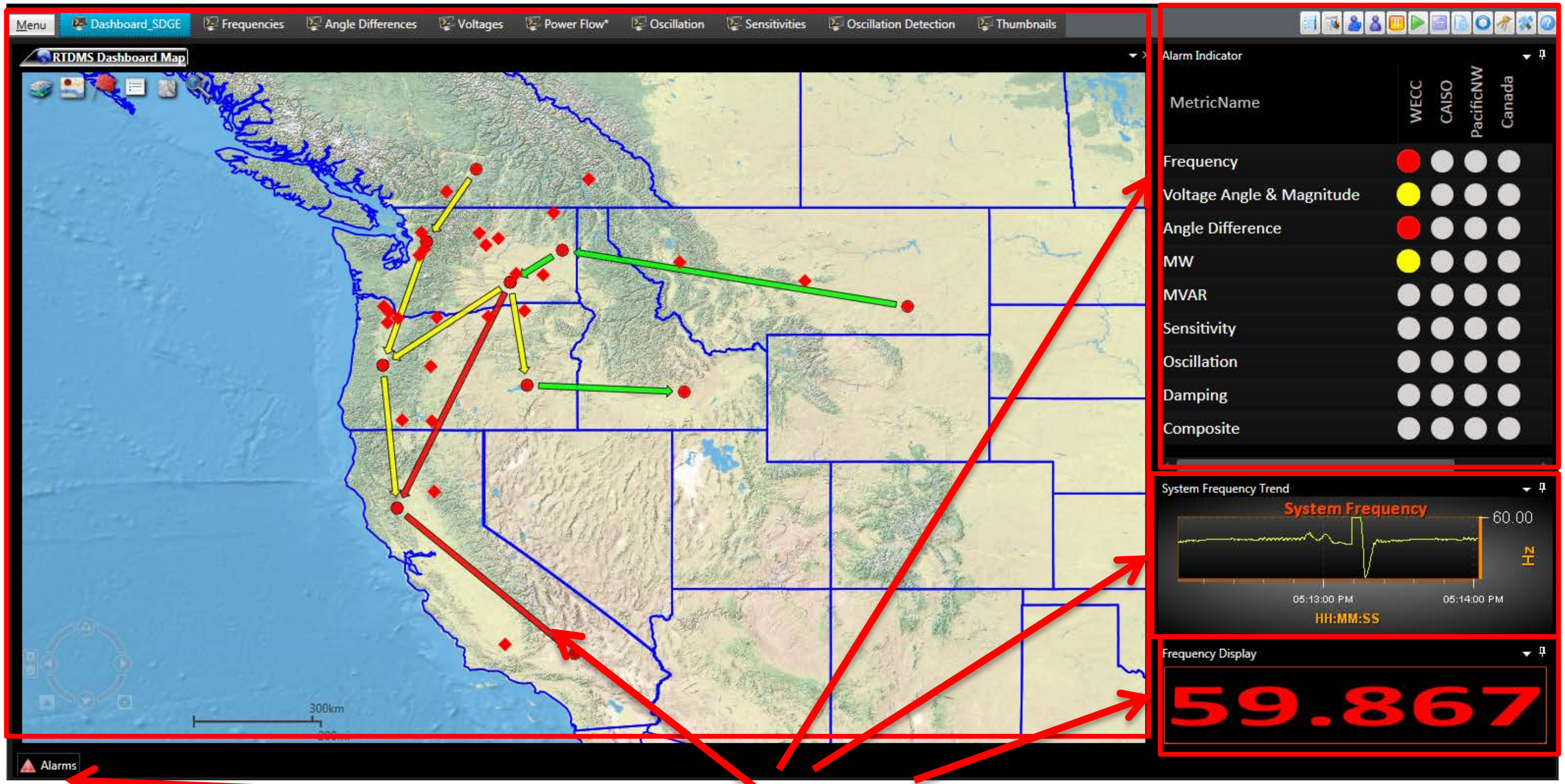



*The Dashboard is a special kind of display that combines geo-spatial, alarms, key metrics etc.*

- Displays are arranged as “tabs”, in the display toolbar.

# Visualization - Profiles, Displays and Views

One or More Displays Make Up A Profile

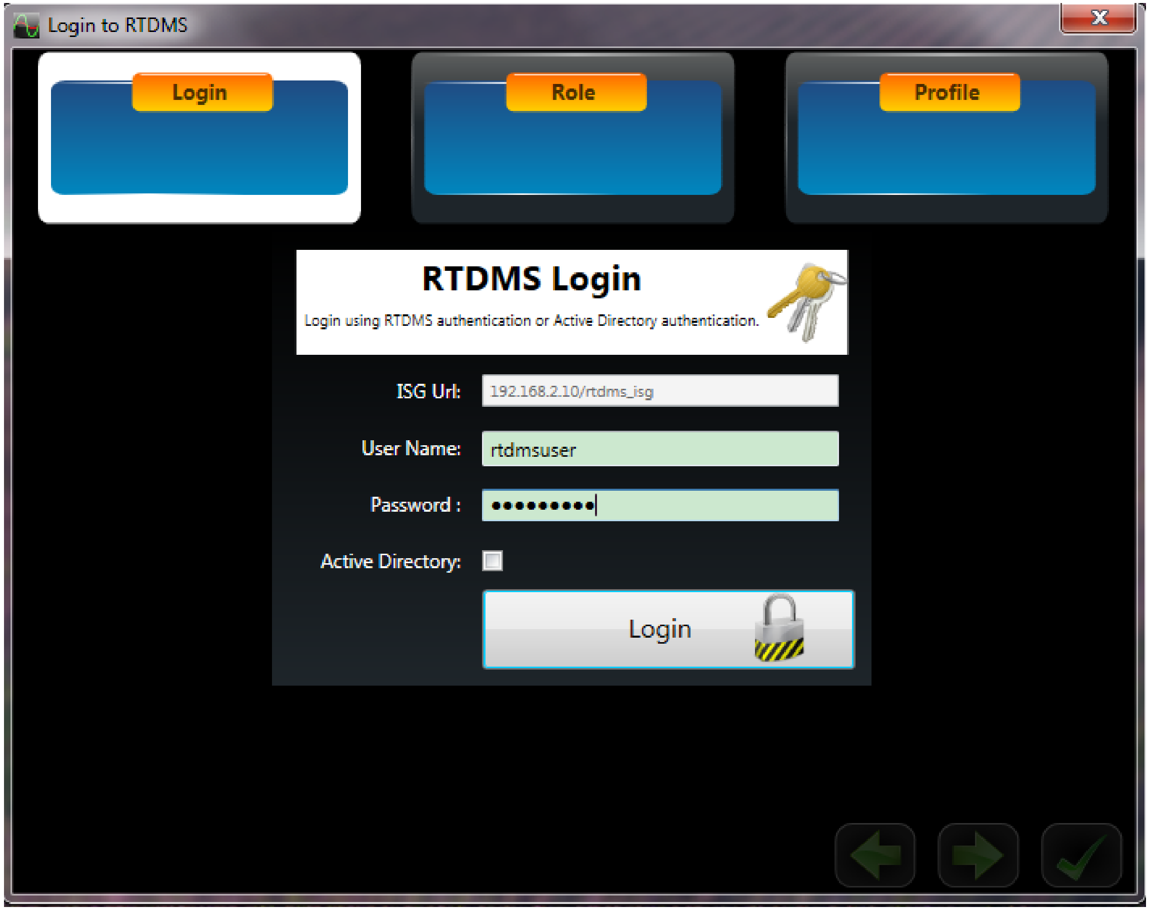



One Or More Views Make Up A Display

# Pre Configured ERCOT Displays in RTDMS (use this)

- ERCOT Training Profile
  - Dashboard
    - Geospatial
    - Alarm Panel
    - System Frequency
    - Incident Indicator
  - Frequency
    - Frequency nearby Gen and Load
    - Selected Frequencies
  - Angle Difference
    - Polar Chart
    - Trend: Angle Differences
  - Voltage
    - Geospatial
    - Trend: Different kV Levels
    - Trend: Per Unit by region
  - Oscillation
    - Mode Trend
    - Mode Damping Gauges
  - Thumbnail
    - System Frequency
    - Selected Frequency
    - Angle Differences
    - Voltages
    - Power Flow

