Applications on openPDC platform at Washington State University

Mani V. Venkatasubramanian

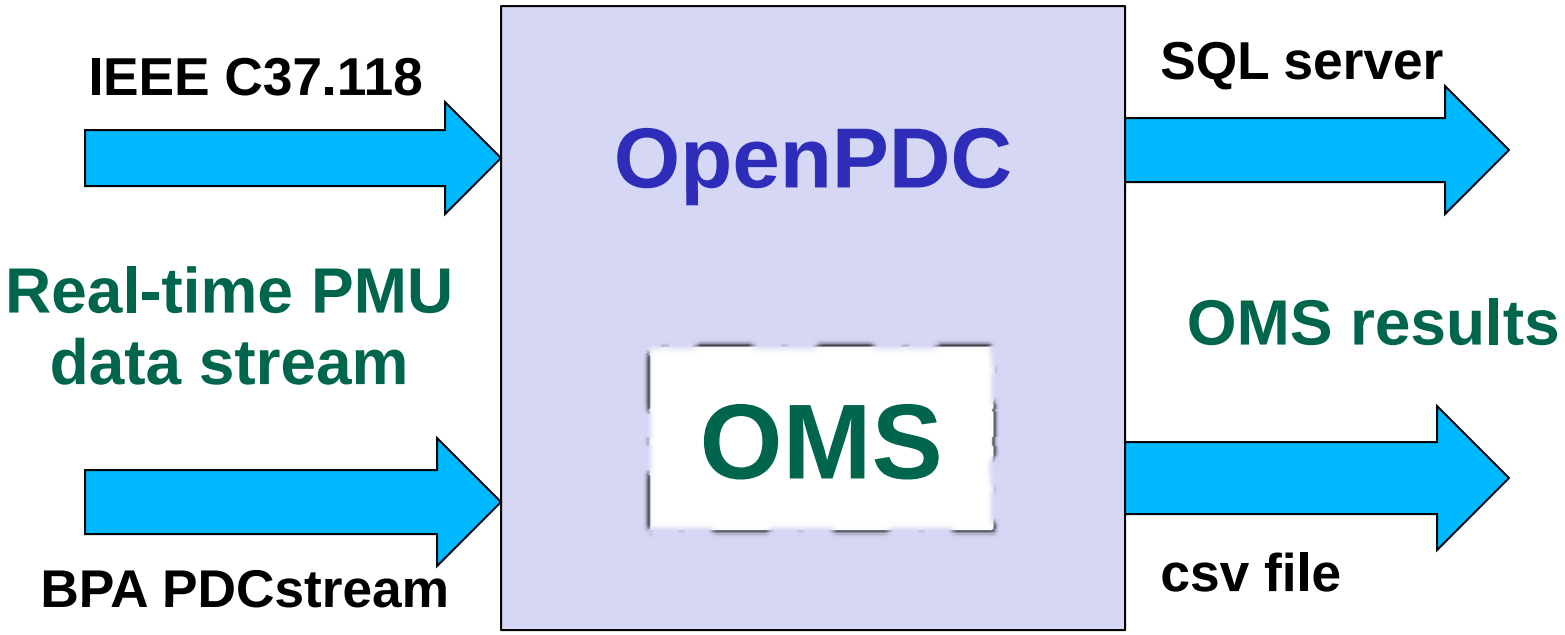
Washington State University
Pullman WA

WASHINGTON STATE UNIVERSITY

WSU projects

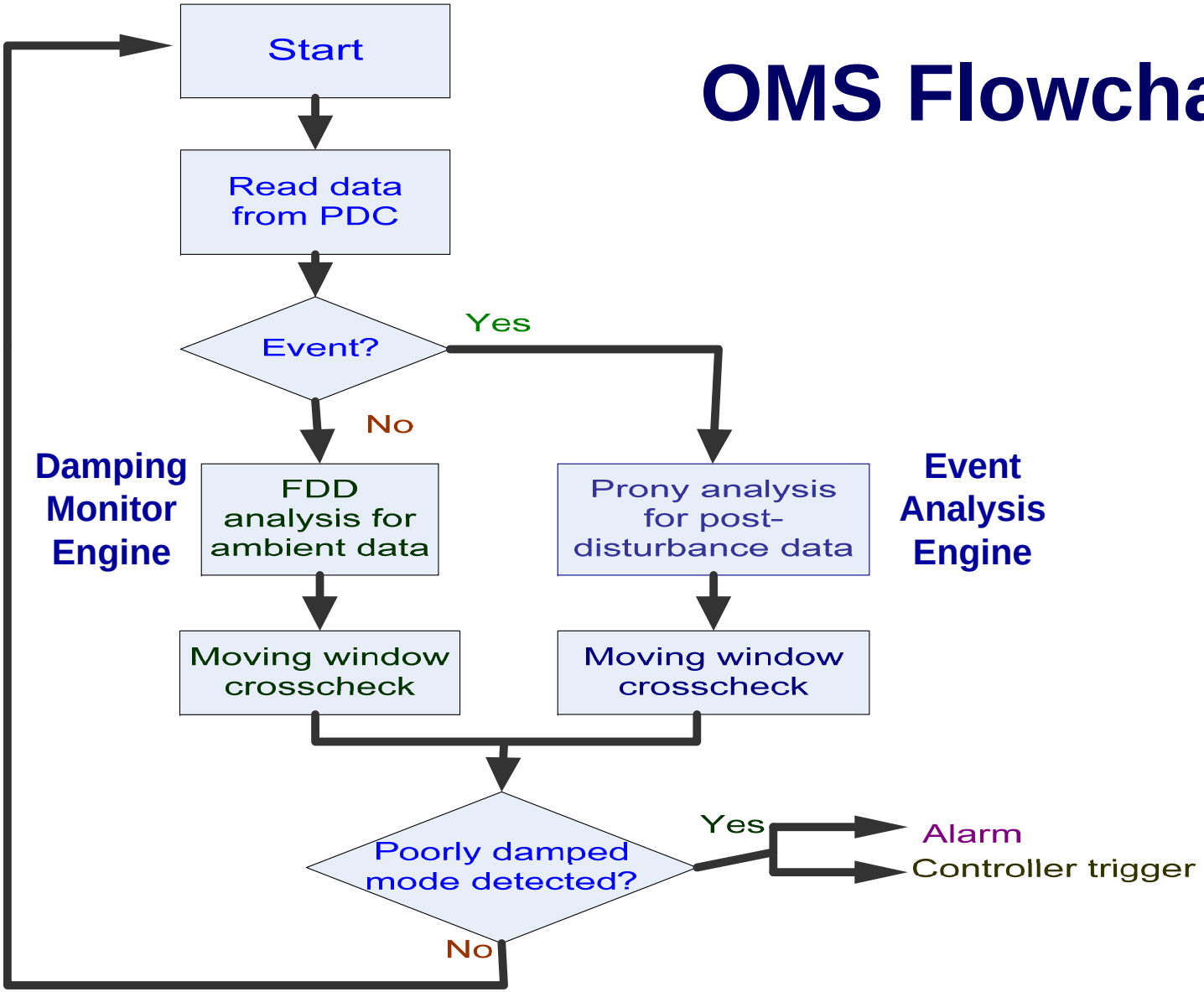
- "OMS" - Oscillation Monitoring System
  - Stand-alone system for oscillation detection and analysis using wide-area PMUs
- "VSMS" - Voltage Stability Monitoring System
  - Stand-alone system for voltage stability stress indicator using wide-area PMUs
- "GridSim" – Large-scale real-time power grid simulator

