Office of Electricity
Delivery & Energy
Reliability

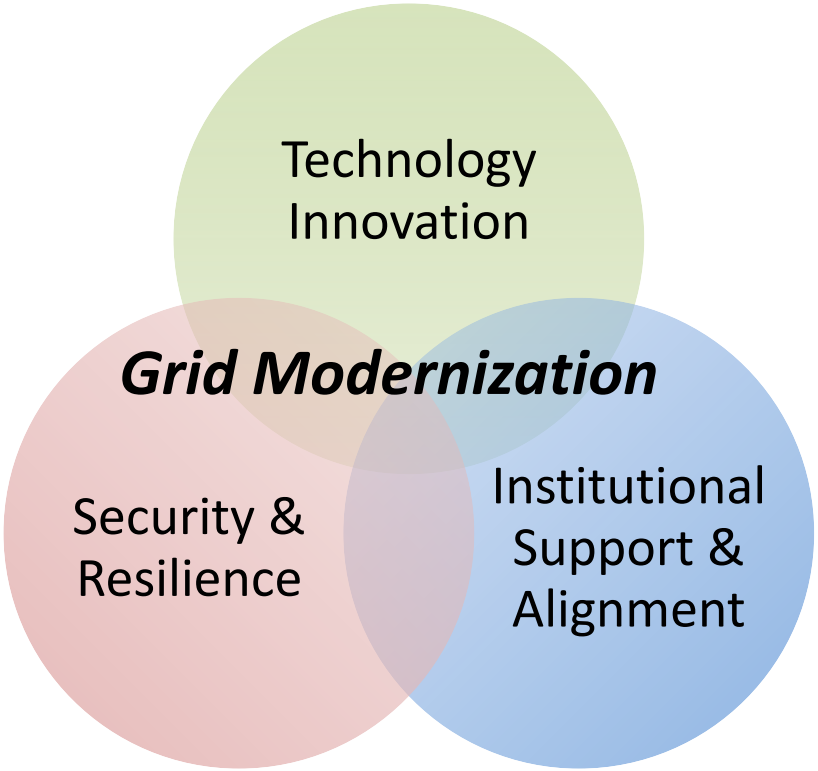
DOE Microgrid Program
Microgrid Controllers

Dan Ton
Power Systems Engineering Research and Development
February 16, 2017

OE Mission

The Office of Electricity Delivery and Energy Reliability (OE) drives electric grid modernization and resiliency in the energy infrastructure.

- OE leads the Department of Energy's efforts to ensure a resilient, reliable, and flexible electricity system.
- OE serves as the Energy Sector Specific lead for the Federal emergency response when activated by DHS/FEMA.



Grid Modernization Vision

*The future grid provides a critical platform for U.S. prosperity, competitiveness, and innovation in a global clean energy economy. It must deliver **reliable, affordable,** and **clean electricity** to consumers where they want it, when they want it, how they want it.*

Achieve Public Policy Objectives

- 80% clean electricity by 2035
- State RPS and EEPS mandates
- Access to reliable, affordable electricity
- Climate adaptation and resilience

Sustain Economic Growth and Innovation

- New energy products and services
- Efficient markets
- Reduce barriers for new technologies
- Clean energy jobs

Mitigate Risks and Secure the Nation

- Extreme weather
- Cyber threats
- Physical attacks
- Natural disasters
- Fuel and supply diversity
- Aging infrastructure

Smart Grid R&D Focus Areas

Microgrid R&D

For commercial viability, reliability, and resiliency

Continue R&D pathway to support achieving the DOE program goals (in reliability, efficiency, CO_2 reduction, and cost effectiveness) and implementing the DOE CAP strategy, leading to creating a smarter and more resilient grid and community.

Advanced Distribution Management System (ADMS)

Providing better control and visibility

Develop architectures that integrate new & existing applications across the utility enterprise to accommodate rapid and complex communications/interactions between D&T; develop operational control strategies using advanced analytics.

Resilient Electric Grid R&D

For enhanced grid resilience

Implement high-priority R&D projects identified in the resilient grid roadmap, developed in a broad stakeholder workshop in 2014 and finalized during the QER in 2015.

