# California Public Utilities Commission

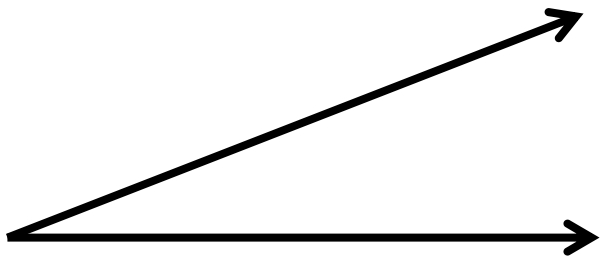
# Power Transmission
# New Technologies Workshop

October 7, 2005

George Rodriguez
Southern California Edison Company

SOUTHERN CALIFORNIA EDISON

# Phasor Measurement Technology to Increase Power Transfer Capability and Improve System Reliability



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## Current Situation

***In the last 10 years, PMUs have been installed in the Western Grid System***

- Phasor Measurement Units (PMUs) have been installed at various locations within the US bulk power system
  - Accurately measure and record the shape of the waveforms
  - Real-time assessment of system-wide operating conditions

- Western Electricity Coordinating Council adopted phasor monitoring in 1995
  - Phasor data collection and assimilation have been effective in observing the propagation of electric instabilities within the Western Interconnection.
  - Software standards need to be developed for managing and analyzing and interpreting PMU data.
  - WECC is coordinating the installation of PMUs at key Western grid locations

# *Phasor Measurement System Technology*

***What is it?***

***A state-of-the-art grid monitoring system which measures and compares Voltage, Current and Phase angles between different electric system points simultaneously.***

***Current system combines data from several PMUs at a Phasor Data Concentrator (PDC).***
***Several PDCs are then linked by high speed data connections to develop a global perspective of the entire grid.***

***The system utilizes individual Phasor Measurement Units (PMU) as a monitoring device.***

# Synchronized Phasor Measurement activities at Southern California Edison Co.

- SCE has
  - sixteen (2005) Phasor Measurement Units installed
  - Installed two Phasor Data Concentrators
  - developed Power System Outlook program to view MW, MVAR, Voltage, currents, modal oscillations and their damping
  - developed Real-time displays and will be installed in the Grid Control Center.
  - been storing streaming and event data files and compressing files for viewing larger time frame history

- SCE is participating in WECC, DOE, EIPP and CEC efforts in advancing this technology for the benefit of our SCE customers

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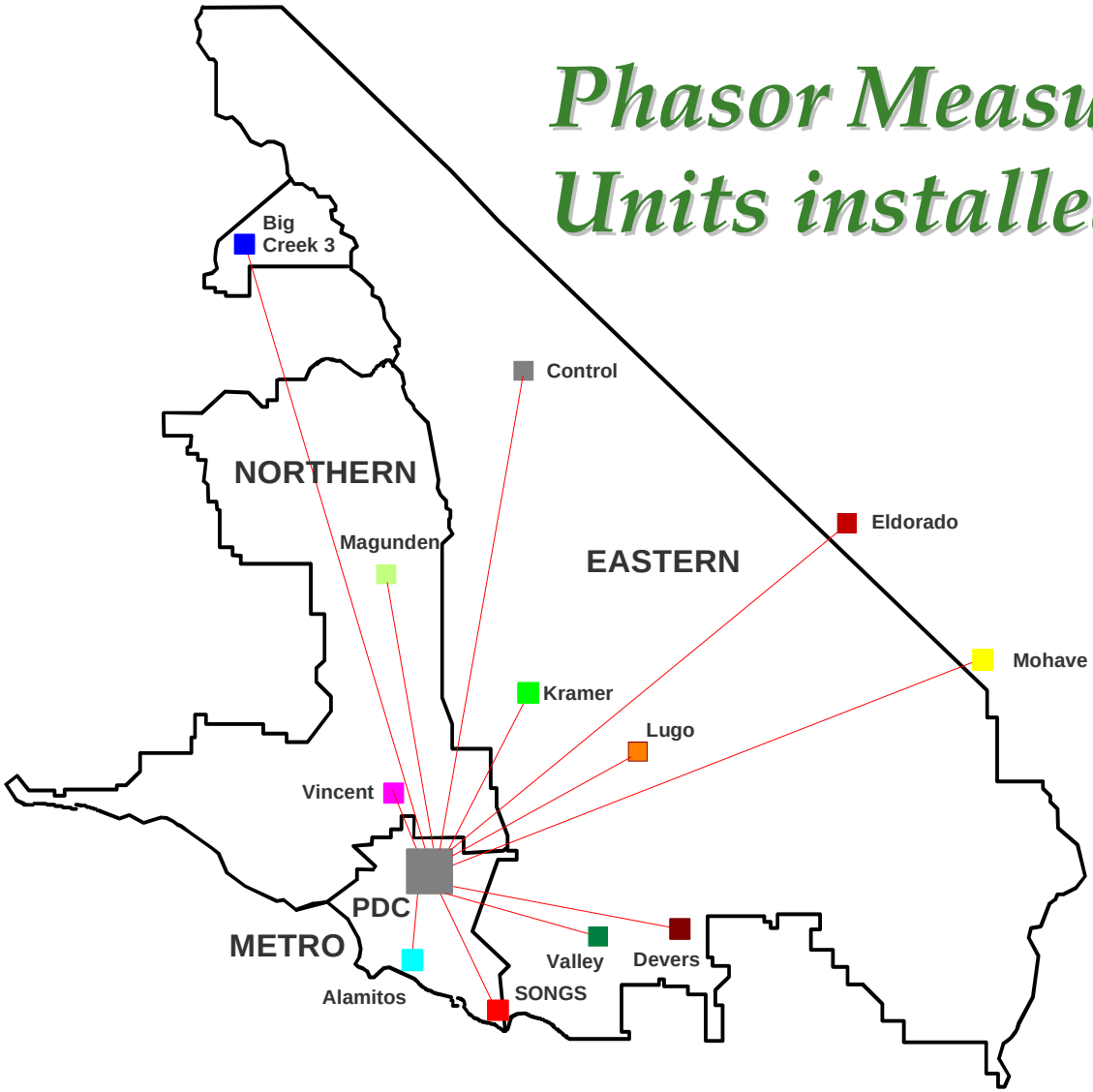
# Phasor Measurement Units installed in SCE

