# 2017 ADMS Program
# Steering Committee Meeting
# Project Summary

| | |
|---|---|
| **Project Title:** | **Community Control of Distributed Resources for Wide Area Reserve Provision** |
| **Organization:** | LBNL (lead), NREL, SNL, Smarter Grid Solutions |
| **Presenter:** | Jason MacDonald (PI: Duncan Callaway, by phone) |
| **FY 2018 Funding ($K):** | $1,075 |

## Project Objectives and Outcomes

Our goal is to develop and demonstrate an advanced distribution management system (ADMS) that allows DERs to improve distribution system operations and simultaneously contribute to transmission-level services. In short, we envision (1) elevating load buses to the level of generator buses with respect to the degree of control authority they present to system operators and (2) simultaneously optimizing distribution-level measures such as resistive losses and managing power flows to ensure voltage and thermal constraints are met.

The project outcome will be interoperable, validated open source protocols that facilitate this vision. The protocols will be implemented on commercial DMS system and demonstrated via HIL testing. We will specifically develop: (1) Tools for spatiotemporal forecasting of DER output, (2) New distribution system operations planning, including battery state of charge management, (3) New real time decentralized optimization tools, (4) Hardware-in-the-loop tests of PV and battery systems for network management, (5) Implementation on industry partner's existing DER management platform and (6) Assessment of value for volt-VAR optimization and delivery of transmission level services.

## Significance and Impact

Accurate distribution network models and full state estimates are not widely available and require significant validation and sensing infrastructure investments if they are to be used as the sole means of decision-making in distribution systems. Therefore an important underlying goal in this research is to develop an ADMS that is fully capable of optimizing distribution system operations and providing transmission level services in the presence of model error and forecast uncertainty, and inaccurate state estimates.

Moreover, using DER for transmission and distribution services faces performance and reliability uncertainties for several reasons. First, ISOs today dispatch DERs without knowing impact on the distribution system or if they are feasible. Second, currently there are limited methods to forecast how DER participation affects net load and voltage, at the T-D interface. Third, the distribution operator does not currently have the same level of visibility, control and situational awareness of DERs as the ISO does with transmission connected generators.

The project's anticipated benefits include: (1) Reduced costs and improved power quality for electricity consumers, (2) New network and DER management products and opportunities for distribution operators to reduce costs in, or even profit from, transmission-level markets, (3) Tools to facilitate greater penetration of variable renewable generation, additional options for flexibility, additional market participants for transmission operators and (4) Open-source algorithms for distribution network management products that can be readily adopted by industry.

## Technical Approach

The core of our solution is a hierarchical control platform, with two levels:

1. An off-line forecasting and network optimization module that solves a model-based optimal power flow problem in combination with transmission-level objectives. The off-line network-level controller is rooted in a model-based optimal power flow solver that identifies optimal DER setpoints based on forecasted power injections and extractions over an optimization time horizon.

2. A decentralized array of controllers that take the off-line network controller solutions and adapt them in real time. The decentralized level of the hierarchical control strategy we are developing is built from a model-free optimization paradigm known as extremum seeking control (ESC), the application of which in the distribution system context was pioneered by the PI and his students at UC Berkeley.

Our proposed control approach initially focuses on controlling real and reactive power output from power electronic inverters of distributed energy resources to manage distribution network power flow and transmission-level objectives. Though we focus on devices that interface via power electronic converters, our framework can be extended to capture the operation of conventional network assets such as voltage regulators and switching capacitor banks.

The framework is complementary to outage management, asset management, workflow management, and customer information systems; we envision that vendors will ultimately integrate our solution into an end-to-end ADMS solution that captures all these functions. Furthermore, we seek to develop and demonstrate an ADMS platform that is capable of operating in parallel and interoperable with legacy distribution management protocols and systems. As distribution system operators gain confidence with the ADMS platform, legacy protocols can be subsumed by the ADMS as desired, facilitating broad but initially conservative rollout of the platform.

The major challenges to a development and demonstration effort of this scope include: (1) Data availability for a physical implementation; we overcome this challenge by building hardware in the loop testing capabilities at LBNL and Sandia. (2) Interoperability of devices and data standards to coordinate multiple DER classes, SCADA equipment and AMI data in a single platform. We will overcome this challenge under the leadership of project partner Smarter Grid Solutions by using open and common data standards and developing modules for interfacing them.

## Technical Progress and Results

Task 1: *Forecasting and offline optimization*. Our geospatial solar forecasting algorithm is developed and implemented in R with a Python wrapper for data management and qualification. The forecasting components are intended for inclusion in the open-source pvlib-python. Validation with SMUD sensor network in progress.

For offline optimization, we are currently in the process of integrating chance constrained formulation into GAMS (optimization solver), where the chance constraints will be formulated with output from solar and load forecasts. We also developed a stochastic framework for determining which locations in distribution feeders are most receptive for Volt/VAR or Volt/Watt control (or both) under high solar penetration; this framework includes uncertainties in load and solar irradiance. Our results demonstrably improve upon the default Volt/VAR settings in the IEEE 1547.8 standard by preventing oscillations in voltage and reactive power.

Task 2: *Real time optimization*. We validated a four-quadrant ESC on the IEEE 37 node test system with additional transmission impedance and 6 ES-controlled DER with real and reactive power control capabilities. Simulation results demonstrate ES control can allow a load bus to mimic generator controls at the T-D interface. We also have new theoretical guarantees of performance of decentralized ES control algorithm; this opens the possibility to use ES control for other distribution system applications. We have completed preliminary work extending ES control to manage battery storage devices.

Task 3: *Interoperability and platform implementation.* We completed the system design specification, developed a network model for real-rime simulation, integrated and tested ESC logic into the platform, integrated GAMS optimization engine using a Java API, and began preliminary OPAL-RT testing.

Task 4: *Simulation and hardware in the loop testing.* We demonstrated ESC voltage regulation in SNL hardware testing environment, configured LBNL FLEXLab OPAL-RT test environment for HIL testing, and completed an RPU uPMU data analysis to identify frequency regions for ESC probe.

## Project Collaborations and Technology Transfer

The project team combines crosscutting expertise in modeling, control, optimization, and hardware-in-the-loop (HIL) experimentation. LBNL and NREL bring significant expertise in network optimization and distributed control of power systems. SNL contributes an established track record in renewable resource forecasting. To translate algorithmic advances into laboratory prototypes, LBNL and SNL are applying HIL techniques to enable realistic validations. As a major outcome, industry partner, Smarter Grid Solutions, leads tech-to-market efforts in developing a next-generation ADMS product. Also Riverside Public Utilities is a project partner here and for follow-on ENERGISE project, and aspects of the ADMS system serve as basis for recent GMLC “GRIP” award led by SLAC (Google, SCE, Tesla, NRECA are key project partners on that project). We are participating in the California T-D interface working group (CAISO, PG&E, SCE, SDG&E also participate). We have published 6 papers and submitted one patent application.