

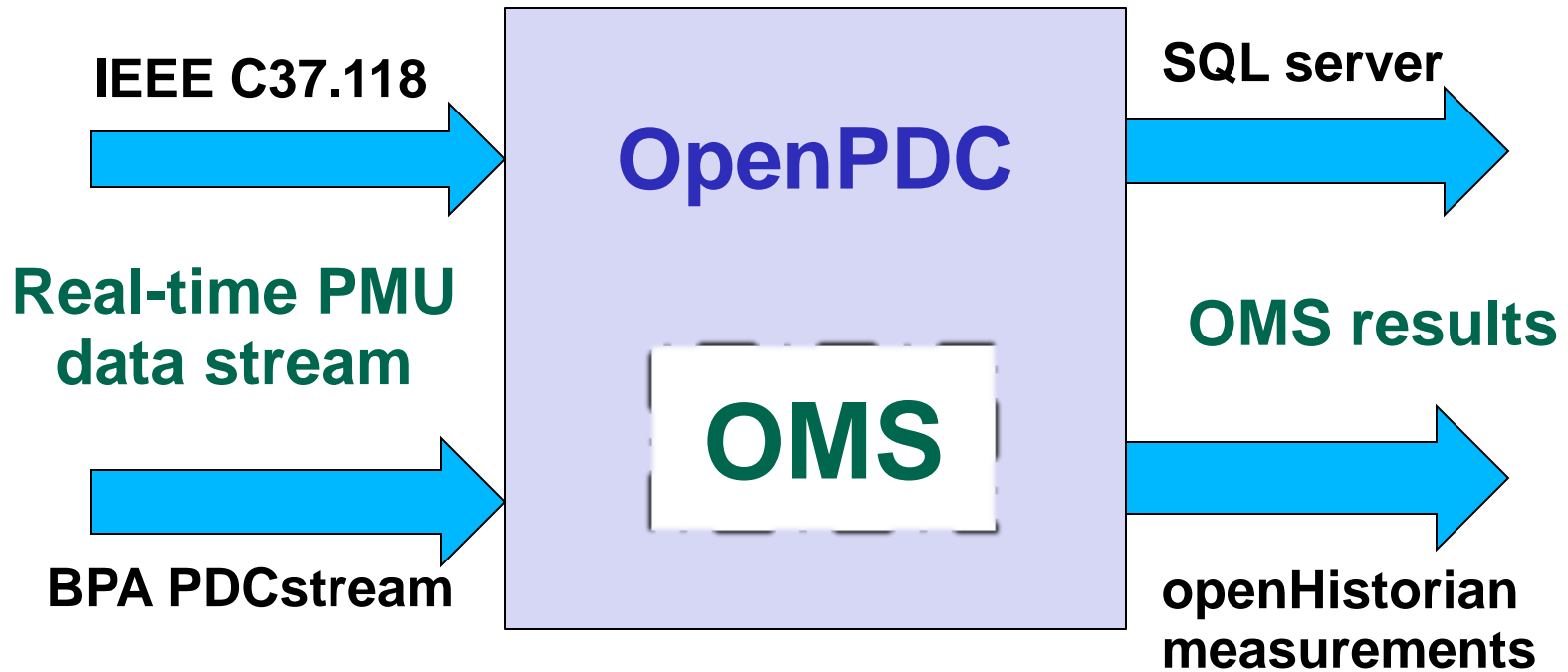
Applications on openPDC platform at Washington State University

Mani V. Venkatasubramanian

**Washington State University
Pullman WA**

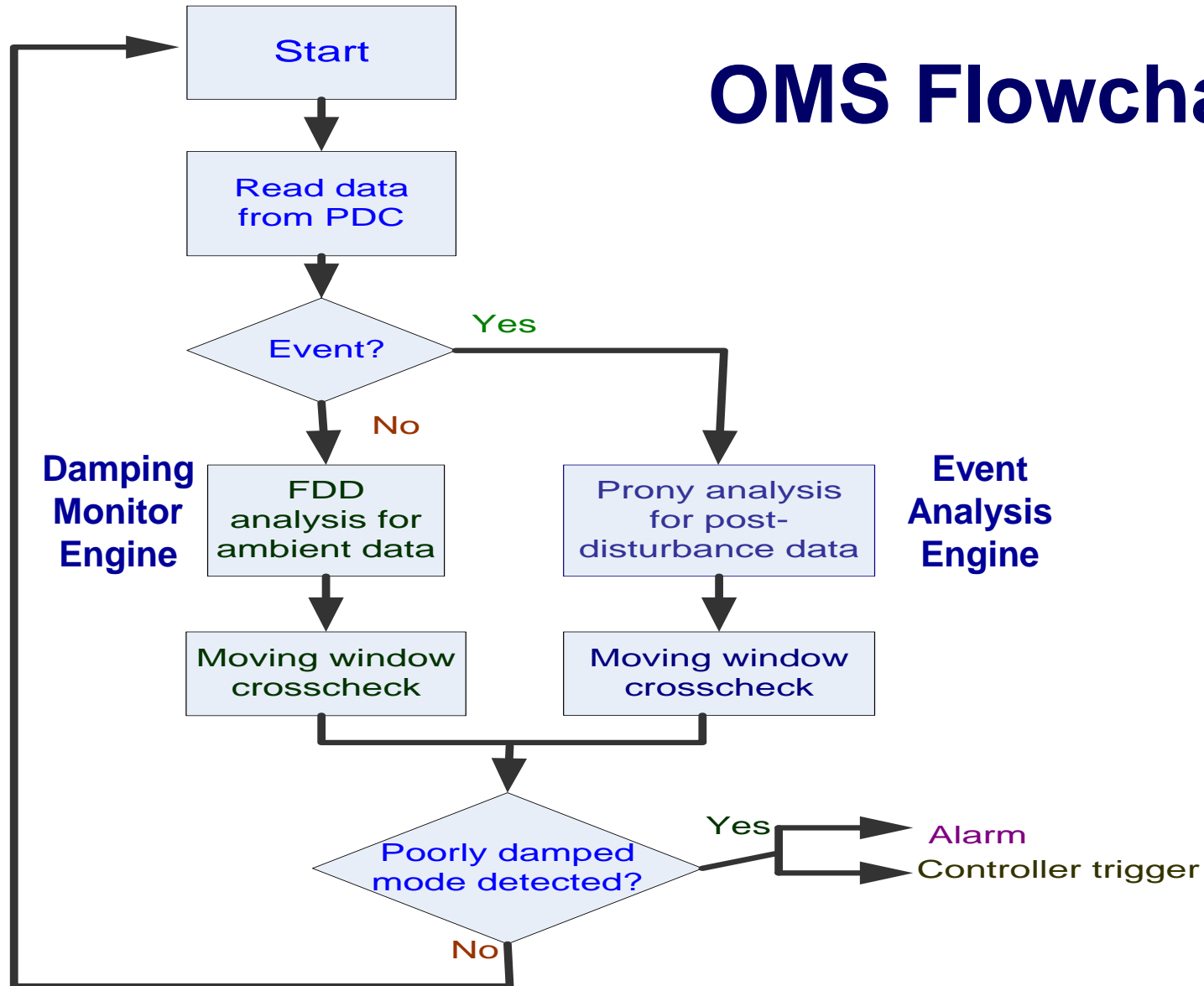
- **OMS** - Oscillation Monitoring System
 - Stand-alone system for oscillation detection and analysis using wide-area PMUs
- **VSMS** - Voltage Stability Monitoring System
 - Stand-alone system for voltage stability stress indicator using wide-area PMUs
- **GridSim** – Large-scale real-time power grid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