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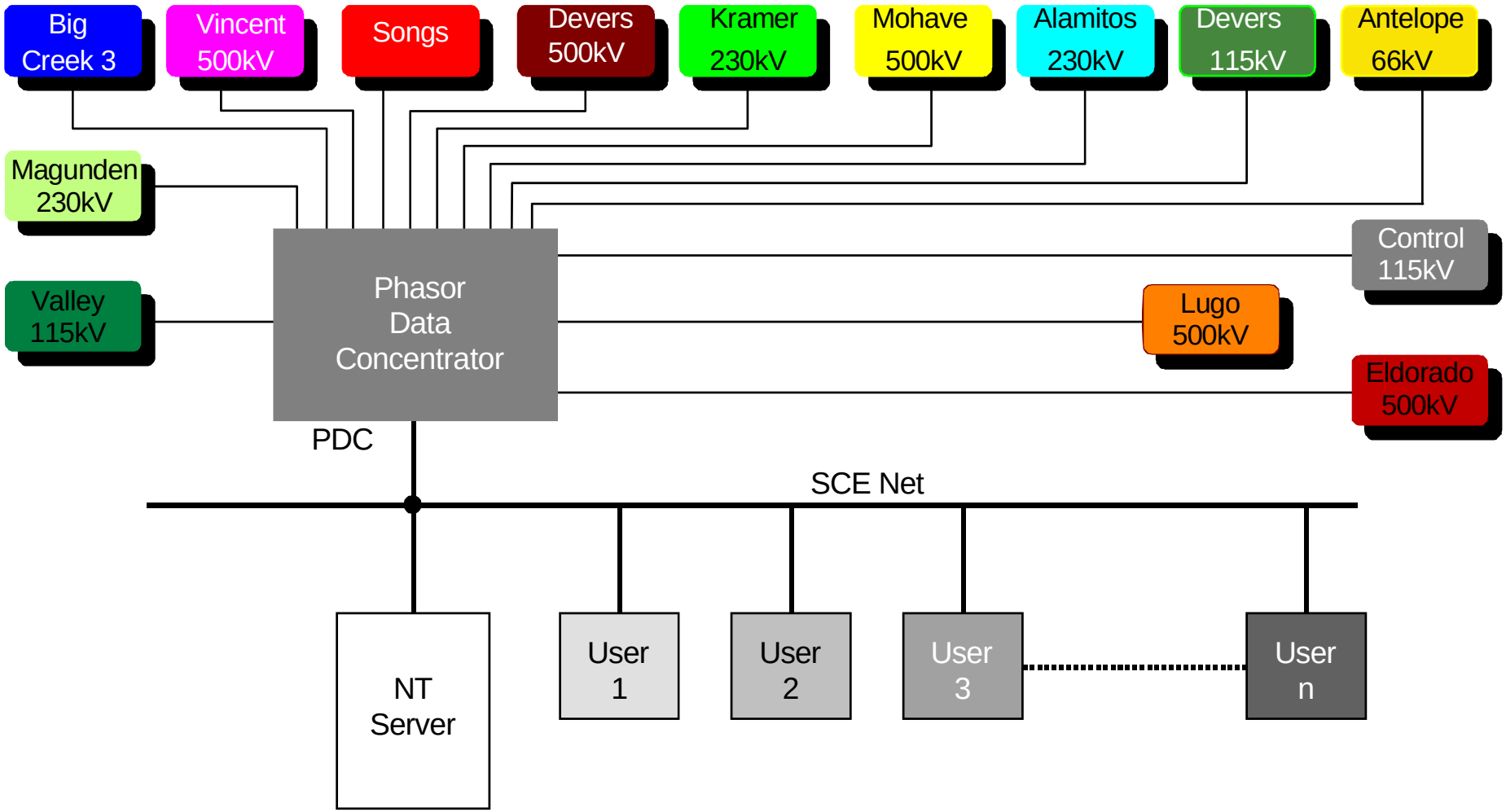
# Phasor Measurement System Network

