Phasor Measurements in the WECC

Ken Martin – Quanta Technology
Dave Hawkins – California ISO
Bharat Bhargava – Southern California Edison

WECC -- DMWG & WIPP

WECC Disturbance Monitor Working Group & Wide Area Measurement Task Force

Early history

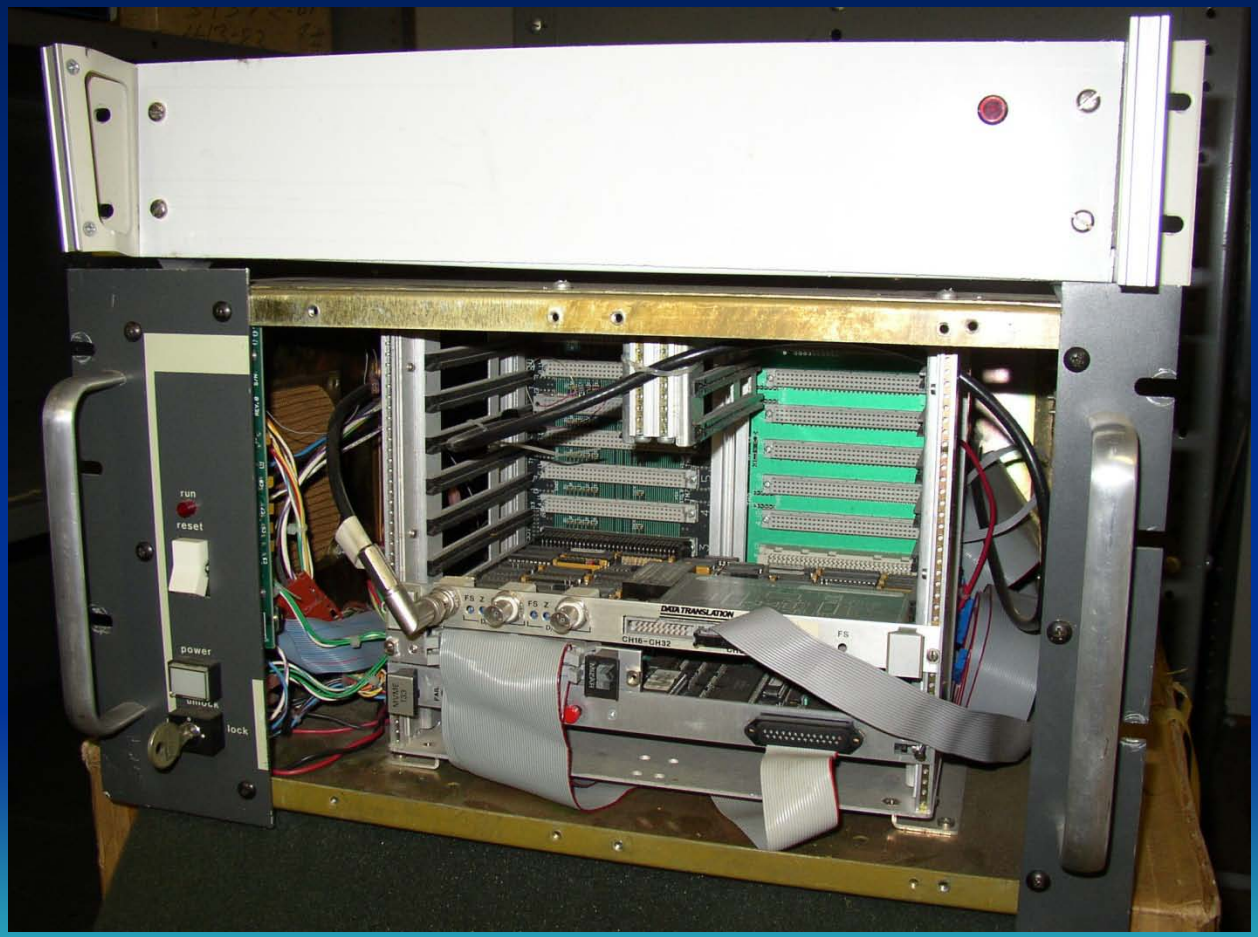
- 1986 Phasor Project at BPA
  - 1st PMU from Virginia Tech
  - Tested on BPA system 1989-92
  - Lab tests 1991-2
- EPRI – WSCC phasor controls project
  - 21 PMUs – APS, BPA, LADWP, PG&E, SCE
  - Real-time damping controls to DC intertie
  - Industry restructuring prevented completion

