Oscillation Monitoring System at TVA

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NASPI Meeting, Sacramento, June 2009

Project Team

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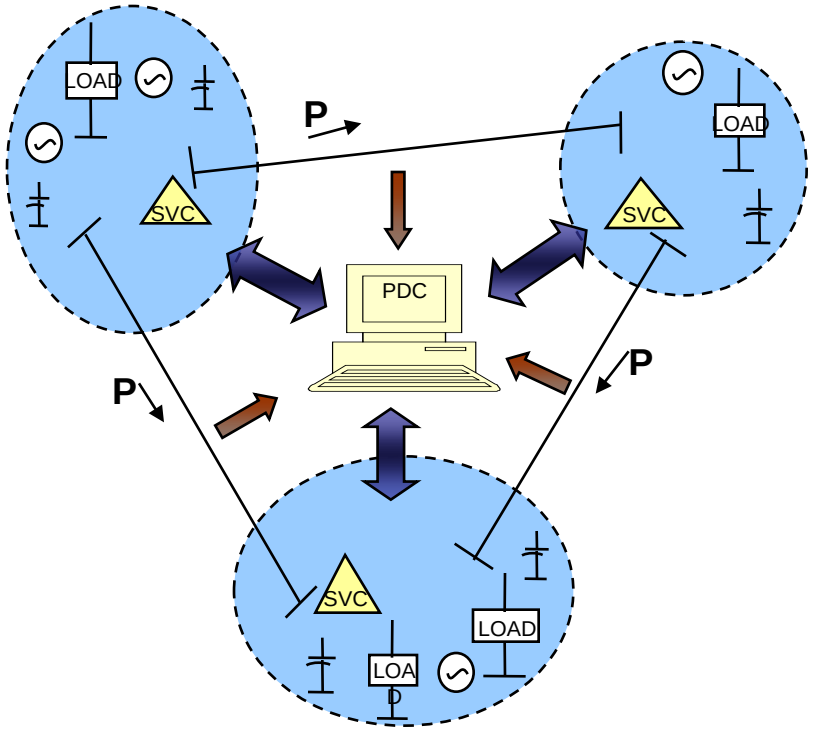
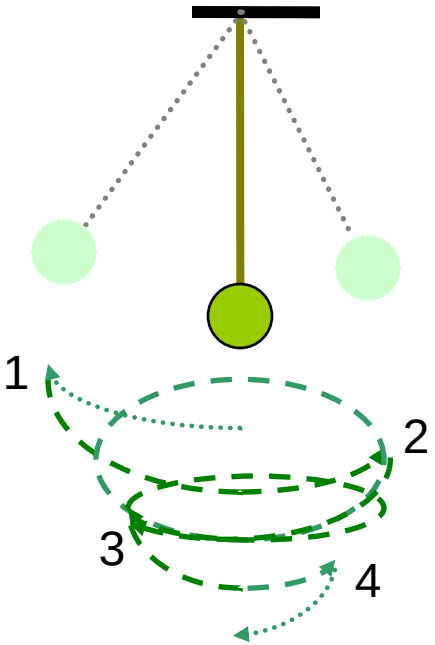
Oscillation Monitoring System (OMS)

- **Goal of Oscillation Monitoring System (OMS)**
  - **Early detection of poorly damped oscillations as they appear**
  - **Trigger warning or control signals**
- **OMS is made possible by wide area PMU Measurements**
  - **Growing numbers of PMUs across the power grid**
  - **Real-time applications needed**
  - **Prototype implementation at TVA since 2007**
  - **Local and inter-area oscillations can be detected**

