

# **Transmission Research Program**



## ***Successes from California Public Interest Energy Research in Phasor Measurement Applications***

**Presented to  
North American SynchroPhasor Initiative  
Working Group Meeting  
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New Orleans, LA**



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Transmission Research**





- **California's Public Interest Energy Research (PEIR) and the Transmission Research Program (TRP)**
- **PIER TRP Phasor Research Efforts**
- **Success Story: Real Time Dynamics Monitoring System (RTDMS©) Platform and Applications Developments and "Commercialization"**
- **Success Story: Phasor "Business Case" Study**

# *Purpose of Transmission Research Program (TRP)...*



*... to develop technology solutions for the  
California transmission system.*

- **1996: California electric deregulation legislation created the Public Interest Energy Research (PIER) Program, managed by the California Energy Commission**
- **2003: TRP created in PIER Energy Systems Integration**
- **2004: The CEC selected CIEE (U of CA) Transmission Research Team**

*TRP strategy driven by state policy and transmission  
community stakeholder needs.*

# The TRP Strategy



*To Conduct Research and Development for New Transmission Technologies That:*



**Accelerate  
New  
Transmission**

**Increase  
Capacity**

**Enhance  
Operations Under  
Uncertainty**

**Enable  
Renewable  
Deployment**

*...while assuring transmission meets the critical requirements for adequacy, reliability, affordability, security, safety, and environmental protection; and fulfills state policies and goals*

# The use of stakeholder advisors is a hallmark of the TRP



*The Policy Advisory Committee (PAC) is composed of senior-level managers from these stakeholders:*

- CEC--Chairman
- BPA
- CAISO
- CPUC
- PG&E
- SCE
- SDG&E
- US DOE - OE
- Utility Wind Integration Group

*Stakeholder advisors provide “guidance” on R&D needs, and help “deliver” its benefits to the electricity consumers of California.*

# Transmission Research Projects Funding (\$1000) Summary



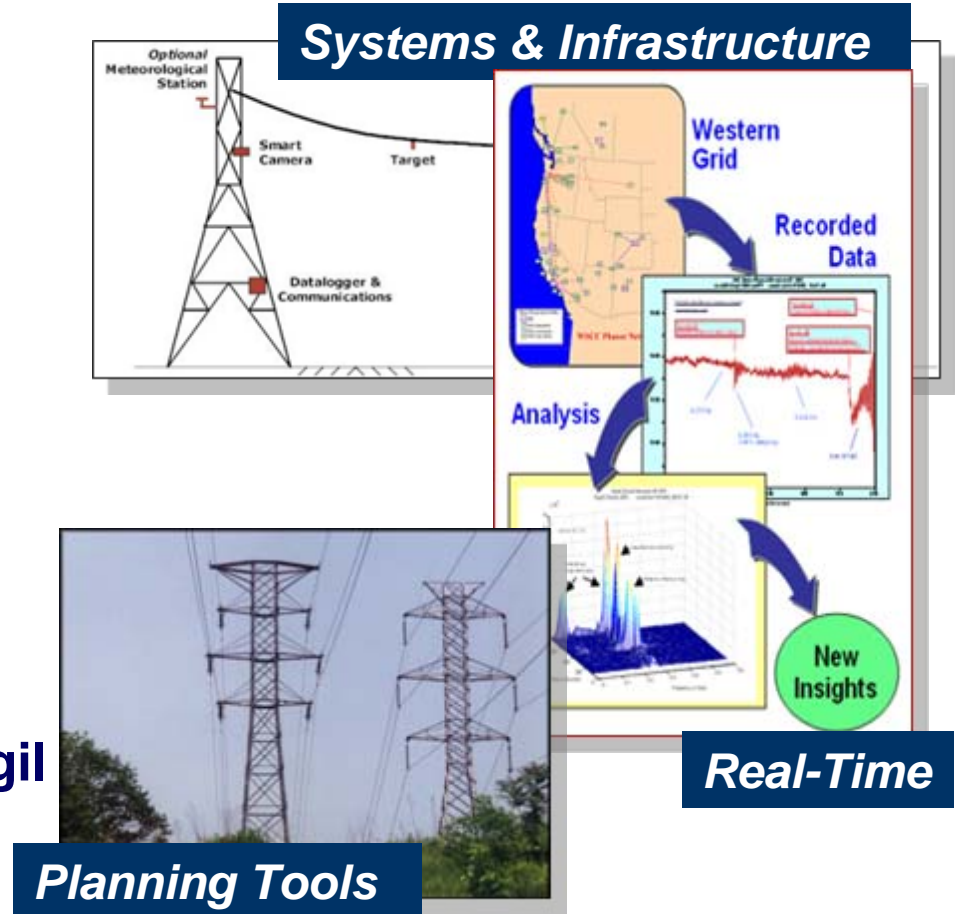
Projects: Past, Present, Pending & Proposed	Amount
Past Projects (Since ~2004)	\$3,802
Present Projects (Active)	\$8,763
Projects Pending Approval	\$4,030
Projects Proposed for Budget by CIEE	\$4,000
Total for Program	\$20,595*

