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Summary of EPRI Synchrophasor Related Activities

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NASPI WG Meeting
Albuquerque, NM
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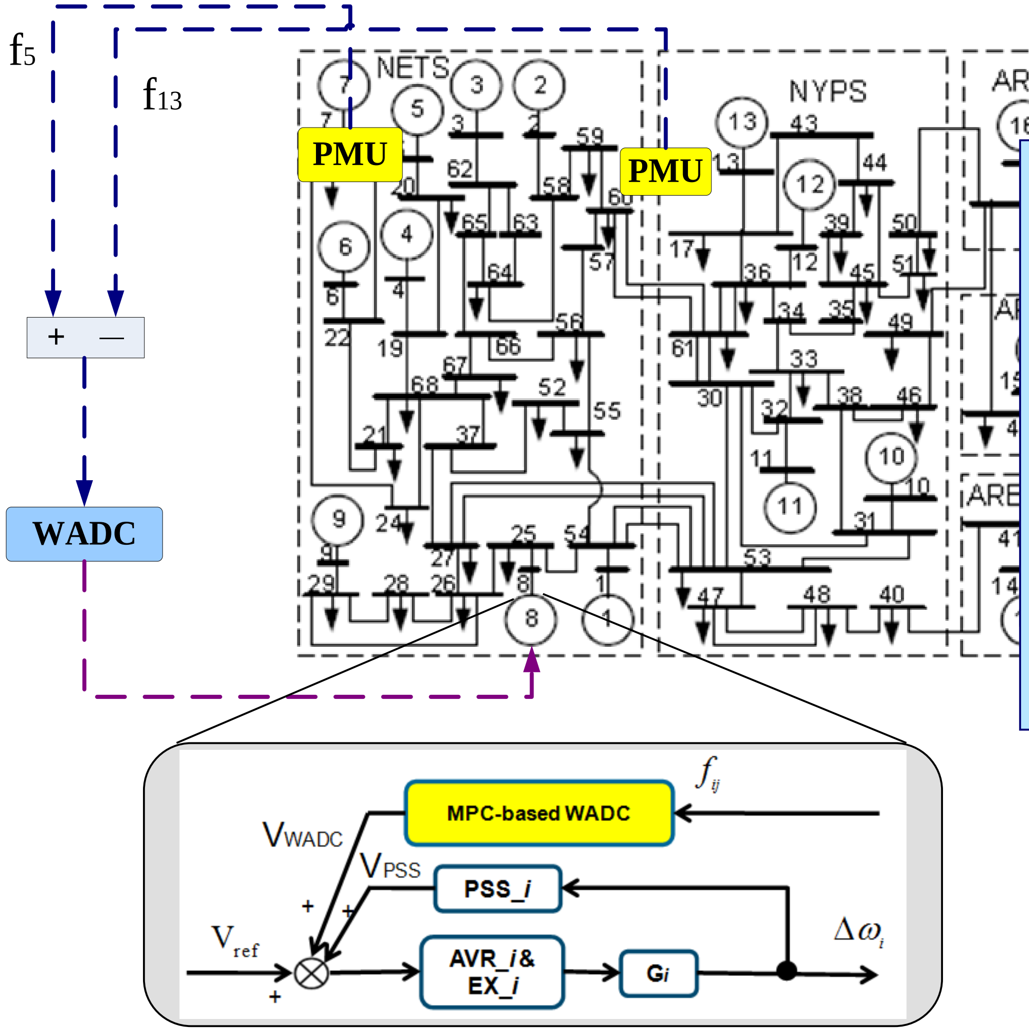
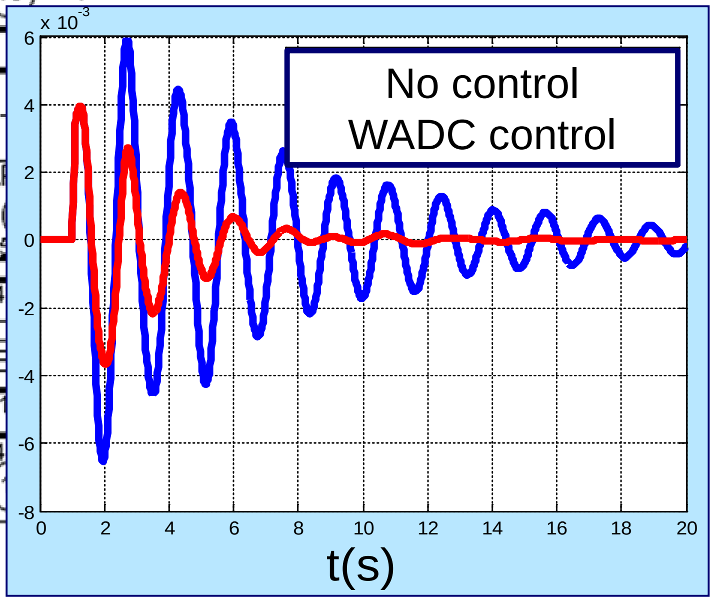
1. Synchrophasor-Based Wide Area Oscillations Damping Controller



