WESTERN INTERCONNECTION PHASOR MONITORING NETWORK AND VISUALIZATION

Presented to the
WECC Performance Work Group

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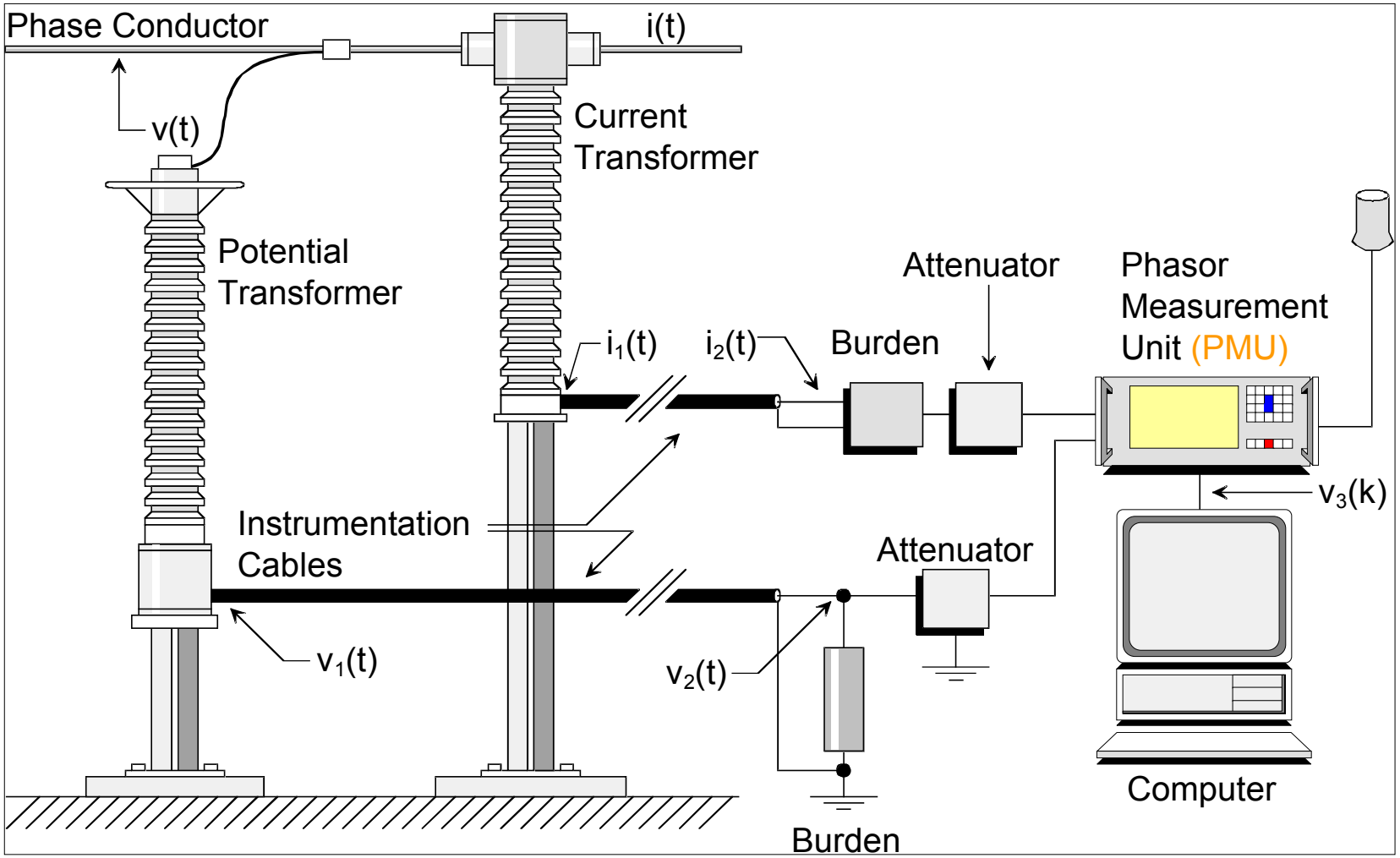
Agenda

- Phasor Technology:
  - Brief Overview
  - Phasor Measurement System
  - The Importance of Using Synchronized Data
  - Industry Applications
  - Example
- CAISO Phasor Network
- Real-Time Dynamics Monitoring System
- Benefits of Phasor Measurement System and RTDMS Visualization
- Future expansion of WECC Phasor Network
  - Work to be done
- Phasor Measurement System and RTDMS Visualization Application Demo

OBJECTIVE

Utilize the WECC Phasor Measurement System and the Real-Time Dynamics Monitoring System (RTDMS™) visualization application to effectively translate raw performance data into meaningful operation information for the operator to reliable operate the Western Interconnection.

