Summary of EPRI Synchrophasor Related Activities

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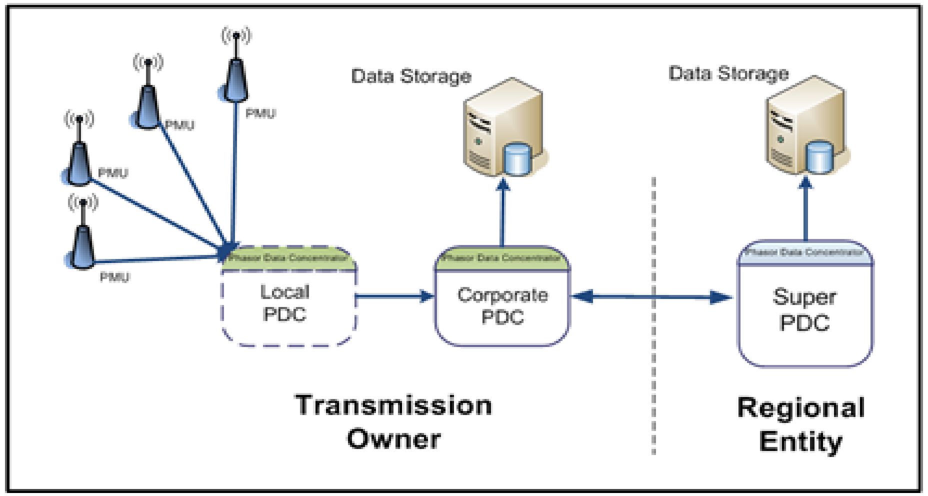
Synchrophasor Data System & Applications

Synchrophasor Data System



Synchrophasor 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

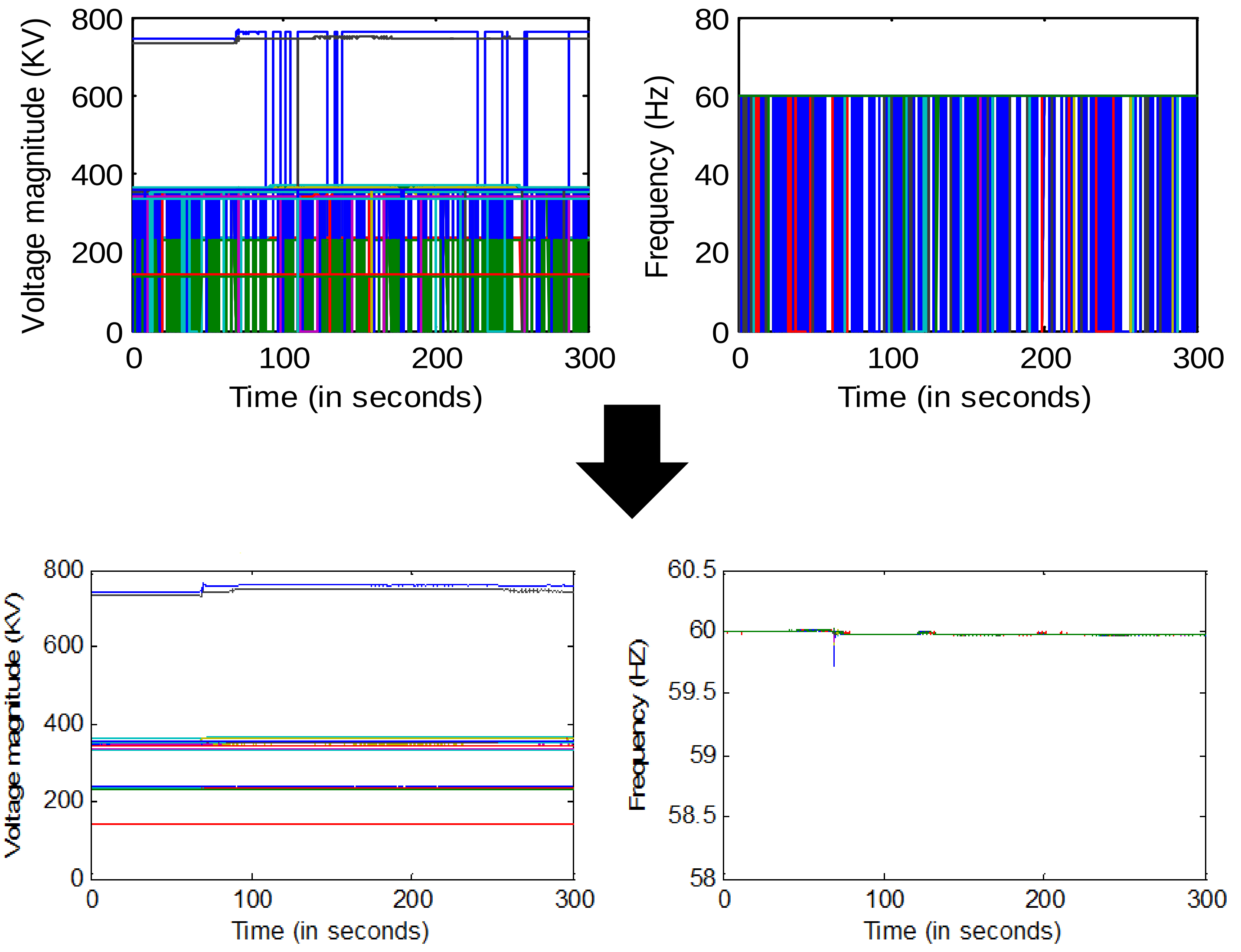
1. Streaming Data Infrastructure and Data Management