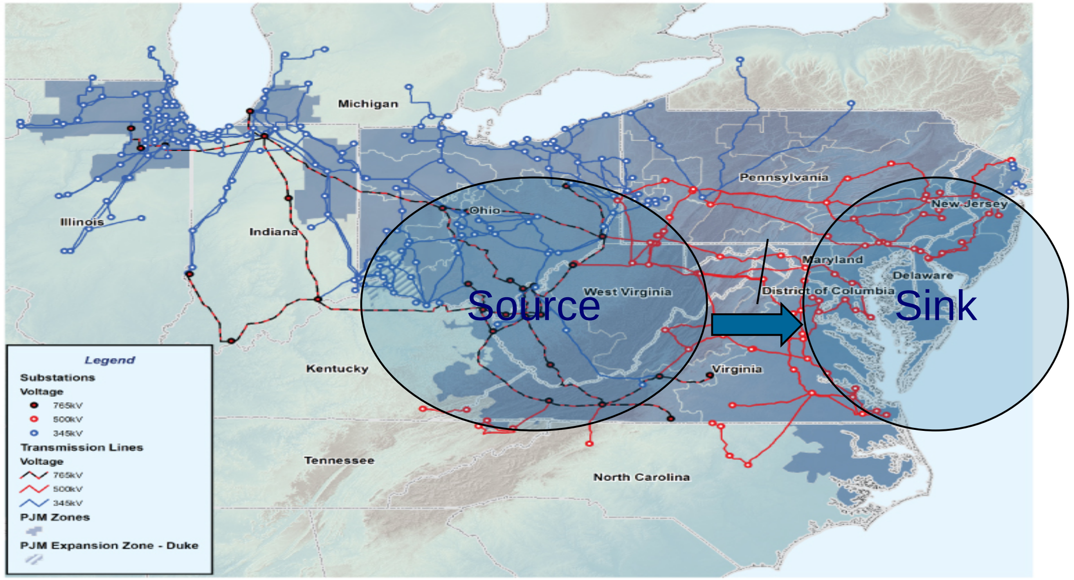


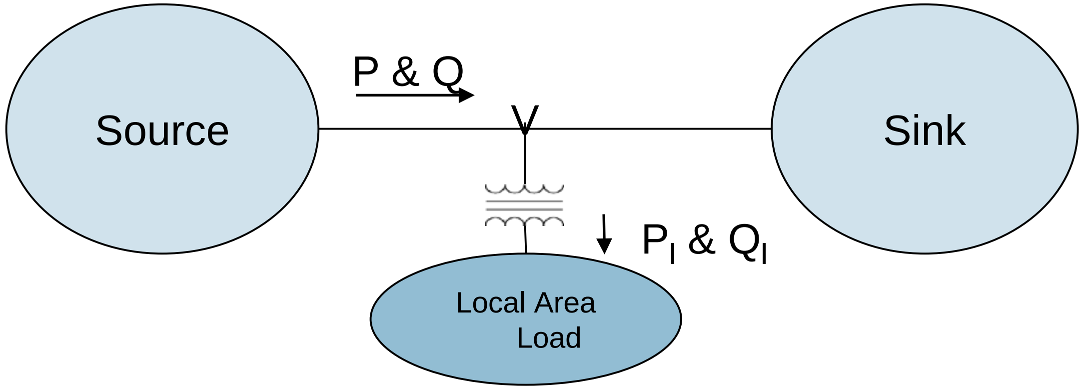
In collaboration with University Tennessee Knoxville (UTK)