# Loading the Training Profile



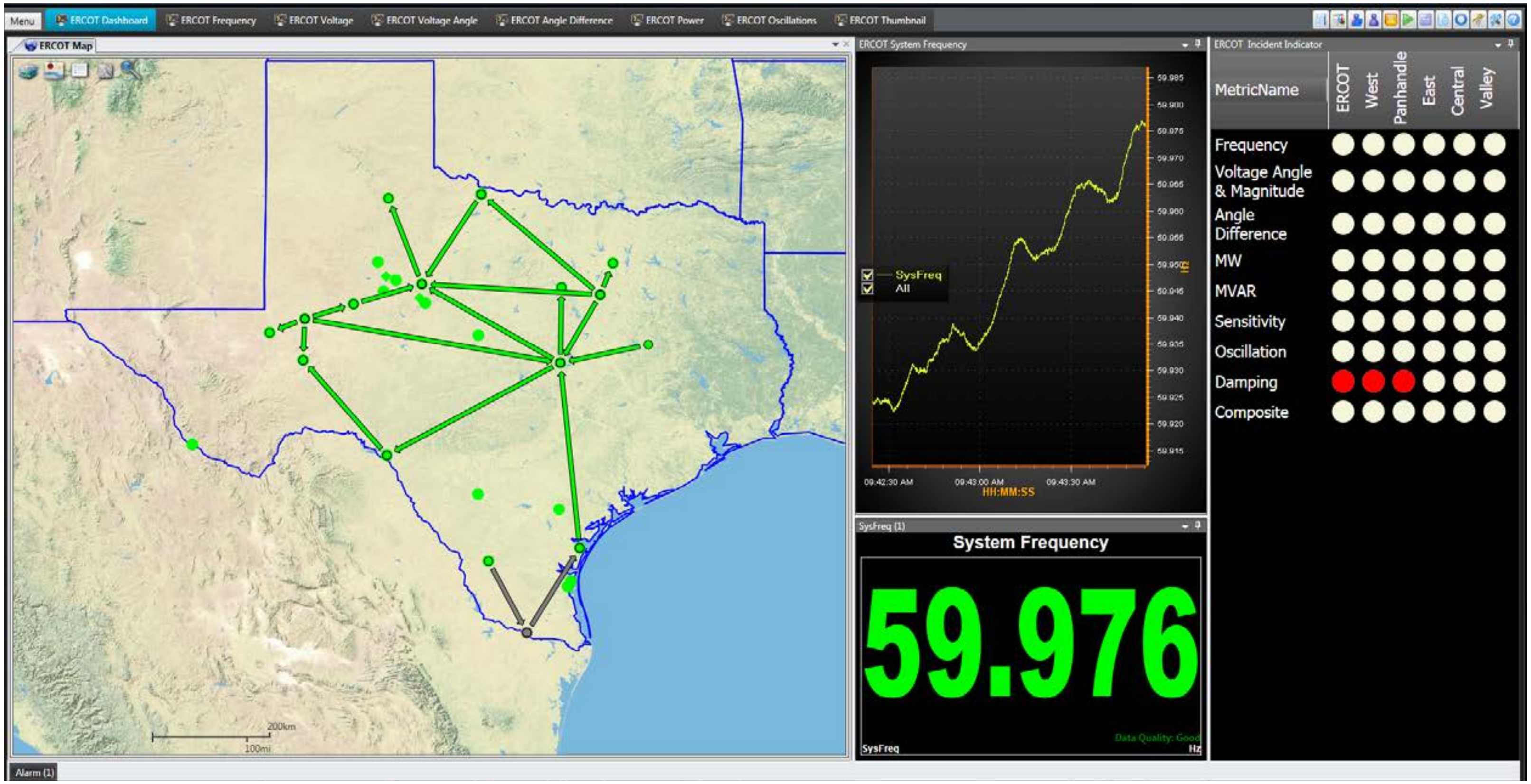

Username: rtdmsuser
Password: rtdms1234

# Navigating RTDMS

# Navigating RTDMS

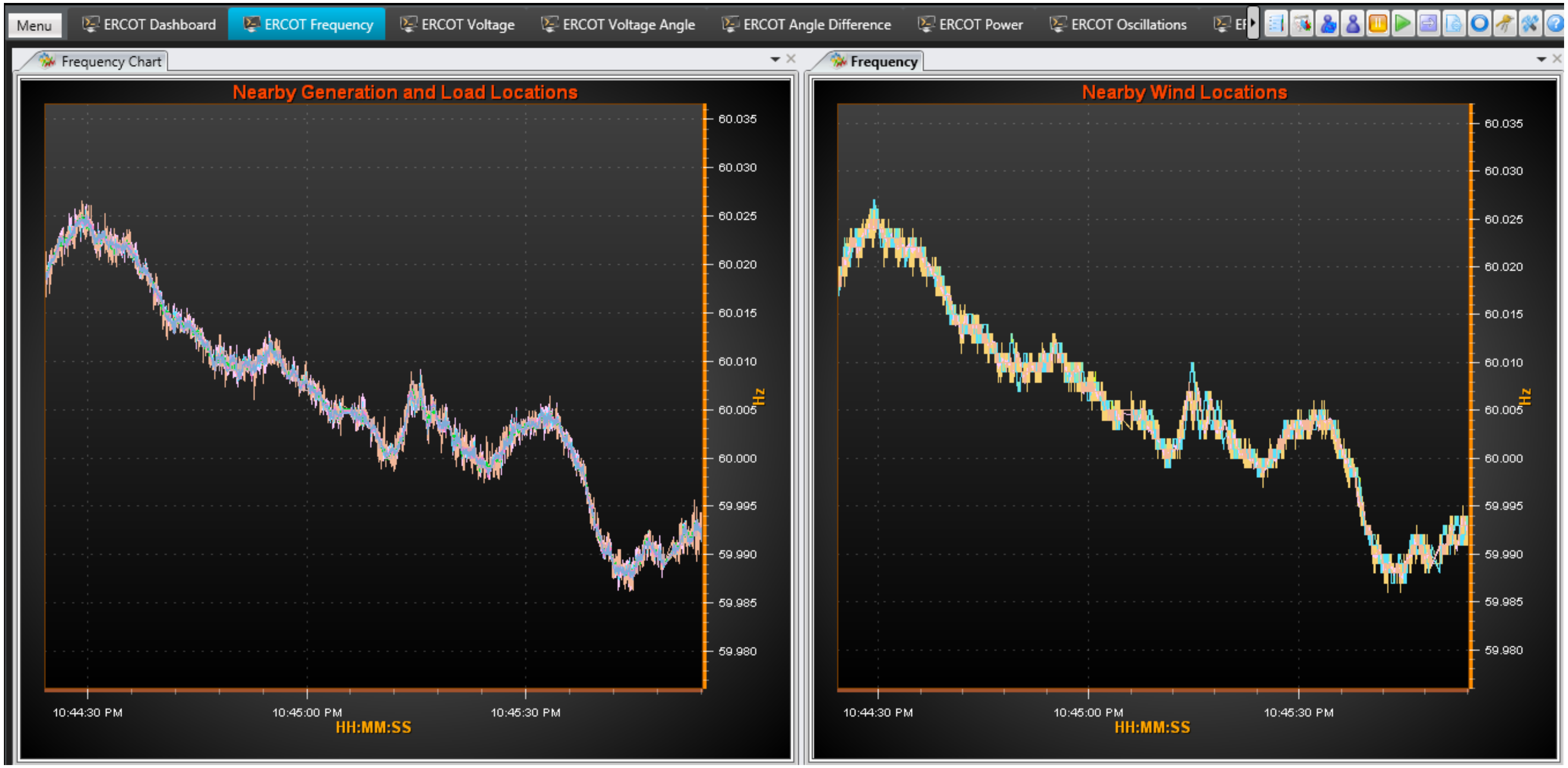
- **What will be covered:**
  - Dashboard
  - Displays
    - Frequency Monitoring
    - Voltage Angle Difference Monitoring
    - Voltage Magnitude Monitoring
    - Power Flow Monitoring (Active & Reactive)
    - Thumbnails
  - Layout Options
- **Navigation Actions**
  - Change display layout
  - Close and open displays, dock

# Dashboard




- Map - Wide Area View
- System Frequency
- Incident Indicator
- Alarm Panel – Auto Hidden
- Click Frequency Tab to Switch to Frequency Display

# Frequency Display

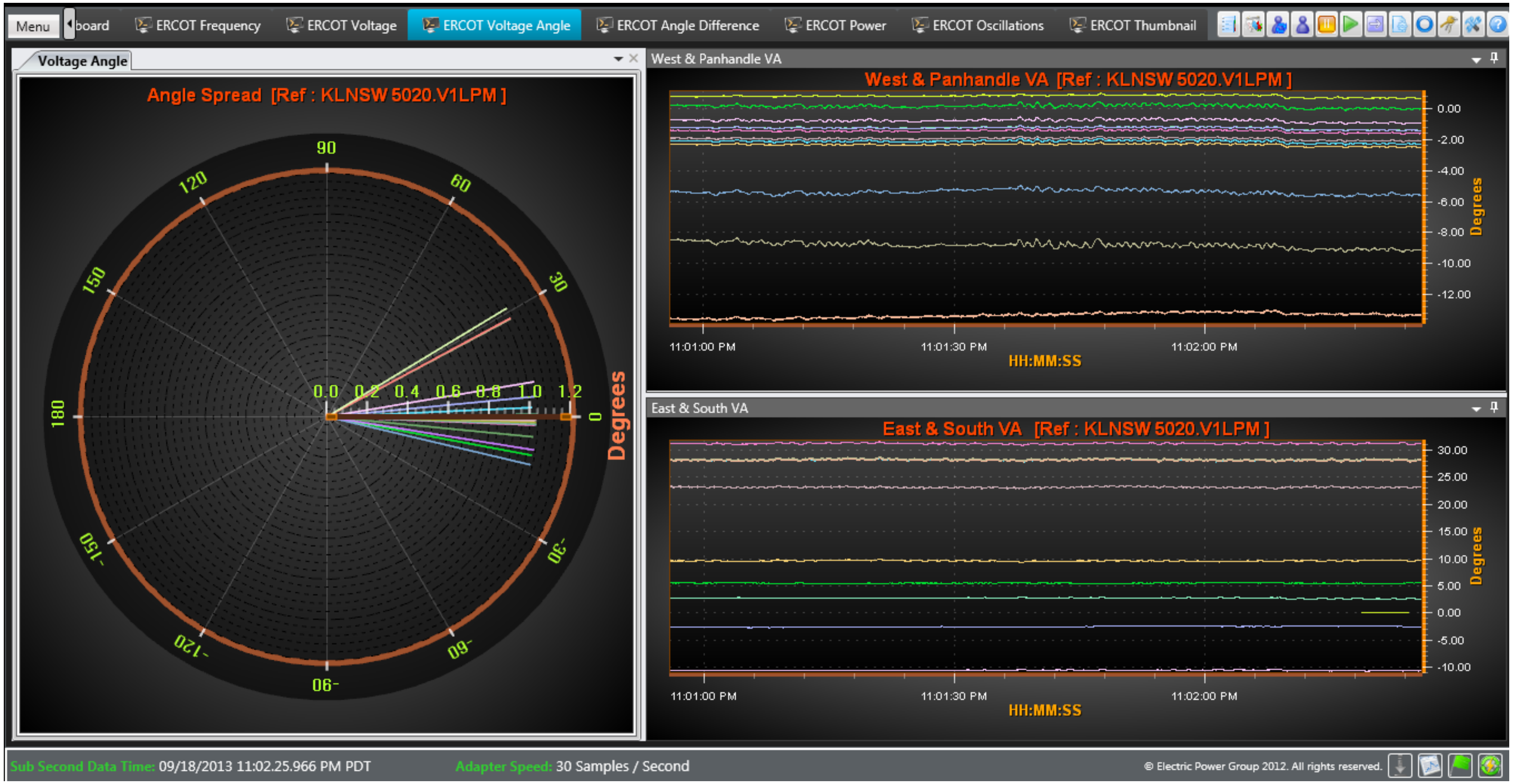



- PMU Frequency near Generation and Load Center
- PMU Frequency near Wind Farm
- Click Voltage Tab to Switch to Voltage Display

# Voltage Display

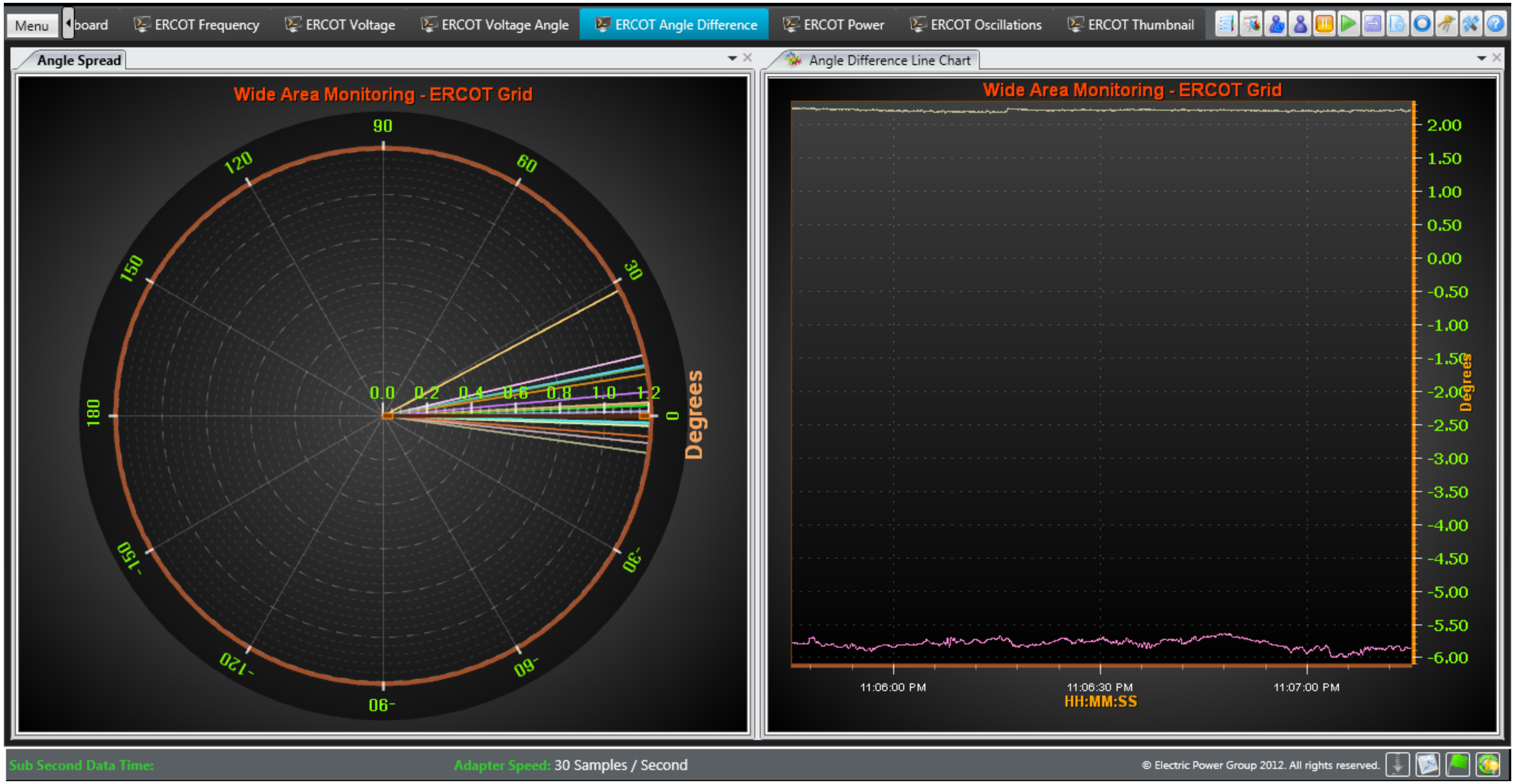

- Voltage Magnitude - Grouped by Voltage Levels
- Voltage Magnitude in Per Unit – Grouped by Region
- Click Voltage Angle Tab to Switch to Voltage Angle Display

# Voltage Angle Display




- Polar Chart - Phasor Representation of Voltage Angles to Common Angle Reference
- Trend Charts – Grouped by Region
- Click Angle Difference Tab to Switch to Angle Difference Display

# Angle Difference Display

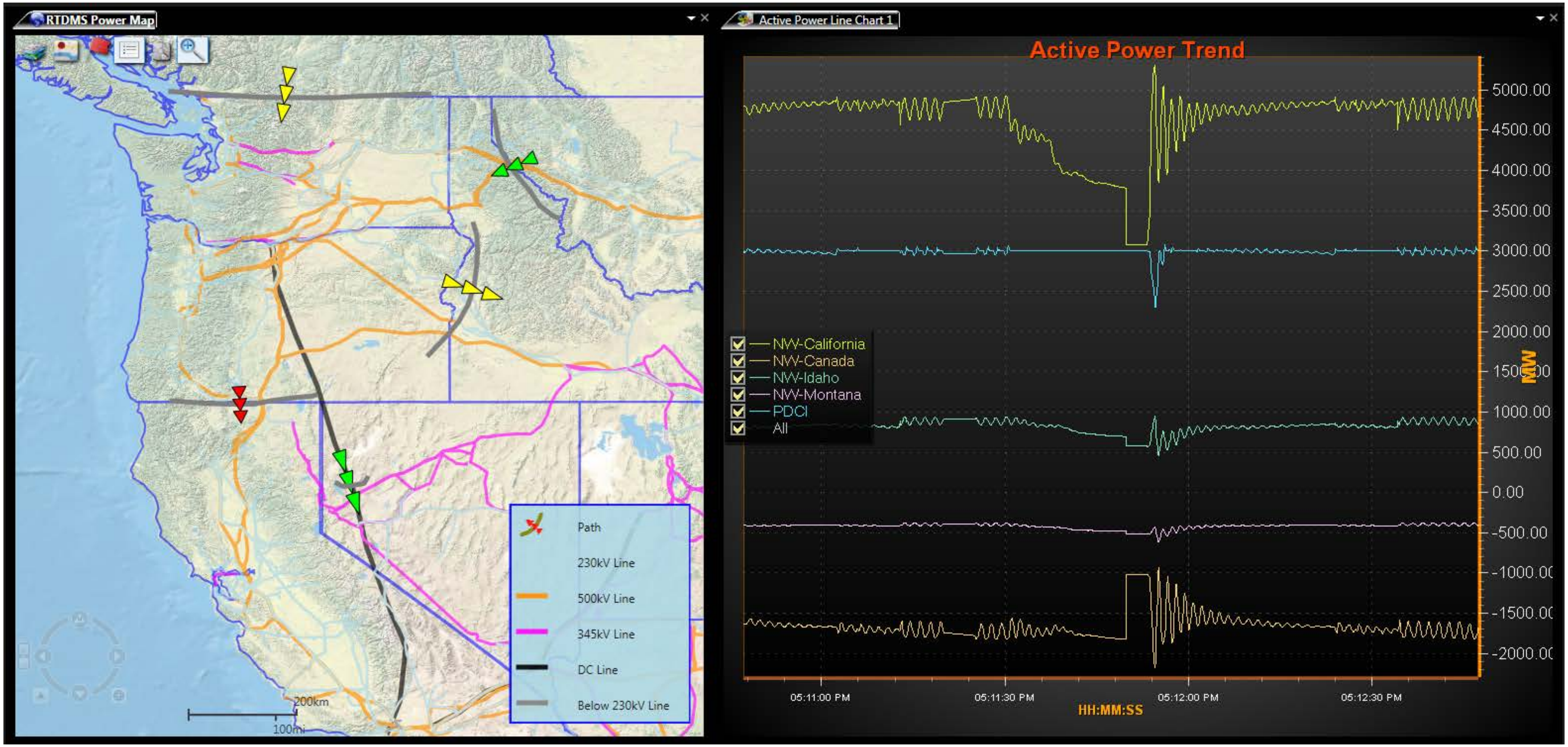



- Polar Chart - Phasor Representation of Angle Differences
- Trend Chart - Phase Angle Differences across Key Flow Gates and Angle Pairs
- Click Power Tab to Switch to Power Display

