Pacific Northwest
NATIONAL LABORATORY

Proudly Operated by Battelle *Since 1965*

Multi-Scale Incentive-Based Control of Distributed Assets

Karan Kalsi, Pacific Northwest National Laboratory (PNNL)

Partners: United Technologies Research Center (UTRC), Southern California Edison, GE Grid Solutions, PJM Interconnection, and California ISO

CRITICAL NEED

The infrastructure that defines the U.S. electric grid is based largely on pre-digital technologies developed in the first part of the 20th century.

Grid development has evolved over the years to improve safety, accessibility, security, resiliency, and reliability. Throughout this evolution, the grid mainly relied on centralized power plants to quickly balance supply and demand to ensure system reliability. However, the increasing use of renewable power generation such as solar and wind power, along with customers' changing energy use patterns, are leading to greater unpredictability in the electric grid.

New operational paradigms are required to meet this increase in renewable generation and DERs, while providing the quality of service, resiliency, and reliability that customers expect.

OUR SOLUTION

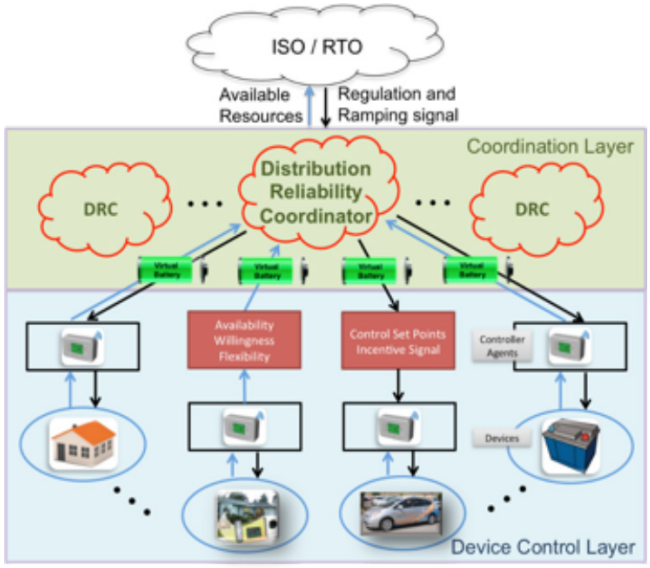
In an effort to improve predictability within the electric grid, PNNL is developing and testing a hierarchical control framework for coordinating the flexibility of a full range of DERs—including residential and commercial building loads, electric vehicles, and photovoltaic inverters to supply reserves to the electric power grid.

The hierarchical control framework will consists of two layers— a coordination layer and device-control layer, operating at different time scales.

Coordination Layer: A distribution reliability coordinator (DRC) will act as an interface between the DERs and the bulk system, coordinating the resources in an economic and reliable manner. The DRC will engage the flexibility of DERs by aligning device capabilities to services that are best suited to the DER, while maximizing system benefits.

Device Layer: Each DER will communicate its own desire and ability to provide grid services to the DRC, while using local, real-time controls to provide those services within its own, self-selected comfort zone.

The performance of the resulting control system will be validated at scale using a co-simulation platform tied to a hardware-in-the-loop testbed, representing tens of thousands of controllable DERs.



Conceptual overview of the proposed hierarchical control strategy.

U.S. DEPARTMENT OF ENERGY

APPROACH

Device Characterization and Control

DER flexibility models will be developed and calibrated using data acquired from the PNNL and United Technologies Research Center test sites. The flexibility models will be used by the following device level controllers to provide different grid services.

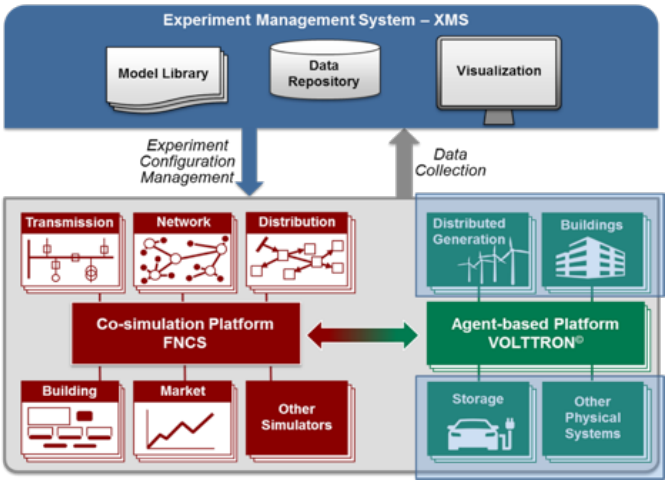
- Frequency responsive controllers autonomously switch on/off in a "droop-like" manner by self-sensing over/under frequency events
- Regulation responsive controllers respond to a broadcasted 4-second signal in a probabilistic manner
- Ramp responsive controller responds to a broadcasted 5-min signal, again in a probabilistic manner

Resource Allocation and Coordination

- Optimize device allocation to each service based on device-level characterization of flexibility
- Forecast aggregate DER flexibility and coordinate the response to meet grid service requirements
- Deliver operating set points to devices to enable a coordinated response

Large-Scale Co-Simulation Platform

- Evaluate the performance with high-resolution simulation under a variety of scenarios
- Large-scale (>10,000 control points; multiple distribution circuits) testing of control strategies using co-simulation platform comprising of transmission, distribution, and market simulators



Hardware-in-the-Loop testing switches between simulated and actual hardware.

Hardware-in-the-Loop Testing

The performance of the hierarchical control system will be evaluated in a Hardware-in-the-Loop setting that seamlessly switches between simulated and actual hardware. This will take place across the PNNL, UTRC, and Southern California Edison test sites.

Hardware testing at PNNL will focus on residential buildings and appliances; UTRC will evaluate the performance of commercial buildings and HVAC equipment; SCE will evaluate the impact and/or benefits to distribution circuits; and GE Grid solutions will investigate the interactions with system operators.

For additional information contact:

Karan Kalsi, karanjit.kalsi@pnnl.gov

Draguna Vrabie, draguna.vrabie@pnnl.gov

Jason Fuller, jason.fuller@pnnl.gov

United Technologies Research Center

Grid Solutions

Southern California Edison

pjm

California ISO

Pacific Northwest National Laboratory

Proudly Operated by Battelle Since 1965