- WADC via additional input to generator excitation system or FACTS/HVDC controller
- Adaptive controller
  - Measurement-derived transfer function model
- Ongoing case studies with NYPA, TERNA (Italy) & SEC (Saudi Arabia)
- Hardware-In-the-Loop implementation
  - Measurement delays
  - Missing/Bad data

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

2. Voltage Sensitive Static ZIP Load Model Using Synchrophasor Data



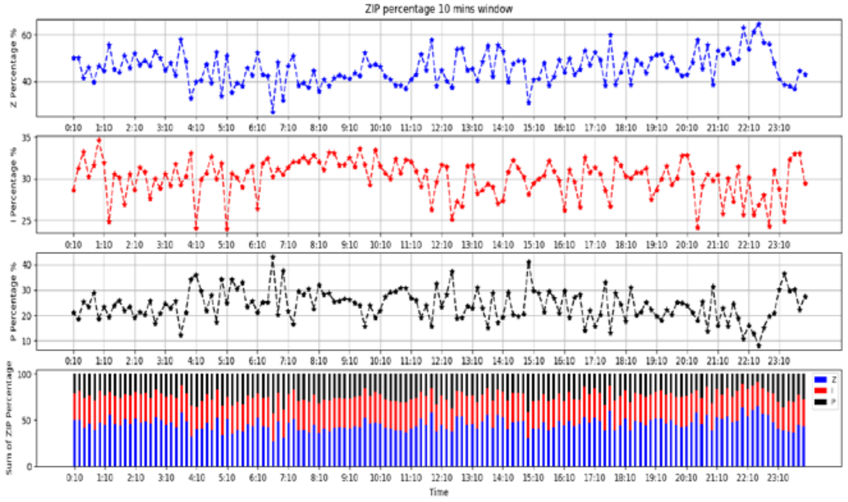


Proof-of-concept software

- 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

$$P_{ZIP}=P_0\,[A\,(V/V_0)^2 + B\,(V/V_0) + C]$$

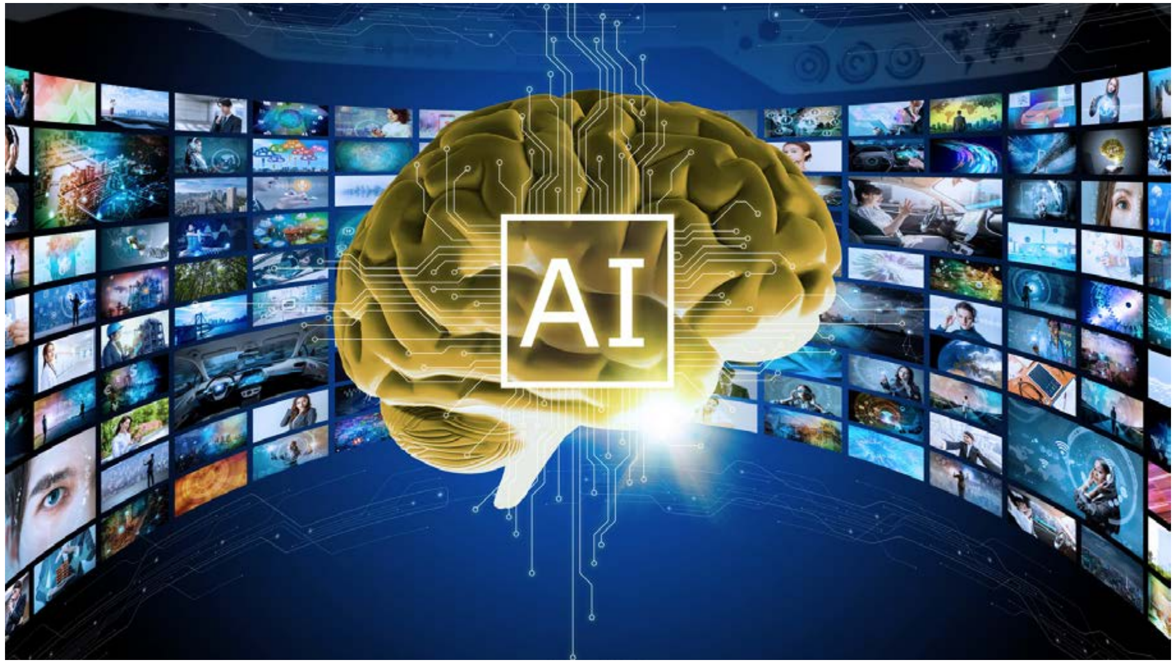
$$Q_{ZIP}=Q_0\,[D\,(V/V_0)^2 + E\,(V/V_0) + F]$$



