Oscillation Monitoring System

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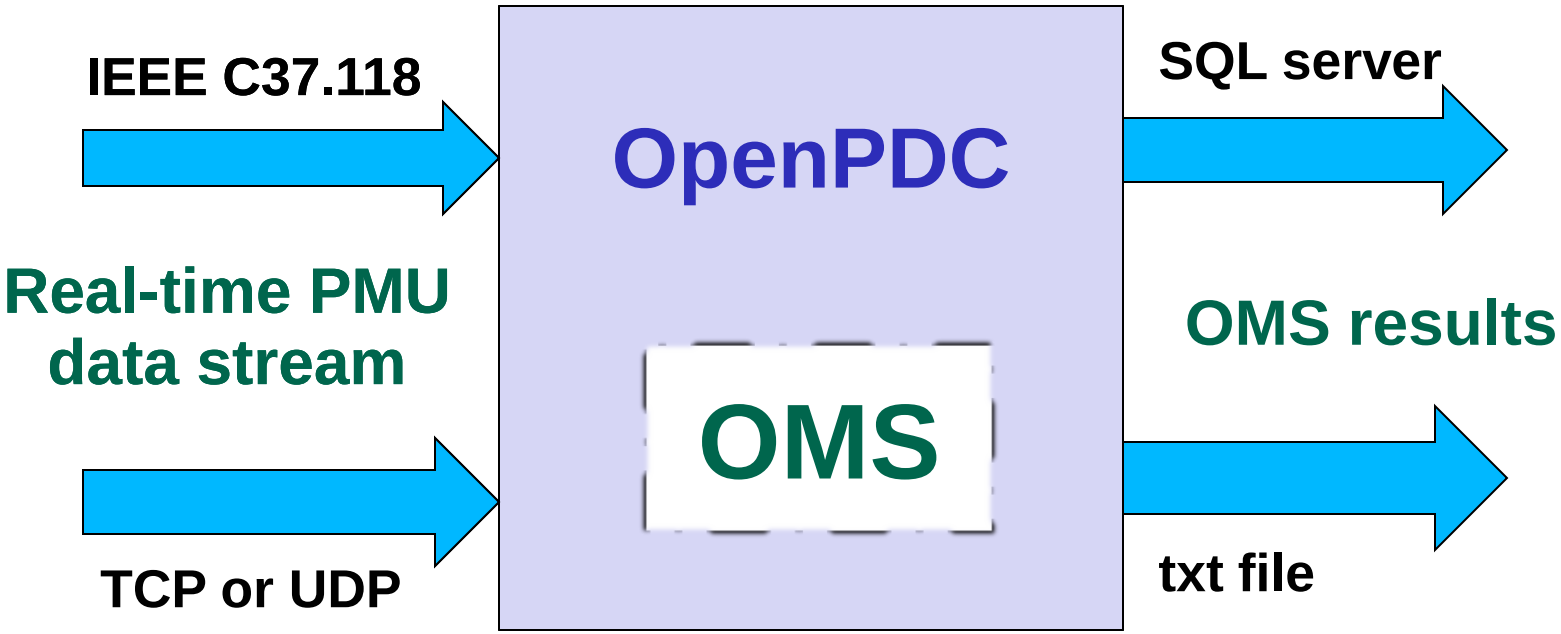
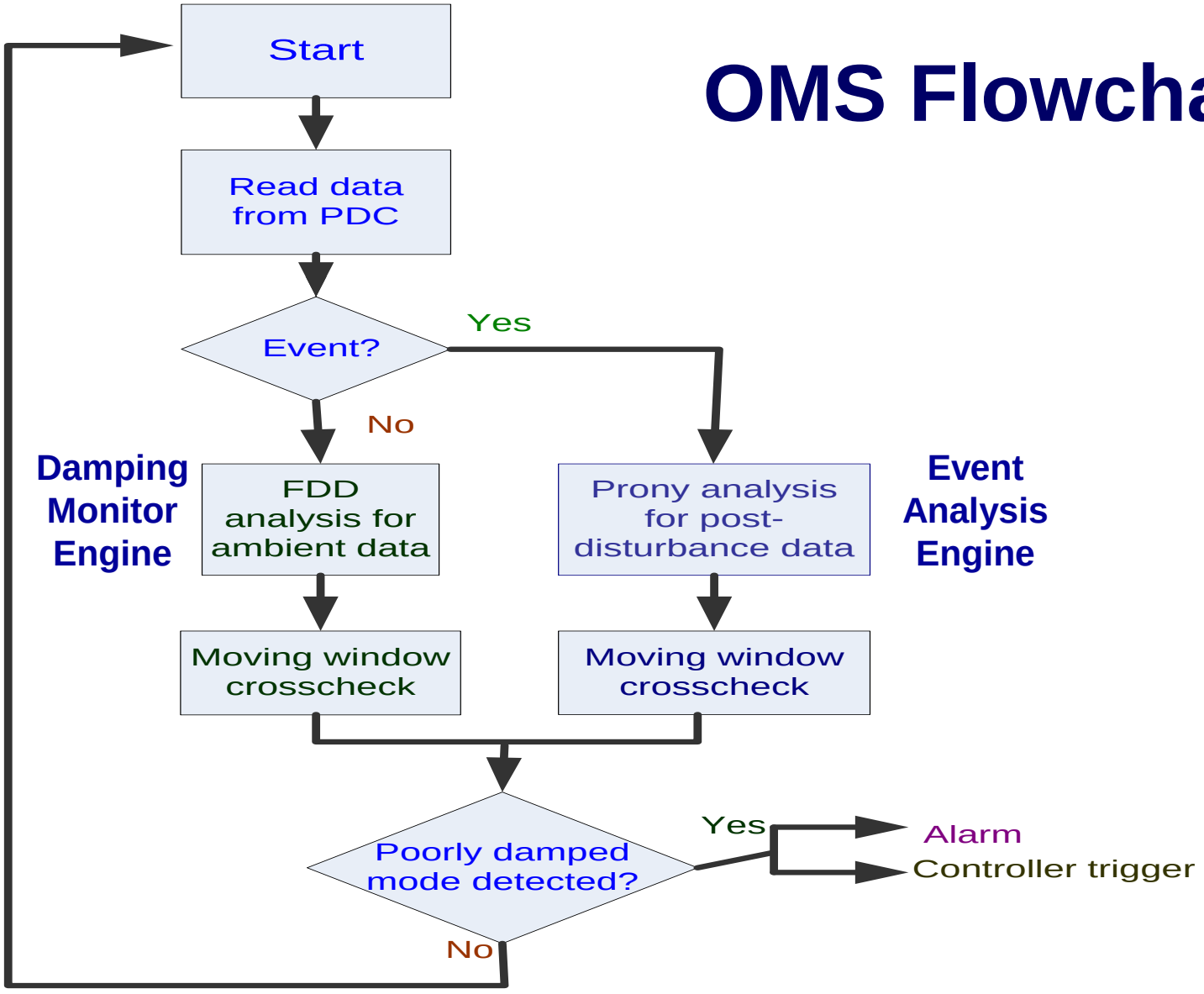
Oscillation Monitoring System