Oscillation Monitoring System



OMS action adapter built into OpenPDC 64 bit version 1.4 sp1. Available for beta testing.

OMS Flowchart

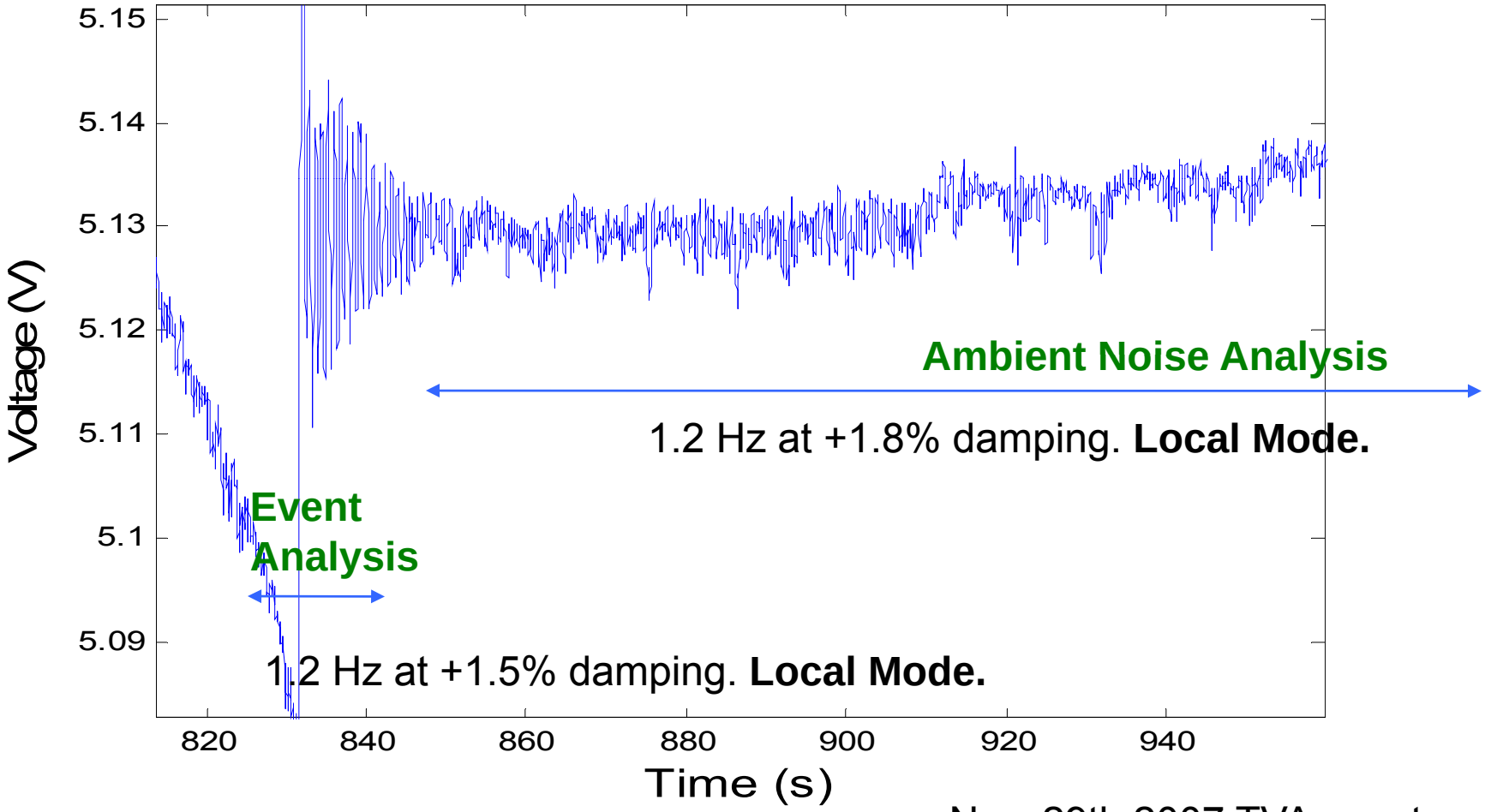


WASHINGTON STATE UNIVERSITY

Complementary Engines

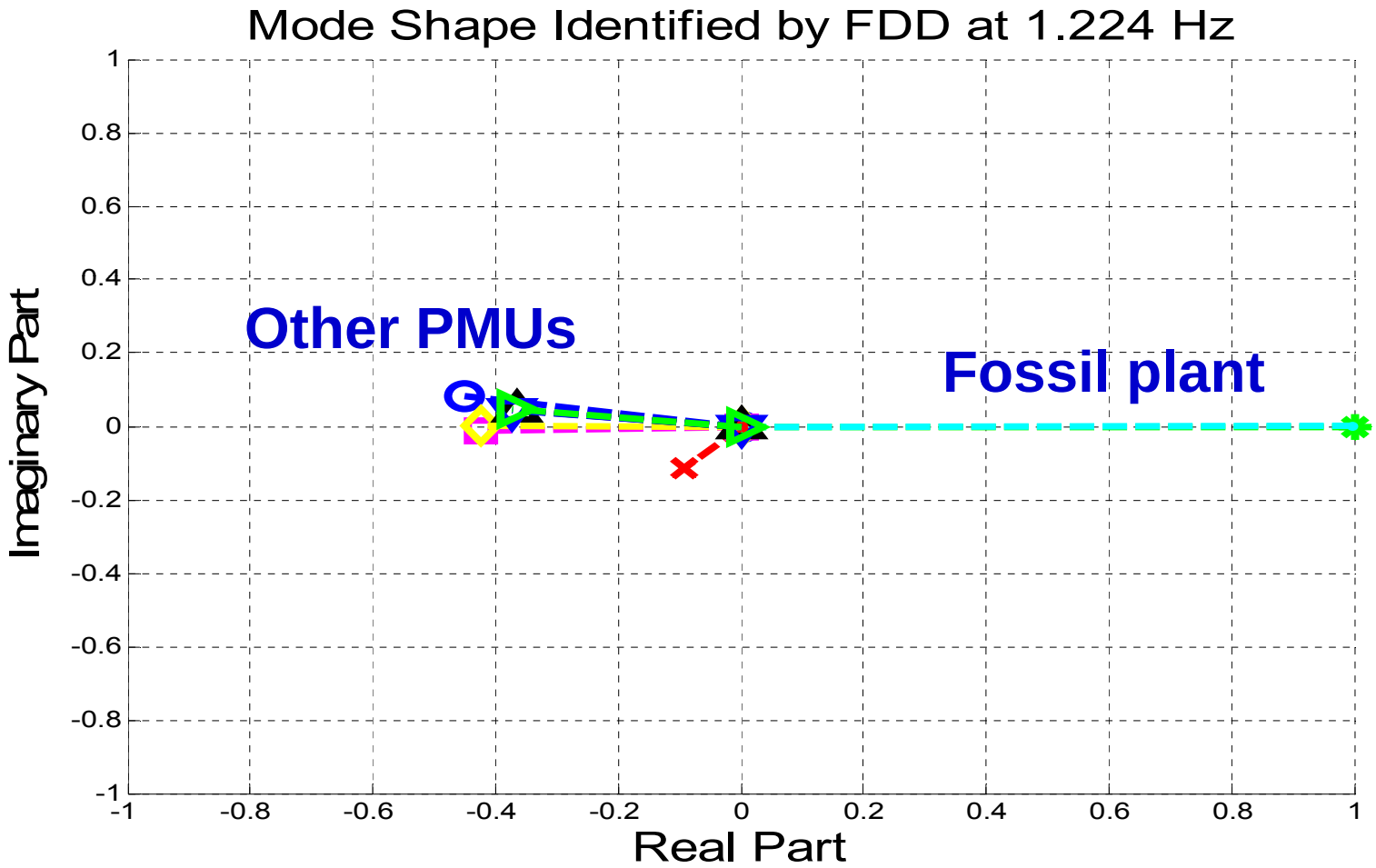
- **Event Analysis Engine**
  - Three algorithms: Prony, Matrix Pencil and Hankel Total Least Square.
  - Aimed at events resulting in sudden changes in damping
- **Damping Monitor Engine**
  - Ambient noise based. Continuous.