# Power Display


- Monitor actual MW and MVAR flows along a transmission line or across a flowgate
- Track flows with respect to predefined thresholds

# Power Flows



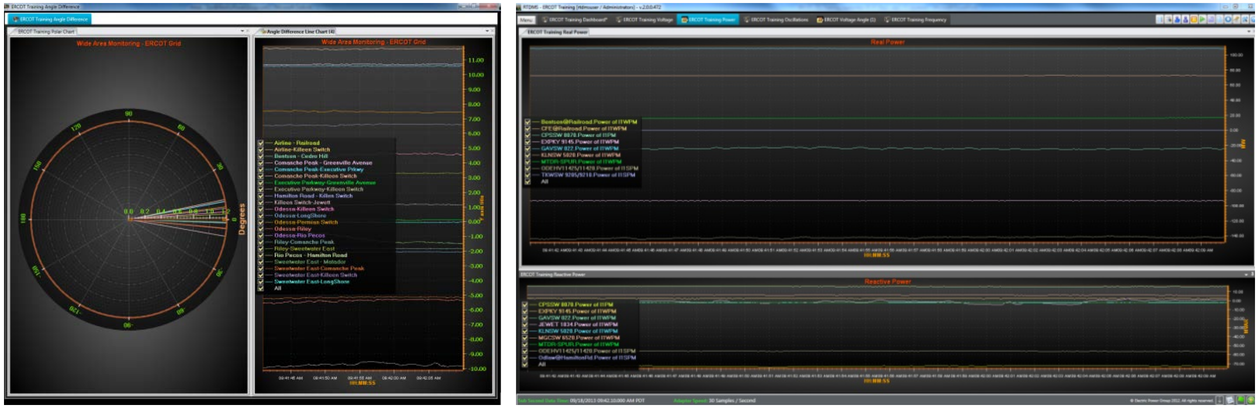

- **Monitor actual MW and MVAR flows along a transmission line or across a flowgate**
- **Track flows with respect to predefined thresholds**

# RTDMS Display Layout Options

**Tile Style**


**Dock Style**


**Multi-Monitor**



# Navigating RTDMS – Hands-on Tutorial

- Navigate through the Dashboard
  - Map view, incident indicator, system frequency trend, numerical value
- Navigate Multi-view display for monitoring
  - Example - Voltage Monitoring:
    - Map View, voltage trend, voltage magnitude bar chart, voltage polar chart
- Change display layout
- Close and open a display

# Understanding RTDMS Views

# Understanding RTDMS Visualization

- **What will be covered:**
  - What does each view mean
  - Work with different views
  - Edit views' properties

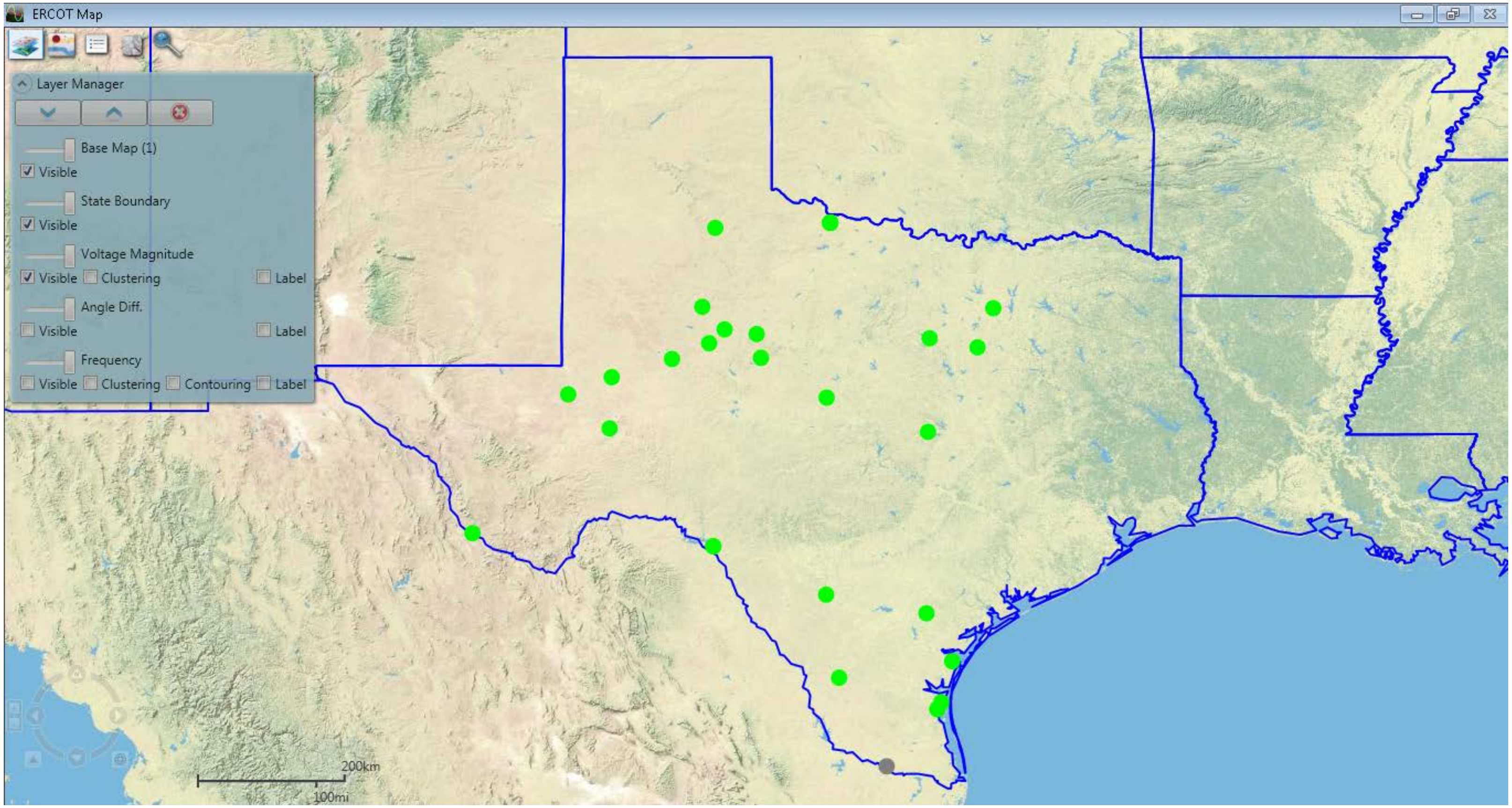
# Working with Views

- **Multi-layered Map Views**
- **Standard Views & Charts**
  - Trend Charts
  - Polar Charts
  - Numerical
  - Incident Indicator
- **Other Visualizations Available**
  - Bar Graphs
  - Contours
  - User Definable Scatter Chart
  - Double Y Axis Charts

# Understanding Map Views

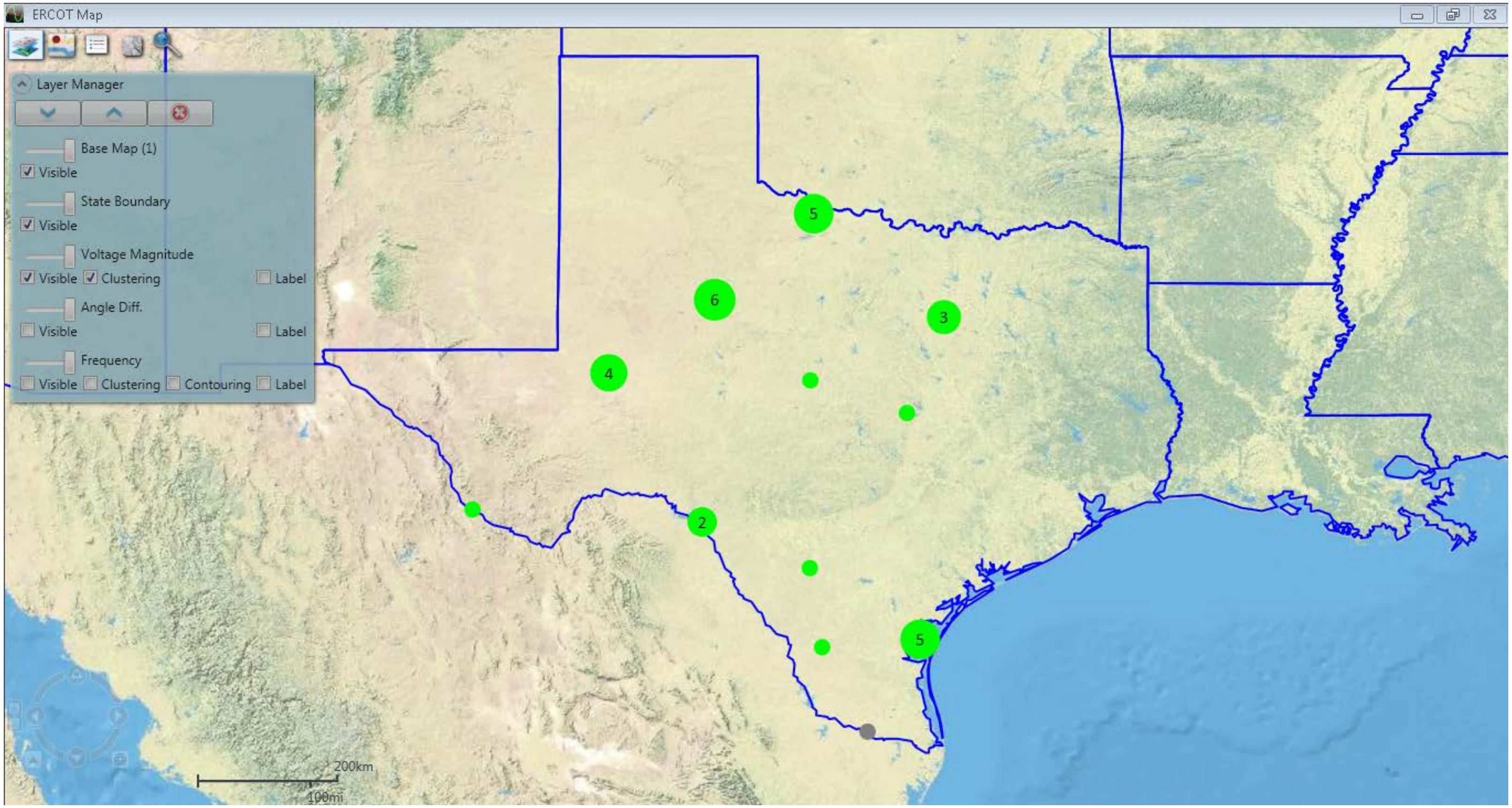
- **Map Layer Elements**
  - General order of map layers
    - Base map, e.g., topography, street view, etc.
    - Shape files, e.g., state boundaries, ISO boundaries, Transmission zones, Transmission lines, etc.
    - Measurements, e.g., frequency, voltage, power flow, etc.
    - Other, i.e., weather, fire, traffic, lightening, etc.
- **Managing Map Views**
  - Toggle on/off layers
  - Adjust layer transparency
  - Zoom Levels
  - Clutter Management – PMU Clustering

# Map View (Voltage)




- **Bird's-eye view of the high and low voltage regions**
- **The color of the Voltage Signals on the map reflects how close the voltage magnitude is to the alarm threshold value**
  - Green – Normal
  - Grey - Invalid

