DOE/OE Transmission Reliability Program
June 2017 Reliability & Markets and NETL FOA 1493

Peer Review Meeting Summary

Modernizing America's electricity infrastructure is one of the U.S. Department of Energy's top priorities. The DOE Strategic Plan[1] states that today's electric grid needs to be more efficient, reliable, and secure. A modern, smarter electric grid may save consumers money, help our economy run more efficiently, allow rapid growth in renewable energy sources, and enhance energy reliability. The Department's research into a variety of tools that will improve advanced system monitoring, visualization, control, operations, and market structure will ultimately modernize the electricity transmission infrastructure to ease congestion, allow for increases in demand, and provide a greater degree of security.

The June 14, 2017 Peer Review meeting featured Transmission Reliability projects awarded by NETL under FOA 1493, and those managed by CERTS under the *Reliability and Markets (R&M)* research area.

These elements of the Transmission Reliability program support research focused on the modeling and computational methodologies and techniques needed to address the increasing risk and uncertainty facing electric power system planners and operators in the future. This research is intended to integrate supply, delivery (transmission and distribution), and demand-side needs into an integrated stochastic planning and operational framework consistent with a vision of future engineering and market functions.

Market functions include investigations into, for example, the best-valued system use of storage, ramp, renewable and micro sources, effects of decreasing inertia, the planning for transmission under supply locational uncertainty, and environmental implications of a shifting policy landscape. Modeling and computation includes investigations into new algorithms for solving difficult nonlinear problems; a stochastic framework for uncertain yet integrated energy, ancillary, and environmental markets; and the development of synthetic test systems to address issues of robust testing of algorithms and ideas.

Within this element of the Transmission Reliability program, we are currently focused on three main areas of research:

- ***Tools and Algorithms***
  Co-optimization of energy and ancillary services that takes proper account of reliability requirements (e.g., contingencies) is at the heart of tool development. This work is based upon the idea that a proper "SuperOPF"—one that is grid-wide in scope and where all limits and "products" are properly priced—is fundamental to being able to move forward with long and short-term market design and operation.
- ***Stochastic Planning and Operations***
  Development of techniques necessary for planning and operating a future grid system that will be required to accommodate many forms of uncertainty—especially that associated with variable renewable energy supply and new technologies such as electric vehicles and storage.
- ***Demand-Side, Environmental, and Reliability Issues***
  Development and applications of integrated market and engineering approaches which, when applied to carefully chosen case studies, provide useful information and analysis that informs policy making and investment decision making.

[1] See http://energy.gov/downloads/2011-strategic-plan

This work is reviewed annually by the U.S. Department of Energy's Office of Electricity Delivery & Reliability, and review materials are posted to the DOE website.[2]

2017 Peer Review Meeting

The 2017 meeting was held on June 14, 2017 in Washington, D.C. Attendees included research performers from participating national labs and research institutions. The meeting included 11 presentations, each with a research talk and a question-and-answer period. Presenters were asked to summarize progress to date, and to describe future activities for the coming fiscal year.

Peer Reviewers

The reviewers participating in the 2017 Program Review were: Vikram Budhraja, of Electric Power Group (EPG); Paul Gribik of Pacific Gas & Electric (PG&E); and Richard O'Neill of the Federal Energy Regulatory Commission (FERC). Reviewers were chosen based on their research and industry knowledge. Reviewers with personal involvement with individual specific projects were recused from scoring those projects.

Reviewer Scoring

Reviewers were asked two questions:

1. How valuable is the research for DOE's R&D program?
2. What (if anything) should be done to improve this research activity?

In response to the first question, reviewers were asked to score each project on a scale of 1-5, with 1 being 'low value' and 5 being 'highest value.' The average score for each presentation is included in the summary section below. Following the meeting, each presenter was provided with their scores and the summary comments provided by the reviewers.

Projects Presented for Review in June 2017

Project:	**Models and Strategies for Optimal Demand Side Management in the Chemical Industries (FOA 1493 #133)**
Presenter:	Michael Baldea, University of Texas at Austin
Avg Score:	3.5

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

[2] See http://energy.gov/oe/services/technology-development/transmission-reiability

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.

Selected Reviewer Comments:

- Important research for improving market efficiency.
- This type of work is very important to future efficiency in power markets. Work on reducing process to a bid function in the day-ahead market and real-time market.

Project:	**Economical and Engineering Aspects of Proactive Demand Participation: Centralized versus Bilateral Control Structure (FOA 1493 #123)**
Presenter:	Nanpeng Yu, University of California, Riverside
Avg Score:	3.5

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.

