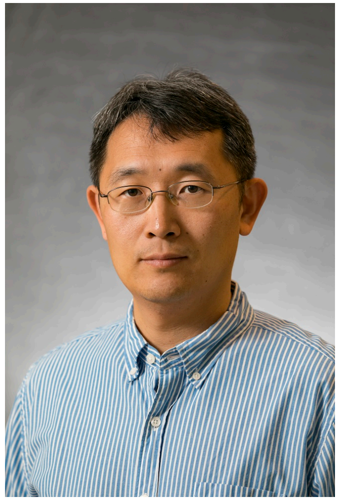

Kai Sun Personal Info

- **UTK Associate Professor in Power Systems**
- **Research Interests: Power System Stability and Control, Prevention and Mitigation of Cascading Outages, and Integration of Renewables.**
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2020-2021 Research Projects

- Nonlinear Modal Decoupling and Control for Resilient Interconnected Power Systems (NSF, CURENT)
- PMU-Based Early Warning and Control of Power System Oscillations (GEIRI)

- A Semi-Analytical Framework for Faster Power System Simulations (NSF, CURENT)
- Parallel-in-Time Power System Simulation (ORNL)
- Semi-Analytical Simulation to Accommodate Multi-timescale Grid Dynamics with Increasing PE Devices (ANL)
- Intelligent Phasor-EMT Partitioning for Accelerated Large-scale IBR Integration Studies (DOE SETO/NREL)

- Prediction and Mitigation of Cascading Outages Using Multi-Layer Interaction Graph Models (CURENT, ORNL)

CURENT

Nonlinear Modal Decoupling and Control for Resilient Interconnected Power Systems

Project Objectives

- Extending the concept of linear mode decomposition to Nonlinear Modal Decoupling (NMD) for transient stability analysis under large disturbances.
- Providing analytical methods for transient stability of future grids with large-scale IBR integration.
- Real-time wide-area stability monitoring and control.

Recent Achievements

- Validated both model- and measurement-based NMD algorithms on CURENT LTBs for critical modes of instabilities.
- More accurate evaluation of participating roles of generators/IBRs into instabilities.
- Demonstration of real-time transient stability prediction and IBR-based control on NPCC LTB.

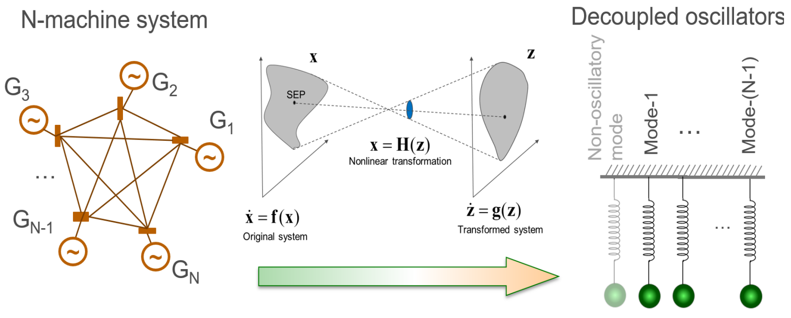

Fig. 1 Nonlinear modal decoupling of a grid into 1-DOF oscillators for stability analysis and control