# Map View (Voltage Cluster)

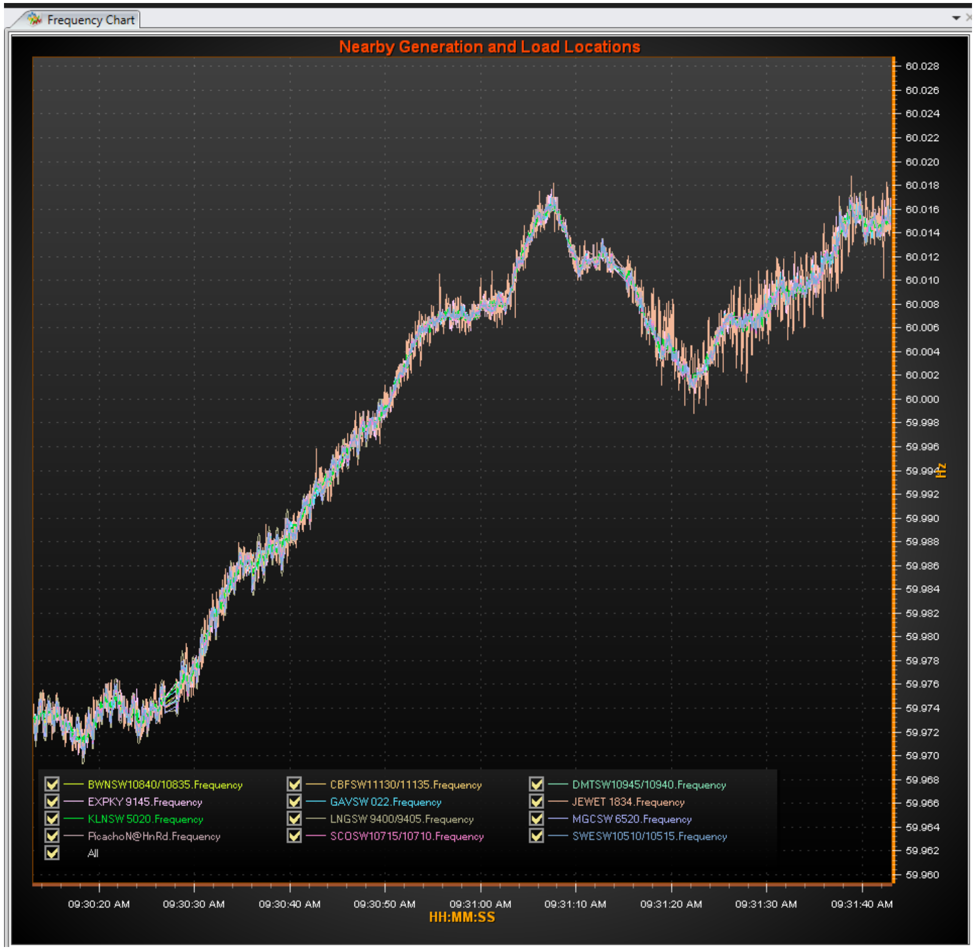



- Voltage Magnitude (Clustered) view displays together the voltage measurements in closer geographic proximity
- Number on the cluster is the number of measurement points clustered
- Color of the cluster is determined by the worst voltage measurement (closer to threshold)

# Understanding Views

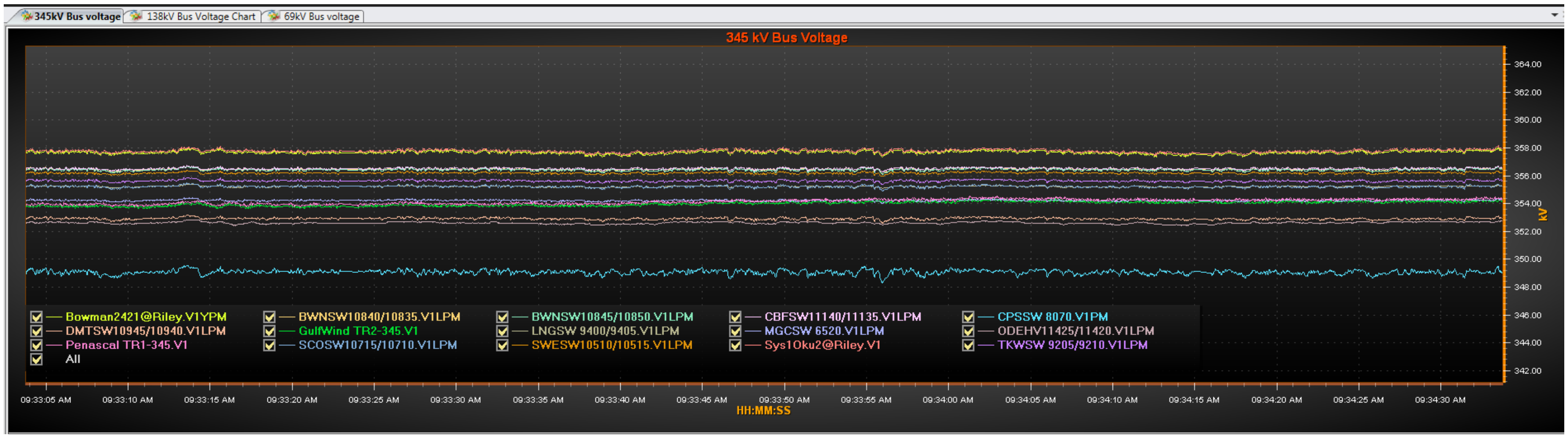
- Trend Chart (Frequency)
- Trend Chart (Voltage)
- Voltage Magnitude and Angle Polar Chart
- Numerical Value
- Incident Indicator

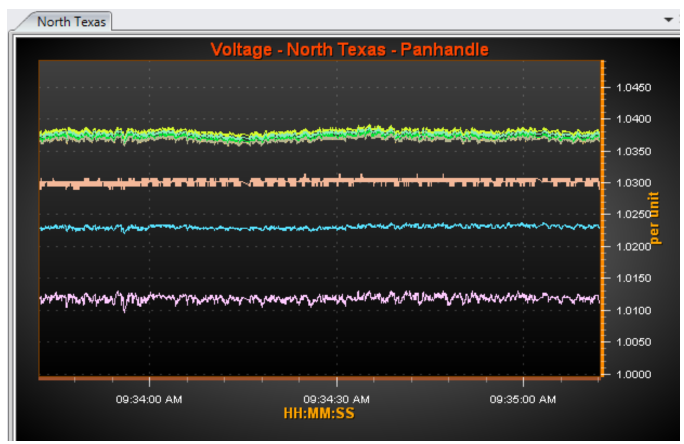
# Trend Chart (Frequency)




- Where the system is operating at
- Where the system has been

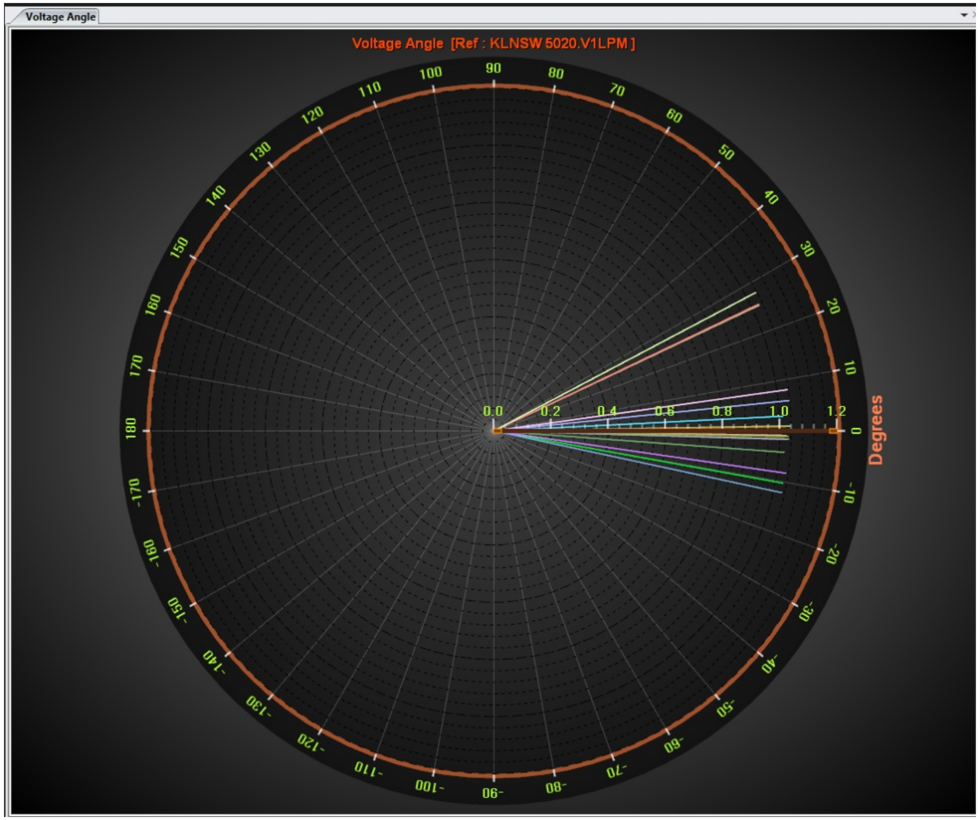
# Trend Chart (Voltage)



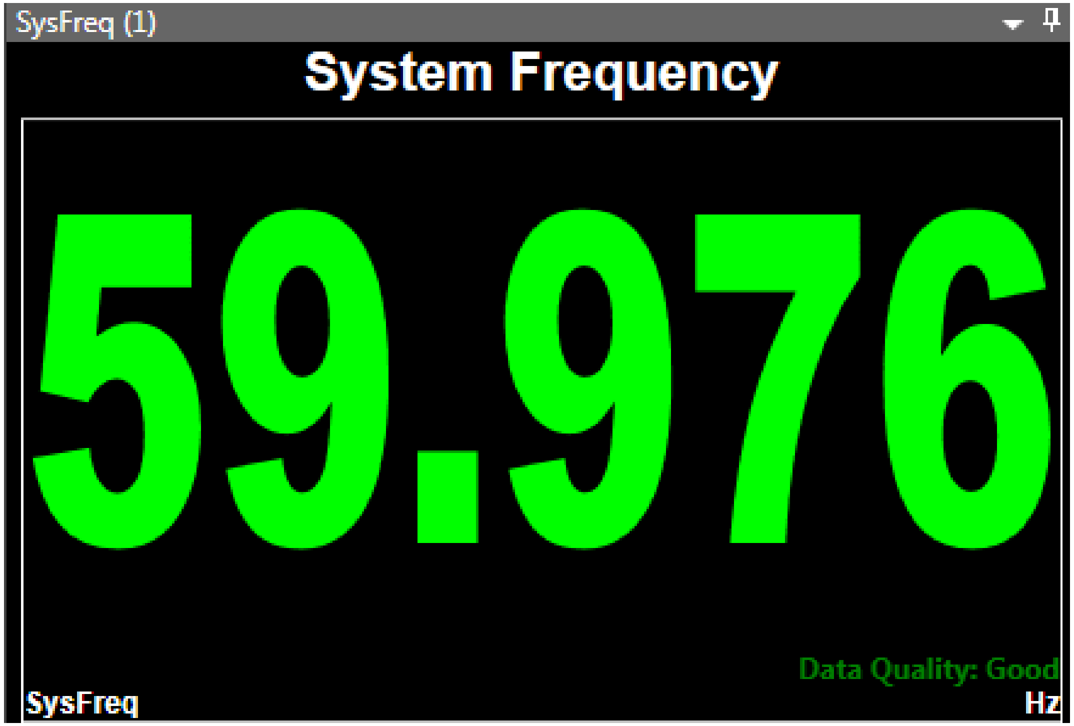

- Tracking Voltage Magnitude over User Selected Time Window
- Absolute Value or Per Unit

# Voltage Magnitude and Angle Polar Chart



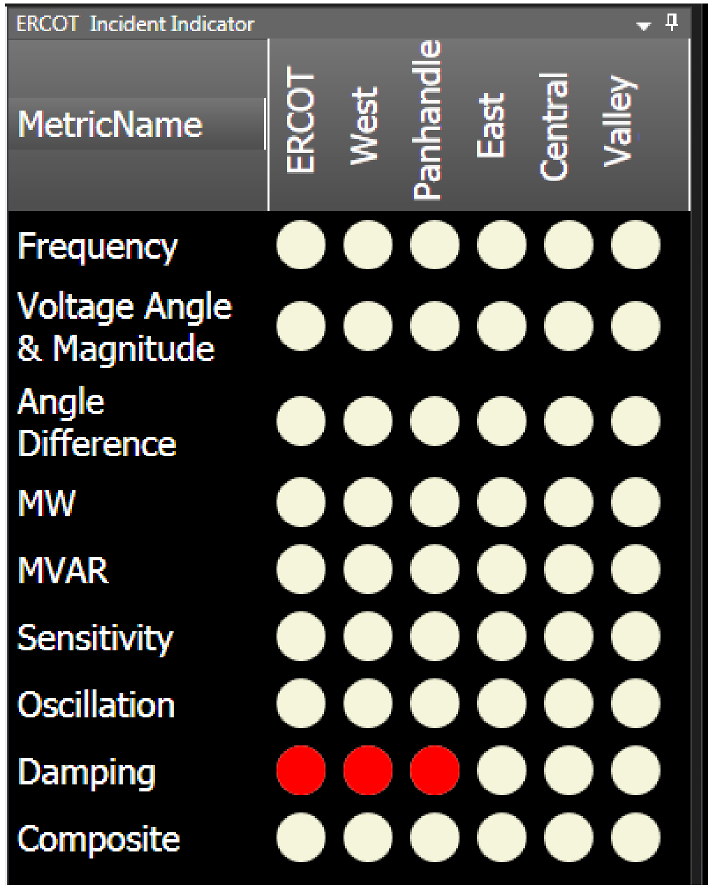

- User selected reference phasor.
- The voltage magnitudes (represented by needle length) are displayed in per unit for easy comparison.
- A large swing in a phasor indicates a system disturbance.