  - Two algorithms: Frequency Domain Decomposition, Frequency Domain Optimization
  - 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

WASHINGTON STATE UNIVERSITY

OMS Engines

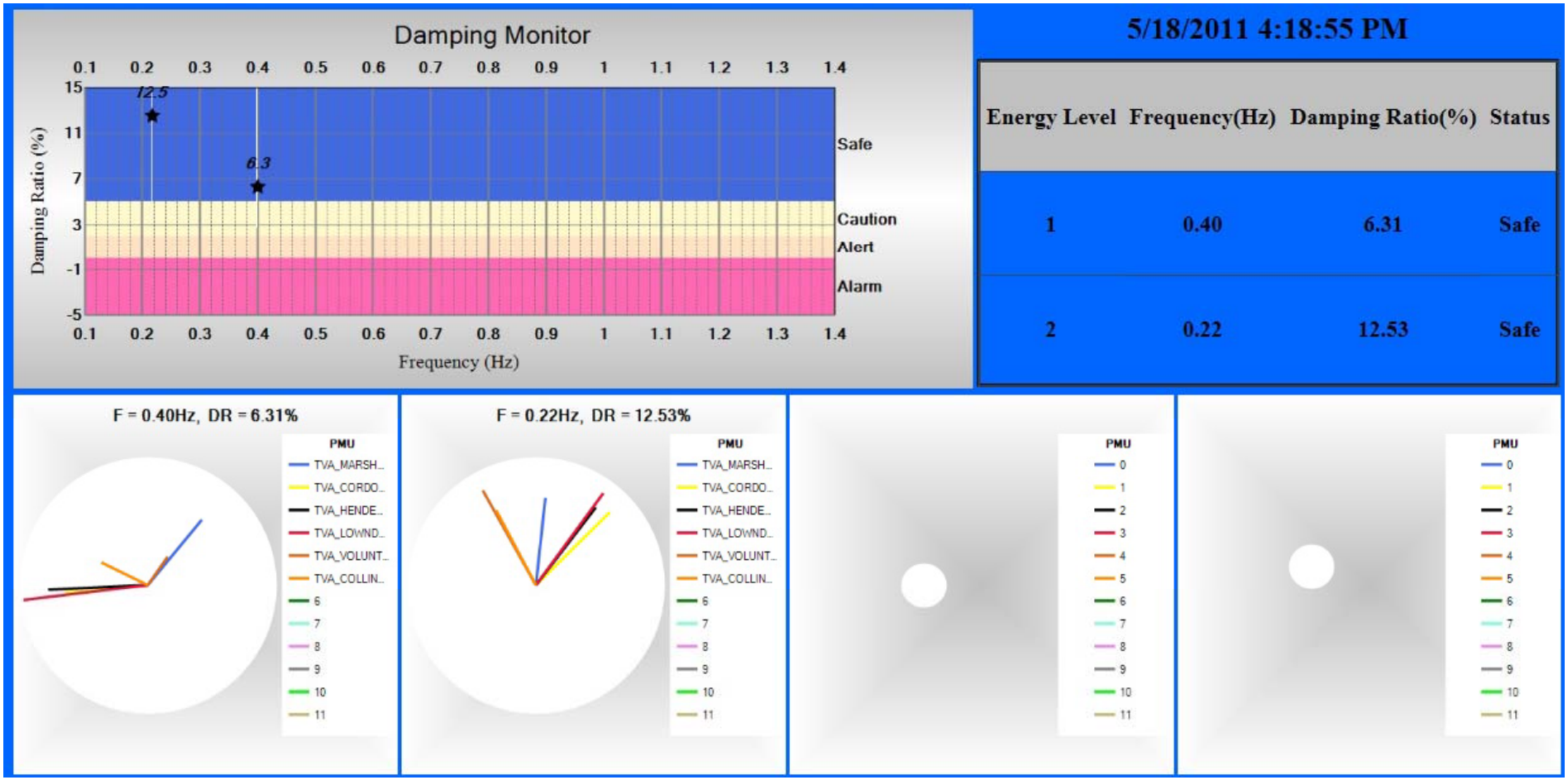
- Event Monitor Engine
  - Automated Prony type analysis of oscillatory ringdown responses
  - *Five seconds* of PMU data analyzed every *one second*
- Damping Monitor Engine
  - Automated analysis of ambient noise data
  - *Four minutes* of PMU data analyzed every *ten seconds*

