Summary of EPRI Synchrophasor Related Activities

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Synchrophasor Data System & Applications

1. Streaming Data Infrastructure and Data Management
2. Data Quality Monitoring and Mitigation of Streaming Synchrophasor Measurements
3. PMU Emulator
4. Synchrophasor-Based Wide Area Oscillations Damping Controller
5. Voltage Sensitive Static ZIP Load Model Using Synchrophasor Data
1. Streaming Data Infrastructure and Data Management

- The program benefit is to provide operators and asset managers more time to mitigate the abnormal conditions leading to improved reliability.
  - Improve transport and management of streaming data
  - Increase knowledge of storage, usage, and archiving issues.

- Investigating Data Transfer issues
  - Coordinating with NASPnet 2.0 review
  - Supporting Grid Protection Alliance on STTP project with DOE
  - Purpose built protocol designed to transfer PMU data especially from control center
  - ASP will be purpose built for high-volume streaming data with rich data types and detailed associated metadata
2. Data Quality Monitoring and Mitigation of Streaming Synchrophasor Measurements

- **Goal:** Improve synchrophasor data quality by estimating missing data and replacing bad data in synchrophasor streams
- **Model free technique, no need for topology information or system parameters**
- **Computationally efficient for real-time implementation**
- **Performs well for simultaneous & consecutive missing data conditions**
Streaming Synchrophasor Data Quality (SSDQ) Software

**Offline Application**

- Algorithms are being tested with recorded synchrophasor data provided by EPRI members
- Next: Demos with streaming synchrophasor data hosted by utilities/ISOs
- Next: Collaboration with vendors for implementation in commercial platforms

**Real-Time Application**

- OpenPDC Server to simulate ISO PDC
- IEEE C37.118 stream
- SSDQ Algorithms in OpenPDC

- Algorithms are being tested with recorded synchrophasor data provided by EPRI members
- Next: Demos with streaming synchrophasor data hosted by utilities/ISOs
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3. PMU Emulator

- Phasor values obtained from dynamic simulation tools may differ from synchrophasors measured by PMUs in the field.

- How a PMU works:
  - Analog signal sampling - A/D Conversion
  - Digital filtering → magnitude attenuation & phase offset
  - Phasor estimation
    - algorithm e.g. DFT
    - window length - P & M class PMUs

- PMU Emulator: interfaced with power system dynamics simulators, and produces “simulated synchrophasors” taking into account PMUs internal signal processing.
PMU Emulator

M-Class - 15 cycles window

- **Proof-of-concept software**

- **Hardware-In-the-Loop benchmarking (RTDS & hardware PMUs)**
- Use cases: Model validation, synchrophasor applications offline testing (especially control applications), operator training, etc
- Vendor PMU library – NASPI may facilitate?
- Next: Collaboration with vendors for implementation in commercial platforms
4. Synchrophasor-Based Wide Area Oscillations Damping Controller

- Improved Damping of Target Inter-area/Intra-area Oscillations Mode
- Application of Synchrophasor Technology in Closed Loop Wide Area Control

![Diagram of WADC and PMU with graph comparing control effectiveness]
Wide Area Oscillations Damping Controller

- WADC via additional input to generator excitation system or FACTS/HVDC controller
- Adaptive controller
  - Measurement-derived transfer function model
- Ongoing case studies with NYPA and Terna
- Hardware-In-the-Loop implementation
  - Measurement delays
  - Missing/Bad data

CURENT/UTK Hardware Testbed

PSS/E User Defined Model
5. Voltage Sensitive Static ZIP Load Model Using Synchrophasor Data

- Develop Analytical Tools to Determine Voltage Sensitivity of Local Loads
  - Use Synchrophasor data for Bus voltage & Load at the critical bus
  - Filter out random noise & bad data
  - Determine appropriate Measurement Window required

- Represent Voltage Sensitivity of Load as a ZIP Load Model
  \[
  P_{ZIP} = P_0 \left[ A \left( \frac{V}{V_0} \right)^2 + B \left( \frac{V}{V_0} \right) + C \right] \\
  Q_{ZIP} = Q_0 \left[ D \left( \frac{V}{V_0} \right)^2 + E \left( \frac{V}{V_0} \right) + F \right]
  \]
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