# Numerical Value




- 1-sec average data
- At a Glance
- Color Indication of Alarm Level
- The threshold values are also displayed below the numerical value

# Incident Indicator

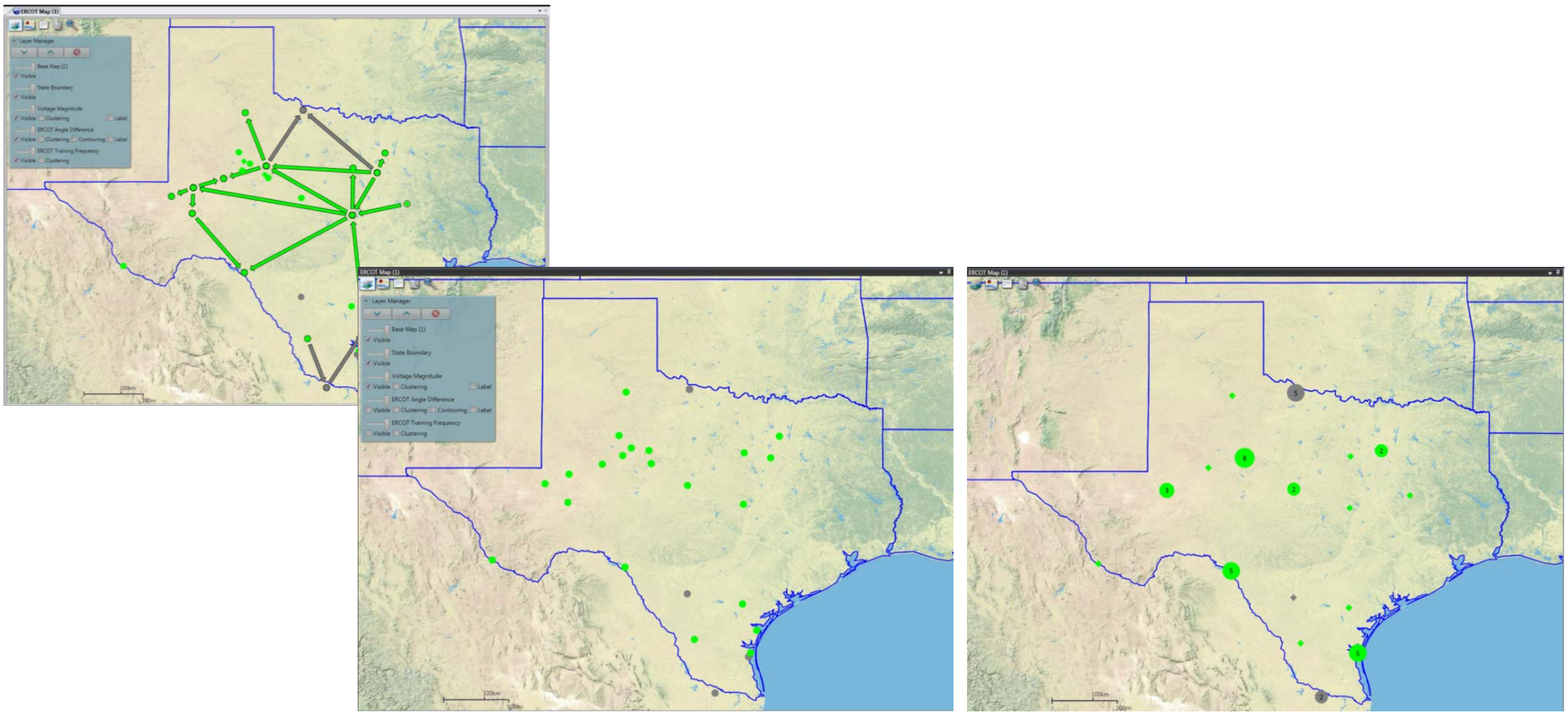



- The Incident indicator groups the PMU measurements into corresponding jurisdiction areas
- The Incident indicator color change to red indicates problem in the corresponding area

# Understanding RTDMS: Hands-On Tutorial

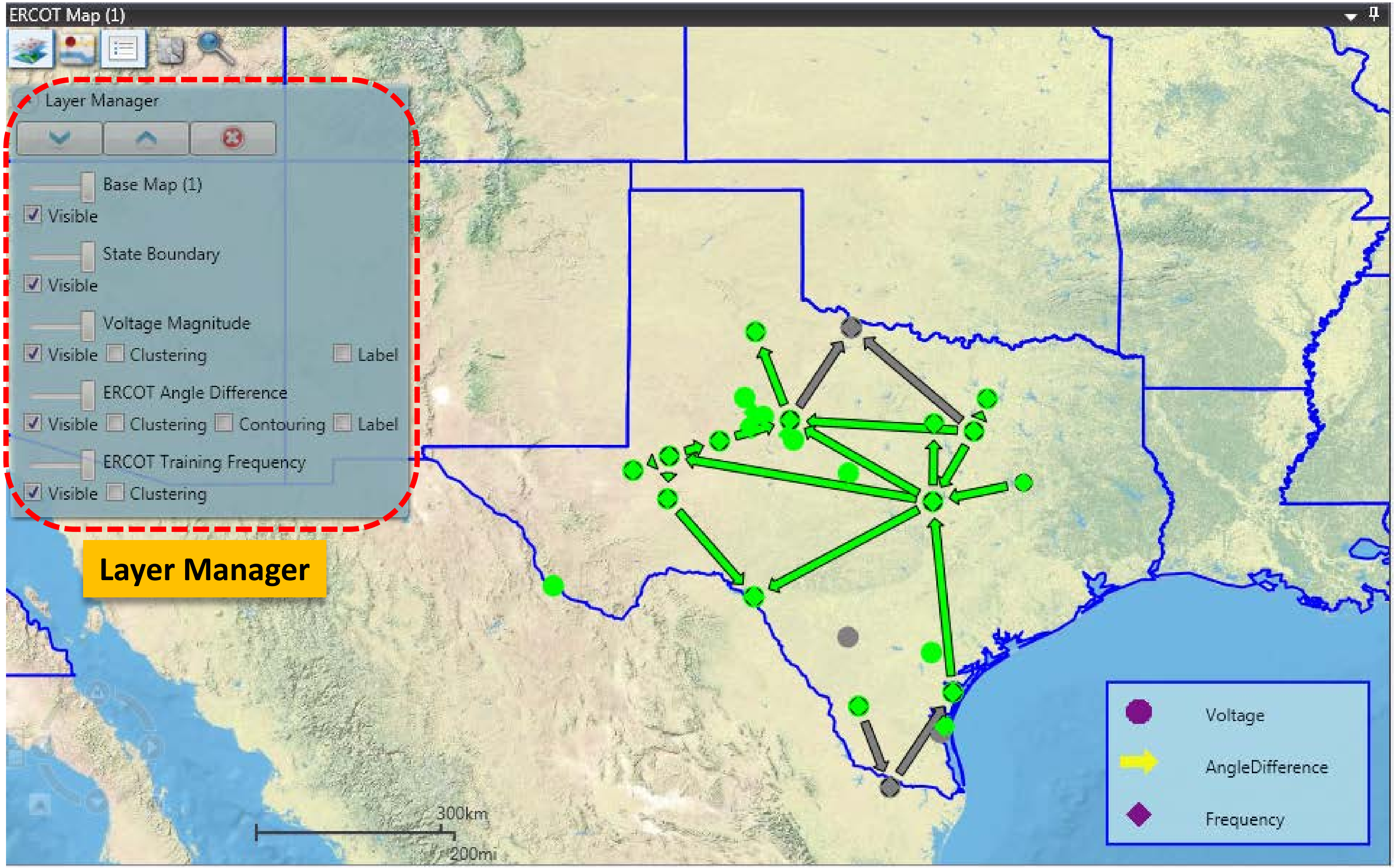
- **Work with the Map View**
  - Base Map
  - Infrastructure
  - Show PMU
  - Angle Difference, Voltage Magnitude and Frequency
  - Zoom
- **Work with other views**
  - Trend Chart
  - Polar chart
  - Numerical Value, etc.
- **Change views' properties**
  - Axis, Title, Legend, Color

# Recap – Multi-layer Maps



- Configurable Multi-layer support for Maps (base map layer, measurement layers, electrical infrastructure layers, shape file, environmental layers etc.)
- De-cluttering features in maps

# Recap – Map Layer Manager



# Pause and Replay Functions

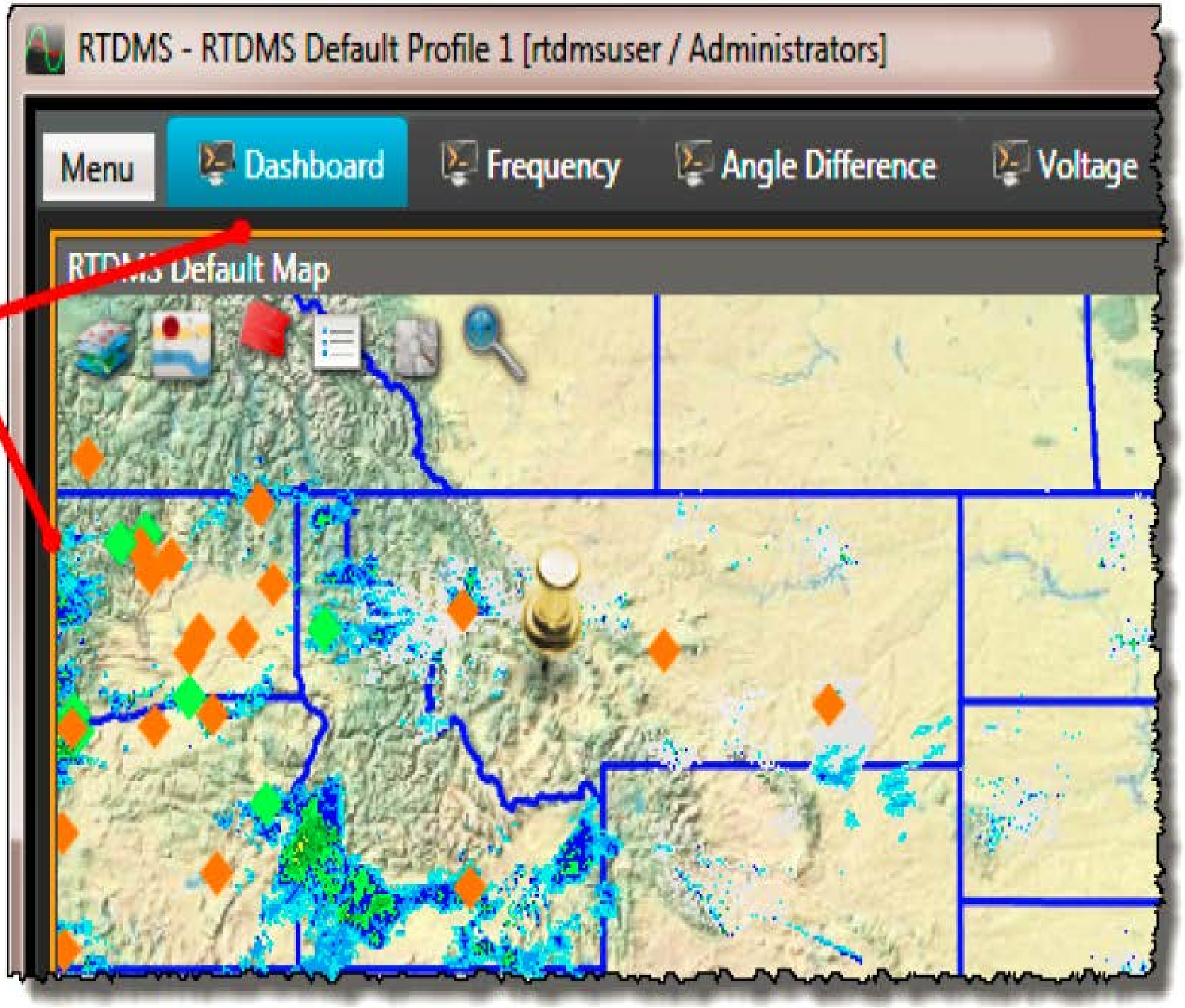
- The Pause function can pause displays so that you can view the data in the displays' views as of the time they are paused. When you resume the displays, the views will adjust back to show real-time data

- The Replay function has 3 options:
  - Replay from RTDMS real-time database
  - Replay from Event Markers
  - Replay from COMTRADE files

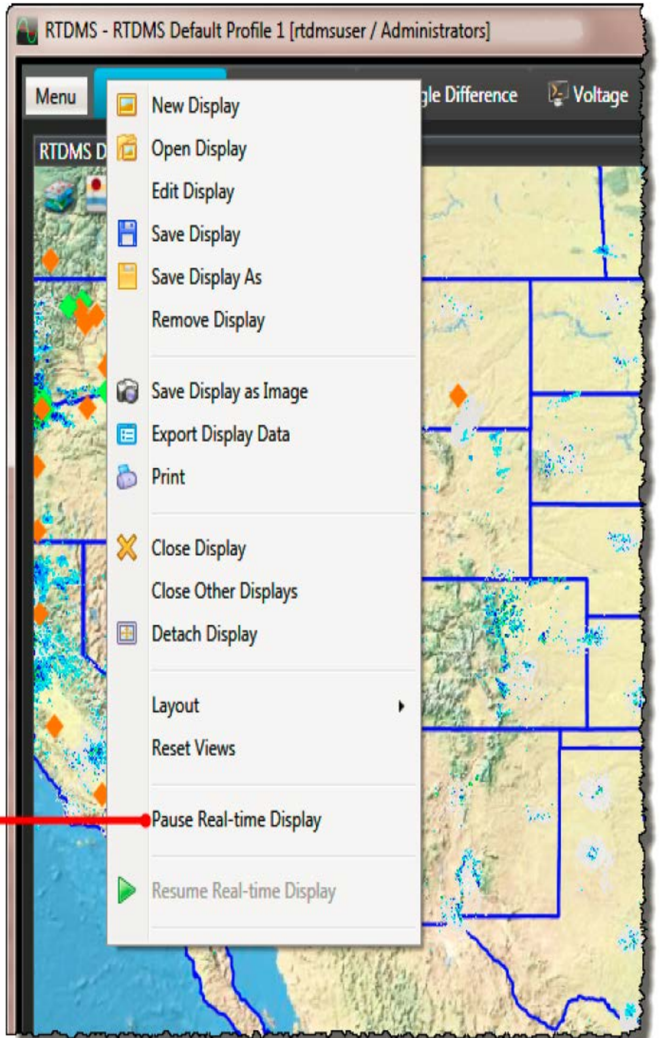
- With the Replay function, the user can review the historical information as it was streamed during that time period