Oscillation Monitoring System



OMS action adapter built into OpenPDC 64 bit version 1.5

OMS Flowchart



Complementary Engines

- **Event Analysis Engine**

- ◆ Four algorithms: Prony, Matrix Pencil, Hankel Total Least Square and ERA.
- ◆ Aimed at events resulting in **sudden changes** in damping

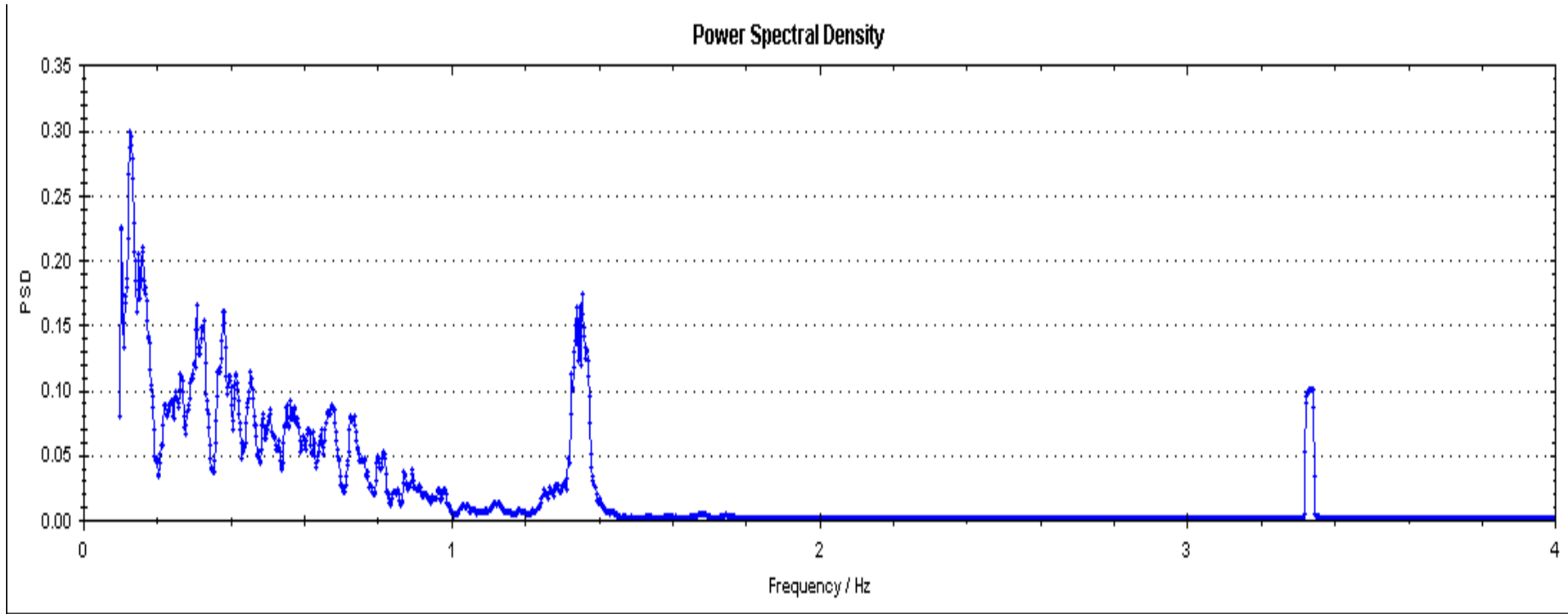
- **Damping Monitor Engine**

- ◆ Ambient noise based. Continuous.
- ◆ Frequency Domain Decomposition
- ◆ Provides **early warning** on poorly damped modes

