Oscillation Monitoring with the PI Server for Large Power Systems

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Project Objectives

- Oscillation Monitoring System for WECC and Entergy


- Damping Monitor Engine – ambient data analysis

- Event Analysis Engine – detection and analysis of ringdowns and oscillations

- Online and off-line engines with easy interfaces for the PI Server
Oscillation Monitoring System Online

OMS action adapters built into OpenPDC 64 bit version 2.1

IEEE C37.118
Real-time PMU data stream
Data stream

OMS

OpenPDC

SQL server
OMS results

PI Interface Adapter
PI Server
Stand alone fast oscillation analysis programs for analyzing large-scale PMU data directly from the PI Server.
Results from Two Engines

Event Analysis
1.2 Hz at +1.5% damping. Local Mode.

Ambient Noise Analysis
1.2 Hz at +1.8% damping. Local Mode.
Complementary Engines

- Event Analysis Engine (EAE)
  - Multiple algorithms
  - Prony, Matrix Pencil, HTLS, ERA, MFRA, METRA.
  - Aimed at events resulting in sudden changes in damping

- Damping Monitor Engine (DME)
  - Fast Frequency Domain Decomposition (FFDD), DFDO, Recursive Adaptive Stochastic Subspace Identification (RASSI), DFDD, RFDD, DRSSI, FSSI.
Damping Monitor Engine


- **Time-domain algorithms:**
  - Stochastic Subspace Identification (SSI-Covariance)
  - Recursive Adaptive Stochastic Subspace Identification (RASSI)
  - Distributed Recursive Stochastic Subspace Identification (DRSSI)
  - **Fast Stochastic Subspace Identification (FSSI)**

- **Frequency-domain algorithms:**
  - Fast Frequency Domain Decomposition (FFDD)
  - Distributed Frequency Domain Optimization (DFDO)
Fast Frequency Domain Decomposition (FFDD)

- Power spectrum estimation by FFT and Multi-Taper Method
- Apply SVD on the power spectrum
- Apply inverse FFT on largest singular values
- Extract pole frequency and damping ratio from exponential form by ringdown analysis
- Can process 1000+ signals simultaneously.
Turbo Oscillation Monitoring

- Can process truly large number of signals 1000+ simultaneously online.
- Offline mode: Can get a quick overview of system modal properties. Mode trends.
- An hour of data from 200 PMU signals can be analyzed in less than 2 minutes on a desktop
- Built using PI AFSDK. Easy Oscillation Analysis of Large-scale PI Server for PMU data
0.38 Hz WECC mode (poorly damped)
June 13th PSD Singular Values from WECC data
Mode Shapes on June 13, 2013

0.37 Hz at Near Zero Damping Ratio (7.30 am to 8.00 am)

0.4 Hz at Near 8% Damping Ratio (10 am to 11 am)
June 13th 0.37 Hz oscillations at Generator
Generator MW Oscillations

- Hydro operated in rough zone when wind power output high.
- Vortex effect in Francis turbine when water flow level is low
- 5 to 25 MW oscillations observed at 0.37 Hz
- Can potentially lead to resonance with system inter-area modes
- Mode shape analysis critical
- Multi-dimensional analysis crucial
Event Analysis Engine

Algorithms for oscillation monitoring

- Prony’s Method, Matrix Pencil Method, Hankel Total Least Square (HTLS), Eigenvalue Realization Algorithm (ERA)

Each algorithm has its own advantages and disadvantages

- Speed
- Noise performance

Consistent estimations needed for reliable estimation
Event Analysis Engine

WECC Event
PI Interfaces
PI Interfaces
PI Interfaces
PI Interfaces
Summary

- PMUs enabling technology for online oscillation analysis
- PI Server efficient storage of large-scale PMU data
- WSU oscillation monitoring engines provide efficient analysis of PI Server historical data
- Fast and easy extraction of historical PI Server data using custom interfaces
- Oscillation analysis of hundreds of PMU signals – fast and easy. Event detection, mode trends, mode shape trends…
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Questions

Please wait for the *microphone* before asking your questions

State your name & company
THANK YOU

Please contact mani@eecs.wsu.edu for information on WSU oscillation monitoring software for the PI Server.