- 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

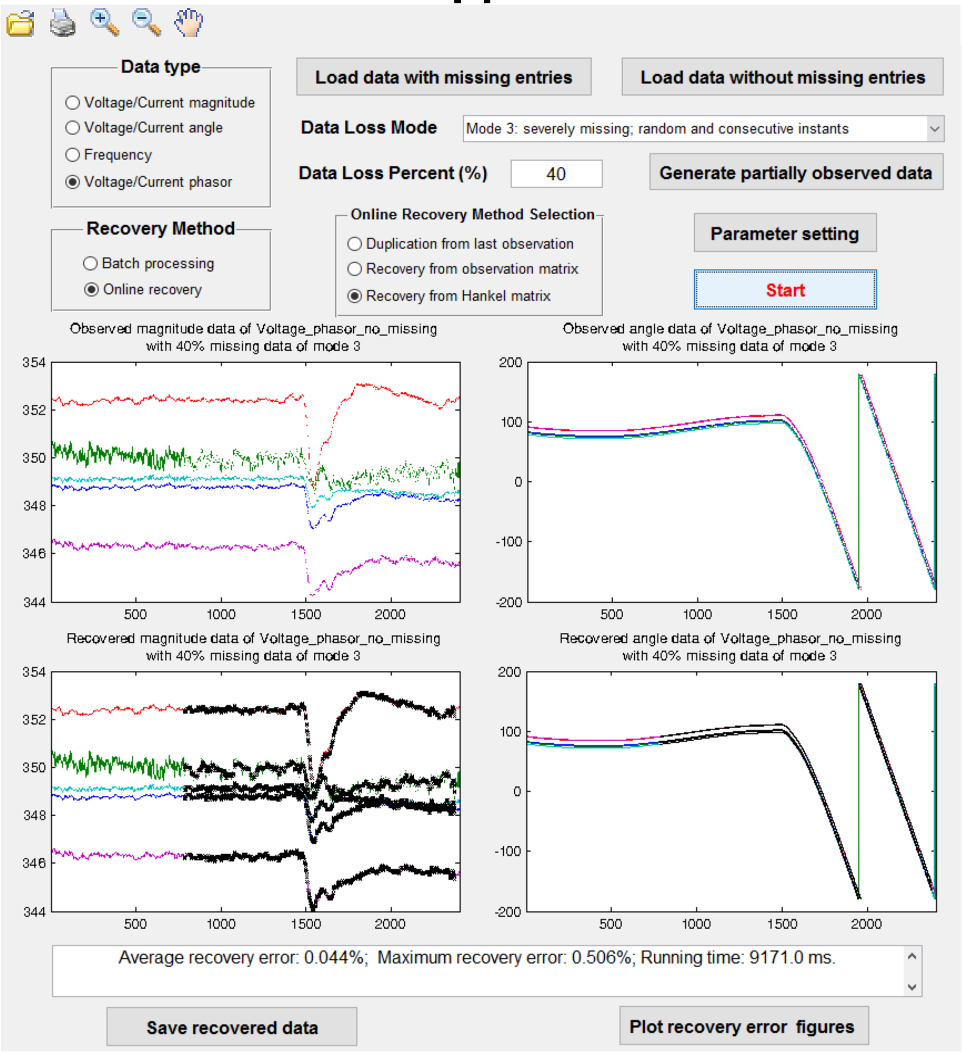
2. Data Quality Monitoring and Mitigation of Streaming Synchrophasor Measurements