Selected Reviewer Comments:

- Interesting and path breaking research. Implementation requirements may be difficult. Likely to be very beneficial in improving understanding of distribution systems.
- Operation of distribution system with DER is becoming more challenging. This work can address aspects.

Project:	**Multi-Stage and Multi-Timescale Robust Co-Optimization Planning for Reliable and Sustainable Power Systems (FOA 1493 #122)**
Presenter:	Lei Wu, Clarkson University
Avg. Score:	2.0

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.

Selected Reviewer Comments:

- Very ambitions – long-term, short term; ISO coordinate planning.
- Unclear to me who will use the product. If generation owner, transmission expansion that RTO will do should be considered a parameter. If RTO, generation expansion should be a parameter.

Project:	**Management of Risk and Uncertainty through Optimized Cooperation of Transmission System and Microgrids with Responsive Loads (FOA 1493 #120)**
Presenter:	Lindsay Anderson, Cornell University
Avg. Score:	3.0

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.

Selected Reviewer Comments:

- Understanding behavior of microgrids under different scenarios is important for informing DSO if they emerge as entities.
- Demand response modeling is important. Methods to better model uncertainty are important.

Project:	**Flexible Service Contracting for Risk Management within Integrated Transmission and Distribution Systems (FOA 1493 #108)**
Presenter:	Zhaoyu Wang, Iowa State University Science & Tech
Avg. Score:	2.5

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.

Selected Reviewer Comments:

- Concept is interesting. Implementation questions should be addressed.
- The simulation investigation is interesting. However, more information on market design is needed to evaluate the importance of the project.

Project:	**Impact of Coordinated Aggregation of DER on Bulk Power System Performance**
Presenter:	Alejandro Dominguez-Garcia, University of Illinois at Urbana-Champaign
Avg. Score:	3.5

The overall objective of this project is to develop a framework to assess the impact on bulk power system performance of distributed energy resources (DERs) when coordinated (via an aggregator) to provide ancillary services, e.g., frequency regulation. Of special interest is understanding the potential negative effects of failures in channels utilized by the aggregator to exchange information with the individual DERs and the hardware used to implement the DER local control. Additionally, we will consider the potential impact of other sources of uncertainty that might affect the performance of DERs when being utilized for providing ancillary services.

A key objective of the project will be to develop dynamic models for collections of aggregated DERs that take into account the aforementioned sources of uncertainty. These models must be compatible with standard dynamic models used in bulk power system dynamic simulations; this is key to be able to conduct system-level studies to assess the impact of the uncertain sources described above (associated with the utilization of DERs to provide ancillary services) on the overall system dynamic performance and reliability.

Selected Reviewer Comments:

- Focus on ancillary services aggregation and dispatch is going to be important. Application will depend on market structure.
- Shows how a DER can incorporate uncertainty when supplying Reg. Important as DER on distribution grows.

Project:	**Managing Uncertainty in the Modern Power System**
Presenter:	Eilyan Bitar, Cornell University
Avg. Score:	4.5

The predominant approach to controlling the power system today makes poor use of information. Many empirical investigations have shown the cost due to this inefficiency to grow large as the fraction of supply from variable renewable energy resources increases. In an effort to quash this inefficiency, we plan to formulate the security constrained unit commitment (SCUC) and economic dispatch (SCED) problems in the language of constrained stochastic optimal control—a framework that enables the characterization of optimal control policies, which are guaranteed to minimize the expected cost of operating the power system.

This research aims to develop novel algorithmic tools to efficiently manage the variability that renewable energy resources bring to bear on power system operations at scale. Specifically, this work aims to (1) develop distributionally robust control algorithms to enable the near-optimal dispatch of uncertain power networks; and (2) design stochastic market clearing mechanisms to provide a competitive medium through which renewable power producers can sell their variable supply on equal footing with conventional power producers and flexible demand.

Selected Reviewer Comments:

- Concept of distributed controllers is very good. Promising results.
- Control of distributed resources on distribution system to enforce distribution level constraints is very important to DSO. Good work.

Project:	**Probabilistic Forecast of Real-Time LMPs**
Presenter:	Lang Tong, Cornell University
Avg. Score:	3.5

The objective of this project is to develop computationally tractable techniques for the *short-term probabilistic forecast* of congestion and real-time locational marginal price (LMP) for large utility-size networks under a multi-area SuperOPF framework. The developed techniques are intended for the service operator to (i) anticipate congestion situations for operation planning; (ii) scheduling flows with neighboring operators; and (iii) provide real-time (non-binding) price forecast to aid operation decisions of its participants and facilitate demand response decisions. To this end, the forecast algorithm will be an integral component of the real-time market operation.