The first Virginia Tech PMU

External signal conditioning unit

&

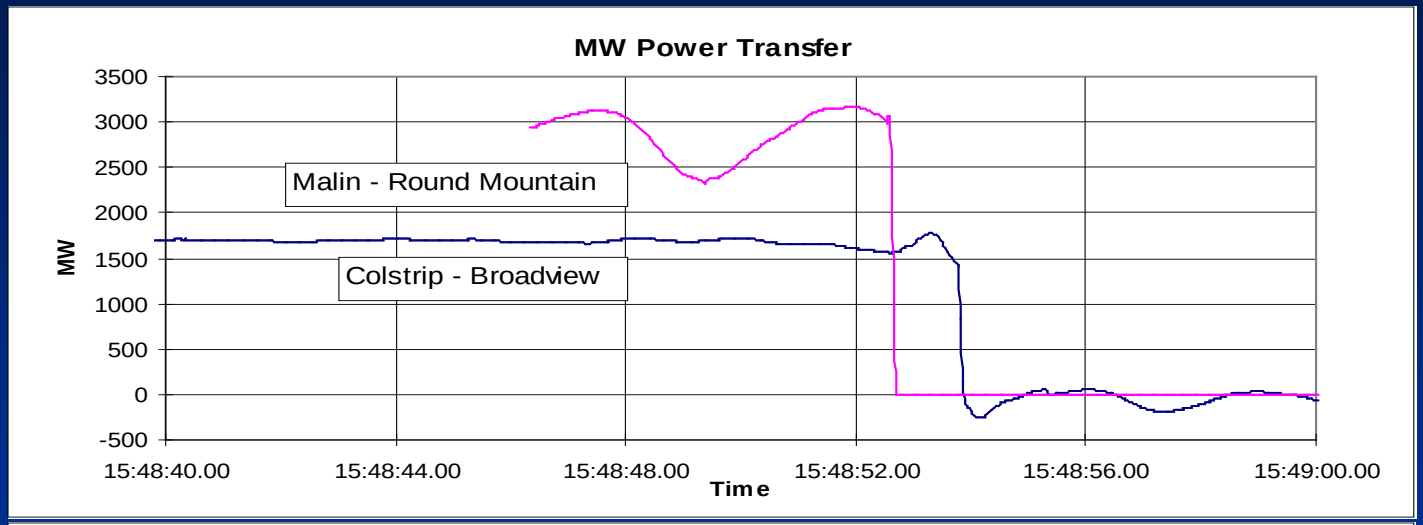
GPS receiver

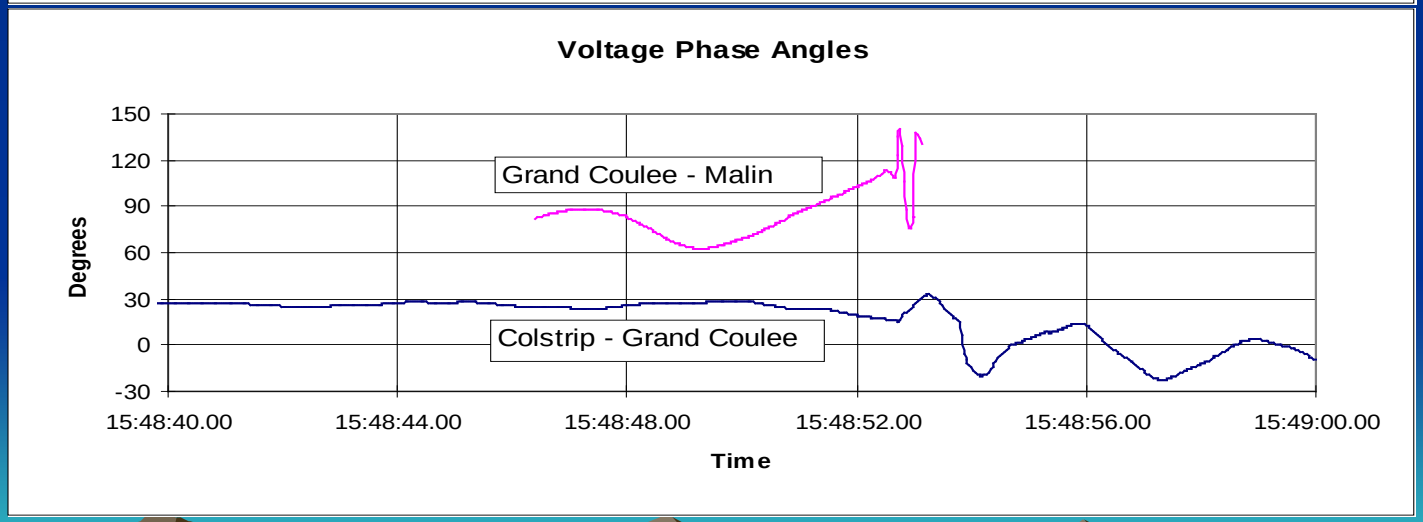


August 10, 1996

- System loses dynamic stability
  - System breaks into islands when it separates at Malin
  - 25, 578 MW of generation lost
  - 30, 489 MW of load lost
  - System restoration takes several hours
- WAMS recordings document the breakup with high accuracy

Phasor measurement data

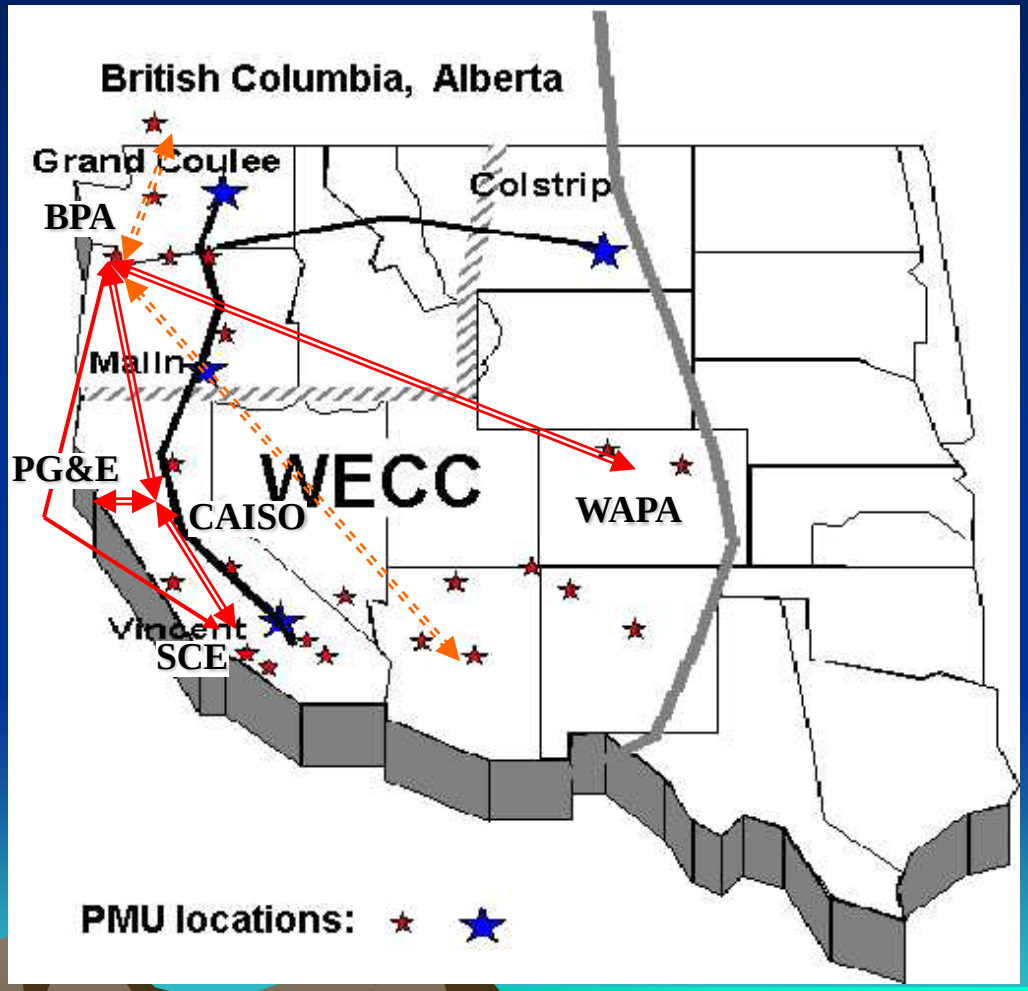




Phasor measurements take on a new life

WAMS Development in WECC

- 1997 real time to PDC
  - BPA – 4 PMUs
  - SCE – 4 PMUs
- 1998
  - BPA – SCE direct link
- 2000 – 2002
  - Local recording systems at AESO & Pacific Power
  - Real-time systems at APS/SRP, BC Hydro, PG&E, PNM, & WAPA
  - BPA—CAISO direct link
- 2004
  - Direct link PG&E—CAISO & BPA
  - Direct link SCE—CAISO