- 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



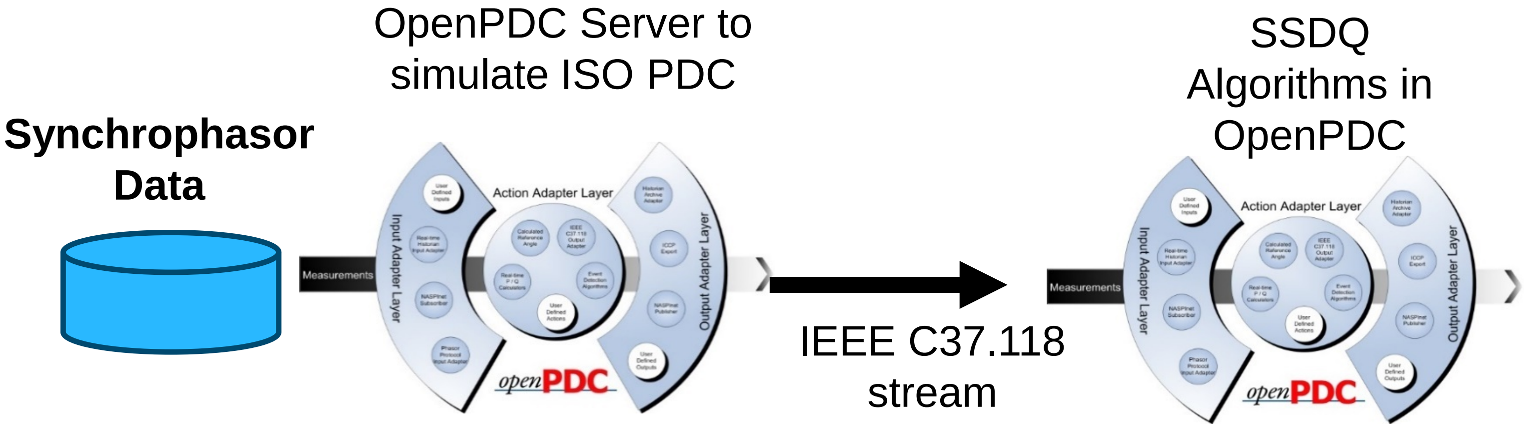
Streaming Synchrophasor Data Quality (SSDQ) Software

Offline Application



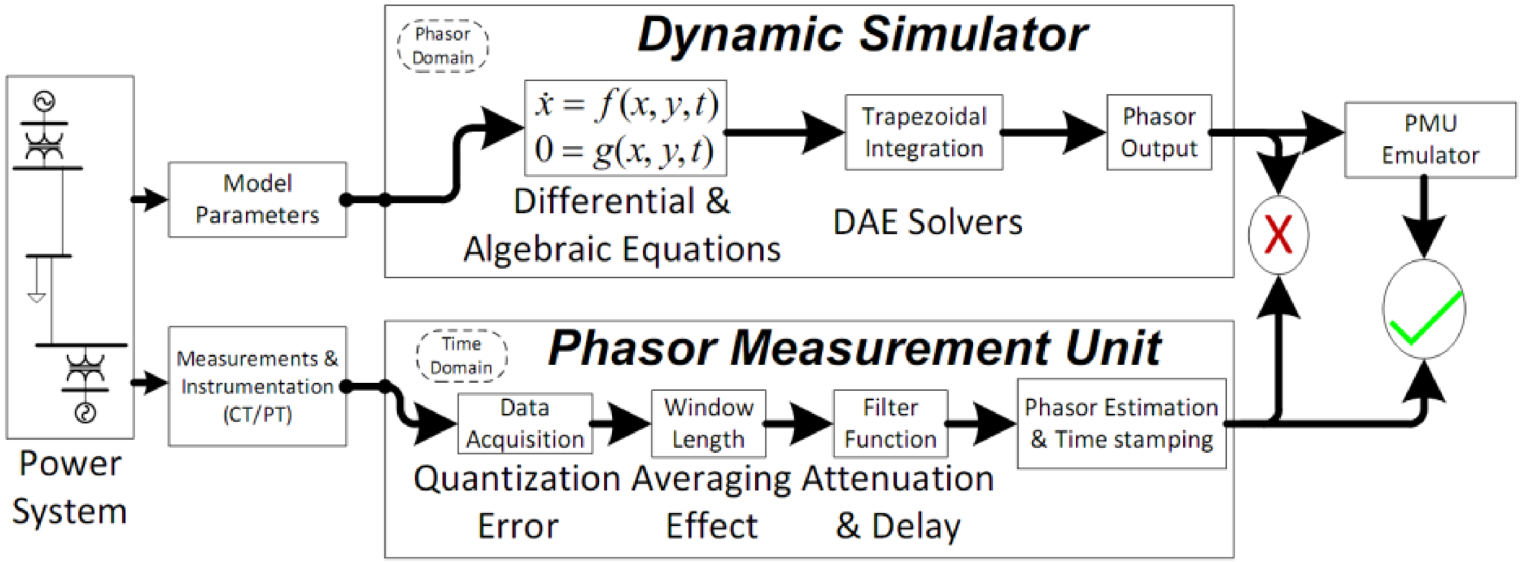
- Algorithms are being tested with recorded synchrophasor data provided by EPRI members
- Next: Demos with streaming synchrophasor data hosted by utilities/ISOs
- Next: Collaboration with vendors for implementation in commercial platforms

