Yilu Liu

- **UT/ORNL Governor's Chair, CURENT Deputy Director**
- **Research Interests: power grid monitoring and large system dynamic simulations, AI in grid data analytics**
- **Liu@utk.edu 865 266 3597, powerit.utk.edu, fnetpublic.utk.edu**

2020-2021 Research Project highlights

1. PV vs Gas generation study at Chesterfield (Dominion)
2. Energy storage system for FIDVR control (ConEd)
3. Reliability and resilience indexes calculation for reclosers and microgrids (Duke)
4. Forced oscillation source location and type classification (DOE/AGM,TVA)
5. Angle based event detection tools using PMU measurements (SOCO)
8. Adaptive Oscillation Damping (EPRI, NYPA, SEC, TERNA, UK, Canada, DOE., NSF) 2021 R&D 100 Award
9. System inertia trending study (Dominion, WPTO)
10. EMP susceptibility characterization – device level (ORNL)
11. Secure timing system using pulsar signal (NSF)
12. Electric-gas dependency, grid strength study (ORNL/Dominion)
13. Inertia estimation in real time (NREL, HELCO, KIUC)
14. Develop low cost syn-wave monitors for PV systems (ORNL).
15. Data compression technologies for PMU and syn-wave measurements (ORNL, SETO)
16. Distribution grid state estimation and transient data generation (ORNL, SETO)
17. Virtual Operator Assistance – AI based transient stability prediction tool (NREL)

Oscillation Damping Control in World Power Grids

Outcome/Accomplishment

- Develop a measurement-based approach for natural oscillation damping control by modulating active and/or reactive power of generator, HVDC, condenser and FACTS devices.
- Set up Hardware-In-the-Loop test environment based on RTDS/OPAL-RT and realize the damping controller implementation on NI's CompactRIO.
- Validate the effectiveness of the proposed damping controller by mimicking the realistic system operating condition (Including NYPA, Europe, Saudi and Great Britain system).

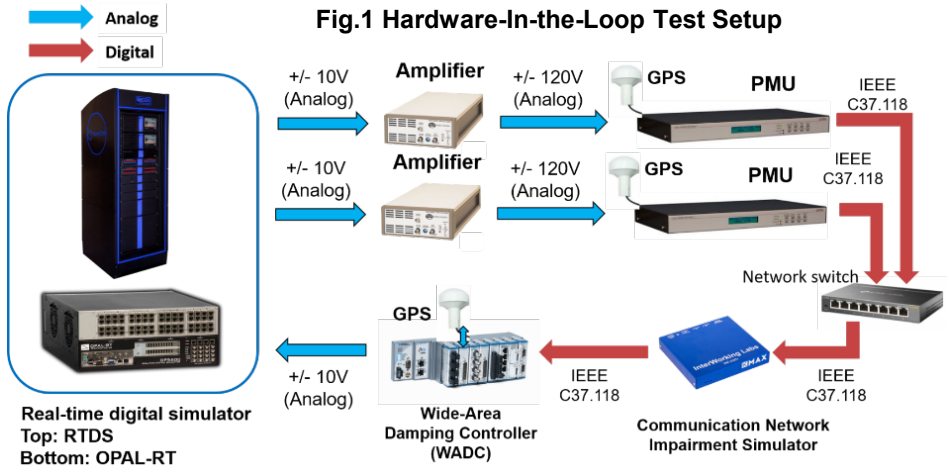


Fig.1 Hardware-In-the-Loop Test Setup

Impact and Benefits

- A natural oscillation damping controller was designed for different types of actuators.
- The performance of natural oscillation damping controller was tested under HIL environment and prepared for the field test in Europe system.