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

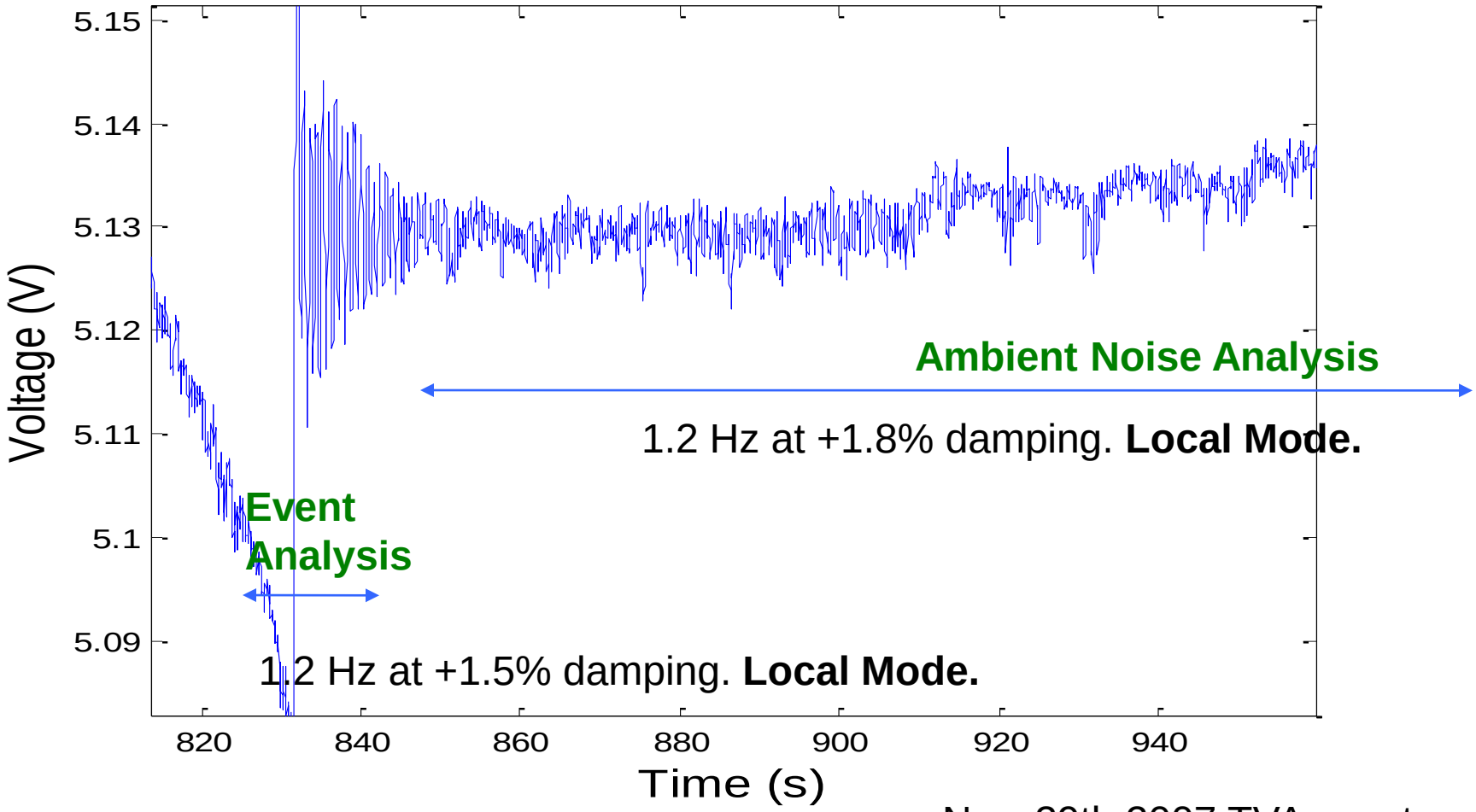
OMS Flowchart



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.
  - Frequency Domain Decomposition
  - Provides early warning on poorly damped modes

Results from Two Engines



Nov. 29th 2007 TVA event

OMS Engines

- Event Monitor Engine
  - Automated Prony type analysis of oscillatory ringdown responses
  - *Ten seconds* of PMU data analyzed every *one second*
- Damping Monitor Engine
  - Automated analysis of ambient noise data
  - *Five minutes* of PMU data analyzed every *ten seconds*
  - Multiple PMUs – Fast and Accurate

CERTS/DOE Projects

- **WECC Project**
  - **Evaluation of OMS tools using MiniWECC and PSLF simulation data and WECC archived data.**
- **Entergy Project**
  - **Implementation of OMS tools for analyzing Entergy PMUs.**
  - **Damping Monitor Engine: 5 minute data length, 10 second refresh time, 30+ PMUs.**
  - **Excellent feedback from operations: New developments: Estimation confidence measures, Mode Energy measures, Novel displays (STI).**

FY12 Technical Progress

- **Damping Monitor Engine**
  - Four minute and two minute engines developed and tested
  - Efficient post-processing algorithms developed
  - Real-time engine implemented in WECC test server since November 2011
- **Event Analysis Engine**
  - Real-time version updated to openPDC 1.4 sp1
  - Handles 37.118 streaming PMU data
  - Outputs to SQL server database