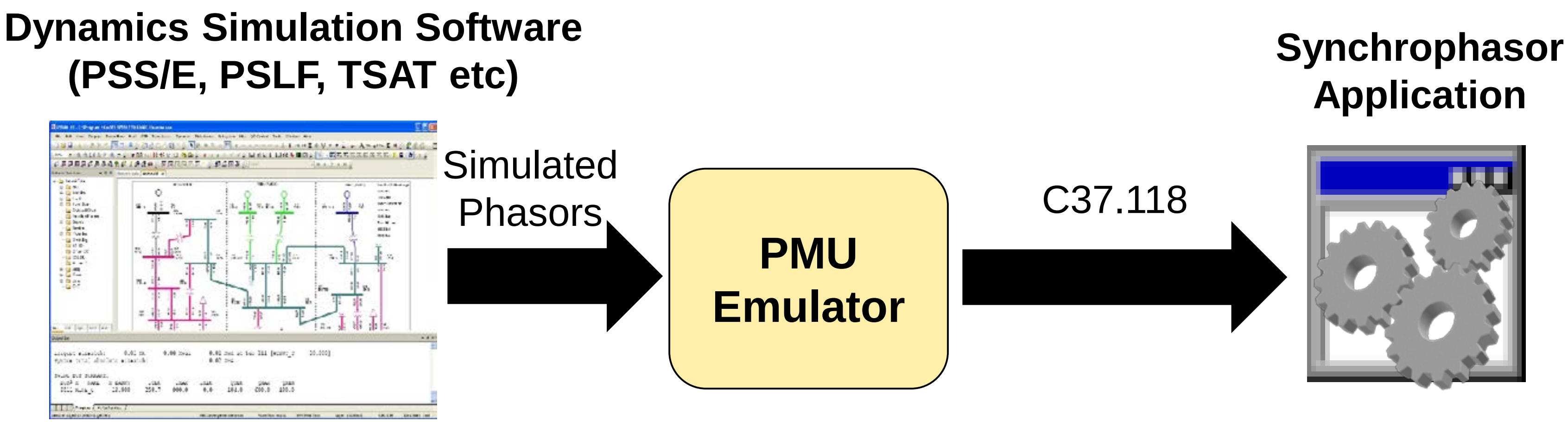
Real-Time Application



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