\*Exclusive of administration costs

**The research portfolio is implemented through 3 integrated research focus areas:**



- **Focus Area I: Systems and Infrastructure (Lloyd Cibulka)**
- **Focus Area II: Real-Time System Operations (Merwin Brown/Jim Cole)**
- **Focus Area III: Planning Tools and Environment (Virgil Rose)**



**Most phasor development is funded within Focus Area II.**

# The phasor story for the West and California begins in late 1980s



- **1987 – BPA engineers see low-frequency grid oscillation, but don't have instrumentation to discern much.**
  - Models couldn't “see” oscillation
  - Launched efforts deploy PMUs in a wide-area (BPA, WA, PNNL), leading to WAMS
- **Early 1990s – DOE, EPRI, BPA, WA, PNNL conduct early phasor R&D**
- **1996 – Western wide-area blackout in summer escalates number of “subscribers” to, and the deployment of, PMUs in the West.**
  - SCE adds PMUs, and begins development of in-house application, Power System Outlook (PSO ), followed much later by SCE Synchronized Measurement and Analysis in Real Time (SMART™)
  - PG&E adds PMUs
- **1999 - Consortium for Electric Reliability Technology Solutions (CERTS) created**
- **2000 – CERTS begins first CEC PIER funded phasor application development project, i.e., real-time system monitoring and control (RTSMC). CAISO is the host; EPRI co-funded.**



# Summer PAC Workshop,

July 29-30, 2006, at PG&E in San Ramon, CA



- Interim draft of *Public Interest Technology Assessment of Phasor-Based, Real-Time Dynamic Information Systems*, a.k.a., "Phasor Business Case" study
- PAC observed: Even with conservative assumptions, there is real value for ratepayers and society from the wide-area deployment of PMUs in the WECC
- Outlined a possible three prong strategy:
  - Facilitate the wide-spread deployment of PMUs in WECC
  - Develop (finish) the business case with a roadmap for application development
  - Conduct the R&D to develop application tools and critical infrastructure components and standards

***The TRP phasor efforts focused on application R&D.***

# TRP Phasor Projects (~\$7.6M)



- **Real Time Dynamics Monitoring System (RTDMS©) Platform and Applications for Monitoring, Alarming and Control Initiative (CERTS)**
  - Dashboard Type Display
  - Real Time Alarming
  - Multiple metric monitoring (Frequency, Voltages, Phase Angle Differences, MW & MVAR Flows, System Damping, Voltage Sensitivities)
  - Off-line Analytics
  - Automated Event Capture
  - Mode Monitoring
  - Data Archiving, Management, Retrieval Services
  - Open platform – compliant with IEEE Standards
  - Extensive configurability