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*

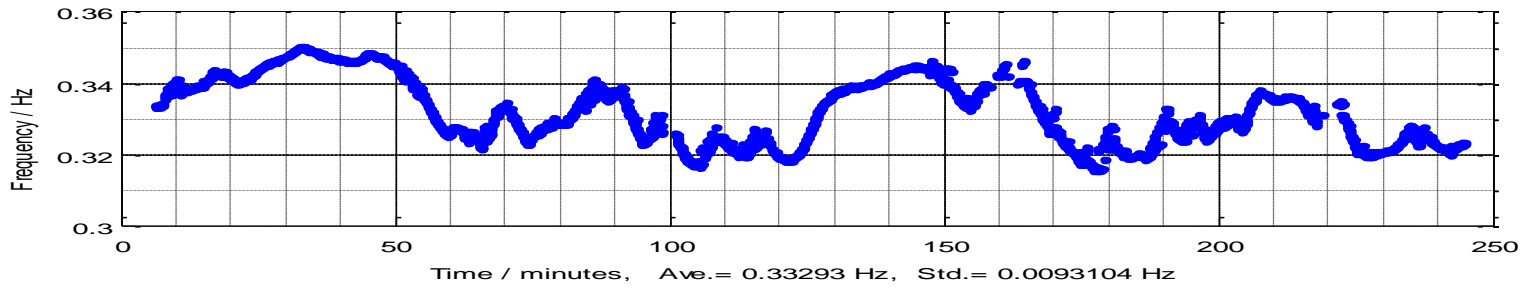
Different modes in a real system



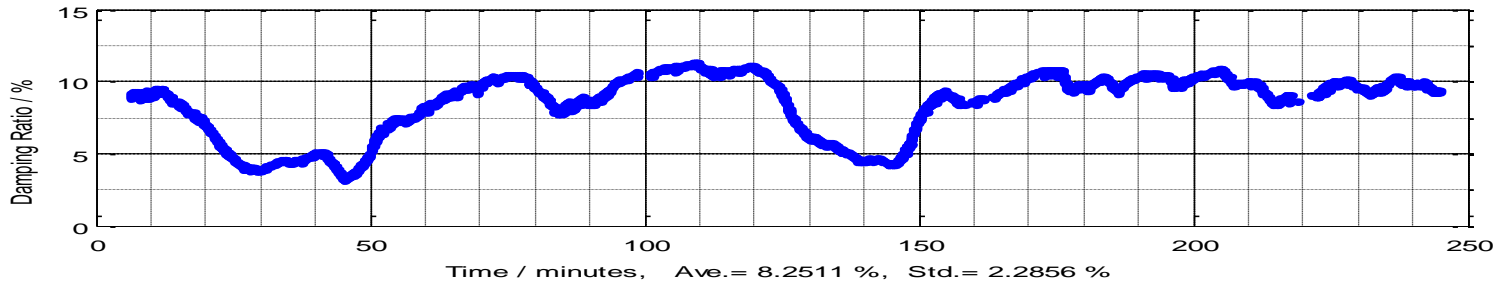
Poorly damped local mode at 1.3 Hz

Zero damping mode at 3.3 Hz

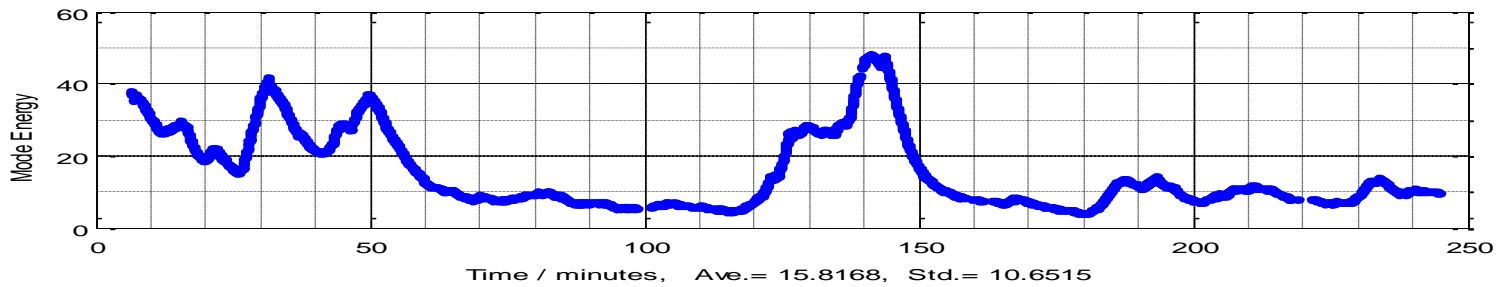
Western Data Analysis