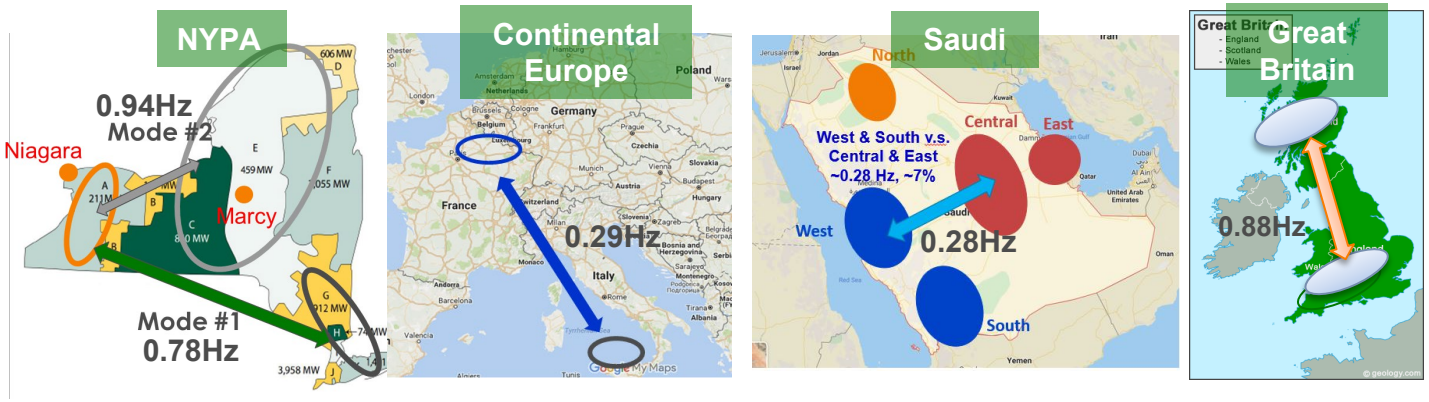
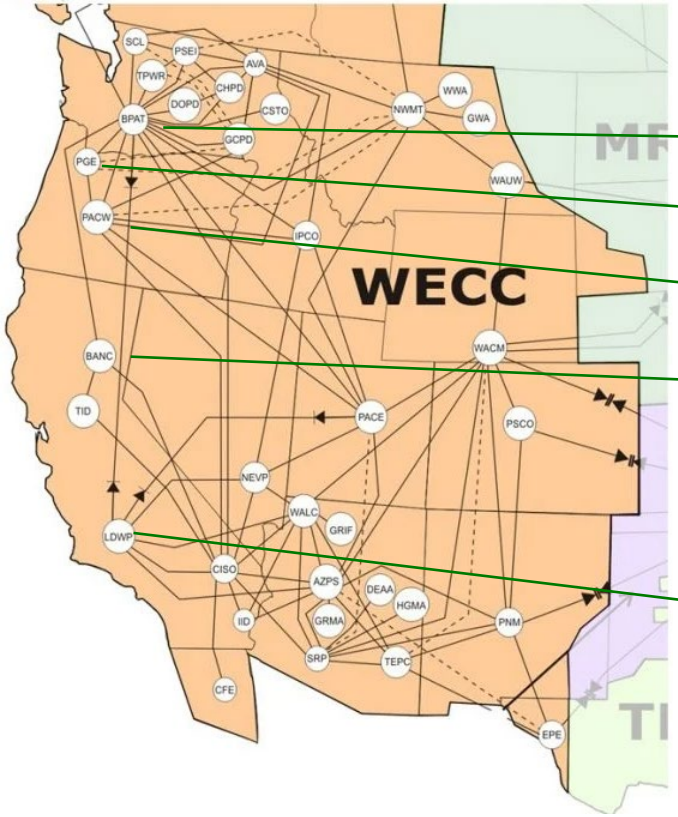
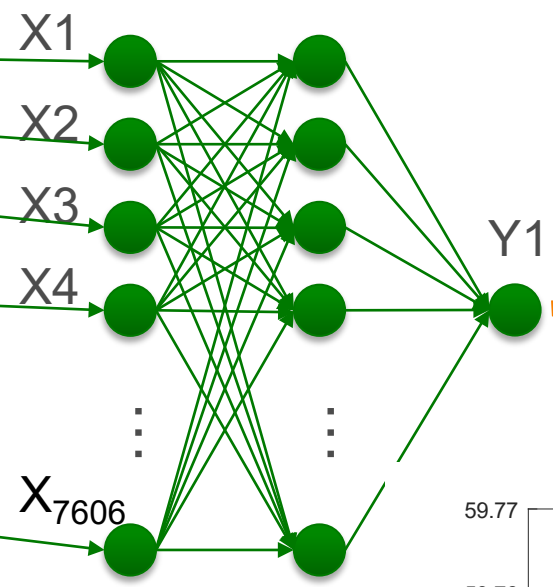