*Phasor R&D continued on next slide*

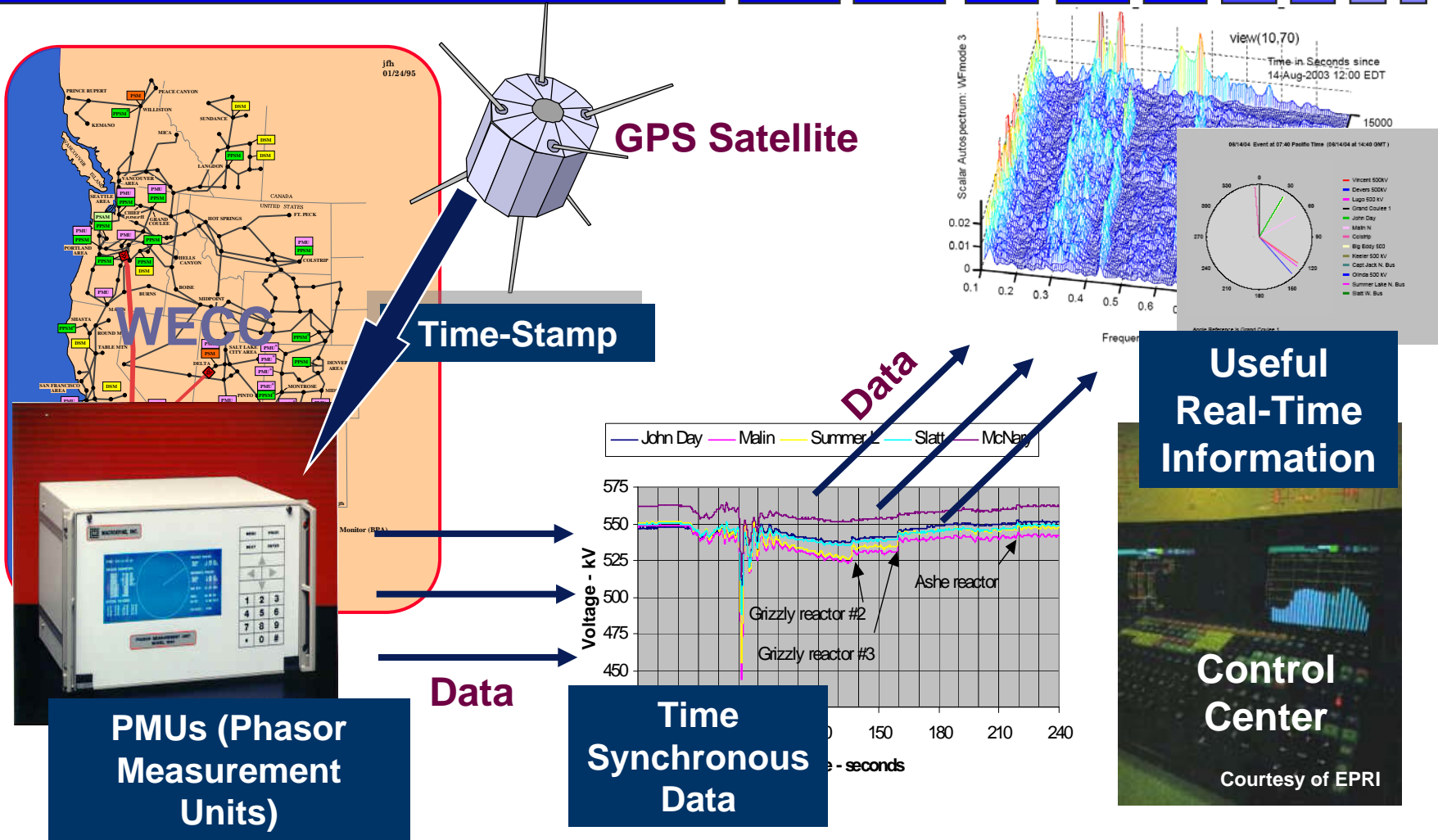
# TRP Phasor Projects (~\$7.6M) (cont'd)



- **Public Interest Technology Assessment of Phasor-Based, Real-Time Dynamic Information Systems (KEMA "Phasor Business Case")**
- **Intelligent Grid Protection Systems Feasibility Study (Stuart & Bose)**
- **Enhancement of SDG&E Transmission State Estimation Results using Real Time Phasor Measurement Data (EPG)**
- **Advanced Protection Systems Using Wide Area Measurements (Virginia Tech)**

