Real Time Monitoring for SMART Grid Initiatives

Synchronized Measurement & Analysis in Real Time SMART® program by

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FACTS (I hope you will agree)

- *Power transfer economics and system reliability are competing goals.*
- *Systems are designed considering the worst loading condition scenarios and for loss of one element.*
- *Systems are generally well planned and designed as they withstand outage of one element*
- *Most disturbances occur, not for loss of one element, but multiple contingencies occurring over an extended time period*
- *Very often, the line loadings and margins are not adjusted when line outages occur outside one's control area.*
- *Tools are needed to monitor Wider Area and for keeping an eye on other systems as well*

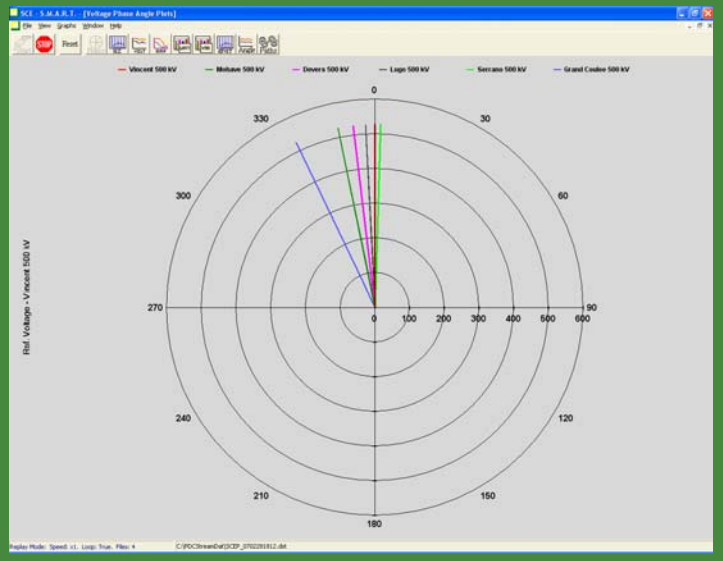
Increasing Transmission Capacity and reliability

We can increase transmission capacity using SPMS by

- *Establishing static phase angle limits*
  - *Increasing loadings if margin is there*
  - *Reducing loading if the safe limits are exceeded*
- *Comparing phase angle measurements with bench marked cases and keeping adequate dynamic margin*
  - *for critical outages*
  - *Maintaining adequate margins if line outages occur and adjusting phase angles as necessary.*
- *Monitoring Modal oscillations frequencies and damping*
  - *Modal damping should not fall below 7 to 8 percent on any mode*
  - *Modal frequencies should not continue to drift lower*
- *Monitoring voltage support at intermediate locations*
  - *when operating at large phase angles separations.*
- *Event reconstruction and model validation*