FY12 Technical Objectives

- **WECC system and Entergy system**
  - **Design and Testing of Damping Monitor Engine for shorter data lengths**
  - **Design and Testing of Event Analysis Engine for handling complex events**
  - **Portability and Cybersecurity of algorithms**
  - **Engineer friendly and operator friendly**
  - **Robust algorithms towards data quality issues**
  - **Develop off-line versions for engineers**

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FY12 Technical Work

- **Damping Monitor Engine**
  - Field demonstration of real-time engine at Entergy
  - Off-line engine – prototype for WECC
- **Event Analysis Engine**
  - Field demonstration of real-time engine at Entergy
  - Off-line engine – prototype for WECC

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FY12 Risk Factors

- **Data quality issues**
- **Different PMU vendors**
- **Computational burden**
- **OpenPDC updates**
- **Validation of results**

FY13 Technical Work

- **WECC system and Entergy system**
  - **Extend engines to handle hundreds of PMU data in real-time by efficient multithreading**
  - **Robust algorithms for addressing data quality issues**
  - **Improve Damping Monitor Engine by running multiple tasks while using shorter data lengths**
  - **Improve Event Analysis Engine for handling complex events among multiple processors**
  - **Develop off-line versions for engineers**

Back-up slides

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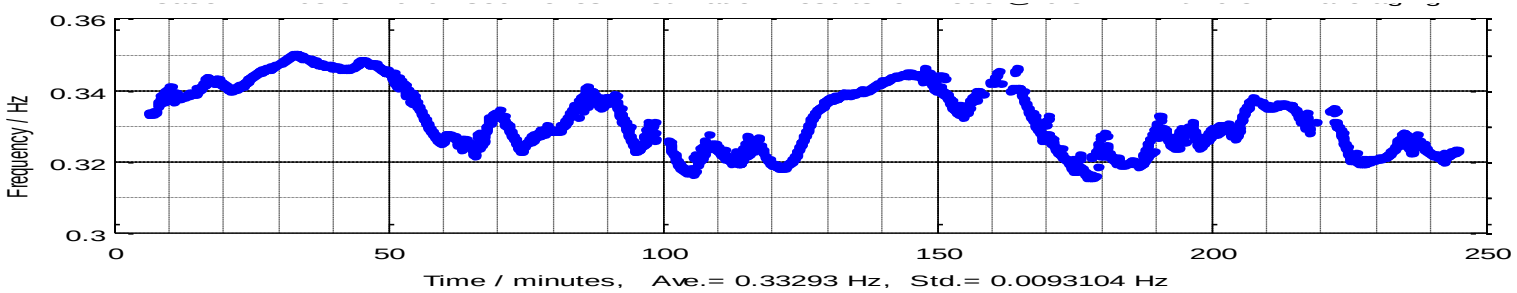
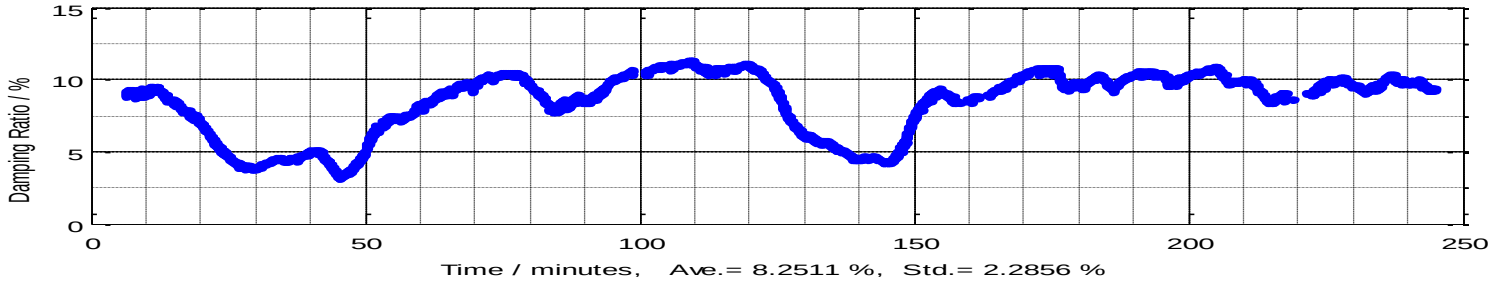
Damping Monitor Estimation Results

- Dominant modes are analyzed for each data set (every ten seconds)
- For each mode:
  - Mode frequency
  - Mode damping ratio
  - Mode energy
  - Mode shape
  - Estimation summary flag
  - Estimation confidence level

