Grid Modernization Initiative (GMI) Portfolio

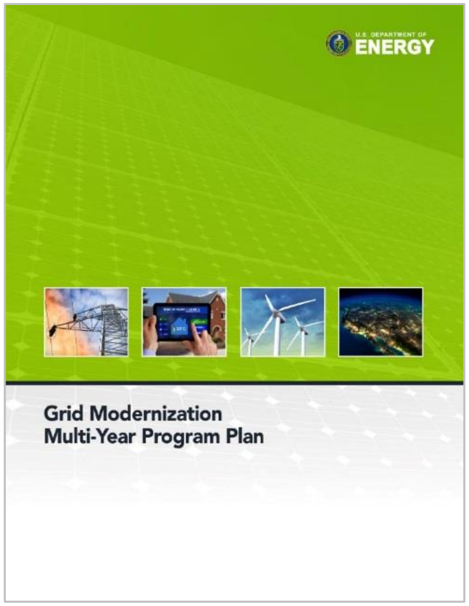
Integration of Renewable and Distributed Energy Resources (IRED) 2018

KEVIN LYNN

U.S. DEPARTMENT OF ENERGY

Grid Modernization Multi-Year Program Plan (MYPP)

- Design and Planning Tools
- System Operations, Power Flow, and Control
- Sensing and Measurements
- Devices and Integrated Systems
- Security and Resilience
- Institutional Support



GMLC Structure Supporting the Grid Modernization MYPP

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

National Lab Lead Integrators

Co-Chairs: Carl Imhoff (PNNL) and Juan Torres (NREL)

Technical Team Lead: Design and Planning Tools

John Grosh, LLNL

Technical Team Lead: System Operations and Control

Jeff Dagle, PNNL

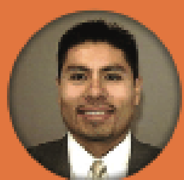
Technical Team Lead: Sensing and Measurements