SMART program Capabilities

SMART Viewing capabilities

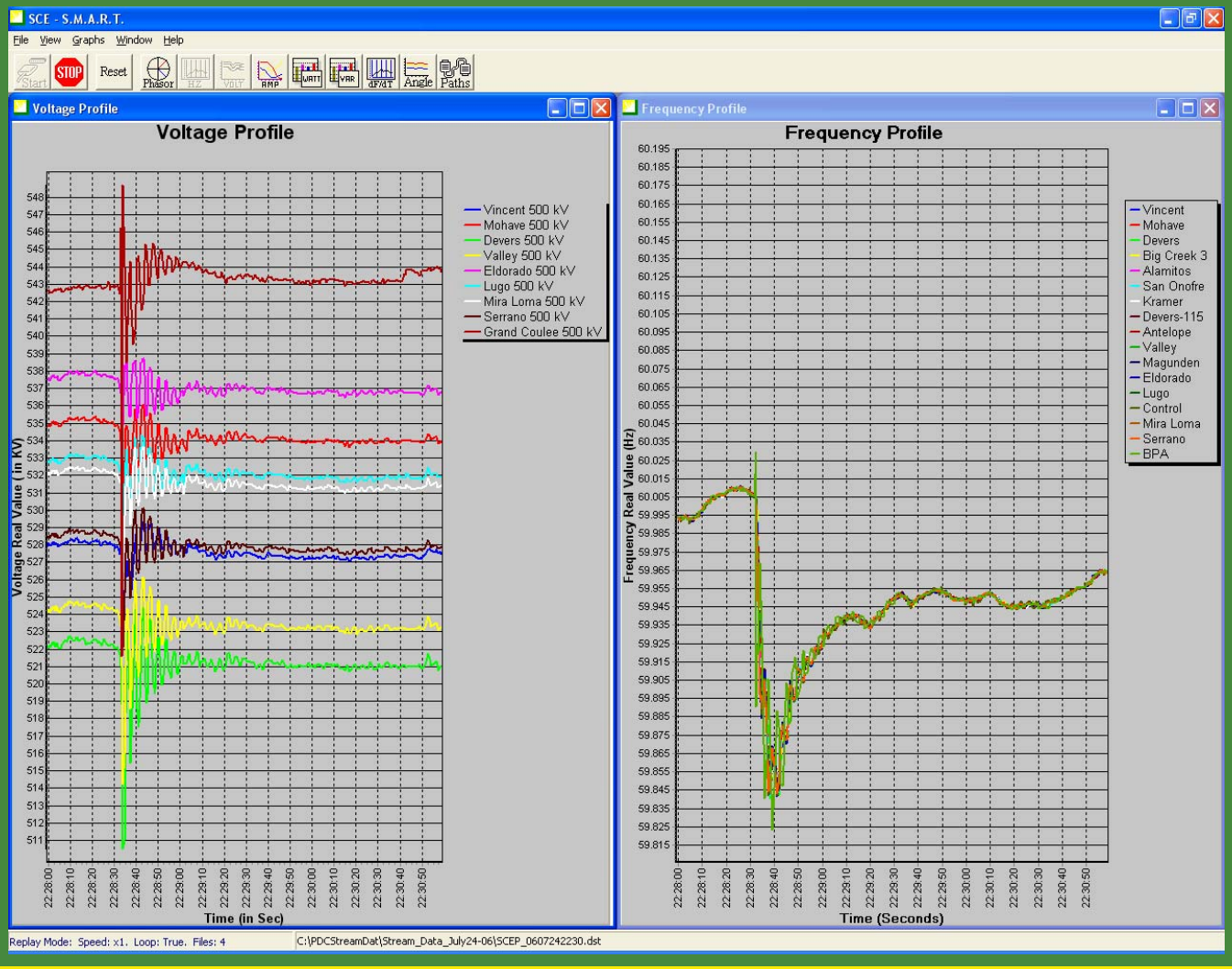


- Voltage 500, 230, 115 and 66 kV
- Currents on the monitored circuits
- Power and reactive power
- Path flows Active, Reactive on Path 26, 49-south, 49- North
- Frequency and frequency deviation
- Df/dt at all PMU locations
- Phase angle difference from referenced bus
- Percent deviation for voltage, current, Power, reactive power
- Voltage Phasor replay

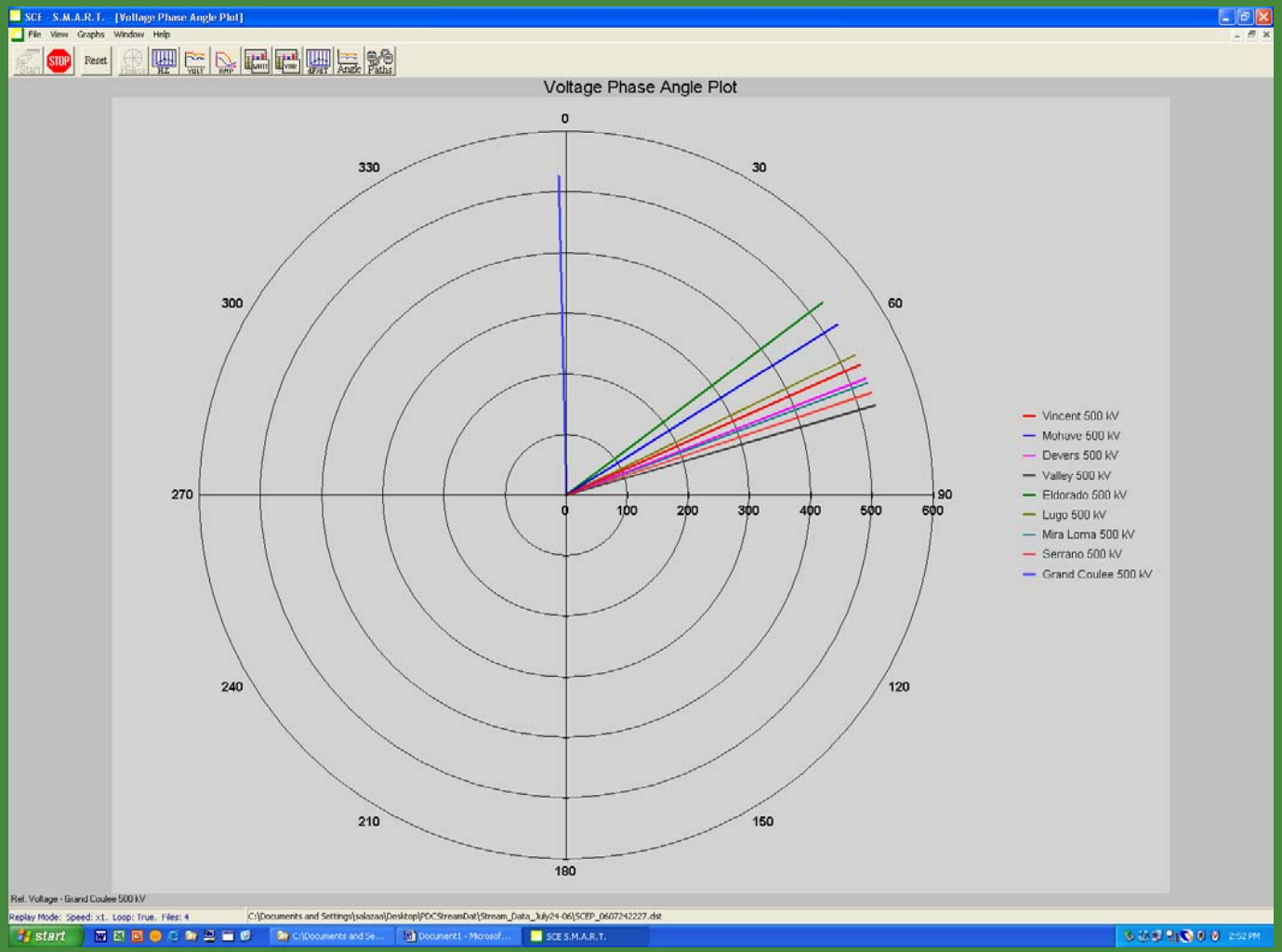
SMART program
Showing July 24, 2006 event
at 22:28:30 GMT

System frequency to 59.841 Hz momentarily and normal in six minutes when BPA Vantage-Hanford 500 kV Line relayed and approximately 1550 MW of generation tripped via remedial action scheme.