Source of Phasor Measurements



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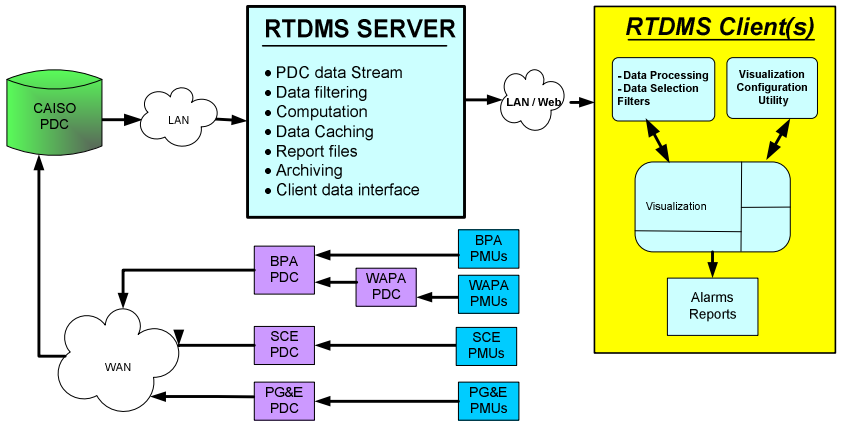
Phasor Technology: Networking and Synchronization

Phasor Network (CAISO)

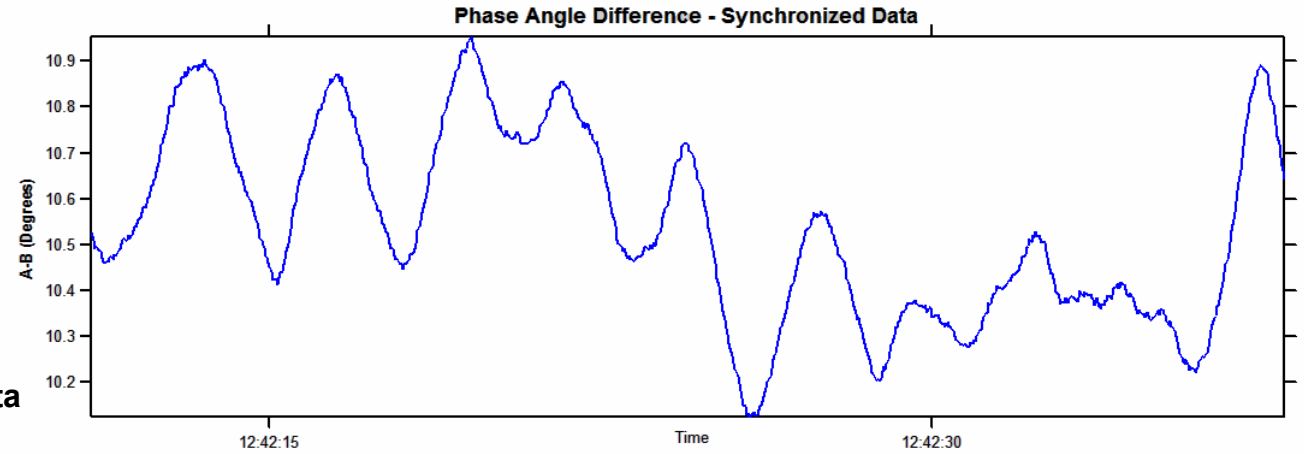


Networking - Most stability events involve oscillations and control interactions between neighboring utilities and geographic operating regions. This dictates the need for multiple recording devices at key locations throughout the interconnection.

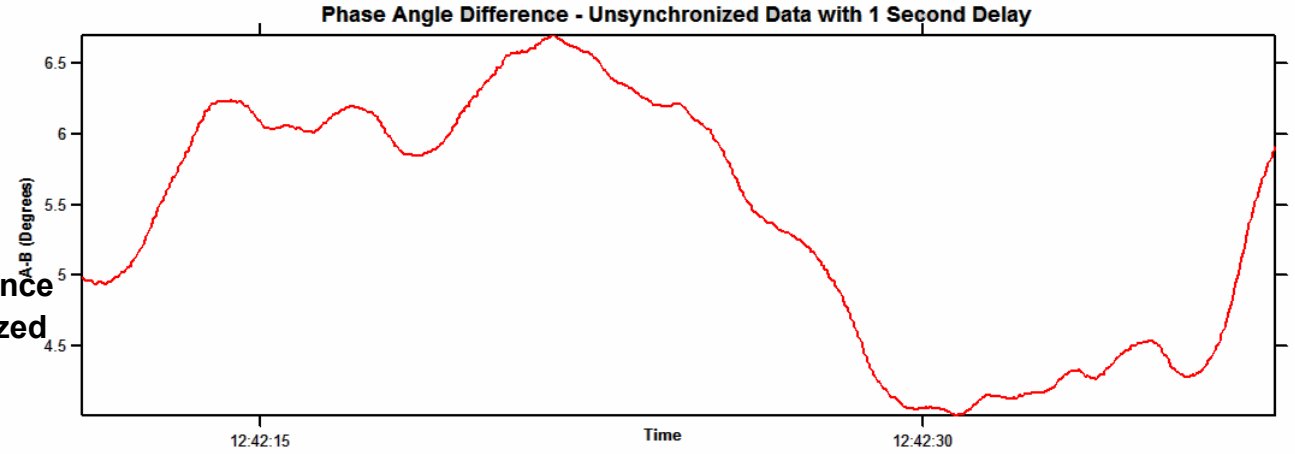
Time Synchronization - Phasor measurements are time-stamped using the global satellite positioning system so that measurements from across the interconnection can be precisely aligned for comparison against one another.