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# Remedial Action Scheme (RAS) Operations

- Identifing and defining set of RAS schemes to take preventive measures to maximize power transfer capability and avoid critical system conditions on a dynamic and global basis using PMU data

- Intelligent monitoring and control of RAS schemes using PMU information will avoid unnecessary grid system and generation trips

- RAS operations will be tied to system stress conditions considering phase angle and voltage conditions

# Voltage Control and VAR Management

- **SCE is working on the development of an intelligent system to manage reactive power, support the voltage at Devers, and to ensure the WECC system stability using the PMU and SCADA system data**

- **PMU data will also be used to coordinate the SVC FACTS device operation with other reactive power sources in 2006. (Shunt caps, series caps)**

# FACTS Applications

FACTS are power electronic devices that can act very fast and provide substantial benefits by equalizing power flows, providing dynamic shunt and/or series compensation to better utilize the existing transmission system and to improve reliability. Reactive power (MVARs) is dynamically injected or consumed to support the local voltage condition.

**SCE Applications**

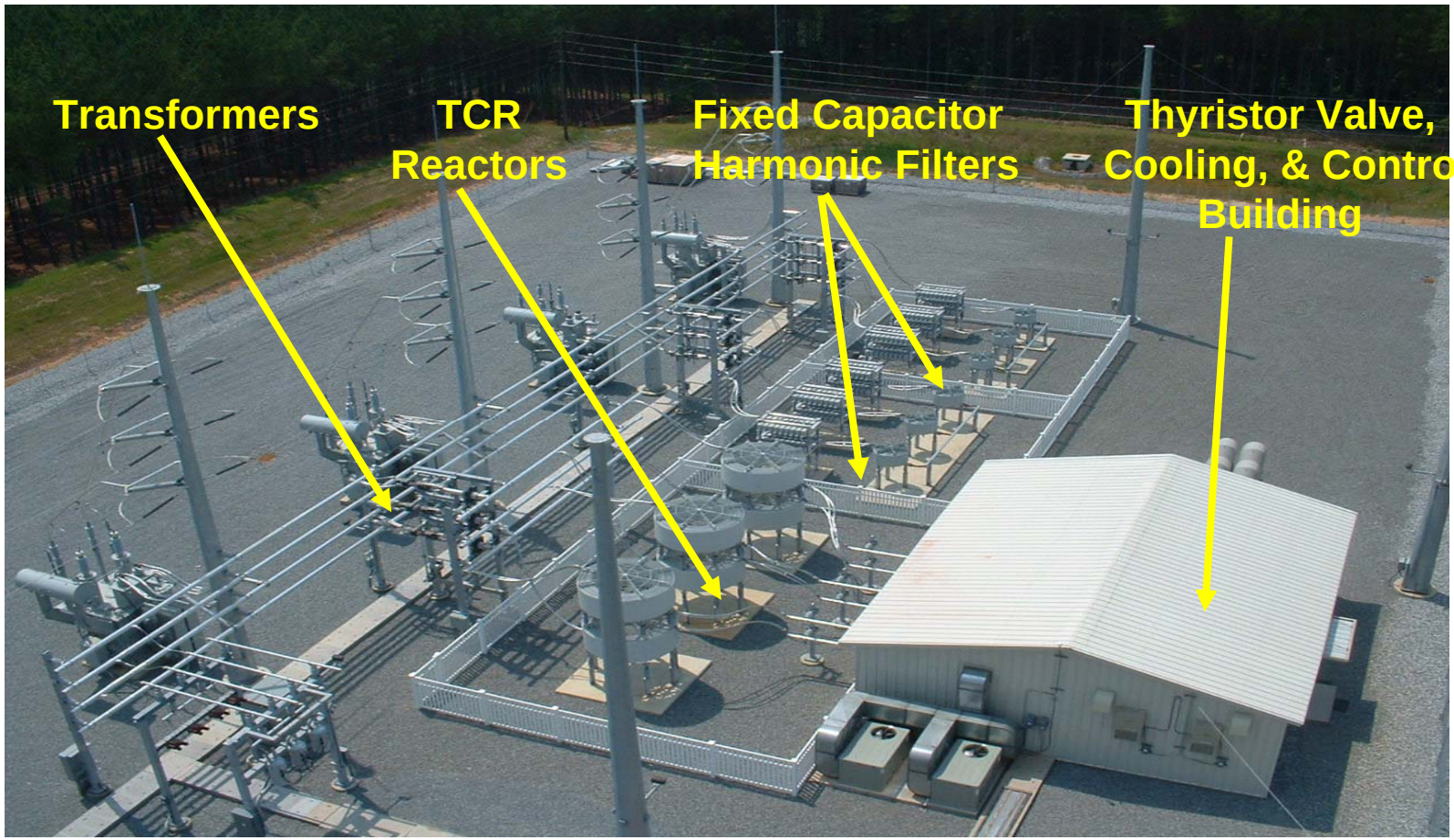
- **NGH SSR Damping Device (Lugo Sub)**
- **TPSC at Vincent and Eldorado Subs**
- **10 MW-40 MWh Battery Energy Storage System (Chino Sub)**
- **SVS at Devers Substations (2006)**
- **VAR Wind Sub at Tehachapi (14 MVAR minivar system)**