In collaboration with WSU

3. Data Mining and Machine Learning Techniques Using Synchrophasor Data

- Data mining/pattern recognition/machine learning techniques that use streaming synchrophasor data to:
  - Characterize in a near real-time environment the operating condition of the system
  - Classify secure vs insecure operating conditions
  - Identify events
  - Perform early-event detection
  - 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

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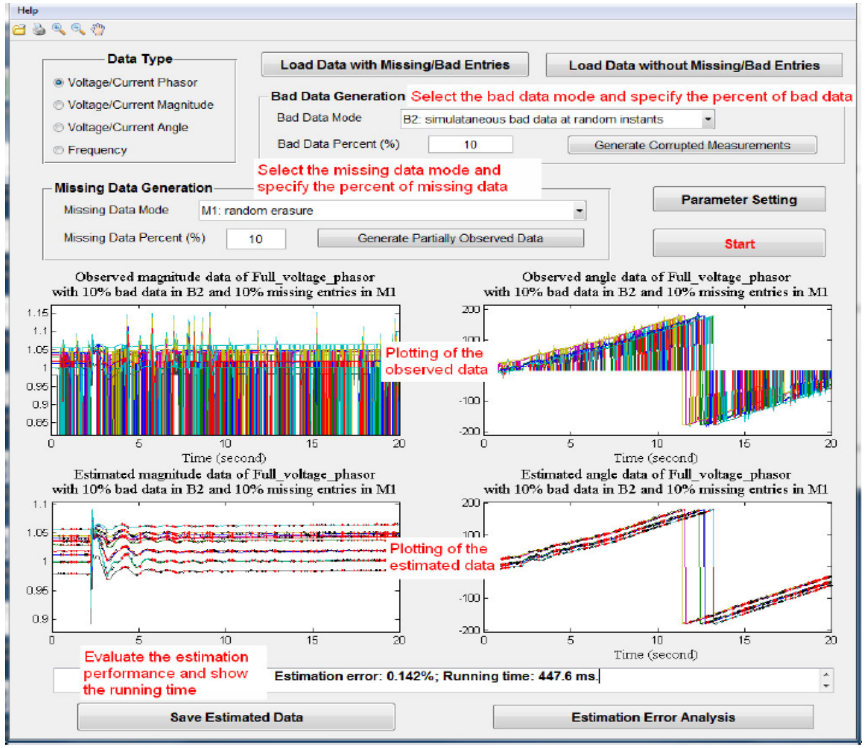
4. Data Quality Monitoring and Mitigation of Streaming Synchrophasor Measurements