# Pause Mode

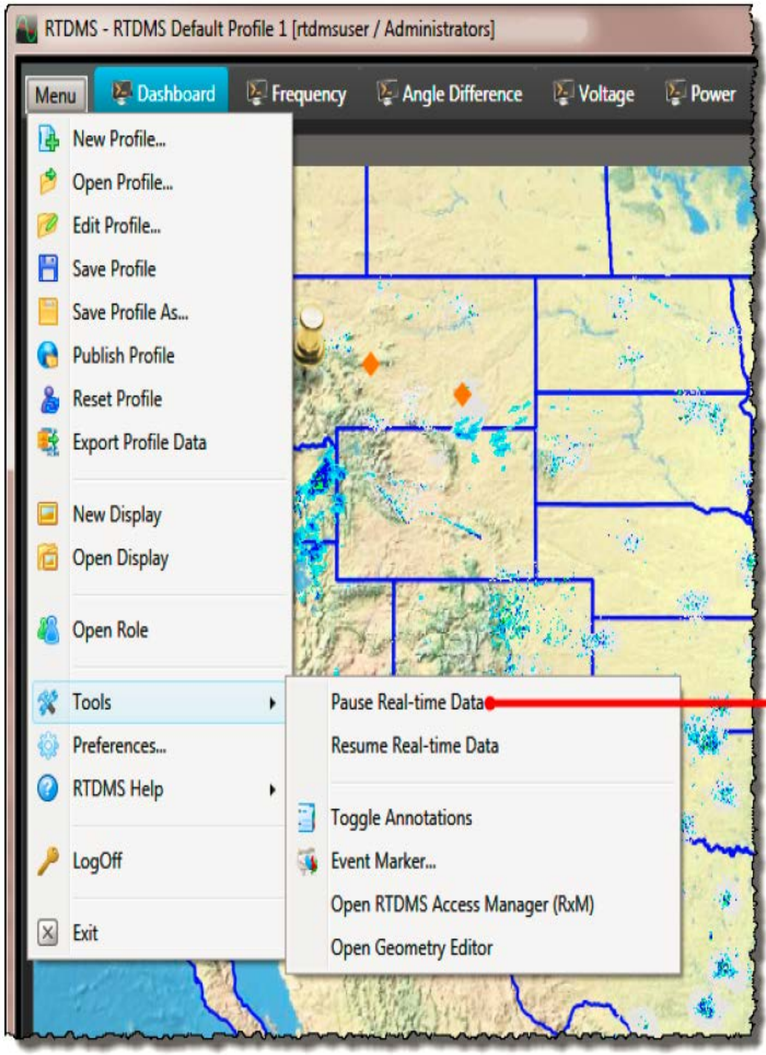
Orange border indicates display is paused.



# How to pause display

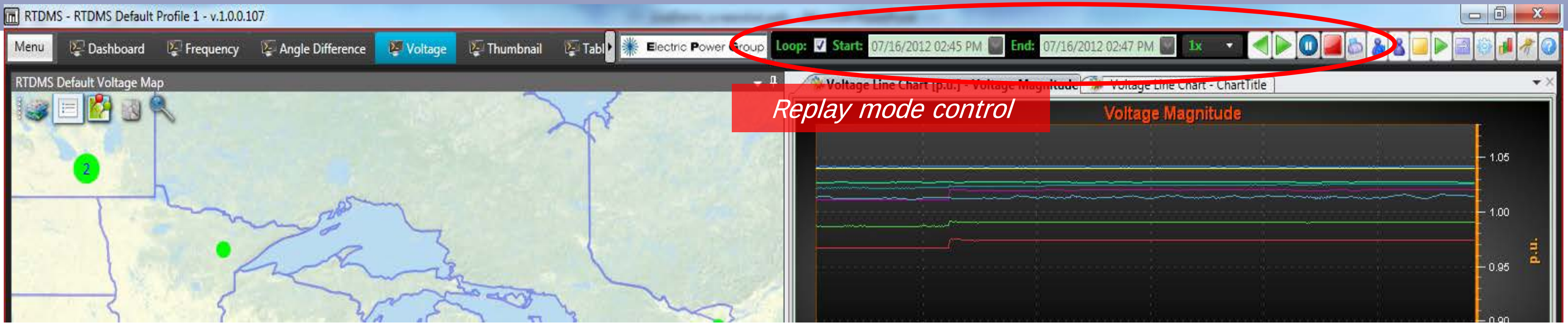


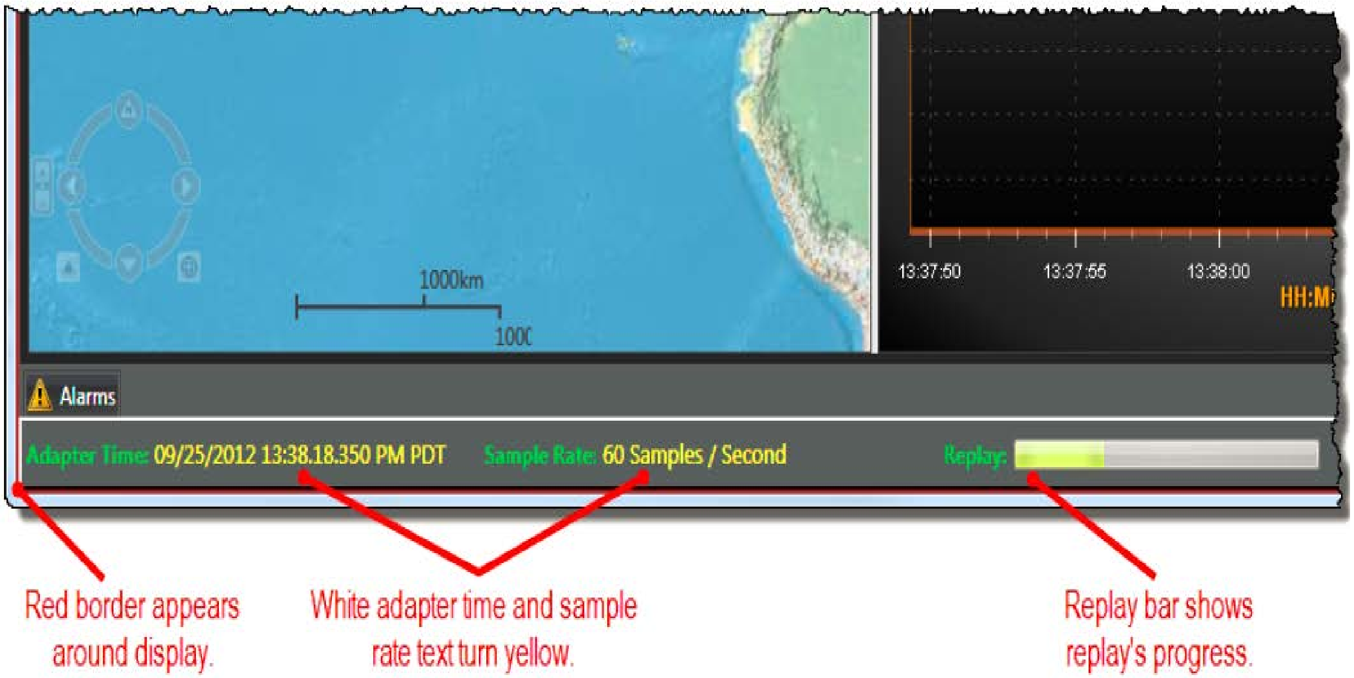

Pause display.




Pause all displays in the profile.

# Replay Mode

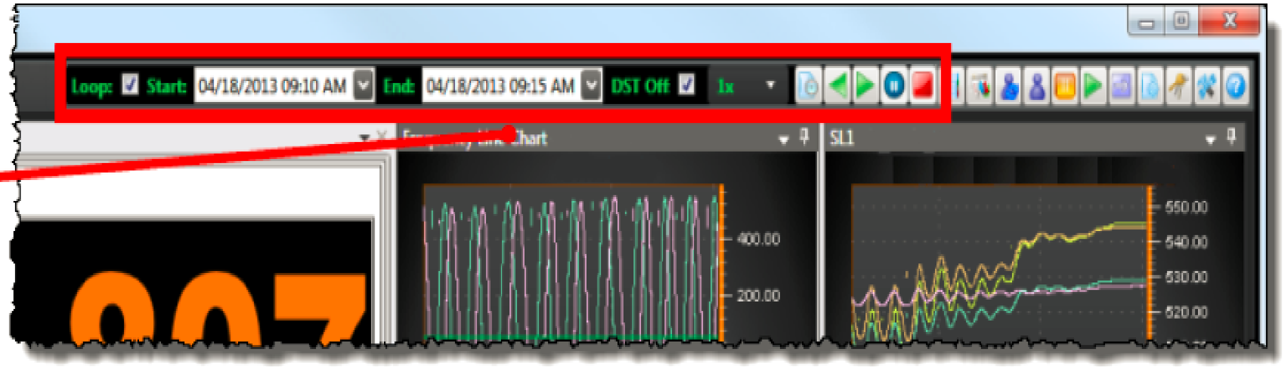

RTDMS - RTDMS Default Profile 1 - v.1.0.0.107
Menu
Dashboard
Frequency
Angle Difference
Voltage
Thumbnail
Loop:
Start: 07/16/2012 02:45 PM
End: 07/16/2012 02:47 PM
1x
RTDMS Default Voltage Map
Replay mode control
Voltage Magnitude
p.u.


1000km
13:37:50
13:37:55
13:38:00
Alarms
Adapter Time: 09/25/2012 13:38.18.350 PM PDT
Sample Rate: 60 Samples / Second
Replay:
Red border appears around display.
White adapter time and sample rate text turn yellow.
Replay bar shows replay's progress.

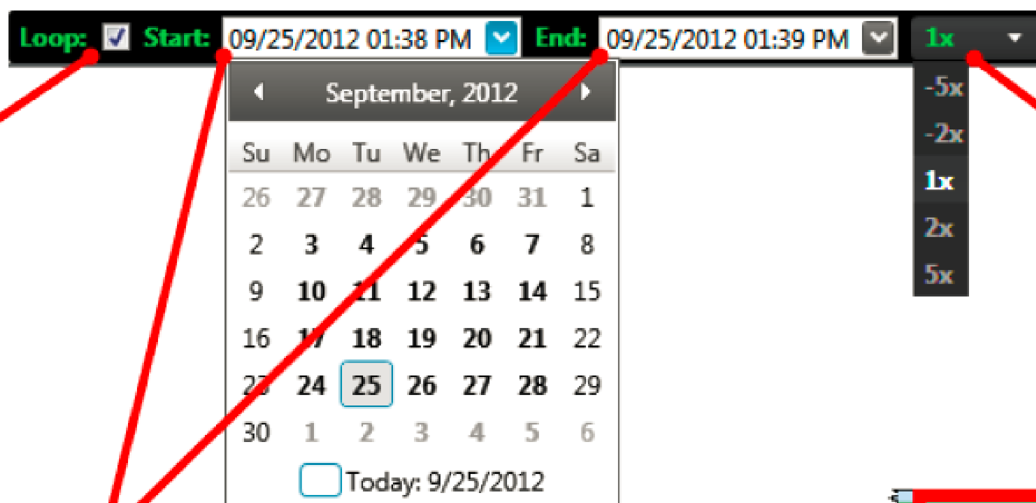
# How to use Replay from RTDMS Database

1

Expanded replay toolbar includes controls and buttons for using replay features.



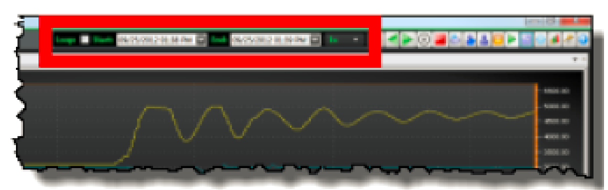

Select whether or not you want the replay to continually loop.




Select the sample rate to control the speed at which the replay is shown.

2

Specify the start date and time and the end date and time of the sample you want to replay. The calendar drop downs help you select start and end dates. Type exact start and end times.



