**Title:** Koopman Operator based Data-driven Characterization and Control of Power System Dynamics and Stability

**Abstract:**

Integration of renewable energy sources, advancement in sensing and communication technology and restructuring of electricity market has transformed the electric grid in past few decades. Increase in the load levels, uncertainty in loads and renewable energy sources has complicated the task of ensuring the stable operation of electric grid. On the other end, the advent of phasor measurement units (PMUs) and advancements in monitoring methods has increased the visibility of electric grid with higher fidelity and granularity.

This research aims to develop data-driven methods for power system dynamic and stability characterization utilizing the high proliferation of sensors in the electric grid. We have developed Koopman operator-based methods for modal identification, participation factor computation, parameter estimation and trajectory prediction. In this research, a novel Extended subspace identification (ESI) approach is developed that is suitable for system identification with output measurements when direct state measurements are not available. This approach is robust to measurement noises and is suitable for PMU measurement-based system identification and participation factor computation.

Further, we have also developed a robust extended dynamic mode decomposition (EDMD) method for system identification and trajectory prediction for power systems. The developed method is suitable for predicting the evolution of dynamic state trajectories for power system based on past measurements. This method is suitable for stability studies and predicting the future evolution of system states.

One of the key objectives of this work is to utilize the sensor measurements for better operation and control of the electric grid with penetration of renewable energy resources. We have extended the developed linear operator based modal identification approach for control applications. In this work, we have developed a data-driven adaptive controller for doubly fed induction generator (DFIG) based wind farms to provide damping support to the electric grid. The developed adaptive controller utilizes PMU measurements for real-time oscillation monitoring and control. In our studies, we have shown that the designed controller is suitable for both small-signal and large disturbances and oscillation.

In this work, we have developed a causality-based stability characterization for power systems that is rooted in the control theoretic notion of information transfer in a dynamical system. Recent work on information transfer theory extends the concept to characterize influence in a dynamical system. In this work, a theoretic notion of power system stability and causality of dynamic events based on influence characterization between dynamic system states is developed and validated.