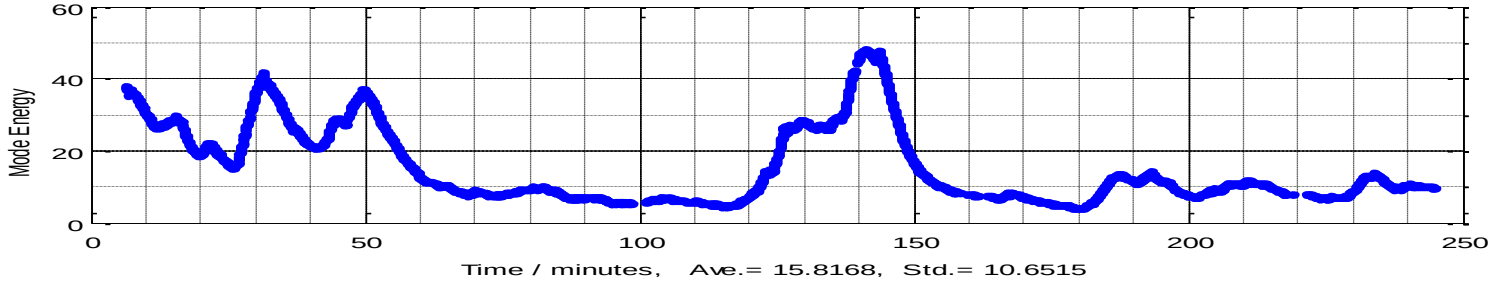
Western Data Analysis



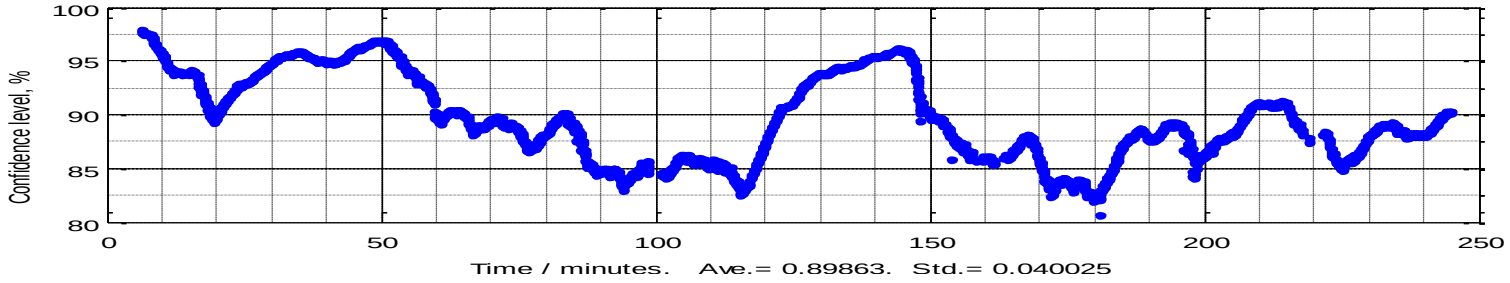
Mode Frequency



Damping Ratio



Energy Estimate



Estimate Confidence

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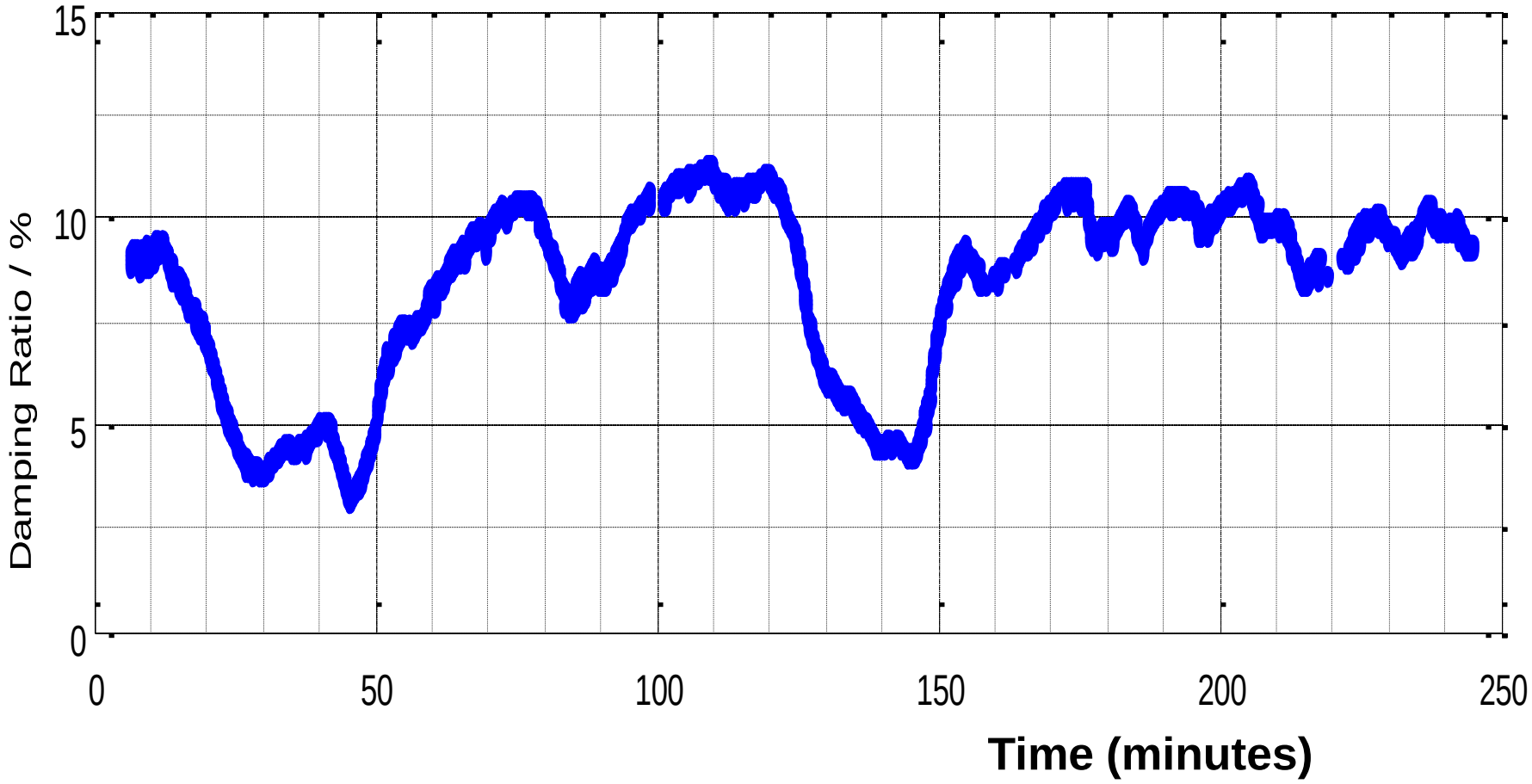
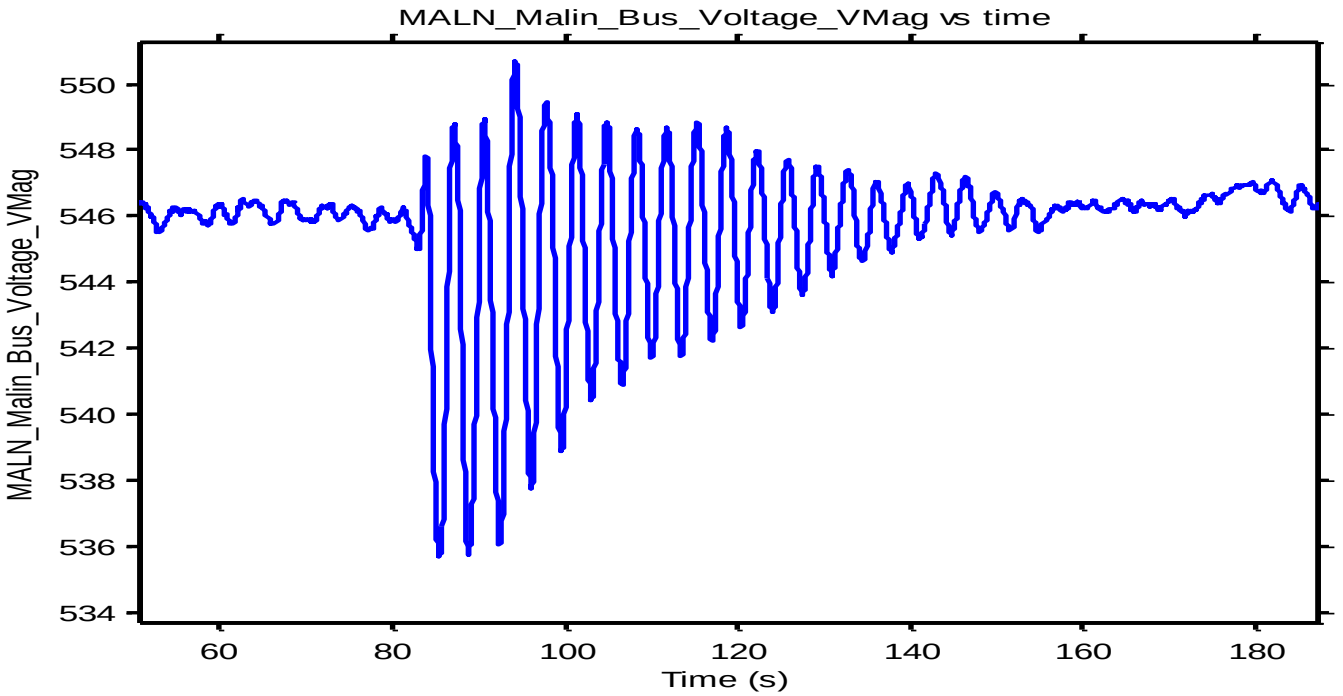
Rapid Changes in System Damping