Phasor Technology - Importance of Synchronization

phase angle difference using synchronized data



phase angle difference using unsynchronized data with 1 second mismatch



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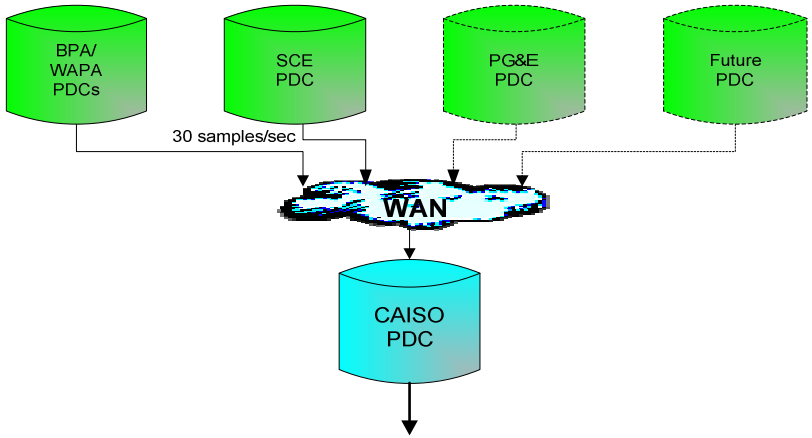
Phasor Technology – Hardware Elements

Phasor Network (CAISO)

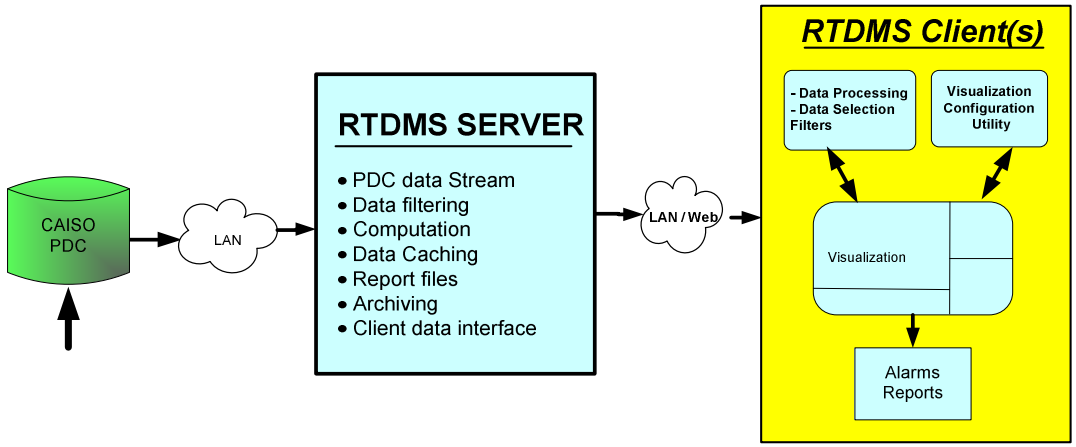


The Primary Hardware Elements in a Phasor Network are:

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. 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. The voltage and current data is used to calculate MW and MVAR flows on key lines.

Phasor Technology – RTDMS Software Elements



The Primary Software Elements for RTDMS Visualization are:

RTDMS Server Unit – The RTDMS server collects data from PDC, performs calculations and data filtering, completes data caching and sends data, via an interface, to the RTDMS client for visualization.

RTDMS Client Unit – The RTDMS client is installed at the user's Personal Computer for visualization. The RTDMS client processes the data received from the server and displays the data to user on demand. This application has configuration capability that allows the user to select PMUs, select system data, change thresholds and modify displays to meet user's needs.