Screen Shot from SCE SMART program showing Voltage profile and frequency for July 24, 2006 event



Screen Shot from SCE SMART program showing Voltage phase angle plot for July 24, 2006 event



Static and Dynamic phase angles from some recorded and simulated cases

500 kV system events (WECC)

Phase Angle separation between Grand Coulee (BPA) and Devers (SCE)

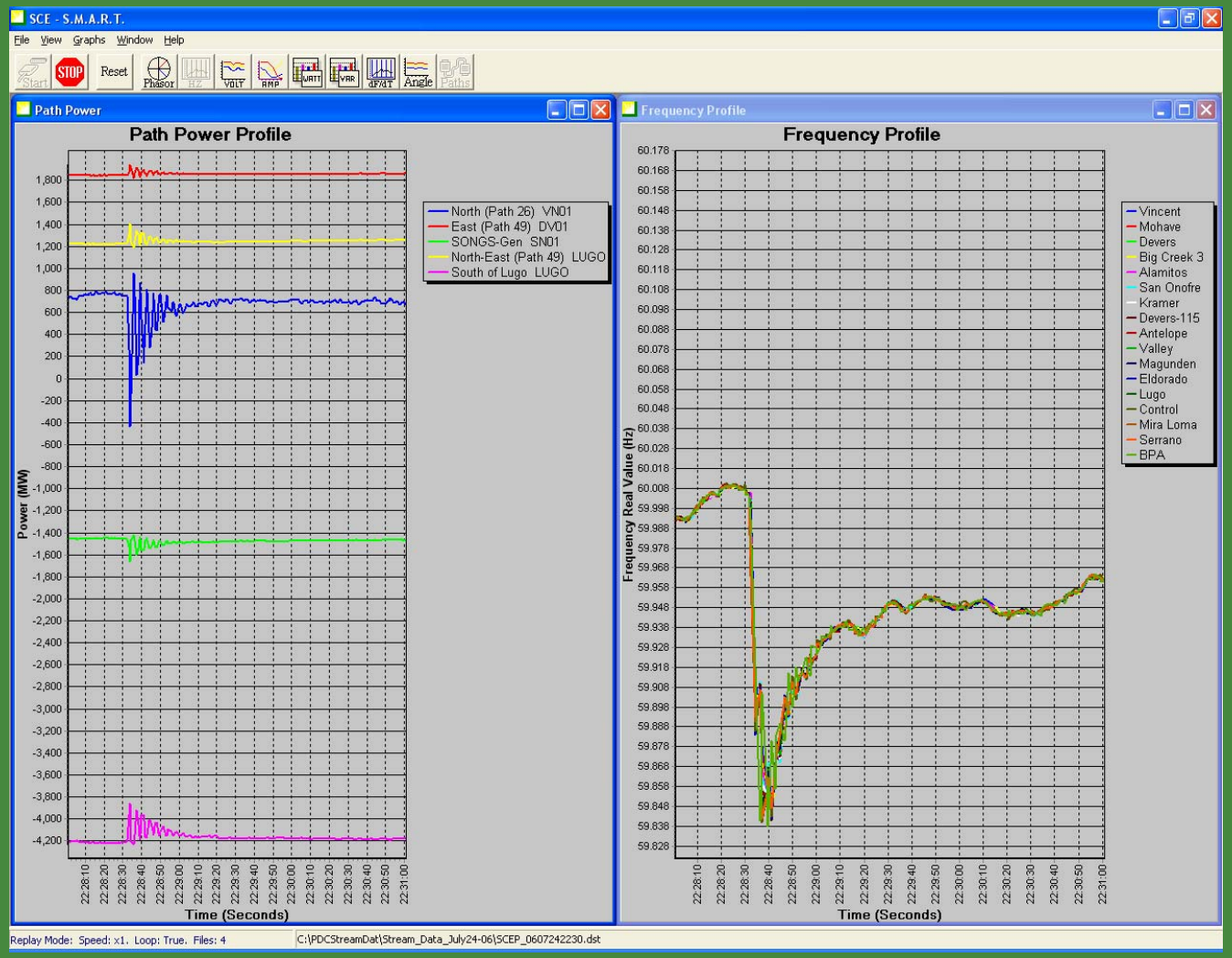
Date	*Static phase angle*	*Dynamic phase angle swing*	*Stability Type*
Aug. 10, 1996	94 deg. (Simul.)	Growing	Unstable – dynamic
Aug. 4, 2000	92 deg.	15 deg.	Dynamic / stable
June 6, 2002	74 deg.	73 deg.	Transient / stable
July 15, 2002	82 deg.	-35 deg.	Transient / Stable
June 14, 2004	55 deg.	90 deg.	Transient / stable
April 20, 2006	86 deg.	-10 deg.	Transient / Stable

230 kV system event (SCE Big Creek system)