WASHINGTON STATE UNIVERSITY

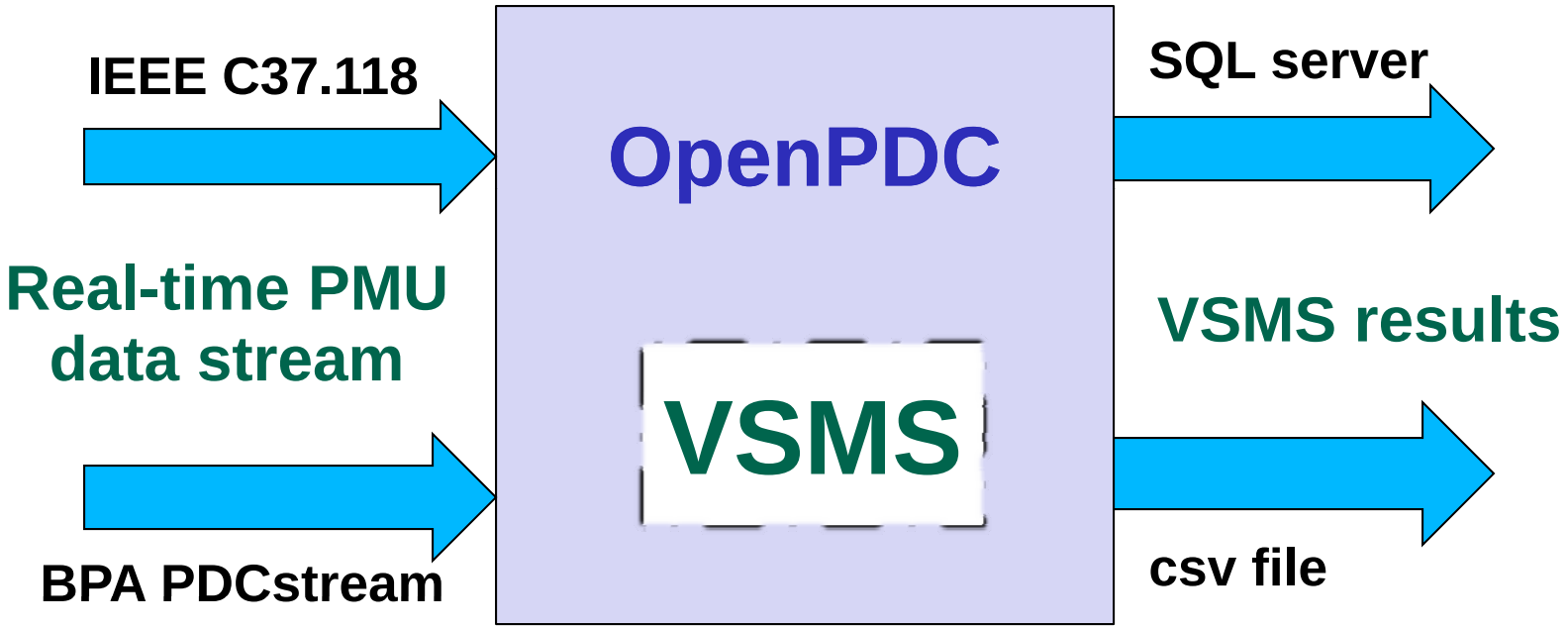
Oscillation Monitoring System

- US patent
- Real-time code integrated into GPA 64 bit openPDC
- Stand-alone OMS test engine available
  – can interface with any PDC
- GridApp project to test on eastern system PMUs
- SGIG project to implement in Entergy system
- DOE/CERTS project to test beta version at WECC

Recent test results at GPA



Voltage Stability Monitoring System

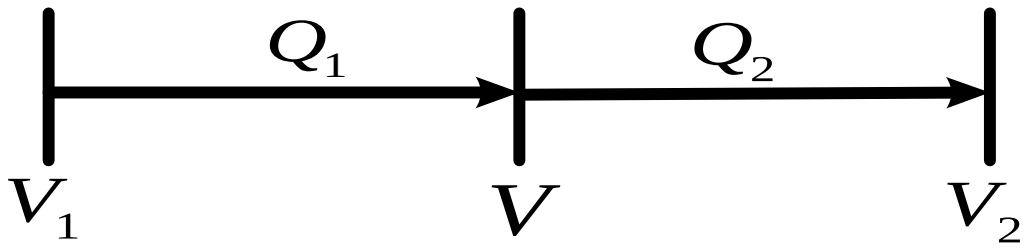


VSMS action adapter built into OpenPDC early release. Being moved to 64 bit version 1.4 sp1. Available for beta testing in October 2011.

