DOE/OE Reliability & Markets Program
June 2018 Peer Review

Project Summaries

Project:	**A Probability-based Model for Cost-effective Integration of Renewables into the Electricity Grid (FOA 1493)**
Performer:	Virginia Polytechnic Institute and State University
PI:	Saifur Rahman, Rajendra Adhikari

The goal of this project is to address two issues for variable generation (1) Effective Load Carrying Capability (ELCC) numbers for resource adequacy (RA) calculations; and (2) production costing analysis based on uncertain renewable energy generation.

To address these issues, Virginia Tech is developing a production costing tool that use probabilistic data for renewable energy sources (both solar PV and wind farms), and treat these as generation candidates in a power system expansion plan. This is different from treating these as negative loads as is the current practice. This work will be carried out in three phases:

- **Phase I** will involve the development of the proposed expansion planning tool.
- **Phase II** will involve validation of the proposed tool with a well-known expansion planning tool, (such as WASP), as well as determining all possible alternatives.
- **Phase III** will involve running of a case study based on a real-world data to show applicability of the proposed tool.

The software tool and algorithm to be developed for this project will be presented in conference and journal publications during each year of the project. Additionally, Virginia Tech team is willing to work with ISOs/RTOs/utilities or wind farm operators to provide necessary training if there is an interest in adopting this software.

Project:	**A Multistage Stochastic Transmission Expansion Algorithm for Wide-area Planning under Uncertainty (FOA 1493)**
Performer:	Pennsylvania State University
PI:	Mort Webster

The overall objective of this project is to develop and demonstrate a computational method for solving the optimal transmission plan under uncertainty in future generation in multiple steps for a large network. The algorithm will be parallelizable to take advantage of high-performance computing networks, and will consist of a linear-programming-based approximate dynamic programming algorithm. This work will be completed in three phases:

- The objective of Phase I is to develop the algorithm and software tools to implement it, validate on a small test network where the optimal transmission plan is known, and to demonstrate on a moderate-sized network (e.g., ERCOT) as a test case.
- The objective of Phase II is to demonstrate the results of the method for a larger system (e.g., WECC), extend to solve for three or more decision stages, and to extend the algorithm to co-optimize generation and transmission.

- The objective of Phase III is to extend the algorithm to use AC optimal power flow to evaluate the proposed lines in each stage, and to conduct a detailed comparison of the results of the new solution algorithm to other methods in use, including robust optimization methods.

The primary expected result of the project is a dramatic reduction in the computation time required to determine the best high-voltage transmission lines to add to the existing grid in the near-term when we do not know where future generation, in particular renewable energy sources, will be located. Improved transmission planning would facilitate reduction in the cost of electricity and enable the integration of greater capacity of renewable generation.

The method to be developed, which would be placed in the public domain and shared freely, would enable ISO/RTOs and other regional organizations to more effectively plan for changes in the coming decades to the power system, and enable them to consider a broader range of alternative investments and possible future scenarios than current methods.

Project:	**Stochastic Continuous-time Flexibility Scheduling and Pricing in Wholesale Electricity Markets (FOA 1493)**
Performer:	University of Utah
PI:	Masood Parvania

In this project, the University of Utah aims to develop a novel stochastic continuous-time unit commitment (UC) model that offers a different approach to sampling the information and decision variables in the wholesale market operation. The proposed UC formulation schedules the optimal continuous-time power trajectories of dispatchable generation resources and electric energy storage (EES) devices to balance the continuous-time variations of load and renewable energy sources (RES), respecting the transmission network constraints.

The proposed UC model reduces the approximation error in describing the continuous-time ramping phenomena in the day-ahead operation, capturing more accurately the essential information available about the load and RES evolution in time, while revealing the potential operational flexibility of resources that have significant impact on the day-ahead market solution, but is not captured by current UC formulation.

This project includes five main tasks:

1. Project Management and Planning.
2. Development of Continuous-time Energy Generation and Storage Scheduling Models.
3. Development of Continuous-time Locational Marginal Prices of Energy Generation and Storage.
4. Development of Stochastic Continuous-time UC Model for Wholesale Markets Operation.
5. Evaluation of Accuracy and Computational Complexity of Stochastic Continuous-time UC.

Deliverables include technical progress reports and one final report, as well as journal papers, conference presentations and papers, and a PhD dissertation. Project PIs will provide detailed briefings for presentation to DOE/NETL.