Market-Based Control Signals

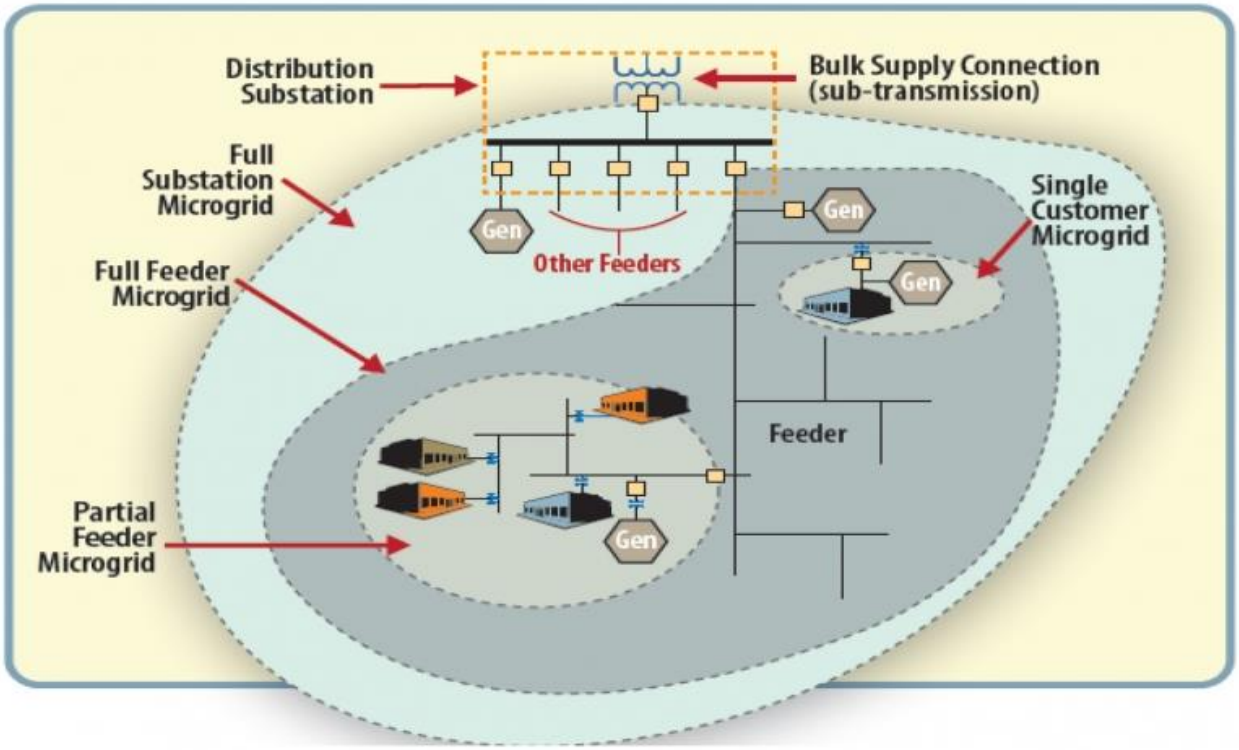
Enabling economical and flexible stability

Develop simulation tools for the impact of transactive control, establish valuation basis for customer-delivered and grid-delivered energy services, and assess how to achieve a more distributed customer-driven grid.

Integrated µGrid R&D Plan

Vision

The Integrated µGrid R&D Program foresees the technical requirements for advancing the microgrid to a fully integrated entity within the distribution system, interacting seamlessly with the Distribution System Operator.



Integrated µGrid R&D Plan
Program Areas

Design and Planning Tools
- Microgrid Design Optimization Using DER-CAM
- Impact Analysis of Interactive Operations of Microgrid and Distribution System

System Control and Power Flow
- Guidelines for DMS for Grid Modernization
- Grid Interactive Microgrid Controllers & Aggregated DER

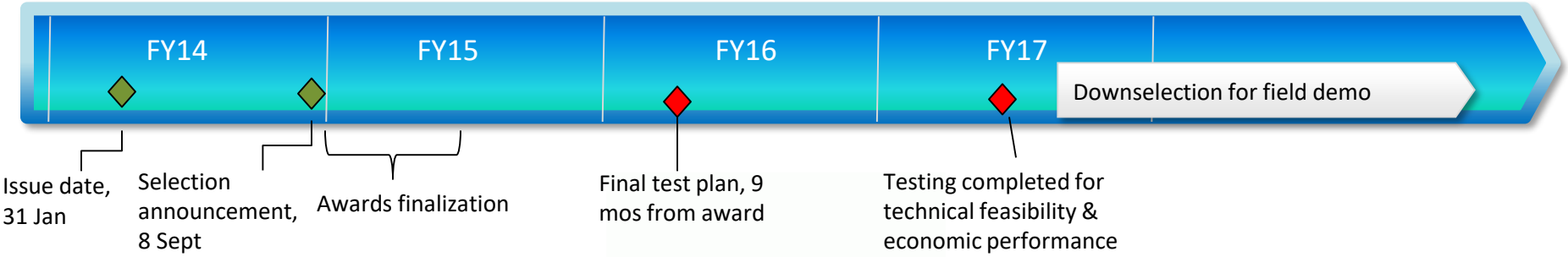
Device and Integrated Testing
- Microgrid Controller HIL Test Bed
- uGrid EMS and DMS – modeling and simulations

Standards
- IEEE p2030.7 Standard for Specification of Microgrid Controllers
- IEEE p2030.8 Standard for Testing of Microgrid Controllers

Microgrid Research, Development, and System Design (DE-FOA-0000997)

FOA Objective:
Advance microgrid system designs (<10MW) and control functionalities to support achievement of DOE program targets and community-defined resilience objectives

FOA Partnered Projects:
>$12M in total investment (OE: 59%; Indian Energy: 9%; private sector: 33%);
2-year project period of performance, including 18-month R&D and 6-month testing, data collection, and analysis



GE Global Research

ComEd An Exelon Company

EPRI ELECTRIC POWER RESEARCH INSTITUTE

ALSTOM | Grid

TDX power a tanadgusix company

Microgrid Institute

UCI University of California, Irvine

DOE Microgrid R&D Program

2011 Workshop

Defined the DOE 2020 targets	Recommended further integration of component- and system-level R&D areas