# Devers Substation SVS Project

- Devers-Palo Verdes 500 kV T/L #2 scheduled to be in operation in 2006

- An SVS will be installed with a nominal rating of 440 Mvar leading (Capacitive) to 110 Mvar lagging (Inductive) at 525-kV (1.0 p.u.)

# Georgia Power SVC Project




Laurens County 115 kV, +87 MVAr SVC System

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# Stability Monitoring

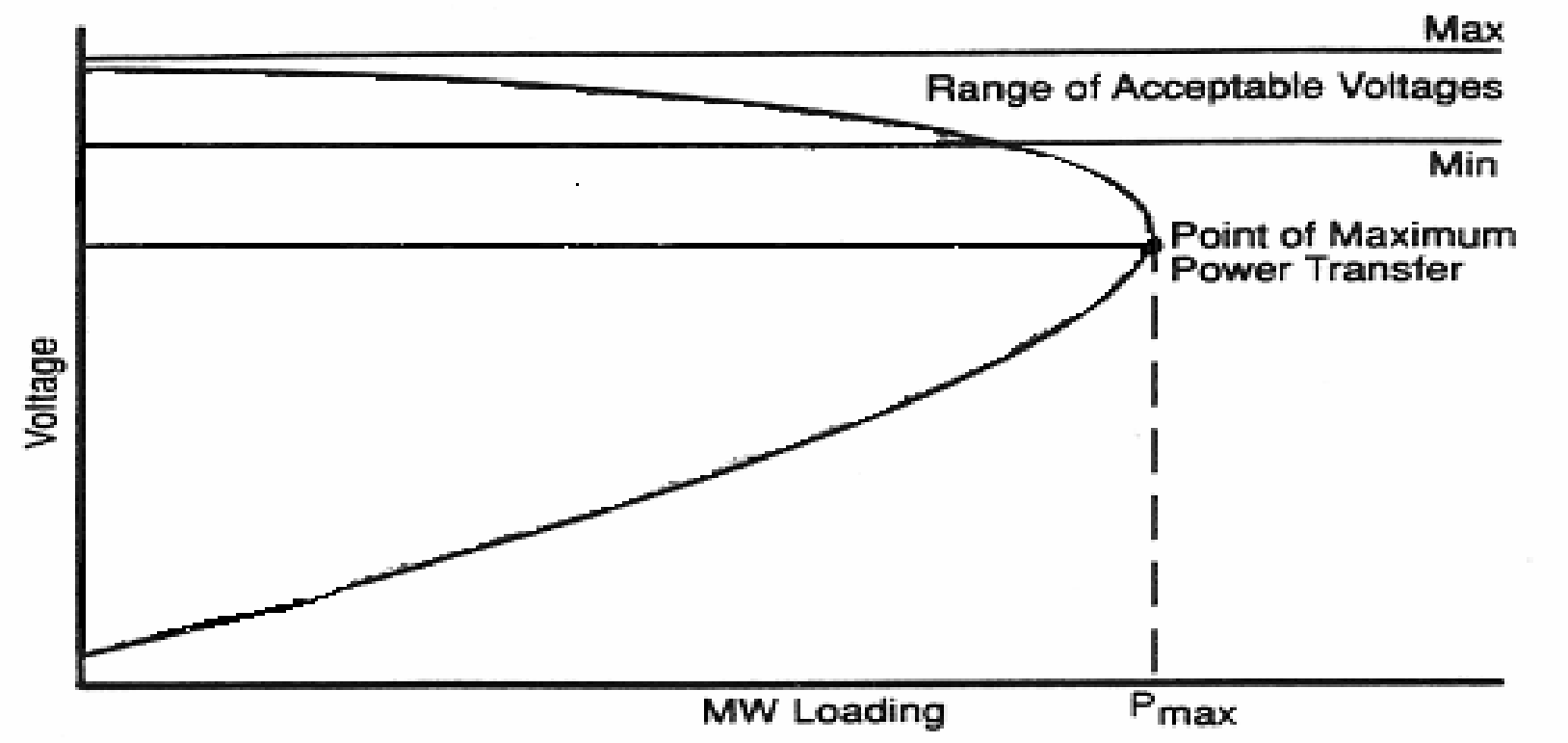
WECC Bulk Power System Monitoring

- North – South DC Links
- System stress
- Modal Oscillations and Damping (e.g. 0.3 Hz)
- Voltage at critical points

Specific controls are enabled by PMU data to

- monitor wind park stability for current and future gen
- control of Big Creek and Casa Diablo Hydro Gen system
- monitor links to neighboring utilities (Path 26, 49,15)

# PV CURVES




- P-V analysis (real power relative to voltage) is a tool which determines the real power transfer capability across a transmission interface for load supply.

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# Other PMU Applications

- **HVDC Modulation to damp AC transmission system oscillations**

- **Transmission Line Power Flow Management**
  - Load Balancing
  - Loss Reduction
  - Voltage Regulation (Tap Changer Management)

