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Electric Grid

Title

Real-Time Dynamic Monitoring System (RTDMS) CA ISO Training Session

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***Consortium for
Electric
Reliability
Technology
Solutions***

Real-Time
Dynamics
Monitoring
System
(RTDMS™)

RTDMS

CA ISO TRAINING SESSION

January 31, 2006

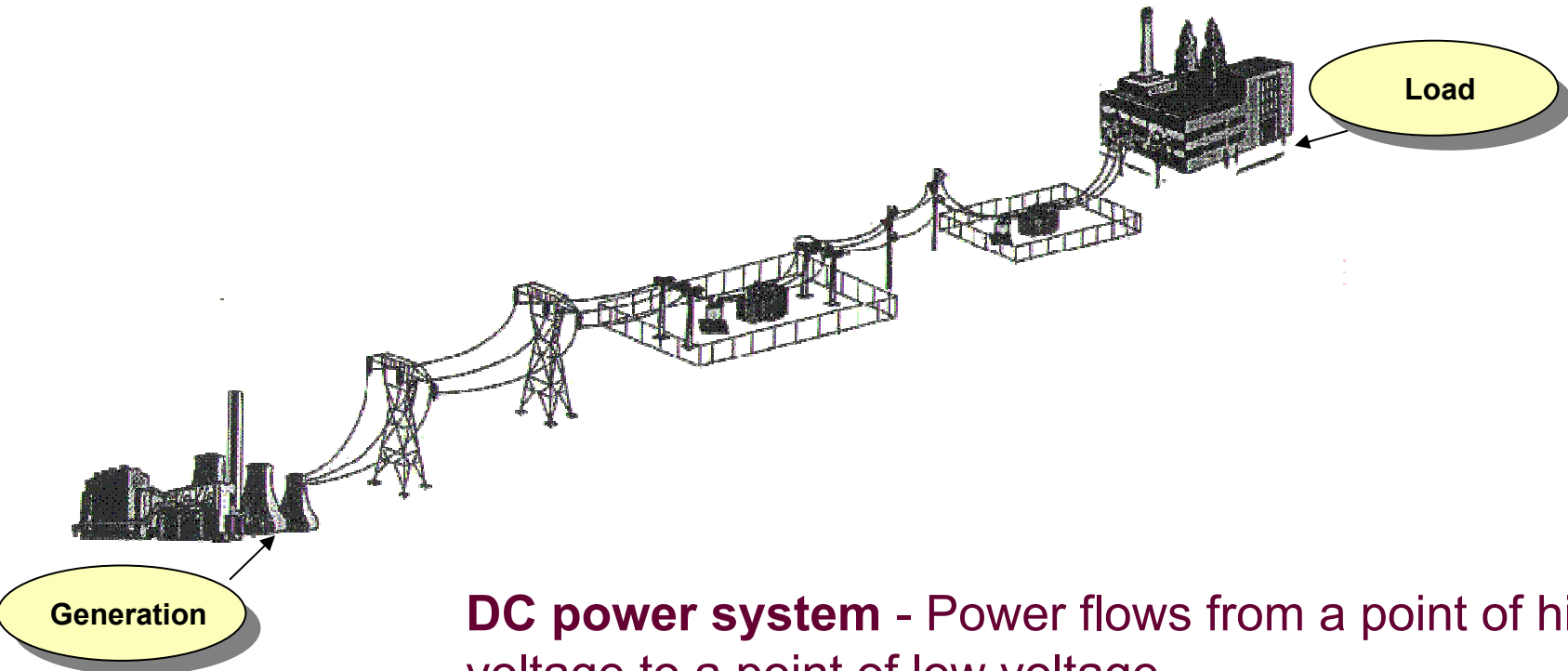
Manu Parashar & Jim Dyer
Electric Power Group (EPG)

Agenda

- **Phasor Technology – Overview**
- **The Importance of Using Synchronized Data**
- **Review of Some WECC Events**
- **CA ISO Real-Time Dynamics Monitoring System**
 - **Project Objectives**
 - **System Architecture**
 - **What the System Operator Will See**
- **RTDMS Visualization**
 - **Architecture**
 - **Navigation Within RTDMS**
 - **Displays**
 - **Client Support**
- **RTDMS Application Demo**

Phasor Technology Overview

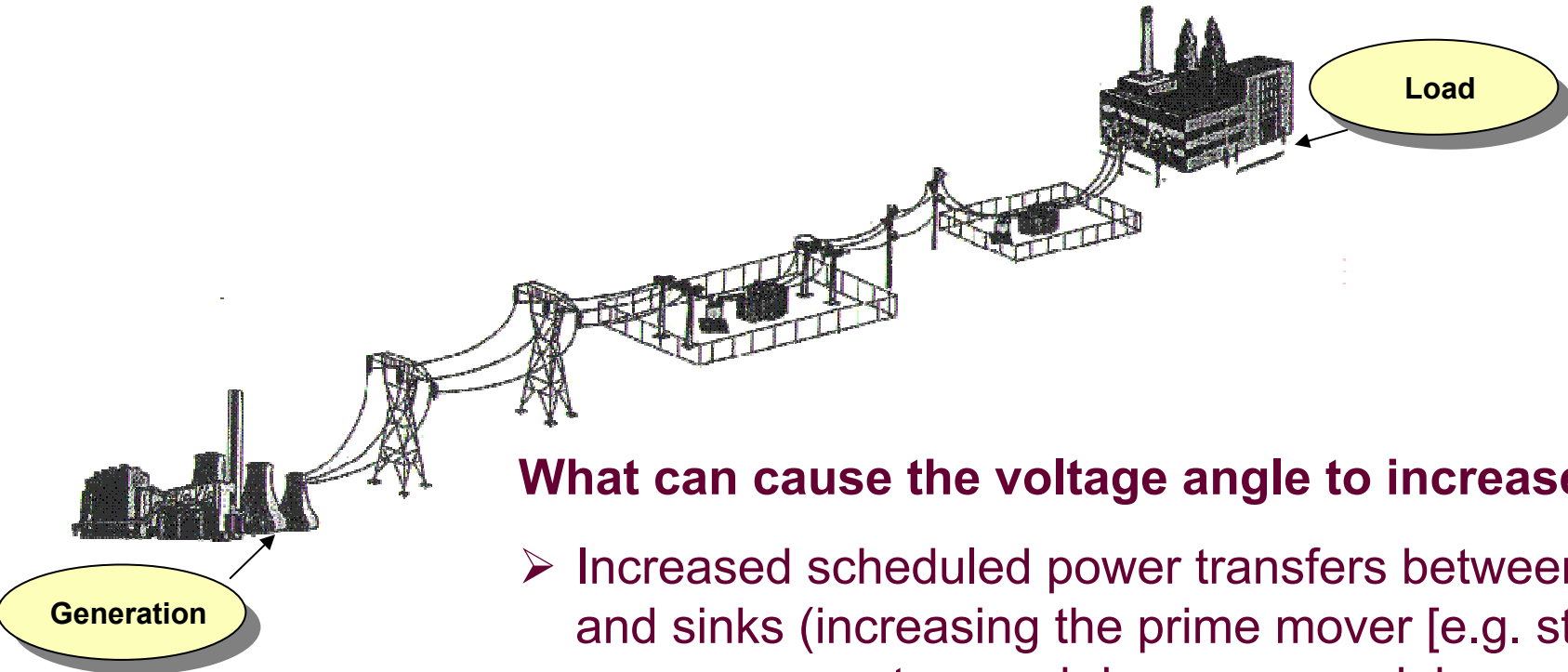
What Causes Power to Flow on the Grid



DC power system - Power flows from a point of high voltage to a point of low voltage.

AC power system - Power flows from a point of high voltage angle to a point of low voltage angle. The higher the angle the greater the power flow.

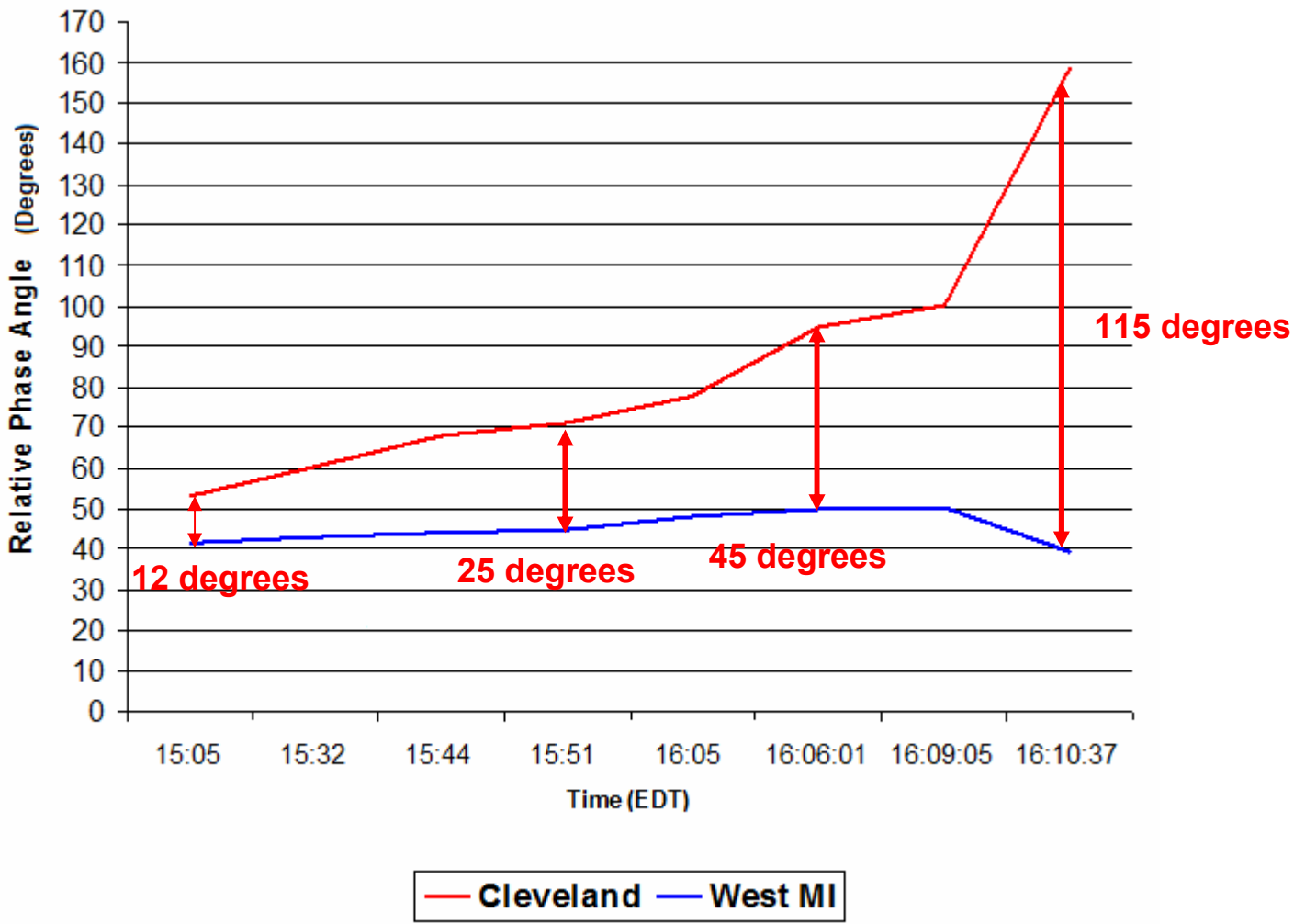
What Causes Voltage Angle to Increase



What can cause the voltage angle to increase?

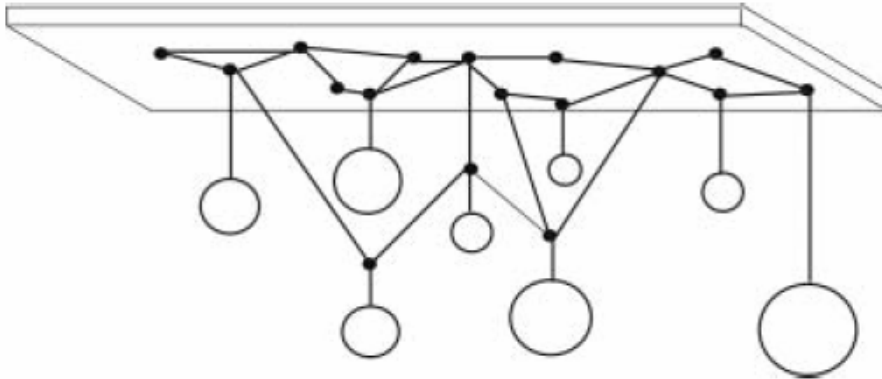
- Increased scheduled power transfers between source and sinks (increasing the prime mover [e.g. steam] in source generators and decrease on sink generators).
- Transmission lines removed (forced or scheduled) from service between source and sink, without adjusting schedules.
- Loss of generation in the sink area.

Eastern Interconnection - Angle Separation on 8-14-03

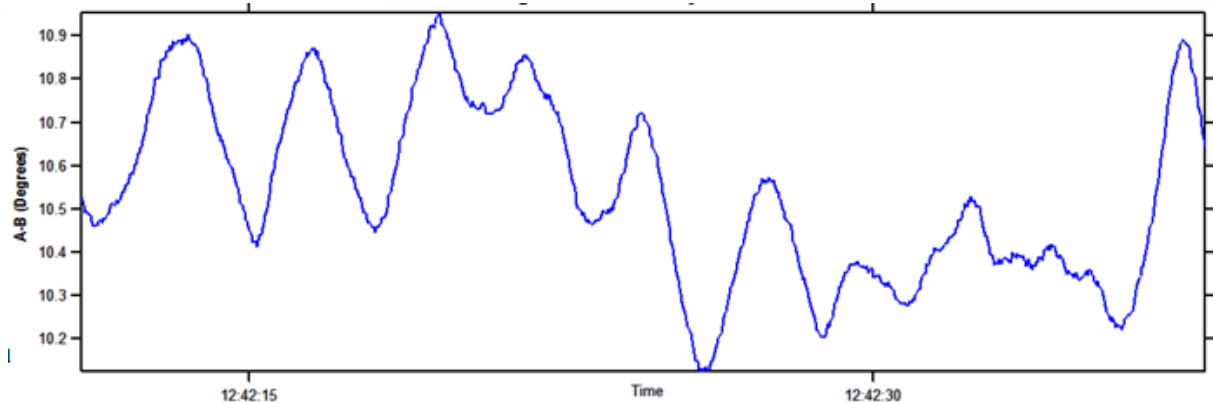


Power System Dynamics

Mechanical Analogy for Power System Dynamics

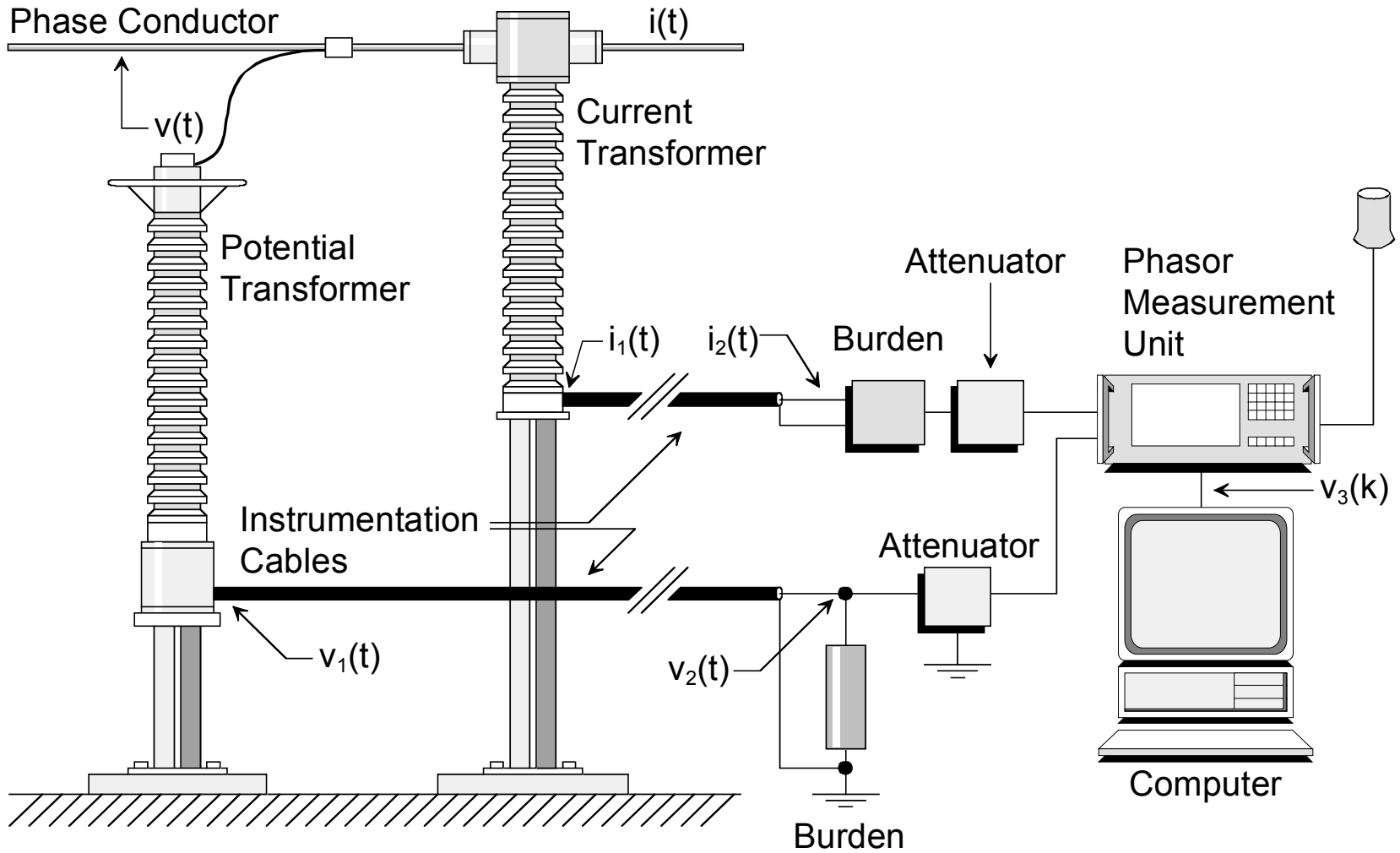


- Balls analogous to generators with different inertia
- Strings analogous to the physical power grid