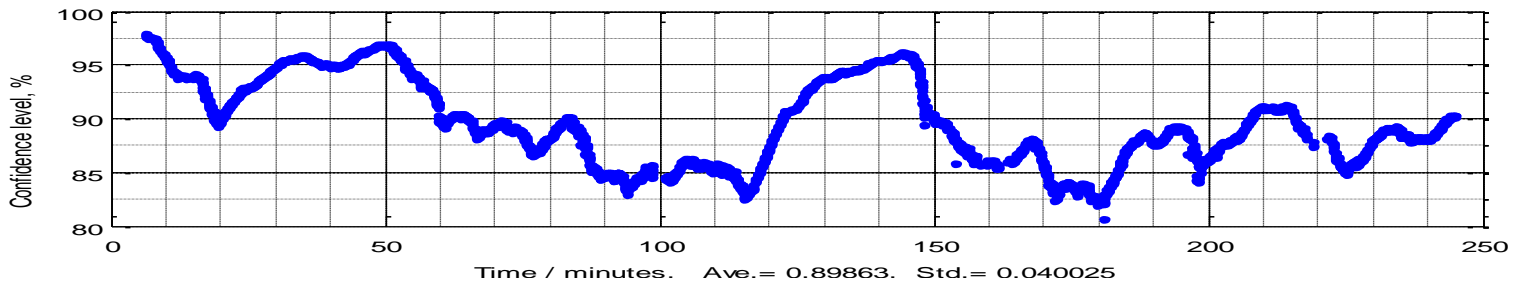
Mode Frequency



Damping Ratio

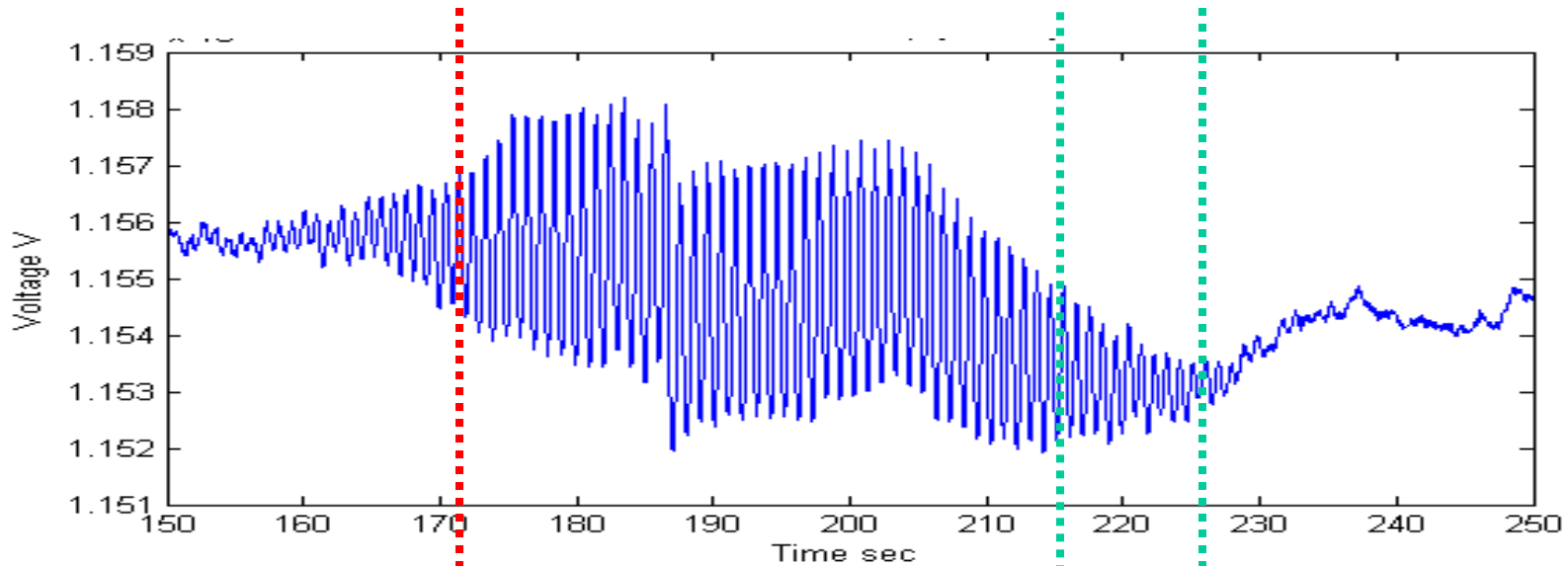


Energy Estimate

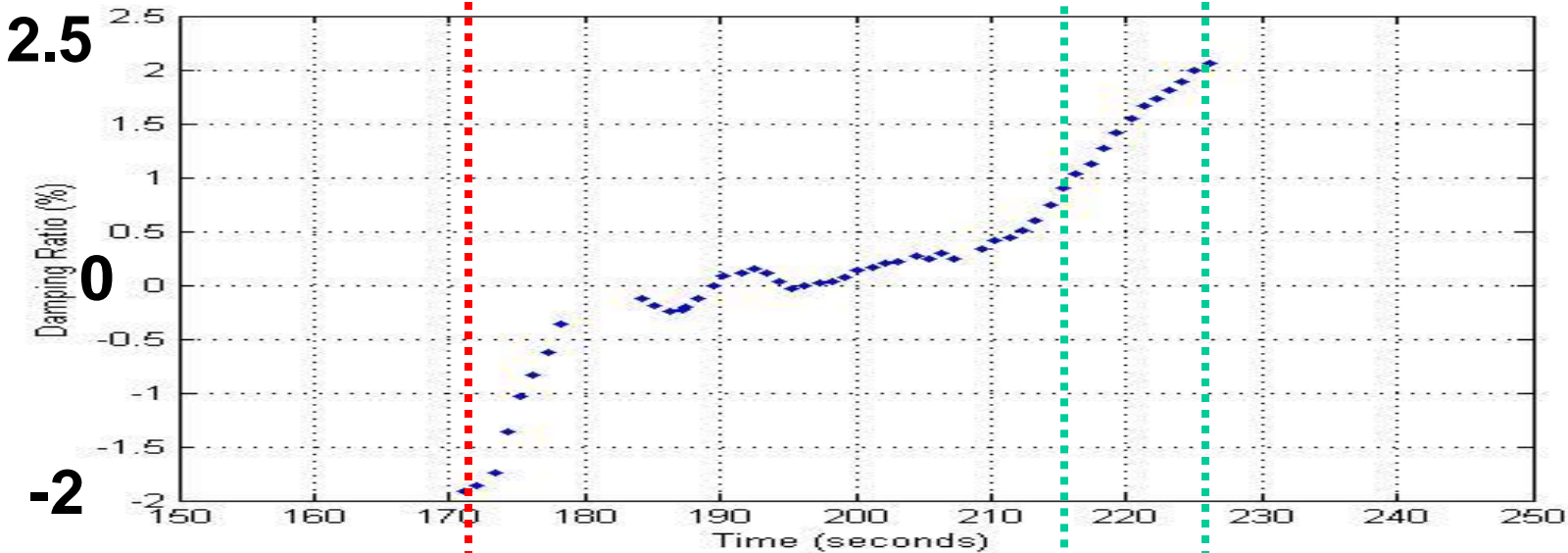


Estimate Confidence

Case Study – Western Event

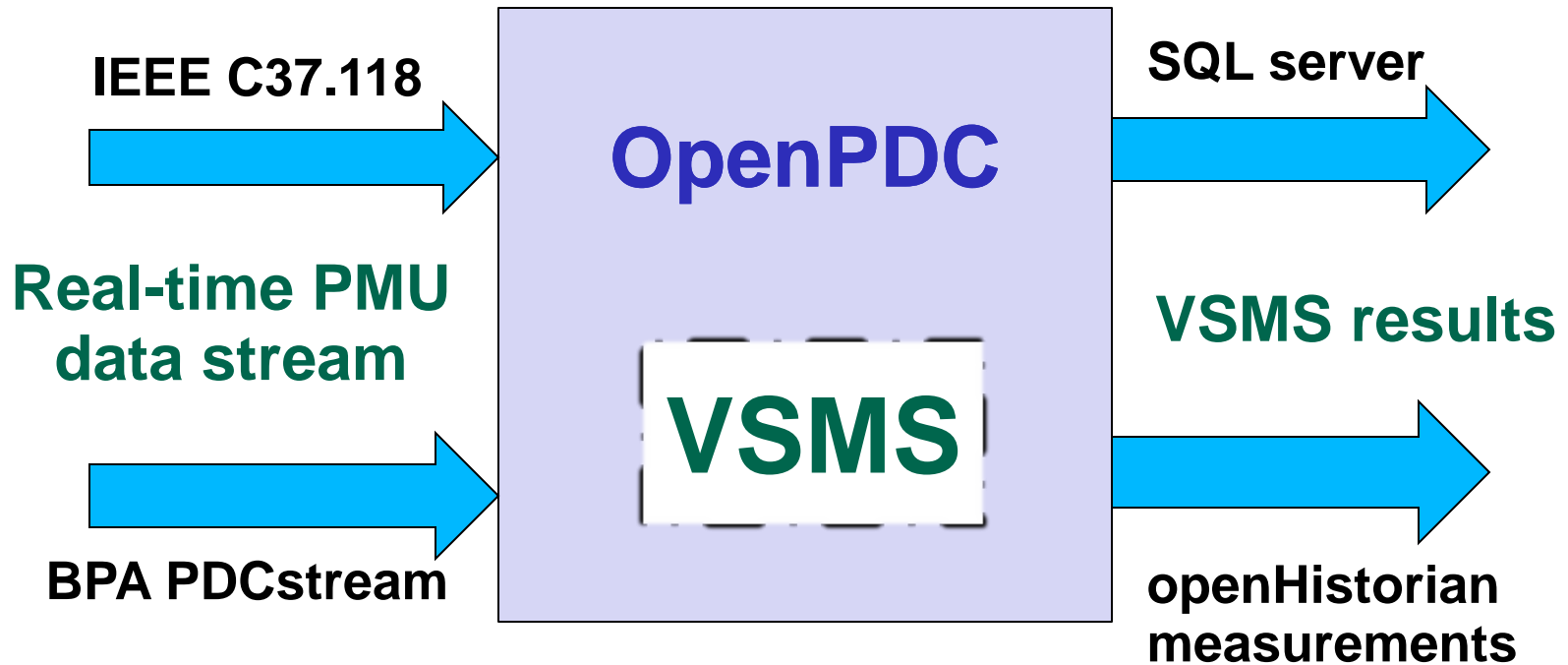


PMU Bus Voltage