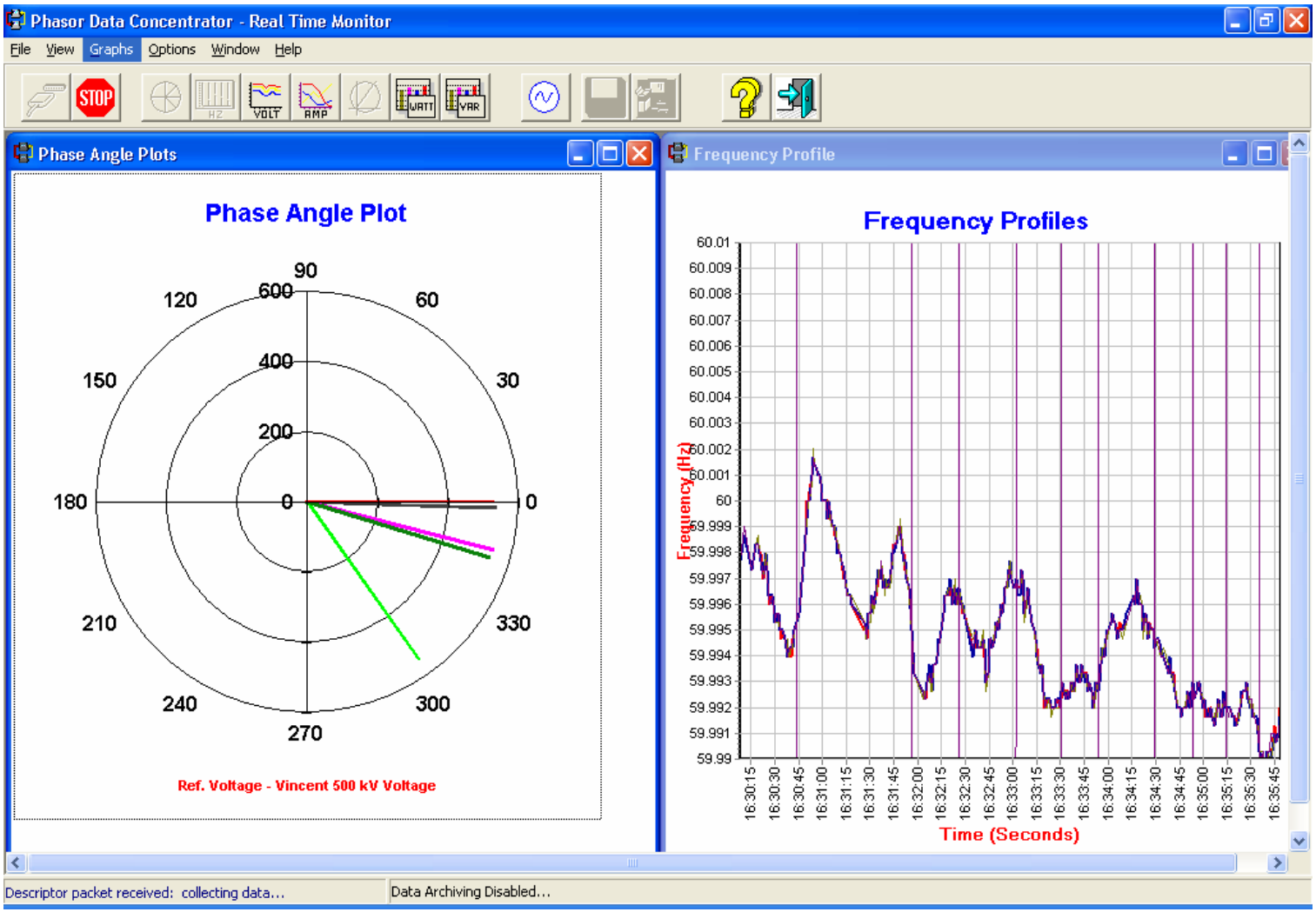
# Power System Outlook Program

- SCE has developed the Phasor System Outlook software which can monitor the system in real-time as well as analyze previously saved data.

- SCE has been using its tool for several years and has gained invaluable experience collecting and analyzing data from its own PMU network. Many of the challenges other utilities will face have already been solved by SCE engineers.