- 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

Offline Tool



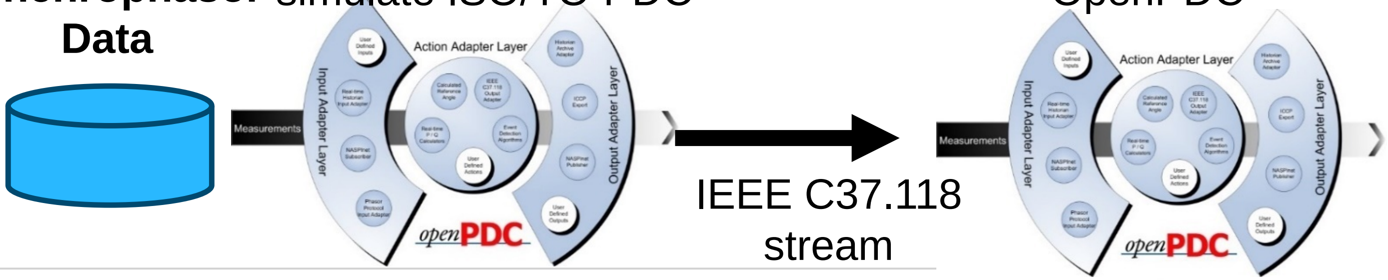
In collaboration with RPI

Online Tool

Synchrophasor Data

OpenPDC Server to simulate ISO/TO PDC

SSDQ Algorithms in OpenPDC



IEEE C37.118 stream

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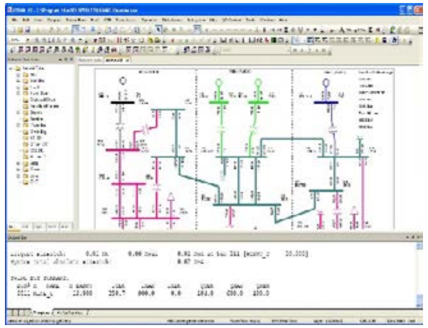
5. PMU Emulator

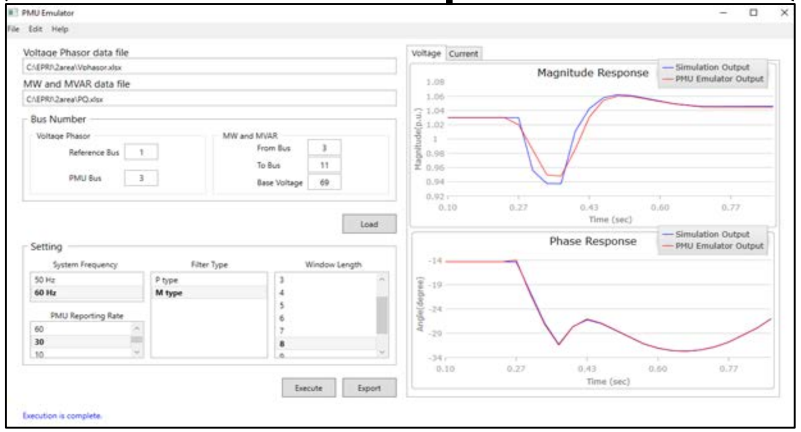
- Phasor values obtained from dynamic simulation tools may differ from synchrophasors measured by PMUs in the field
- How a PMU works:
  - Analog signal sampling - A/D Conversion
  - Digital filtering → magnitude attenuation & phase offset
  - Phasor estimation
    - algorithm e.g. DFT
    - window length - P & M class PMUs
- PMU Emulator: interfaced with power system dynamics simulators, and produces "simulated synchrophasors" taking into account PMUs internal signal processing

Dynamics Simulation Software (PSS/E, PSLF, TSAT etc.)