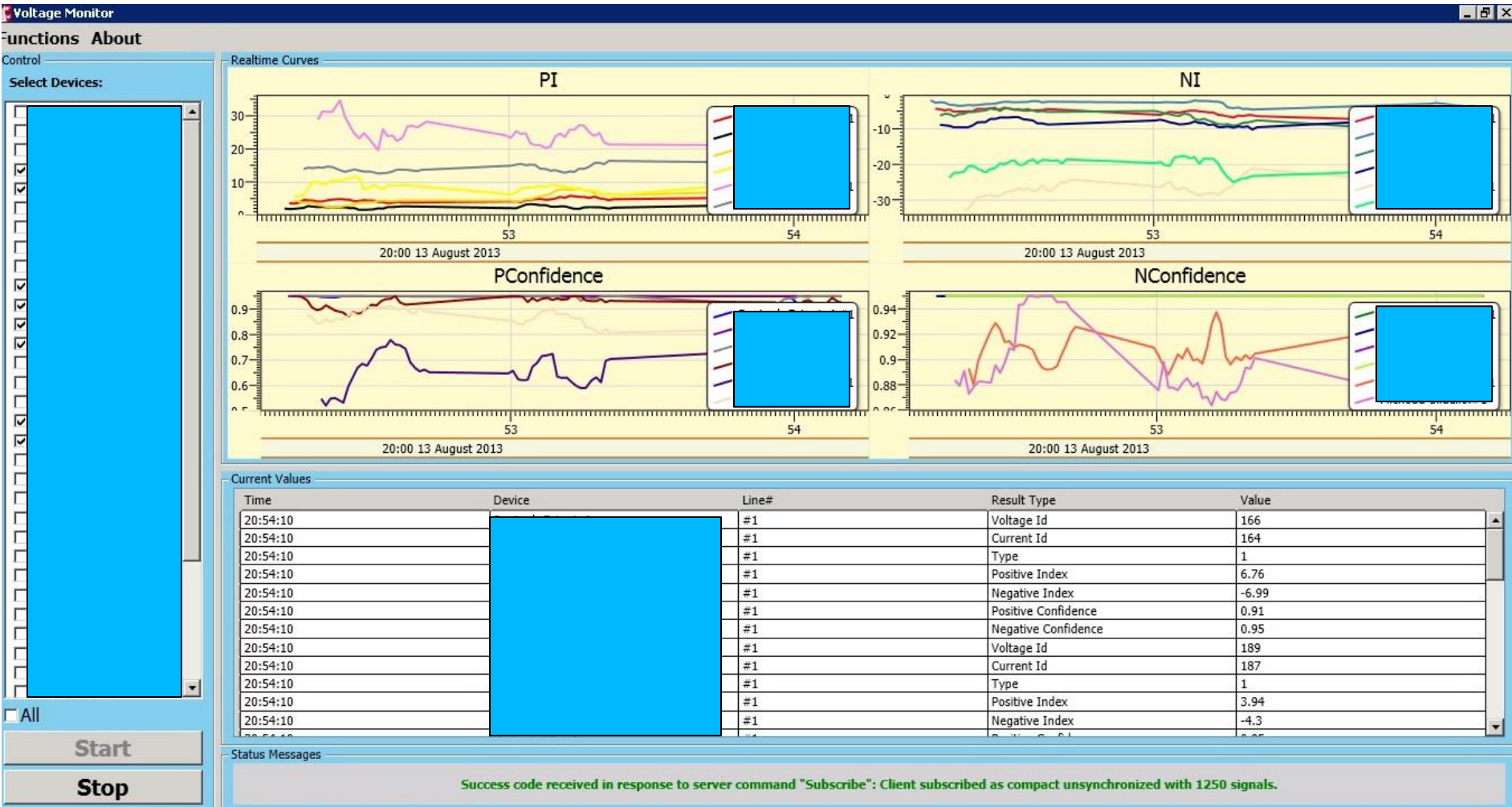


Event Analysis Damping Estimate

Voltage Stability Monitoring System



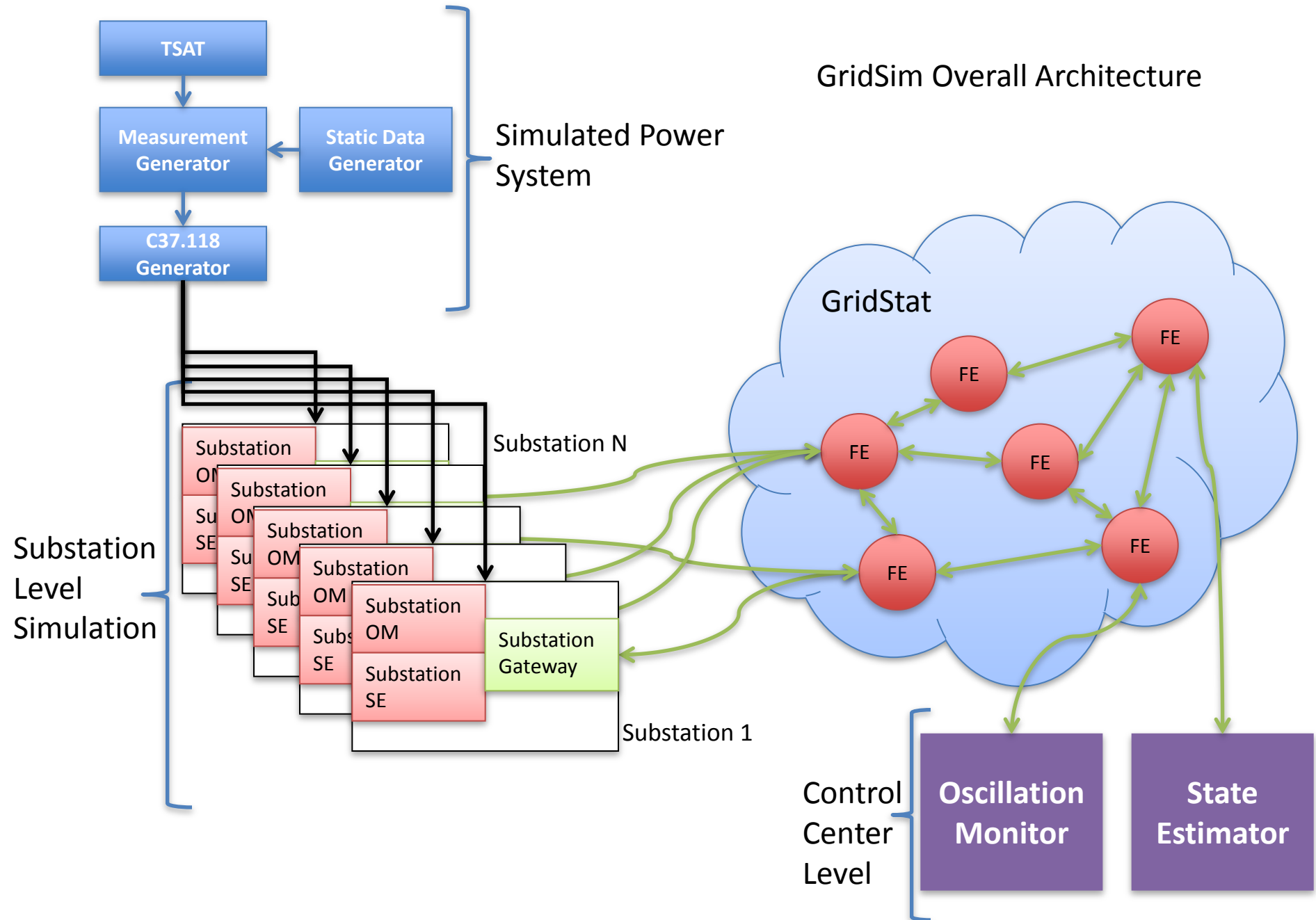
VSMS Real-time Display



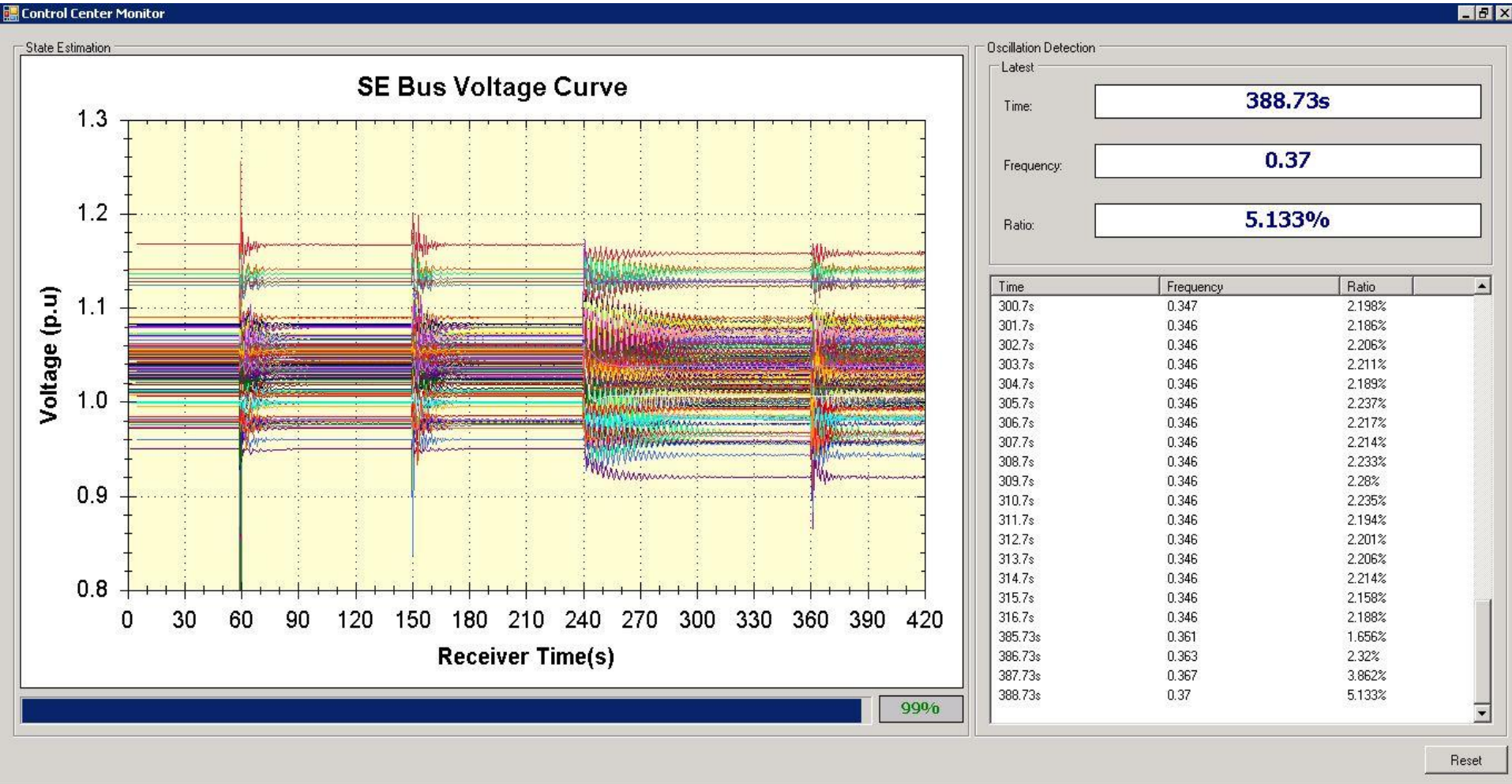
GridSim - Real Time Simulation of Power Grid Operation & Control

