LSE for Synchrophasor Data Quality – Implementation and Performance at BPA

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Outline

- **WECC Synchrophasor Data Validation and Conditioning Application (SDVCA)**
  - Project Overview
  - Modeless Validation and Conditioning
  - Model-based Conditioning - LSE

- **EPG Enhanced Linear State Estimator (eLSE)**
  - Enhancements
  - eLSE Model Builder
  - Historical Data Testing

- **BPA Field Testing and Results**
  - BPA Testing Environment
  - Live Data Testing with ICCP Integration

- **Lesson Learned and Future Work**
Objective is to develop a validation and conditioning application of PMU data for WECC utilities

Specified to include validation & conditioning using:
  > Modeless algorithms
  > Model Based Linear State Estimator (LSE)

Modeless approach uses the algorithms developed under a DOE sponsored project
  > EPG was the contractor for this project

Model based approach uses the LSE
  > Enhanced VT/Dominion LSE code

Test and demonstration at BPA
  > Test site arranged by WECC
  > Historical data testing using archived data
  > Real-time data testing using a live data feed
Modeless & LSE-Based Data Validation and Conditioning

Algorithms = Detect and Flag Bad Data

Input: Raw C37.118

Model-Less/Algorithmic Validation & Conditioning

Data Quality Reports

Data Quality flags

Model-less conditioned C37.118

Linear State Estimator = Replace Bad Data with Validated Model Based Values

Output Selection

LSE-Based Conditioning

LSE-conditioned C37.118

Output: Conditioned C37.118

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Modeless Validation and Conditioning

- **Modeless Error Detection**
  - Communication problems (format, CRC, etc. errors)
  - Problems in measurement (37.118 flags)
  - Timing errors and anomalies
  - Severe measurement anomalies (out of range values)
  - Measurement mismatch (topology comparisons)

- **Modeless Conditioning**
  - Flags bad or suspect values
  - Replace with user set value (NaN, last good, set number)
Model Based Conditioning – LSE

- Network Model (CIM format)
  - Converted into LSE format model
- PMU Data
  - Real-time or recorded
- Topology Info
  - From EMS or recorded

**Diagram:**

- **C37.118 PMU data**
- **Topology Information**
- **LSE Application**
- **Utility Network Model (CIM)**
  - Estimated Synchrophasor Data
  - Virtual PMU’s with Estimated Values
  - List of Measurement Anomalies
EPG’s eLSE and Major Enhancements

- EPG started with this open source code and developed a production grade eLSE that incorporates enhancements to operate on complex systems such as the WECC/BPA system.

- Seven major enhancements
  - Bad data detection and identification module
  - Series Capacitor
  - Shunt capacitor/reactor
  - Split bus
  - Naming convention
  - Bypass breaker modeled in line
  - Breaker status interface to accept Inter-Control Center Communications Protocol (ICCP)
eLSE Network Model Builder – Four Major Components

- Automatic CIM parsing engine
  > Parse the CIM model and convert it to LSE model

- Mapping File Creation
  > Mapping PMU signals to LSE model

- Signal mapping engine
  > Read the mapping file and automatically map PMU signal to the LSE model

- GUI of network model builder
  > Edit network model, eg add or remove lines, breakers
  > Update models
Field Testing on BPA System
65 Observable Substations with PMUs at 37 Substations

- Validated for BPA’s entire 500 kV and portion of 230 kV system
- System reduced to PMU visible area
  > 37 Substations with PMU installed
  > 220 phasor measurements
  > 65 observable substations
- Run properly at 60 frames per second
- Testing with historical and live PMU data

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Historical Event Testing Results

- Chief Joseph Brake event

Chief Joseph 500 kV East Bus Voltage Magnitude

LSE Estimated  
Raw PMU measurement

2kV
• SDVCA replaces measured values with state estimates
• Estimates stored in temporary LSE Data Archive
• Estimate compared to raw signal for reasonability
Live Data Testing Result – 17 hours
With Real-Time ICCP Update

White: SDVCA       Red: Phase A       Blue: Phase B       Green: Phase C
Recent Live Data Testing Result - 24 hours

With Real-Time ICCP Update

White: SDVCA
Red: Raw
Recent Live Data Testing Result – another 24 hours
With Real-Time ICCP Update

White: SDVCA
Red: Raw
Lessons Learned

- **Standard CIM Model**
  > “Common” information model, NOT common, customization required

- **Network parameters**
  > Critical for LSE estimated results

- **Good redundancy of measurements**
  > Help detect bad data and give better estimated results

- **PMU digitals for breaker status, instead of using ICCP**
  > No time skew issue if using PMU digitals
Future Work

- Continue long term testing
- Automate comparison of estimate vs. raw data
  - Flag large differences, trace to issues in field
- Pursue issues with network model parameters
  - Update models as necessary
- Test applications using conditioned data
- Investigate use of LSE in operational environment
Thank You - Questions?

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