# DOE/OE Transmission Reliability Program

## DE-OE0000842
## Multi-Stage and Multi-Timescale Robust Co-Optimization Planning for Reliable and Sustainable Power Systems

**Lei Wu**
Associate Professor, Clarkson University
lwu@Clarkson.edu
June 14, 2017
Washington, DC

# Outline

- **Overall Project Objective**
- **Looking Back** (October 2016-June 2017)
  - Major accomplishments
  - Deliverables and remaining schedule for activities to be completed under FY16 funding
  - A list of accepted publications
- **Looking Forward**
  - Outline planned activities and schedule

# Project Overview

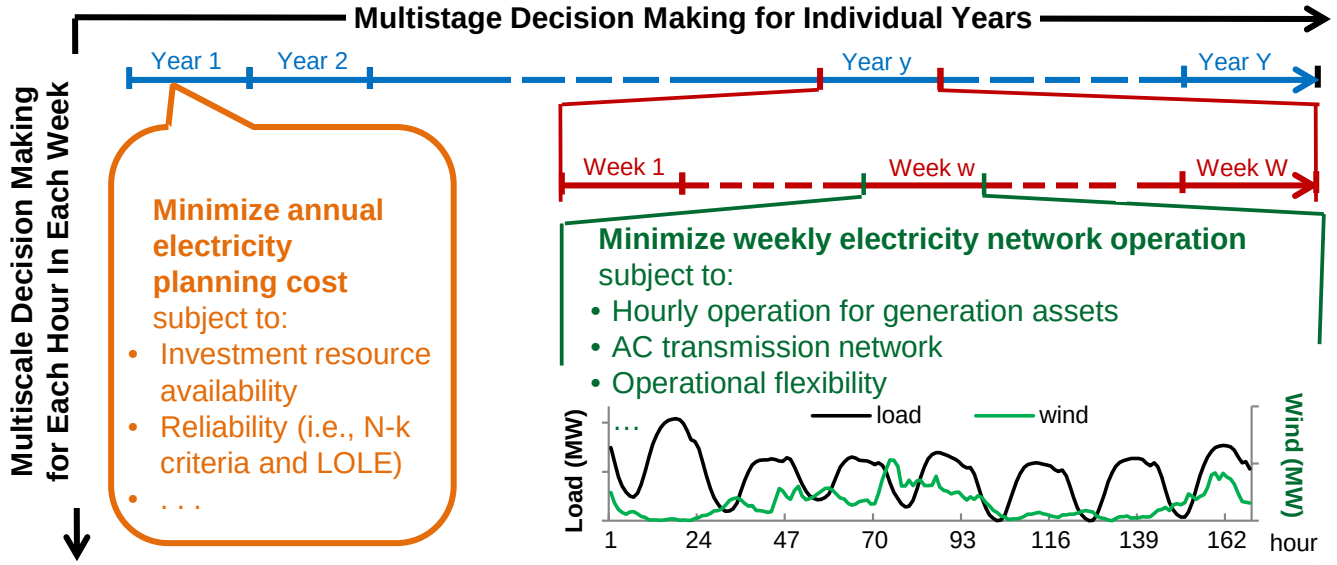
- Period of Performance: October 1, 2016 – September 30, 2019
- Program Manager: Phil Overholt
- Project Officer:  Alicia R. Dalton-Tingler
- Principal Investigator: Lei Wu
- Subrecipient
  - Bo Zeng, University of Pittsburgh
  - Jianhui Wang, Southern Methodist University
- Industry Partners
  - ISO-NE
  - PJM
  - MISO
  - New York State Smart Grid Consortium

# Background

- Long-term power system planning aims at optimizing asset utilization by investing in a proper mix of generation and transmission technologies/capacities to supply the future electrical load growth.
  - Focus on environmental sustainability, energy reliability, and economic well-being over multiple years
  - Mitigate multiple timescale risks and uncertainties, ranging from long-term policy/technology changes to short-term operation dynamics
  - Coordinate long-term **reliability** and short-term **flexibility**
  - Address **computational complexity** of practical-scale power systems, especially considering hourly chronological operation details and nonlinear characteristics of the alternating current (AC) transmission network.

# Overall Project Objective

- Develop **Multi-stage and Multi-timescale robust Co-Optimization Planning** to determine a proper mix of generation and transmission technologies/ capacities as well as novel non-wires alternatives for supplying the future electrical load growth.