- Pendulum swings analogous low-frequency oscillations observed by Phasor Measurement Units (PMUs)
- Oscillations may either decay or grow implying stability or instability respectively

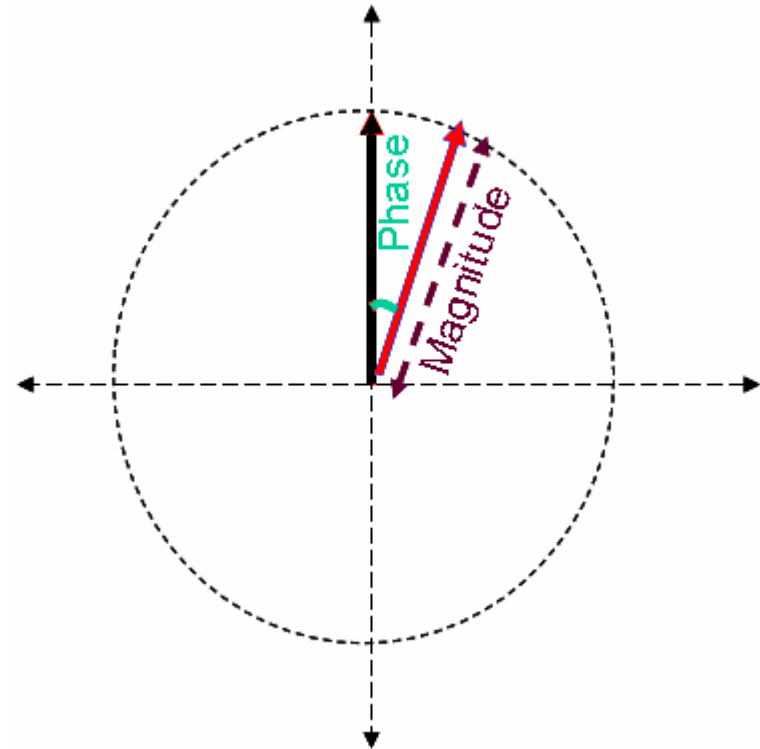
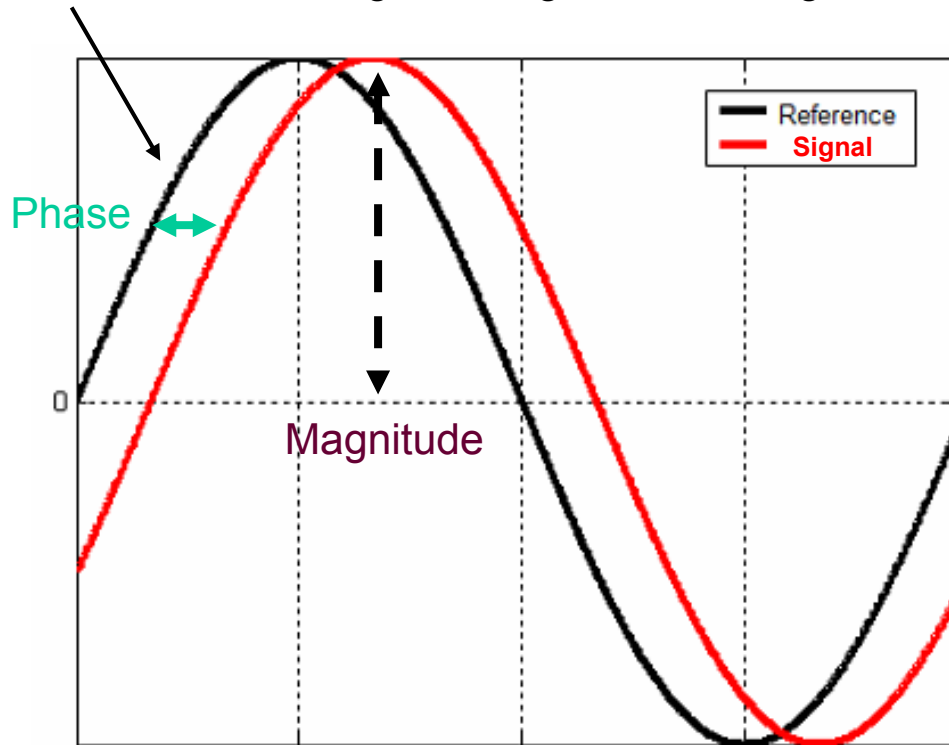
Source of Phasor Measurements



What Phasor Measurements are all about

Phasor Overview

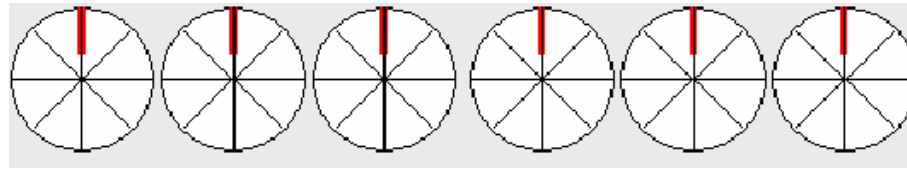
“Reference 60Hz Signal using GPS time signal”



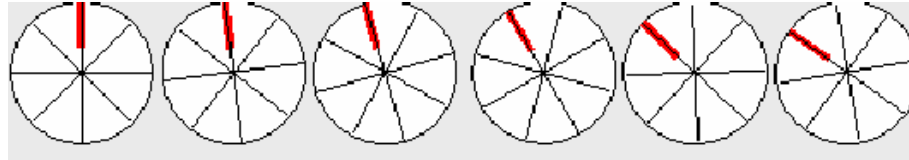
What Phasor Measurements are all about (cont.)

Strobe Light Analogy

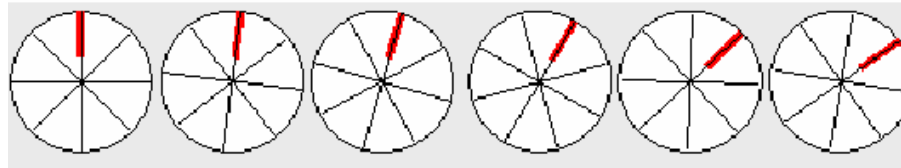
Pure 60Hz Signal



Decelerating System

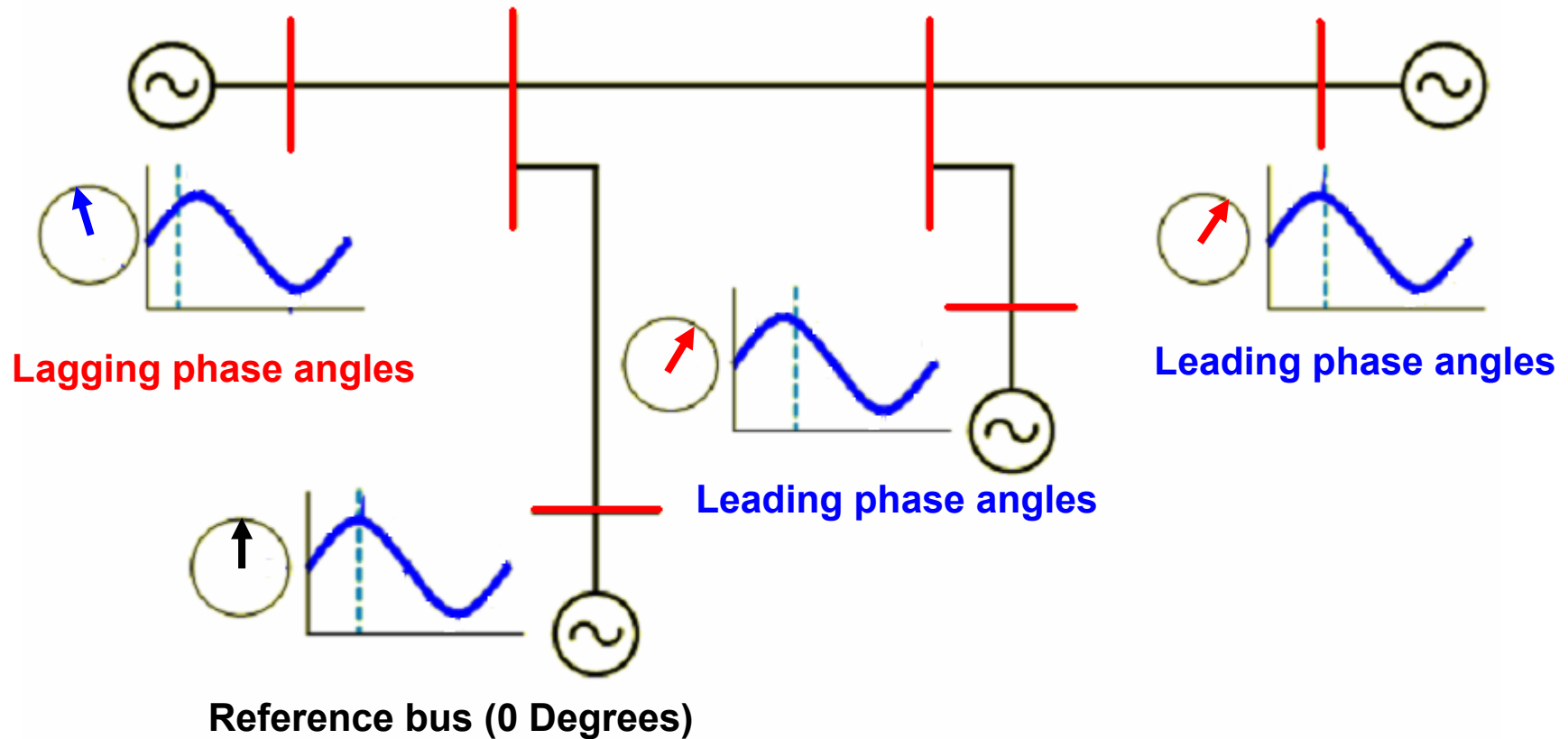


Accelerating System

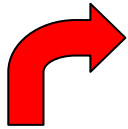


What Phasor Measurements are all about (cont.)

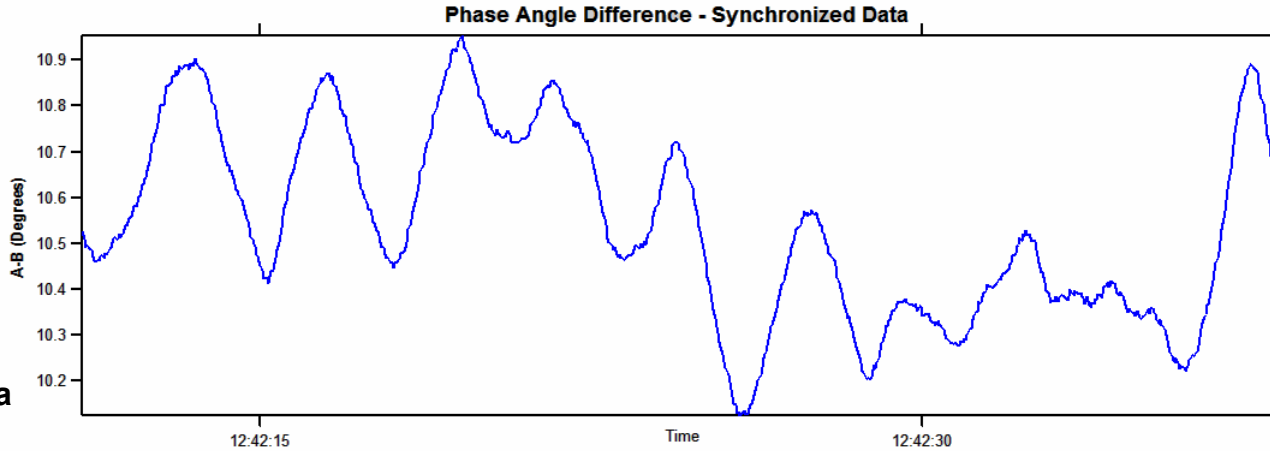
System Wide "Snapshot" Across Power Grid



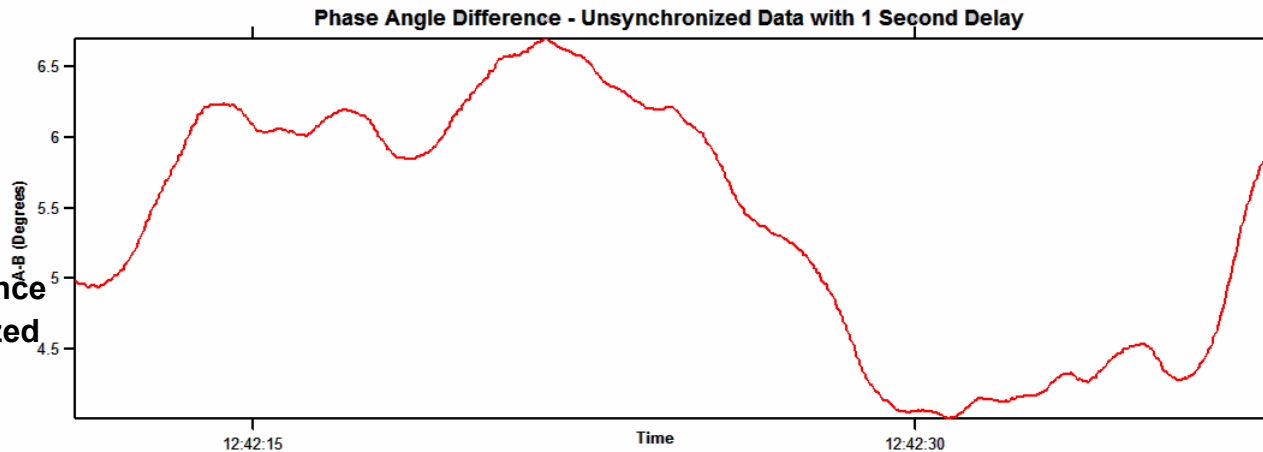
Importance of PMU Data Synchronization



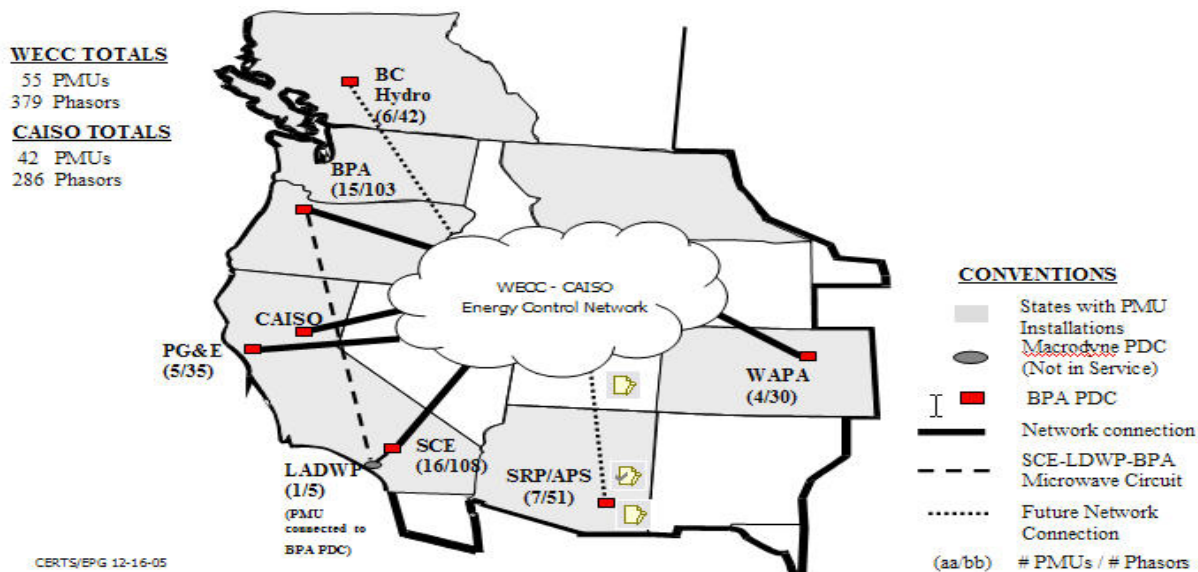
phase angle difference using synchronized data



phase angle difference using unsynchronized data with 1 second mismatch



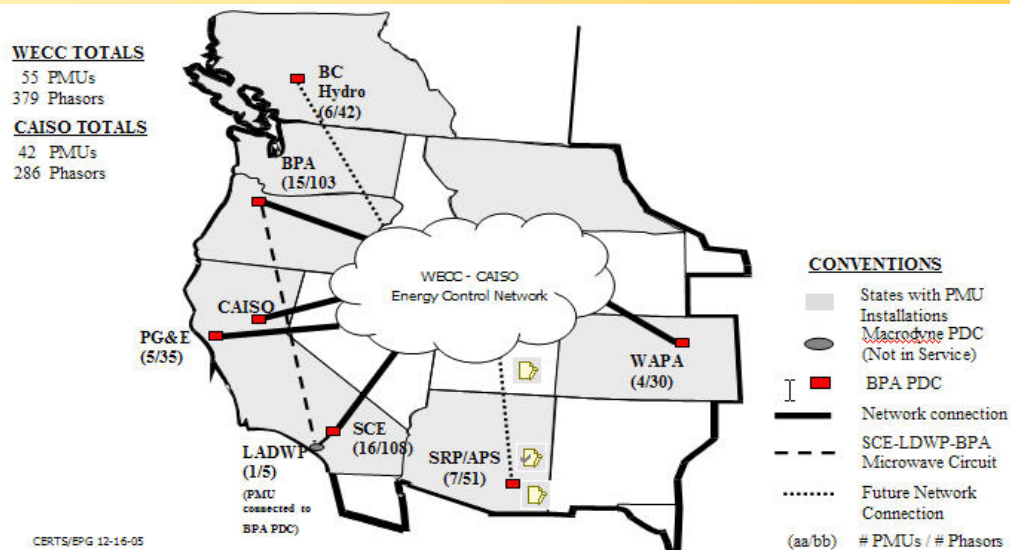
What Phasor Measurements are all about (cont.)