- Funded by USDOE
- 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

GridSim Overall Architecture



179 Bus Example



GridSim PMU Configuration

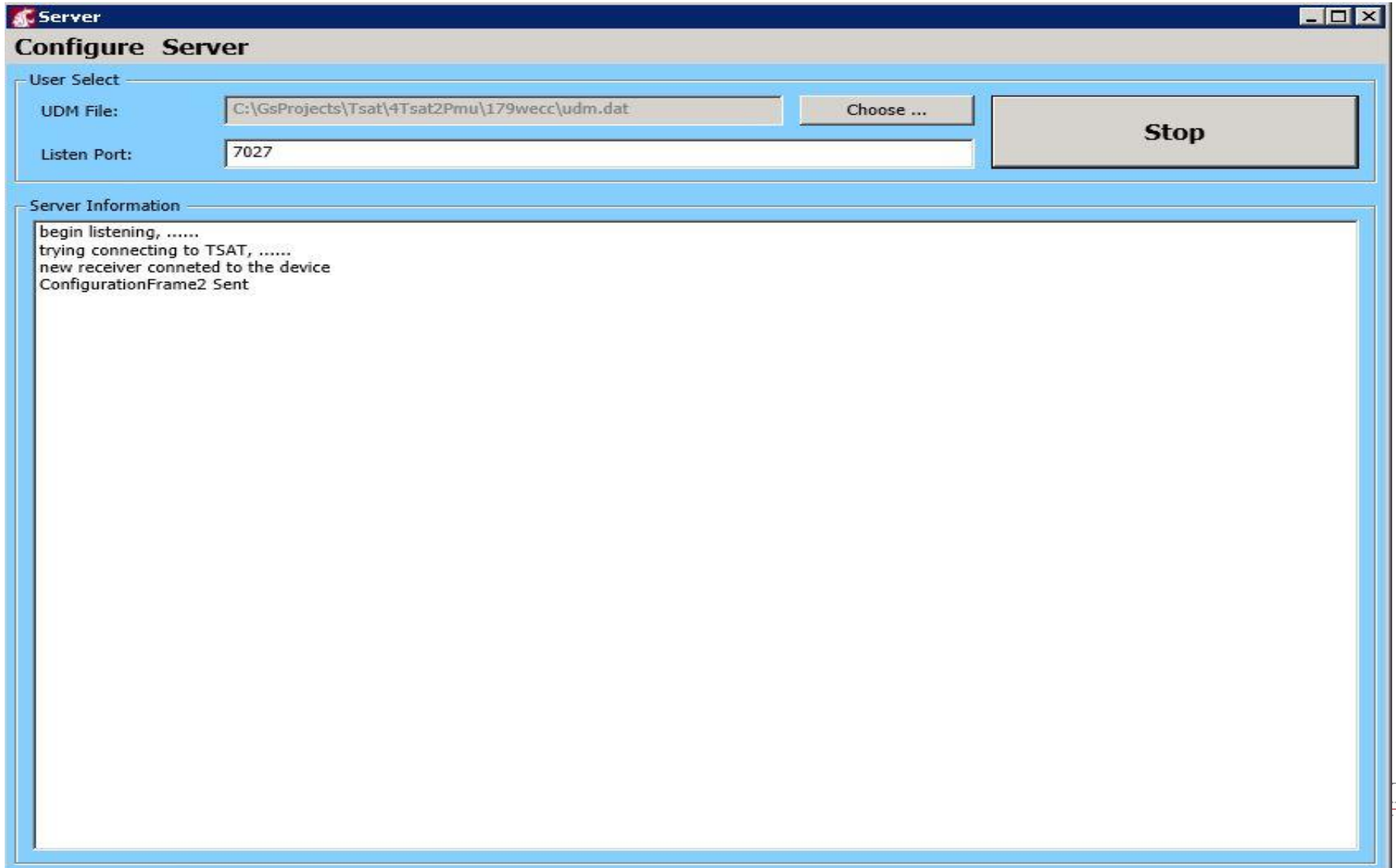
The screenshot shows the 'Configure Server' window with the following components:

- File Path:** C:\GsProjects\Tsat\4Tsat2Pmu\179wecc\p
- Buttons:** Load Power Flow File, Search By From Bus, Save UDM File
- Search Input:** 102
- Table 1 (Left):**

	FromBus	ToBus	Tag	Type
<input type="checkbox"/>	102	N/A		Bus
<input type="checkbox"/>	102	104	1	Branch
<input type="checkbox"/>	102	108	1	Branch
<input type="checkbox"/>	102	108	2	Branch
<input type="checkbox"/>	102	103	1	Branch
<input type="checkbox"/>	102	103	1	Branch
- Table 2 (Right):**

	FromBus	ToBus	Tag	Type
<input type="checkbox"/>	102	104	1	Branch
<input type="checkbox"/>	102	108	1	Branch
- Controls:** +, - buttons between tables; Select/Deselect All checkboxes at the bottom of each table area.
- TSAT Port:** 48000

GridSim Comm Port Spec



GridSim 37.118 outputs

PMU Connection Tester

File Help

Connection Parameters

Tcp Udp Serial File Default IP Stack: IPv4 Protocol

Host IP: 127. 0. 0. 1 Establish Tcp Server

Port: 7027

IEEE C37.118-2005

Device ID Code: 18

Command: Disable Real-time Data

Version 4.2.12

Configure Alternate Command Channel

PMU: ID Code: 1

<97-96-1>

Phasor: (Selected is reference angle)

V: Voltage

Phasors: 2 Nominal Frequency: 60 Hz

Analogs: 0

Digitals: 0

Power: -1328.6350 MW

Vars: 6.4679 MVars

Configured frame rate: 30 frames/second

Graph Settings Messages Protocol Specific

Real-time Frame Detail

Frame Type: DataFrame

Time: 2013-06-06 23:17:56.126

Frequency: 59.9477 Hz

Angle: -146.685456803896°

Magnitude: 533.7237 (924.4365) kV

Display: Hexadecimal

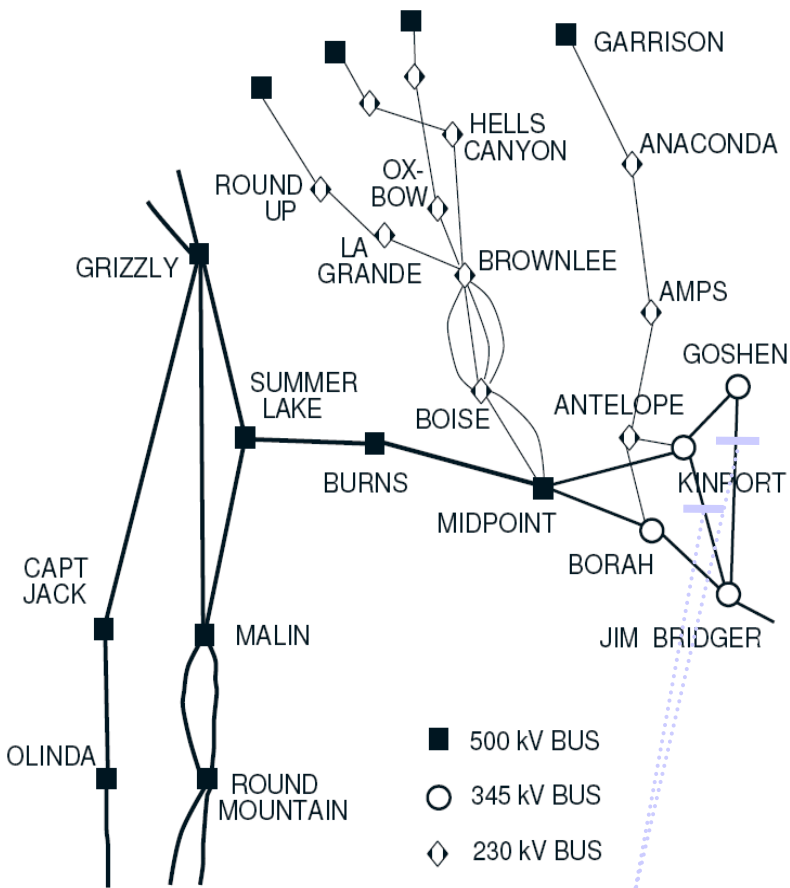
```

AA 01 01 CA 00 12 51 B1 18 A4 00 20 6F AC 00 00 49 02 4D BB C0 23 D9 67 44 4F 73 29 3F 16 18 D7 42
6F CA 75 00 00 00 00 00 00 49 02 4D BB C0 23 D9 67 44 4F 73 26 C0 23 89 A2 42 6F CA 75 00 00 00 00
00 00 49 02 B8 57 C0 1E 6B 1B 44 4F 73 26 3F 16 18 E2 42 6F CA 72 00 00 00 00 00 00 49 02 B8 57 C0
1E 6B 1B 44 4F 73 23 C0 23 89 A4 42 6F CA 72 00 00 00 00 00 00 49 00 AE B0 C0 24 85 6F ...
    
```