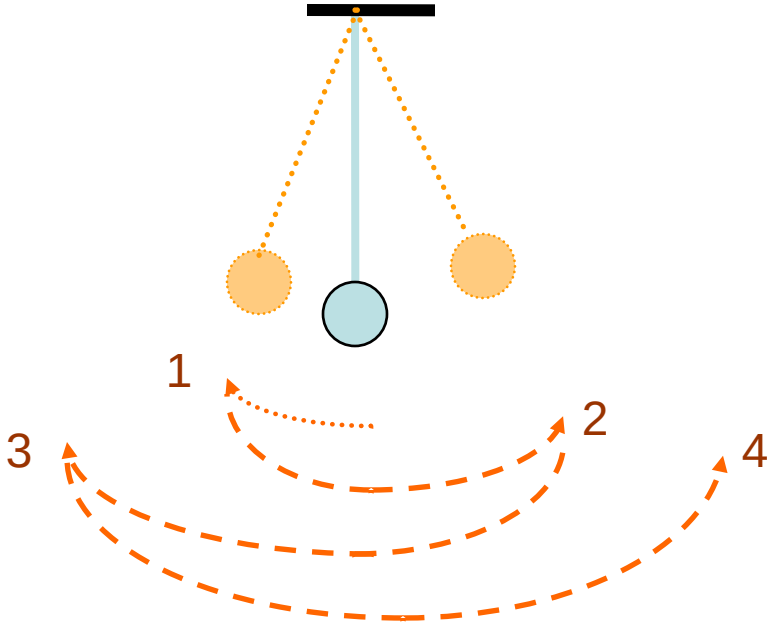


Small-Signal Stability



Positive damping

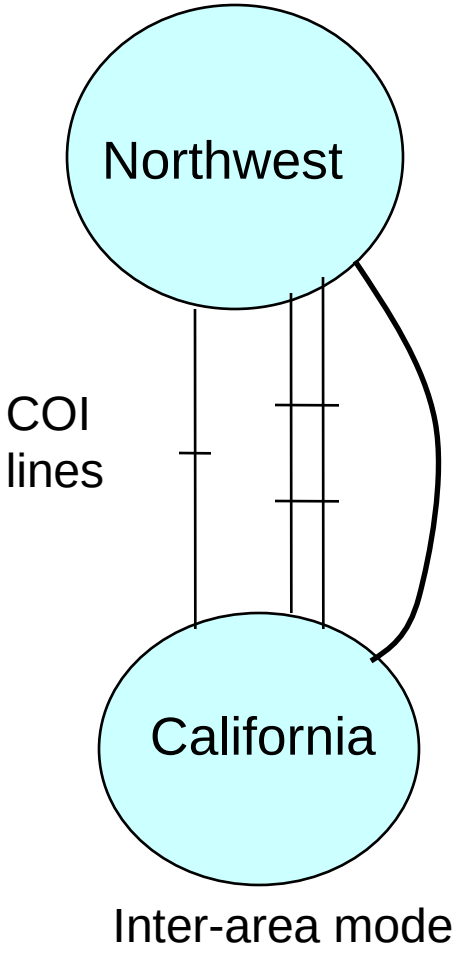
Oscillations damp out



Negative damping

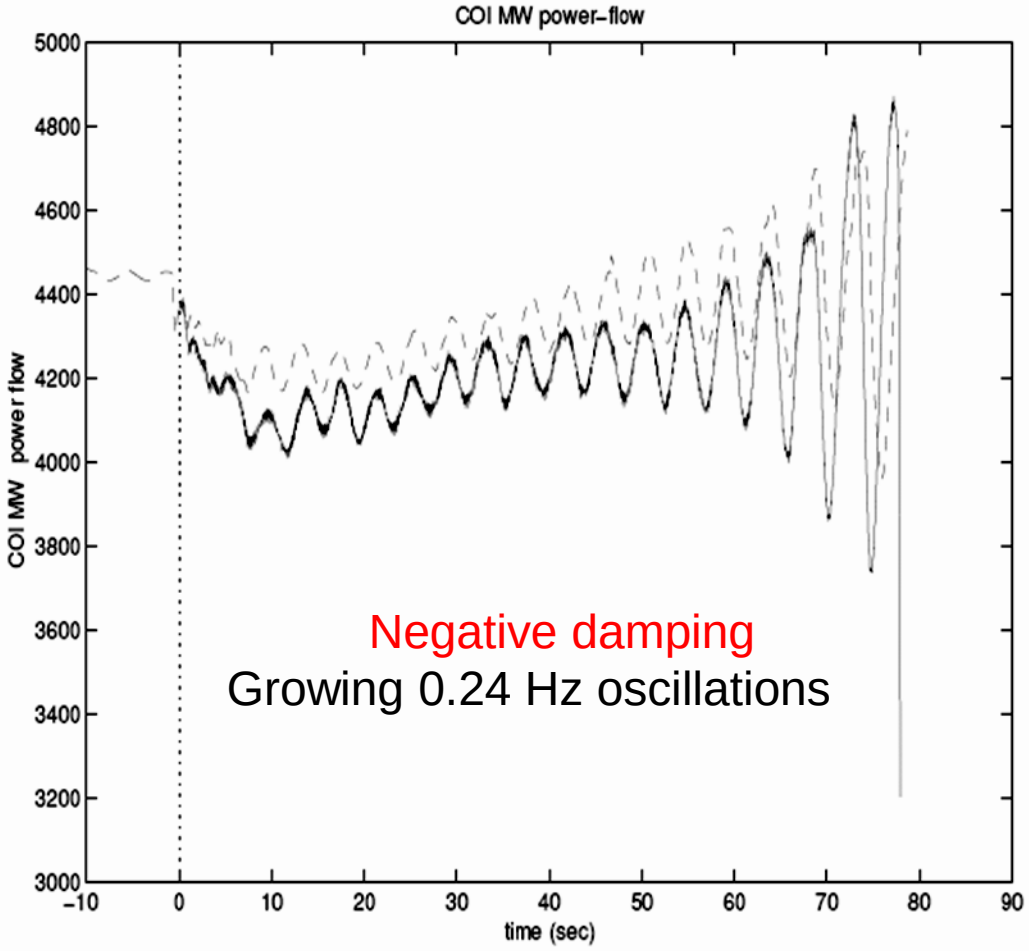
Growing oscillations

Small-signal Instability in WECC



Inter-area mode

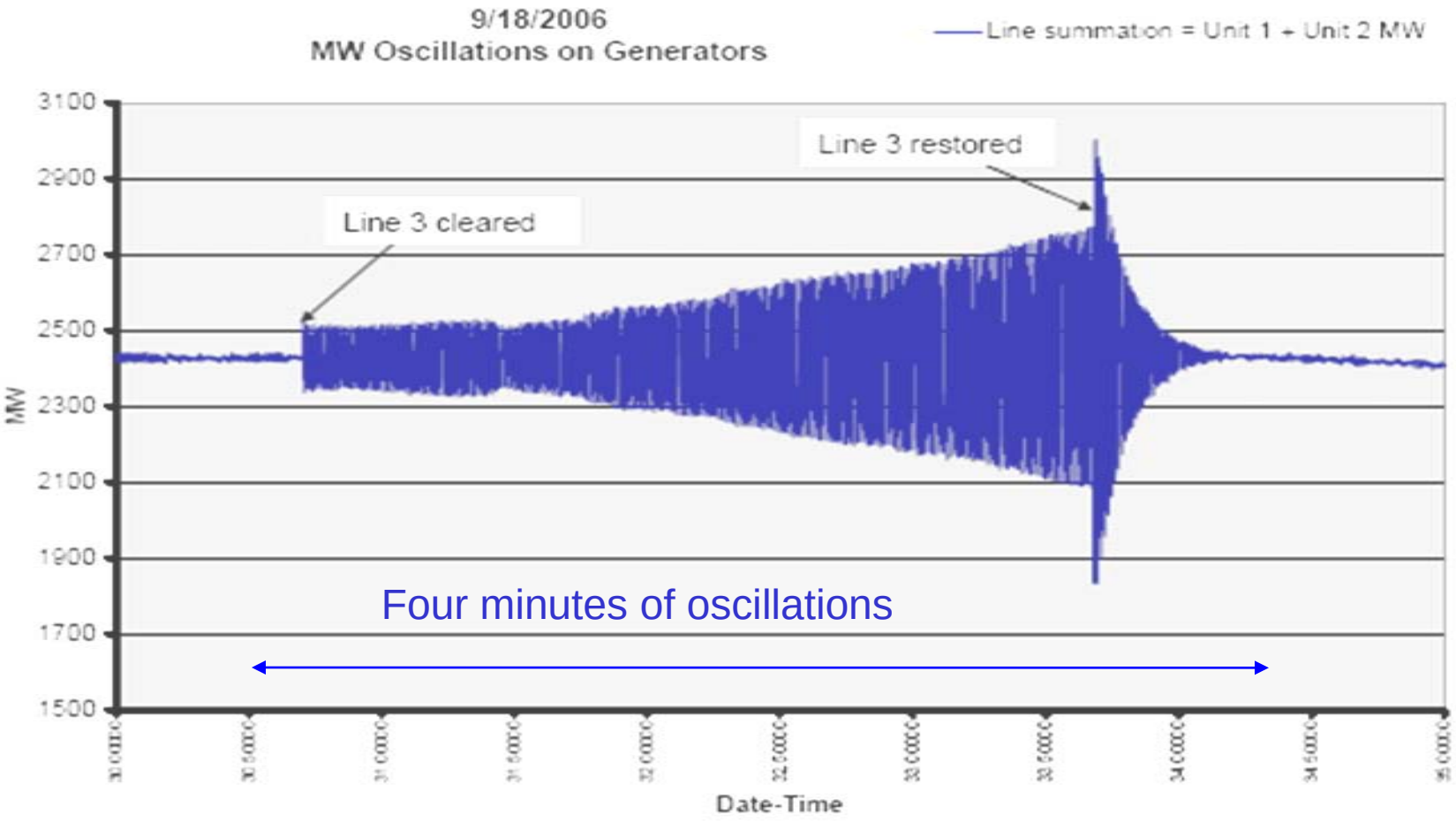
August 10, 1996 WECC blackout



Negative damping

Growing 0.24 Hz oscillations

TVA Cumberland event



Source: Gary Kobet/TVA

Motivation

- Oscillations at Cumberland plant 9/18/2006
- PMU recordings enabled the analysis
- Local 1.2 Hz mode changed from +1.5% damping to –0.2% damping and back to +1.5% damping during the event
- PSS installed at the plant subsequently in early 2007
- PMU based real-time alarm coded by TVA engineers into TVA PDC as back-up measure – uses standard deviation thresholds