Western System Event



Rules for Real-time Prony Analysis



Three types of Consistency Crosscheck rules

- Different Curve-fitting Methods (Redundancy)
- Different Signal Groups (Superposition)
- Moving Window Analysis (Linearity of Reponses)

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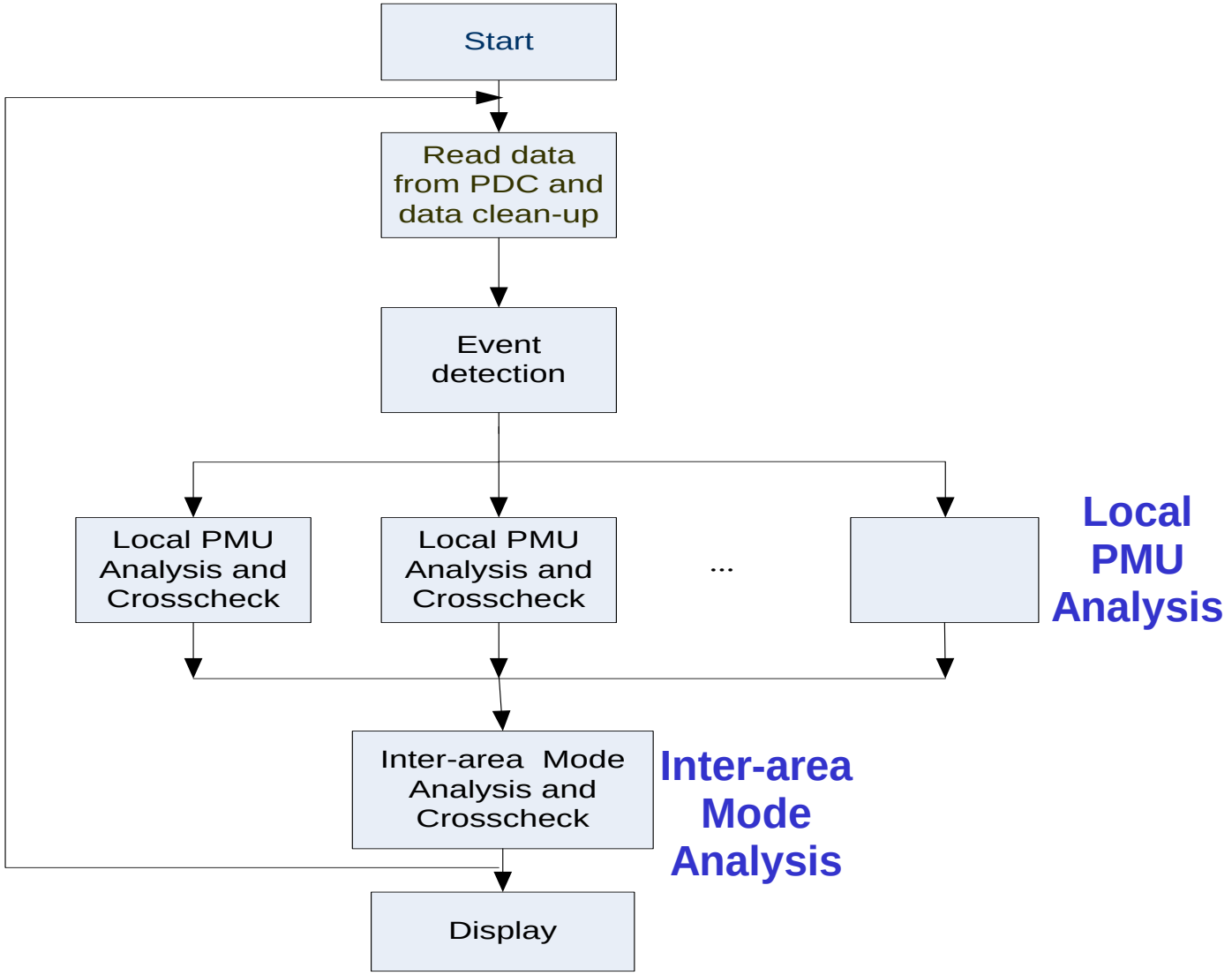
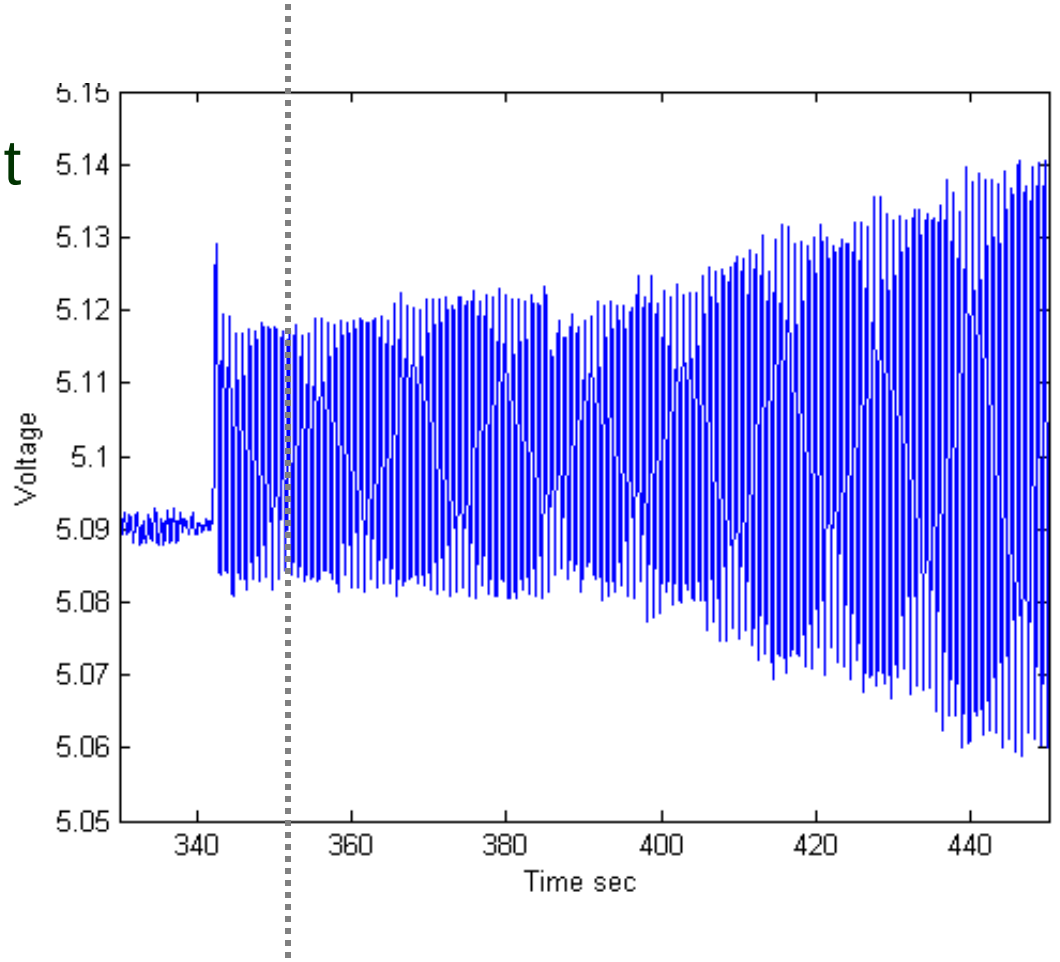
Event Analysis Engine