Networking - Most stability events, involve a widespread area, and involve oscillations and control interactions between neighboring utilities and geographic operational regions. This dictates the need for multiple recording devices across the transmission grid.

Time Synchronization - Phasor measurements are time-stamped using the global satellite positioning system so that measurements from across the interconnection can be precisely aligned for comparison against one another.

What Phasor Measurements are all about (cont)



The Primary Hardware Elements in a Phasor Network are:

Phasor Measurement Unit (PMU) – PMUs are located at key substations and measures and are capable of gathering better data at higher sampling rates than analog monitoring devices. The PMU time stamps the local frequency, voltage and line currents at a rate of 30 to 60 times per second. The voltage and current data is used to calculate MW and MVAR flows on key lines. Substation PMU phasor data is transmitted to a PDC at a central location..

Phasor Data Concentrator (PDC) – Receives, integrates, and stores phasor signals from remote PMUs. Can also exchange records with PDCs at other locations. One of the primary functions of the PDC is to perform data synchronization.

Phasor Technology – Industry Uses

- The use of phasor technology allows the industry to take high resolution “snapshots” of what is happening throughout the Western Interconnection grid and evaluate the grids performance during system events.
- System operators and planners can use data gathered by PMUs for a host of applications, including:
 - State estimation
 - Real-time wide area monitoring
 - Validation of power system models
 - Transient instability protection and fault location systems

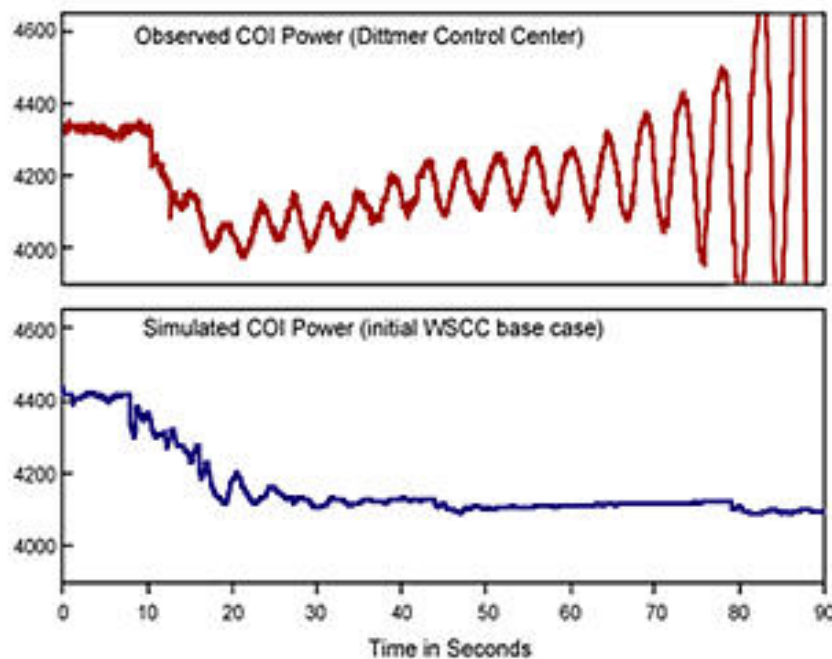
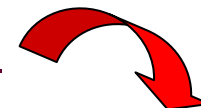
Value of Phasor Technologies - Example

WECC's Experience

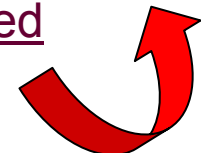
Comparison of model simulation system performance predictions prior to the WECC's August 10, 1996 blackout (lower panel) and conditions actually recorded by phasor technologies (upper panel) showed that the planning models were not able to accurately capture underlying causes of the blackout

The WECC has since modified their simulation models to better represent actual system performance.

Actual System Performance



Model Simulation - Predicted System Performance



Actual WECC Phasor Data Events

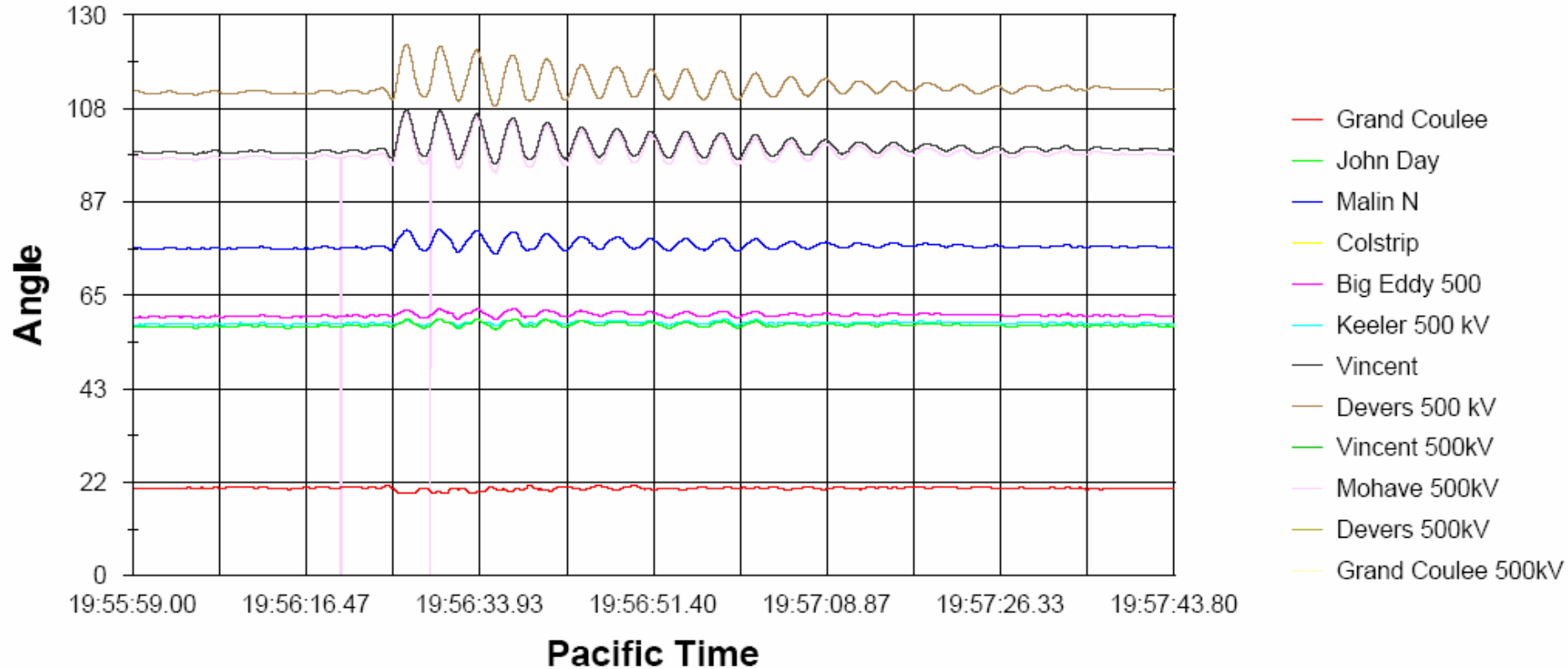
WECC Event - # 1

- Location: Western Interconnection
- Date/Time: Friday, August 4, 2000, 7:56PM
- High Static Stress and Low Dynamic Stress

- System Conditions:
 - 1) System was operating with an angle greater than 90 degrees between Devers Substation (Palm Springs, Ca.) and Grand Coulee Power Plant (near Spokane, Wa.), a distance of over 1,000 miles
 - 2) A 500 kV tie-line exporting power from British Columbia to Alberta, Canada tripped
 - 3) Loss of line resulted in increased flows by 450 MW
 - 4) The dynamic stress between Devers and Grand Coulee increased to 108 degrees (an 18 degree increase)
 - 5) System oscillated for about 60 seconds showing low damping

WECC Event - # 1

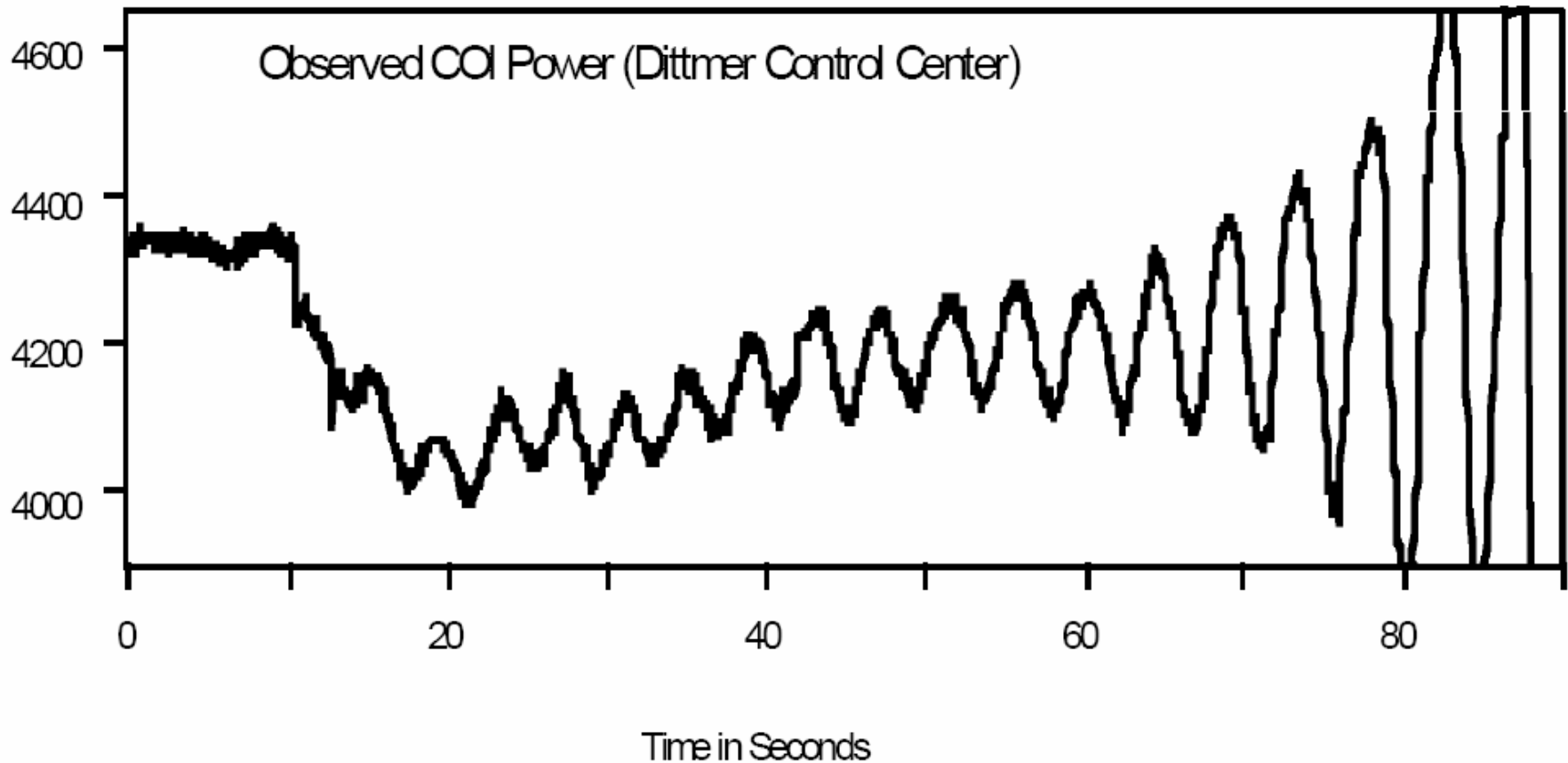
08/04/00 Event at 12:55 Pacific Time (08/04/00 at 19:55 GMT)



Angle Reference is Colstrip

J. Balance, B. Bhargava, G.D. Rodriguez, "Use of Phasor Measurement System for Enhancing AC-DC Power System Transmission Reliability and Capacity."

Comparison with August 10th 1996



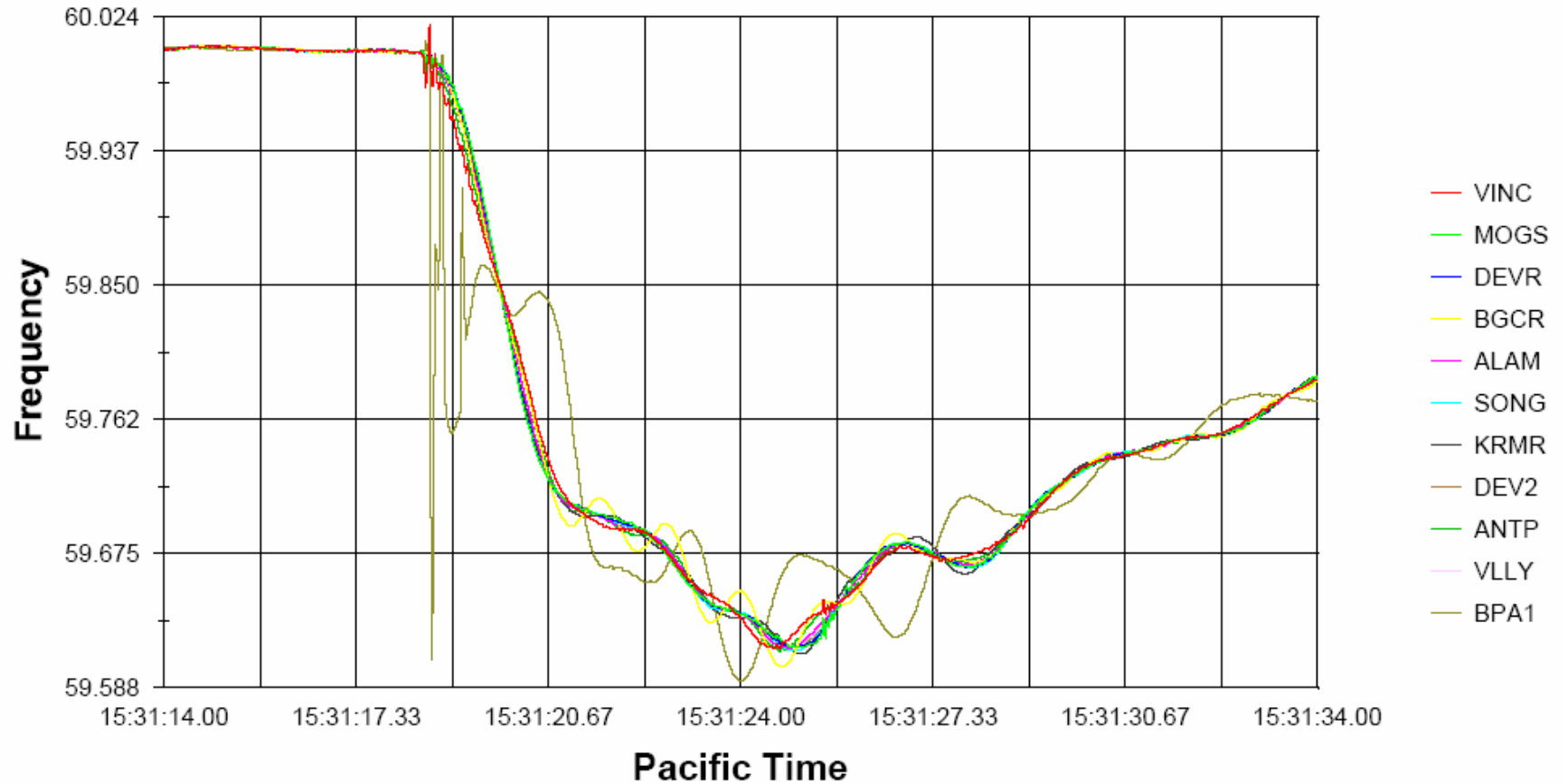
WECC Event # 2

- Location: Western Interconnection
- Date/Time: Tuesday, October 8, 2002, 3:38PM
- Abnormal Interconnection Frequency: 59.62 Hz (380 mHz)

- System Conditions:
 - 1) An AC line fault occurred in the northwest tripping three 500 kV lines
 - 2) SPS operated by applying the 1400 MW Chief Joseph break and tripping 2800 MW of generation in northern WECC system.
 - 3) The frequency dropped to 59.620 Hz.