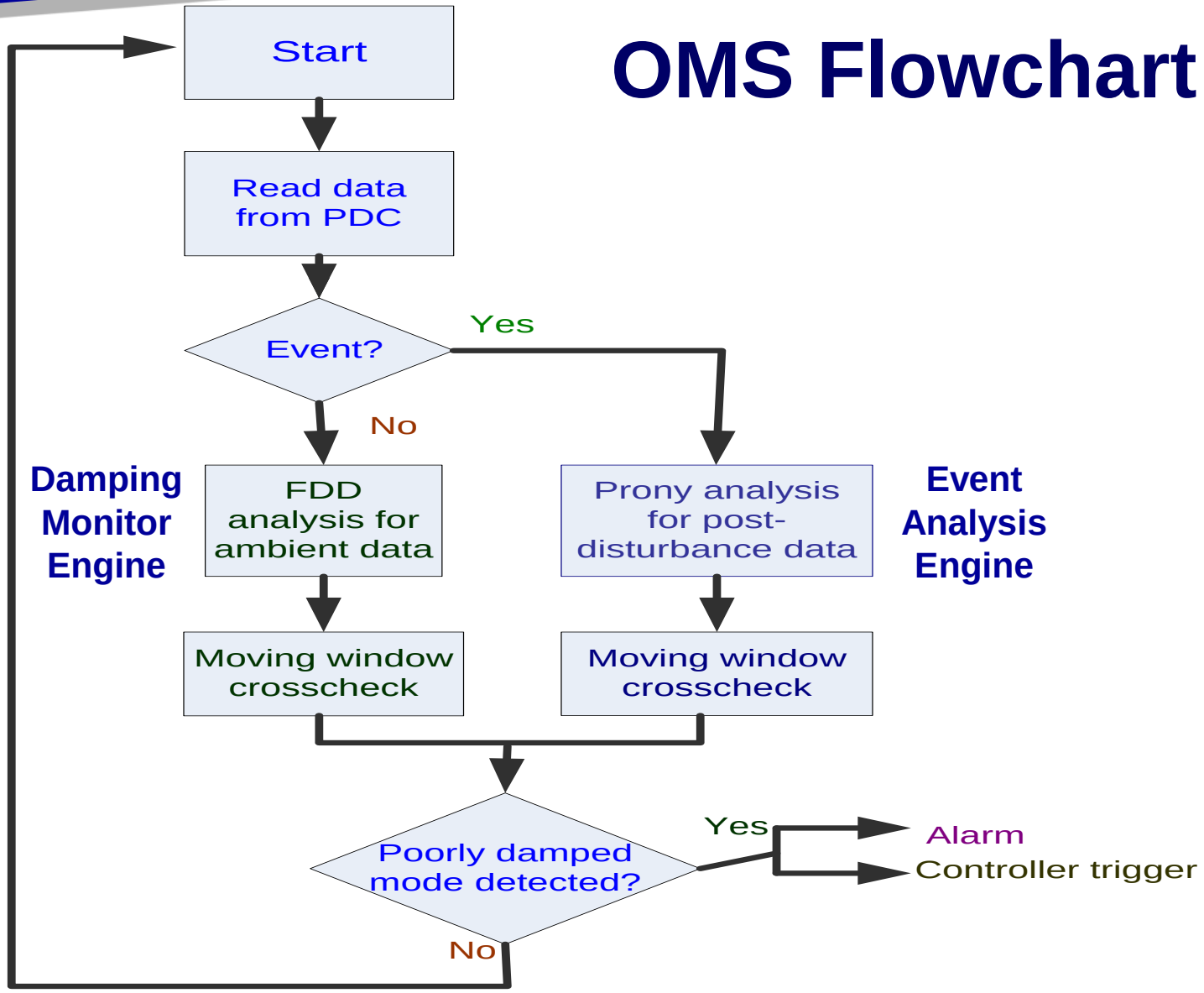
Oscillation Monitoring System

- PSERC projects on real-time oscillation monitoring and control from 2002 to 2008
- Follow-up project from TVA for prototype testing at TVA since 2007
- Recent project from BPA and EPG (CEC and CERTS) on incorporating the event analysis engine of OMS into RTDMS
- Real-time code tested at TVA – speed and memory requirements critical
- Focus on scalability

OMS Engines

- **Event Monitor Engine**
  - Automated Prony type analysis of oscillatory ringdown responses
  - *Five seconds* of PMU data analyzed every *one second*
- **Damping Monitor Engine**
  - Automated analysis of ambient noise data
  - *Four minutes* of PMU data analyzed every *ten seconds*

