Background and Motivation

- More grid disruptions in the last decade than any other similar period in history
- A key lesson from the August 2003 event was that grid operators needed increased situational awareness, and improved understanding of remedial action alternatives available to them
- Current practice uses online contingency analysis but operators rely on offline stability studies to determine which remedial actions to avoid
- This project uses a Lyapunov approach that can rapidly identify which groups of remedial actions will likely result in stabilizing trajectories

Technical Approach: Concept

- Conventional power system models are highly nonlinear (smooth) dynamical systems with multiple equilibria
- These multiple equilibria shape the dynamics of the nonlinear dynamical system
- Solely relying on time-domain simulations of such highly nonlinear systems, which are initial-condition dependent, to explore all scenarios can be a time-consuming exercise if possible at all
- What is needed is a set of tools that reduce this search space by predicting, without completely relying on time-domain simulations, what type of system trajectories are convergent

Project Objectives

1. To develop a Lyapunov function based method of transient stability analysis that can be solved at real-time speed without the use of massively parallel computation resources
2. To apply the method developed in (1) to perform remedial action screening (RAS) at real-time speed. Also develop research-grade algorithm implementing this feature
3. To validate the methods and algorithms, including real-time performance, developed in (1) and (2), on a large-scale real-time digital simulator (RTDS®)
4. To incorporate in the tool described in (2) above the capability to update system status in real time
5. To develop a visualization tool for operator interface

Comprehensive Approach

- Multi-expertise project team for theoretical and algorithmic development
- Real-time interaction, demonstration and validation using equivalenced utility system and scenarios simulated on RTDS® cluster
- Integration with a visualization and operator interface tool (similar to SCADA displays in control rooms, but with embedded RAS)
- Vetting by utility partner

Validation on RTDS®

RTDS® simulator at FSU-CAPS
- An RTDS® model based on real network data will be built
- Since the model will run in real-time, it will mimic the behavior of real system
- PMU hardware will be installed to stream measurements from systems simulation

High performance computing platform at MSU
- It will receive PMU data from FSU-CAPS lab located at Tallahassee
- Ethernet communication will be used
- Based on the simulation results, actuating signals will be sent to the operation/control center

Project Team

- Michigan State University (MSU) – Joydeep Mitra (PI)
- University of Illinois Chicago (UIC) and NextWatt LLC – Sudip K. Mazumder
- Florida State University Center for Advanced Power Systems (FSU-CAPS) – Omar Faruque – Misha Chertkov – Rick Meeker
- Los Alamos National Lab (LANL) – Scott Backhaus
- Southern California Edison (SCE) – Juan Castaneda – Michael Montoya

Project Functions and Deliverables

1. Online Remedial Action Screening Tool
   - Computer software integrated with visualization tool and operator interface
2. Test Bed and Operator Training Facility for Remedial Action Screening and Grid Security Research
3. Workshops and Project Web Site
   - Research outcomes disseminated through journals, conferences, workshops
   - Articles, reports, webinars published on web site

Statistical Trajectory Analysis

- 10% joint probability distribution of forecast errors
- An instanton measures the distance and direction from the most probable configuration of the uncertain resources to the boundary of the feasibility domain in the space 5 of fluctuating network injections. The instanton also quantifies the probability of encountering failure along this direction