Phasor Technology – Industry Applications

- Phasor technology allows monitoring of Substations and Transmission lines on a wide-area basis
- Phasor technology will allow reliability coordinators and dispatchers to take high resolution “snapshots” of the WECC Interconnection grid and evaluate the grid 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
  - Special protection systems
  - Transient instability protection and fault location systems

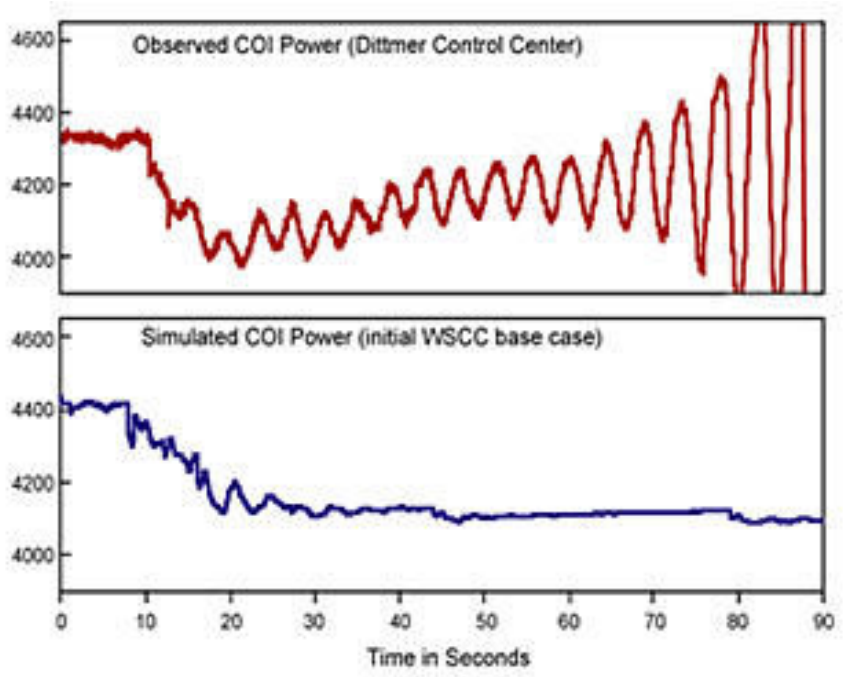
Value of Phasor Technologies - Example

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

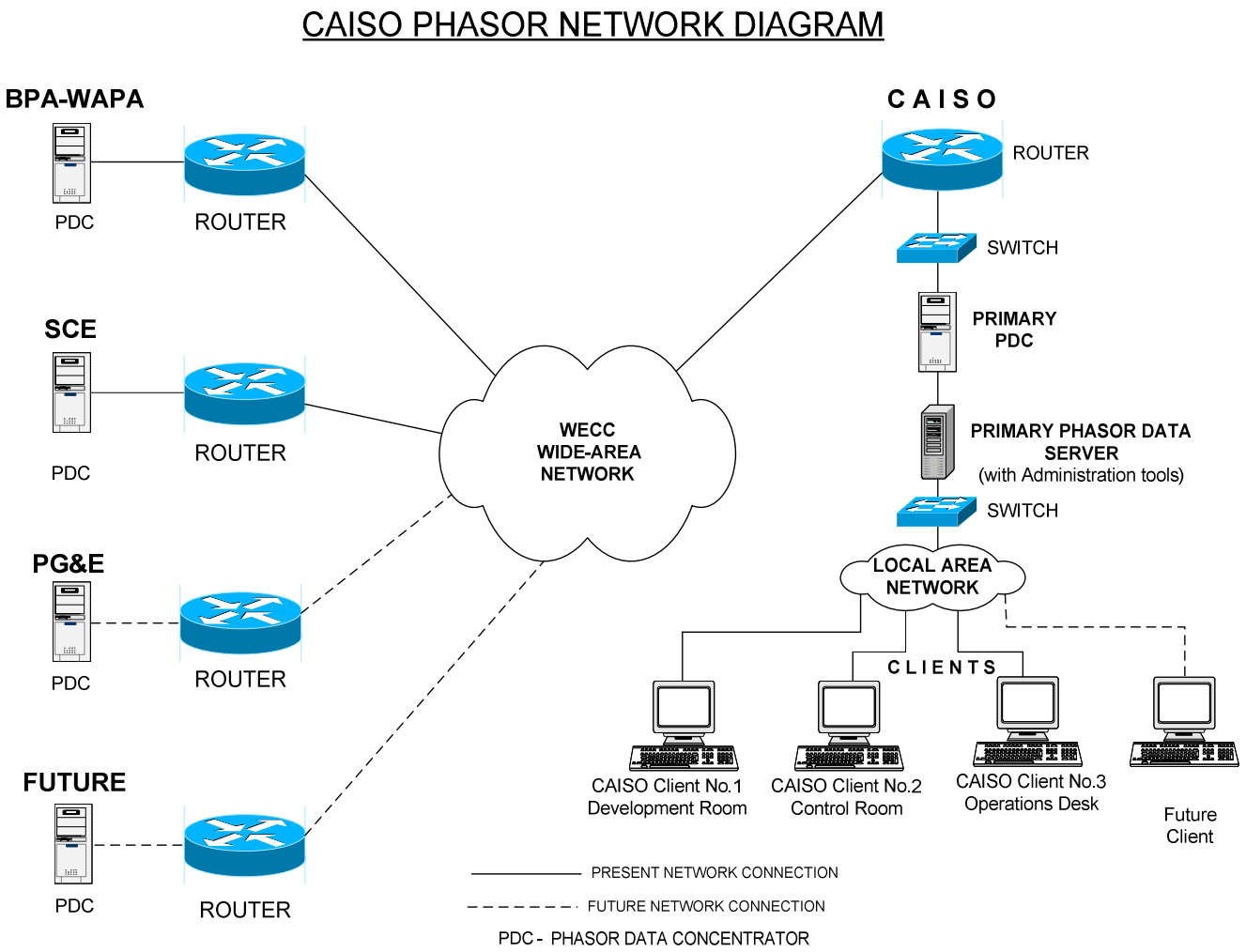
The WECC has since modified their simulation models to better represent actual system performance.