2012 Workshop

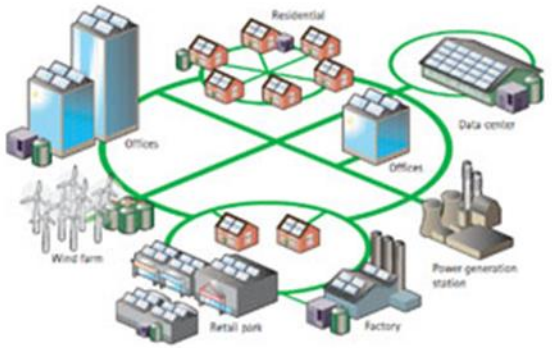
Prioritized R&D topics in planning/design	Prioritized R&D topics in operations/control

Develop <u>commercial scale</u> (<10 MW) microgrid systems capable of meeting the 2020 targets:

- Reduce outage time of critical loads by >98% at a cost comparable to non-integrated baseline solutions (uninterruptible power supply + diesel generator)
- Reduce emissions by >20%
- Improve system energy efficiencies by >20%

Status of Microgrid Controller Projects

- Analysis of load profiles
- Definitions of functional requirements
- Microgrid and microgrid controller design
- Test plans
- Simulations
- Analysis of microgrid costs and emissions
- Energy models
- Financial models
- Policy and regulatory issues, e.g., rate design, business models
- Use cases and scenarios impacting designs
- Clarify application of IEEE 1547 requirements
- Stakeholder interactions



Design Support Tool for Remote Off-Grid Microgrid Projects

Scope of Work

"… seeking a design support tool that is capable of providing decision support analysis on AC and DC microgrids to meet user-defined objectives and constraints for costs and energy system security."

- Remote community defined as distant, isolated, populated area
  - Limited or no accessibility to distributed power system
  - High cost of electricity due to transporting fossil fuels
- Develop, test, & transition the design support tool into practice
- Expandable to include grid-connected; AC-DC hybrids; and transient dynamics for microgrid survivability

Standards for Microgrid Controllers and Testing

IEEE P2030.7 *Standard for the Specification of Microgrid Controllers*.

- PAR Approved by IEEE SA on June 11, 2014
- Working Group formed – FOA Awardees encouraged to participate
- Projected Completion Date – August 2017

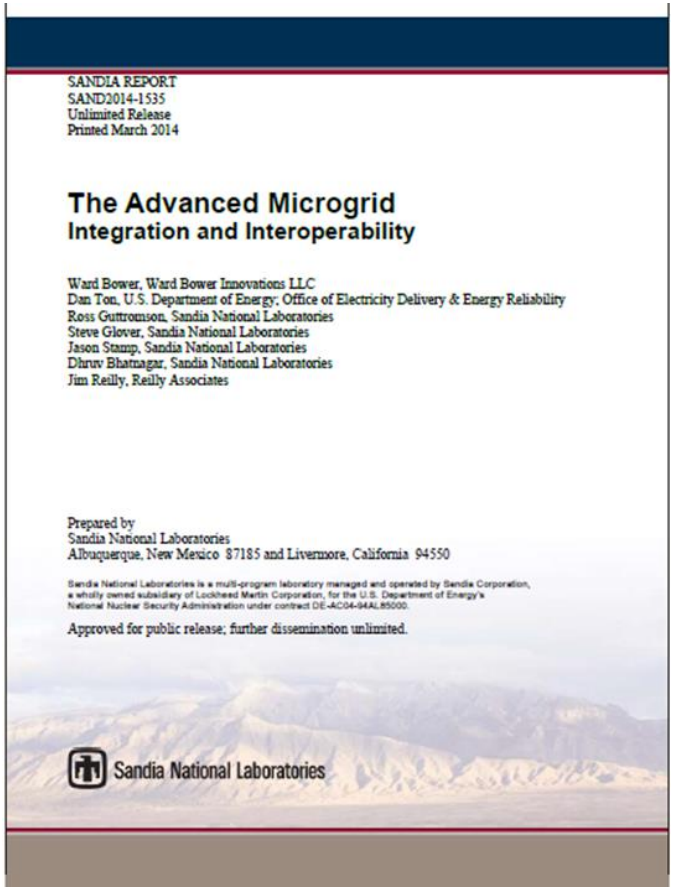
IEEE P2030.8 *Standard for the Testing of Microgrid Controllers.*

- PAR Approved by IEEE SA on June 11, 2015
- Working Group being formed – FOA Awardees encouraged to participate
- Projected Completion Date – May 2018

Advanced Microgrid

SAND 2014-1525

- Objectives
- Operational modes
- System architecture
- Technical challenges
- Development impact areas
- Ownership of microgrids
- Microgrid applications
- Standards and codes
- Microcontrollers
- References