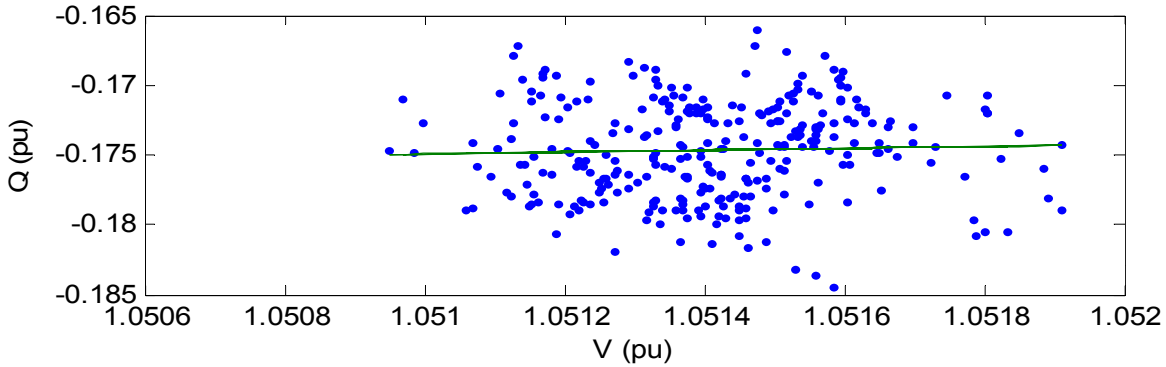
WASHINGTON STATE UNIVERSITY

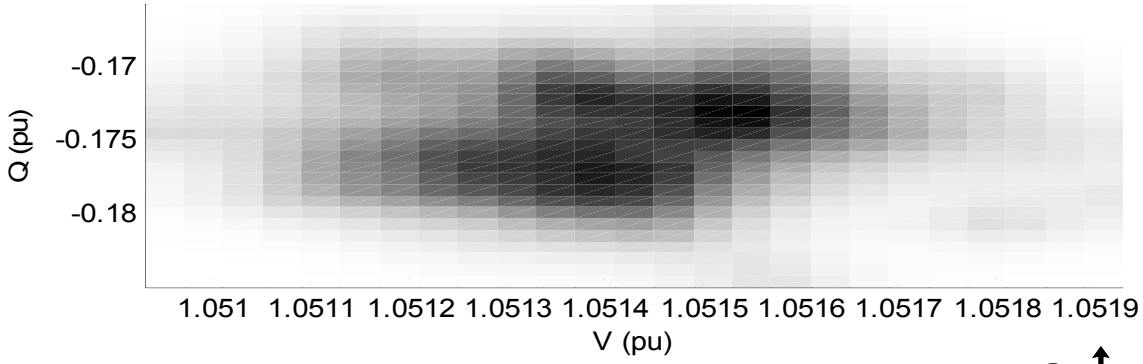
QV Sensitivity Calculation

- Causality Issue
- Change in V_1 leads to change in V or vice versa?
- Two different types of slopes and two different QV sensitivities

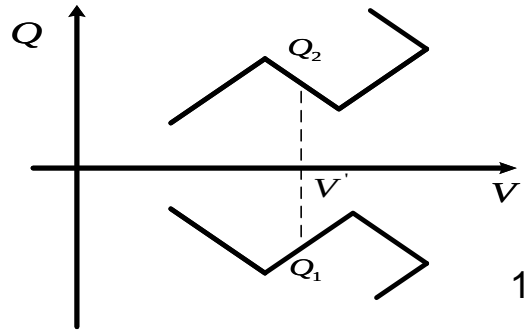


Real-time Calculation is Tricky

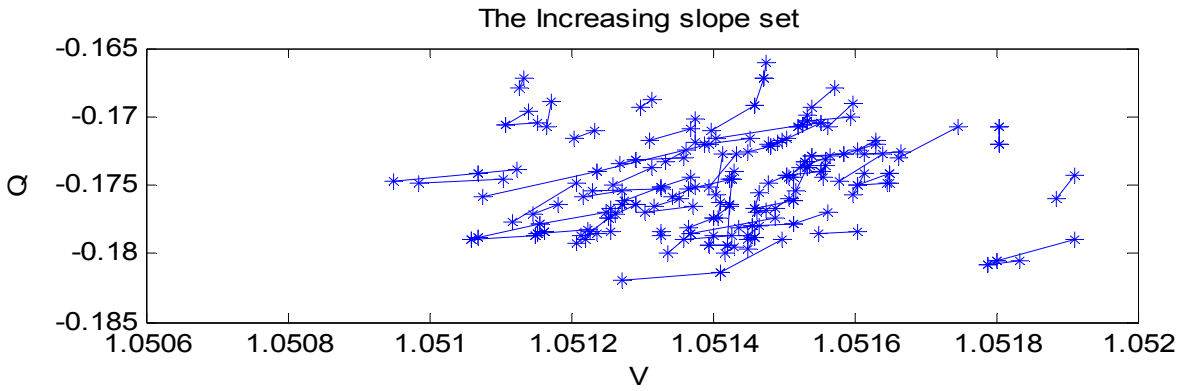




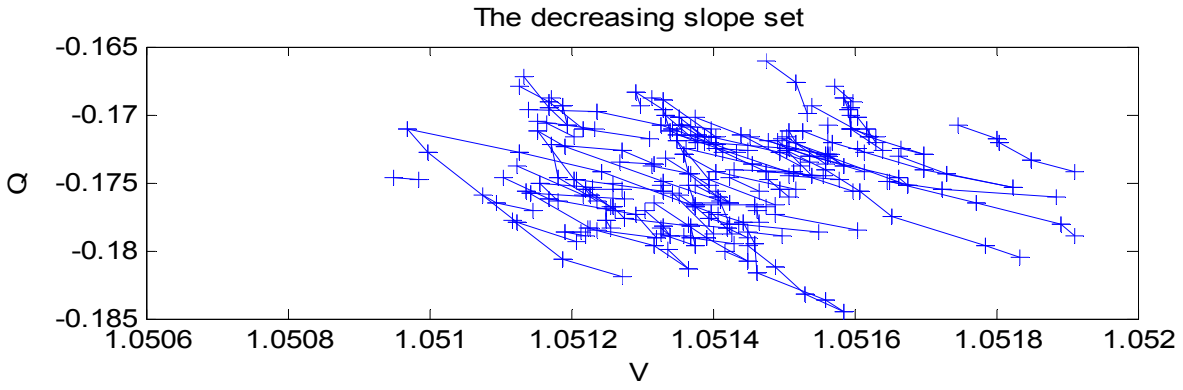
Typical PMU data: mix of both types of responses. Usual least square fit gives zero slope.