Actual System Performance



Model Simulation - Predicted System Performance

Existing Western Phasor Network



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Real-Time Dynamic Monitoring System

- The RTDMS reads, process and displays real-time phasor frequency, voltage magnitudes and angles, and calculate and display MW and MVARS for:
  - Wide are reliability management
  - Post-disturbance analysis
  - Validation of off-line study results
- Future applications
  - Improved control against voltage collapse
  - Enhanced state estimation
  - Wide-area coordinated protection and control

BENEFITS OF WIDE-AREA PHASOR MEASUREMENT SYSTEMS

- Comprehensive wide-area view of the system
- Rapid assessment of actual system conditions
- Allow corrective action before voltage collapse
- Facilitate prompt post-disturbance analysis
  - *sequence of events*
  - *readily available synchronized data*
- Power swing detection by on-line angle difference monitoring
- Increased power system performance
- Improved system models for steady-state and dynamic analysis

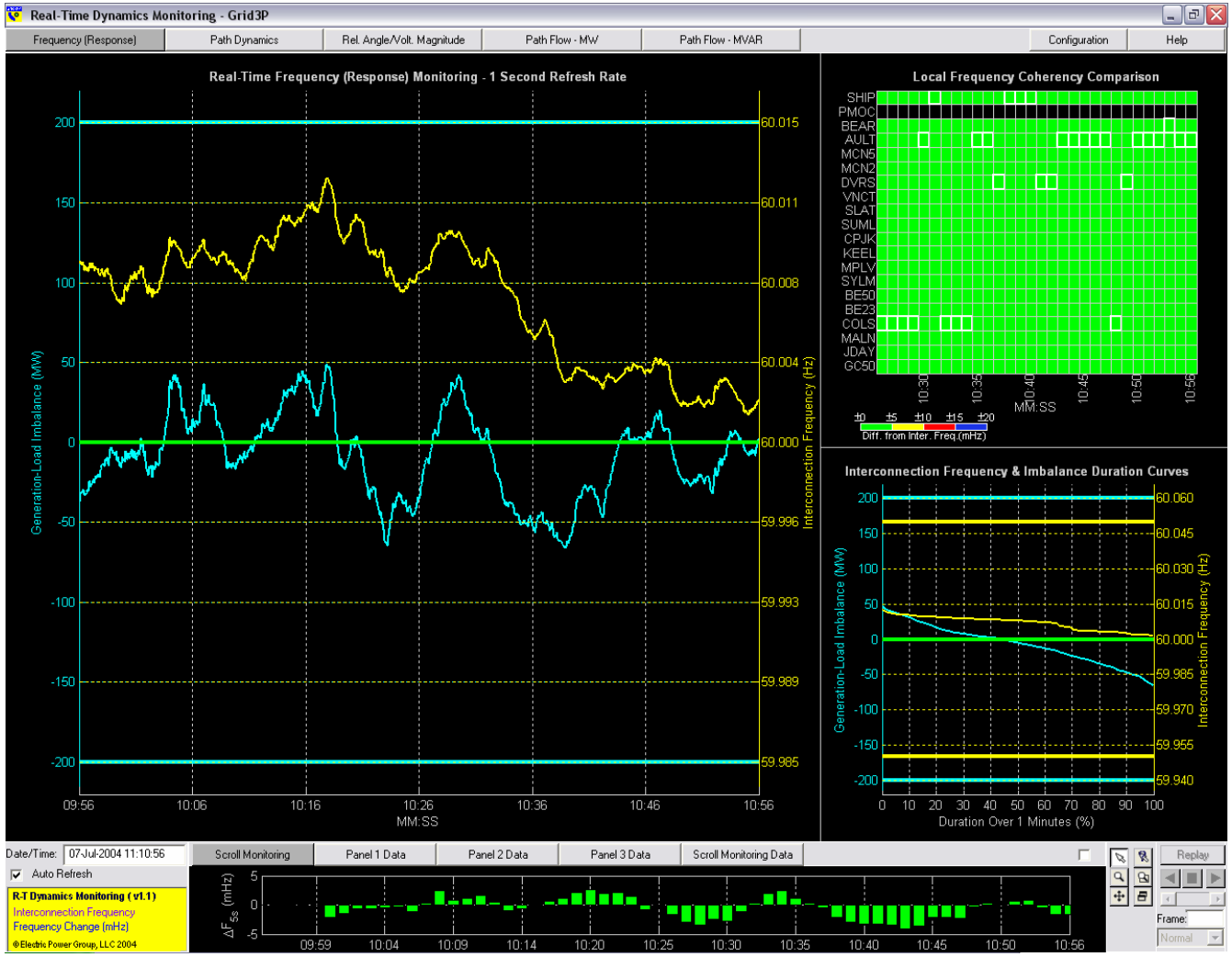
Future Expansion of WECC System Phasor Network