Current WECC Phasors

WECC TOTALS

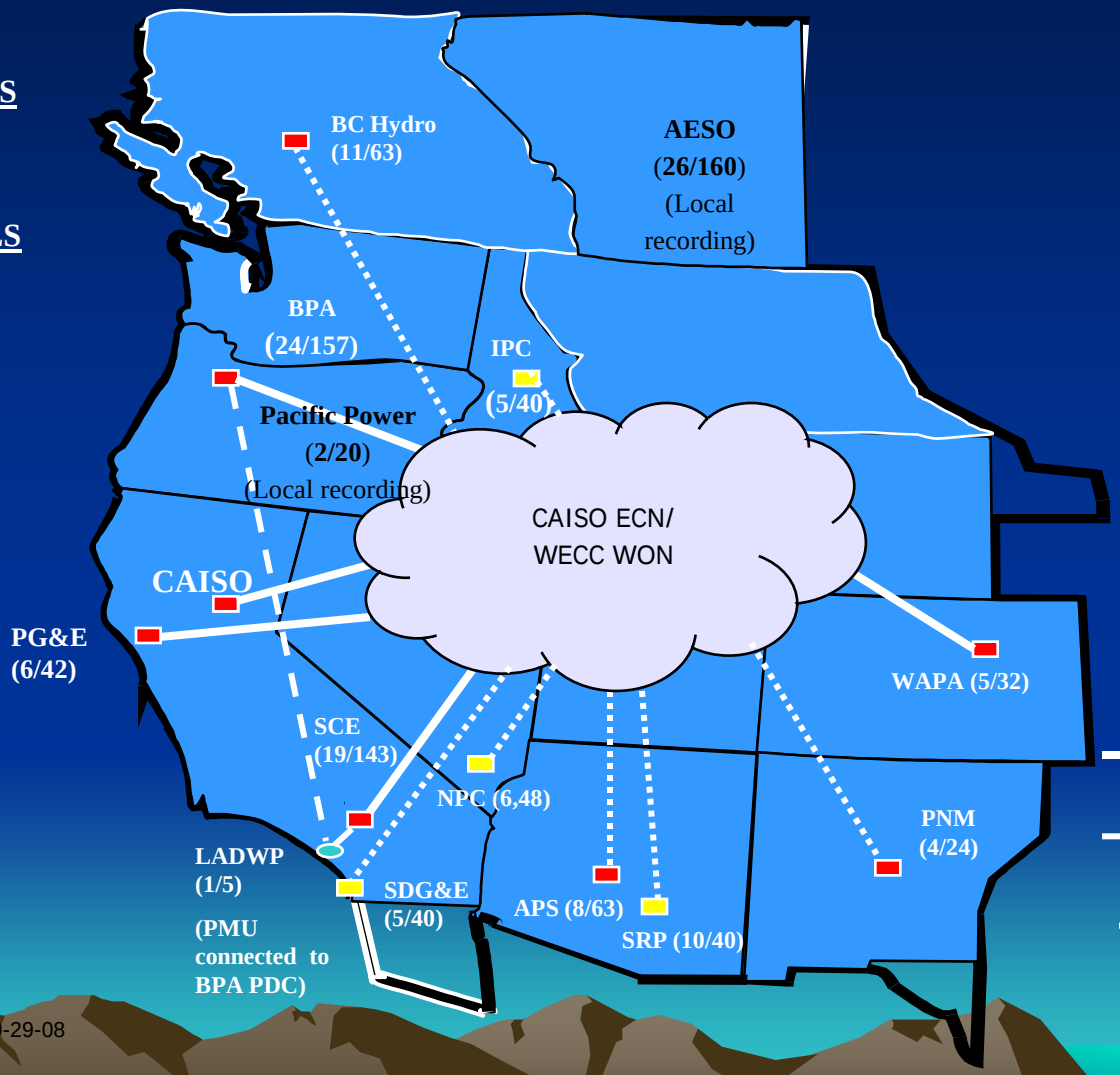
132 PMUs

877 Phasors

CAISO TOTALS

54 PMUs

369 Phasors



CONVENTIONS

- States/Provences with PMU Installations
- Macrodyne PDC (Not in Service)
- BPA PDC
- SEL PDC
- Network connection
- SCE-LDWP-BPA Microwave Circuit
- Possible Future Network Connection
- (aa/bb) # PMUs / # Phasors

WECC – WAMS real-time net

- Real-time phasor data exchange net
  - Disturbance Monitor WG & WAMS TF
- Builds on current development
  - BPA – CAISO link 2002, additions in 2004-6
  - Use utility PDC units, standard router/firewalls
  - T1 communication links, utility or leased
- If approved, deployment can start in 2009
  - 3 year deployment, start with central links & RCs
  - Expand out to all participating utilities

Current WECC Phasor Net

WECC TOTALS

132 PMUs

877 Phasors

CAISO TOTALS

54 PMUs

369 Phasors

CONVENTIONS

- States/Provences with PMU Installations
- Macrodyne PDC (Not in Service)
- BPA PDC
- SEL PDC
- Network connection
- SCE-LDWP-BPA Microwave Circuit
- Possible Future Network Connection
- (aa/bb) # PMUs / # Phasors

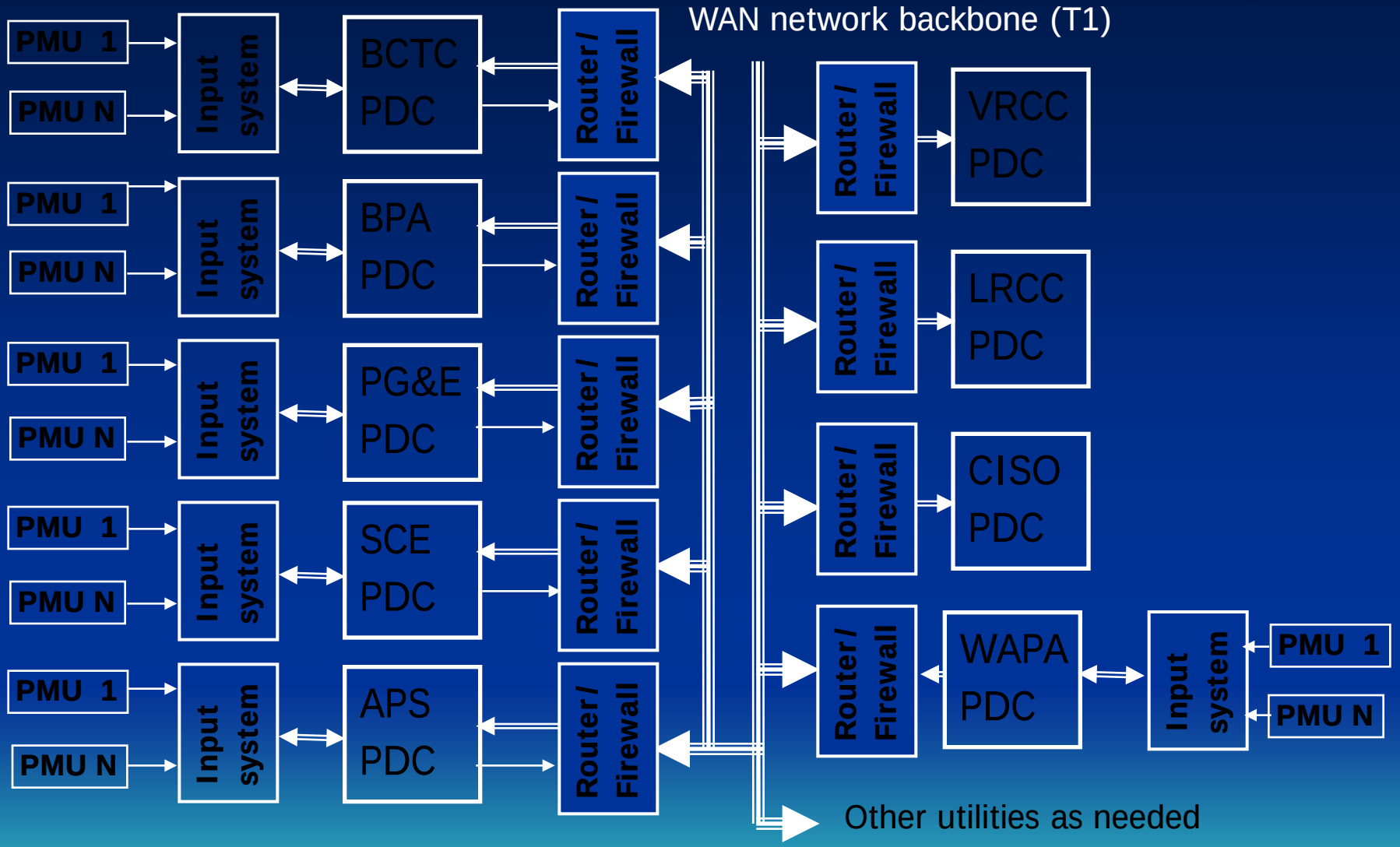
Proposed WECC Synchronized Phasor Network

Functional diagram
Point-to-point links connected at signal access points.
Actual paths and connection points may differ – will be determined by optimal design.

CONVENTIONS

- PDCs
- T1 links
- XXX Utility host or RC

WECC phasor network (WAMS)



Real-time Data Sharing Agreement

- Terms of (new) data sharing agreement have been completed and signing of the document expected in February.
- Scope is limited to data sharing between Transmission Operators and Reliability Coordinators (SCE, BPA, PG&E, WAPA, CAISO, and RC's).
- Includes an amendment page for other TO's to sign that are interested in sharing their PMU data.
- Elements of system can be used in NASPInet when it is available