SANDIA REPORT
SAND2014-1535
Unlimited Release
Printed March 2014

The Advanced Microgrid
Integration and Interoperability

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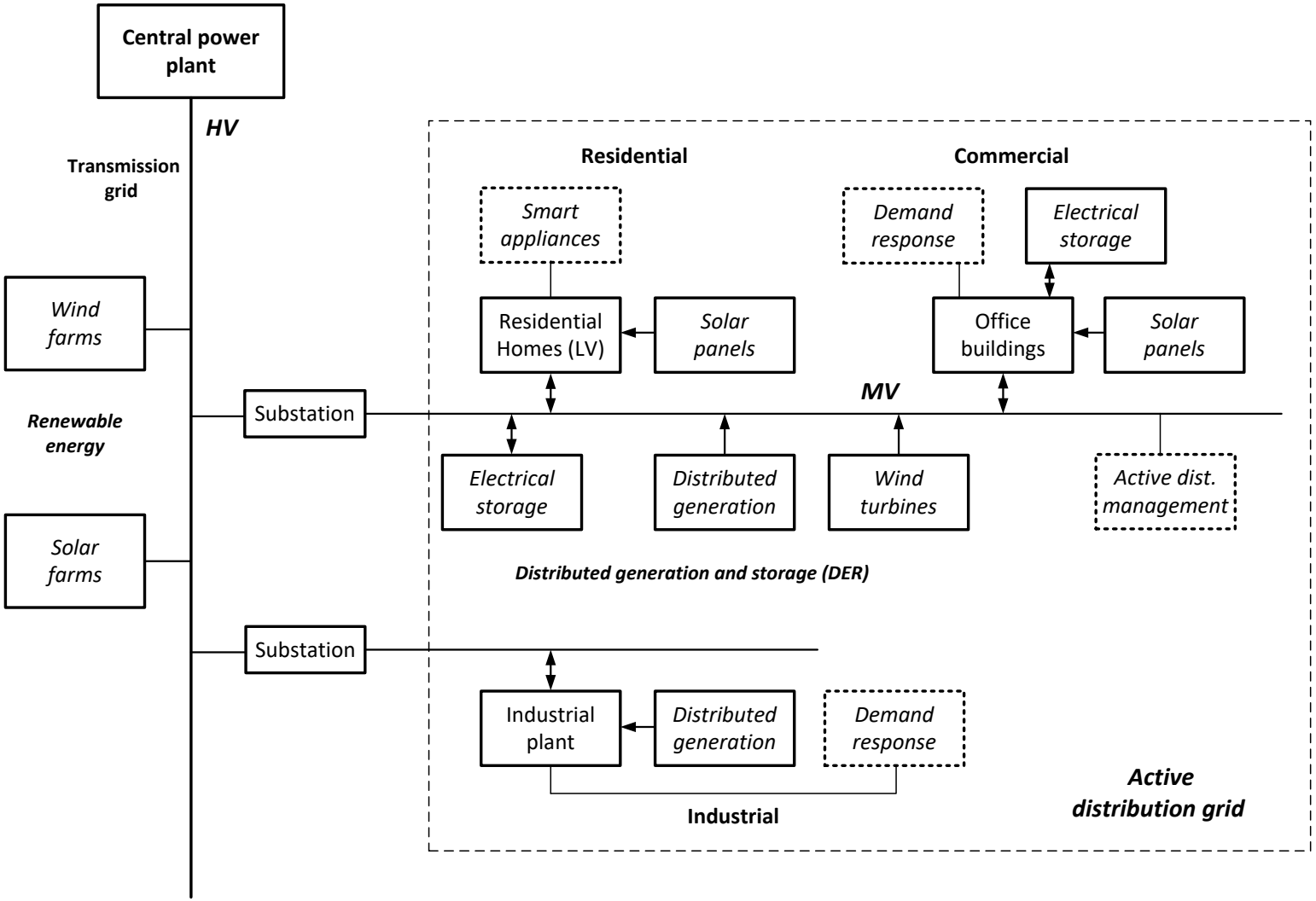
Sandia National Laboratories

"An advanced microgrid is one that provides functions at the PCC beyond basic islanding (disconnect) and synchronization (reconnection) functions. An Advanced Microgrid interacts with the larger grid (macrogrid) cooperatively managing power flows across the PCC optimizing benefits for both the microgrid and macrogrid."

Microgrid and Constitutive Components



Hardware-in-Loop (HIL) Testing

Digital real-time simulation allows researchers to study multiple scenarios in near real conditions and without risk. They can integrate a power amplifier to introduce more realism and perform tests using real power flow between the simulated environment and real hardware. This is known as Power-Hardware-In-the-Loop (PHIL) simulation.

Purpose

- Provide standardized and independent testing
- Reduce deployment cost for new devices and solutions
- Perform research
- Investigate safety issues
- Facilitate standards development

Conduct testing of:

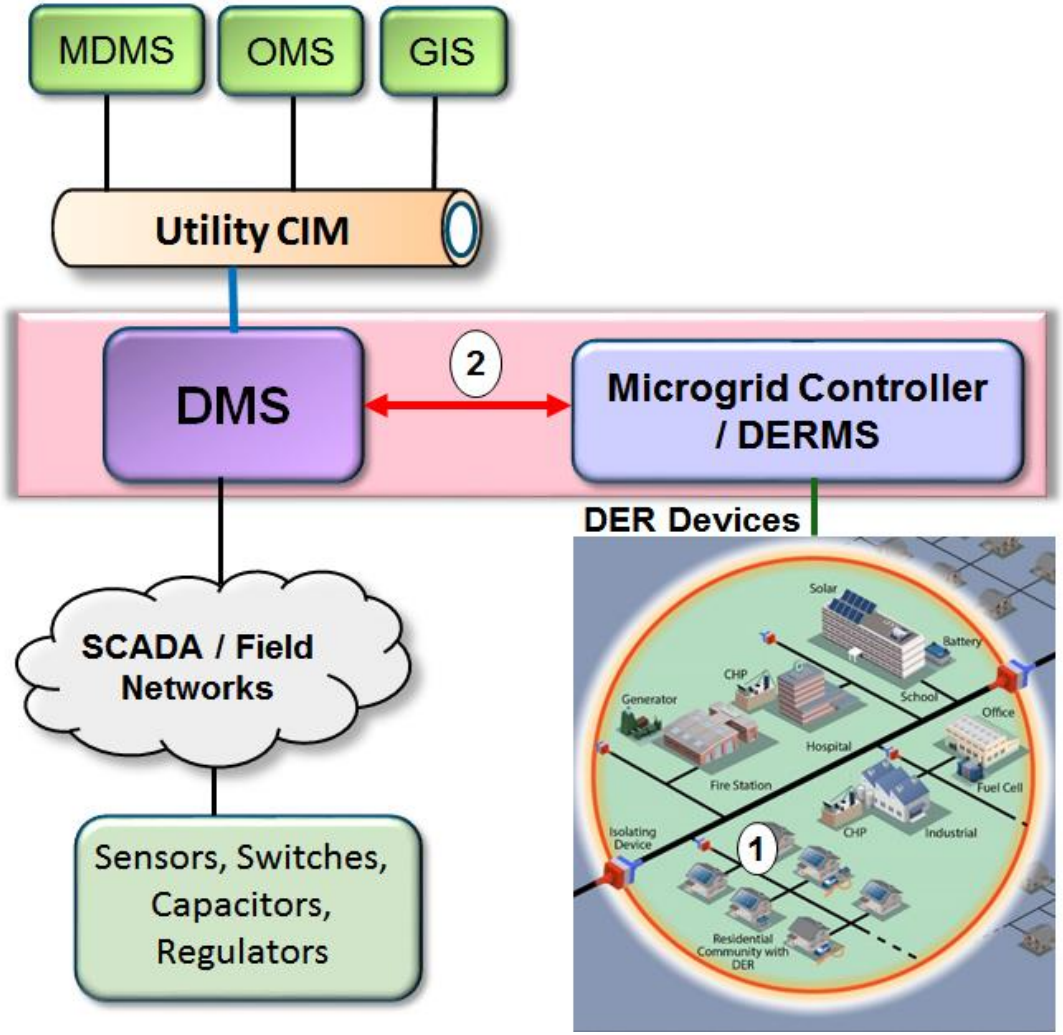
- Both system level and device level
- Microgrid energy management
- Microgrid control and operation
- Communication
- Protection

HILLTOP and EPHCC
MIT-LL

Projects funded by the DOE/OE microgrid program for testing microgrid systems at MIT-LL

- HILLTOP –power system Hardware-in-the-Loop Laboratory Testbed and Open Platform
- Electric Power Hardware-in-the-loop Controls Collaborative (EPHCC)
  - repository to share HILLTOP and HIL models from national labs and industry for real-time distribution engineering.
  - pilot program for the GMLC Open Library (GMLC-OL) effort, in coordination with Sandia and Idaho National Labs.
- Microgrid and DER Controller Symposium (February 16, 2017) to demonstrate to the integration of the HILLTOP platform with commercial vendors.

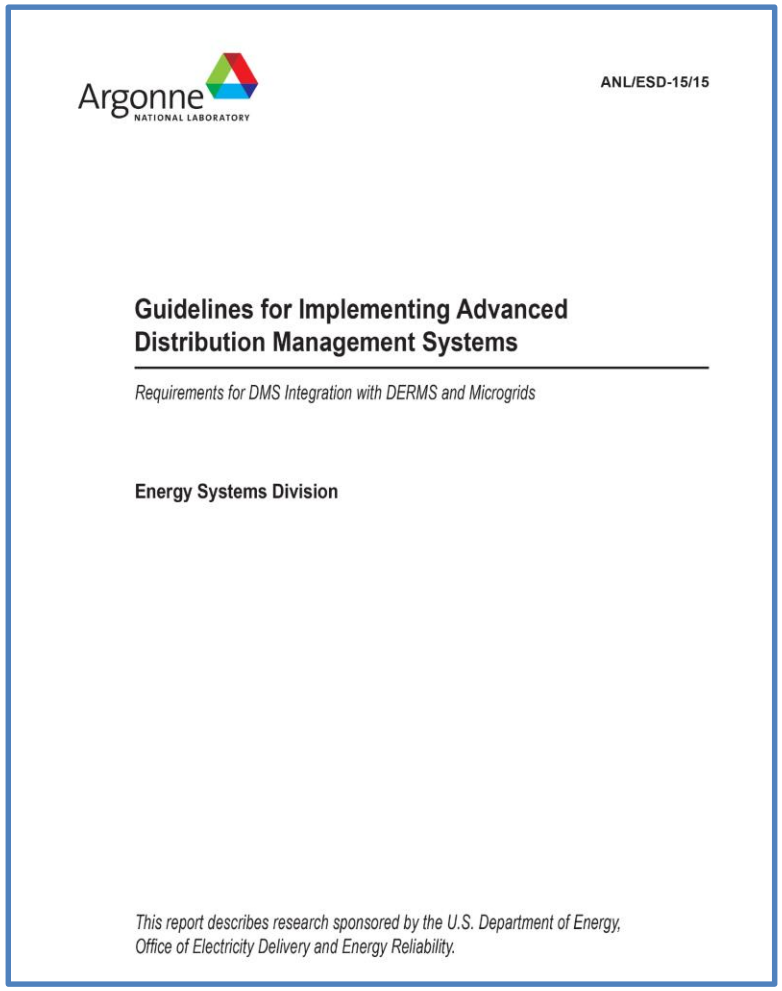
Relationship Between Microgrid Controller and DERMS



There is a need to develop standardized functions for the microgrid controller and establish the relationship with the utility DMS system at the DSO level leading to technical and business processes that are both effective and replicable in many jurisdictions with increasing adoption of microgrids and DER.

courtesy: EPRI

Microgrid Controller – Integration with DMS


Argonne NATIONAL LABORATORY

ANL/ESD-15/15

Guidelines for Implementing Advanced Distribution Management Systems

Requirements for DMS Integration with DERMS and Microgrids

Energy Systems Division

This report describes research sponsored by the U.S. Department of Energy, Office of Electricity Delivery and Energy Reliability.