Tom King, ORNL

Technical Team Lead: Devices and Integrated Systems

Ben Kroposki, NREL

Technical Team Lead: Security and Resilience



Juan Torres, NREL

Technical Team Lead: Institutional Support

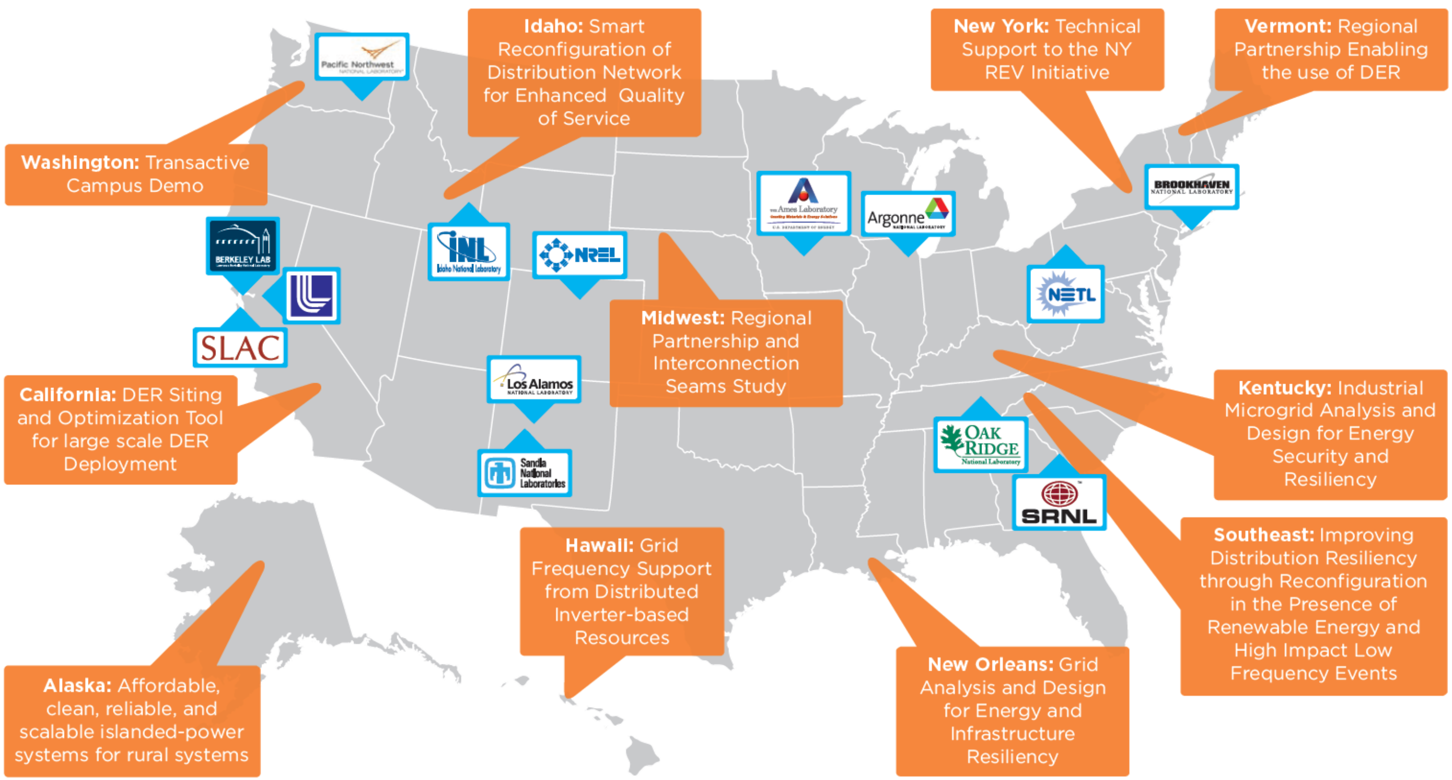
Chuck Goldman, LBNL

Lab leads coordinate teams and projects across the GMLC to ensure DOE and the national laboratories are meeting the goals of the Grid Modernization MYPP

Grid Modernization Lab Call 2016

Working across the country

GRID
MODERNIZATION INITIATIVE
U.S. Department of Energy



- Up to $220M
- 13 national laboratories
- 88 projects
- 150+ partners

Resilient Distribution Systems

Lab Call Overview

- Seeks to develop and validate innovative approaches to enhance the resilience of distribution systems, including microgrids, with high penetration of clean distributed energy resources (DERs).

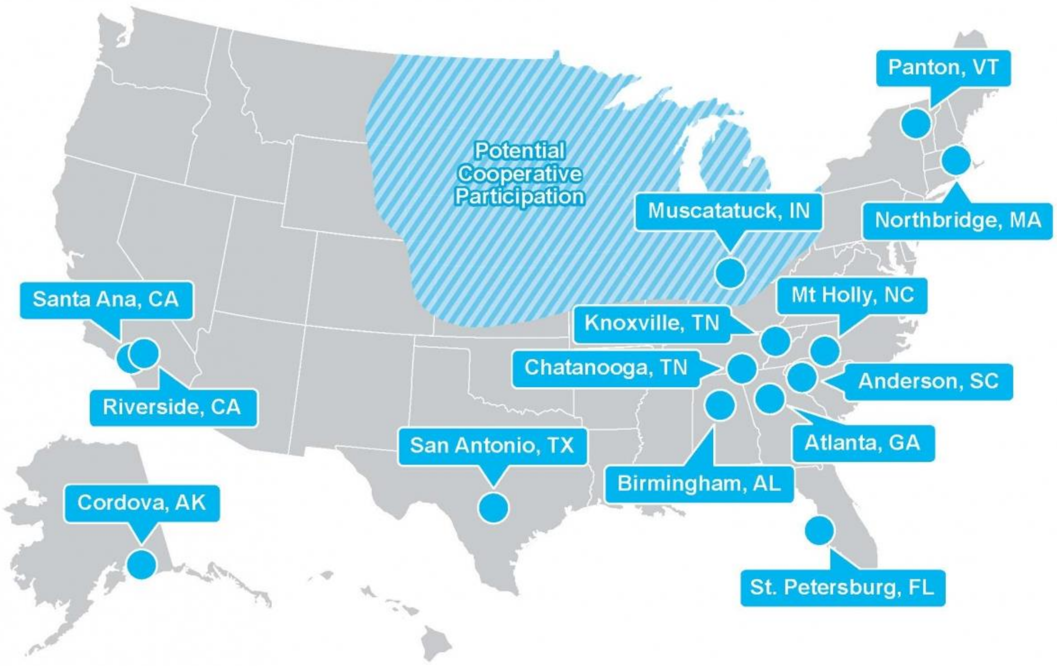
- Focuses on field validations, including control/coordination strategies, real-time system monitoring, robust communications infrastructure, grid planning and analytical platforms, and integration of multiple DER technologies.