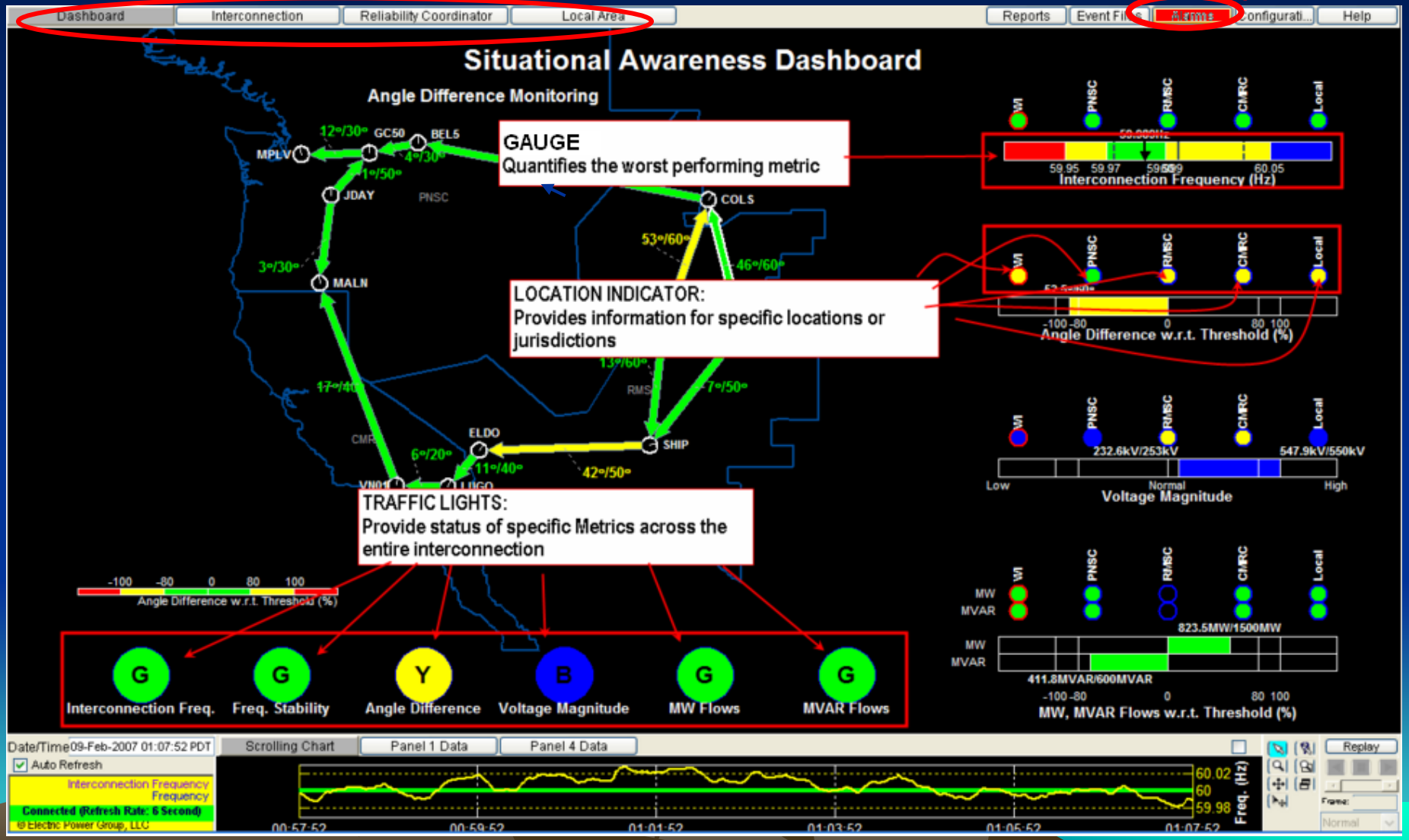
News from around WECC

- PG&E adding PMUs on Pacific intertie
- SCE update
  - Added 2 new PMUs
  - Rate case financing
  - Situation awareness center
  - Controls projects
- Interesting incidents

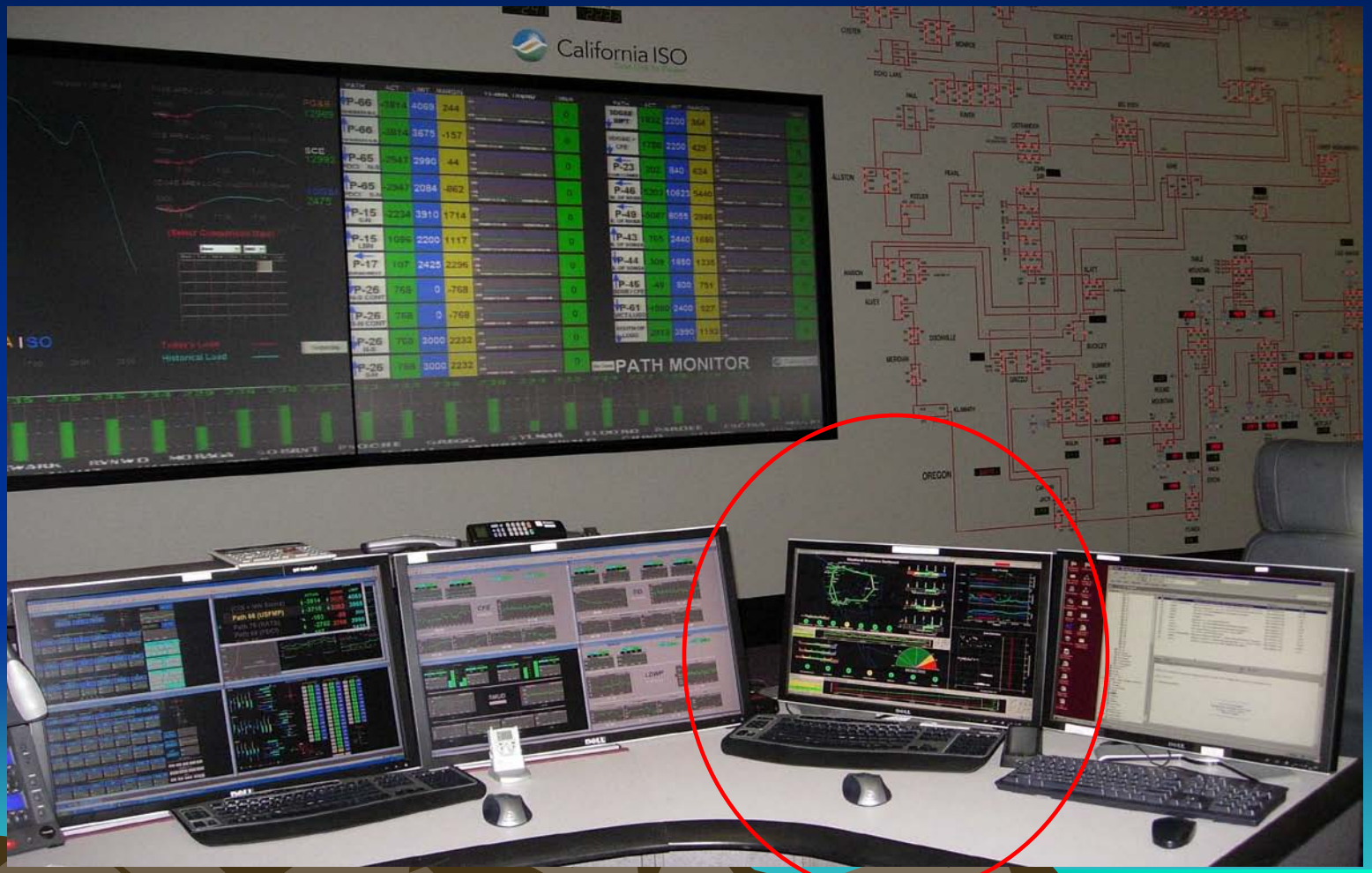
Visualization – In Use at CAISO

Visualization Tiers – Dashboard, Interconnection, Reliability Coordinator, Local Area