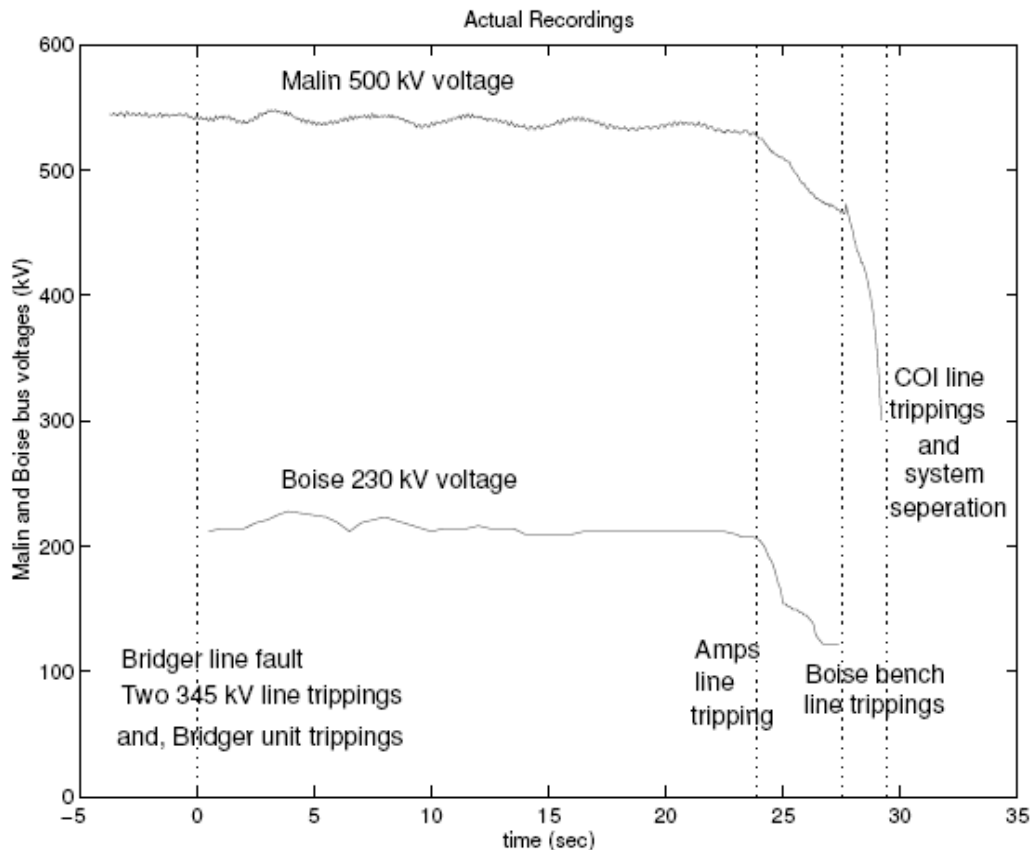
Total frames: 1782 Frames/sec: 26.5560 Total bytes: 817370 Bit rate (mbps): 0.0928 Queued buffers: 0

July 2, 1996 WECC Blackout

- Heavy loads
- Double line outage near Bridger plants

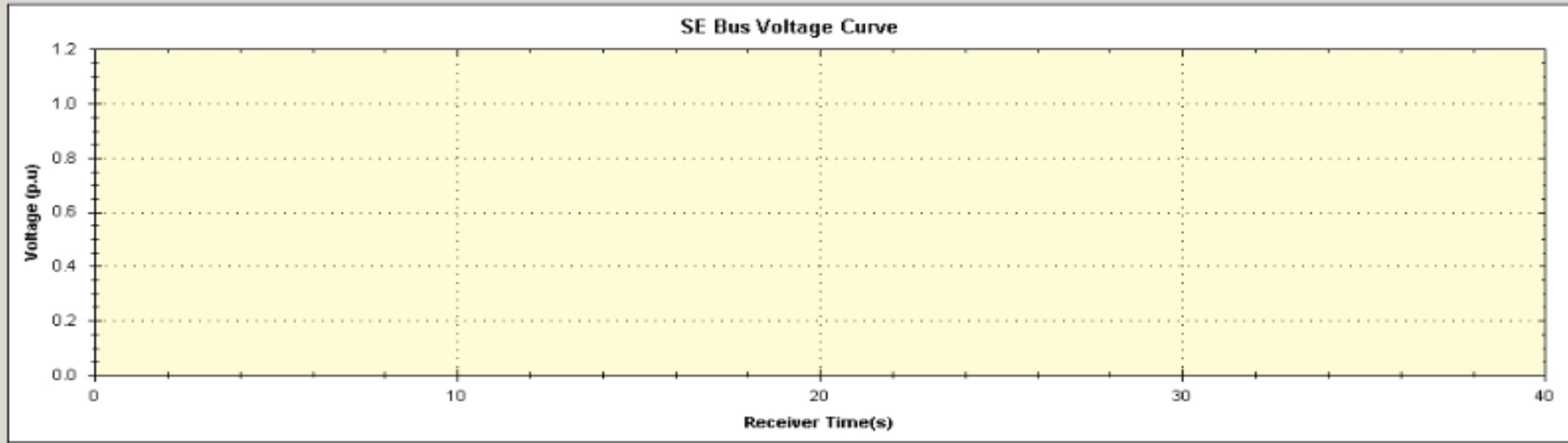


These Two Lines Tripped



WECC Test System

- WECC July 2, 1996 blackout case
 - 6180 buses
 - 1005 generators
 - 11982 branches
 - Idaho area monitored by PMUs
 - 109 buses in Idaho
 - 223 branches, 25 generators, 46 loads, 77 transformers
 - 480 PMUs streamed from simulator