This project includes the following tasks:

1. *Real-time congestion forecast:* For the 2016 CERTS project, we have focused on real-time LMP forecast and developed two techniques, one based on a non-homogeneous Markov chain model of the LMP state, the other based on the multi-parametric linear programming. While

congestion and LMP are results of the same linear program, their relation is not one-one correspondence. We will extend these techniques for congestion forecast. The developed technique will provide an estimated probability mass function of congestion.

2. *Embedding congestion and contingency forecast in SuperOPF:* We extend and incorporate the forecasting techniques for SuperOPF that incorporates probabilistic scenarios. In particular, we will develop probabilistic forecast methods that provide estimated contingency probabilities of contingencies and LMP distributions that can be incorporated into multi-period SuperOPF calculation.
3. *Demand/supply function forecast for interregional coordination:* An important open problem is the scheduling and exchange among neighboring ISOs. The current ad hoc approaches and the lack of coordination may lead to increased operation cost in scheduling and interface pricing discrepancies. In this research, we develop probabilistic forecasting techniques for demand and supply functions that can be used for interregional coordination. In particular, for the export region, we provide a probabilistic supply function that gives the probably distribution of export LMP for the given exported quantity. Similarly, for the import region, we provide the probability distribution of import LMP as a function of the import quantity.

Selected Reviewer Comments:

- Good research.
- Unclear how this improved CTS will address and eliminate loopflow, which can arise from schedules in a single RTO.

Project:	**On Valuing System Inertia and Fast Storage Response**
Presenter:	Ti Xu, University of Illinois at Urbana-Champaign
Avg. Score:	4.0

The objective of the proposed work is to investigate the value of inertia as a service to grid operations. We will consider questions such as how much inertia is needed for grid operation, how much location comes into play in determining governor response, what magnitude and rate of charge/discharge storage would be needed to mimic system inertia, and what procedures would be used to value system inertia.

The overall research plan is to examine inertial and governor response as an ancillary resource and develop techniques to assign a value to this resource. Determining the value of response involves being able to characterize the locational sensitivity of frequency. Some regions can provide more response than others, but the details depend on which contingency has occurred, where the response is being measured, and what other resources contribute.

Selected Reviewer Comments:

- Inertia is important (including primary frequency control) and increasing. Need for inertia and pfc should be evaluated and locational needs also should be evaluated. This work provides some needed info.
- The presentation was hard to understand and follow.

Project:	**Dynamic Reserve Policies for Market Management Systems**
Presenter:	Nikita Singhal, Arizona State University
Avg. Score:	4.0

This project is conducting optimization-based analyses to examine: (a) new reserve policies for contingency-based reserves and ramping products, which may be needed to compensate for resource uncertainty; (b) the possible creation of dynamic zonal reserve policies; and (c) the creation of response-set reserve policies that specify a set of generators (or resources providing reserves) that will respond given a specific event—while taking into consideration network limitations.

Objectives and tasks include:

- Design a multi-stage framework accounting for:
  - A look-ahead stage prior to day-ahead market model
  - A day-ahead market SCUC
  - Adjustment period modifications
  - A real-time market SCED

- Use the multi-stage framework to design and test models and algorithms for each of the core building blocks

- Replicate and enhance work by EPRI for CAISO
  - EPRI is formulating and solving a stochastic program within the adjustment period, which determines the reserve requirement inputs for the real-time deterministic market based SCED. Such work is similar to prior work by Dr. Hedman. This project will enhance the step-by-step process taken by EPRI.

- Develop data mining techniques to determine reserve policies

- Compare and contrast dynamic reserve policies with stochastic programming approaches

Selected Reviewer Comments:

- Investigates using stochastic optimization to inform RTO markets re reserve requirements and deployment. Good path to get benefits of stochastic models into today's market structure.
- Very interesting but difficult to follow.

Project:	**Random Topology Power Grid Modeling and Automated Simulation Platform**
Presenter:	Zhifang Wang, Virginia Commonwealth University
Avg. Score:	3.0

This project is developing approaches for automatically generating hypothetical power grid models that preserve key attributes of real power grids—which can then be used to study issues that affect these grids but do not require provision of sensitive or hard-to-find information on the true attributes of real power grids. This research addresses a key limitation of many current studies, which is access to detailed information on actual power systems.

Selected Reviewer Comments:

- Development of synthetic grid models is very useful.
- Need to convince to users that testing on synthetic problems has value.