# Overall Project Objective

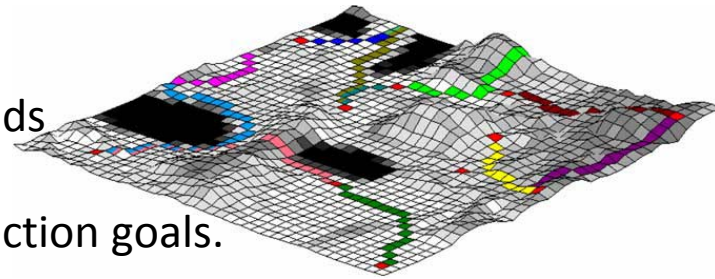
- Advanced features for the modeling and simulation
  - Risks and uncertainties related to the time, location, and type of additional generation technologies
  - Annual, seasonal, and hourly variation of renewable energy sources
  - Integrated long-term reliable planning and short-term economic operation
  - AC transmission network
  - Various environmental considerations
- Innovative solution methodologies
  - Dynamic transmission network reduction
  - Tighter convex approximation for AC power flow
  - Integrated decomposition approaches
  - Distributed computation methods

# Look Back (October 2016-June 2017)

- Major accomplishments during the past year
  - The **Kickoff Meeting** was held on March 3rd, 2017.
  - The **Project Management Plan** was finalized on March 13th, 2017.
  - Deterministic multi-stage and multi-timescale generation and transmission **co-optimization planning model with AC constraints**
    - Simultaneously study network configurations along with the detailed characterization of their functionalities with AC power flow representation.
    - Integrating long-term reliability and short-term flexibility in a single analytical framework.
  - **Subcontractors** from Southern Methodist University and University of Pittsburgh, and **collaborators** from China and Denmark on optimal AC power flow, wind-storage coordination, microgrid, and advanced optimization algorithms to support large-scale system planning.

# Look Back (October 2016-June 2017)

- Deliverables and remaining schedule for activities to be completed under FY16 funding
  - AC constrained co-optimization planning model **with environmental constraints**
    - Investment cost of candidate lines depends on environmental factors such as terrain, climate, and certain environmental protection goals.



    - Exploring **optimal routes of candidate lines** according to actual environmental factors and power system reliability requirements.
    - Incorporating spatial transmission network planning into the proposed co-optimization planning model to simultaneously ensure **feasibility of line paths and reliability of power systems**.
  - Annual One Deliverables: programmatic metrics, publications, and presentations

# Look Back (October 2016-June 2017)

- A list of accepted publications and presentations
  - [J3] Z. Bao, Q. Zhou, **L. Wu**, Z. Yang, and J. Zhang, "Optimal capacity planning of MG with multi-energy coordinated scheduling under uncertainties considered," *IET Generation, Transmission & Distribution*, 2017.
  - [J2] H. Ding, P. Pinson, Z. Hu, **J. Wang**, and Y. Song, "Optimal offering and operating strategies for a large wind-storage system as a price maker", *IEEE Trans. Power Systems* , 2017.
  - [J1] W. Wei, **J. Wang**, N. Li, and S. Mei, "Optimal power flow of radial networks and its variations: a sequential convex optimization approach," *IEEE Trans. Smart Grid* , 2017.
  - [P1] **L. Wu** and **B. Zeng**, "Multi-Stage and Multi-Timescale Robust Co-Optimization Planning for Reliable and Sustainable Power Systems," *INFORMS Annual Meeting*, 2017.

# Looking Forward (July 2017- June 2018)

- Planned activities and schedule for July 2017- June 2018
  - AC-constrained co-optimization planning model with risks and uncertainties – November 2017
    - Considering **risks and uncertainties** related to as load, renewable energy, and policy/technology changes, as well as spatiotemporal correlations among generator and transmission line outages
  - Multi-area coordinated planning model – March 2018
    - Achieve **overall reliability and economic efficiency of the interconnect electricity infrastructure** with the growing interconnection of regional electricity networks and large-scale integration of renewable energy
  - Enhancement of computational methods – March 2018
    - Design and implement efficient computation methods using three strategies of **approximation, decomposition, and distributed computation**
  - Implementation – June 2018

# *Thank you!*