WECC Event #2

10/08/02 Event at 15:30 Pacific Time (10/08/02 at 22:30 GMT)



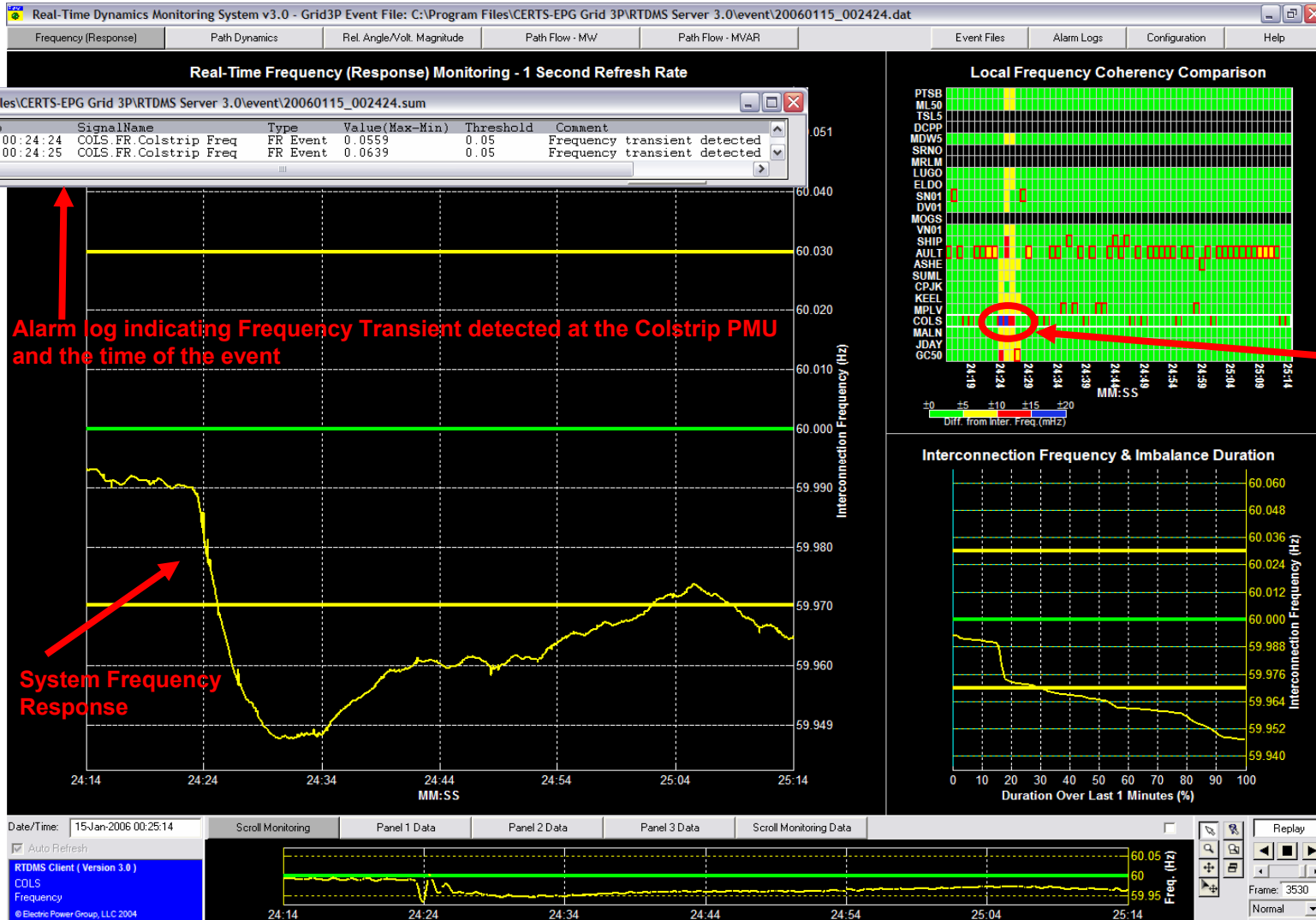
WECC Event # 3

- Location: Western Interconnection
- Date/Time: Sunday, January 15, 2006, 00:24AM
- Generator Trip (System Frequency Response Captured by RTDMS)

- System Conditions:
 - 1) NEW Colstrip Unit 1 relayed while carrying 240 MW
 - 2) System frequency deviated from 59.995Hz to 59.947Hz
 - 3) Recovered to 59.961Hz by governor action
 - 4) Returned to pre-disturbance level at 00:29

WECC Event #3

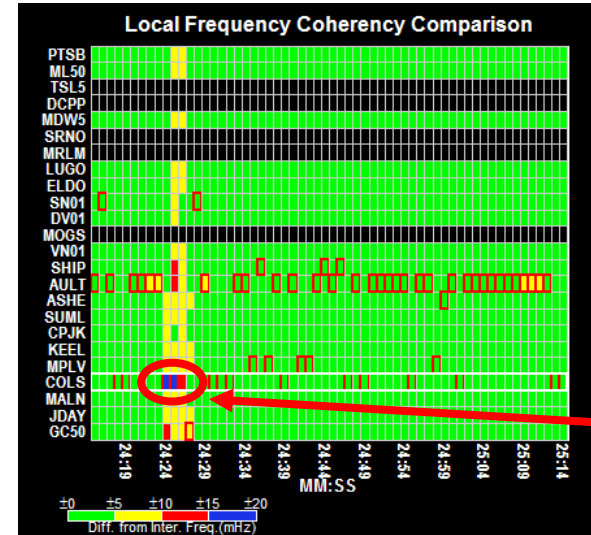
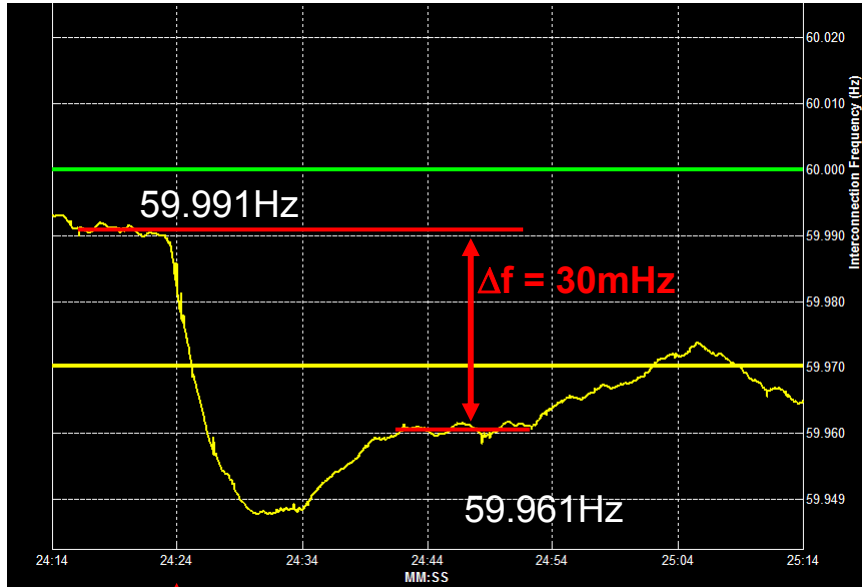
RTDMS Event File Name "20060115_002424"



WECC Event #3 (Frequency Response)

January 15, 2006 (CA ISO Log)

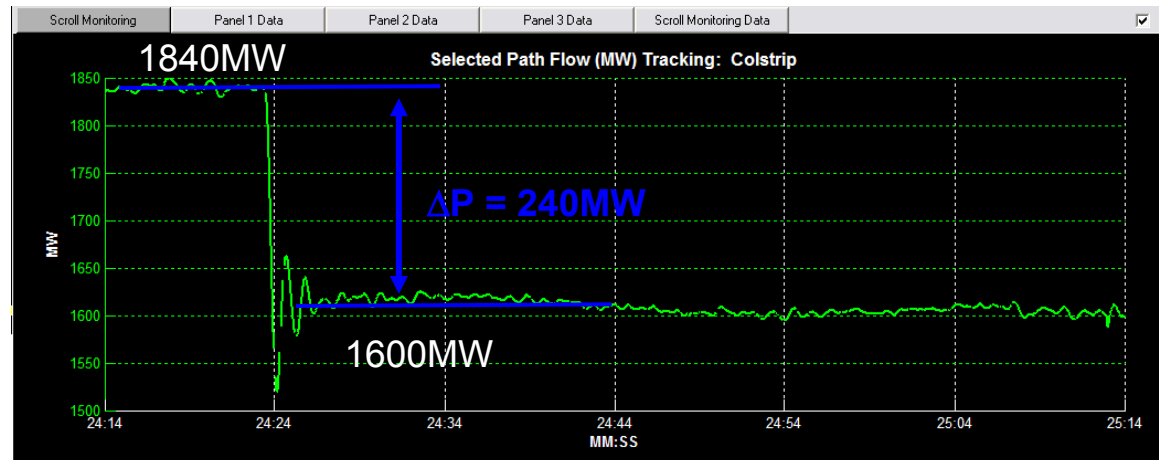
01/15/2006 - 00:24 System frequency deviated from 59.995Hz to 59.947Hz and recovered to 59.961Hz by governor action when NWE Colstrip Unit 1 relayed while carrying 240 MW. System frequency returned to pre-disturbance level at 00:29.



Identify Trip near Colstrip PMU

Jan 15, 2005 00:24:24 AM

$$\beta = \Delta P / \Delta f = 800\text{MW} / 0.1\text{Hz}$$



*Any Questions
About Phasor Technology?*

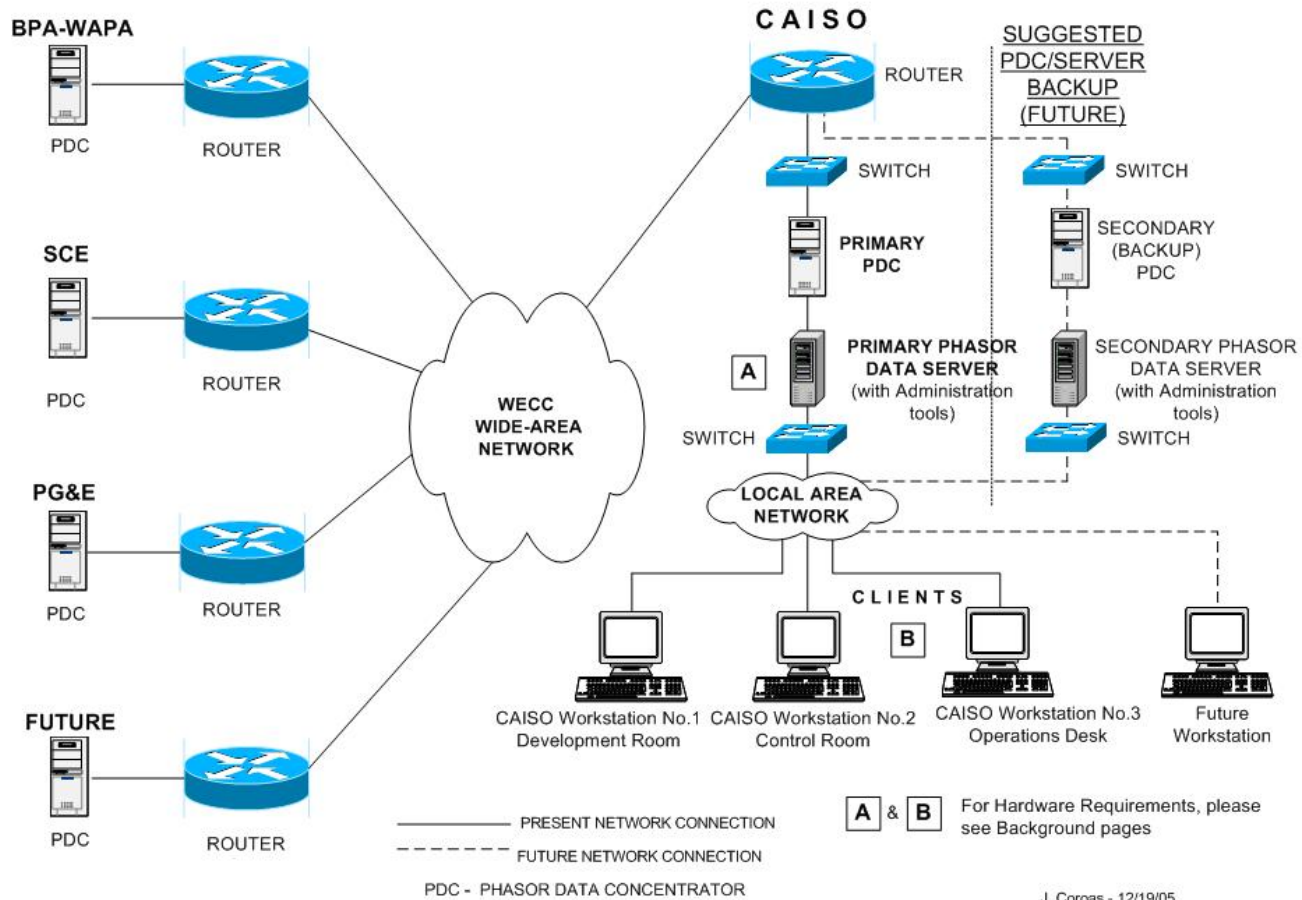
Real-Time Dynamics Monitoring System (RTDMS)

Project Objectives for RTDMS Applications

- Develop a Real-Time Phasor Monitoring Prototype System for use by system operators at utilities, ISOs and reliability coordination centers.
- Enable system operators to gain familiarity with phasor technology for reliability monitoring and real-time operations.
- Learn to utilize phasor data to recognize normal and abnormal conditions, and assess grid stress.
- Provide system operators with real-time wide area information to increase situational awareness to avoid August 10, 1996 type blackouts.
- Monitor across the entire Western Interconnection (WI) for reliability, stability, system dynamics, and other key metrics using time synchronized phasor data.
- Enable system operators to evaluate and provide feedback on metrics monitored, visualization formats, functionality and displays.

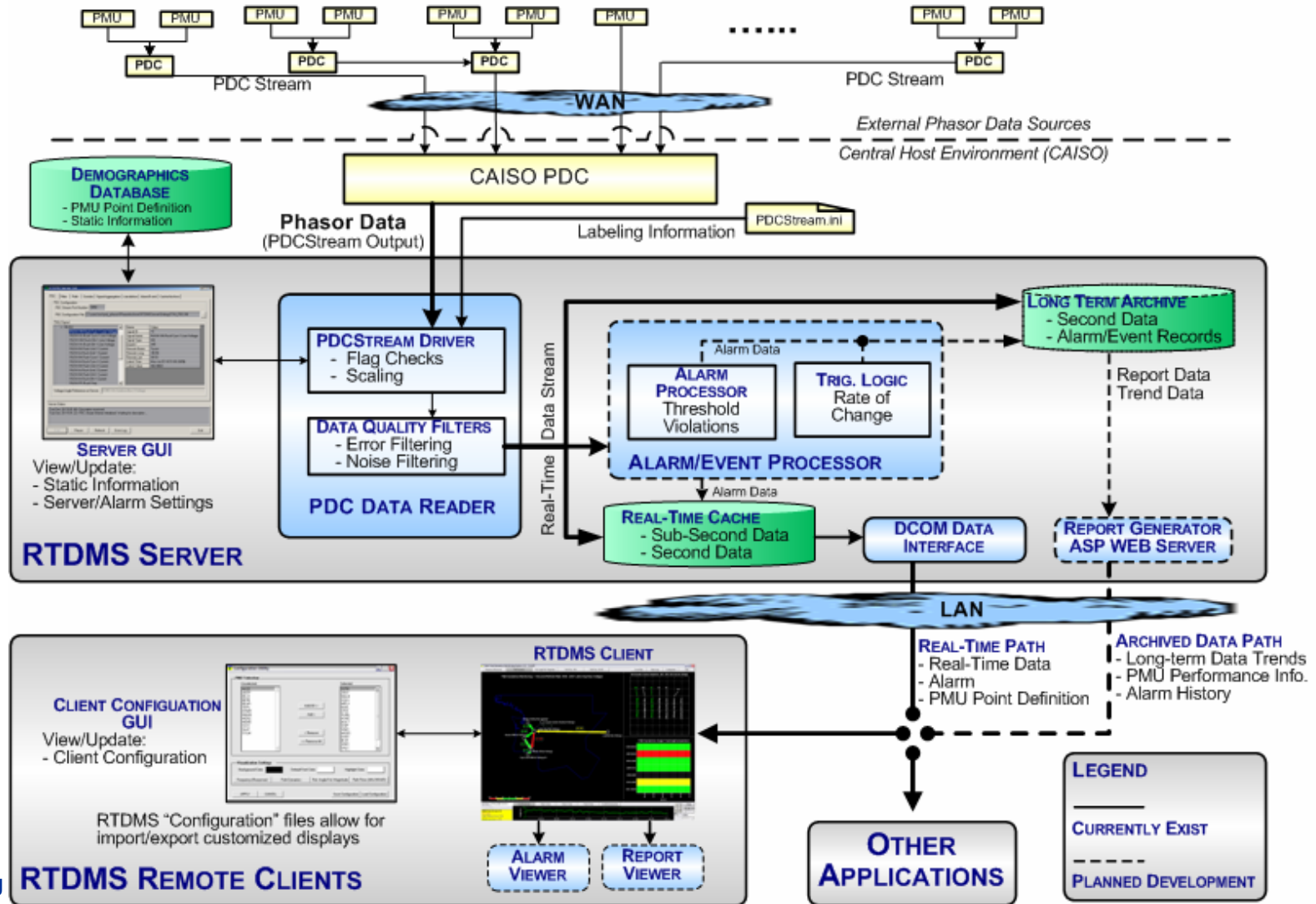
CA ISO RTDMS System Architecture

CAISO PHASOR NETWORK DIAGRAM
(PRESENT AND FUTURE)



J. Coroas - 12/19/05

CA ISO RTDMS System Architecture



Data Acquisition

- Data Reading
- Data Cleansing
- Data Processing

Data Management

- Short-Term Buffer for RT Monitoring and Alarming
- Historical Data for Trending/Reporting

Remote Monitoring

Clients

- Data Retrieval
- RT Monitoring & Alarming
- Trending & Reporting

RTDMS – What will the System Operator See?