Phase Angle separation between Big Creek and Vincent

Sept. 13, 2000	30 deg.	15 deg.	Dynamic / stable

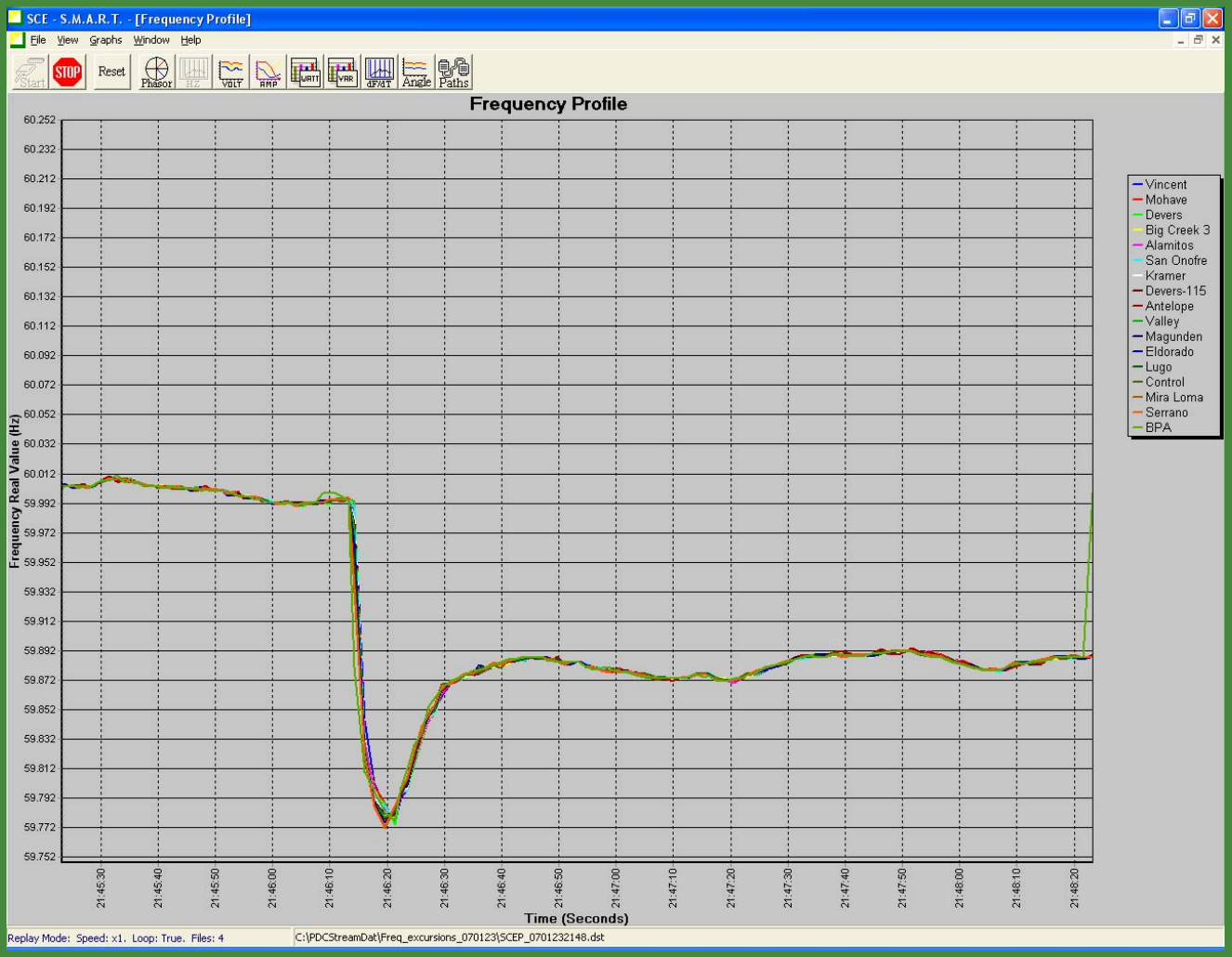
Screen Shot from SCE SMART program showing path power flows and frequency for July 24, 2006 event



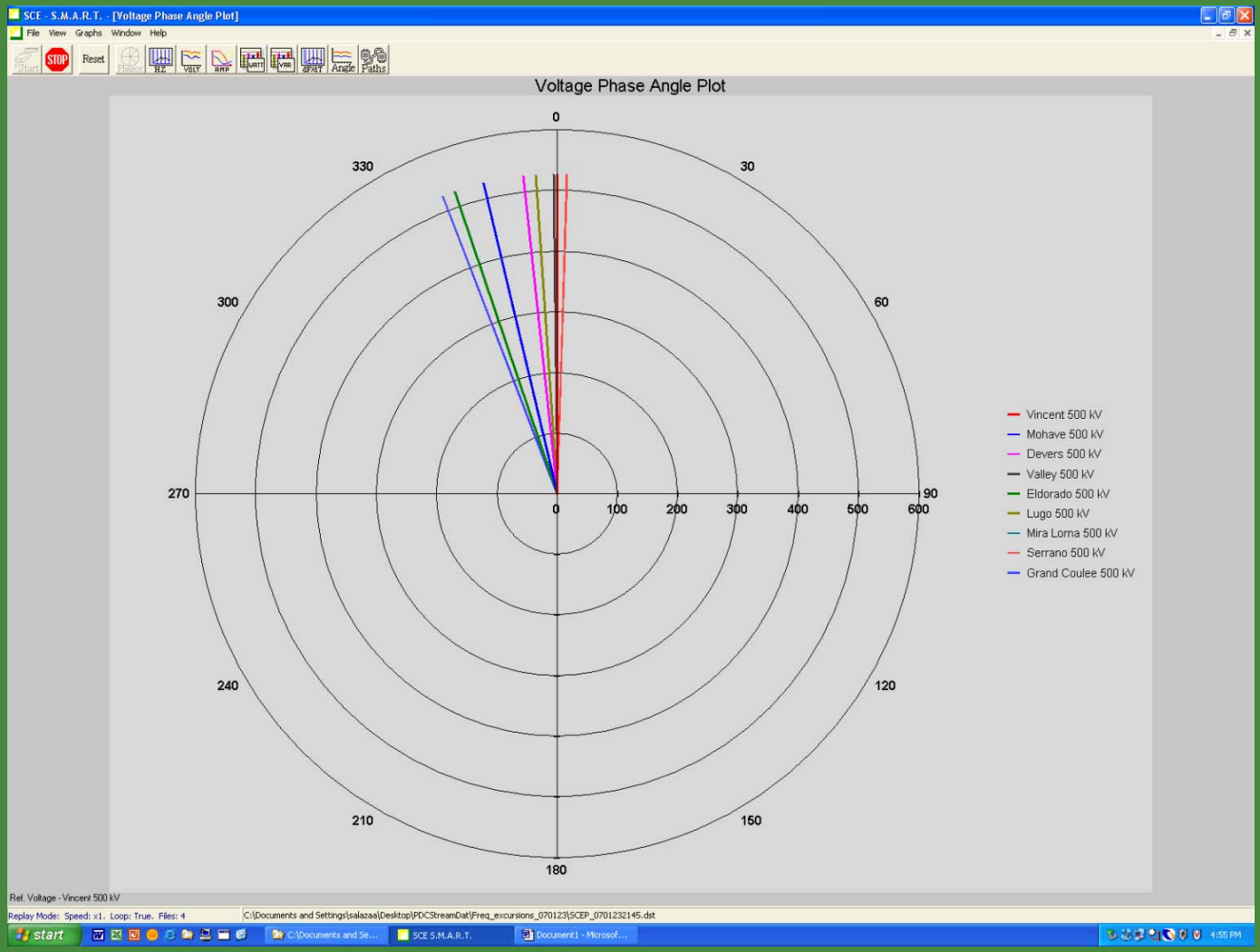
SMART program
Showing January 23, 2007 event
at 21:46 GMT