Real Time Alarms within ALL RTDMS Client Applications



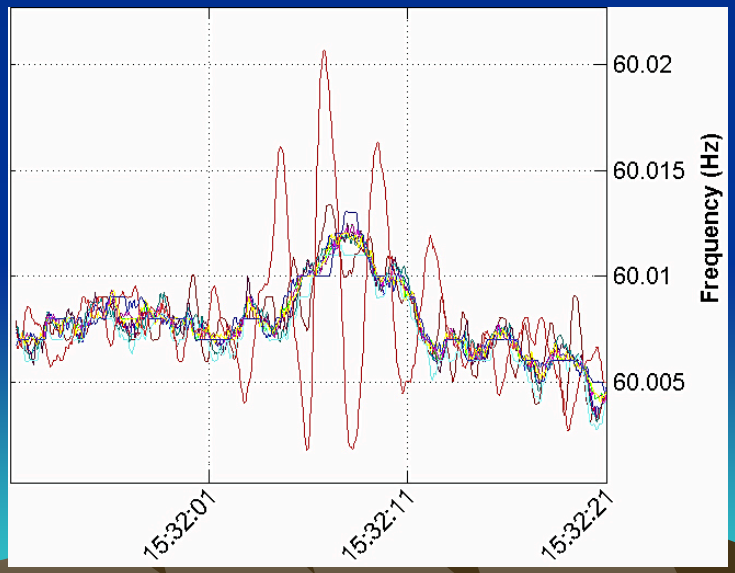
Phasor Workstation in CAISO Control Room

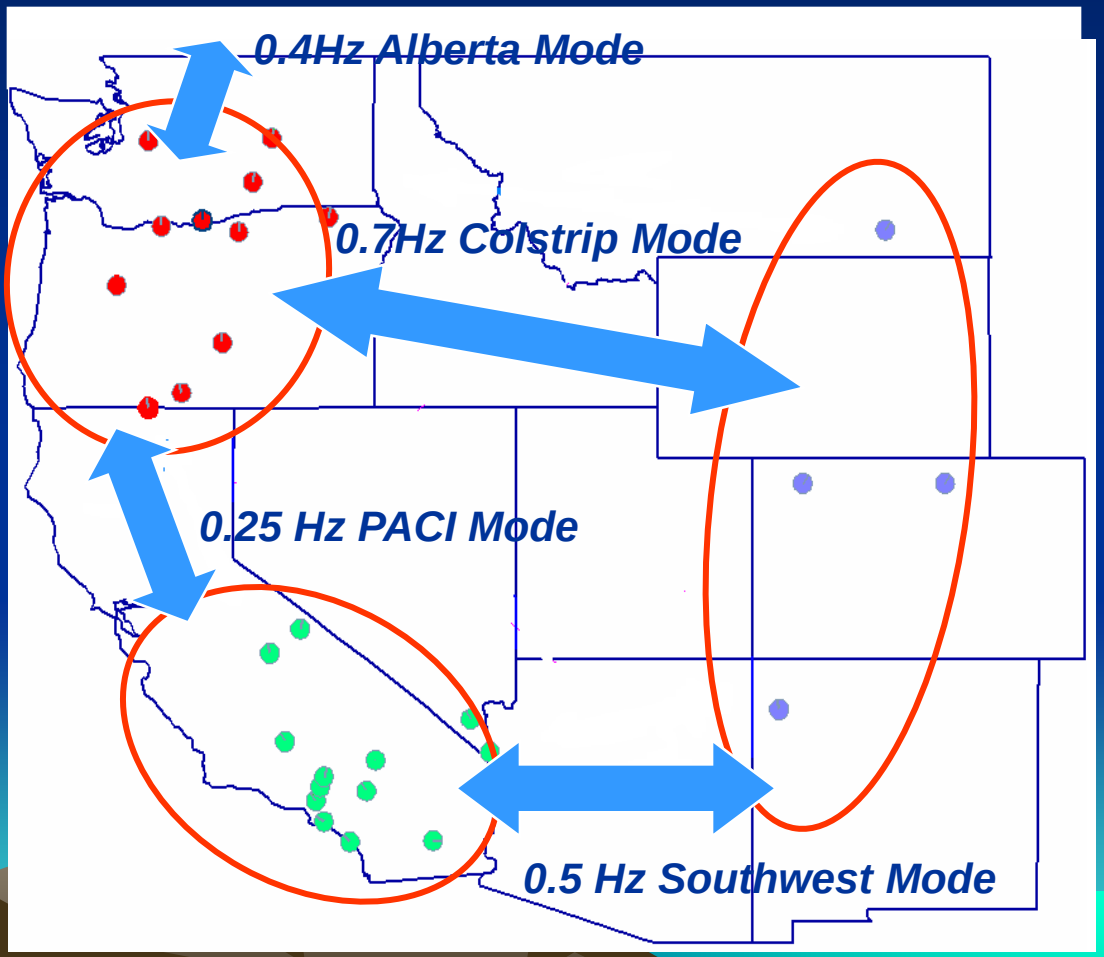


Small Signal Stability is an Emerging Focus – Mode Identification and Characterization

Goal: ***Real-time*** identification of oscillatory modes from ***ambient*** phasor data

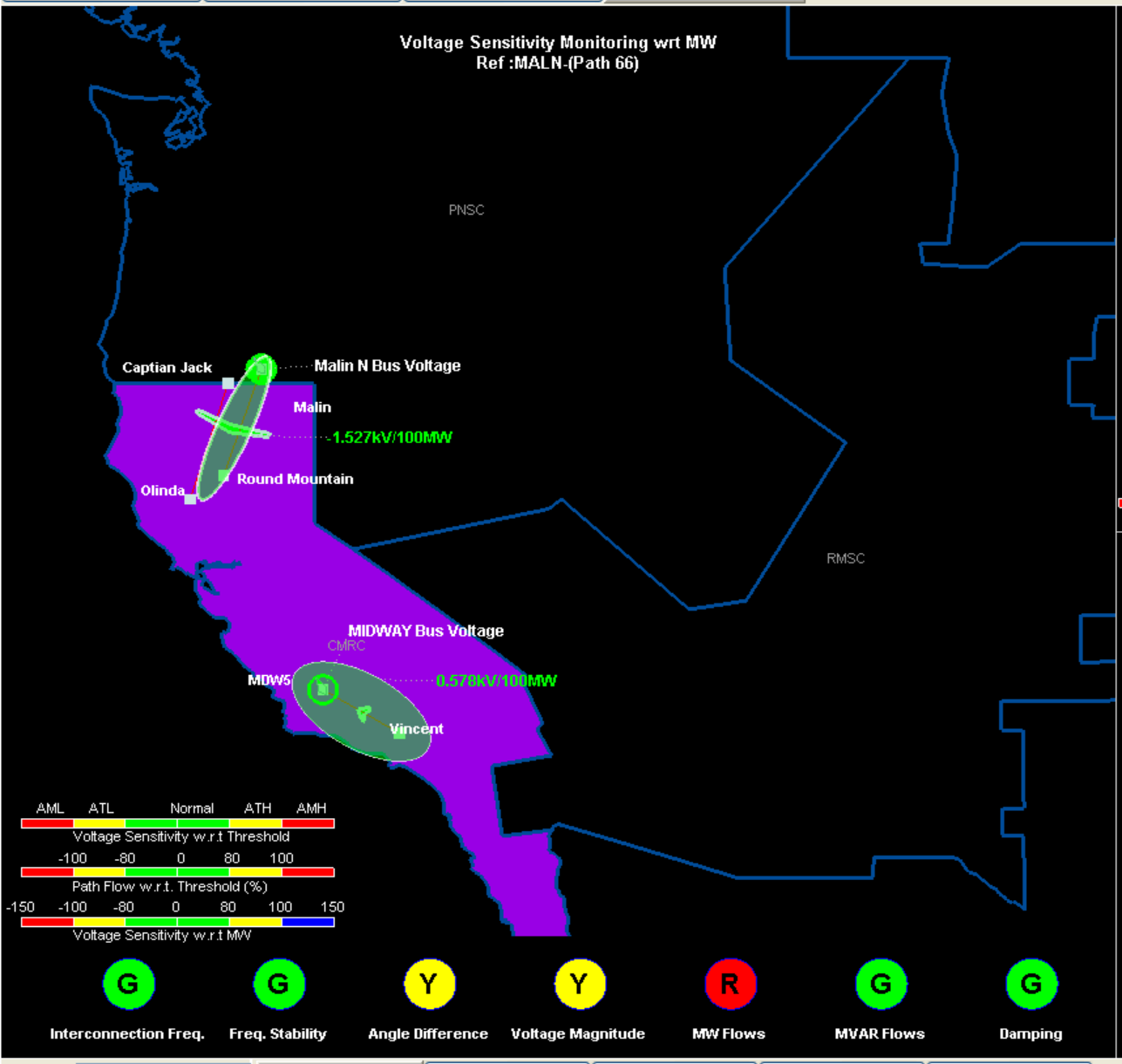
Higher Damping ⇔ ***Greater Stability***