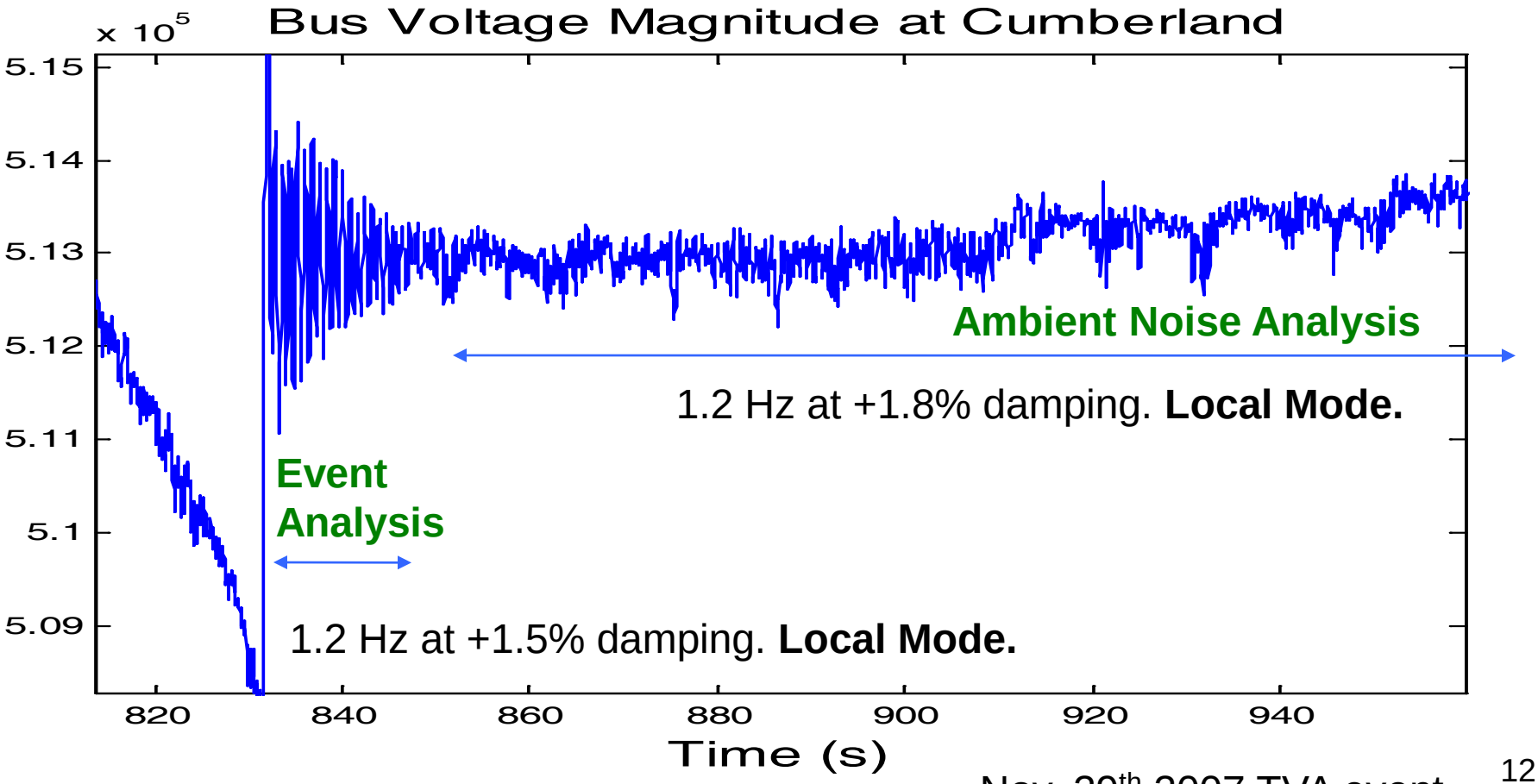
OMS Flowchart



Complementary Engines

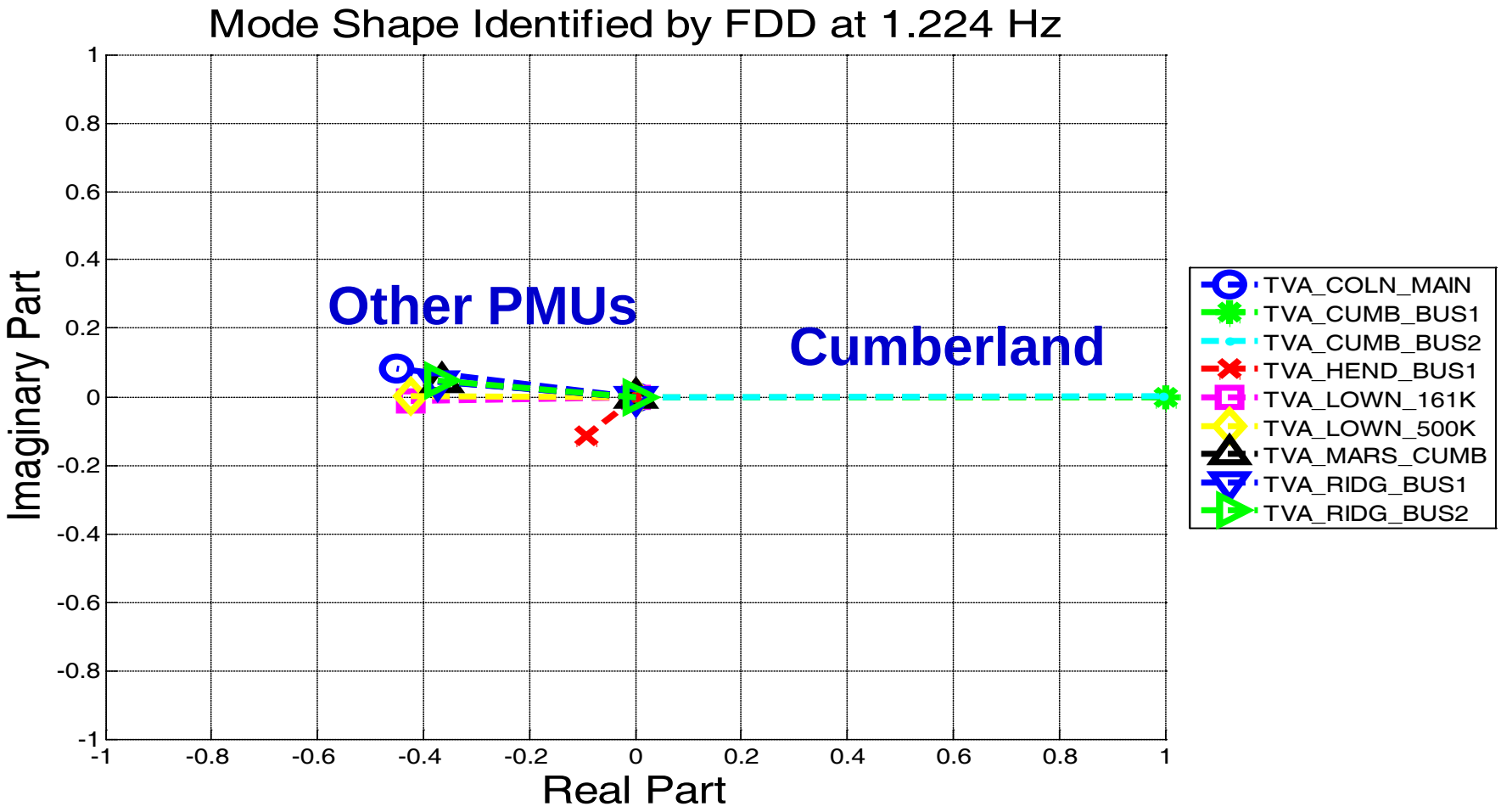
- **Event Analysis Engine**
  - Three algorithms: Prony, Matrix Pencil and Hankel Total Least Square
    - Coded into off-line tool within RTDMS
  - Aimed at events resulting in sudden changes in damping
- **Damping Monitor Engine**
  - Ambient noise based. Continuous.
  - Frequency Domain Decomposition Algorithm
  - Provides early warning on poorly damped modes