System frequency to 59.765 Hz momentarily and normal in 12 minutes due to loss of 2935 MW of generation in BCHA control area.

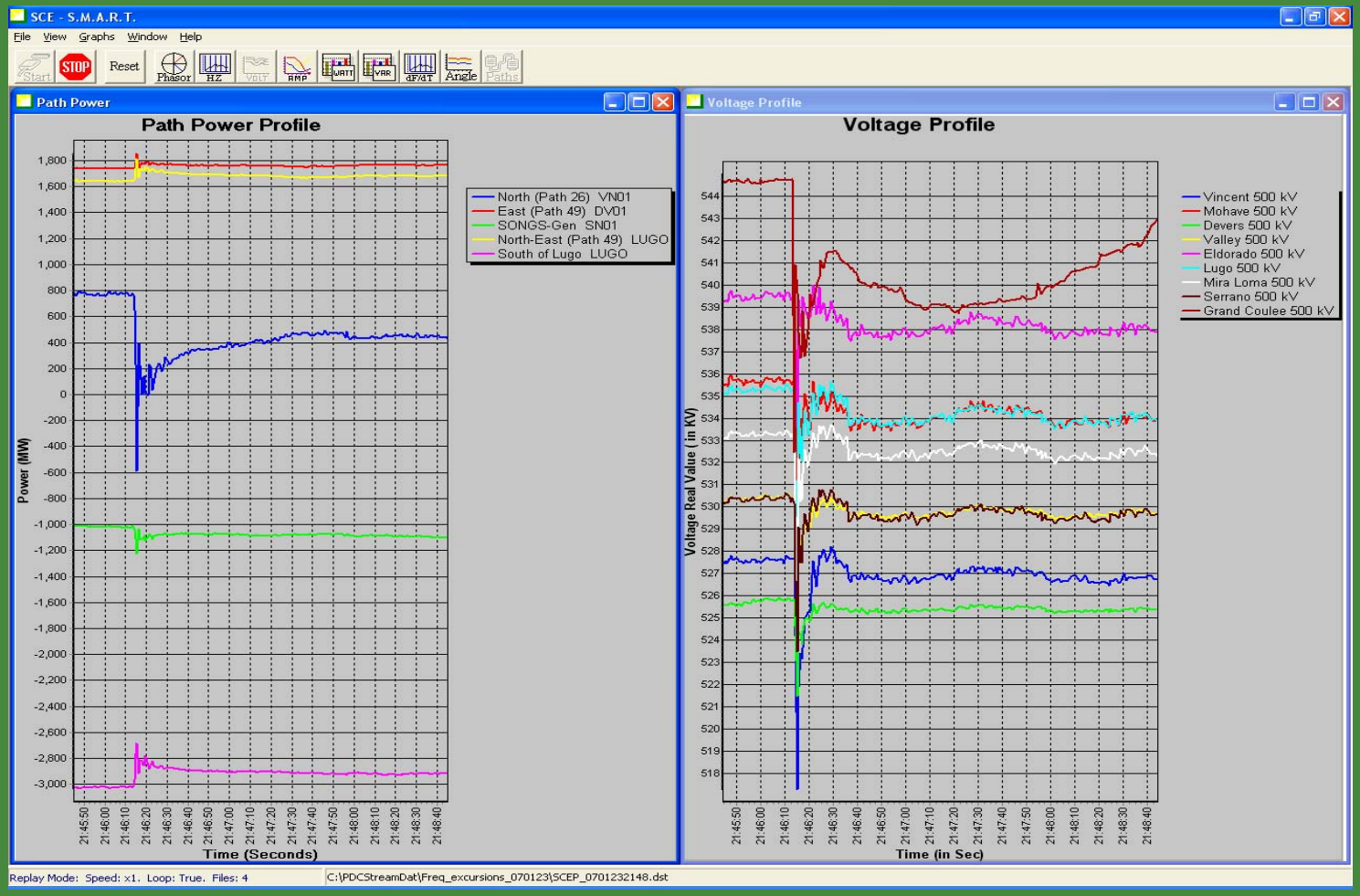
Screen Shot from SCE SMART program showing frequency profile for January 23, 2007 event



Screen Shot from SCE SMART program showing Voltage phasor angle plot for January 23, 2007 event



Screen Shot from SCE SMART program showing path flows and voltage profile for January 23, 2007 event