- PG&E's PMUs and PDC will be integrated into WECC Phasor Monitoring Network in 2005
- Current PDC network can accommodate other isolated PDCs for WECC wide-area monitoring

Work to be Done

- Integrate all existing PMUs to access and disseminate phasor data for monitoring reliability
- Develop standard displays for visualization of phasor data
- Coordinate deployment of visualization applications
- Identify need and location of new PMUs
- Select off-line tools for post transient analysis

SAMPLE DISPLAY - Frequency



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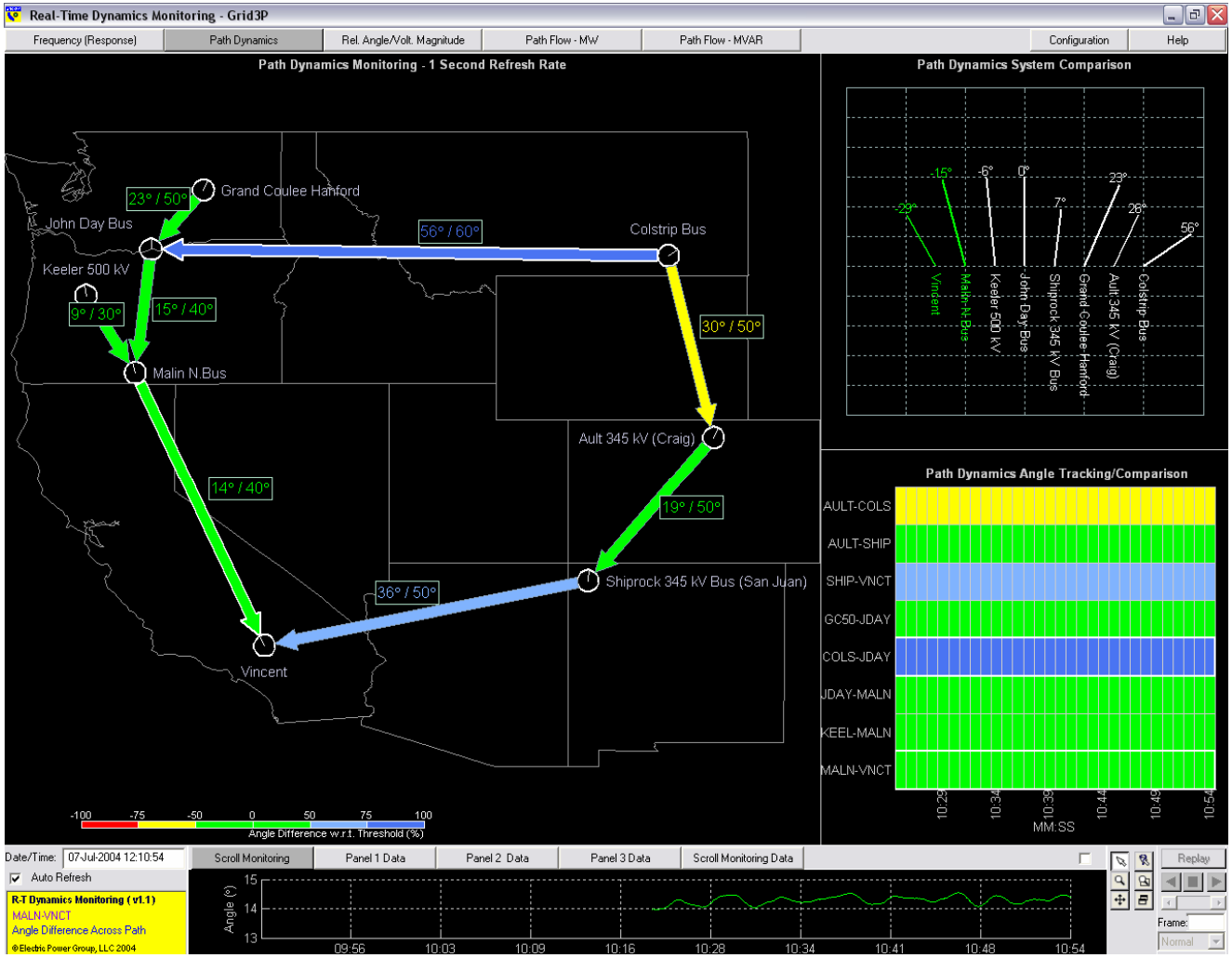
SAMPLE DISPLAY – Path Dynamics