# How to use Replay Function

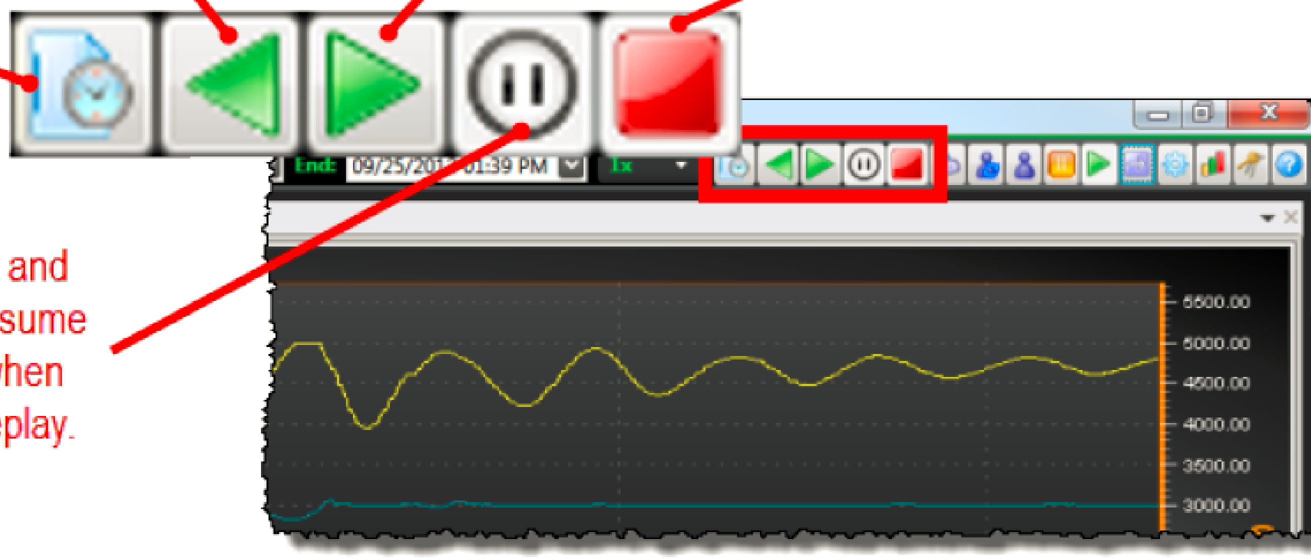
3

Run the replay backwards from end time to start time.

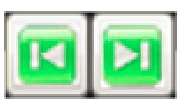
Run the replay forwards from start time to end time.

Stop the replay.

Reset the time frame to the most recent five minutes.




Pause the replay. The forward and backward buttons change to resume buttons, which you can click when you are ready to resume the replay.

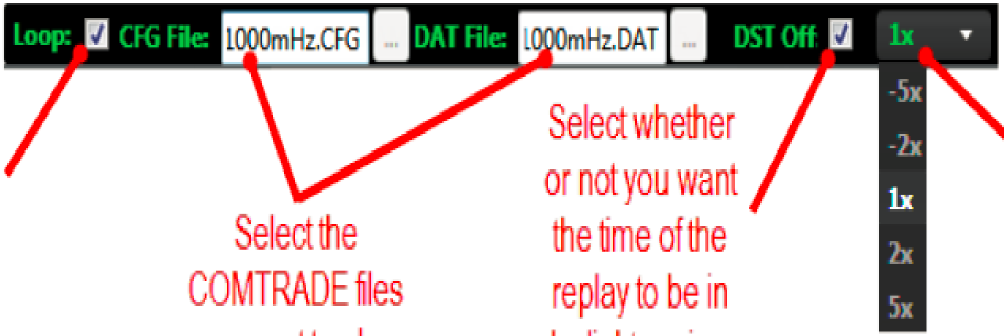


# How to use Replay from COMTRADE file

1

Expanded COMTRADE toolbar includes controls and buttons for playing COMTRADE files.


2




Select whether or not you want the replay to continually loop.

Select the COMTRADE files you want to play.

Select whether or not you want the time of the replay to be in daylight savings time.

Select the sample rate to control the speed at which the replay is shown.

# Understanding RTDMS: Hands-On Tutorial

- **Pause functions**
  - Pause an individual display; Pause all displays within the profile
  - Resume paused displays

- **Replay functions – replay from RTDMS DB**
  - Fast short term replay: change speed, rewind, forward
  - Replay historical data: set start & end time, looping

- **Replay functions – replay from COMTRADE file ***

# Hands-on Guided Training Exercises
# Case Studies of ERCOT Interconnection

# Hands-On Guided Training Exercises
# Case Studies of ERCOT Interconnection

- **What will be covered:**
  - Training cases – actual events to familiarize you how to use RTDMS

# RTDMS and PGDA Training Cases Analysis Template

**SYNCHROPHASOR CASE ANALYSIS**
**DATA COLLECTOR**

CASE TITLE ________________________ DATE OF EVENT __________________________

| WHAT CHANGED | START TIME | TYPE OF DISPLAY | PMU | OBSERVATIONS* |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |

* OBSERVATIONS

Frequency : minimum, maximum, rates of descent and recovery, when back to normal
Voltages: highest, lowest, rates of descent and recovery, grouping of pmus behaving similarly
Voltage angle: largest changes, direction of change, grouping of pmus behaving similarly
Line current: significant changes, overloads
Oscillations: observed in frequency, voltage or current
Start/stop times
Oscillation frequency
Damping (growing, sustained or decaying)

# Case Study # 1

## Analysis of An Event

Presented By


**Wayne Schmus**

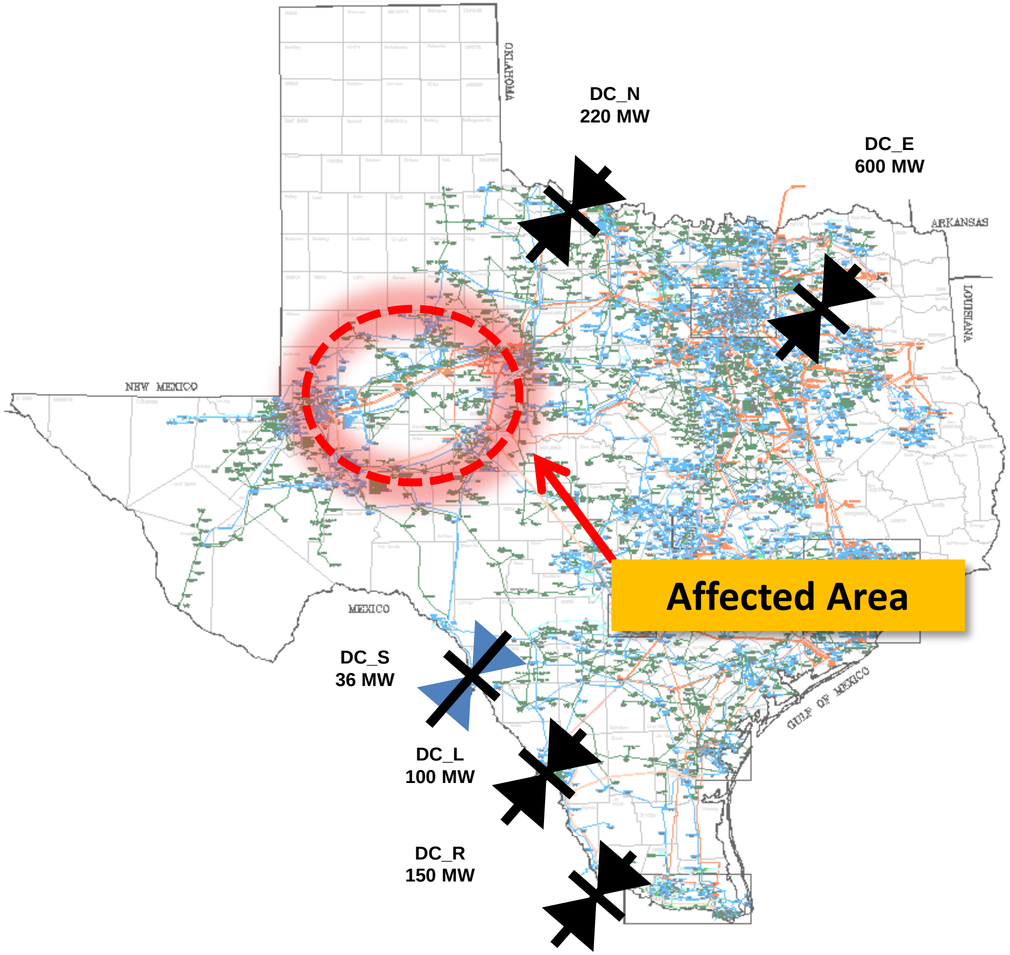
**Kevin Chen**

Electric Power Group

# Event Analysis

- **June 2013: Wind farm trip after storm**
  - Power Point Presentation Summary
  - RTDMS Demo

# ERCOT Transmission Network



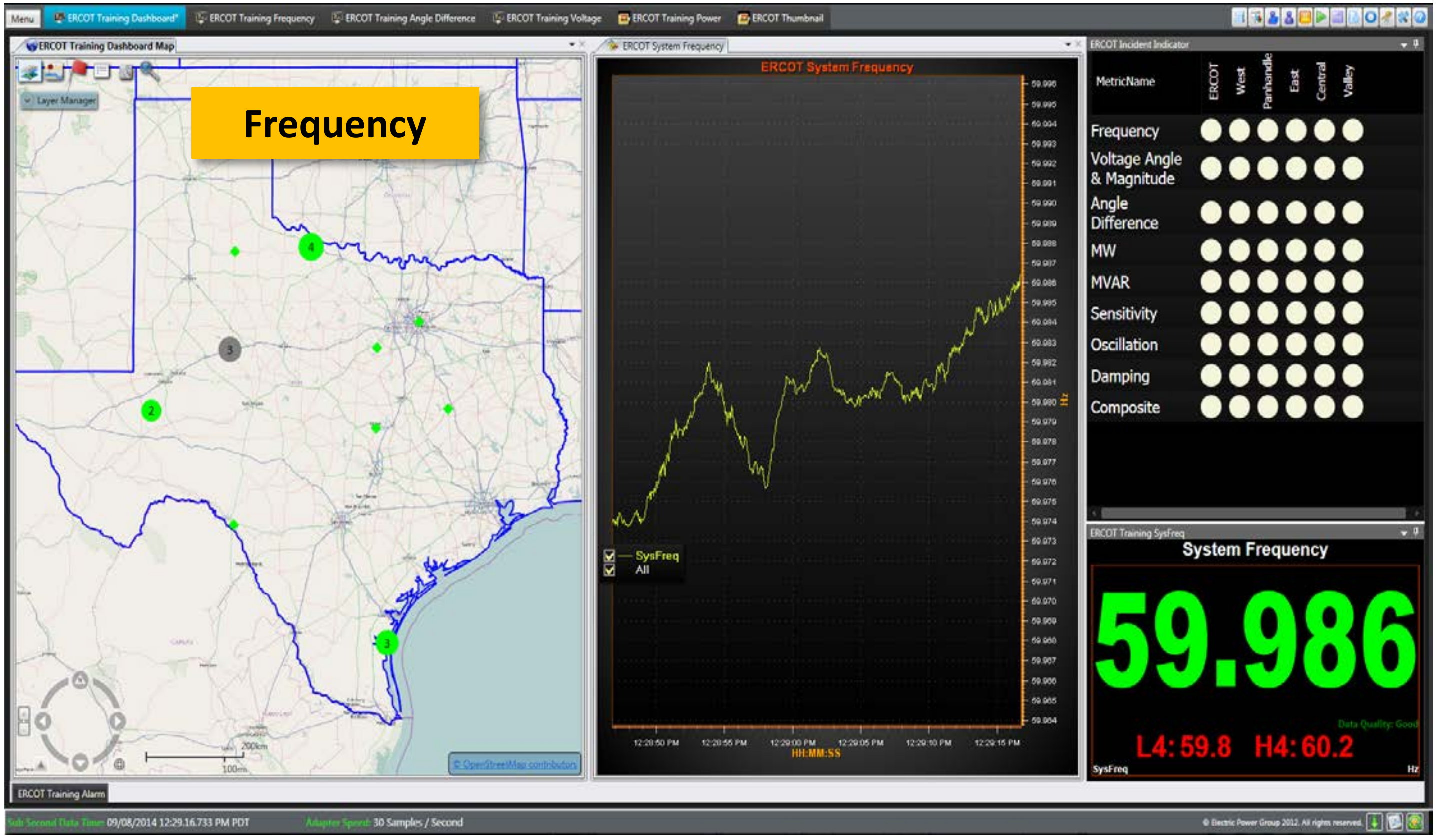
# Monitoring, Event Detection and Diagnose with RTDMS