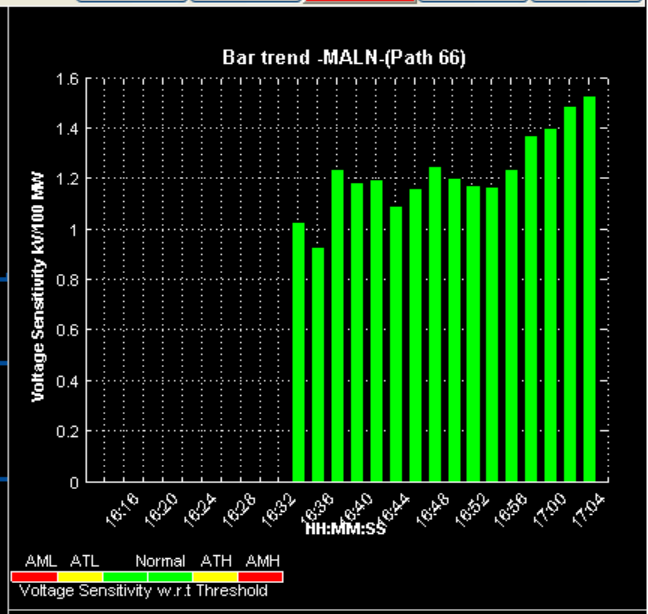


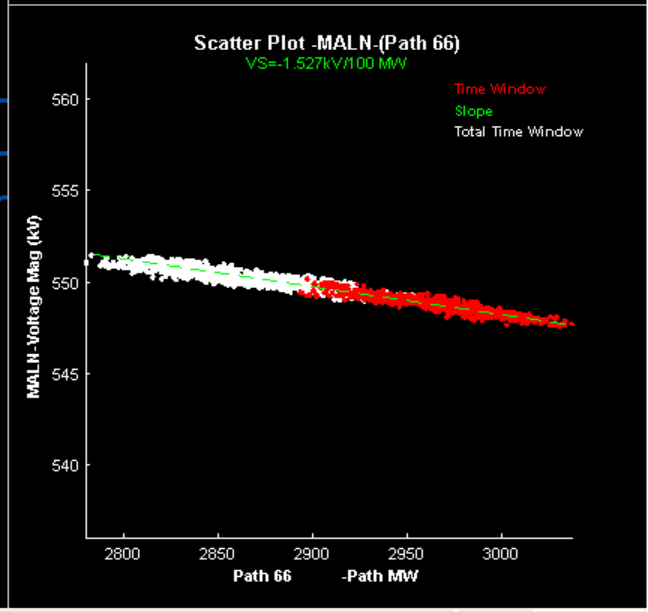


Phasor Real Time Dynamics Monitoring System (Phasor-RTDMS™) - Visualization and Event Alarms Client v5.5

Dashboard | Interconnection | Reliability Coordinator | Local Area | Reports | Event Files | Alarms | Configurati... | Help







G Interconnection Freq. | G Freq. Stability | Y Angle Difference | Y Voltage Magnitude | R MW Flows | G MVAR Flows | G Damping

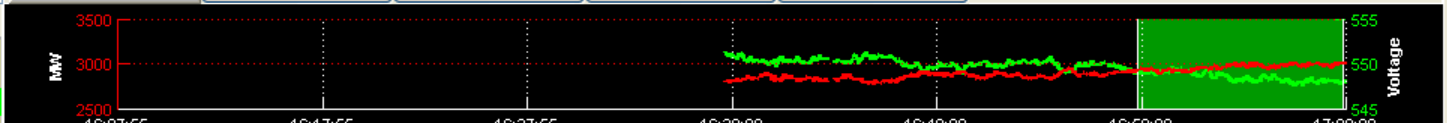
Date/Time 29-May-2008 17:08:00 PDT

Auto Refresh

VS Flows (MW)

Connected (Refresh Rate: 5 Second)

Scrolling Chart | Panel 1 Data | Panel 2 Data | Panel 3 Data | Panel 4 Data



Replay

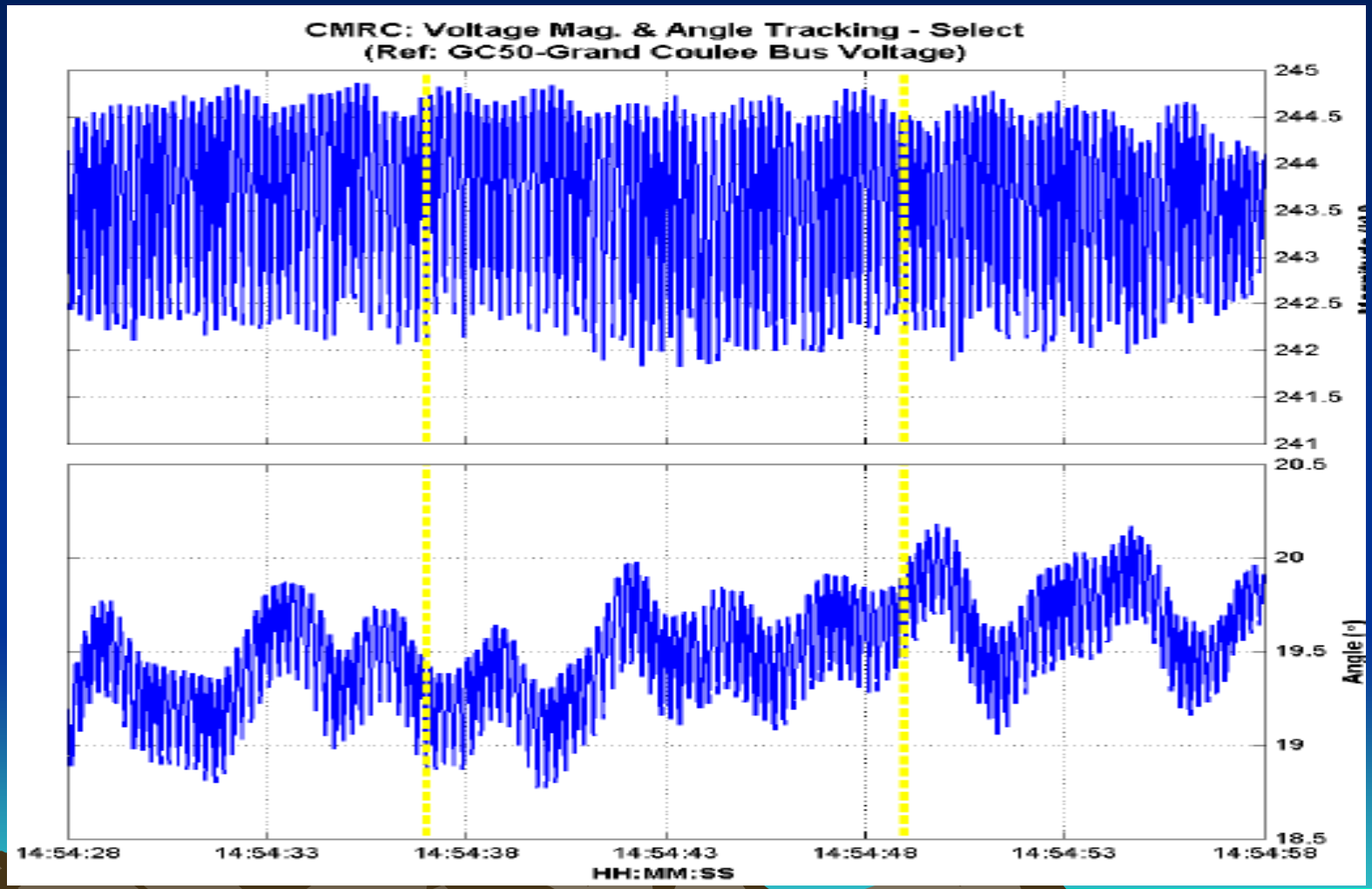
Frame:

Normal

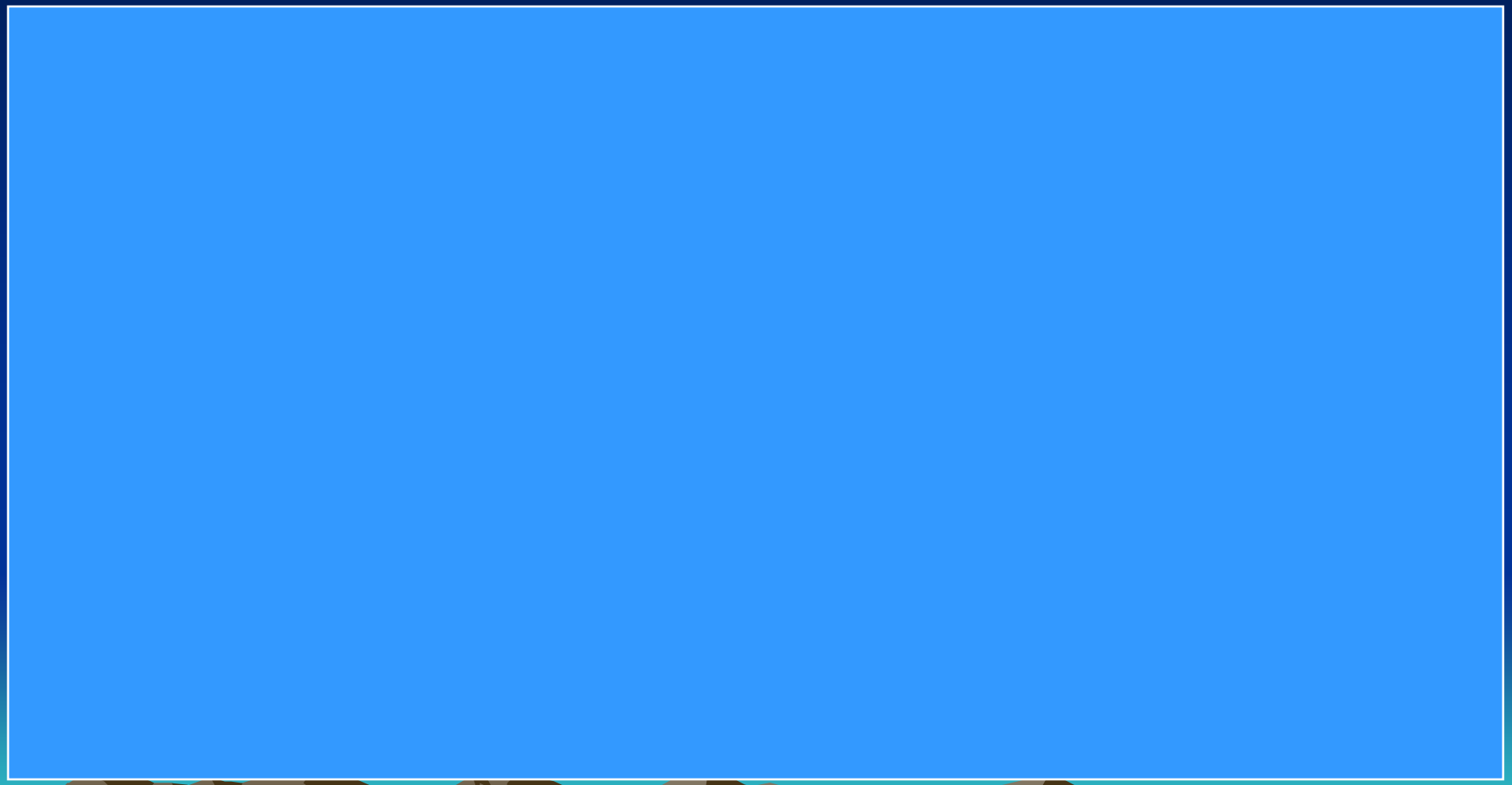
2008-1-26 Pacific DC Line event

- PDCI – Path 65 operating at 1700 MW - South to North flow
- Short circuit at Big Eddy substation resulted in loss of transformers between 500Kv and 230kV (Ice storm)
- The loss of the Big Eddy 500/230 kV ties affected the PDCI controls and an oscillation occurred with the DC current fluctuating approximately +/- 150 amps.
- The SCE operator noticed the oscillations on the analog recorder but the oscillations were not visible on SCADA
- Oscillations continued for an extended period of time and were finally observed by the CMRC on the phasor monitoring system.
- PDCI link was then shut down.

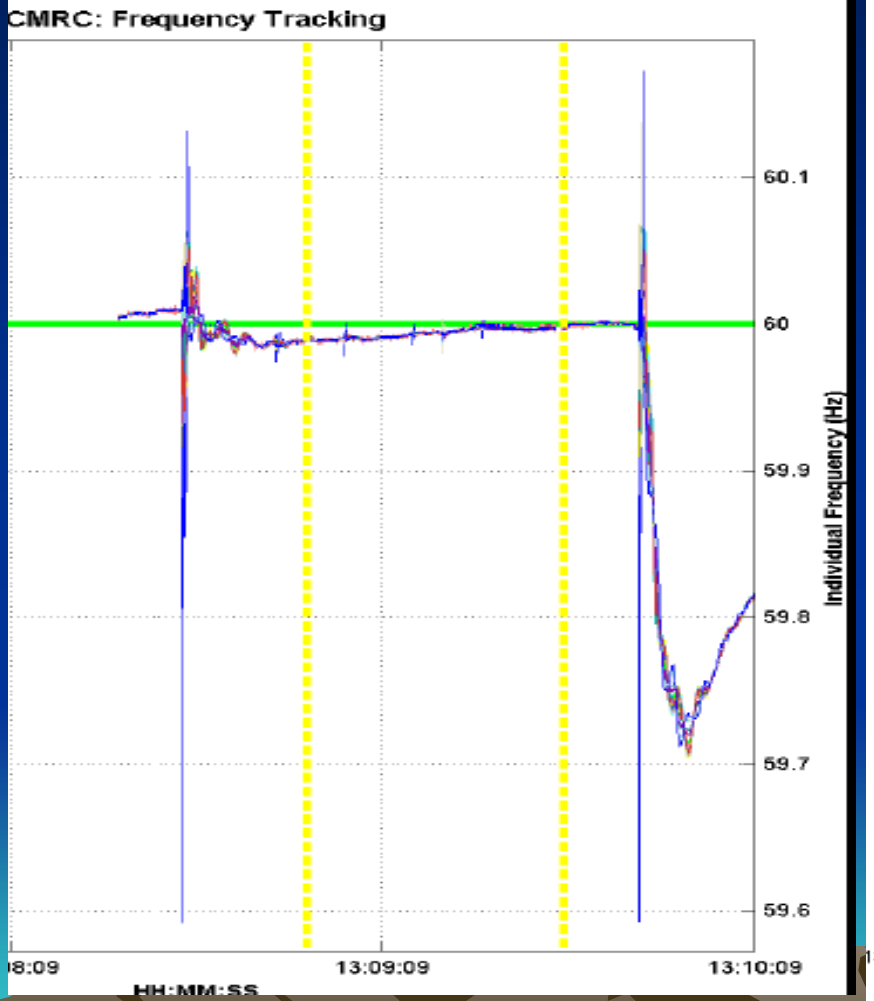
2008-1-26 PDCI event – Sylmar voltage oscillation