Novel Data Split Method

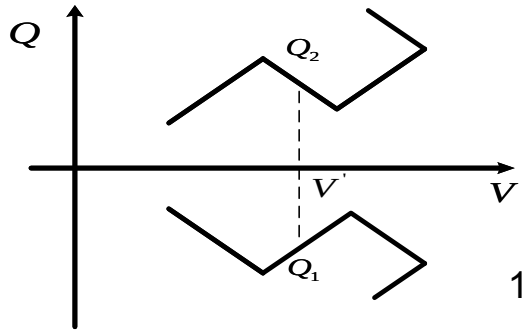


Subset: Positive

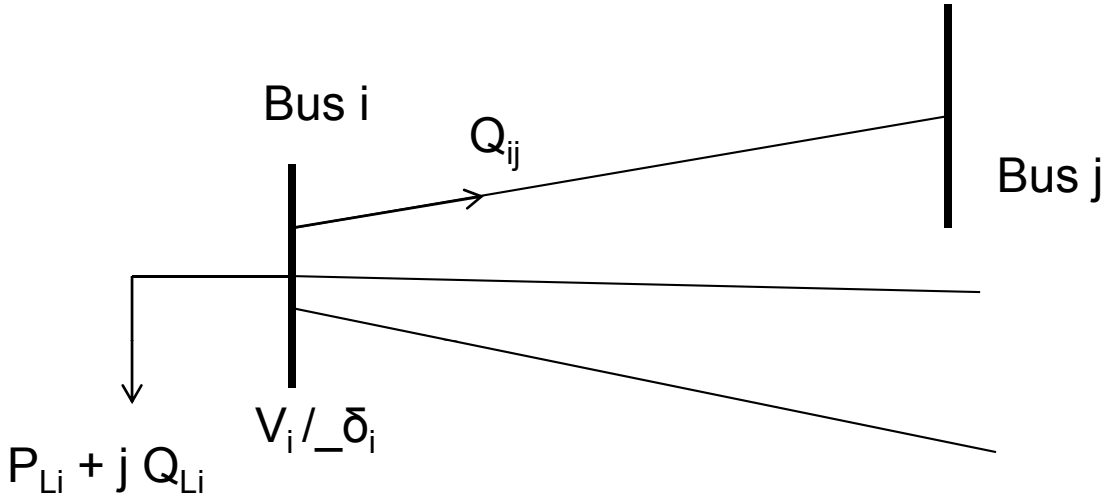


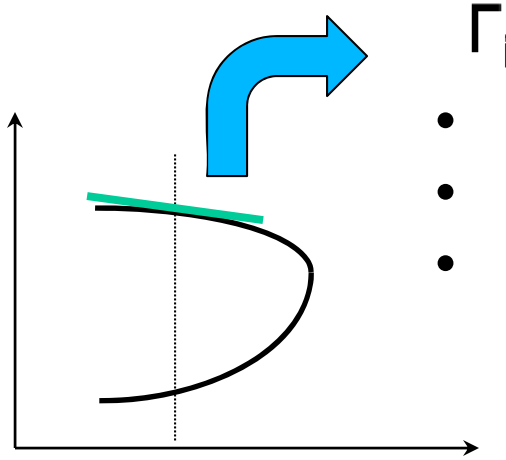
Subset: Negative

Divide the data into two subsets – the two different slopes become apparent. QV sensitivities match expected values.



Voltage Stress Indicator





$$\Gamma_i = \partial Q_i / \partial V_i = \Sigma\, \partial Q_{ij} / \partial V_i$$

- Γ_i is the slope of QV curve at Bus i
- Γ_i small near static voltage stability limit
- Γ_i directly estimated from ambient PMU data

GridSim - Real Time Simulation of Power Grid Operation & Control

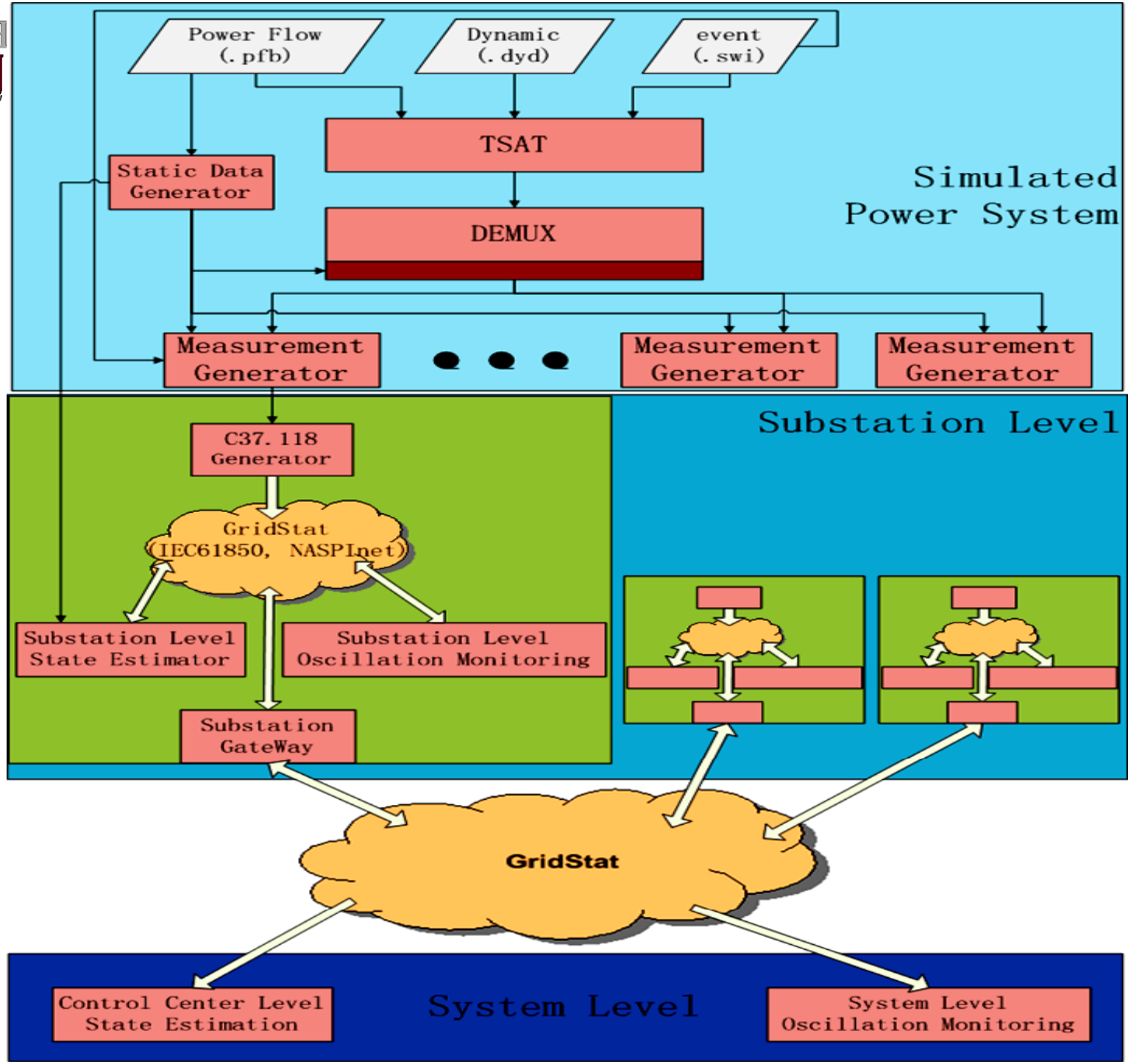
- Funded by USDOE
- Project team: Anjan Bose (Project Lead), Mani Venkatasubramanian, Dave Bakken, Carl Hauser, Chuanlin Zhao, Dave Anderson, *Tao Yang, Alex Ning, Ming Meng, Lin Zhang*
- Simulate PMU like real-time responses of large-scale power system including power grid dynamics and communication network
- Most of the following slides contributed by Chuanlin Zhao