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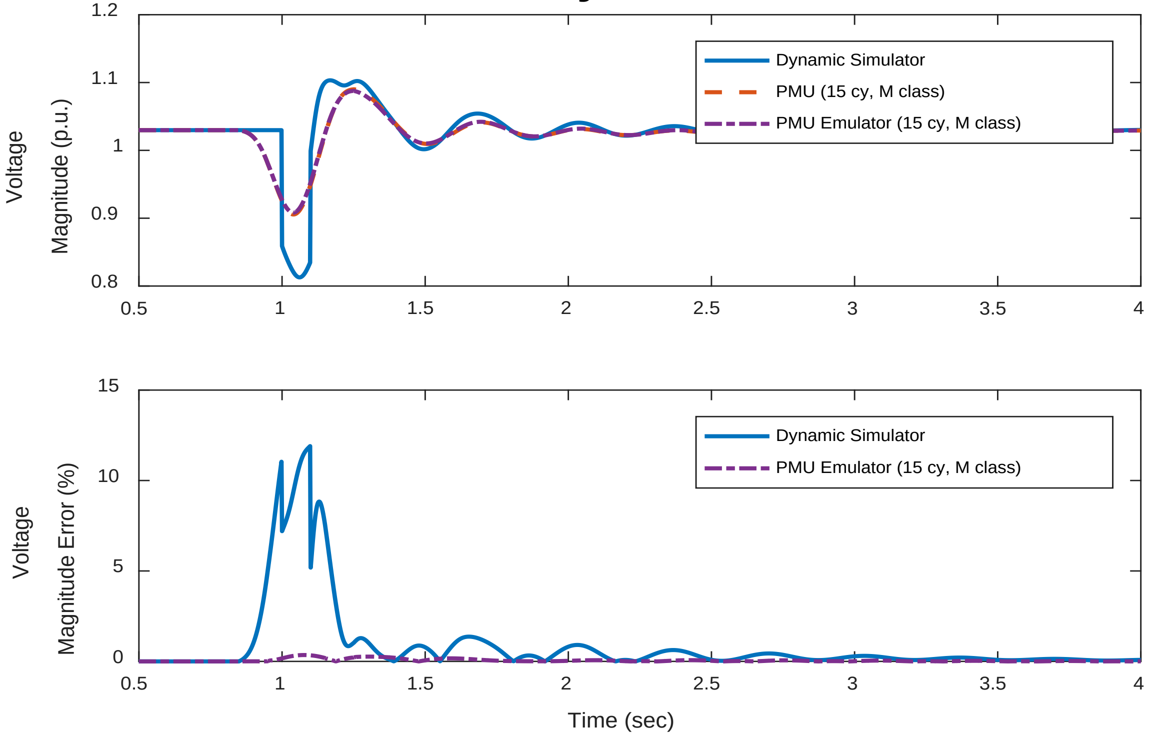
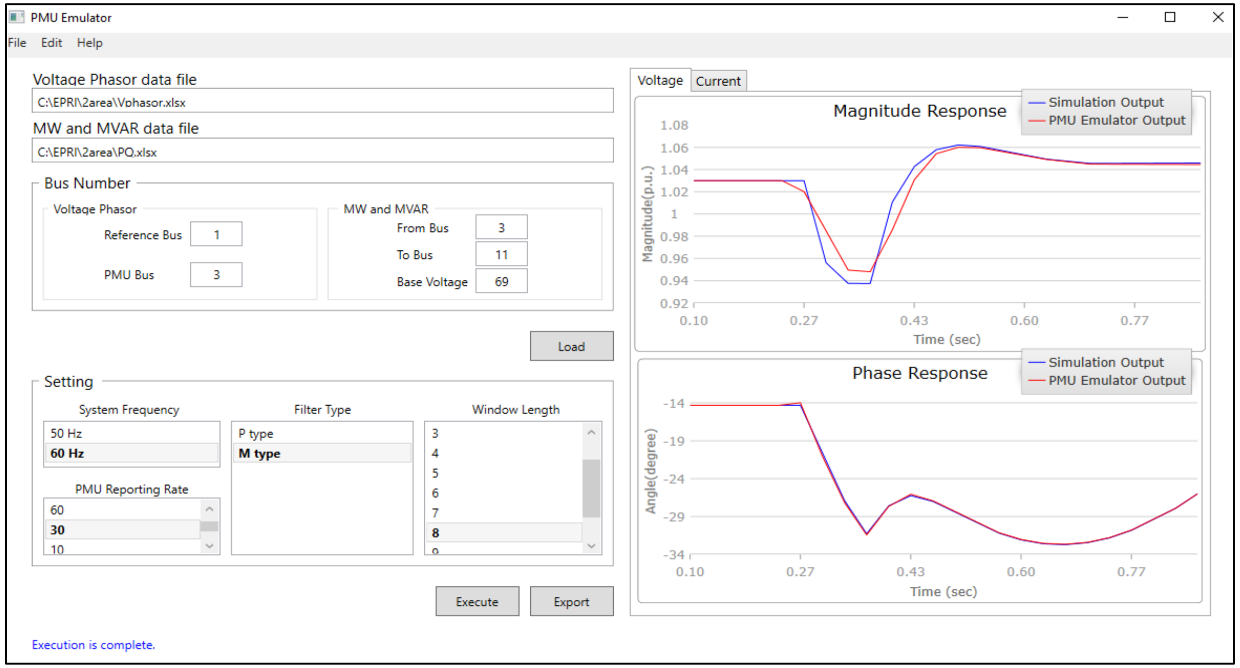
PMU Emulator