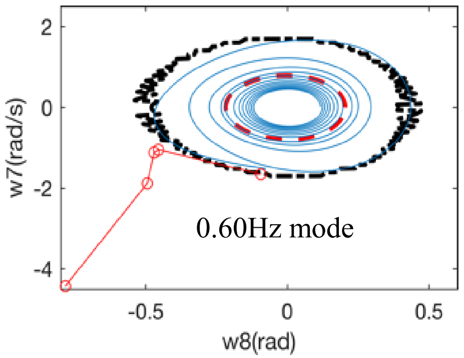

Fig. 2 Real-time instability prediction on NPCC LTB

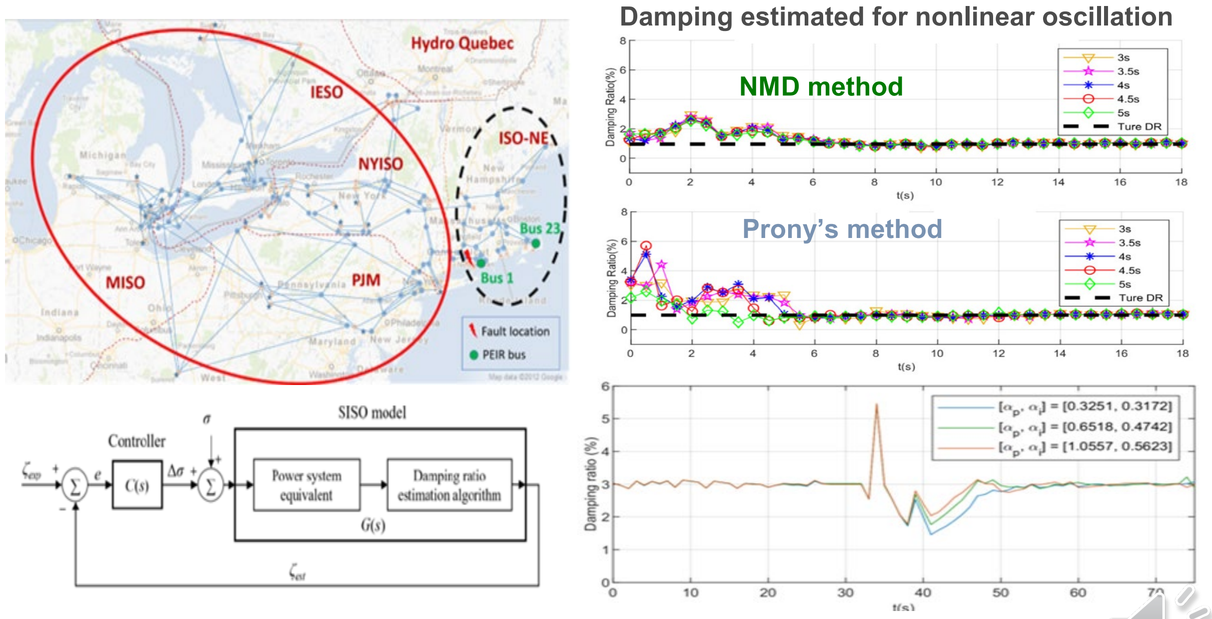

Fig. 3 Robust direct damping feedback control to stabilize NPCC LTB against a large disturbance

A Semi-Analytical Framework for Parallel Power System Simulations on Phasor-EMT Models for Large-scale IBR Integration

Project Objectives

- Highly efficient semi-analytical solvers for nonlinear DAEs.
- Faster-than-real-time grid simulators leveraged by HPCs.
- Look-ahead capability on instabilities and control effects.

Recent Achievements

- Developed a number of semi-analytical DAE solvers using, e.g., Adomian Decomposition, Holomorphic Embedding, Differential Transformation (DT), Homotopy Analysis, etc.
- Transient stability simulation using 8th-10th order SAS demonstrated at least 10x speedup and 10x longer time steps than numerical solvers on a 693-machine 2K-bus Polish system.
- Integrated into ORNL's Parareal platform **RAPID** (**R**esilient **A**daptive **P**arallel s**I**mulator for gri**D**) to simulate 70k-bus EI model on supercomputers.
- SAS-based solvers demonstrate 3-4x faster EMT simulation than TRAP and RK4 methods on small systems.