SCE SMART program Showing January 26, 2008 event at 22:09:30 GMT

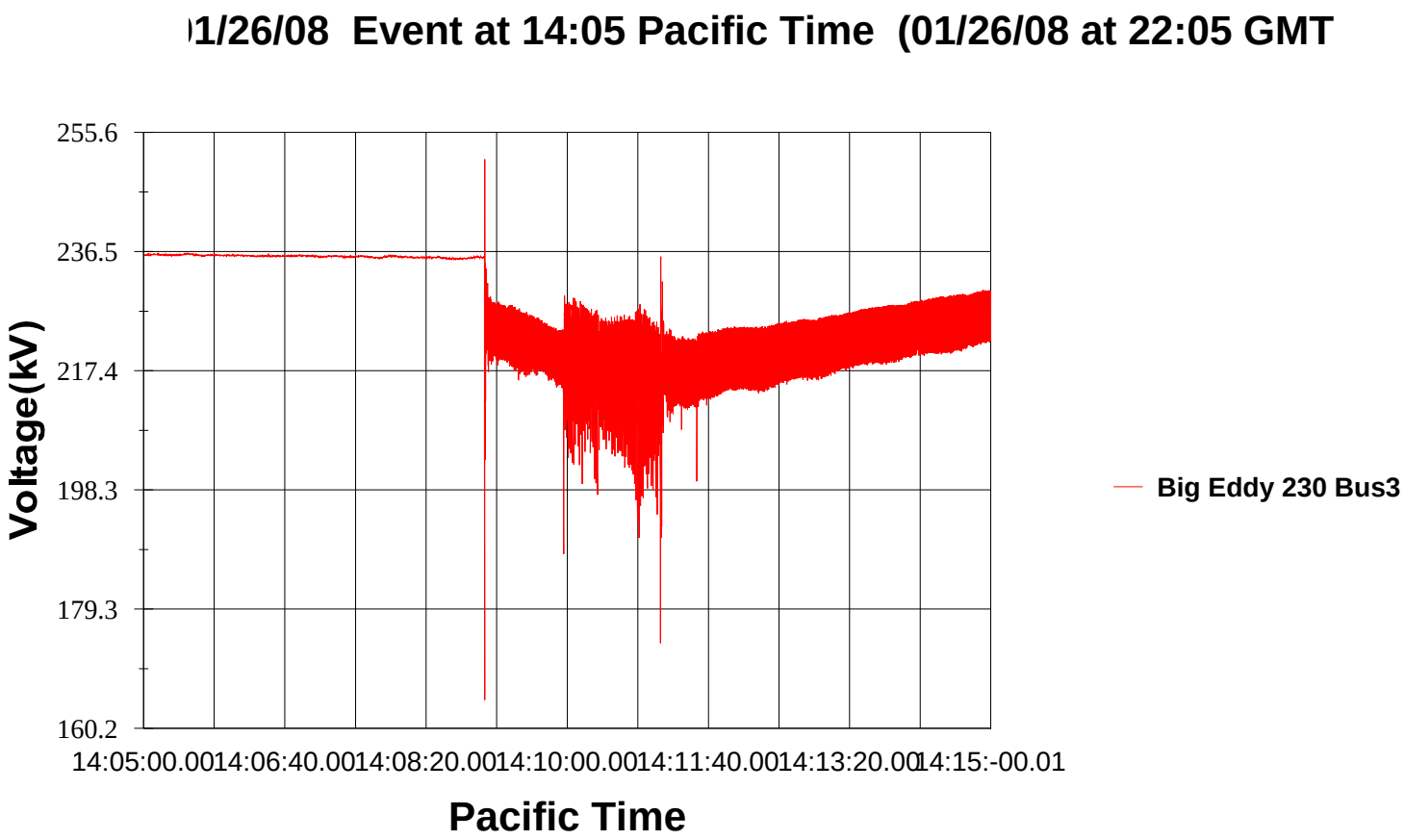
1409 ***PDCI 1000 kV DC Line appeared to block and restart. Significant voltage dip felt throughout western portion of SCE system. System frequency swung between 59.94 Hz and 60.06 Hz momentarily.***