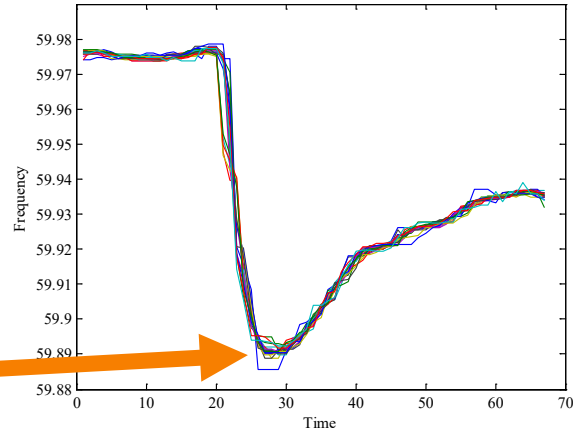
Table 1 Summary of Wide-area study cases

	Study System	Actuator	Simulation in Software	HIL Test	Field Test preparation
1	New York State Power Grid	STATCOM Generator exciter	PSS/e ***Finished***	HIL test with OPAL-RT ***Finished***	
2	Continental Europe Power Grid	Synchronous Condenser	PSS/e ***Finished***	HIL test with OPAL-RT ***Finished***	In progress (with openPDC)
3	Saudi Arabia Power Grid	Generator exciter Generator governor SVC	PSS/e ***Finished***	HIL test with RTDS ***Finished***	
4	Great Britain Power Grid	HVDC link	PowerFactory ***Finished***	HIL test with RTDS ***Finished***	

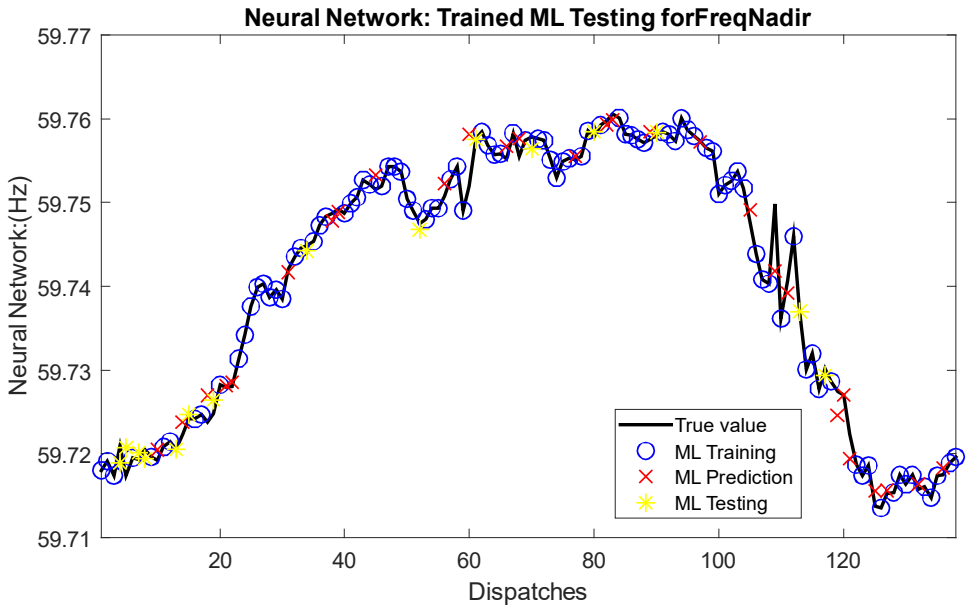
AI Agent for Real Time Stability Assessment







Forecasted Frequency nadir



Input Features:

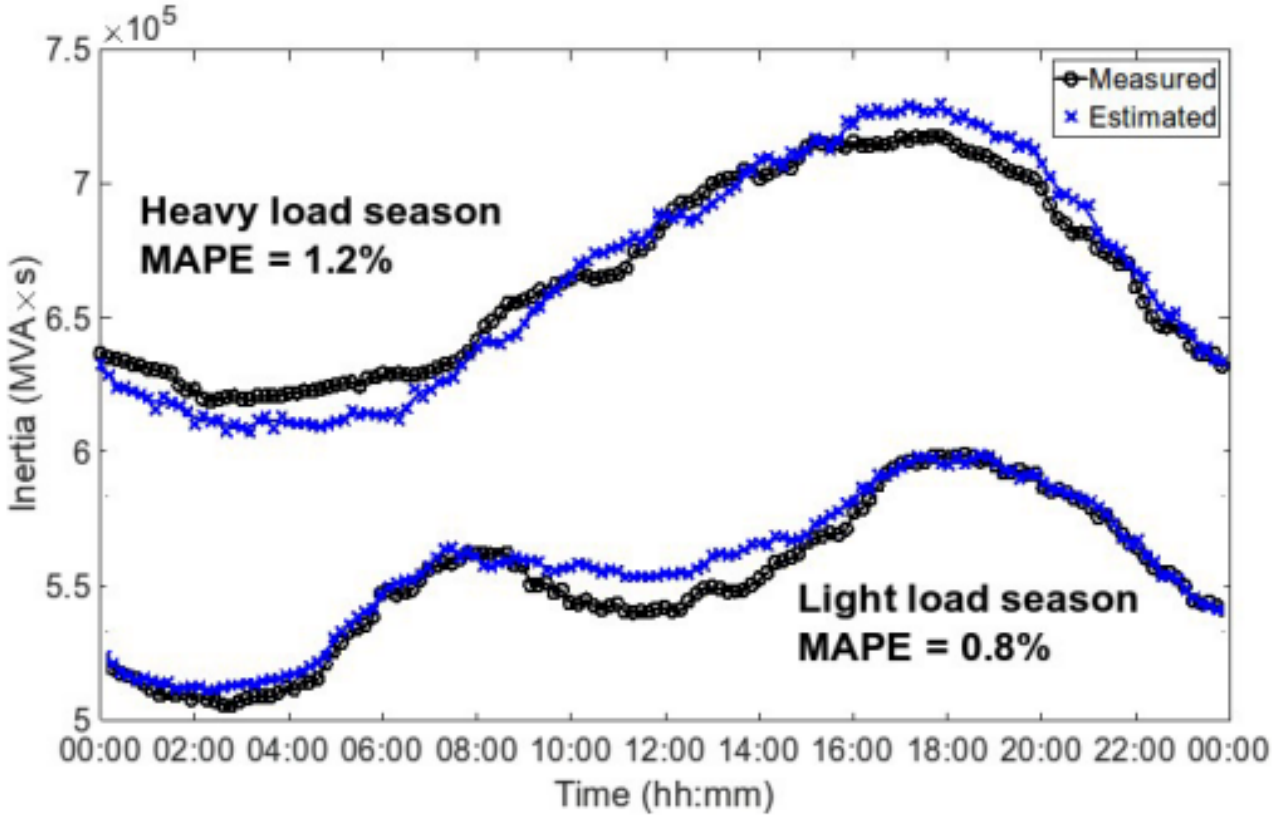
- Active power of 4270 generators
- Inertia of 3336 non-PV generators
- WECC system has 7606 inputs in total

Real-Time Inertia Estimation Using Ambient Frequency

Machine learning – WECC results vs NERC Data

Inputs to ML:

- Ambient frequency
- Weather
- Load profile



Performance of the machine-learning based inertia estimation using ambient frequency signal

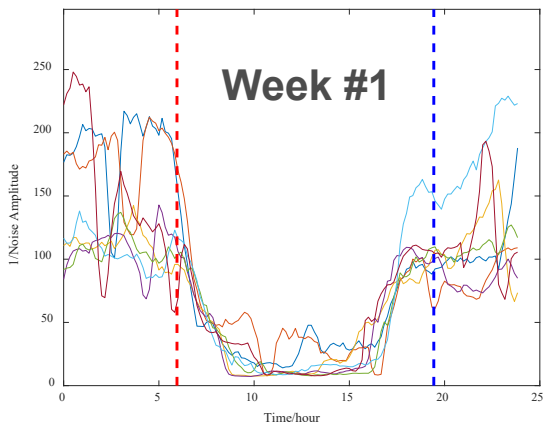
Inertia Estimation Using Ambient Frequency Signal