Project:	**Models and Strategies for Optimal Demand Side Management in the Chemical Industries (FOA 1493 #133)**
Performer:	University of Texas at Austin
PI:	Michael Baldea

University of Texas (UT) aims to exploit the Demand Response (DR) potential of industry, focusing on Dispatchable Demand Response (DDR) and Non-Dispatchable Demand Response (NDDR) of chemical, petrochemical, and refining processes—collectively referred to as "chemical processes." Chemical processes account for about 30% of industrial electricity consumption, and have significant DR capabilities. Yet, estimates put the actual exploited DR potential at about 20-50% of the available capacity, leaving an enormous portion untapped. UT's project will remedy this situation by addressing the following specific objectives:

1. Characterize the DR-relevant dynamics of chemical and petrochemical processes.
2. Develop models and DR scheduling optimization problem formulations that are amenable to real-time solution.
3. Create representations of the DR behavior of chemical process that can be embedded in power system models.

The research will to lead to generic tools and methodologies that are applicable to all manufacturing facilities in the chemical and petrochemical sector, and can be extended to other industries. UT will apply and validate its findings by collaborating with an industrial partner from the energy-intensive air separation sector. In addition to the benefits provided to the grid, UT's preliminary results suggest that engaging in DR programs can save up to 3% of operating cost in this sector, compared to operating at a constant production rate with fixed energy prices. Significant additional income can be generated from providing ancillary services, such as responsive reserve.

Project:	**Economical and Engineering Aspects of Proactive Demand Participation: Centralized versus Bilateral Control Structure (FOA 1493 #123)**
Performer:	University of California at Riverside
PI:	Nanpeng Yu

The goal of this project is to perform critically needed research related to the retail market development and impact assessment of demand-side participation and its integration into the wholesale market. Specifically, the project objectives are as follows:

1. Develop and validate centralized and decentralized control algorithms at the distribution system level to coordinate the operations of heterogeneous flexible loads and Distributed Energy Resources (DERs);
2. Develop algorithms at the customer level which will enable proactive consumers to participate in the power system resource dispatch and price formation; and
3. Evaluate the impacts of demand-side participation on power system operations.

The proposed control frameworks and algorithms consider both engineering and economical aspects of proactive demand-side participation. Moreover, the proposed demand-side participation markets will be validated using small-scale campus demonstrations and large-scale computer simulations. Using rigorous mathematical analysis and real-world demonstrations, this proposal is aimed at providing a comprehensive framework for formulating, validating, and comparing demand-side participation markets.

By developing and evaluating demand-side participation for both centralized and decentralized control structures, while considering both engineering and economical aspects, this project addresses both theoretical and practical issues of demand-side participation. The project deliverables will enable high levels of penetration of flexible loads and DER economically through (1) transformation of grid operation from load-following to supply-following; (2) active participation of flexible loads and DERs; and (3) efficient distribution system management with centralized and decentralized coordination of largescale, heterogeneous and proactive customers.

The experience gained through control algorithm development, large-scale simulation, and small-scale demonstration will provide valuable guidance to ISO and electric utilities in policy making and in designing distribution system operator managed markets. The technologies developed will remove the barriers to further penetration of demand-side participation and promote the integration of DERs such as PVs, PHEVs, and energy storage units. By jointly optimizing the centralized power plants and large-scale heterogeneous flexible loads and DERs, the proposed proactive demand-side participation scheme will be a critical tool for the mitigation of supply intermittency and for achieving a higher energy efficiency in the electricity markets.

Project:	**Multi-Stage and Multi-Timescale Robust Co-Optimization Planning for Reliable and Sustainable Power Systems (FOA 1493 #122)**
Performer:	Clarkson University
PI:	Lei Wu

The objective of this project is to develop a sophisticated decision tool called Multi-stage and Multi-timescale robust Co-Optimization Planning (MMCOP). This tool will help planner's facilitate generation and transmission co-optimization planning of emerging power systems. MMCOP will represent an efficient decision tool for augmenting the existing power utility capabilities to support collaborative planning, analysis, and implementation of emerging power systems and to effectively mitigate risks and uncertainties in both short-term operation dynamics and long-term policy/technology changes.