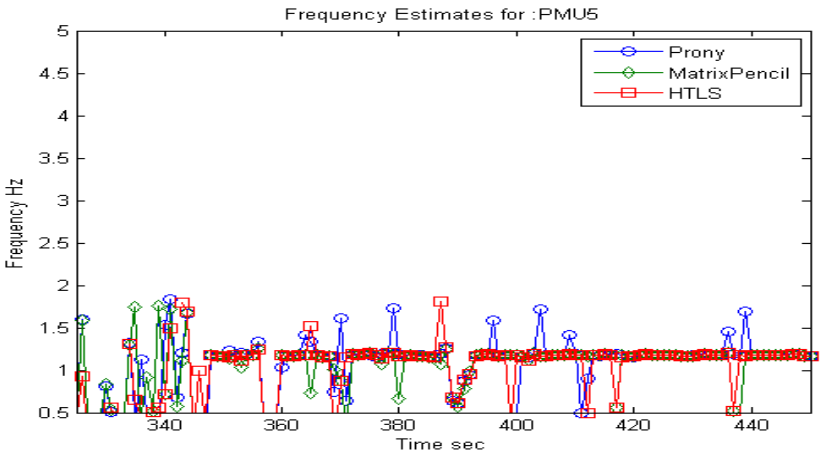


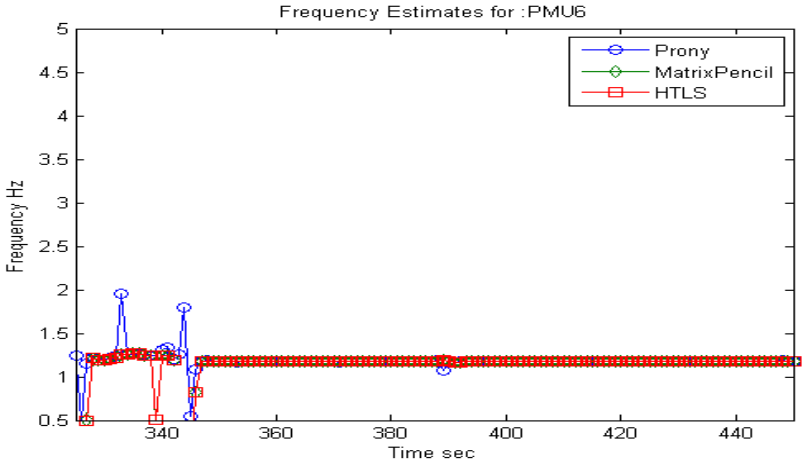
Event Analysis Example

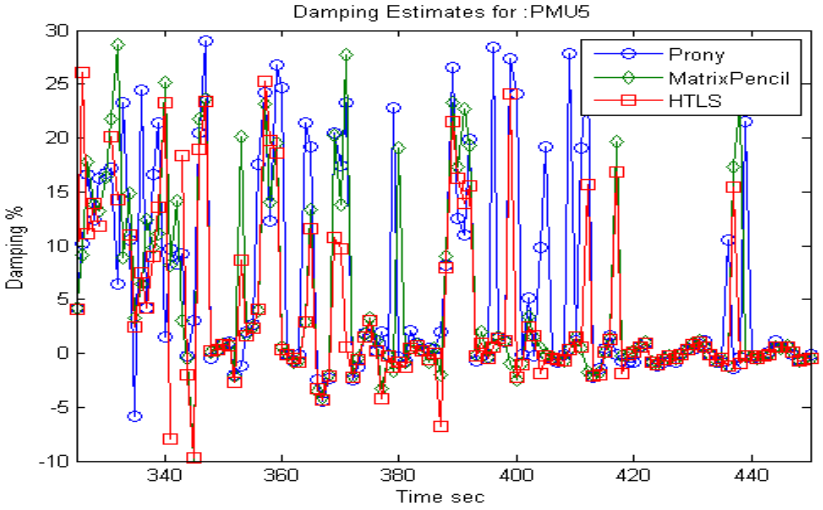
- Eastern System Event
- Local oscillations at a generating plant
- 1.18 Hz oscillations