*Two "commercial" success stories follow:*

# Success: Real Time Dynamics Monitoring System (RTDMS©) Platform and Applications



**Storyline: Real Time Phasor System from Concept to Control Room**

# Success: Real Time Dynamics Monitoring System (RTDMS©) Platform and Applications

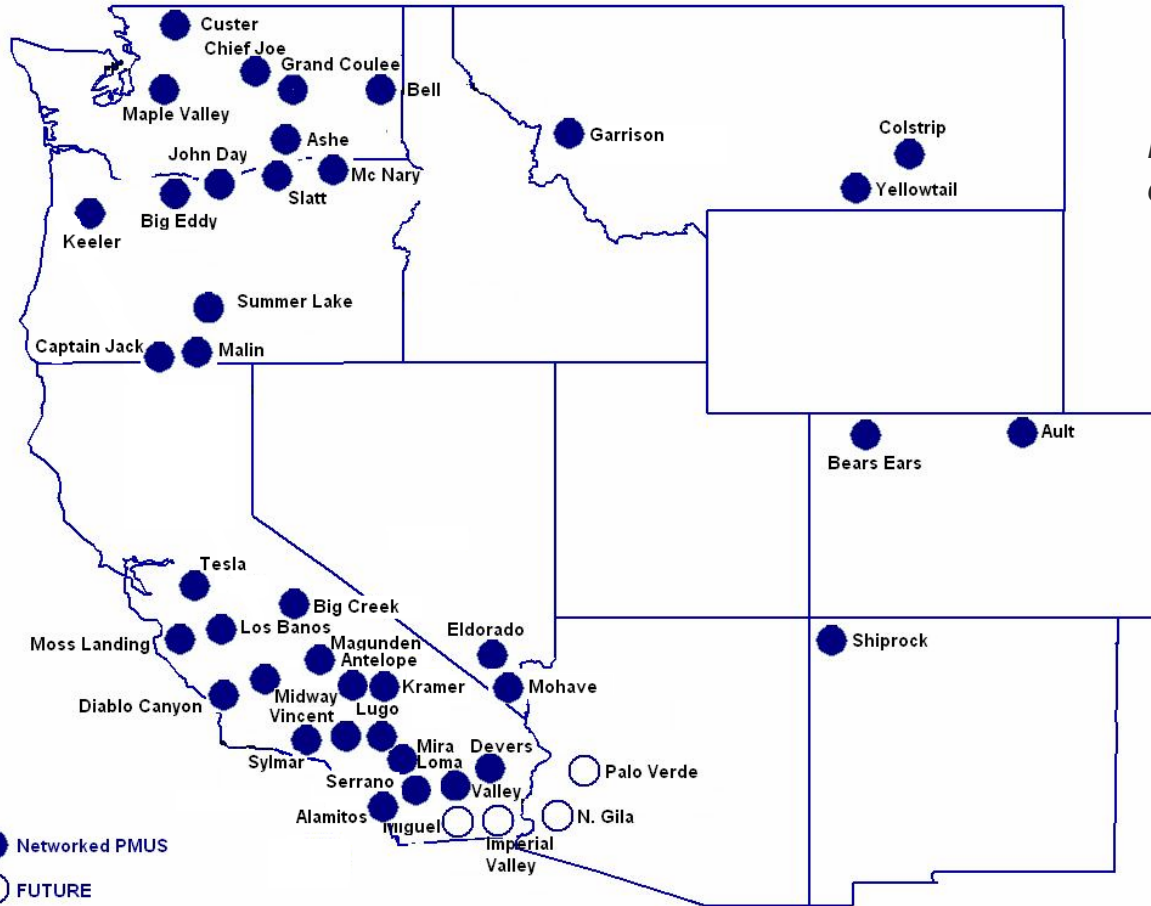


Figure courtesy of CERTS

**Over 50 PMUs Are Now Networked To CAISO.**

# Success: Real Time Dynamics Monitoring System (RTDMS©) Platform and Applications

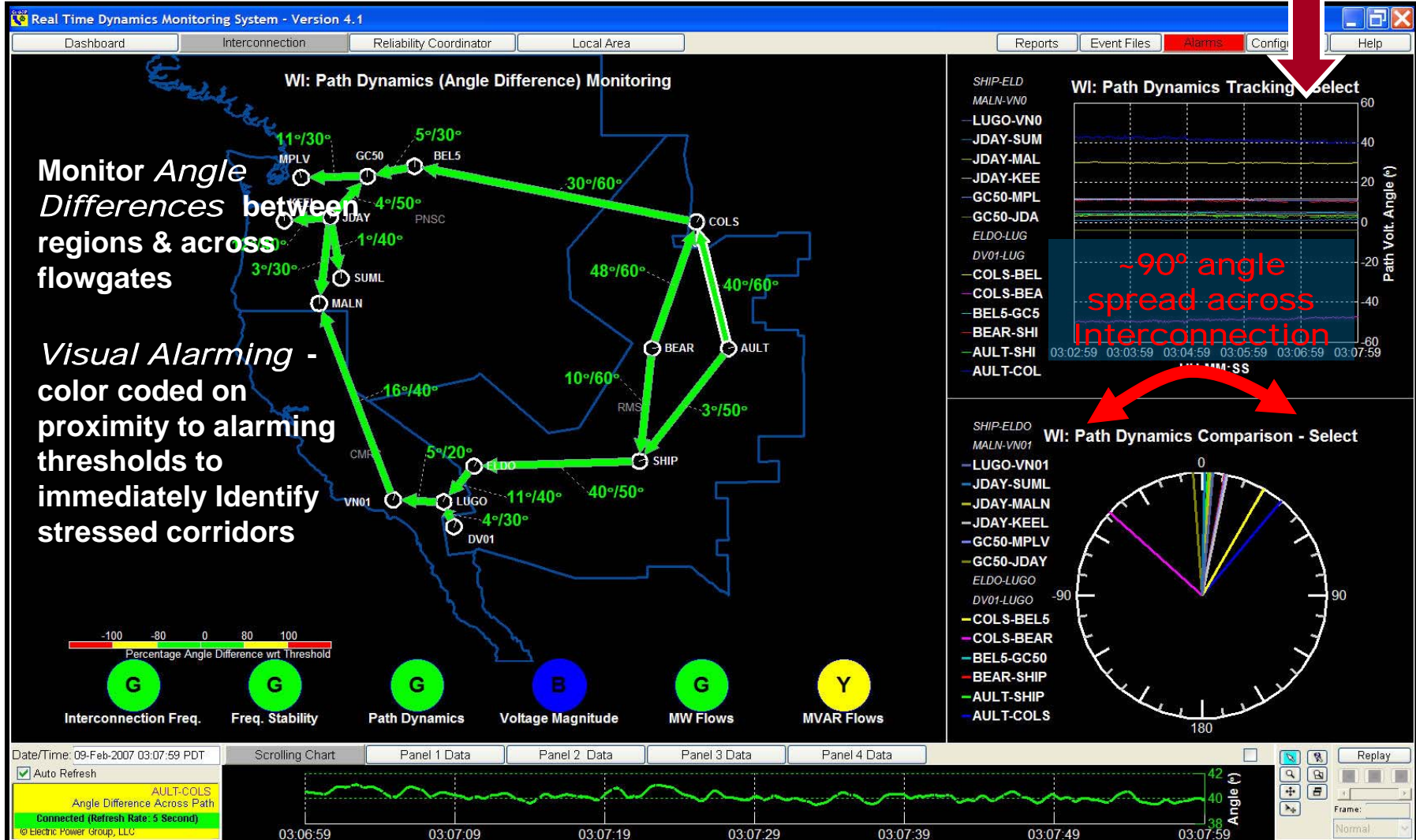


- CAISO started working with the CERTS, and its member Electric Power Group (EPG), on application of phasor technologies in 2002.
- This initiative, Real Time Dynamics Monitoring System (RTDMS©) Platform and Applications, received research funding from Department of Energy (DOE) and California Energy Commission (CEC) PIER TRP.
- In June 2007, the system was migrated to production standards on the CAISO secure corporate network, supported by CAISO IT.
- An indication of the improved reliability is that RTDMS is now at the Reliability Coordinator (RC) Desk in the Folsom Control Room.
- CAISO has integrated the PI Historian with RTDMS as a link into its EMS. This enables CAISO to simultaneously use both the SCADA and Phasor data in applications.
- The CAISO RTDMS system is now an integral part of the real time operations decision making process.