M-Class - 15 cycles window

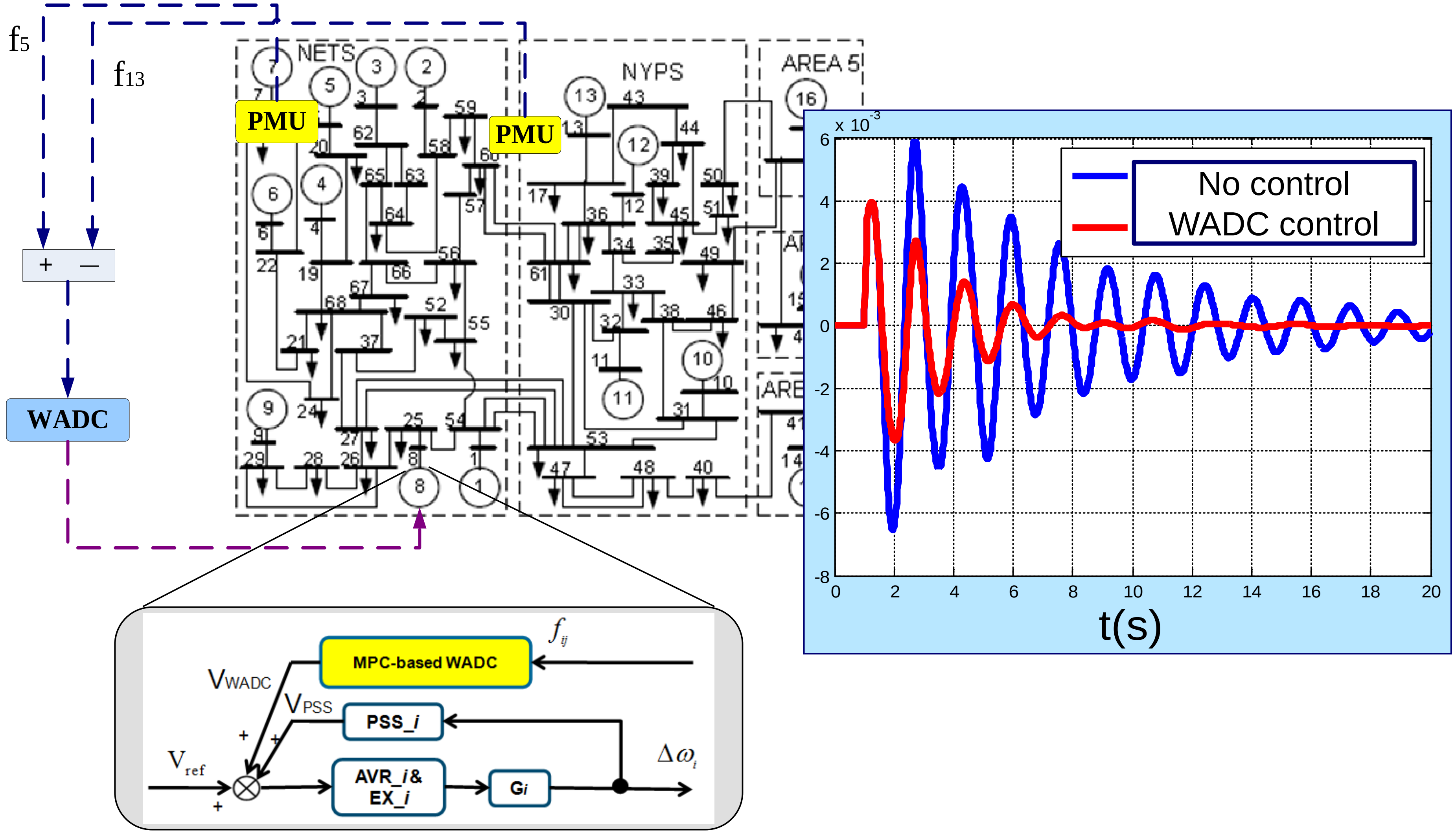


Proof-of-concept software



- 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

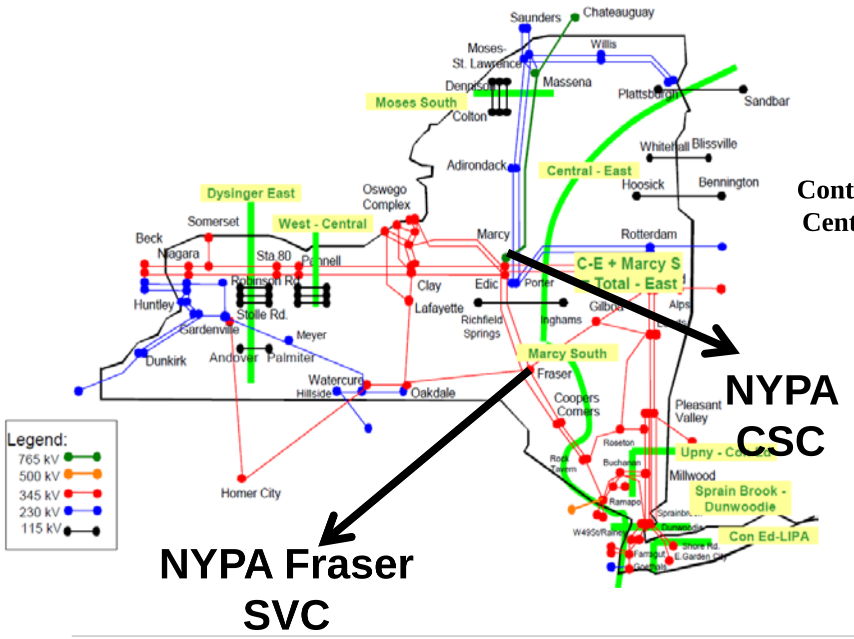
4. Synchrophasor-Based Wide Area Oscillations Damping Controller