- Addresses cybersecurity needs in grid technologies from the earliest stages to survive a cyber incident.

- Builds on FY16–18 GMLC Lab Call

- **Period of Performance –** FY18/19/20

- **Total Funding –** $32M



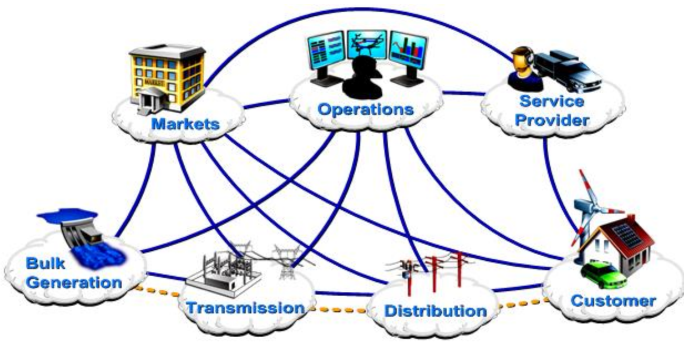
Map of Research Locations for Selected Projects

Design and Planning Tools

Objective: Drive development of next-generation tools that address evolving grid needs

<u>Expected Outcomes</u>

- A software framework to couple grid transmission, distribution, and communications models to understand cross-domain effects
- The incorporation of uncertainty and system dynamics into planning tools to accurately model renewables, extreme events, etc.
- Computational tools, methods, and libraries that enable a 1,000x improvement in performance



Simulating Interactions across Domains

Computational Speedup

Transmission, Distribution, and Communications Models

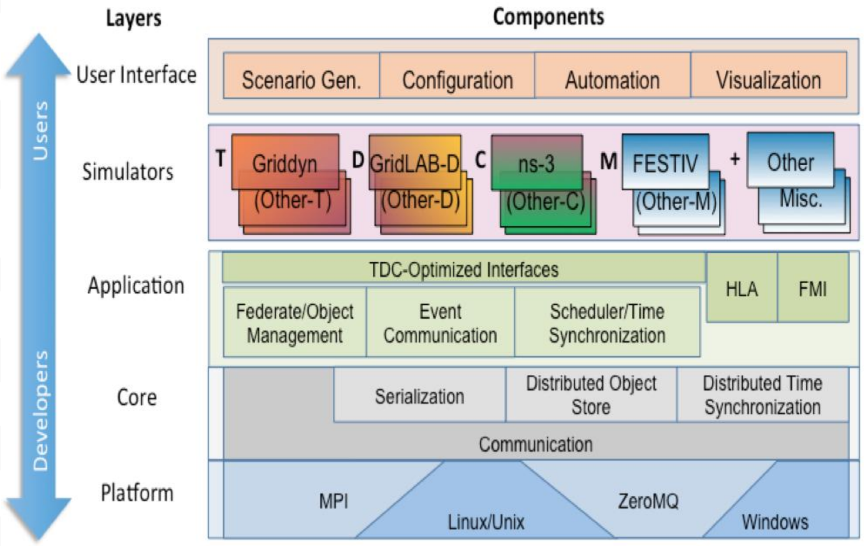
Project Description
This project aims to enable large-scale TDC interdependency studies through a flexible and scalable, open-source co-simulation platform for the following industry drivers

Project Objectives

✓ Provide foundational capabilities for grid planning, operation, and control
✓ Engage and educate grid developers on the value of multi-domain planning

Value Proposition

✓ There is currently a gap in simulation and modeling technology that inhibits integrated planning across multiple domains
✓ Left to it's own devices, the grid community is unlikely to develop capabilities to overcome planning stovepipes (in near term)
✓ The DOE plays a unique role in initiating this effort and creating foundational tools that support both research and industry