# Visualization Dashboard Display – Phase Angle Separation



Historical Angle Difference trends



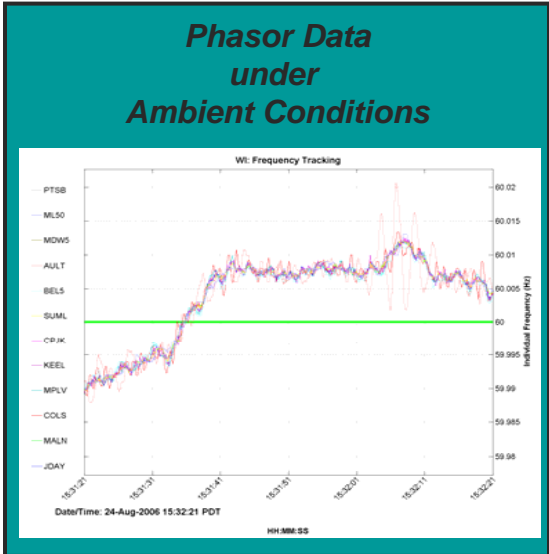
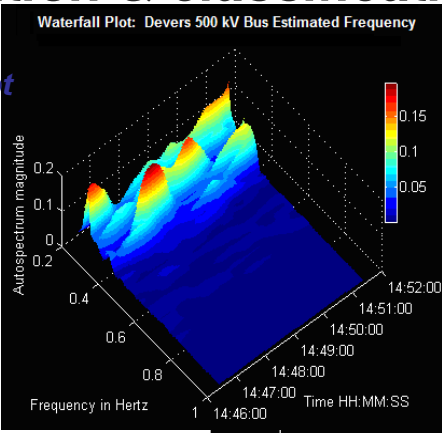
# Small Signal Stability Monitoring Application



Application focuses on *Real-time identification & classification of oscillatory modes from ambient data*

- oscillatory mode frequency (in Hz)
- mode damping (in %)

Waterfall plot showing oscillatory activity



Oscillations visible under ambient conditions

## Mode Meter Application

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**Pre-Processing**  
(Pre-condition raw data)

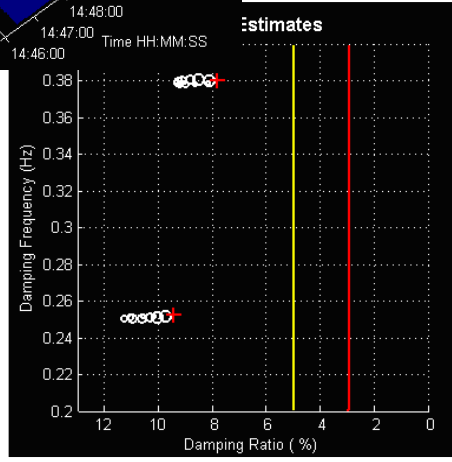
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**System Identification Algorithms**  
(estimate mode parameters)

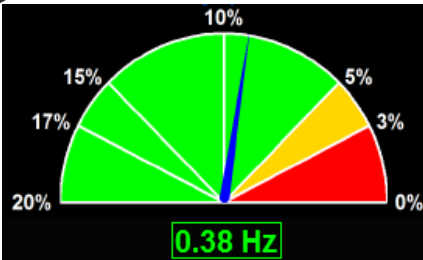
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**Post-Processing**  
(Eliminate false estimates)

Damping trends (Two mode traces shown)



Gauge showing modal information i.e. mode frequency (0.38 Hz) & damping (~8%)