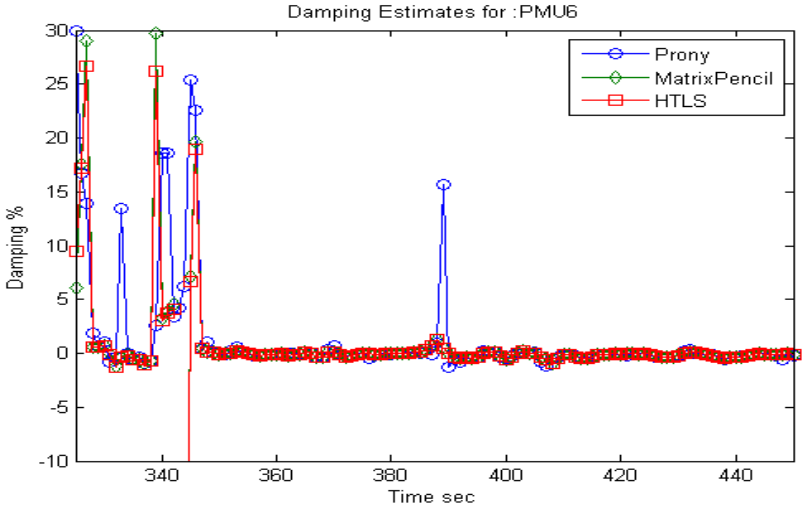


Case Study 1 – Local PMU Analysis





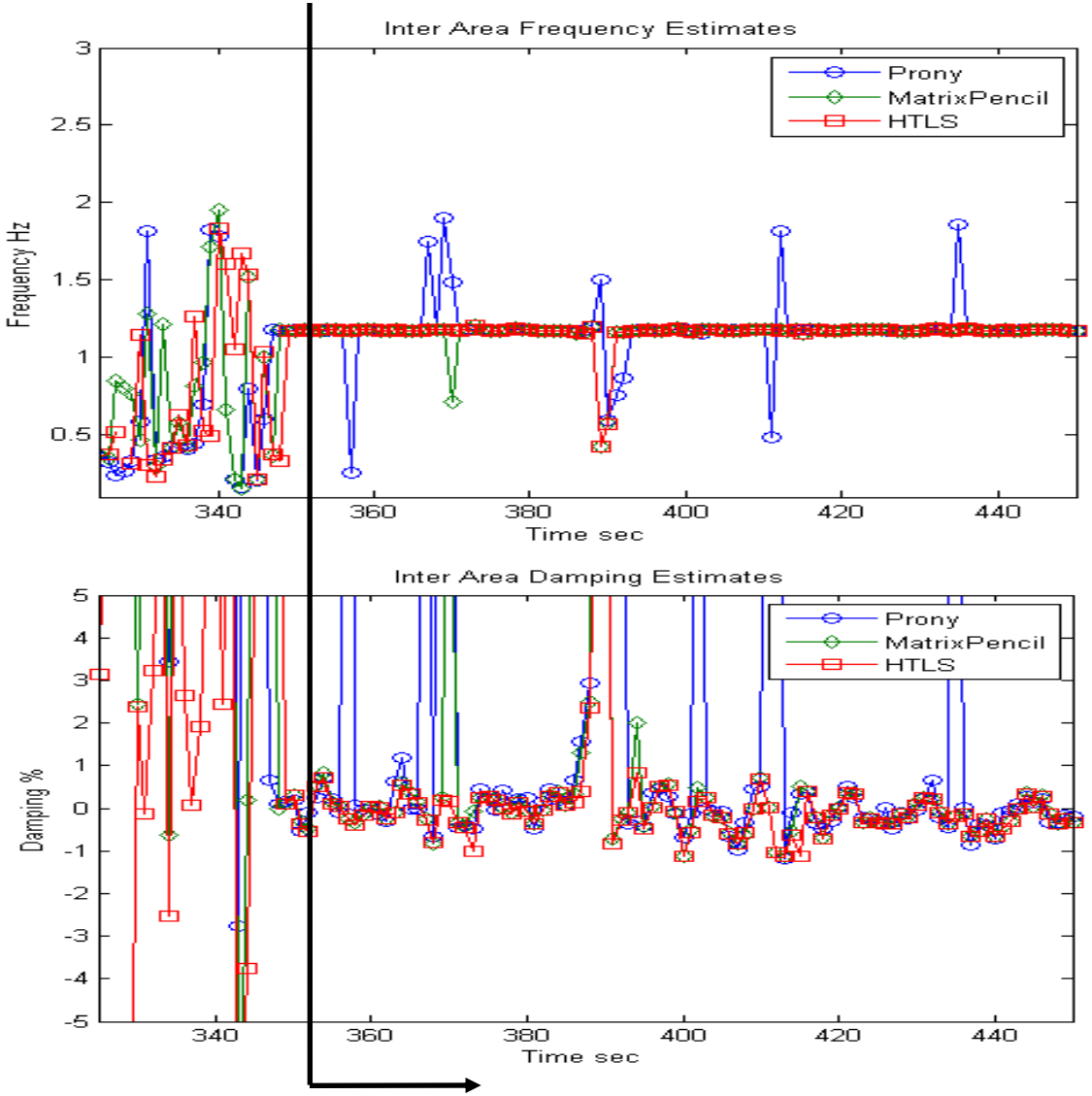




PMU5

PMU6

Case Study 1 – Multiple PMU Analysis

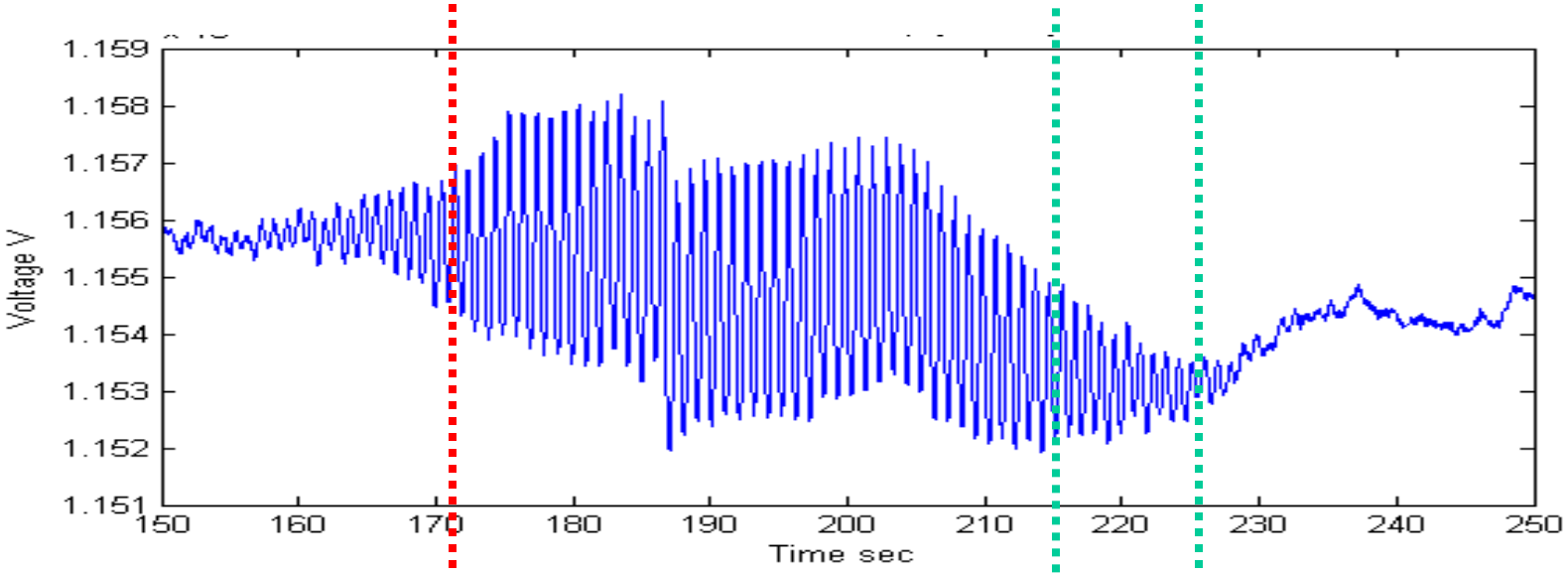