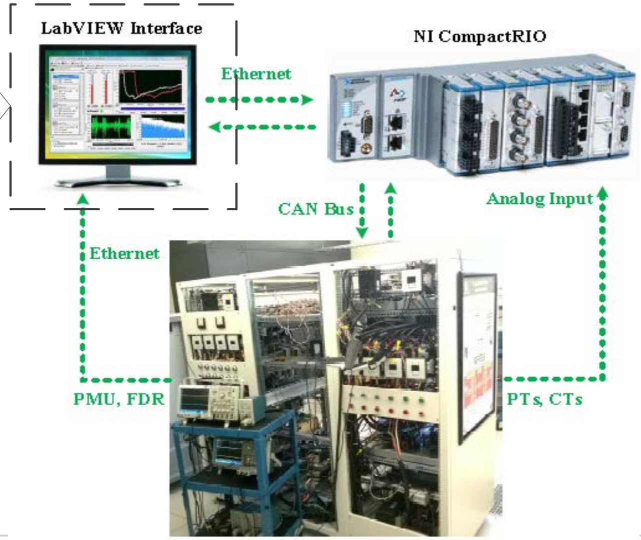
- **Improved Damping of Target Inter-area/Intra-area Oscillations Mode**
- **Application of Synchrophasor Technology in Closed Loop Wide Area Control**

Wide Area Oscillations Damping Controller

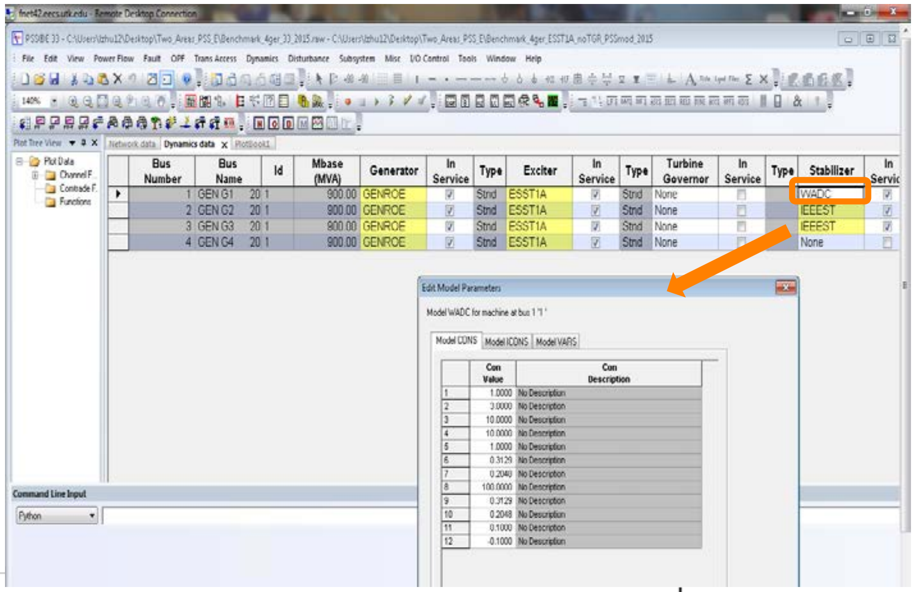
- WADC via additional input to generator excitation system or FACTS/HVDC controller
- Adaptive controller
  - Measurement-derived transfer function model
- Ongoing case studies with NYPA and TERNA
- Hardware-In-the-Loop implementation
  - Measurement delays
  - Missing/Bad data