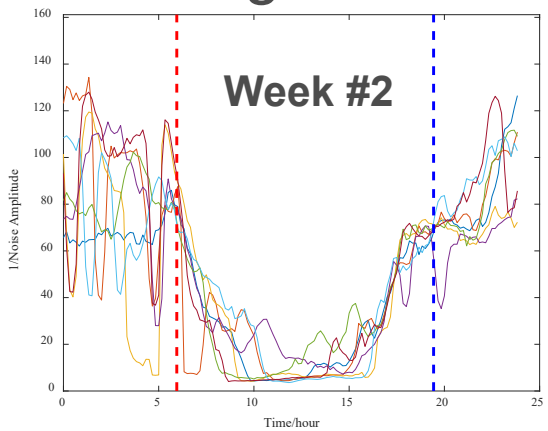
Data + Physics based method

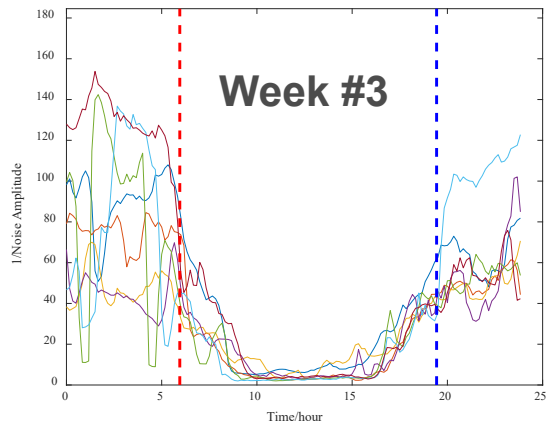
- ‘relative inertia’ results from island grid

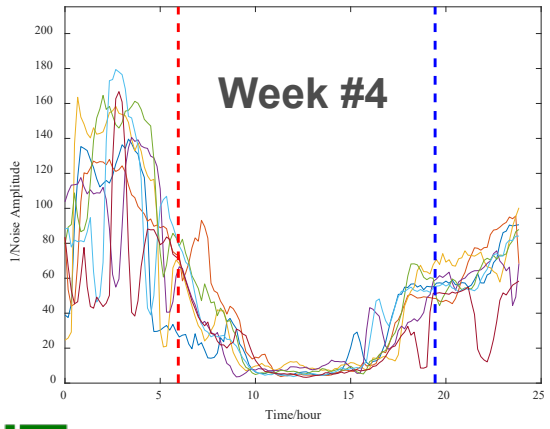
------ Local sunrise time

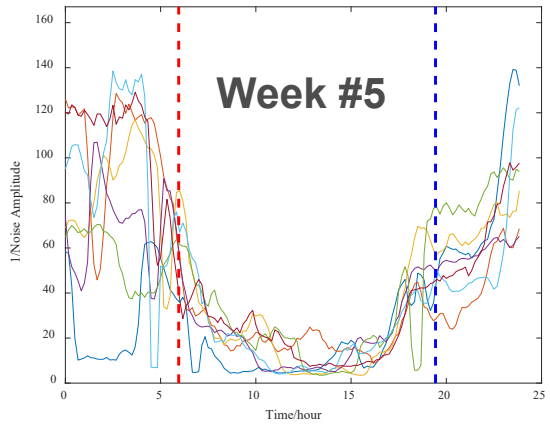
------ Local sunset time

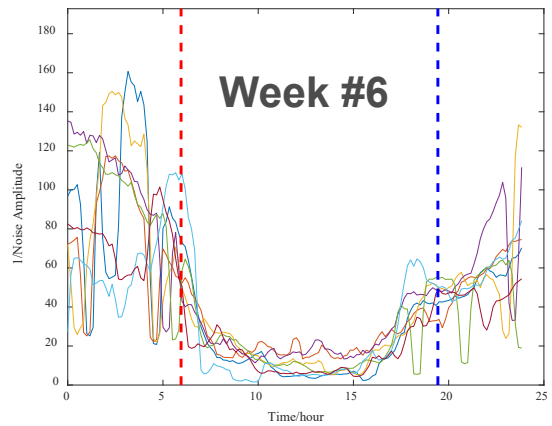












Grid Strength Study - Dominion Area