- Wide Area View of WECC – Key metrics at selected locations and transmission corridors.
- Key Metrics Include – System frequency, voltages, phase angles and angle differences between major sources and sinks
- Violation of Key Thresholds (defined limits) – Visual alarming (color coded)
- Rapid Changes in Metrics - Visual alarming
- Identify System Anomalies

How To Navigate Around The RTDMS Screens

RTDMS Visualization Architecture

Real-Time Monitoring Mode

RTDMS Client (Version 3.0)

Path 75
Path Flow (MVAR)

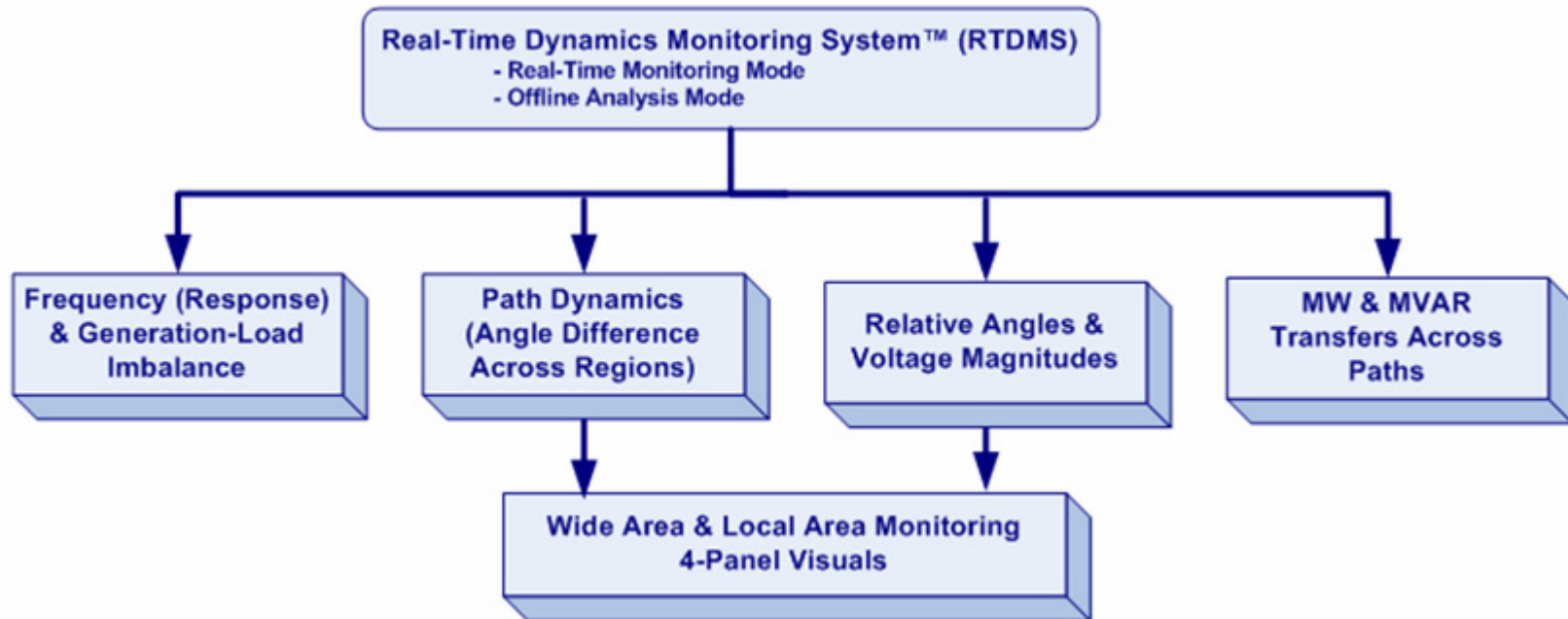
© Electric Power Group, LLC 2004

Offline Analysis Mode

RTDMS Client (Version 3.0)

Path 75
Path Flow (MVAR)

© Electric Power Group, LLC 2004



Four-Panel Display Major Functions

Display Tabs

Configuration/Help Functions

The screenshot shows a software interface with four main panels and several control elements:

- Top Panel (Blue):** Labeled "Real-Time Monitoring".
- Top-Right Panel (Yellow):** Labeled "Tracking/Comparison".
- Bottom-Right Panel (Green):** Labeled "Tracking/Analysis".
- Bottom Panel (Orange):** Labeled "Scrolling/Tabular Text".

Annotations and UI elements include:

- Display Tabs:** A red box highlights the top navigation bar containing "Interconnections", "Reliability Regions", "Reliability Authority", "Control Areas", and "ISO RTD".
- Configuration/Help Functions:** A red box highlights the top right corner with "Data Collection Tool", "Logon & Preferences", and "Help".
- Date/Time:** A red box highlights the bottom left corner showing "Date/Time 04/29/2002 18:50:00" and an "Auto Refresh" checkbox.
- Text Box:** A red box highlights a yellow box in the bottom left corner containing the text "Currently Selected Global ACE Monitoring Data © Electric Power Group, LLC 2002".
- Navigation Icons:** A red box highlights the bottom right corner containing navigation icons (back, forward, home, search) and a "View Angle 55" label.

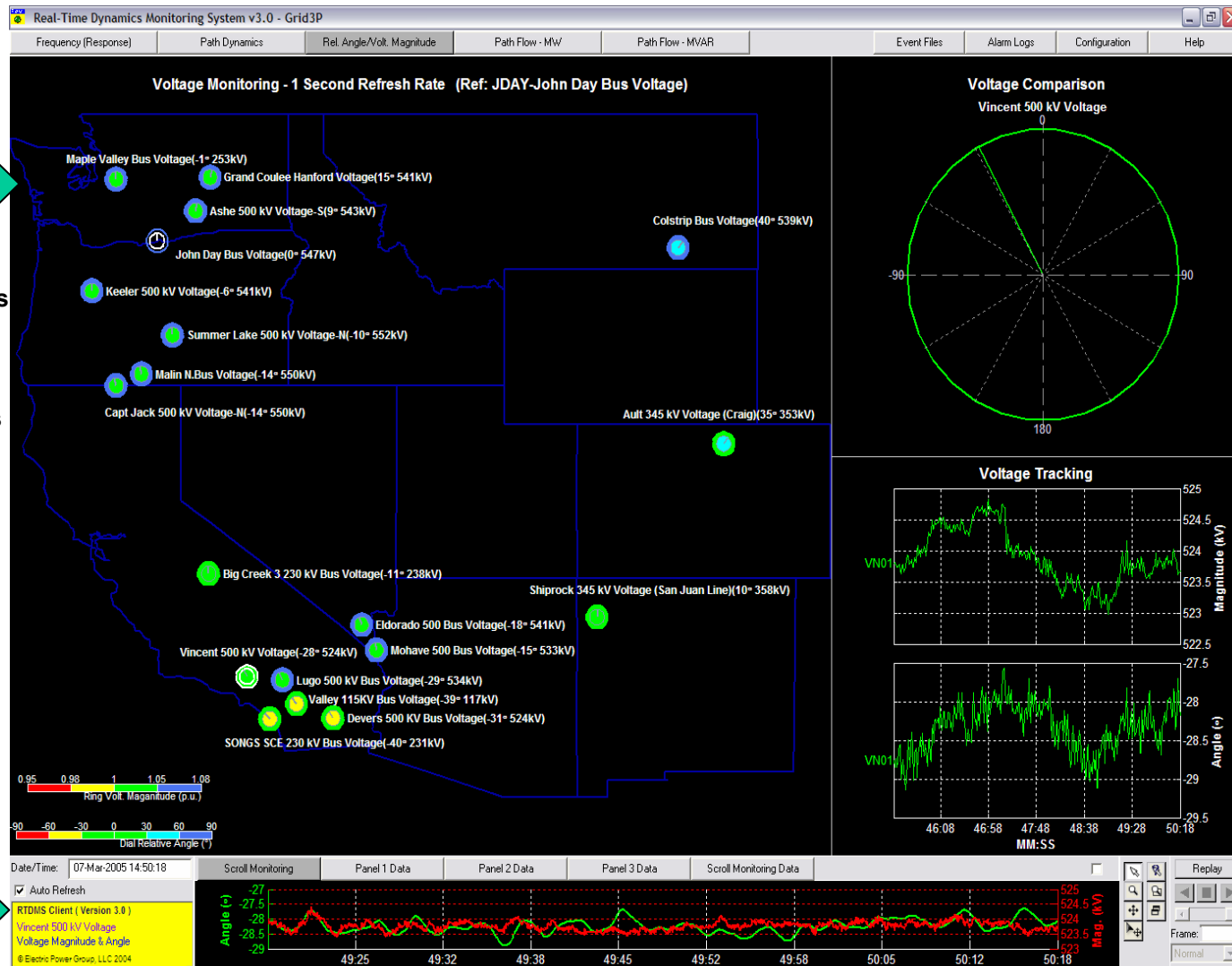
Date/Time

Text Box

Scrolling/Tabular Text

Navigation Icons

Sample Four-Panel Display



Monitor :

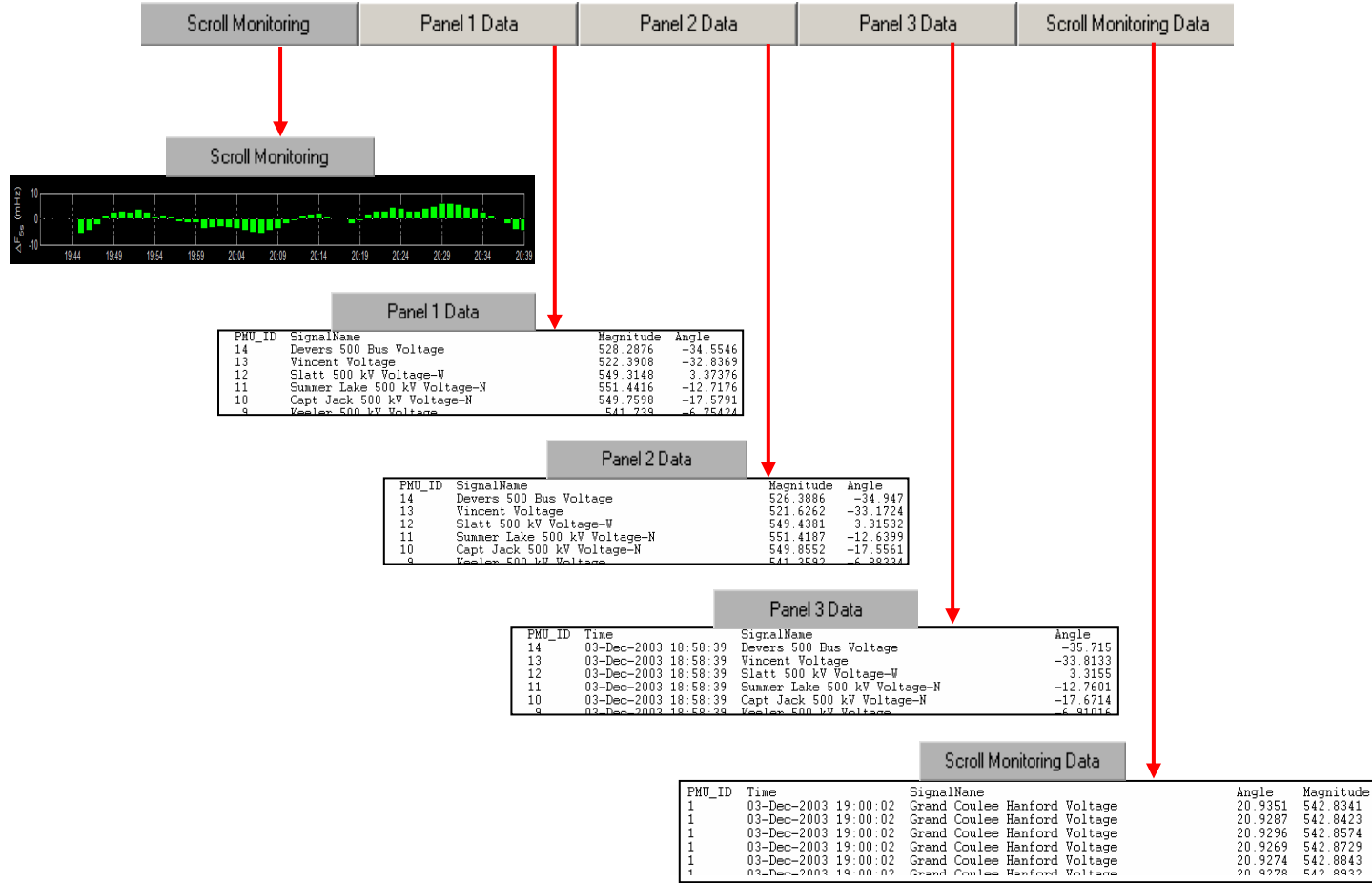
- voltage angles and magnitudes
- color coded
- quickly identify low or high voltage regions

compare angles selected

historical tracking and comparison over specified time duration

System Status

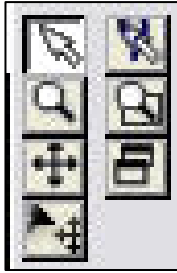
Tabular Table



Time	Frequency	Load_Imbalance	Threshold
28-Sep-2004 13:28:10	60.005	NaN	200
28-Sep-2004 13:28:10	60.005	NaN	200
28-Sep-2004 13:28:10	60.0051	NaN	200
28-Sep-2004 13:28:10	60.0051	NaN	200
28-Sep-2004 13:28:10	60.0053	NaN	200
28-Sep-2004 13:28:10	60.0054	NaN	200

View/Print Panel Data

Navigation Tools



Selection Arrow

This is the default Navigation tool. Selecting this tool allows the user to click and move through the different plots and data tables



Zoom In/Out

With the mouse on the image hold the button and slide the mouse down or to the left to reduce the size of the image or move the mouse up or to the right to increase the size of the image.