Results from Two Engines



Nov. 29th 2007 TVA event

Mode Shape – Local Mode



Cumberland oscillating against rest of system – local mode

Recent results at TVA

- **Sept 18, 2006 Cumberland event:**
  - Local 1.3 Hz mode damping changed from +1.5% to -0.2% and back to +1.5% during the event
  - TVA in-house oscillation alarm implemented
  - PSS installation recommended
- **December 16, 2006:**
  - One Cumberland unit in service
  - PSS had been installed at one unit
  - Local mode damping at +7.2% from OMS

Recent results at TVA

- **Nov 29, 2007:**
  - Two Cumberland units in service
  - OMS showed local plant mode damping at +1.7% (alarm)
  - PSS had been taken off-line
- **Feb. 5, 2008:**
  - Two Cumberland units in service
  - OMS showed local mode damping at +3% (alarm)
  - PSS was in service. Tuning recommended. Faulty PSS card found by manufacturer and fixed.

Recent results at TVA

- OMS helpful in detecting when PSS went off-line at Cumberland
- OMS helpful in showing PSS not effective even when on-line. Hardware problem fixed.
- OMS able to verify the local mode well-damped subsequently. No recent alarm from this mode.
- All recent alarms related to 0.45 Hz and 0.21 Hz eastern system inter-area modes.
- Benefits of real-time continuous monitoring from PMUs. Can detect oscillation problems early.