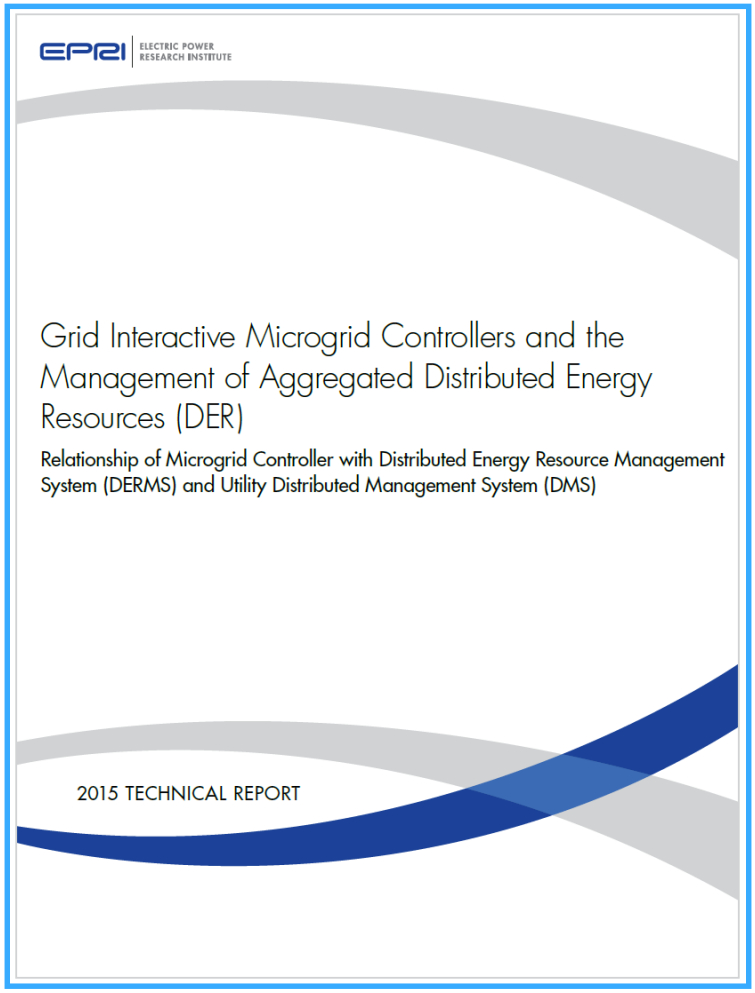
Responsibilities of microgrid for DMS

- Microgrid controllers are responsible for maintaining real power exchange, healthy voltage profiles at the active POCs when connected to the distribution grid
- Microgrids should automatically disconnect from the distribution grid in any grid fault condition beyond the threshold of ride-through

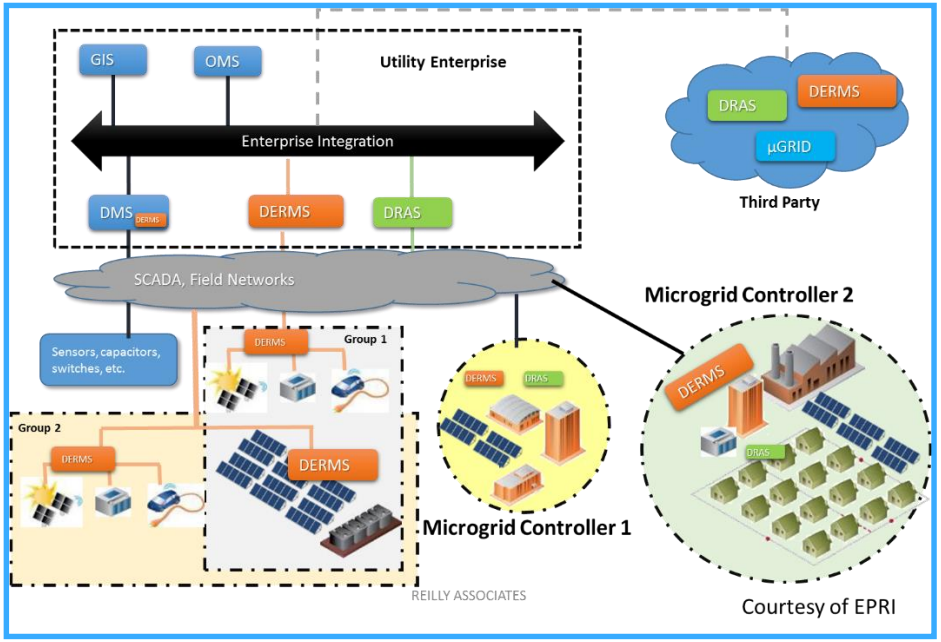
Responsibilities of DMS for microgrid

- DMS should provide operation guidance, including the voltage ranges and power exchange fluctuation tolerance around the scheduled targets at active POCs to the microgrids
- DMS can initiate emergency requests to microgrids for clearly defined specific emergency support, including support through wheeling