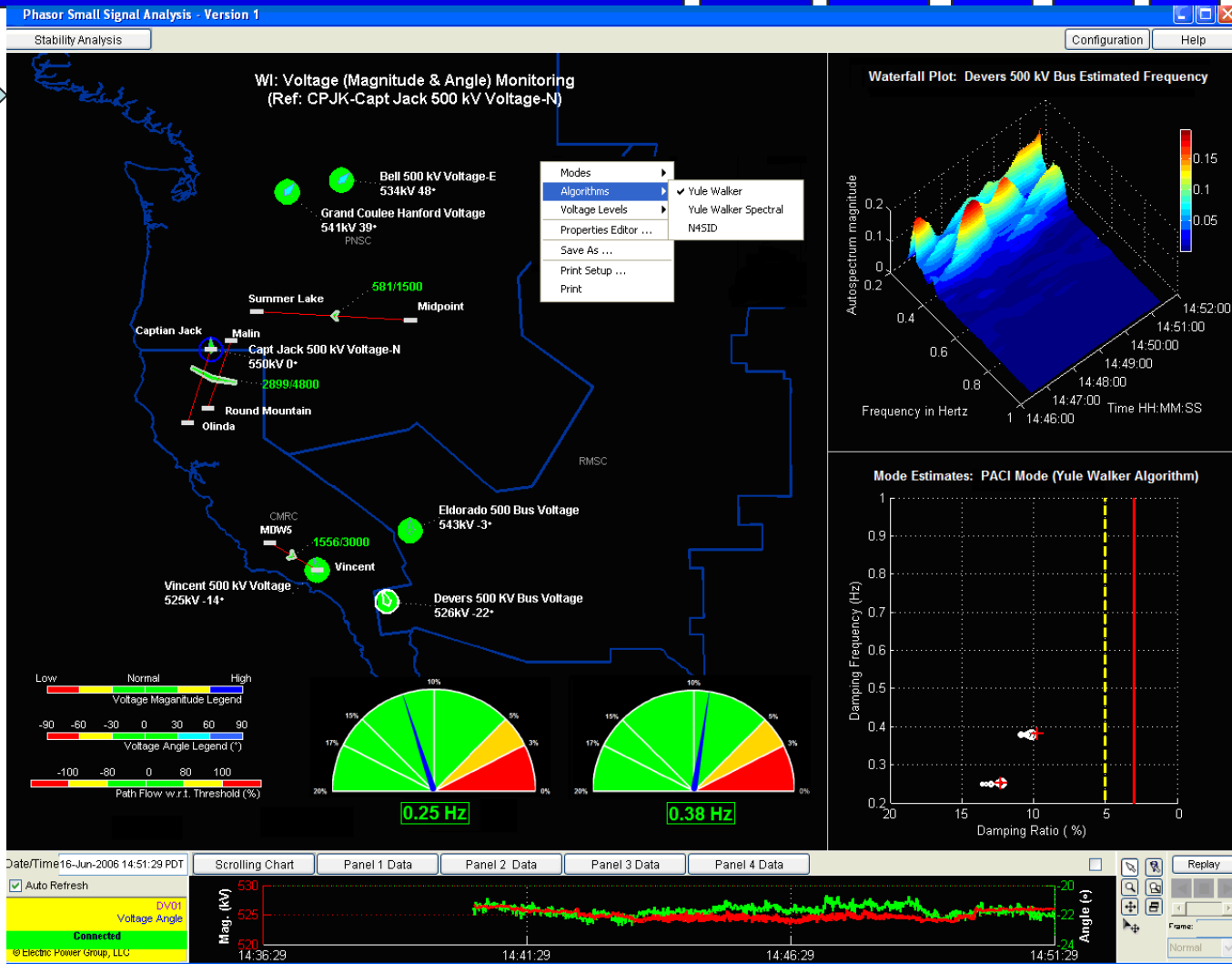
Photos courtesy CERTS



# Small-Signal Stability Monitoring Operator Display



Monitor :  
Low Frequency  
oscillatory  
modes  
across the  
interconnection



Waterfall to identify  
oscillation freq.  
and it's trend over  
time

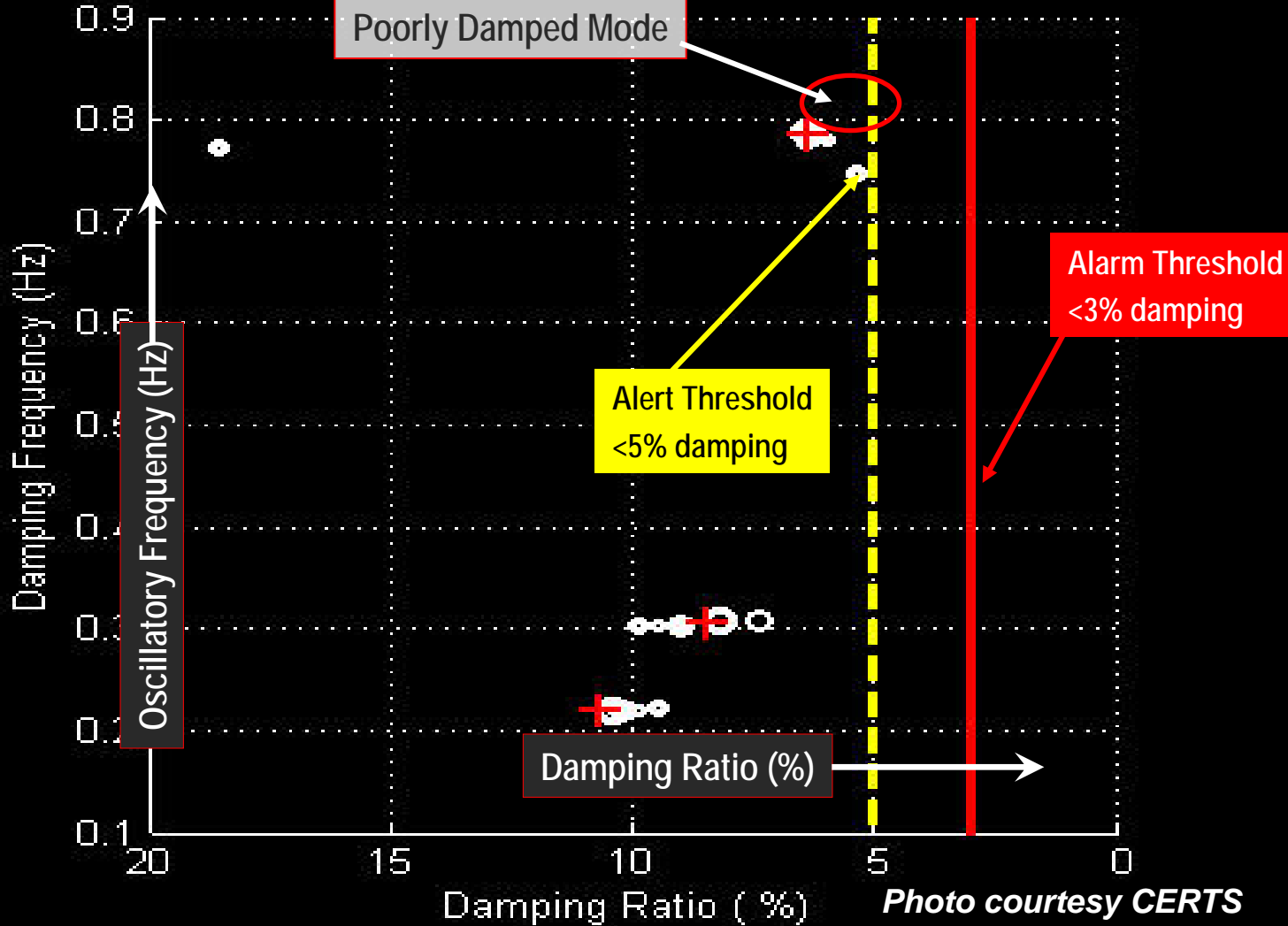
Frequency-damping  
plots to track %  
damping of different  
oscillatory modes in  
real time  
(3% and 5% alerting  
and alarming  
thresholds shown)

Photo courtesy CERTS

# Mode Estimate: Example



## Mode Estimates: All Modes (Yule Walker Spectral)



# Success: Real Time Dynamics Monitoring System (RTDMS©) Platform and Applications



- **CAISO, morning, April 19, 2006, Reliability Coordinator on used the information of the RTDMS, while still in research stage, to flag a serious voltage problem on the system and the operator took action to see the problem was resolved by dropping two of the Helms (hydro) Pumps.**
- **January 26, 2008, RTDMS small signal mode meter alerted operator to an oscillation problem, leading to decision to drop DC intertie.**

# Success: Phasor “Business Case” Study



- Identified 16 beneficial applications & clear net reliability benefits for society.
- Technology development roadmap
- Results presented in many forums throughout U.S. & used for planning by NASPI task forces
- Publication: “Dawn of Grid Synchronization,” Damir Novosel, Vahid Madani, Bharat Bhargava, Jim Cole, IEEE Power and Energy Magazine, Jan/Feb 2008