MMCOP will assist power market participants in vertically integrated utilities and regulatory agencies to analyze economics, reliability, and sustainability of various options for transmission upgrades along with planning new generation and transmission facilities. MMCOP can also be used by industry for teaching and training next-generation power system planners and operators for analyzing renewable energy integration uncertainties, identifying critical spots in power system operation, analyzing power system vulnerabilities, and providing credible decisions for examining operation and planning options. Upon the completion of the proposed study, a prototype version of MMCOP will be made available to DOE including a publicly available set of data, the proposed MMCOP features, and supporting documents.

The project will generate direct and profound impacts on the energy reliability and sustainability to the society through helping electricity grid planners and operators better plan additional resources, manage available resources, achieve higher reliability standards, and increase renewable energy penetration, which otherwise may not have been explored due to the lack of analytical tools for simultaneously addressing co-optimization of generation and transmission assets under uncertain environments. The project will increase public awareness and understanding of the complexity of power system planning, and appeal to researchers and educators with interests in power systems-based research and education.

Project:	**Management of Risk and Uncertainty through Optimized Cooperation of Transmission System and Microgrids with Responsive Loads (FOA 1493 #120)**
Performer:	Cornell University
PI:	Lindsay Anderson

Cornell University's overarching objective of this project is the development of a scalable co-optimization solution for transmission and microgrids that includes demand response, storage, and renewable resources. This solution will incorporate realistic modeling and integration of responsive demand in the low-voltage system, to assist in management of uncertainty in the transmission system induced by renewable generation sources and contingencies. To achieve this objective, the project will proceed through four overlapping phases:

- Phase I will focus on new optimization and statistical approaches to properly characterize the uncertainty, spatial correlation, and serial correlation of renewables, including solar and wind.
- Phase II will be conducted in parallel with Phase I, which will identify and develop viable strategies and models for integrating demand response in the low-voltage grid and evaluating potential applications to mitigate risk and uncertainty in the grid.
- In Phase III of the project, the results of Phases I and II will be incorporated to examine the interaction between the high voltage and low voltage grid, with the objective of identifying synergistic strategies that will benefit the combined systems.
- The first three phases will then support Phase IV, which will develop the overall co-optimization framework that includes transmission and distribution systems with renewables, demand response, and storage capabilities. Solution methods will be implemented and used to conduct numerical case studies on various test systems.

Several outcomes are expected from the proposed research:

1. A performance comparison of renewable output forecasting/scenario generation methods.
2. A comprehensive framework for the interplay between the micro and macro grids.
3. An analysis of the impacts of different demand response strategies on power grid operation.
4. An analysis of the performance of combined stochastic decomposition methods to tackle the integration problem of responsive demand in the low voltage system.

Project:	**Flexible Service Contracting for Risk Management within Integrated Transmission and Distribution Systems (FOA 1493 #108)**
Performer:	Iowa State University Science & Tech
PI:	Zhaoyu Wang

Iowa State University's project aims to investigate the ability of "distribution resource aggregators" making use of innovative types of "swing contracts" to ensure the availability and real-time provision of flexible services from distribution resources (DRs) in order to facilitate the robust efficient management of risks and uncertainties for integrated transmission and distribution (T&D) systems. A Distribution Resource Aggregator (DRA) is any entity capable of providing dispatchable real-time services from DRs. A swing contract is a contract whose terms permit a diverse spectrum of services to be offered as ranges of values rather than as point values, thus permitting greater flexibility in their real-time implementation.

The specific objectives of this project are:

1. Market-based net service scheduling algorithms for various types of DRs.
2. A new methodology permitting DRAs to combine individual DR net service schedules into aggregate net service schedules permitting flexible services to be harnessed from DRs in valuable and usable forms.
3. A new market design based on swing contracting that permits DRAs to make use of aggregate net service schedules in order to offer both advance availability and real-time provision of flexible services in support of wholesale power market operations, with appropriate separate market-based compensation of availability and real-time performance.

The outcome of this project will be a new business model that will provide a new robust-control approach to the management of integrated T&D system risks/uncertainties that does not require detailed scenario and probability specifications or reliance on overly conservative worst-case designs. Iowa State University is proposing to partner with nine subrecipients. Of these, Iowa Energy Center, is providing cost share in the form of tuition, stipend, fringe and other associated costs dealing with student and faculty work on this project. The Energy Center is administered through the university. The subrecipients' roles are technical advisors and providing data.