WASHINGTON STATE UNIVERSITY

Project Objectives

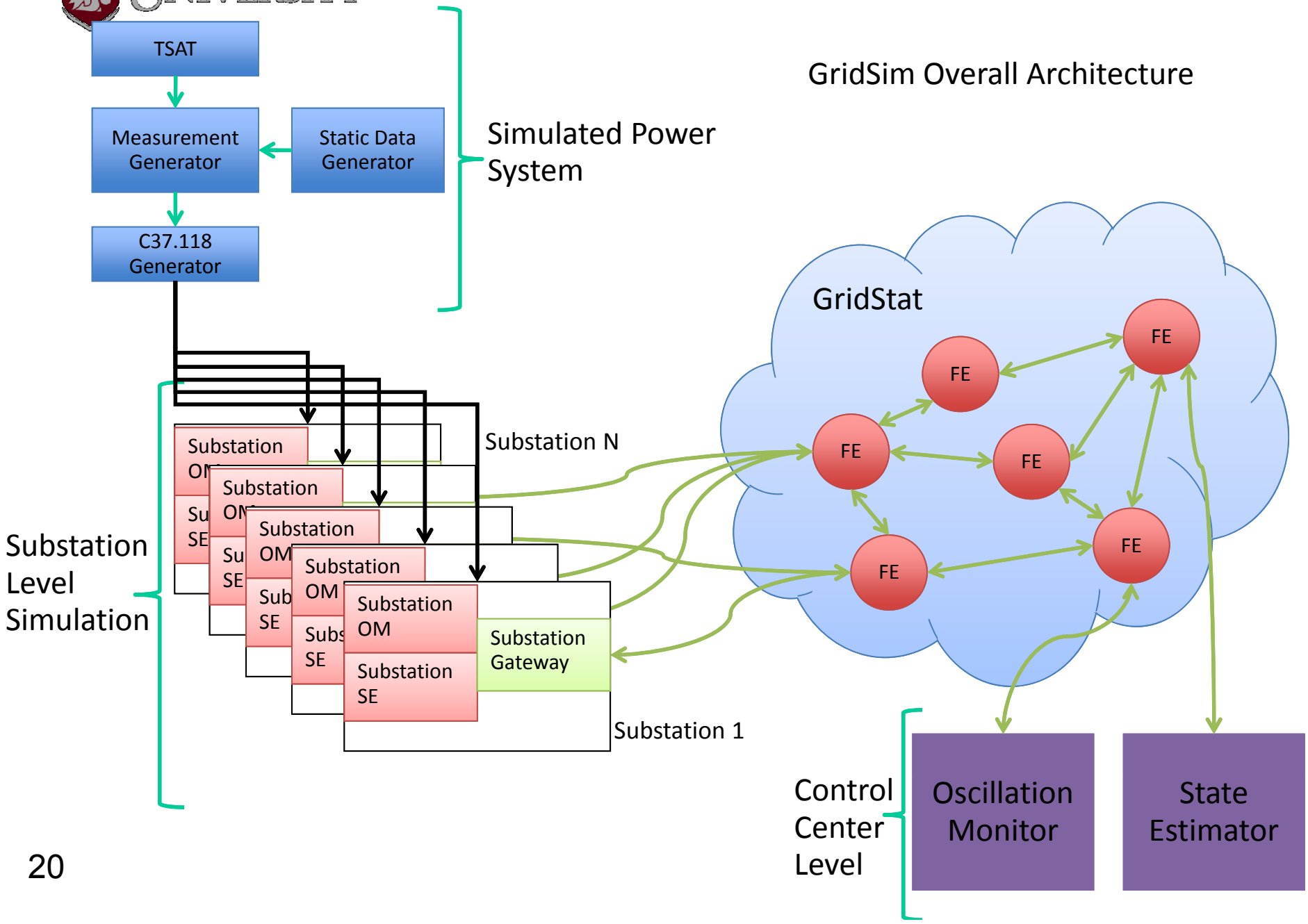
Improve Reliability and Security of the Electric Power Grid by developing

- The new communications and information systems needed to support better automatic controls and operator support tools
- The new wide area automatic controls needed for detecting and mitigating oscillations and instabilities
- The new operator support tools, like next generation state estimators, for better human decision making


Power Flow
(.pfb)
Dynamic
(.dyd)
event
(.swi)
TSAT
Static Data
Generator
DEMUX
Simulated
Power System
Measurement
Generator
Measurement
Generator
Measurement
Generator
Substation Level
C37.118
Generator
GridStat
(IEC61850, NASPInet)
Substation Level
State Estimator
Substation Level
Oscillation Monitoring
Substation
GateWay
GridStat
Control Center Level
State Estimation
System Level
System Level
Oscillation Monitoring