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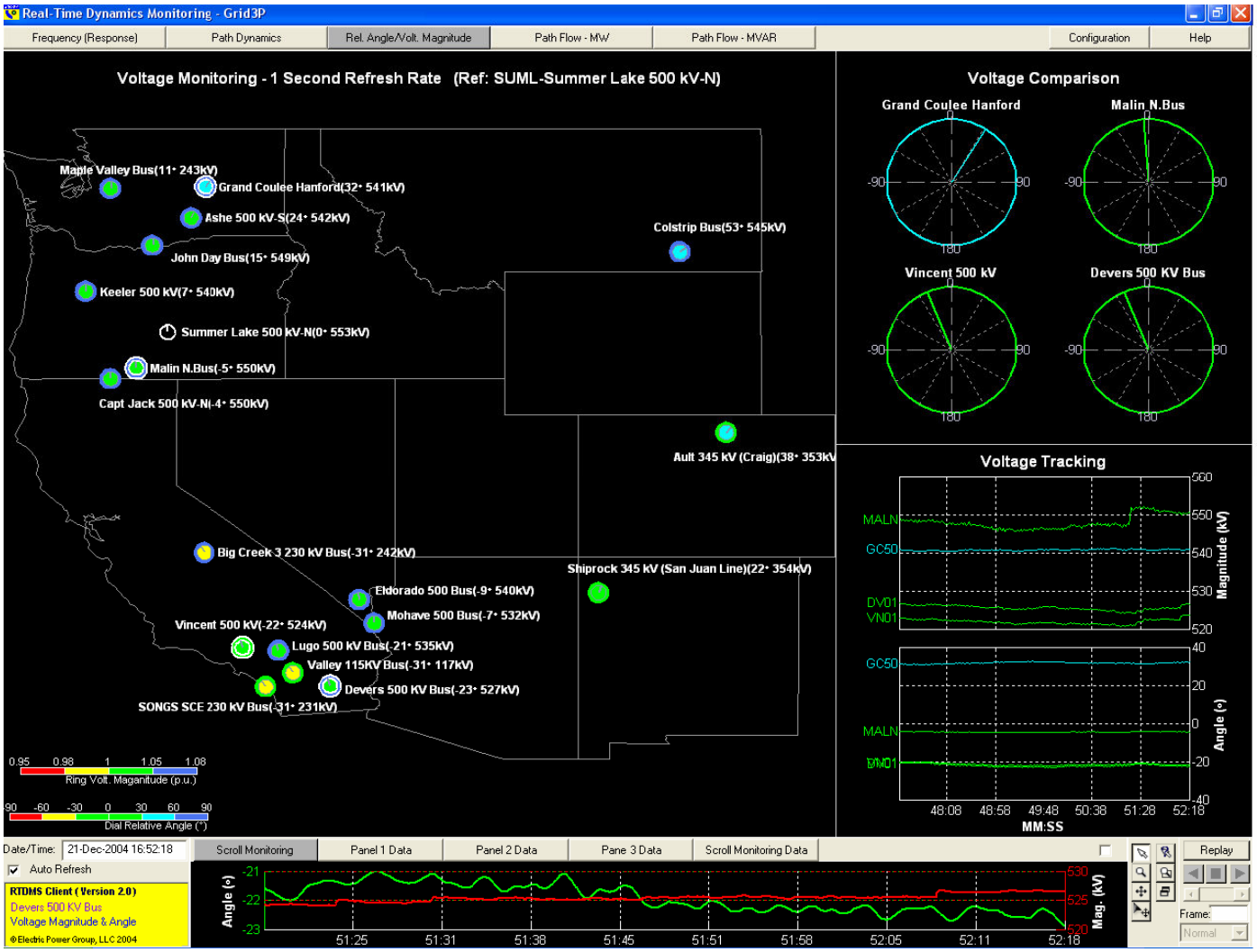
SAMPLE DISPLAY – Relative Angle/Voltage Magnitude