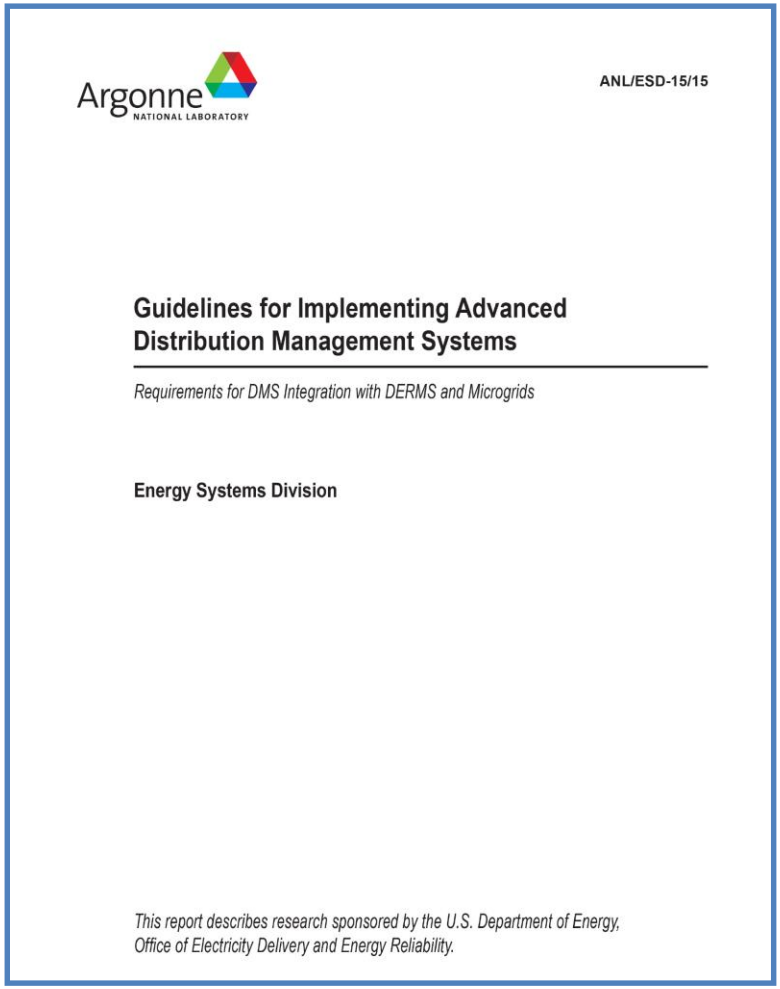
Grid Interactive Microgrid Controller



Microgrid Controller and DMS Relationship



Distribution Management System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PECO – Navy Yard Project

Provides technical support to the Navy Yard Microgrid project in the area of utility interconnection and protection

Structuring DMS Project

Objectives

- Develop integrated control and management systems for distribution systems
- Address high penetrations of interconnected DER.

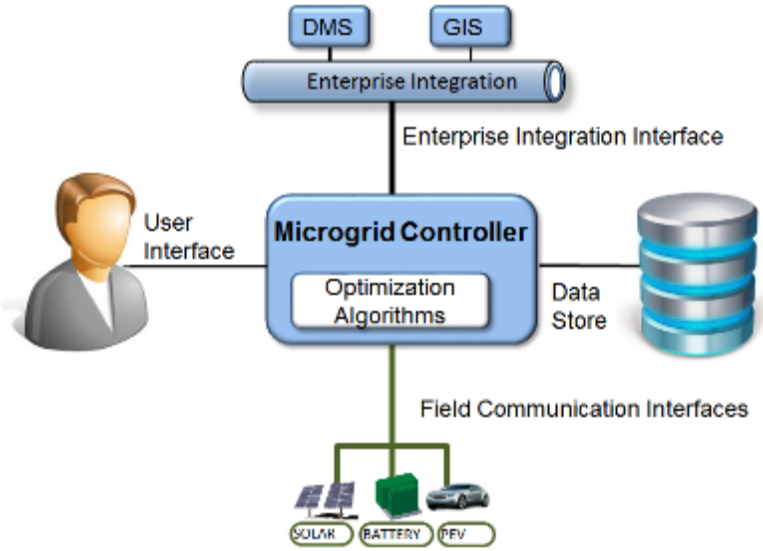
Project built on 2015 reports

- Argonne National Laboratory (ANL) and
- Electric Power Research Institute (EPRI)

Discover need for integration

- Distribution management system (DMS),
- Microgrid energy management systems (µEMS)
- Distributed energy resource management system (DERMS).

Microgrid Controller Interfaces



Structuring DMS Project

Scope

- Identify gaps and enabling technologies for integrating DMS, µEMS and DERMS
- Identify and define the interactive functions of controllers to fill those gaps
- Conduct a proof-of-concept simulation to evaluate the effectiveness of integrating the three control and management systems
- Establish the criteria for selecting a testing site(s) to verify the integration of the three control and management systems in field operations at a distribution utility.

Deliverable

Field site / demonstration project recommendations for validating the operational viability and effectiveness of integrated control and management systems.