We lost 525/230 kV transformers at Big Eddy

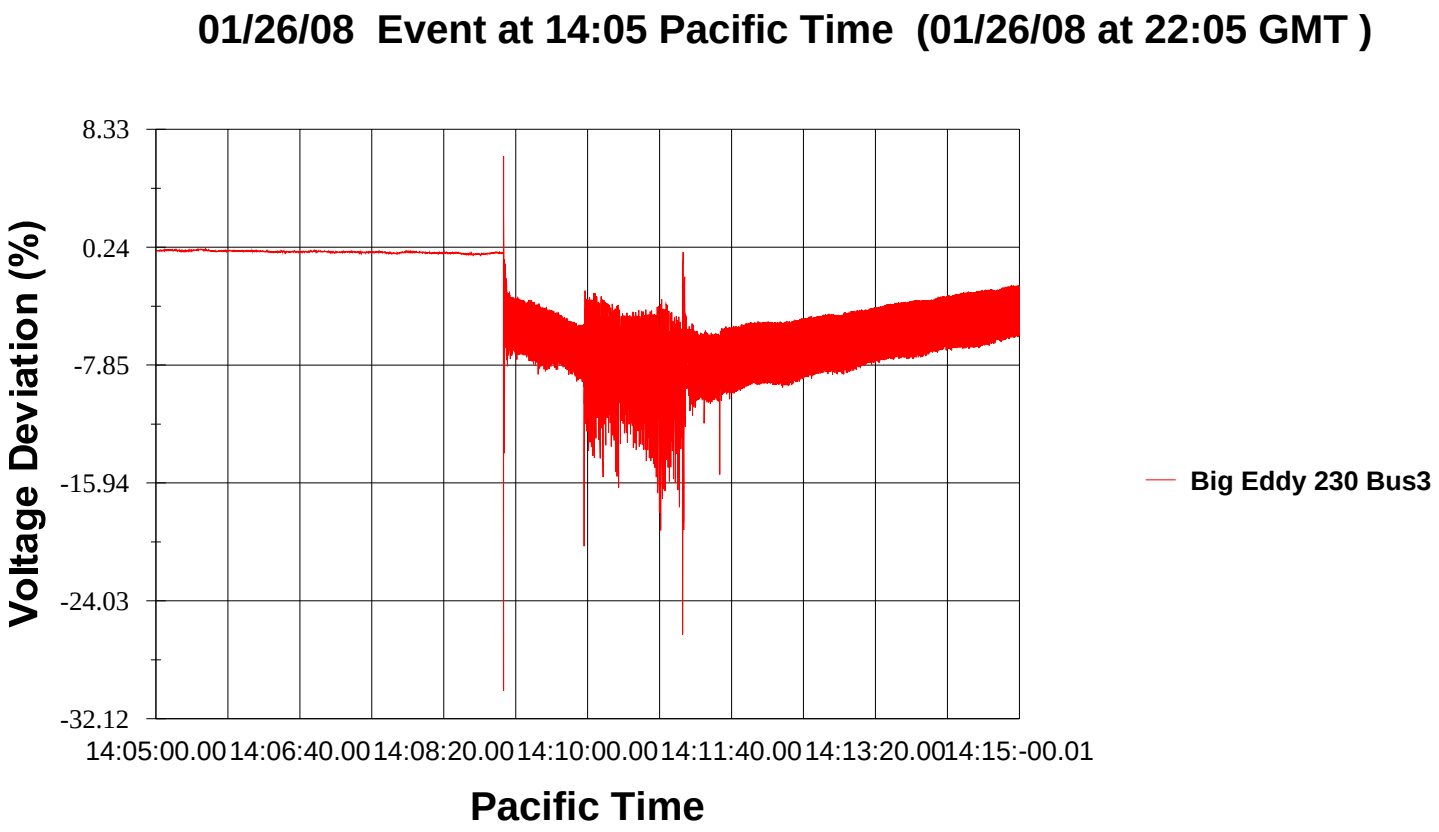
1505: ***PDCI ramped to zero, WECC Transfer Path 65 unavailable. System frequency to 60.06 Hz momentarily and normal in five minutes. Oscillations and swings stopped.***

Power System Outlook Plots from BPA Phasor Measurement system files

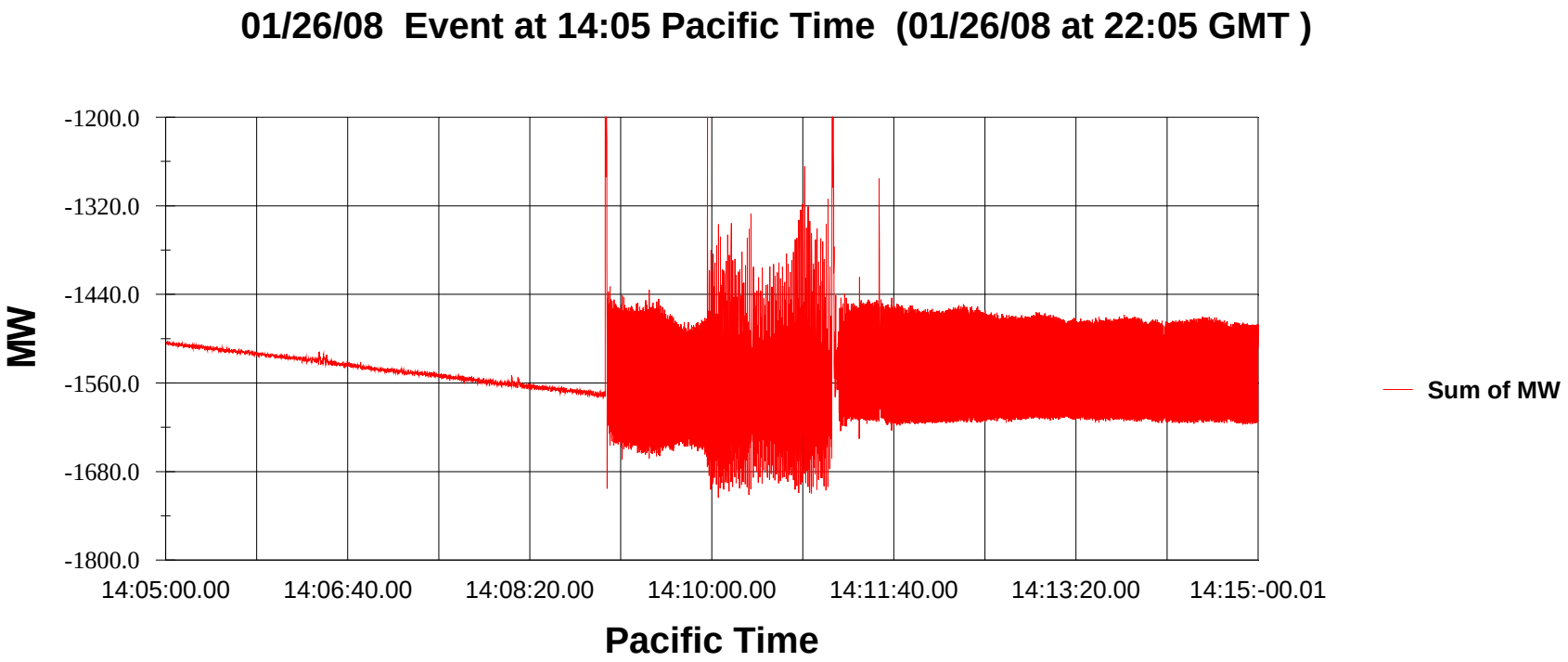
Bus Voltages at Big Eddy 230 kV from 14:05 to 14:15 PDT



