Synchrophasor Solutions Deployment at PG&E Off-Line Analysis

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Outline

• Offline Engineering Applications at PG&E
• Post Event Analysis (May 30th Event)
• Dynamic Performance Baselining
• Dynamic DTS and Historical Playback
• Linear State Estimator (LSE)
Phasor Project High Level Architecture

(Redundancy not shown)

Engineering Environment

WECC or other external entities

60 phasors/s

Interface

Rugged Environment EDC Platform Engineering Applications

Network

EMS Environment

EMS Applications

EMS SuperPDC

PDC Function

Substation / Aggregate Site PDC

PMU

LAN

PMU Linear State Estimator (LSE)

Fault Location

Substation State Estimator

Post Event Analysis

Real-Time Voltage Instability Monitoring

Other Utilities

Other Subs

Other PG&E Internal users

DAS

DAS Server (PP)

M60, P60 (2 ASDU, 1 plus 1), Multicast

{P120 option available}

P120 and event outcome data

Authentication

PG&E Active Directory

EMS Applications

Other Subs

Other Utilities

Substation level applications and Visualization

PMU

LAN

DFR (as needed)

M & P Class

PMU

Multi-function PMU-based device

M & P Class

M & P Class

PMU

LAN

M & P Class

PMU

Substation State Estimator

Fault Location

PMU Linear State Estimator (LSE)

Substation / Aggregate Site PDC

PDC Function

Substation level applications and Visualization

Post Event Analysis

Real-Time Voltage Instability Monitoring

PMU Linear State Estimator (LSE)

Fault Location

-M class not to exceed 60 phasors/s.
- P class 10 to 120 phasors/s not-filtered.
Offline Engineering Analysis Use Cases

Leveraging WAMS in Operations Planning

Post Event Analysis
- Quicker post-mortem analysis.
- Sequence of events & root cause analysis.

Dynamic Model Validation
- Dynamic model verification.
- Generator model calibration.
- Load characterization.

Baselining
- Assess dynamic performance of the grid.
- Steady-state angular Measurements
- System and asset performance analysis
- System disturbance impact measures

Compliance Monitoring
- Primary frequency (governing) response.
- Power System Stabilizer (PSS) tuning

Synchrophasor benefits for Post-Event Analysis

Phasor data are also valuable for investigation of grid disturbances, improving both the speed and quality of analysis.

In the case of the 2007 Florida blackout, NERC investigators used phasor data to create the sequence of events and determine the cause of the blackout in only two days; in contrast, lacking high-speed, time-synchronized disturbance data it took many engineer years of labor to compile a correct sequence of events for the 2003 blackout in the Northeast U.S. and Ontario.

Post Event Analysis

May 30th, 2013 Event
Overview of May 30, 2013 Event

- 2000MW Automatic Gen drop
- Celilo-Sylmar DC Intertie restarted
- Frequency recovered
- Series and Shunt Capacitors bypassed
- Series Capacitors inserted
Time of Event (22:55 – 22:59 UTC)

Celilo-Sylmar DC Intertie restarted

2000MW Gen drop

Series and Shunt Capacitors inserted
Time of Event (23:00 – 23:12 UTC)

Series Capacitors bypassed

Shunt Capacitors removed
Ringdown Analysis – PDCI block/restart

Oscillation mostly at 0.38Hz mode

- Using HTLS algorithm.
- Processed @ 5 samples/second.
- Sorted by proprietary index (RI).
- First voltage swing not considered.
Damping of 0.38 Hz improves

- Using HTLS algorithm.
- Processed @ 5 samples/second.
- Sorted by proprietary index (RI).
- First couple voltage swings not considered.

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<th>Mag</th>
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M and P Class Data

The image shows a graph with two sets of data: M Class Data and P Class Data. The graph plots frequency (Hz) against time. The M Class Data is represented by green dots and the P Class Data by blue dots. The graph also shows time in AM and PM formats.
Spectral Estimation – M-Class

- Phasor reported once every cycle – 60 phasors/sec.
- More accurate phasors.

Frequency axis shown up to 24Hz.
Spectral Estimation – P-Class

- Phasor reported once half cycle – 120 phasors/sec.
  - Double freq. resolution as M-class.
- Captures faster dynamics – more high frequency content.

Local and inter-area modes
Unknown dynamics
MORE unknown dynamics
No information here!

Not available in M-class data

Frequency axis shown up to 48Hz.
Baselining

Dynamic Performance
Questions we are looking to answer are:

- **What** oscillatory modes are we seeing in our system (governor, inter-area, local, forced, etc)?

- **Where** (i.e. location) are we seeing these oscillatory modes and their ‘typical’ damping and amplitude (MW, mHz, etc).

- **When** are we seeing ‘dangerous’ oscillations (i.e. outliers)?

- **How** are these correlated with control actions (i.e. MW flows)?
Dynamic Performance Baselining Example

Histogram of observed modes (48 hour dataset)
Dynamic Performance Baselining Example

Focus on Sub-band (0.25-0.30 Hz)
Locus of particular oscillatory mode (to identify outliers)
Dynamic Performance Baselining Example

Legend by Locations

Large Amplitude Oscillations
Spectrogram of mode trends
Dynamic DTS and Playback

Training Environment
Dynamic DTS and Historical Playback

**Dynamic Simulation (DynTS)**

- DynTS Initialization
- Topology Processor
- Relay Processor
- Power Flow Solution
  - SCADA Scapi
  - C37.118 Generator

**Historical Playback**

- HDR
  - PhasorPoint Historian

**Simulation/Playback Environment**

- COMTRADE / HDR / TSAT Bin Files
  - Real Time Streaming Data
  - On Demand Offline Data

**Real-Time Applications**

- PhasorPoint
  - Web Services
  - SCADA
  - RTNET
  - GSA
  - VSAT
  - TSAT
  - PowerTech

- PhasorPoint Historian
  - Alarm System
  - QKNET
  - RTDCP

**Offline Applications**

- PhasorAnalytics
  - Post Disturbance
  - Model Validation
  - Baselining
LSE Application

Network model from EMS

Static database (Read once when LSE starts)

Control Center Topology Processor

Control Center LSE

LSE output to EMS

PMU data OpenPDC

Real time database

Breaker status (EMS)
LSE Test – In EMS Environment

LSE Input Measurement Magnitude Chart

LSE Estimated Measurement Magnitude Chart

Time

15:00 10 October 2013
Framework – Parallel State Estimator

State Estimator

- Network model (without PMUs)
- Network model (with PMUs)

SCADA (with PMUs)

Parallel State Estimator

Compare both Solutions