- The SCE software has been successfully integrated and used by other utilities for monitoring and integrating phasor data in the Western Interconnection.

# Real-time Phasor Measurement system display developed at SCE

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# Phasor Measurement Unit showing voltage vector


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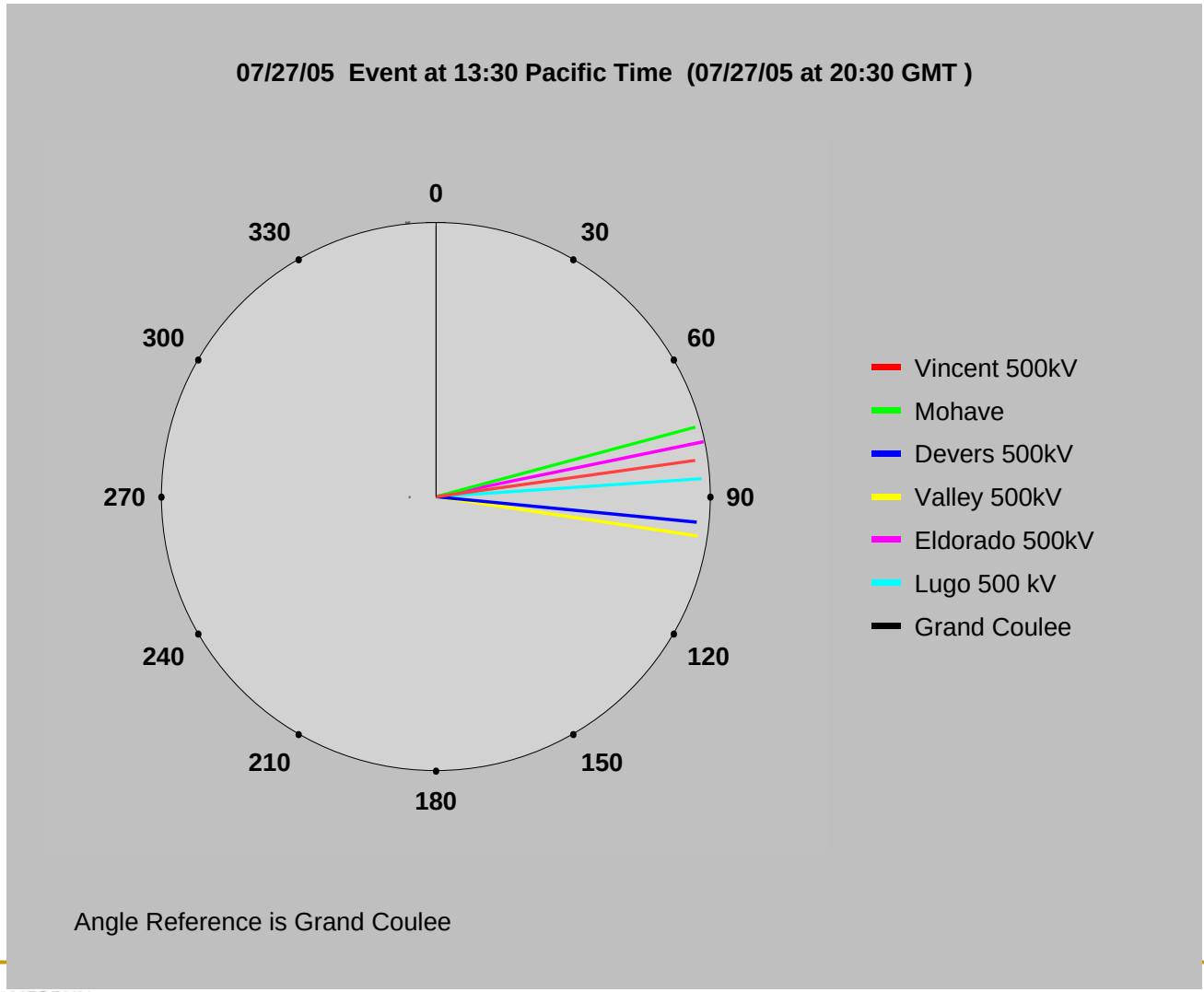