Bus Voltages at Big Eddy 230 kV from 14:05 to 14:15 PDT



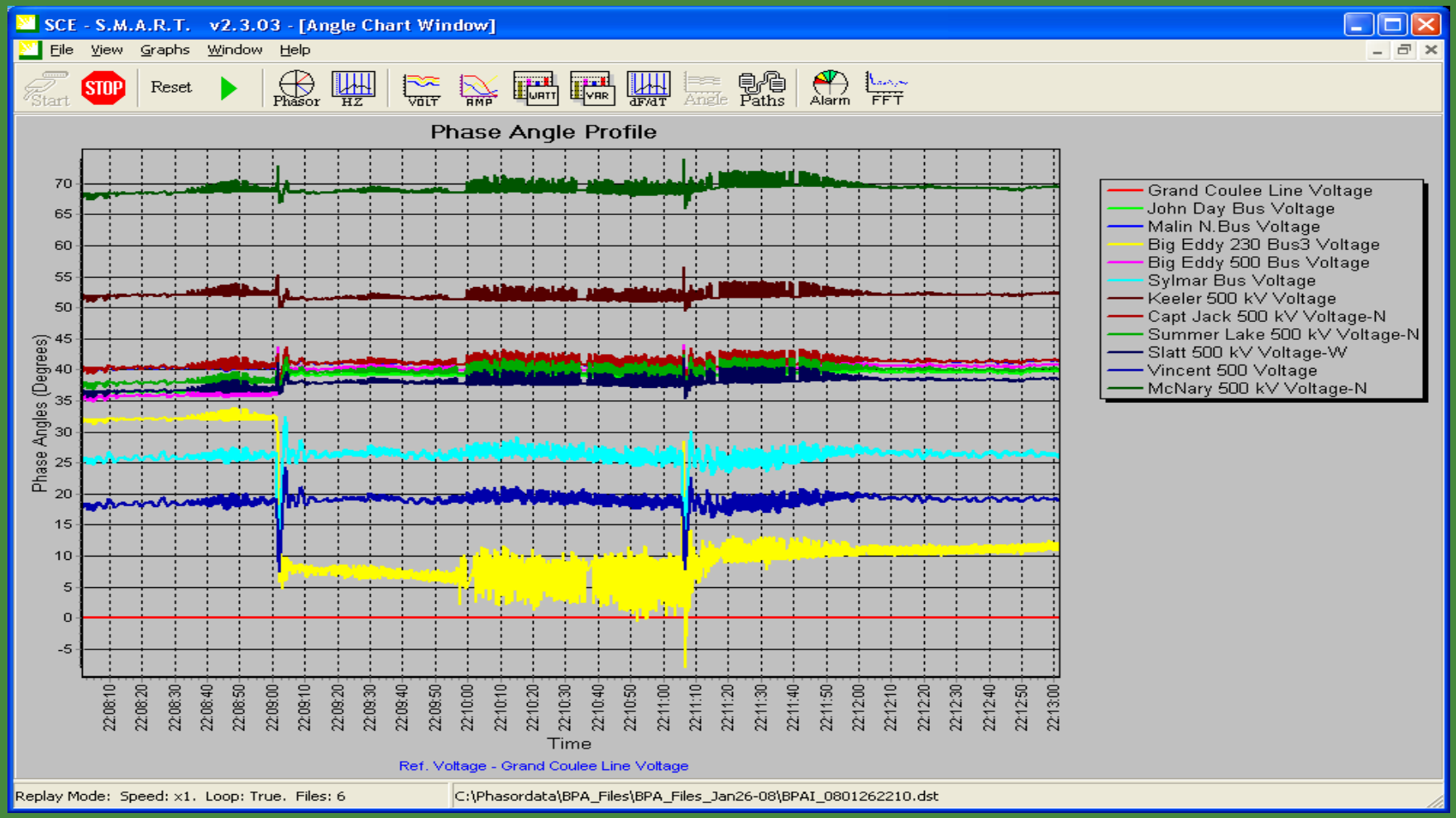
Power flow on DC line at Big Eddy 230 kV



Sum of MW = Celilo 3 Current + Celilo 4 Current

Bus Voltage Angles of some WECC busses from SCE SMART Program

from 14:08 to 14:13 PDT



Synchronized Phasor Measurement Real-time Applications:

- *Monitoring system stress (Phase angle separations)*
- *Monitoring critical voltage support*
- *Monitoring frequency and df/dt*
- *Monitoring critical path loadings & generation*
- *Monitoring dynamic power swings*
- *Monitoring modal oscillations and modal damping*
- *Integration with SCADA, EM & State Estimator systems*
- *Real-time control such as on HVDC Modulation and FACTS devices*
- *Alarms and triggers for stressed conditions*
- *Monitoring machine excitation and governors*
- *Voltage and reactive power management*
- *AI and Pattern recognition tools for quick event analysis*

SMART Program demonstration

- *Voltage plots & Voltage deviation*
- *Power flow & Reactive power flow*
- *Phase angle & System stress (Phase angle separations) & Phasor display plot*
- *Monitoring critical voltage support*
- *Monitoring frequency and df/dt*
- *Monitoring critical path loadings & generation*
- *Monitoring dynamic power swings*
- *Real time software in Grid Control Center*
- *Review & Replay of some past events*
  - *January 26, 2008 event*

Synchronized Phasor Measurements

Conclusions:

- *Synchronized Phasor Measurement*
  - *is a maturing and accepted Technology*
  - *can provide Real-time system monitoring, for reliability and post event analysis*
  - *can be used for active system component control like FACTS, HVDC control / modulation etc.*
  - *can be integrated with existing SCADA / EMS systems*
  - *can avoid disturbances like the Northeast-2003 and Western system – 1996 blackouts*
- *System can provide information on event locations and severity, Situational Awareness and quick system restoration after system disturbances*

Thanks, any questions ?