Network Optimized Distributed Energy Systems (NODES)

The Network Optimized Distributed Energy Systems (NODES) Program aspires to enable renewables penetration at the 50% level or greater, by developing transformational grid control methods that optimize use of flexible load and distributed energy resources (DERs). The challenge is to reliably manage changes in the grid by leveraging these additional grid resources, while maintaining customer quality of service. The expected benefits include improving grid efficiency, reducing CO_2 emissions in power generation by directly offsetting load consumption with renewable energy production, and lowering required operating reserves. Additional savings are expected to reduce energy-delivery losses by distributing energy where it's needed, and when it's needed. The NODES Program will bring together different scientific communities with expertise in power systems, control systems, computer science, and distributed systems to accelerate the development of new technologies enabling active control of load and DERs in coordination with the grid.

PROJECT DESCRIPTIONS

University of Vermont – Burlington, VT

Packetized Energy Management: Coordinating Transmission and Distribution - $1,537,904

The University of Vermont (UVM) will develop and test a new approach for demand-side management called packetized energy management (PEM) that builds on approaches used to manage data in communication networks without centralized control and requires a high level of privacy. The PEM system will allow millions of small end-use devices to cooperatively balance energy supply and demand in real time without jeopardizing the reliability of the grid or the quality of service to consumers. The project will develop the PEM method to manage large, rapid fluctuations associated with renewable power generation, while simultaneously ensuring grid reliability. To ensure UVM's PEM method, the integrated system will undergo extensive simulation testing with large-scale hardware implementation for the bulk power grid and in industry-scale, micro-grid environments.

University of California: San Diego – La Jolla, CA

Distributed Grid Control of Flexible Loads and DERs for Optimized Provision of Synthetic Regulating Reserves - $2,338,485

The University of California, San Diego (UCSD) will develop coordination algorithms and software using intelligent control and optimization for flexible load and DERs to provide reliable frequency regulation services for the bulk power grid. The project will develop a multi-layer framework for larger-scale energy aggregators to act on behalf of their smaller-sized customers to help respond to incoming requests from regional transmission operators. The team will develop approaches that aggregators can use to quantify reserves, system objectives and constraints, customer usage patterns, and generation forecasts. Aggregators will use distributed coordination algorithms to rapidly respond to operators while considering network constraints and quality of services for customers. The UCSD's technology to manage flexible loads and DERs offers economic and operational advantages for utilities, operators and customers.

Arizona State University – Tempe, AZ

Stochastic Optimal Power Flow for Real-Time Management of Distributed Renewable Generation and Demand Response - $3,000,000

Arizona State University (ASU) will develop a stochastic (randomly determined) optimal power flow (SOPF) framework, which would integrate uncertainty from renewable resources, load, distributed storage, and demand response technologies into bulk power system in a holistic manner. The algorithms will be implemented in a SOPF software tool to provide system operators with real-time guidance to help coordinate between DERs and

demand response. ASU's project features unique data-analytics based short-term forecast for bulk wind and solar generation and an advisory tool that generates real-time recommendations for market operators based on algorithm outputs.

Stanford University – Stanford, CA

Open and Scalable Distributed Energy Resource Networks - $3,500,000

Stanford University will develop Powernet, an open-source and open architecture platform for scalable and secure coordination of consumer flexible load and DERs. Powernet will be based on the principle of connecting information networks to the power network (connecting bits and watts). It uses a layered architecture that enables real-time coordination of centralized resources with millions of DERs by integrating embedded sensing and computing, power electronics, and networking with cloud computing. The team will develop a Home Hub system capable of networking with existing inverters and appliances in a home and controlling power via smart switches that replace traditional fuses. The Home Hub will also use algorithms for aggregating local customer resources to meet local constraints and global coordination objectives. A cloud-based cloud coordinator platform will be developed that executes optimization and monitoring functions to coordinate Home Hubs by minimizing costs while increasing aggregate consumer quality-of-service.

General Electric Global Research – Niskayuna, NY

Synthetic Reserves from Aggregated Distributed Flexible Resources - $3,900,000

General Electric Global Research along with its partners will develop a novel distributed flexibility resource (DFR) technology that aggregates responsive flexible loads and DERs to provide synthetic reserve services to the grid while maintaining customer quality-of-service. One of the key novelties of the project is to develop a forecast tool that will use short-term and real-time weather forecasts along with other data to estimate the reserve potential of aggregate loads and DERs on a day-ahead basis. An optimization framework that will enable aggregation of large numbers of flexible loads and DERs and determine the optimal day-ahead schedule to bid into the market will also be developed. A scalable control and communication architecture will be developed for coordinating and controlling the resources in real-time based on a two-tier hierarchical optimal control algorithm.

National Renewable Energy Laboratory – Golden, CO

Real-time Optimization and Control of Next-Generation Distribution Infrastructure - $3,900,000

The National Renewable Energy Laboratory (NREL) project will develop a comprehensive distribution network management framework that unifies real-time voltage and frequency control at the home/DER controllers' level with network-wide energy management at the utility/aggregator level. The distributed control architecture will leverage the real-time feedback control to continuously steer frequency and voltages towards optimal operating points while dynamically procuring and dispatching synthetic reserves based on current system state and forecasts of ambient and load conditions. The NREL framework enables computationally affordable distributed implementations by decomposing network-level optimization into smaller sub-problems and applying appropriate approximations. This allows implementation across distributed low-cost microcontrollers and control is carried out via elementary operations. Responsiveness to rapidly changing conditions is facilitated by incorporating intrinsic network physics into the control formulation and by processing real-time measurements.