Scenarios

1 A D V F F R

0.00%

The Scenario Has Not Been Processed

Scenario 1

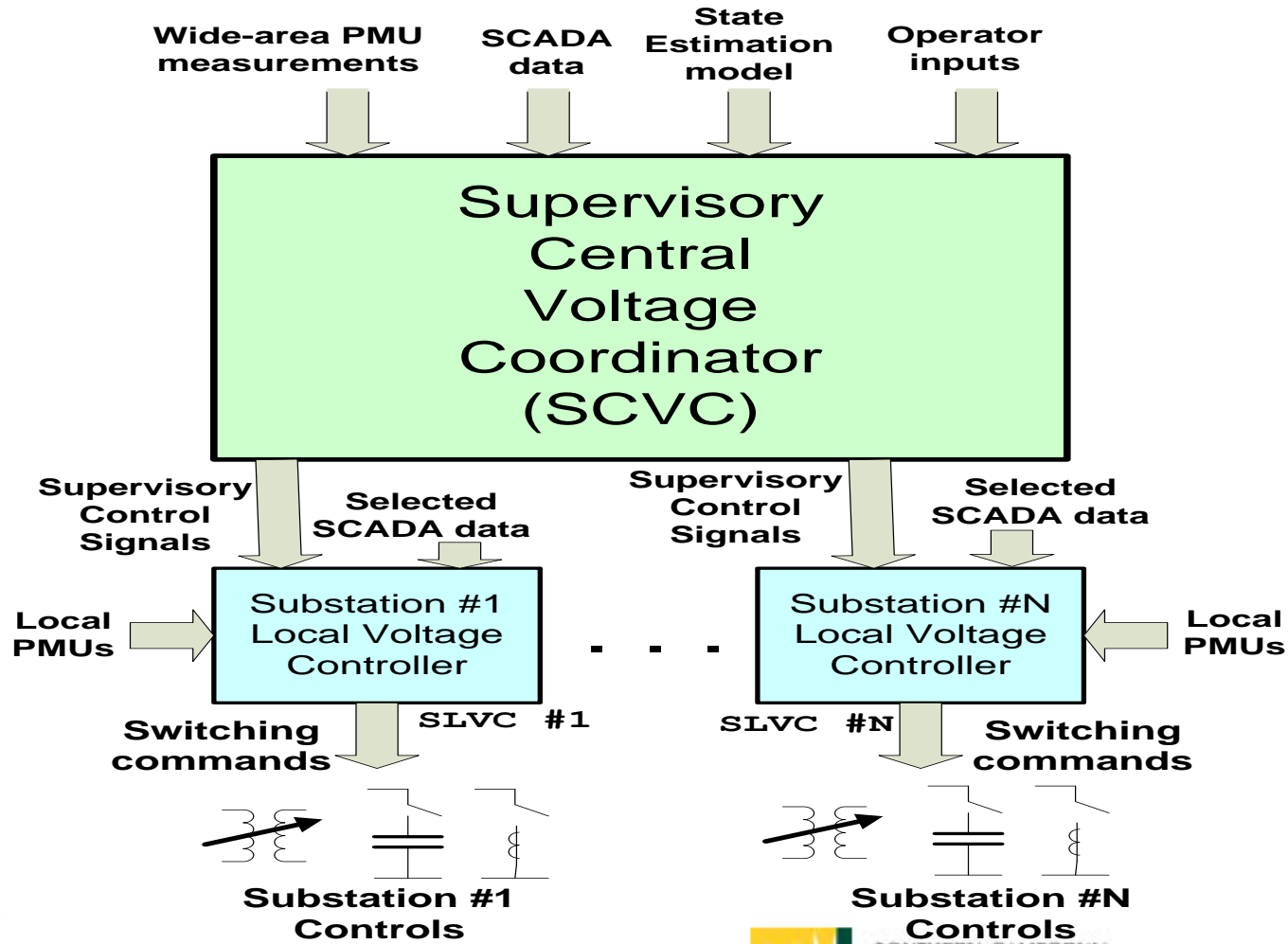
Generator Rotor Angle (Degrees)



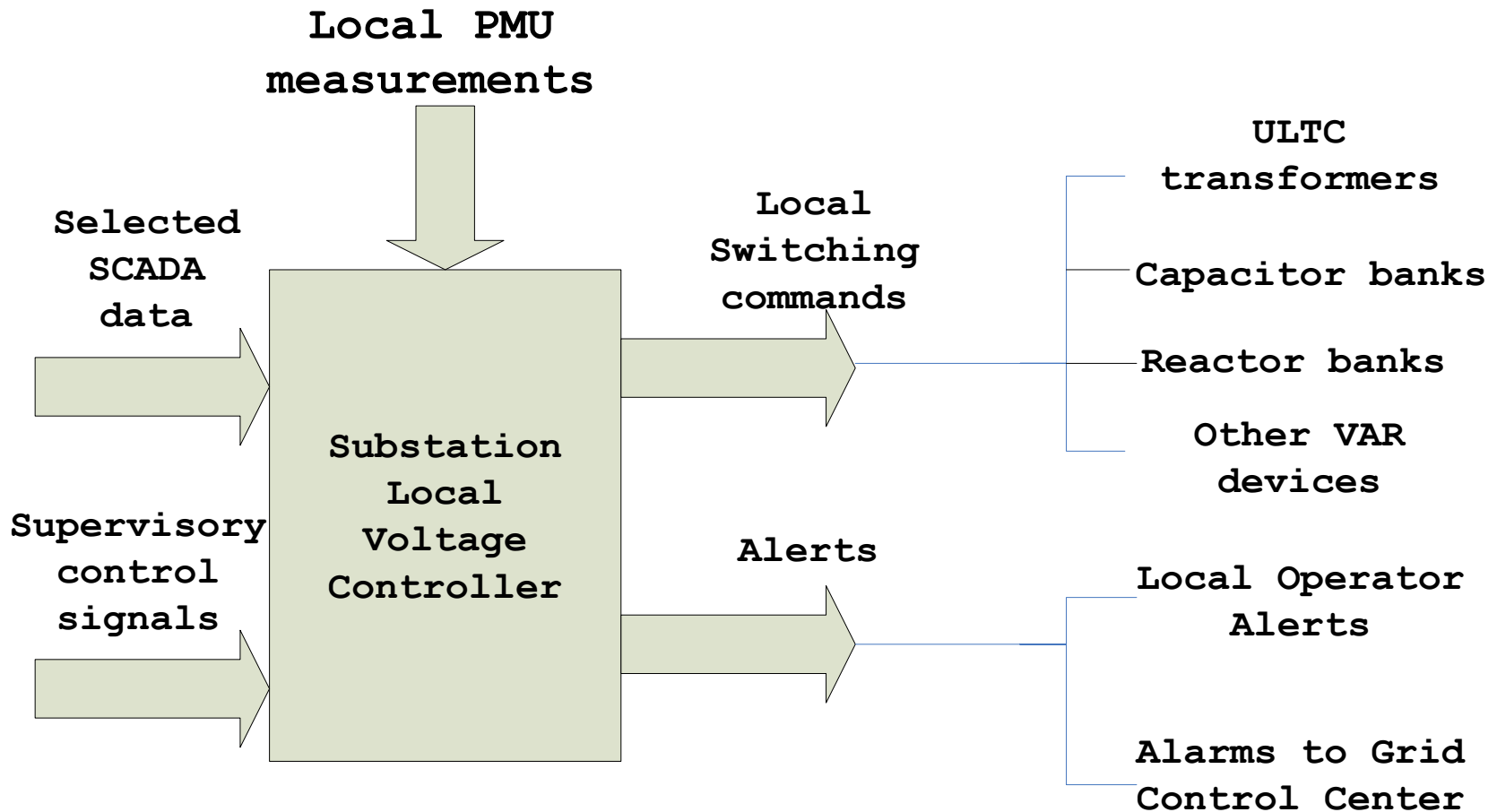
Bus Voltage Magnitude (pu)



Voltage Controller Structure



SLVC Controller



OpenPDC at WSU

- OpenPDC used extensively in several projects
- OpenPDC based PMU applications installed at Entergy, TVA, and Idaho Power.
- GridSim – large-scale real-time simulator, commercial version from Powertech.
- Suggestions, Debugging, and WSU code contribution
- Config tools, Visualization tools
- Closed-loop controls for substations and control centers