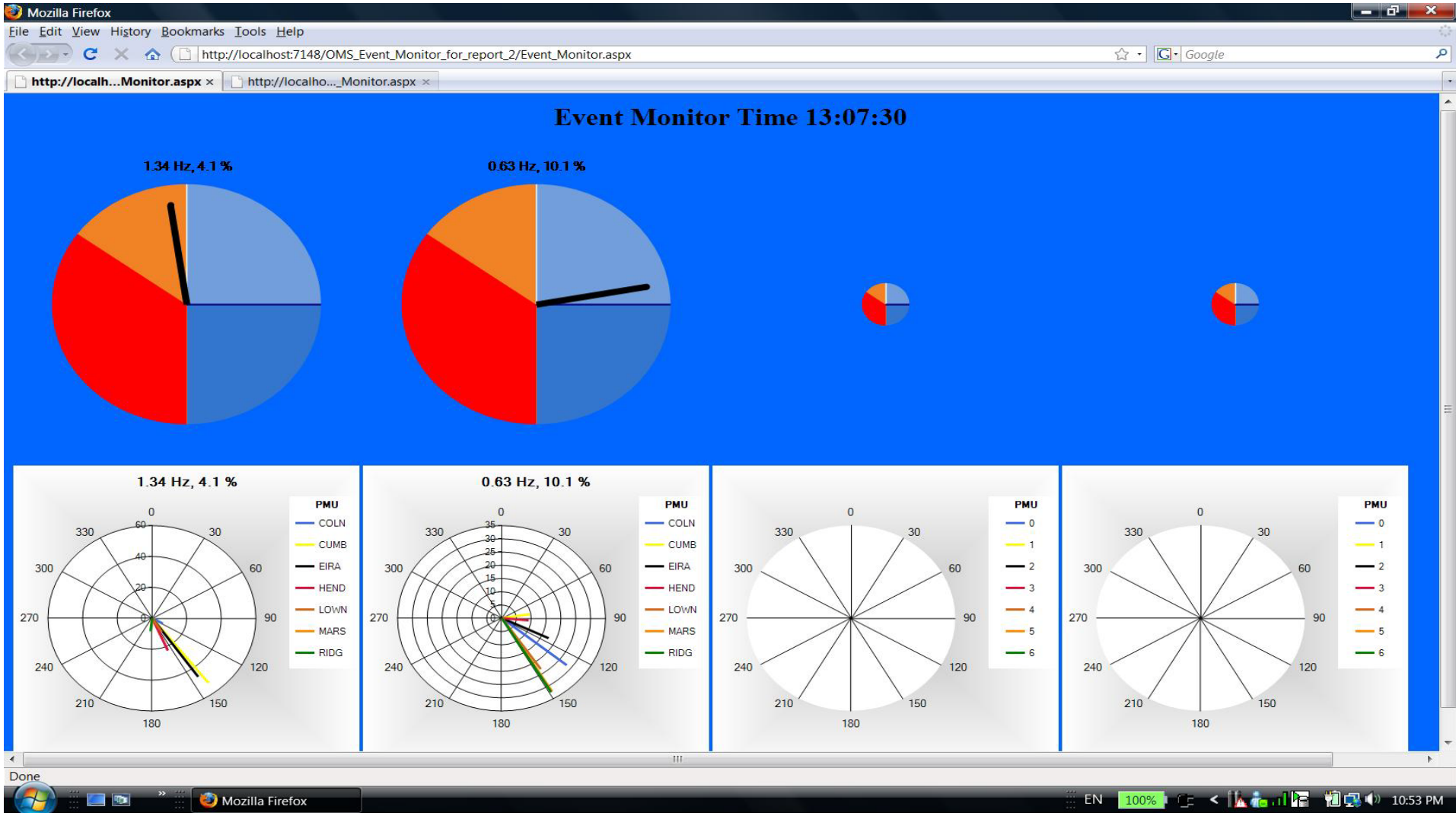
OMS Status

- Successful implementation of real-time code into TVA PDC
- Automatic detection of poorly damped electromechanical modes and their mode shapes
- Immense data size – 30 samples a second, many minutes of data, many channels per PMU, many PMUs – memory requirements grow quickly.
- Reaching the limitations of 32 bit architecture already….
- Dedicated 64 bit 8 core processor at TVA
- OMS code translated into 64 bit architecture by Ryan Zuo at TVA

OMS Status

- OMS handles only TVA PMUs at present
- Results stored into a real-time database
- Other applications under development to export the results
  - graphical displays
  - protected webpages
  - operator alarms
  - real-time data streams for other utilities
- Near real-time displays updated onto a protected website at the moment
- Plan to extend engines to other eastern PMUs

TVA Website example



TVA Website example

Future Work

- Implementation, testing and tuning at TVA
- Protected website for displaying OMS results
- Historical trends of mode damping from daily load changes, seasonal patterns, special events.
- OMS engines for Entergy and for Eastern Grid
- Operator alerts and alarms
- Operator Actions? Mode shape can tell between local mode, regional mode and inter-area mode. What then?
- Automatic controls