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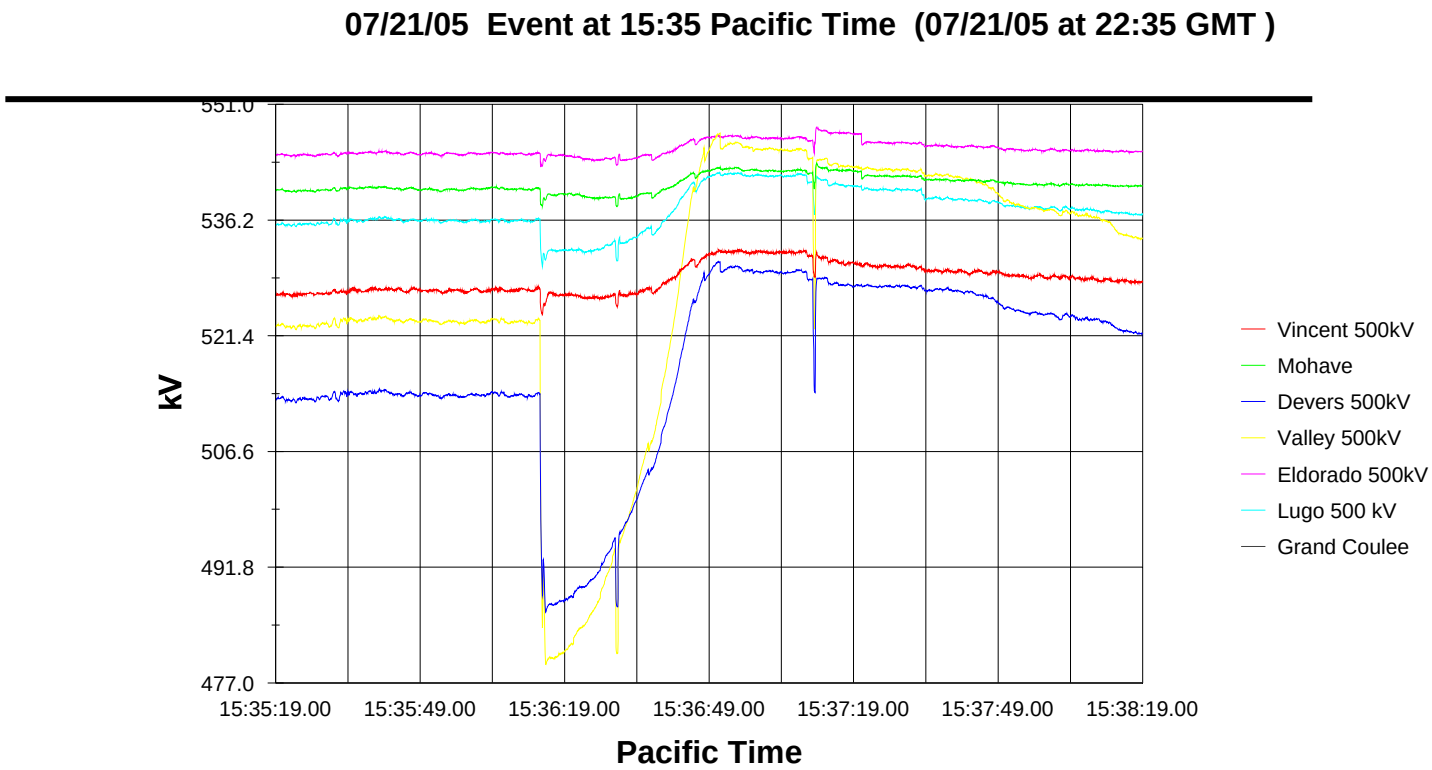
# Phasor Measurement system plots for July 21, 2005 Voltage Recovery event at Devers and Valley substations