Consistent estimate at 352 sec

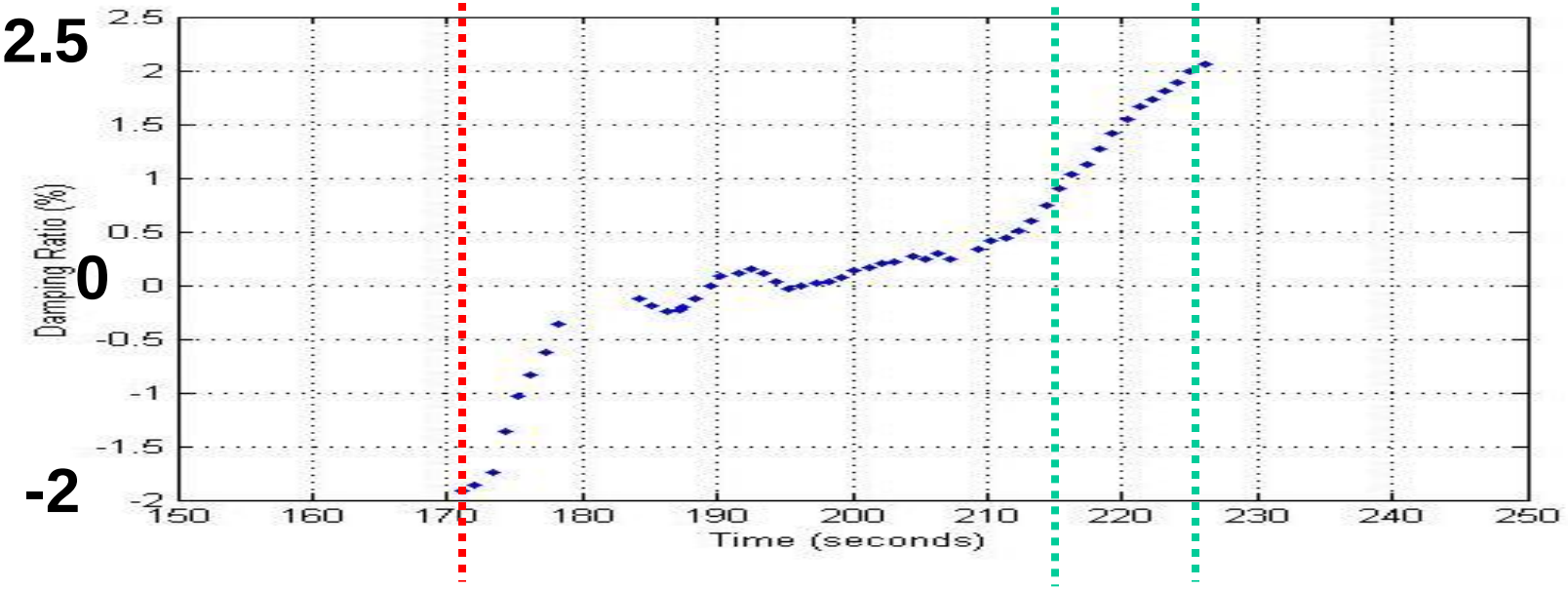
Oscillation frequency = 1.18 Hz

Mean damping ratio = 0.09%

Case Study 2 – Western event



PMU Bus Voltage



Event Analysis Damping Estimate