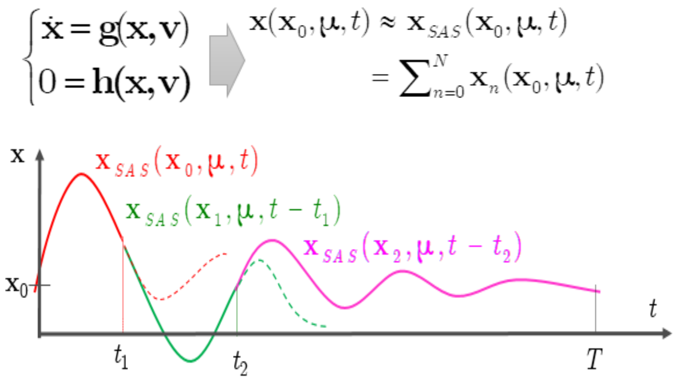

Fig. 1 Semi-analytical solution (SAS) of nonlinear DAEs

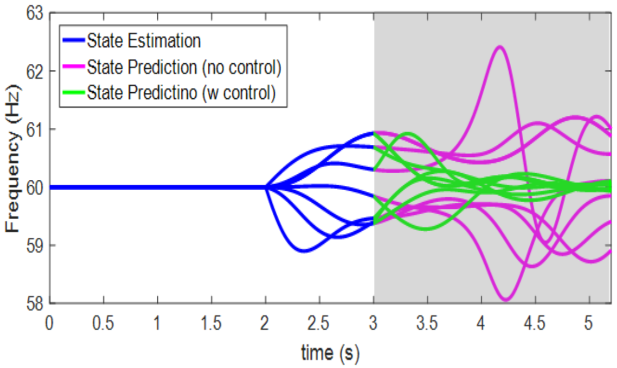

Fig. 2 SAS-enabled state prediction and proactive control on WECC HTB

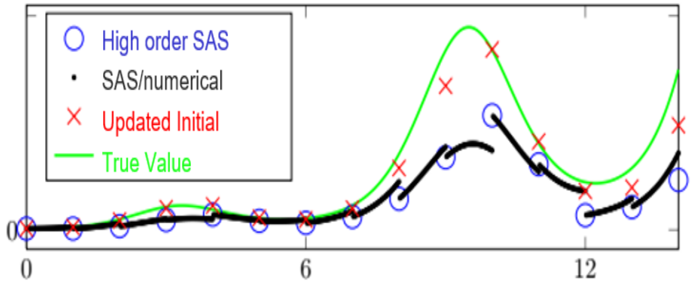

Fig. 3 Integration into ORNL's RAPID platform

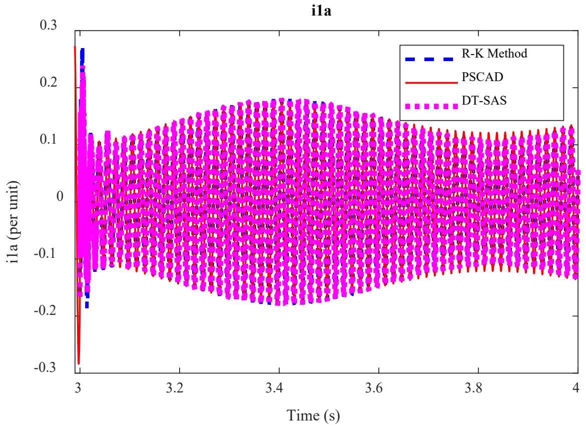

Fig. 4 SAS-based EMT simulation (benchmark with PSCAD)

CURENT

OAK RIDGE National Laboratory

Argonne NATIONAL LABORATORY

NREL Transforming ENERGY

Prediction and Mitigation of Cascading Outages Using Multi-Layer Interaction Graph Models

Project Objectives

- Modeling interactions of component failure to predict paths of outage propagation under cascading failures
- Finding mitigation strategies that isolate outages or break linkages of key component failures.
- Providing actionable visual information for grid operators' decision support under emergency.

Recent Achievements

- Developed a quasi-dynamic cascading outage simulator and a testbed system based on the NPCC LTB.
- Interfaced the simulator with transient stability programs.
- Developed a multi-layer interaction graph that predicts outage propagation paths in terms of the number of outages, load losses, electrical distances, etc.
- Demonstrated visualizations of outages/risks together with weather information (temperature, wind speed, etc.)