Simulated Phasors → **PMU Emulator** → C37.118 → **Synchrophasor Application**

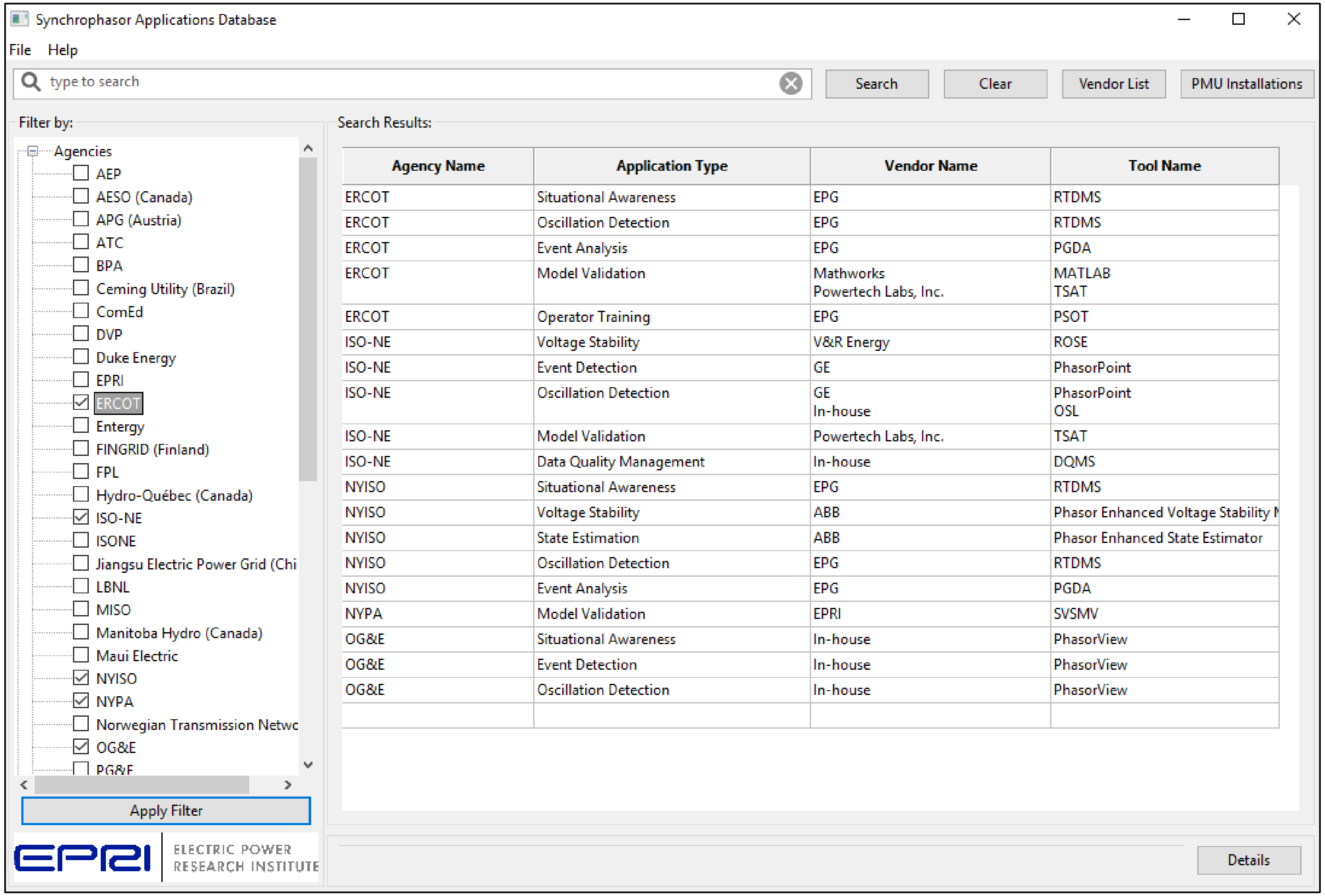
Proof-of-concept software

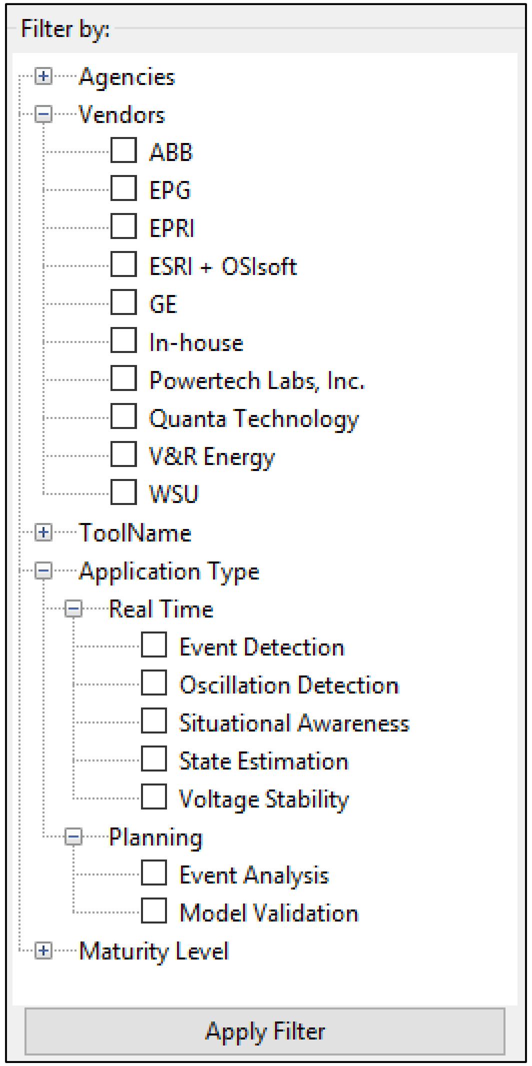


In collaboration with WSU

- 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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