**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**

# Real-Time Situational Awareness Dashboard

## Pre-Event

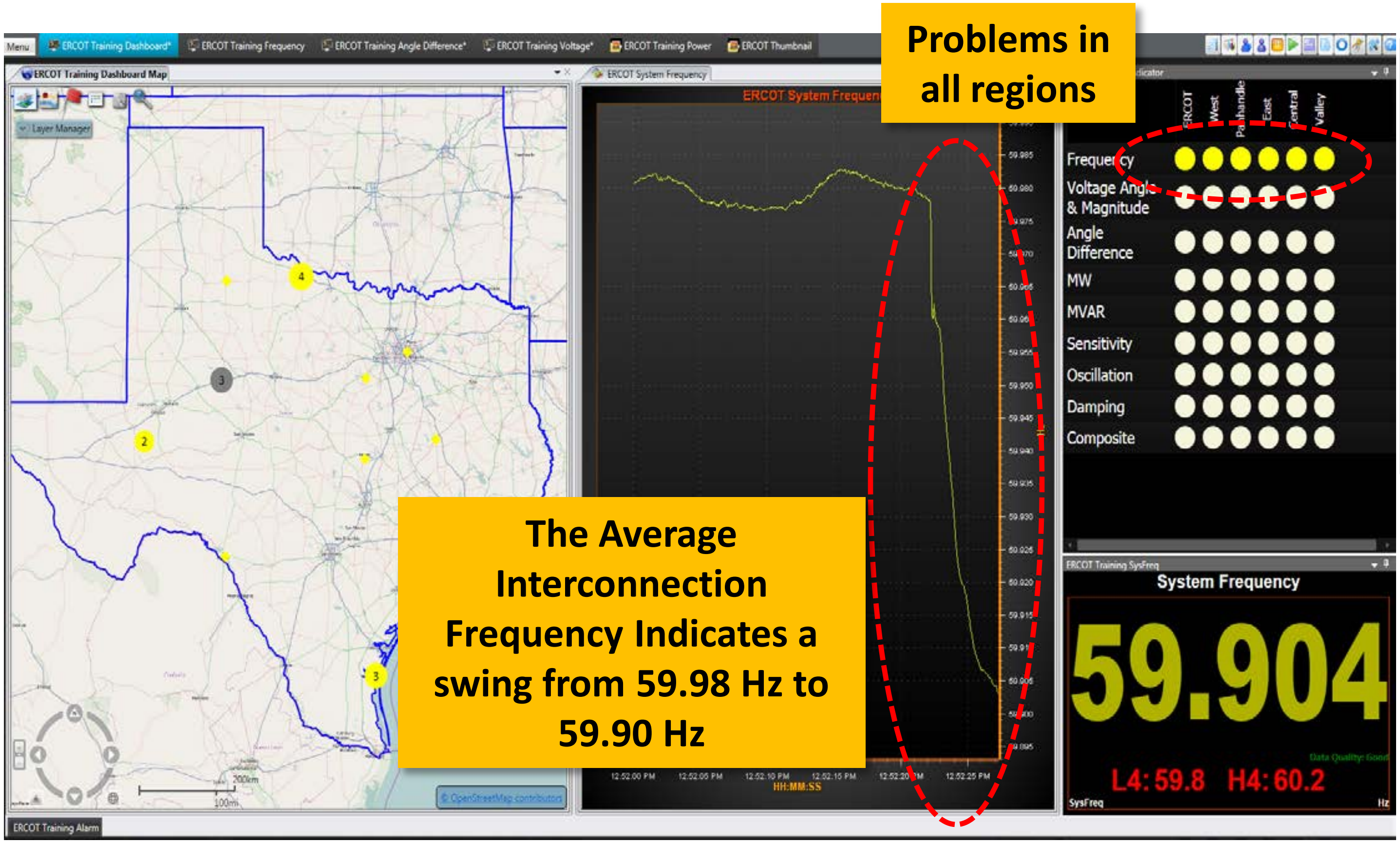



1. **Situational Awareness Dashboard (Real-Time Wide Area Monitoring)**
2. **Detect Emerging Problem**
3. **Diagnose the Situation**
4. **Assess System Vulnerability**
5. **Event Summary**

**Observation: System is operating at normal condition before the event.**

# Emerging Problem Detected:

## Interconnect Frequency




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: Frequency signals exceed thresholds and trigger 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

**Transient observed prior and following the event**

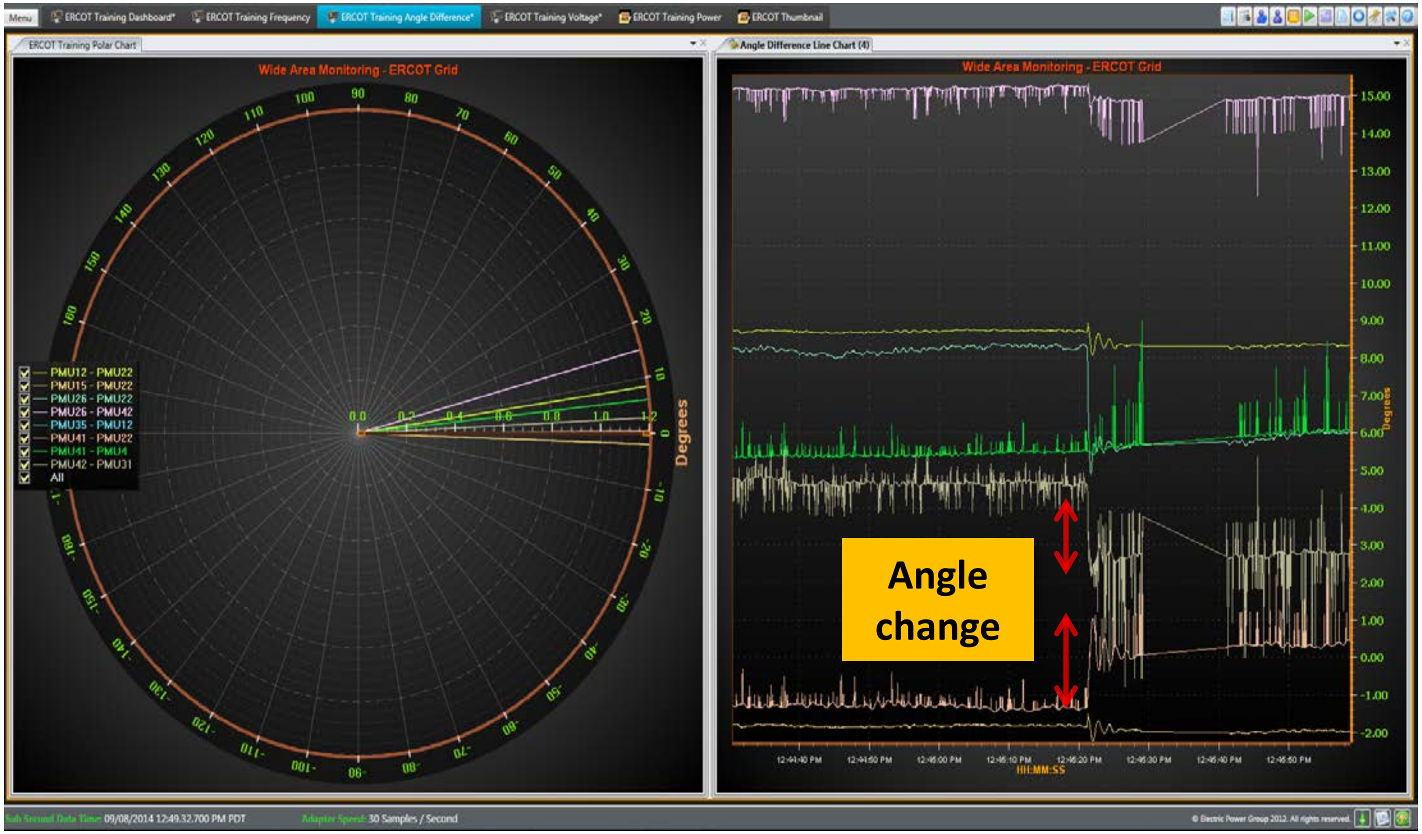
**Observation: Swing in Frequency in all regions of the system.**

# Assessing Vulnerability:
## Voltage Magnitude 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: Voltage magnitudes in all regions sag during event, but recover quickly.**

# Assessing Vulnerability:
## Angle Difference 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

**Conclusion: Angle Differences across the system change in response to event.**

# Analysis Summary

- **What happened?**
  - Frequency drops to 59.902Hz
  - Voltage dips but not severe
  - Transient observed in frequency, voltage
  - Power re-dispatched
- **Where did it happen?**
  - West side of the grid
- **Is the system at risk after the event?**
  - Frequency recovers back
  - No sustained low voltage

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

# Case Study # 2 - 4

## Analysis of An Event – Student Hands-on Exercise

Presented By

**Wayne Schmus**

**Kevin Chen**

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)**
2. **Detect Emerging Problem**
3. **Diagnose the Situation**
4. **Assess System Vulnerability**
5. **Event Summary**

# Thank You!


**Wayne Schmus**

schmus@electricpowergroup.com

**Prashant Palayam**

palayam@electricpowergroup.com

**Heng (Kevin) Chen**

chen@electricpowergroup.com

**Iknoor Singh**

singh@electricpowergroup.com

**Pankaj Mishra**

mishra@electricpowergroup.com

**Sandeep Dua**

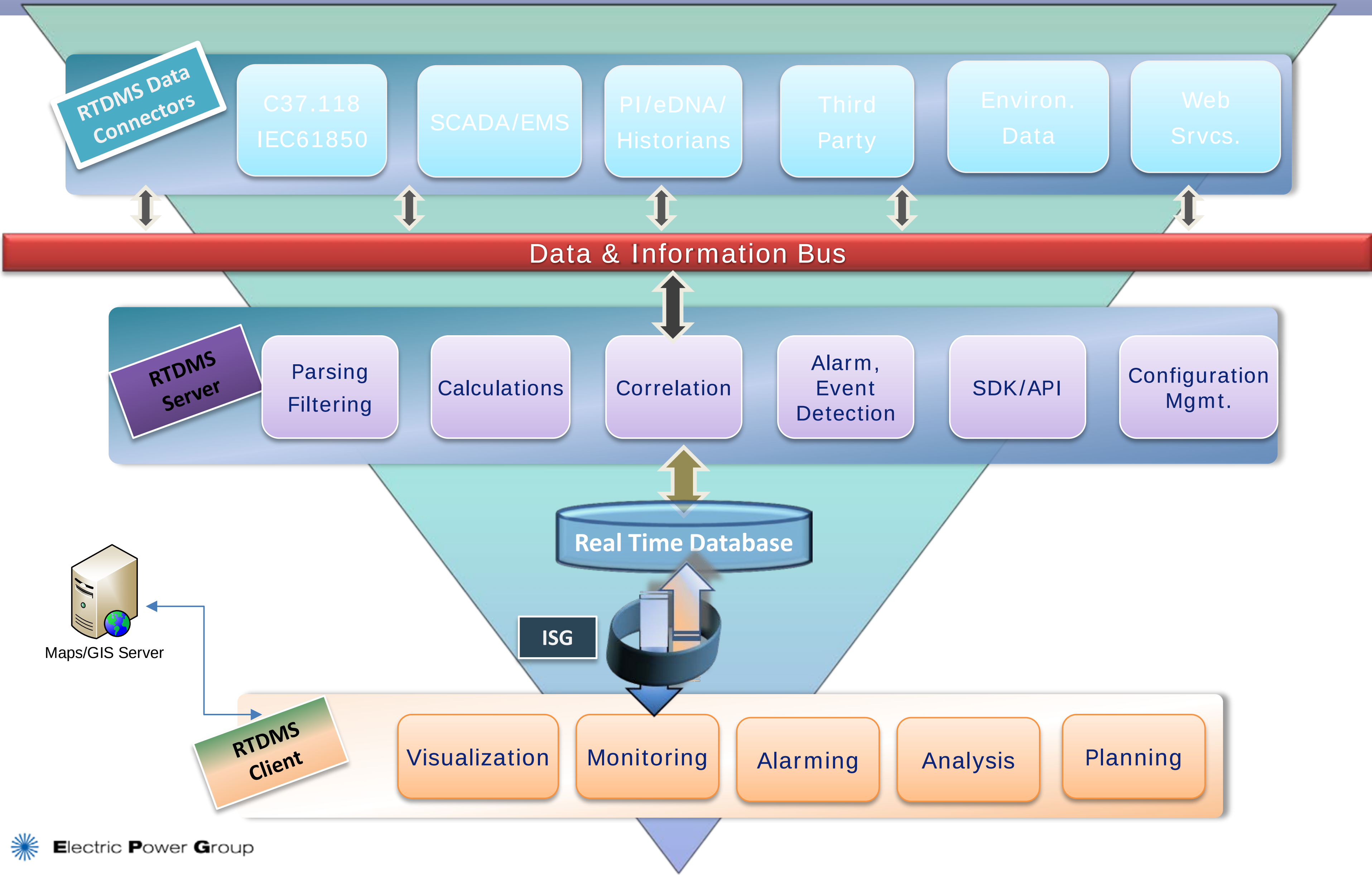
dua@electricpowergroup.com

Electric Power Group

201 S. Lake Ave., Ste. 400
Pasadena, CA 91101
626-685-2015

# Backup Slides

# RTDMS Platform Overview



# Client Architecture

**Data Layer**

| Real Time | Historical | Meta Data | Security |
|---|---|---|---|

**Core Components**

| Shell | Designer | Geospatial | Charting |
|---|---|---|---|

**Visualization/Presentment Layer**

| Displays and Views | UI | Client Functions |
|---|---|---|

# The RTDMS Platform

### Data Hub
- Data Collection,
- Pre-processing
- Archiving and Access
- Central Server  Design with Configurability,
- Data Filters
- Output Formats

### Open, Extensible Platform
- Data input – standard C37.118 format
- Open architecture
- Integrate data sources, API's i.e., Fnet
- Modular build – ability to plug in new functionality, algorithms, monitoring tools/techniques

### Configurability
- Central Configurability on Server
- Local Configurability on Clients
- Facilitates "plug-n-play".
- Allows for online modification/ expansion as new devices are added or removed.

## PLATFORM SERVICES


### Visualization
- Dashboard Display
- Tiered Visualization Architecture
- Wide-Area Displays
- Local Displays
- Configurability

### Monitoring/ Algorithms/Metrics
- Voltage – Magnitude & Angles
- Angular Separation
- Frequency
- Real and Reactive Power
- Small Signal Stability (% Damping)
- Voltage/Angle Sensitivities

### Real Time Alarming
- Real Time Alarming on Threshold and Rate of Change Violation
- Engineering Thresholds or Mandatory Standards
- Automatic Notification
- Configurability

## WIDE AREA SITUATIONAL AWARENESS

### Reporting
- PMU Performance
- Baseline – Trends
- Alarm Logs
- Daily/Monthly Reports (Customizable)

### Offline
- Event Files
- Replay
- Event Analysis – Forensic,
- Performance Analysis

## REPORTING & ANALYTICS