Pacific Northwest National Laboratory – Richland, WA

Multi-scale Incentive-Based Control of Distributed Assets - $2,700,000

Pacific Northwest National Laboratory (PNNL) will develop and test a hierarchical control framework for coordinating the flexibility of a full range of DERs, including flexible building loads, to supply reserves to the electric power grid. The hierarchical control framework consists of incentive-based control strategies across multiple time-scales. The system will use a slower incentive-based approach to acquire flexible assets that provide services, combined with faster device-level controls that use minimal communication to provide desired

responses to the grid. Each DER that chooses to participate will communicate its ability to provide flexibility and the time scale over which it can provide the service. A distribution reliability coordinator acts as an interface between the DERs and the bulk system, coordinating the resources in an economic and reliable manner. The team will characterize various DER types to quantify the maximum flexibility that can be extracted from a collection of DERs in aggregate. The performance of the resulting hierarchical control system will be tested at scale in a co-simulation environment spanning transmission, distribution, ancillary markets, and communication systems.

Regents of the University of Minnesota – Minneapolis, MN

A Robust Distributed Framework for Flexible Power Grids - $2,950,000

The University of Minnesota will develop a comprehensive approach that addresses the challenges to system reliability and power quality presented by widespread stochastic renewable power generation. By developing techniques for both centralized cloud-based and distributed peer-to-peer networks, the proposed system will enable coordinated response of many local units to adjust consumption and generation of energy, satisfy physical constraints, and provide ancillary services requested by a grid operator. The project will apply concepts from nonlinear and robust control theory to design self-organizing power systems that effectively respond to the grid events and variability. A key feature enabled by the proposed methodology is a flexible plug and play architecture wherein devices and small power networks can easily engage or disengage from other power networks or the grid.

Northwestern University – Evanston, IL

A Novel Hierarchical Frequency-Based Load Control Architecture - $2,692,845

Northwestern University and its partners will develop a frequency-based load control architecture to provide additional frequency response capability and allow increased renewable generation on the grid. The work will focus on developing and demonstrating algorithms that adapt to rapid changes of loads, generation, and system configuration while taking into account various constraints arising from the transmission and distribution networks. The multi-layer control architecture makes it possible to simultaneously ensure system stability at the transmission network level, control frequency at the local distribution network level, and maintain the quality-of-service for individual customers at the building level, all under a single framework. At the transmission level, coordination among different areas will be achieved through a centralized scheme to ensure stable frequency synchronization, while the control decisions within a single area will be made based on local information. The project will also develop a new Micro-Phasor Measurement Unit (µPMU), based on existing smart meters, to produce sensor measurements required for the real-time state estimation of the transmission/distribution networks.

DNV GL – Chalfont, PA

Enabling the Internet of Energy through Network Optimized Distributed Energy Resources - $2,150,000

DNV GL together with its partners will develop an innovative Internet of Energy (IoEn) platform for the automated scheduling, aggregating, dispatch, and performance validation of network optimized DERs and controllable load. The IoEn platform will simultaneously manage both system level regulation and distribution level support functions to facilitate large-scale integration of distributed generation onto the grid. The IoEn will demonstrate a novel and scalable approach for the fast registration and automated dispatch of DERs by combining DNV GL's power system simulation tools and independent third-party validation with Geli's innovative networking, control, and market balancing software. The platform will demonstrate the ability of customer-sited DERs to provide grid frequency regulation and distribution reliability functions with minimal impact to their local behind-the-meter demand management applications. The IoEn will be demonstrated and tested at Group NIRE's utility-connected microgrid test facility in Lubbock, Texas, where it will be integrated with local utility monitoring, control and data acquisition systems. By increasing the number of local devices able to connect and contribute to the IoEn, this

project aims to increase renewables penetration above 50% while maintaining required levels of grid performance.

National Rural Electric Cooperative Association – Arlington, VA

GridBallast - Autonomous Load Control for Grid Resilience - $1,335,507

The National Rural Electric Cooperative Association will develop GridBallast, a low-cost demand-side management technology, to address resiliency and stability concerns accompanying the exponential growth in DERs deployment in the North American electric grid. Specifically, devices based on GridBallast technology will monitor grid voltage and frequency and control the target load in order to address excursions from grid operating targets. The devices will operate autonomously to provide rapid local response, removing the need for costly infrastructure to communicate with a central controller. If the devices are installed with an optional radio, they will be able to support traditional demand response through peer-to-peer collaborative operation from a central operator. The team includes experts from Carnegie Mellon University, Eaton Corporation, and SparkMeter, and will focus development on two specific devices: a water heater controller, and a smart circuit controller. The GridBallast project aims to improve resiliency and reduce the cost of demand side management for voltage and frequency control by at least 50% using a streamlined design and removing the need for extensive communications infrastructure.

Eaton Corporation – Menomonee Falls, WI

Cloud-Based Cascaded Multi-rate DER Control for Synthetic Regulating Reserves - $3,311,532

Eaton Corporation proposes to develop and validate a disruptive cloud-computing solution that will provide agile and robust synthetic regulating reserve services to the power grid. This approach separates the decision-making of synthetic regulating reserve services into two-levels to significantly reduce the computational and communication complexity, thereby enabling large-scale coordinated control of a vast number of DERs and flexible loads. The system-operator level estimates and predicts reserve capacity of the distribution network and decides on the appropriate economic incentives for DERs to participate in future services. At the local level, an energy node comprised of a cluster of DERs will automatically decide its own reserve services strategy that takes into account short-term net load and economic incentives. By splitting these decisions between the two levels, the solution does not require extensive communication or negotiation between the local DERs and the system operators in the cloud.