CURENT/UTK Hardware Testbed



PSS/E User Defined Model



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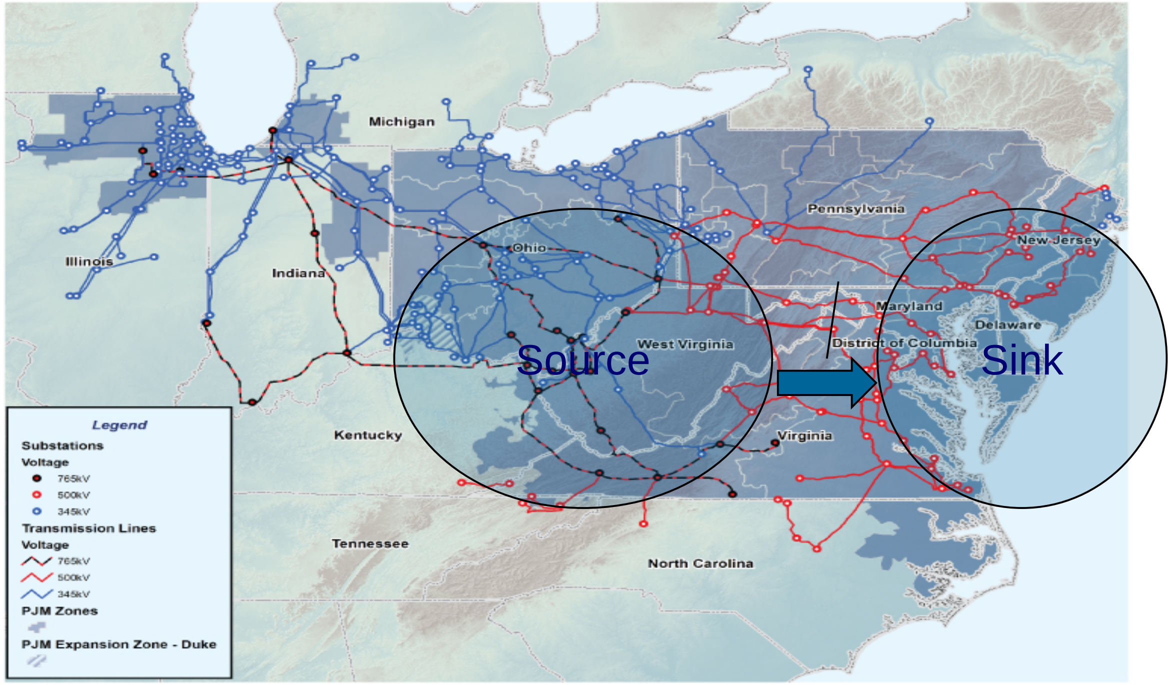
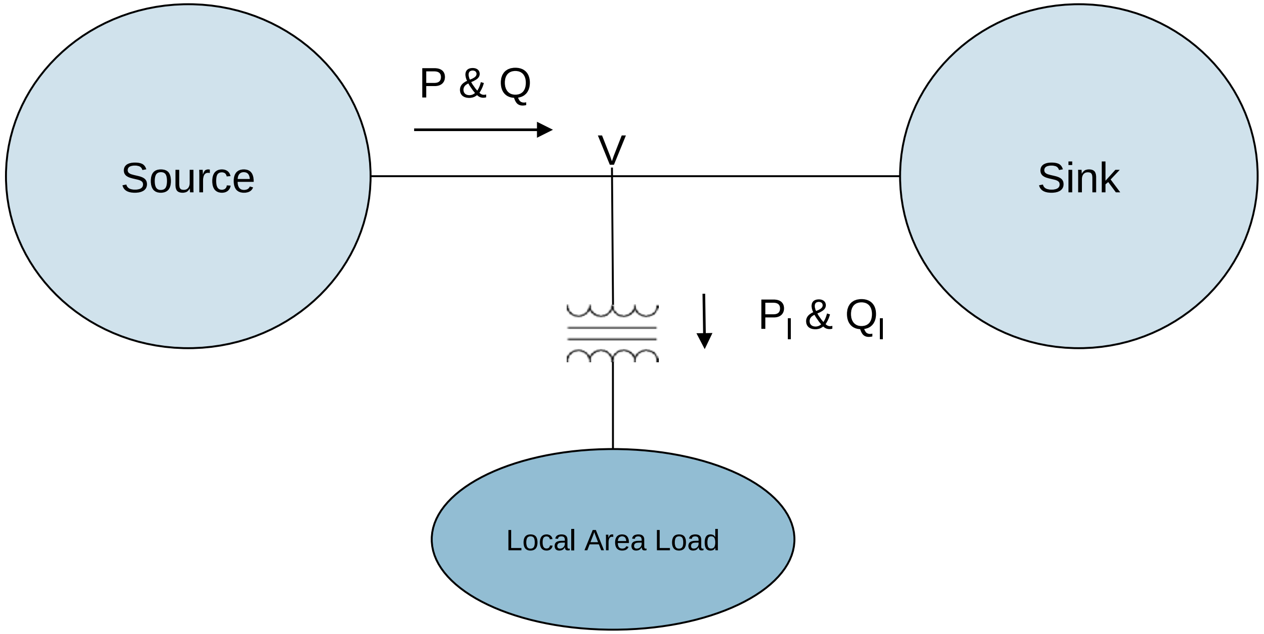
5. Voltage Sensitive Static ZIP Load Model Using Synchrophasor Data





- 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

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

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

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