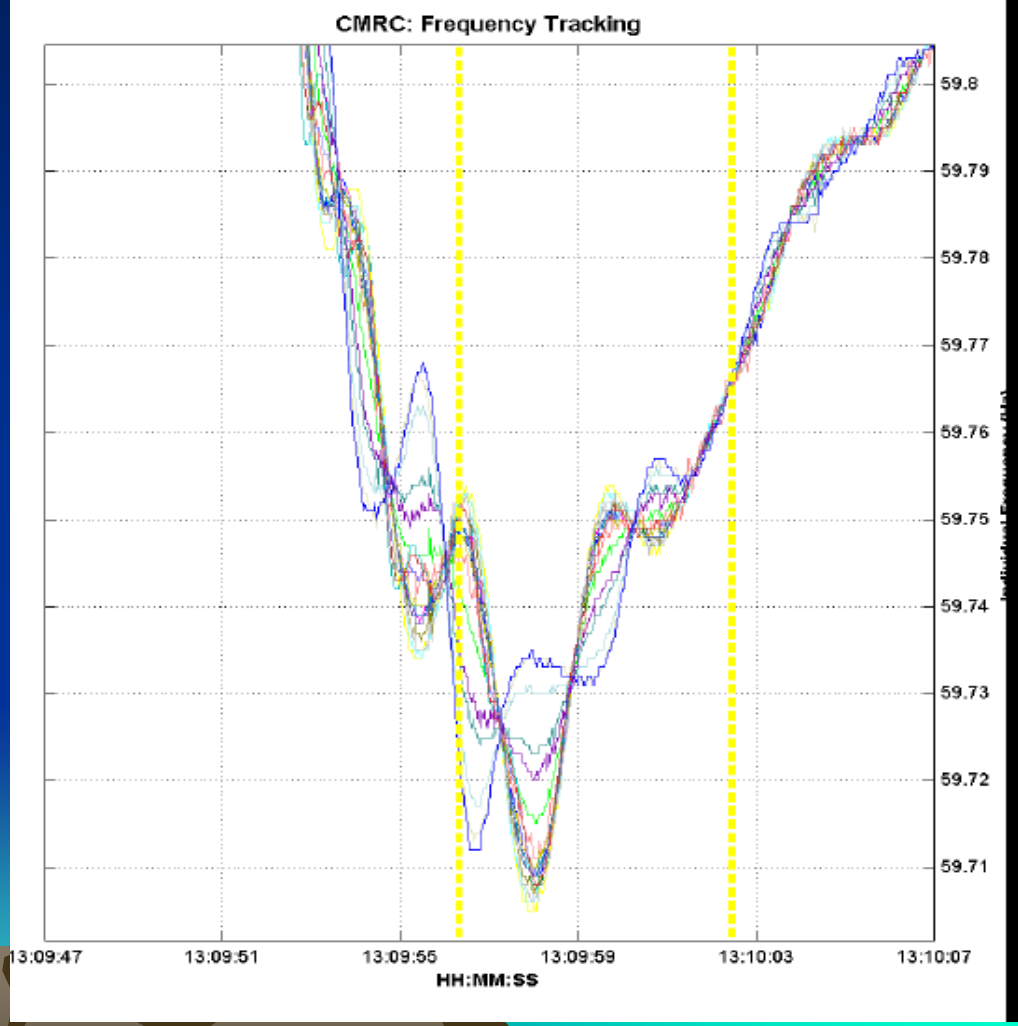


EMS 4 second data

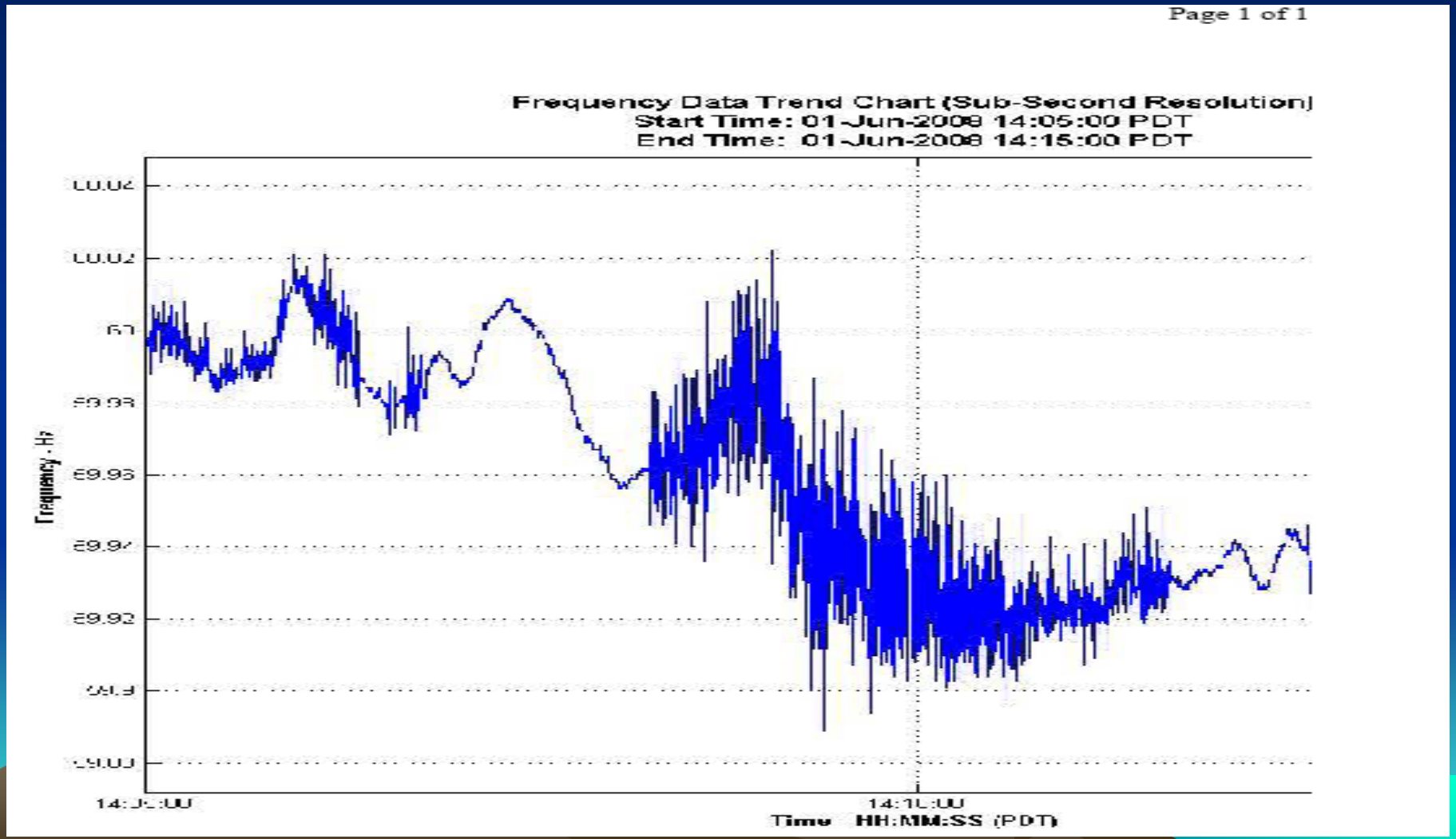


2008-5-20 PDCI multiple events-BPA gen. trip





June 1 – Pacific DC Interconnection Oscillation



Southwest Power Link outage

- 500 kV transmission line trip
- Major angle separation between San Diego area and Arizona made it very difficult to close the breaker to reconnect the two areas
  - Load drop required to bring angles into line
  - Real-time PMU measurements could simplify process, perhaps minimize load drop
- PMU coverage insufficient to due show angle of separation but do show some of the resulting transients on the SCE system

The Direction Forward

- System analysis
  - Incident analysis & problem solving
  - Operation verification
  - Model validation
- Real time monitoring
  - System awareness
  - Instability & islanding alarms
  - State estimation
- Measurement based controls