Reposition

Click the cross arrows, move the cursor to the viewing panel, click the left mouse and drag the object to the desired location in the panel



Pick to Move Text

Click on the cross arrows with the pointer, move the cursor to the text label, click the left mouse and drag the text label to the desired location in the panel



Pick to Display Data

Click on the arrow within the question mark to select data within the plot or diagram



Rubber Band Zoom

Click the magnifying glass with the box in the background, place mouse within the plot or diagram and left click to select the zoom desired



Restore to Original Size

Click on the double plot icon and click on the appropriate panel to restore the plot or diagram to its original size

Auto Refresh, Freeze and Replay

Real-Time Streaming Data (Auto Refresh)



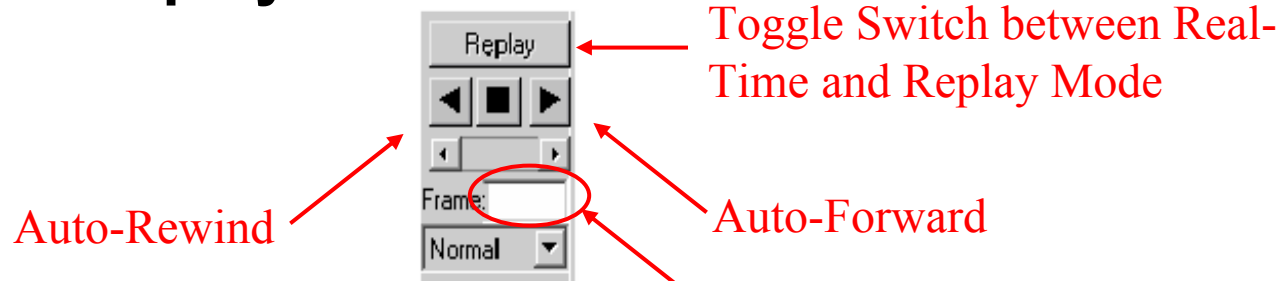
Click to remove “check” mark

Freeze Data



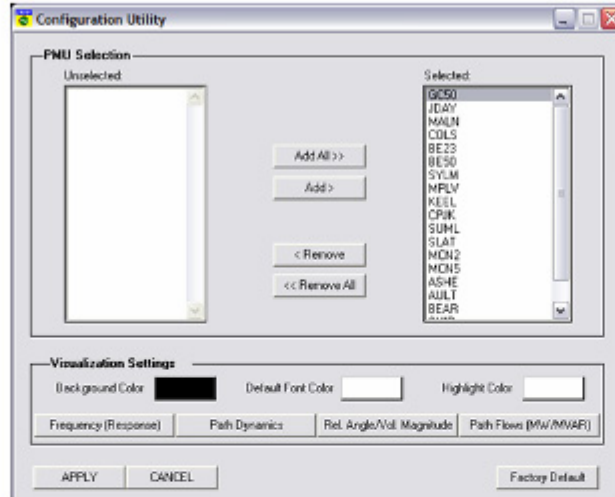
When “check” mark is removed the current data is held

Replay Data

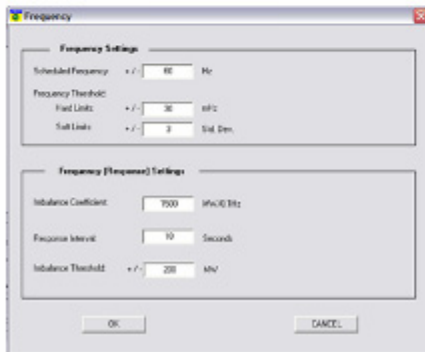


RTDMS Client Configuration Utility

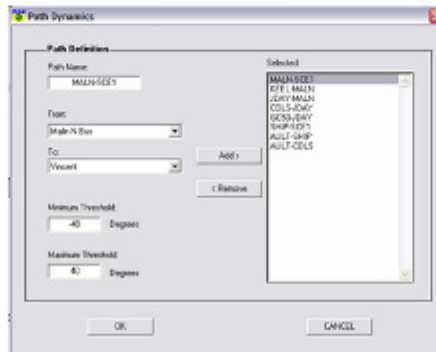
Configuration menus allow easy scalability as new monitoring devices are added to the system



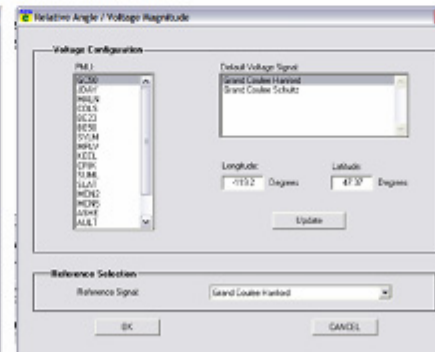
User-Defined Clusters



Frequency Monitoring Display



Path Dynamics Display



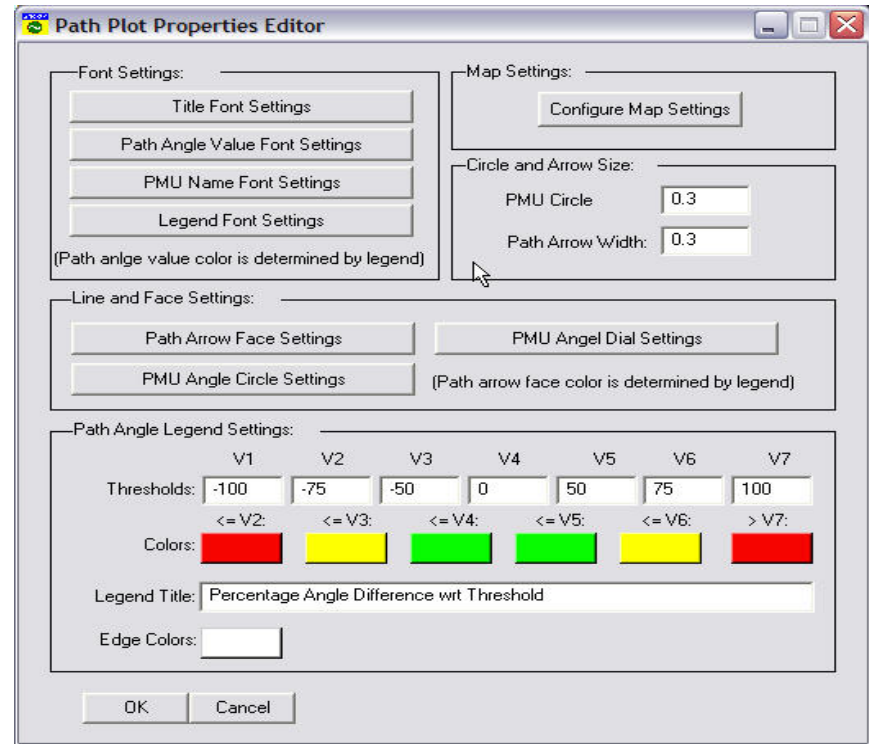
Relative Angle / Voltage Magnitude Display



MW / MVAR Path Monitoring Display

RTDMS Property Editor

- Change the maps in geographic displays
- Modify font settings of titles, axis labels, legend labels, identifiers, text values etc
- Change graphics Properties
Adjust legends – their thresholds and associated colors



Alarm Logs

Whenever there are any preset threshold violations (i.e., a new alarm), the "Alarm Logs" tab is highlighted in Red until the alarm is acknowledged – reappears in Red if a new alarm occurs



Alarm Log Pop-up Box



Clicking on the "Alarm Logs" tab acknowledges the alarm and the Alarm Log pop-up box appears

Click check box to show/eliminate the alarms on different types of monitored metrics from being displayed

SignalName	StartTime	LastTime	Val
SysFreq	07-Mar-2005 14:12:28	07-Mar-2005 14:12:28	0.0
SysFreq	07-Mar-2005 13:58:08	07-Mar-2005 13:58:08	0.0
SLAT_FR_Slatt Freq	07-Mar-2005 14:26:57	07-Mar-2005 14:26:58	0.0
AULT_FR_Ault Freq	07-Mar-2005 14:25:41	07-Mar-2005 14:25:41	0.0
AULT_FR_Ault Freq	07-Mar-2005 14:25:38	07-Mar-2005 14:25:38	0.0
BEAR_FR_Bears Ears Freq	07-Mar-2005 14:25:38	07-Mar-2005 14:25:38	0.0
AULT_FR_Ault Freq	07-Mar-2005 14:25:35	07-Mar-2005 14:25:35	0
AULT_FR_Ault Freq	07-Mar-2005 14:23:03	07-Mar-2005 14:23:03	0.0
SLAT_FR_Slatt Freq	07-Mar-2005 14:12:26	07-Mar-2005 14:12:28	0.3
SLAT_FR_Slatt Freq	07-Mar-2005 13:58:06	07-Mar-2005 13:58:08	0.3
SLAT_VM_Slatt 500 kV Voltage-V	07-Mar-2005 14:26:57	07-Mar-2005 14:26:58	0.0
SLAT_VM_Slatt 500 kV Voltage-E	07-Mar-2005 14:26:57	07-Mar-2005 14:26:58	0.0
SLAT_VM_Slatt 500 kV Voltage-E	07-Mar-2005 14:12:26	07-Mar-2005 14:12:26	0.0
SLAT_VM_Slatt 500 kV Voltage-V	07-Mar-2005 13:58:06	07-Mar-2005 13:58:06	0.0
SLAT_VM_Slatt 500 kV Voltage-E	07-Mar-2005 13:58:06	07-Mar-2005 13:58:06	0.0

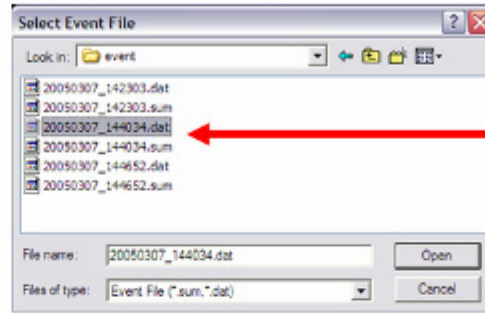
List the various alarms and relevant information (e.g. violation type, violation start time, violation end time, violation threshold, etc)

Click in "Refresh" to update alarm list during viewing

Click in "Save" to save current list of alarms into a text file

Event Files (RTDMS Offline Analysis)

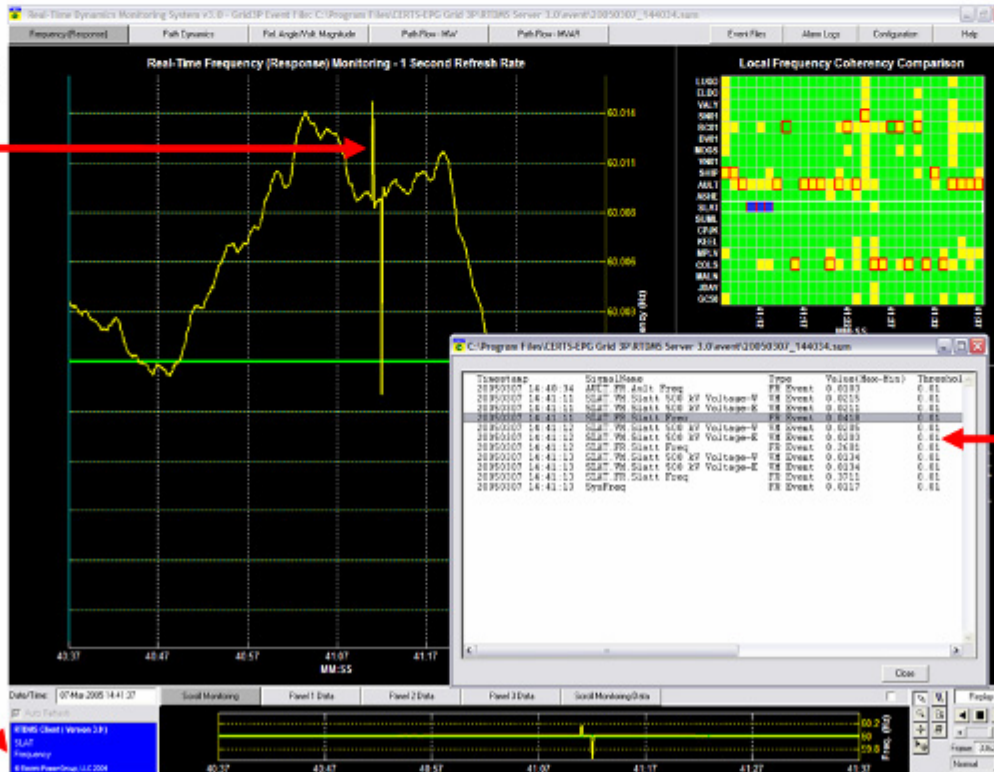
Click on "Event Files" tab to load an archived event file into the RTDMS application



Select an Event File to load into RTDMS for offline analysis (files labeled by date/time)

RTDMS in Offline Mode

Transient in frequency measurements triggered event capture



User-Defined Clusters

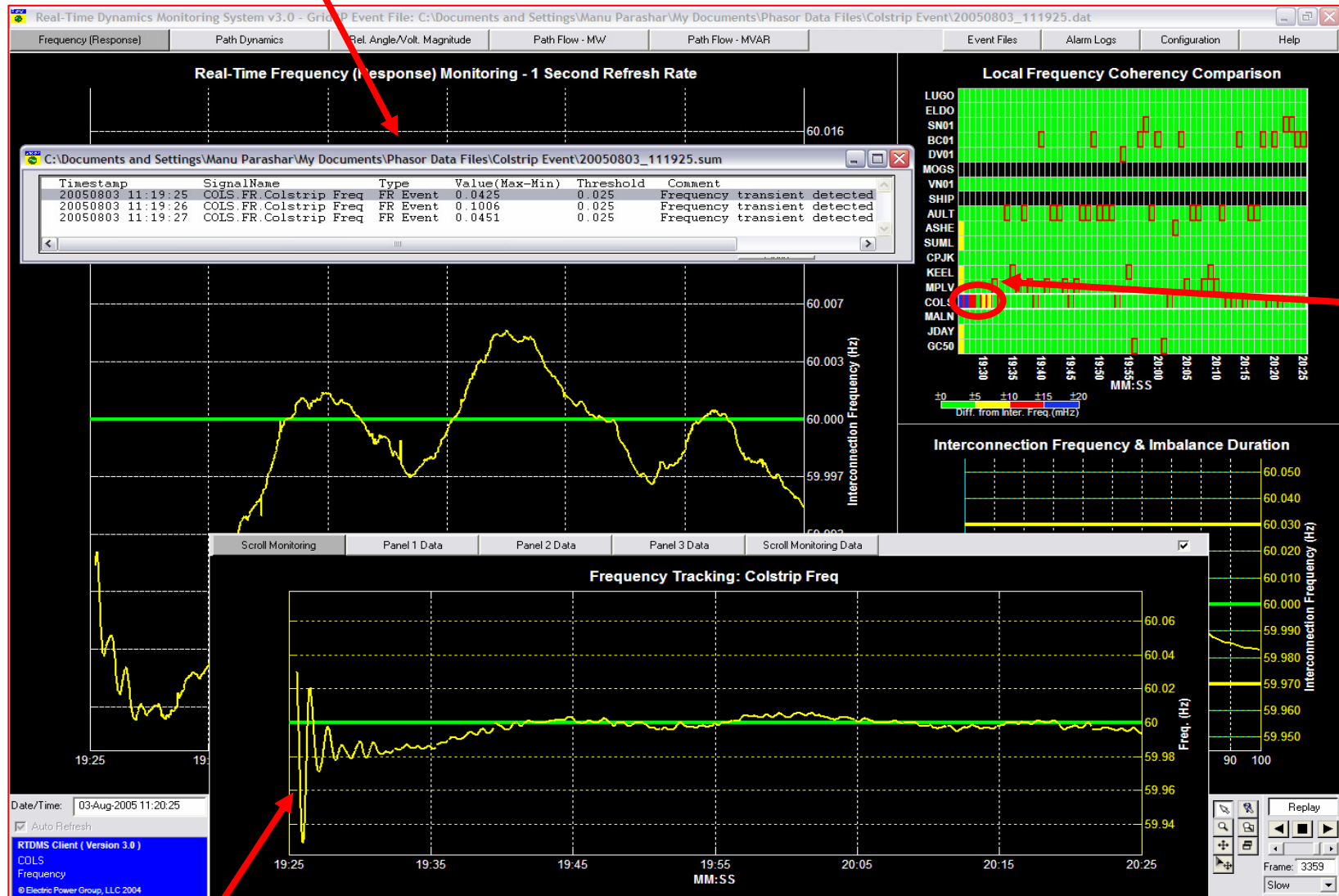
Alarm Summary box listing all violations during event capture

Title Box with blue background implies RTDMS is running in offline mode

Click on "Replay" button to switch back to real-time monitoring mode

RTDMS – Frequency Transient Example

Alarm log indicating Frequency Transient detected at the Colstrip PMU and the time of the event



Identify Trip near Colstrip PMU

Frequency response at Colstrip PMU

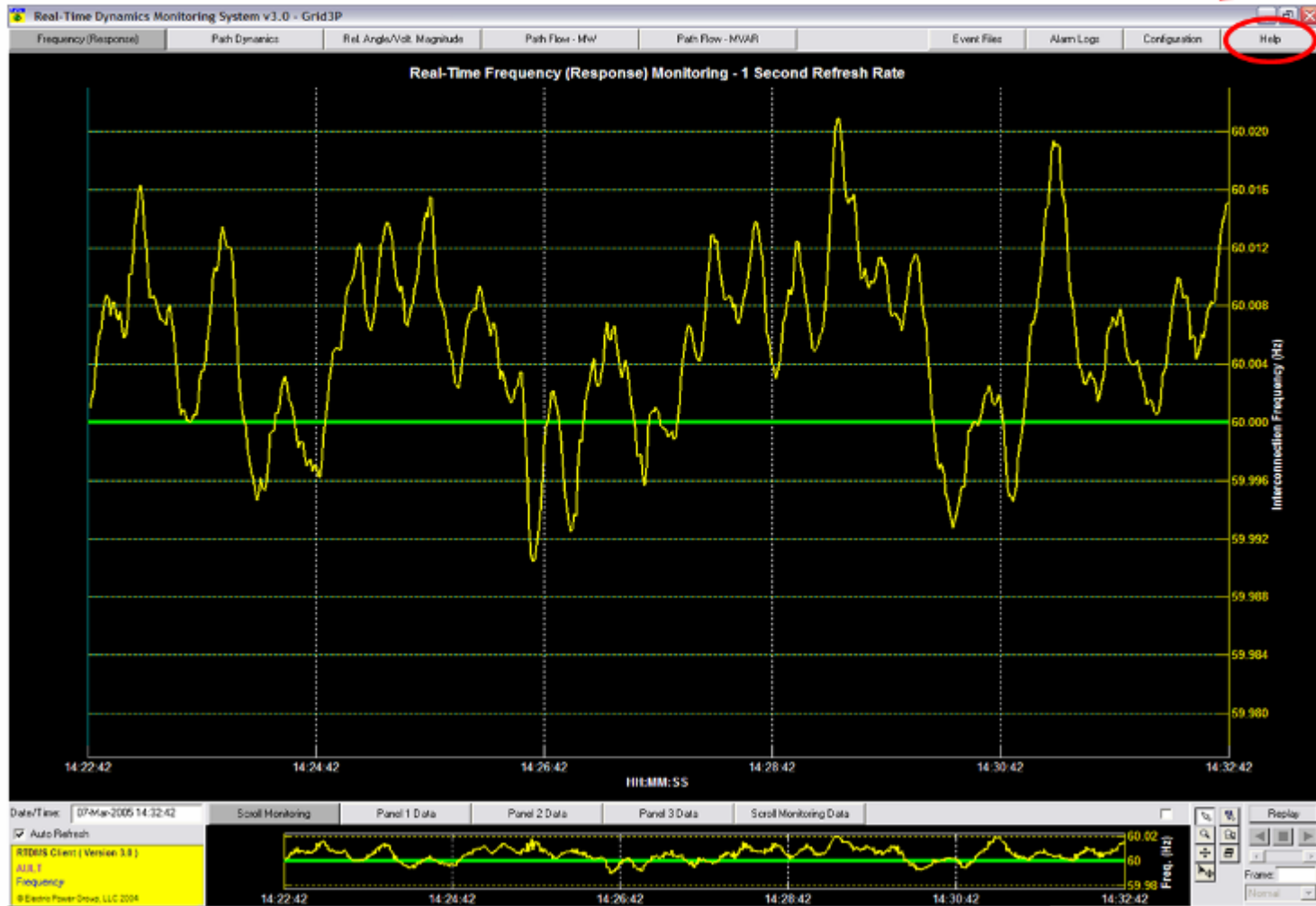
CA ISO RTDMS Functionalities Summary

RTDMS Functionalities at CA ISO:

- **Includes BPA, SCE, WAPA, and PGE phasor data shown in real-time**
- **Server-Client architecture (Multi-user capability)**
- **Geographic visualization on Voltages, Angle Differences, Frequency, MW & MVAR**
- **End user configurability**
- **Replay capability**
- **Real-time alarming and event detection**
- **Event archiving and playback**

System Support and Help Tab

Help Tab



Help Overview

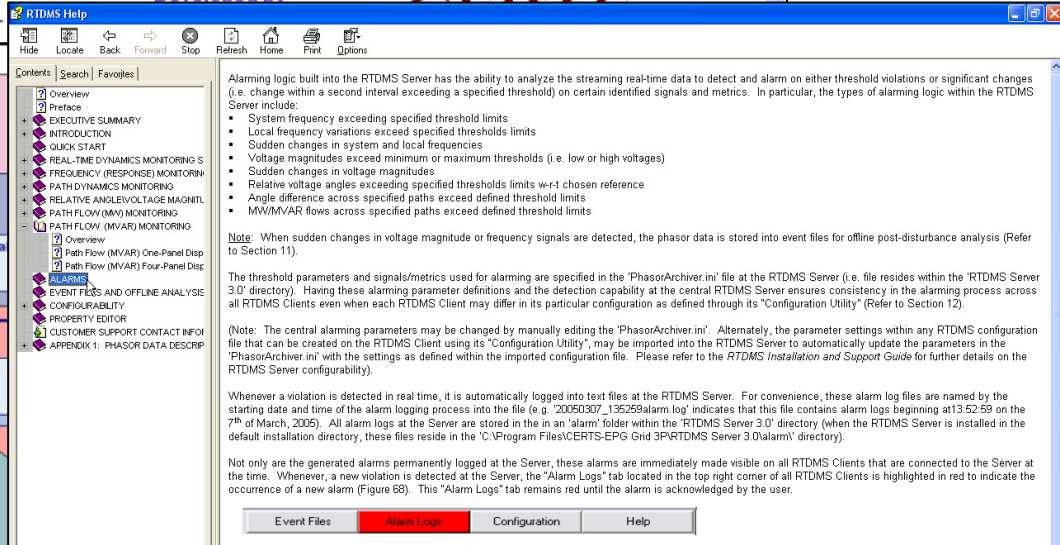
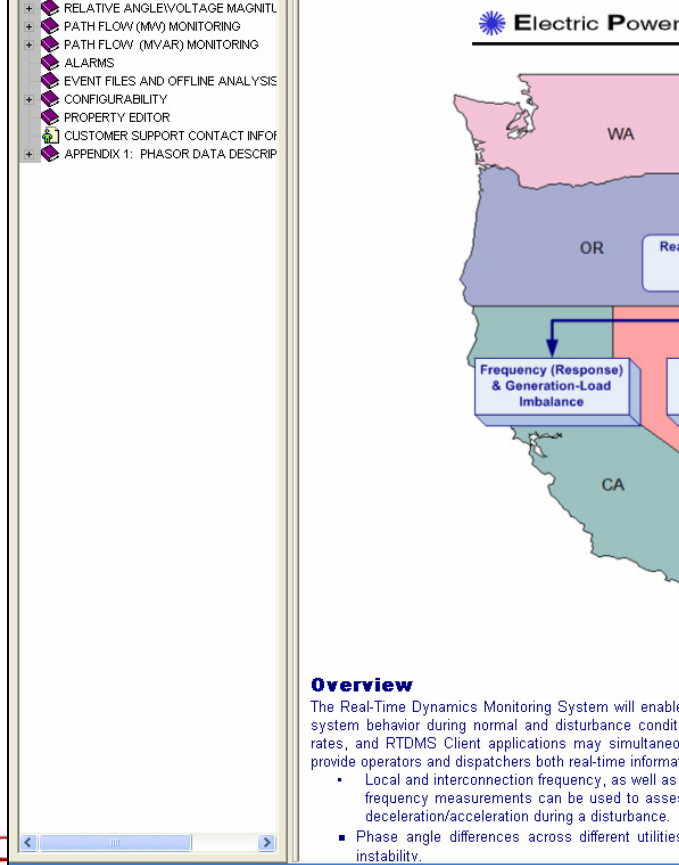
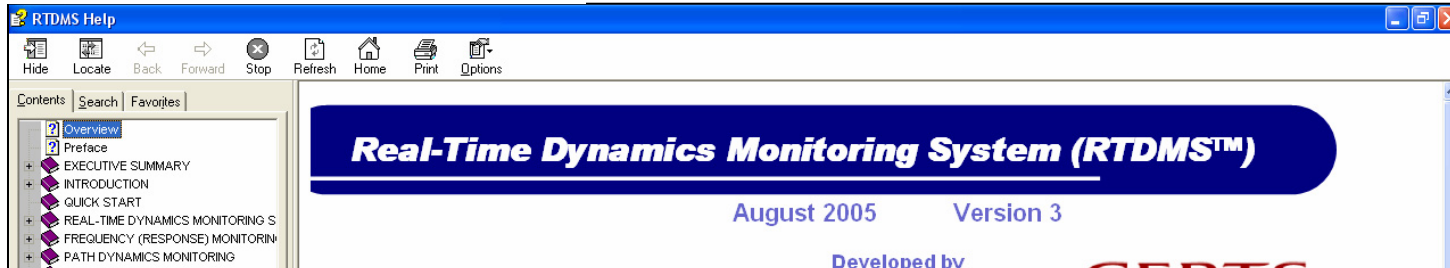
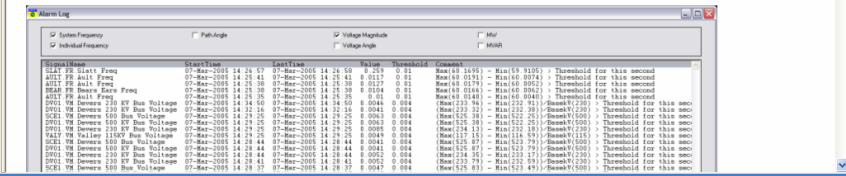


Figure 68: "Alarm Logs" Tab Highlighted in Red to Alert RTDMS User of New Alarm

To acknowledge the alarm, click on this tab and the "Alarm Log" box pops-up (Figure 69). Though all the alarms are logged at the RTDMS Server as a text file, the user may be selective on the alarms he wishes to see at the RTDMS Client. This is done by selecting/deselecting the appropriate alarm types within the "Alarm Log" box. For each alarm listed in the box, the alarm log provides information on the signal associated with the violation, the start time of the violation, the end time of the violation (or most current time during a violation), the violation value and corresponding threshold, and the nature of the violation.



Overview

The Real-Time Dynamics Monitoring System will enable system behavior during normal and disturbance condition rates, and RTDMS Client applications may simultaneously provide operators and dispatchers both real-time information.

- Local and interconnection frequency, as well as frequency measurements can be used to assess deceleration/acceleration during a disturbance.
- Phase angle differences across different utilities with respect to their alarming thresholds to assess the static stress across the system and its proximity to instability.

Contact Information

Manu Parashar

Office: (626) 685-2015 ext 130

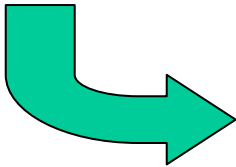
parashar@electricpowergroup.com

***Any Questions
Before We Move
On To The Demo?***

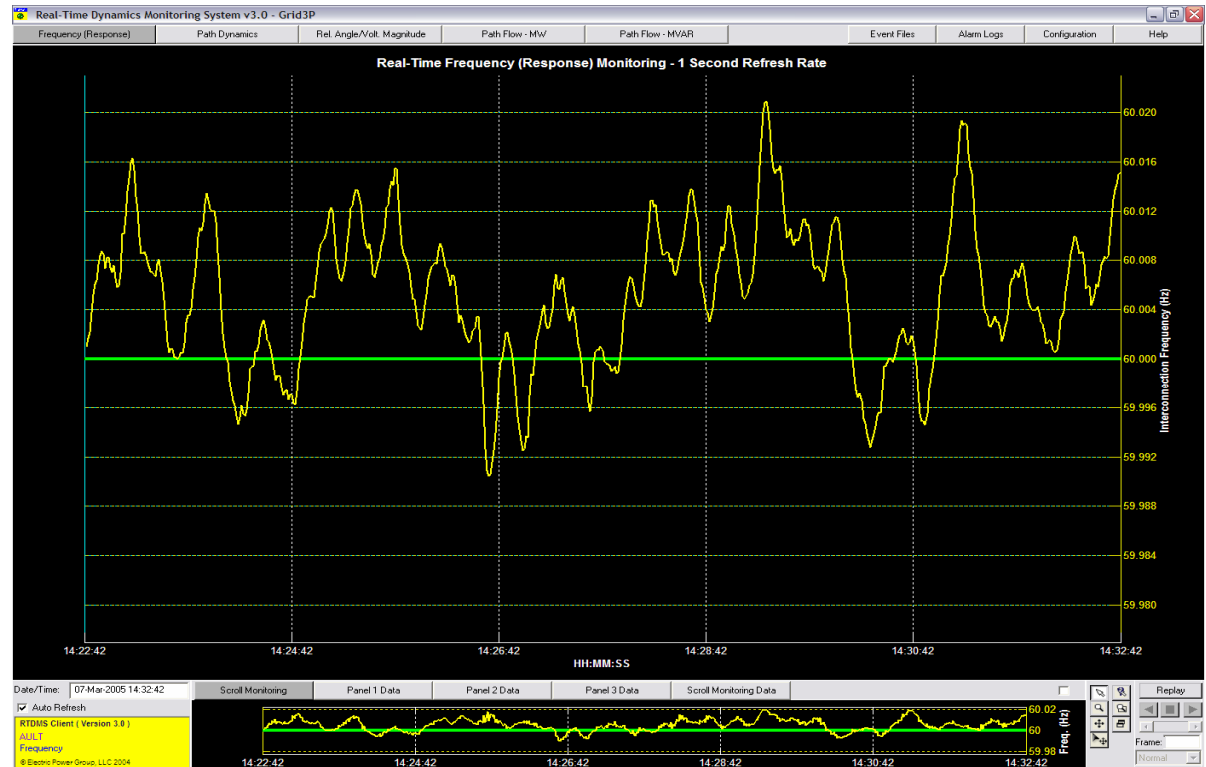
Start RTDMS Client Application



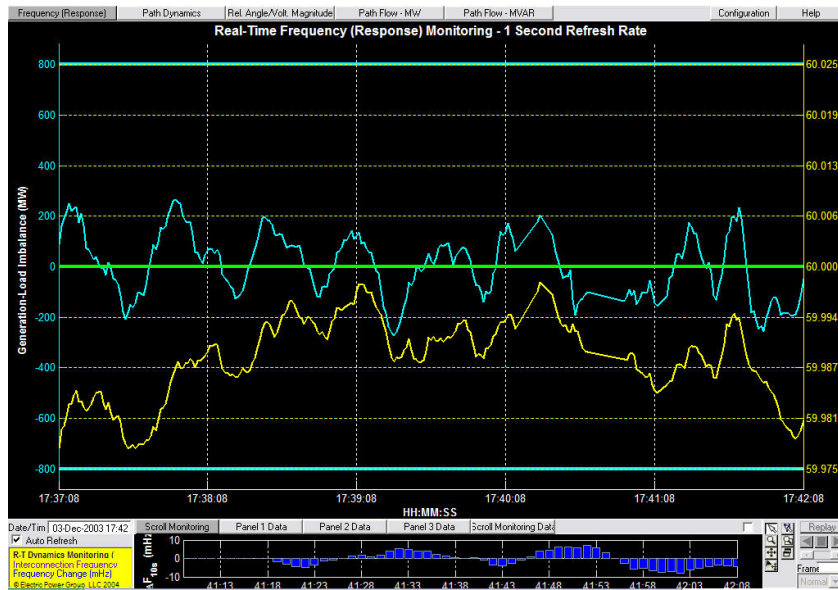
CAISO RTDMS Client 3.0



Frequency (Response) Monitoring Display (default)



Frequency Monitoring Display



1-Panel Visual

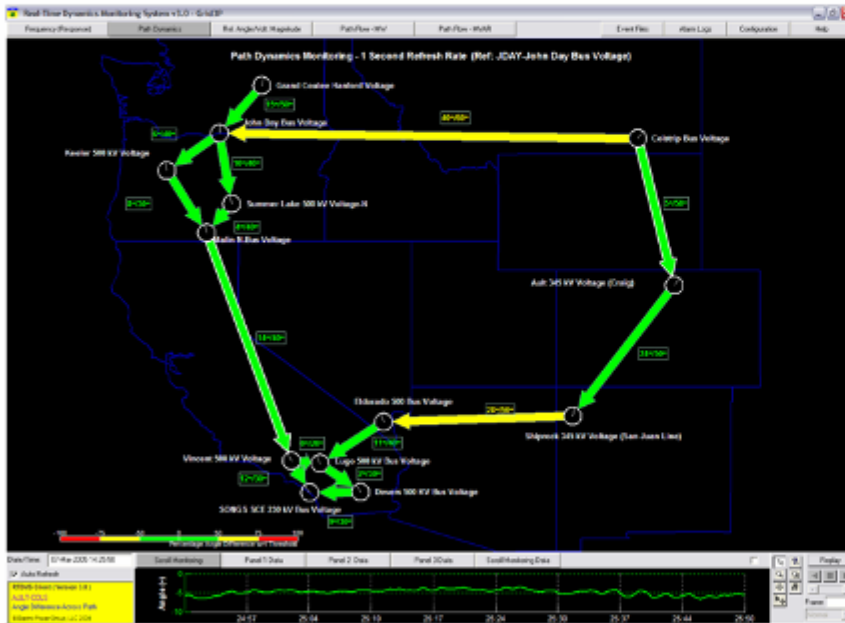


4-Panel Visual



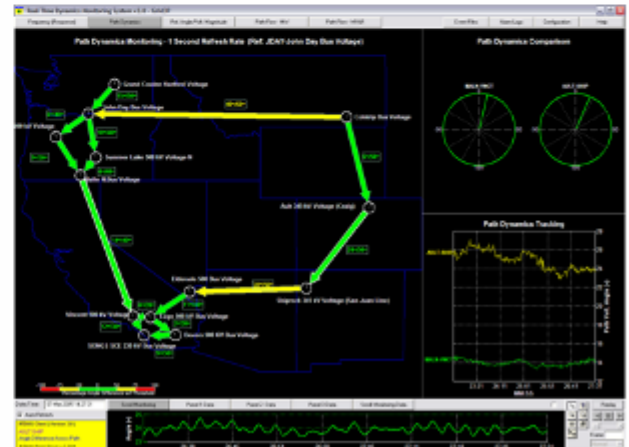
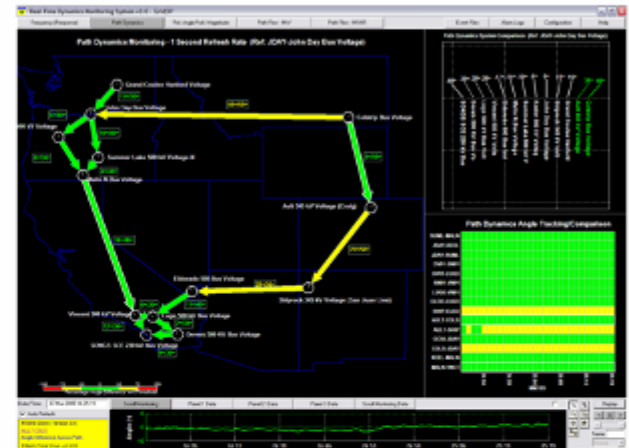
Path Dynamics Monitoring Display