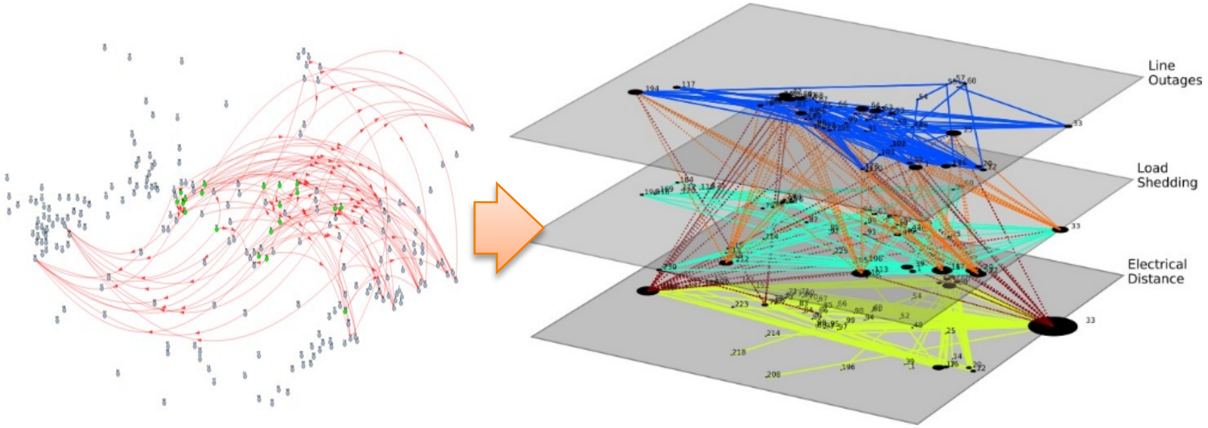

Fig. 1 Multi-layer Interaction Graph of NPCC LTB on outage propagation paths

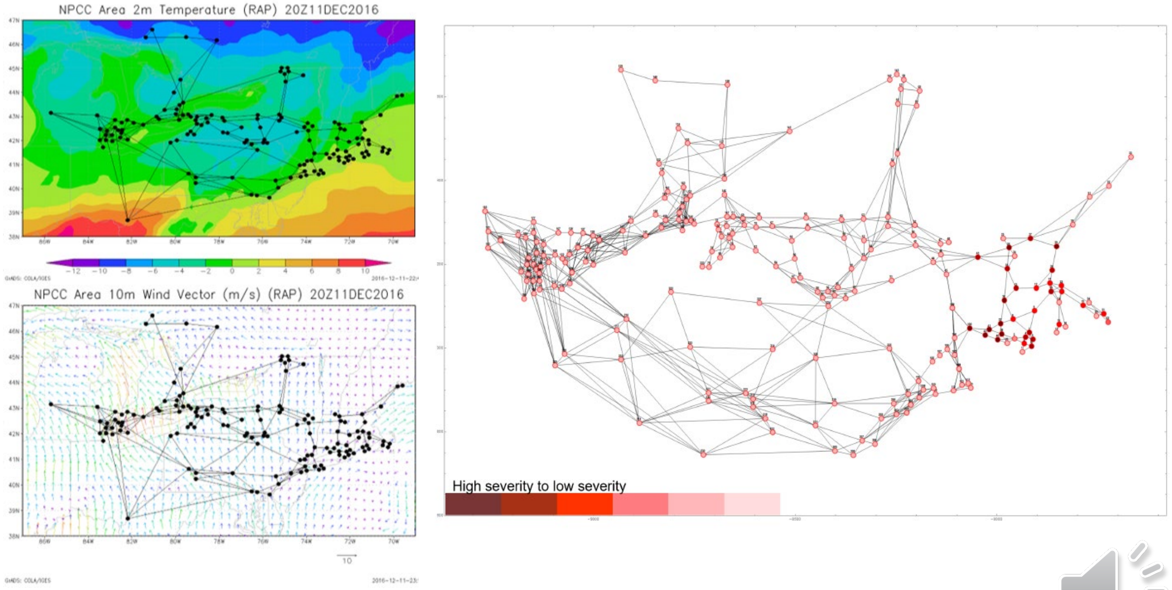

Fig. 2 Visualization on risks of key component failures on NPCC LTB

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