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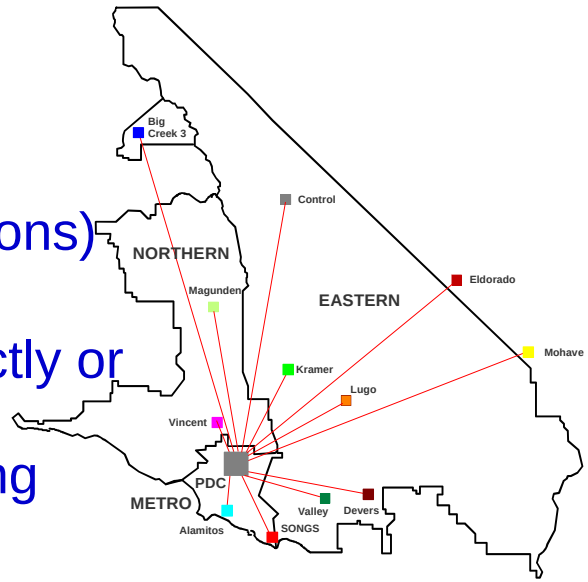
# Phasor Measurement Units

## Off-line Applications




**Today (Production)**

- Monitoring system stress (Phase angle separations)
- Monitoring voltage support at critical locations
- Post disturbance analysis (what operated correctly or incorrectly)
- Monitoring modal oscillations and modal damping
- Monitoring dynamic power swings

**Future (Target)**

- Model validation/establishing limits using off-line analysis tools
- Monitoring machine excitations and governor systems
- System Voltage and reactive power management
- Pattern recognition and AI tools for quick event analysis
- System load response to voltage and frequency variations

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# Phasor Measurement Units

## Real Time Applications

**Today**

- Monitoring system stress (Phase angle separations)
- Monitoring frequency and df/dt
- Monitoring voltage, currents, active and reactive power

**Future (Target)**

- Monitoring critical line status and outages
- Monitoring modal oscillations and modal damping
- Monitoring dynamic power swings
- Real-time control of HVDC Modulations and FACTS devices
- Monitoring machine excitation and governors
- Voltage and reactive power management
- AI and Pattern recognition tools for quick event analysis

# Issues

*While many utilities have installed PMUs, there are many issues to resolve in order to create a PM system.*

| Area | Issues/Questions |
|---|---|
| **System Monitoring** | • What data must be obtained to provide the information necessary for meeting our objectives?<br>• From what locations must we obtain this data? |
| **Analysis Tools** | • Tools must be developed to turn an overwhelming amount of data into information that can be used by system operators and planners |
| **Data Structure and Archiving** | • Structures for PM data must be developed and codified<br>• The industry must reach agreement on what data to save, where to save it, and for how long |
| **Data and Information Sharing** | • Current data formats and analysis software may be incompatible within and among the interconnections<br>• System data may raise issues of security and liability |
| **Action Protocols** | • Operators and planners must have confidence in PM systems before they can be expected to use them<br>• Operators in neighboring control areas must commonly interpret and act upon information to ensure system reliability |

# Phasor Measurement Units


**Conclusions:**

- Synchronized Phasor Measurement
  - Is a maturing and accepted Technology
  - Can assess system separations and system situation
  - Can provide Real-time system monitoring for reliability and post event analysis
  - Can be used for active system component control like SPS, FACTS and HVDC Modulation
  - Can be integrated with existing SCADA systems
  - Can avoid disturbances like the Northeast-2003 blackouts
  - Will enable to move from State Estimator to State Measurements
- Post event data analysis can provide information on event locations and severity
- Requires appropriate agreements to safeguard data use
- SCE is working with WECC members and SCE neighbors like APS, SPR, PG&E, LA DWP and WAPA for data / information exchange