WASHINGTON STATE UNIVERSITY

GridSim Overall Architecture



WASHINGTON STATE UNIVERSITY

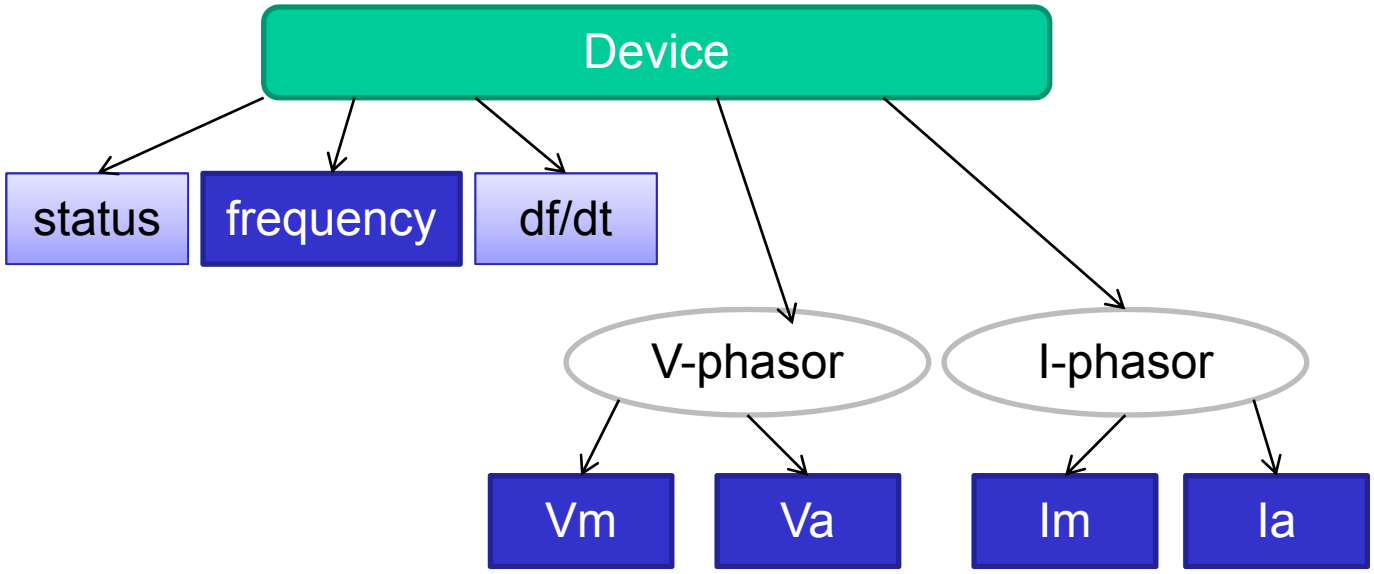
Automatic Configuration

- OpenPDC depends on configurations
  - Devices, phasors, measurements, and how they connect to each other
- By default, openPDC provides manual configuration method
  - By using openPDCManager
- For GridSim, a large-scale simulator, difficult to configure thousands of devices manually

WASHINGTON STATE UNIVERSITY

Automatic Configuration

- GridSim develops program which can automatically configure openPDC
- Device model



WASHINGTON STATE UNIVERSITY

User-defined Adapters

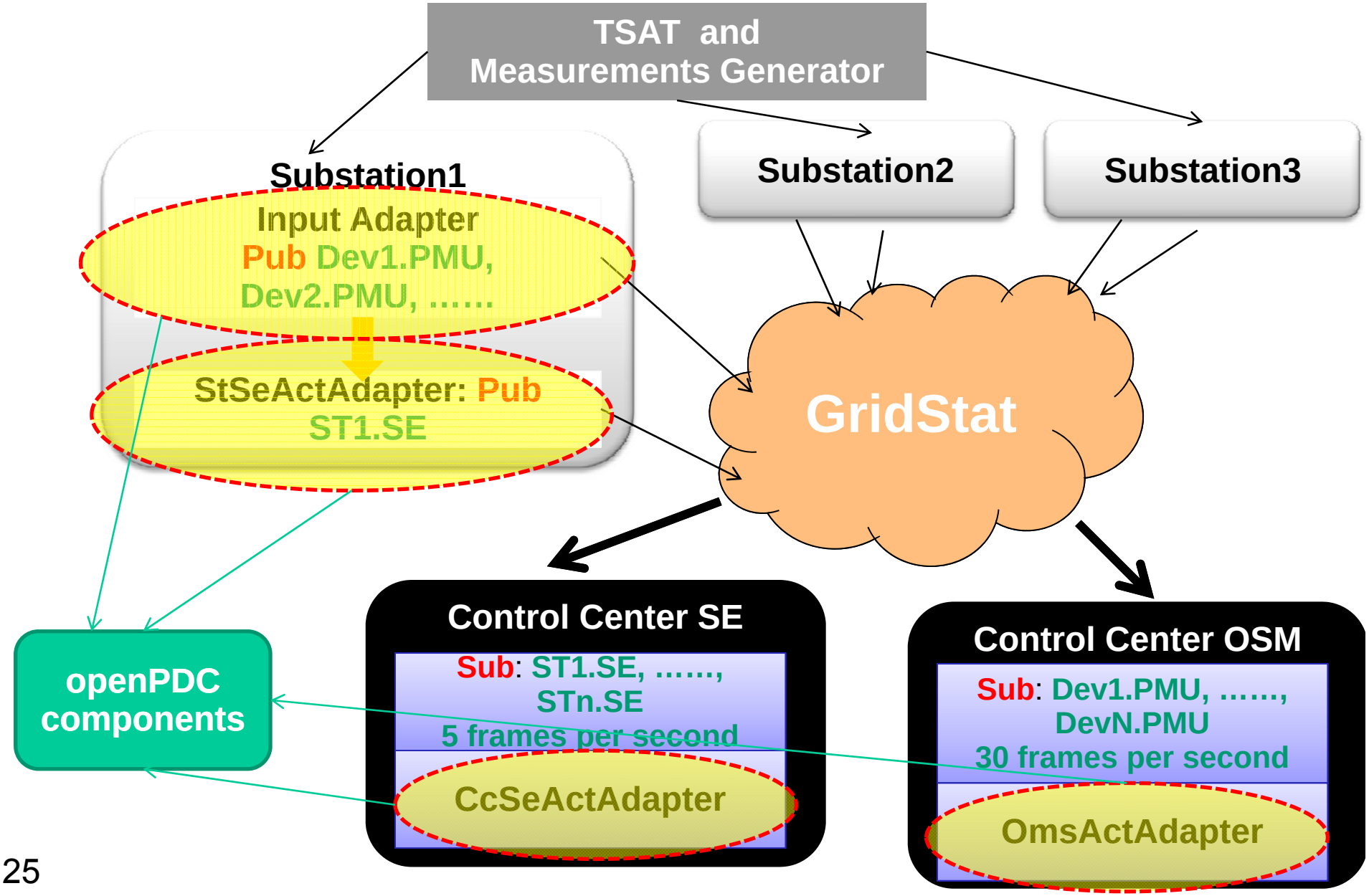
- Input Adapter
  - Develop new input adapter to communicate with GridStat
  - Support Pub/Sub communication pattern
- Action Adapter
  - Each action adapter comprise two parts: built-in part (time-alignment) and user-defined part (extended to implement WSU algorithms)
  - GridSim extends user-defined parts to implement
    - Substation and control center level SE
    - Substation and control center level Oscillation Detection

WASHINGTON STATE UNIVERSITY

Overall Architecture

- GridSim uses openPDC in two ways:
  - Embed OSM engine into openPDC.exe, and run openPDC.exe directly
  - Most of the time, we don’t run openPDC.exe directly, but develop our own program based on the library provided by openPDC

Overall Architecture



WASHINGTON STATE UNIVERSITY

OpenPDC at WSU

- OpenPDC used extensively in several projects
- OpenPDC based PMU applications being installed at Entergy, TVA, and WECC
- GridSim – large-scale simulator, Concurrent implementation of thousands of openPDC hosts in servers?
- Suggestions, Debugging, and WSU code contribution
- Config tools, Visualization tools
- Exciting future…