Project team members

- Argonne National Laboratory
- Electric Power Research Institute
- National Renewable Energy Laboratory

System Impact Analysis
µGrids and Distribution Systems

Background

- Multiple µGrids may be interconnected to the distribution system in complex configurations.
- The impacts of µGrids on single feeders and the system are not yet well known.

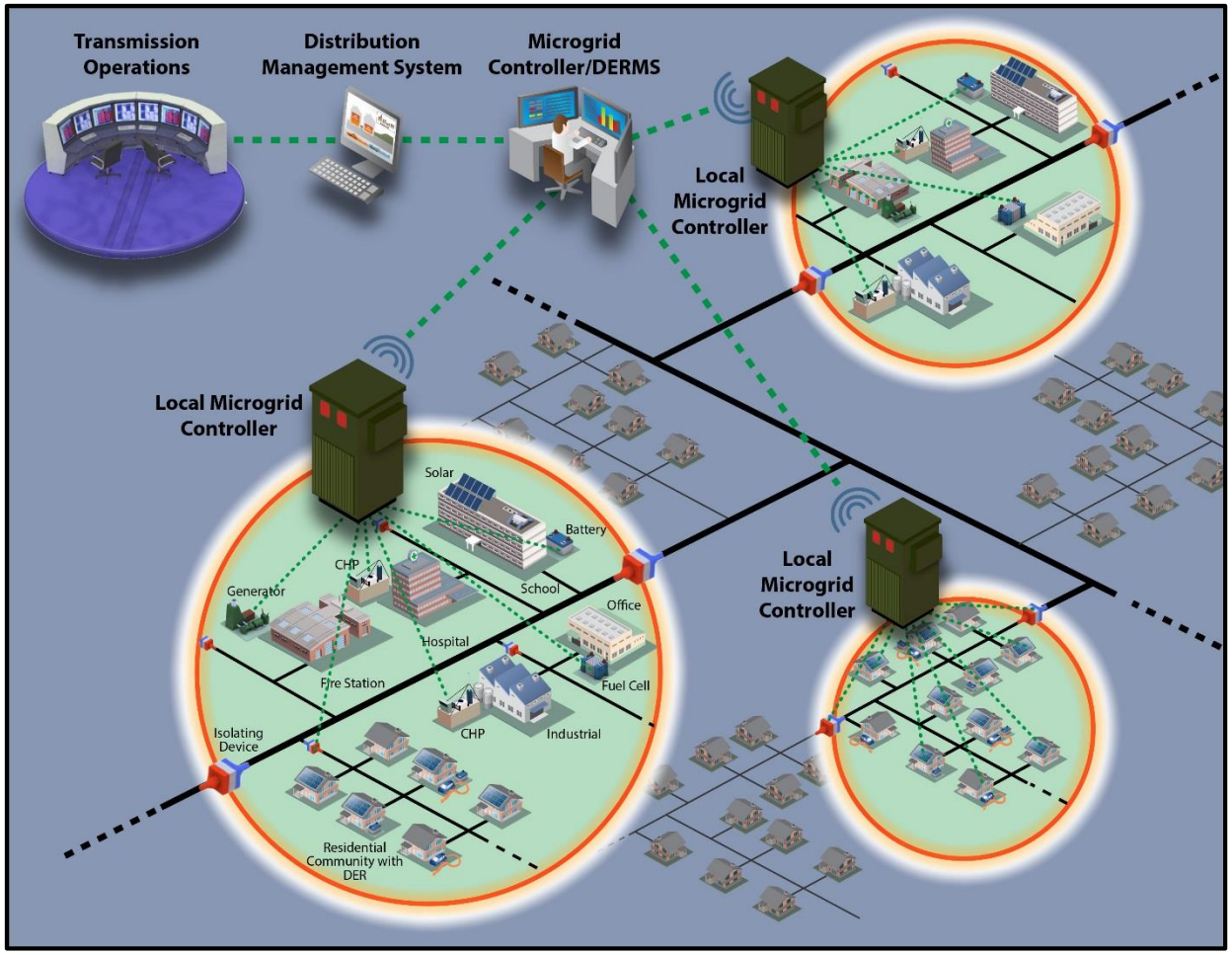
Objective

- Focus on the technical issues related to integrating advanced µEMS for multiple µGrids and existing DMS.
- Impact analysis for interactive operation of the µGrid and distribution system based on a multi-scale modeling framework.

Scope

- Analyze the interactions between integrated µGrids and the distribution system under various event scenarios/use cases
- Identify µGrid operation modes and strategies for connection and disconnection with the distribution system.

Integrating Microgrids and Distributed Controls



Source: EPRI

Microgrid Controller Program Timeline

2011 - 2012	2013 - 2014	2014 - 2017	2015 - 2018	2014 - 2017	2017 - 2020
Workshops	Use Cases	FOA 997	Metrics + Testing	IEEE Standards	uGrid Controller + DMS Simulations

Dissemination of Results

- Reports on Distribution Service Platform for REV
- Technical Transfer of DER-CAM microgrid model to national laboratories, EPRI, major integrators (including workshops)
- Guidelines on Distribution Management Systems (Argonne National Laboratory report)
- Grid Interactive Microgrid (EPRI report)
- Demonstration projects
- IEEE Standards Association working groups
- NIST/SGIP PAP-24 Microgrid Operational Interfaces
- Microgrid Symposium – HIL Testing Platform