– Local and Wide-Area Views



One Panel View

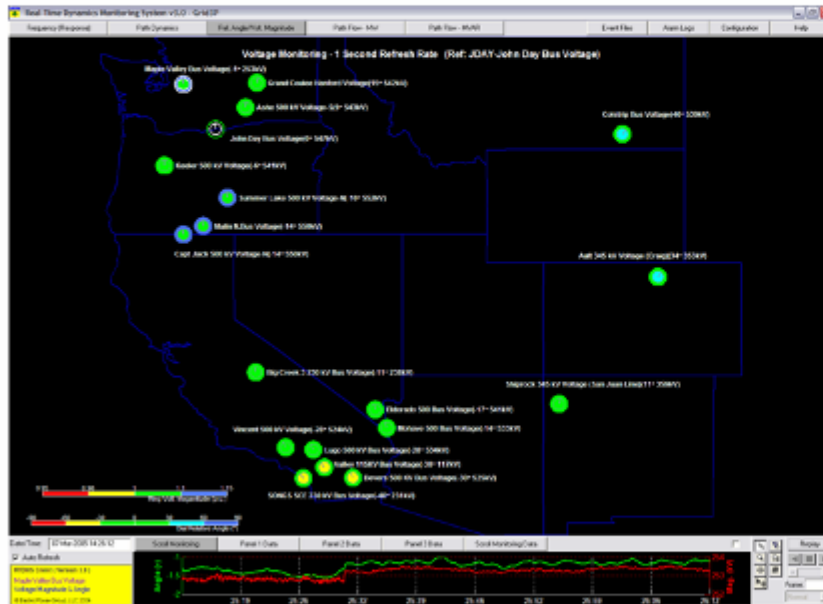
Wide-Area View



Local View

Relative Angle/Voltage Magnitude Monitoring Display

– Local and Wide-Area Views

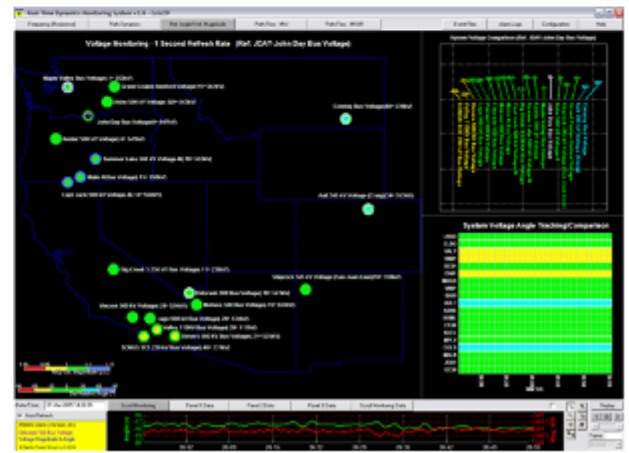


One Panel View

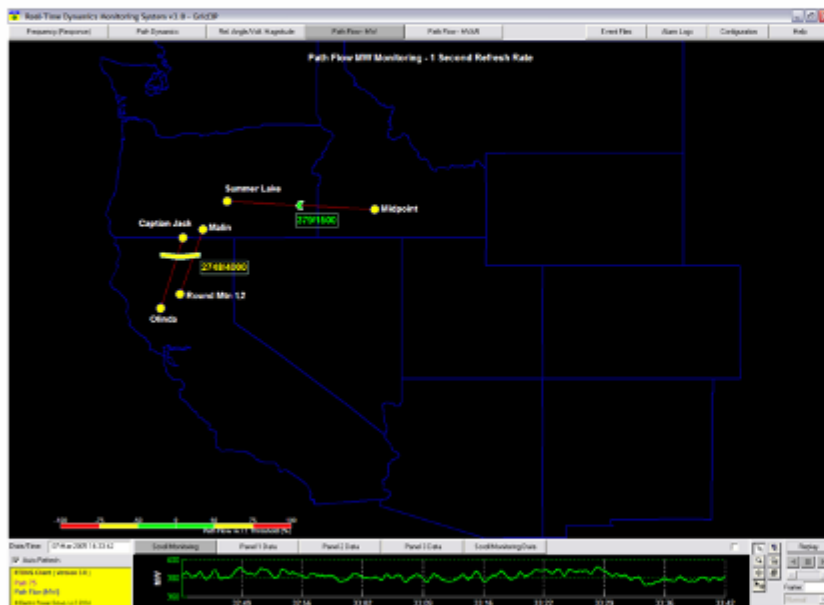
Wide-Area View



Local View

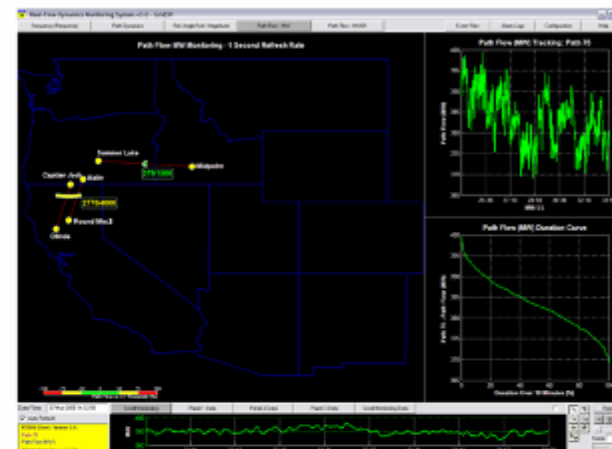


MW and MVAR Monitoring Displays

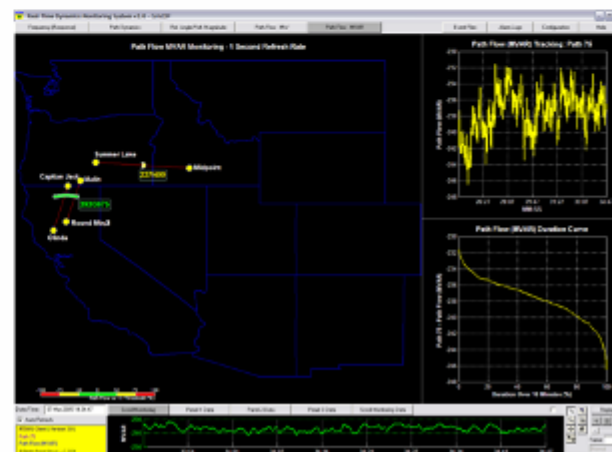


One Panel MW/MVAR

4-Panel View MW

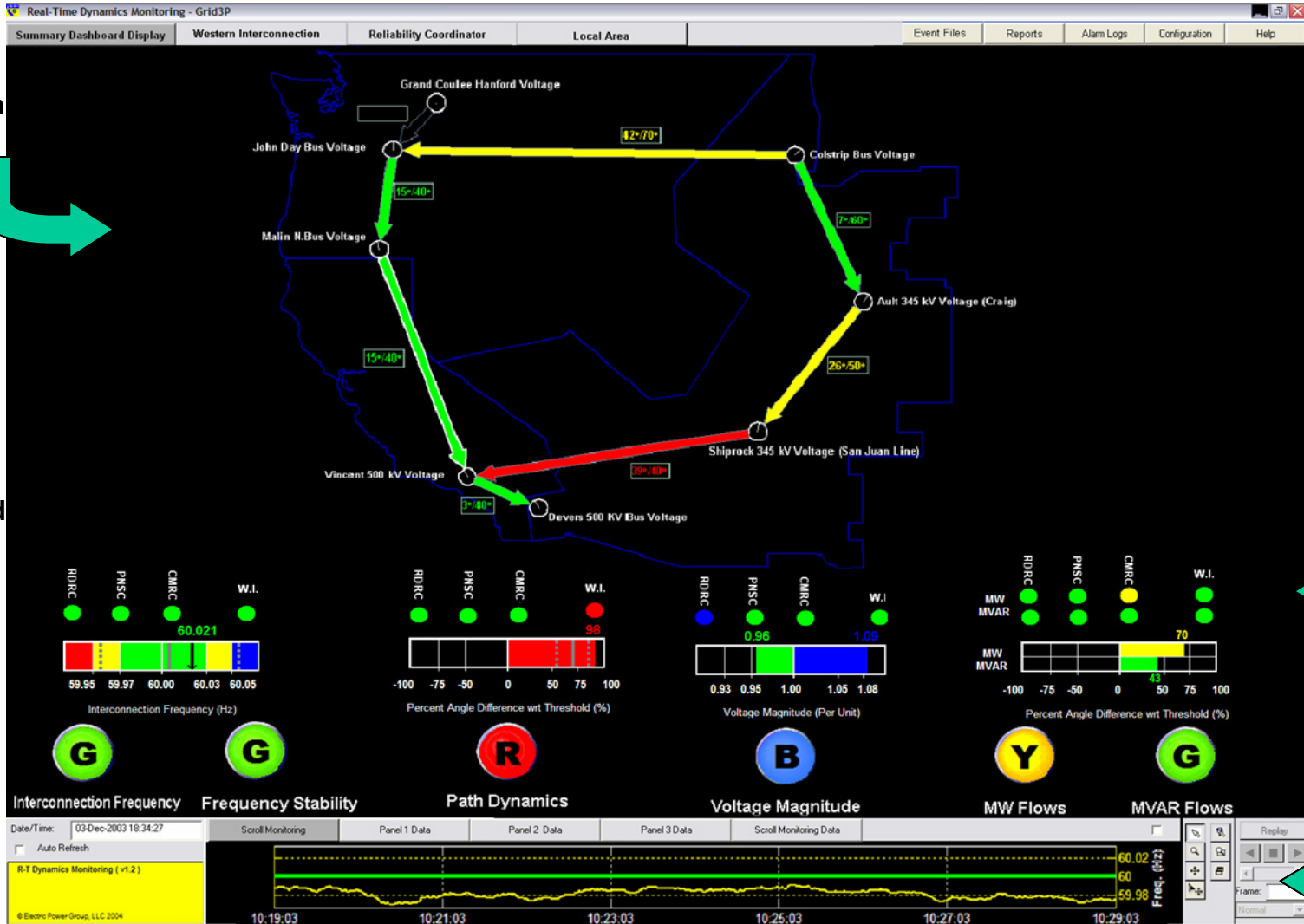


4-Panel View MVAR



RTDMS Version 4.0 - End of 1 Quarter 2006

RTDMS DASHBOARD SUMMARY



WI Partitioned into 3 Regions
Inter-Area Path Dynamics Shown in Geographic Display

Gauges to quantify worst performing metric (i.e., current value, mean, standard deviation, etc)

Monitor status of key WI metrics

Monitor status of metrics at each RC

Track worst performing point/path for selected metric

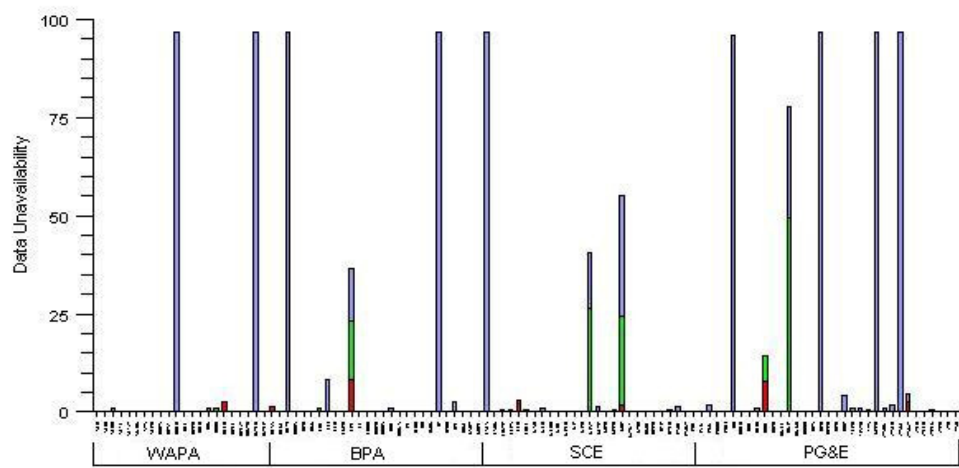
RTDMS PMU PERFORMANCE MONITORING

- Real-time PMU status information provided within RTDMS displays
- Historical PMU performance shown as charts/tables:

PMU Data Unavailability Chart

Friday, September 16, 2005 11:25 AM PST

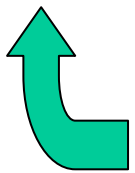
■ Drop out
■ Trans. Error
■ Sync Error



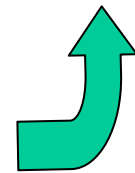
PMU Data Unavailability Report

Friday, September 16, 2005 11:25 AM PST

PMU Name	Available (%)	Unavailable (%)			Contact Information	
		Drop out	Trans. Error	Sync. Error		
WAPA	WAPA PMU1	99.10	0.70	0.20	0	(123) 456-7890
	WAPA PMU2	0	100.00	0	0	(123) 456-7890
	WAPA PMU3	98.00	1.00	0	1.00	(123) 456-7890
BPA	BPA PMU1	100	0	0	0	(123) 456-7890
	BPA PMU2	100	0	0	0	(123) 456-7890
	BPA PMU3	0	100.00	0	0	(123) 456-7890
	BPA PMU4	65.00	34.00	0	1.00	(123) 456-7890



Daily



Plots and Tables indicate data unavailability by: 'Dropouts', 'Transmission Errors', 'Synchronization Errors'

RTDMS TRENDING AND REPORTING

Data Trends Report Dialog

Start Date/Time: Fri, Sep 16, 2005 11:25:00 AM

Report Types: Hourly Daily

Signal Type: Relative Angle

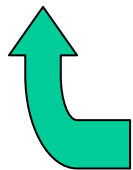
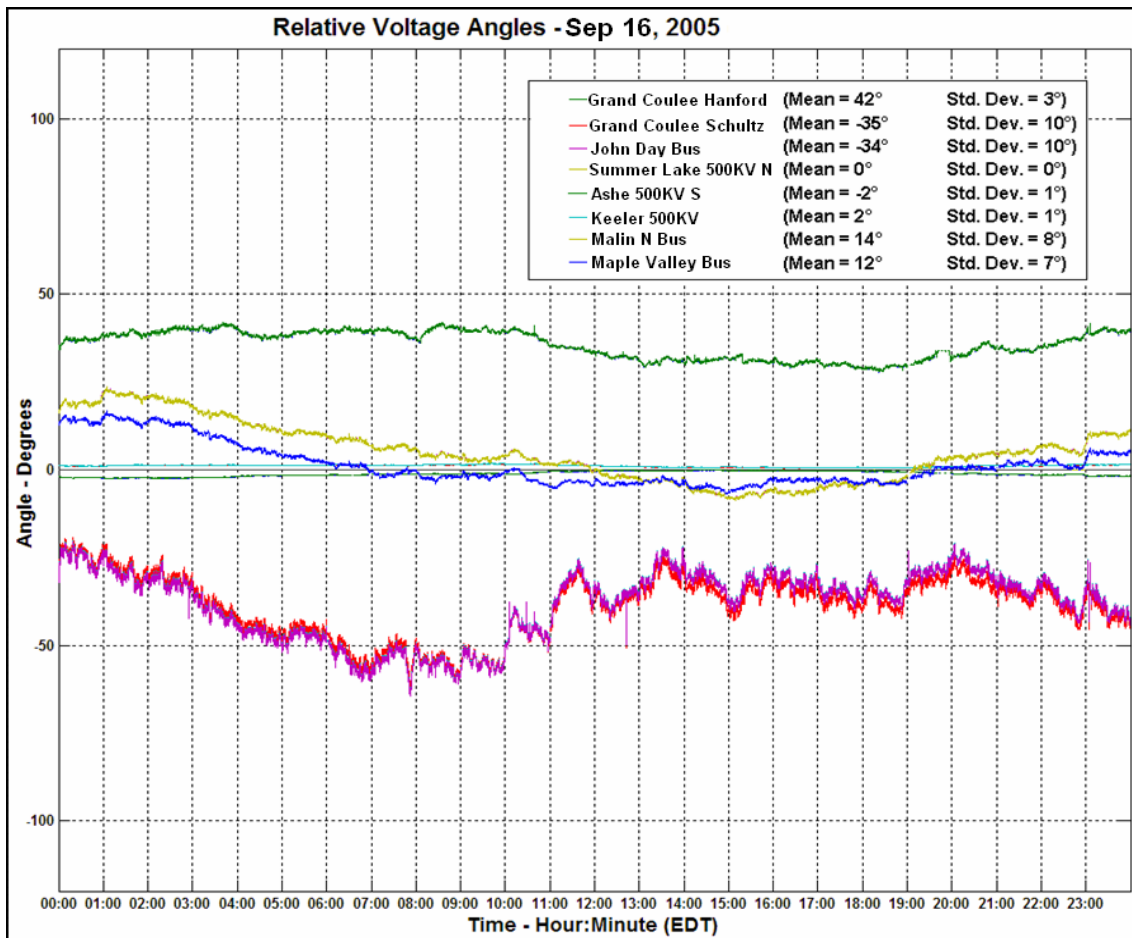
Signal Selection:

Unselected Signals	Selected Signals
Grand Coulee Hanford	Summer Lake 500 kV Voltage-N
Grand Coulee Schultz	Summer Lake 500 kV Voltage-S
John Day Bus	Ashe 500 kV Voltage-S
Malin N. Bus	
Colstrip Bus	
Maple Valley Bus	
Keeler 500 kV	
Keeler 230 kV Bus	
Capt. Jack 500 kV	

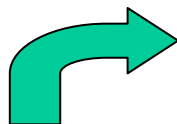
Reference Selection:

Reference Signal: Ashe 500 kV

OK Export Cancel



Select 'Signals', 'Signal Type' and 'Date/Time'



- Create trend plots
- Export data into excel or text files