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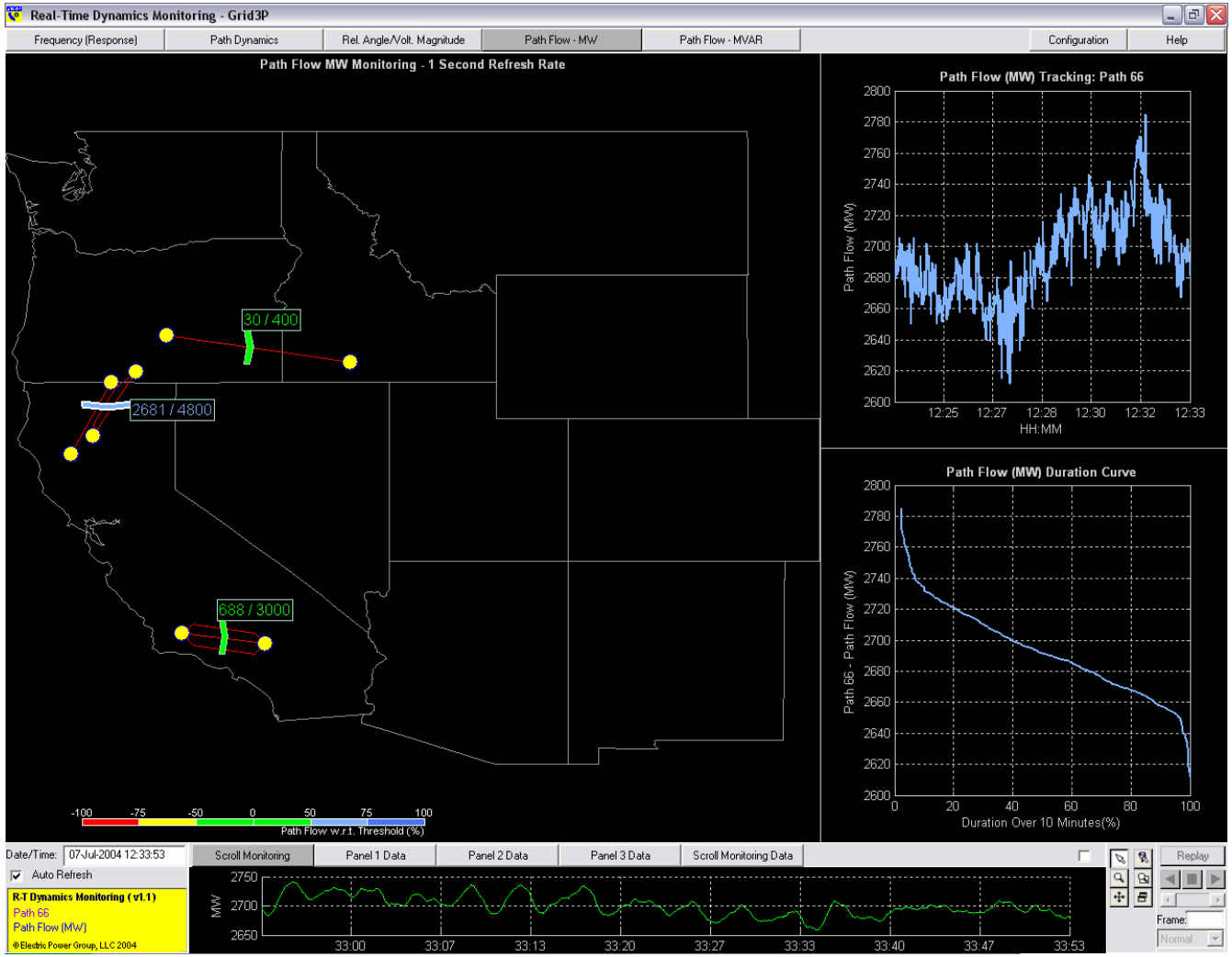
SAMPLE DISPLAY – MW FLOW



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Information: EIPP Working Group

Task Team Organization