Summary of EPRI Synchrophasor Related Activities

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1. 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

- Adaptive controller
  - Measurement-derived transfer function model (Probing signal or ringdown data)

- Ongoing case studies with NYPA, TERNA (Italy) & SEC (Saudi Arabia)

- Hardware-In-the-Loop implementation
  - Measurement delays
  - Missing/Bad data

In collaboration with University Tennessee Knoxville (UTK)

- Improved Damping of Target Inter-area/Intra-area Oscillations Mode
- Application of Synchrophasor Technology in Closed Loop Wide Area Control
2. Data Mining and Machine Learning Techniques Using Synchrophasor Data

- Data mining/pattern recognition/machine learning techniques that use streaming synchrophasor data to:
  - Identify Events
  - Classify secure vs insecure operating conditions
  - Provide guidance to operators for potential mitigation actions
  - Define metrics as precursors of system insecurity
  - Define system performance indicators (Grid Health Index)

Value: Increased System Reliability Through Advanced Situational Awareness
3. 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
  \[ P_{ZIP} = P_0 \left[ A \left( \frac{V}{V_0} \right)^2 + B \left( \frac{V}{V_0} \right) + C \right] \]
  \[ Q_{ZIP} = Q_0 \left[ D \left( \frac{V}{V_0} \right)^2 + E \left( \frac{V}{V_0} \right) + F \right] \]

In collaboration with WSU
4. 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
  - 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
5. 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.

- 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
- Next: Collaboration with vendors for implementation in commercial platforms
6. Synchrophasor Applications Database

• Entries based on publicly available documents – including NASPI material
• For each entry, summary description of application and related references
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