Development and Deployment of Multi-Scale Production Cost Models

High-Level Project Summary

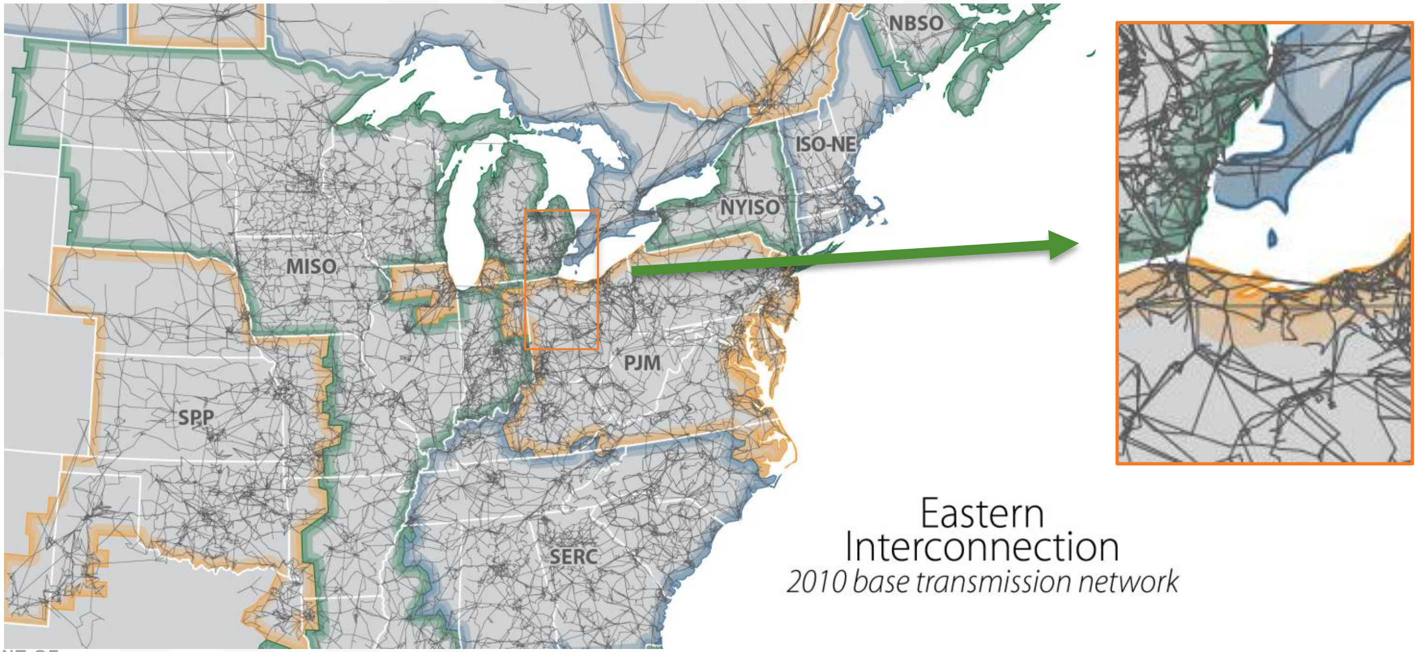
GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Project Description

Dramatically reduce the time required by industry to analyze **high-fidelity** power system scenarios through production cost modeling (PCM)

Project Objectives

- ✓ Develop **new models and algorithms**
- ✓ **Expand PCM capabilities through** high-performance computing (HPC)
- ✓ Deploy capabilities and data to **industry**
- ✓ Provide reference implementations for **vendors**

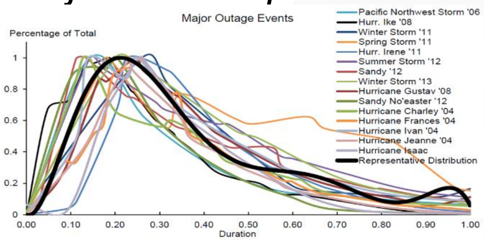


Eastern Interconnection
2010 base transmission network

Extreme Event Modeling

Natural and man-made extreme events pose threats

Project Description

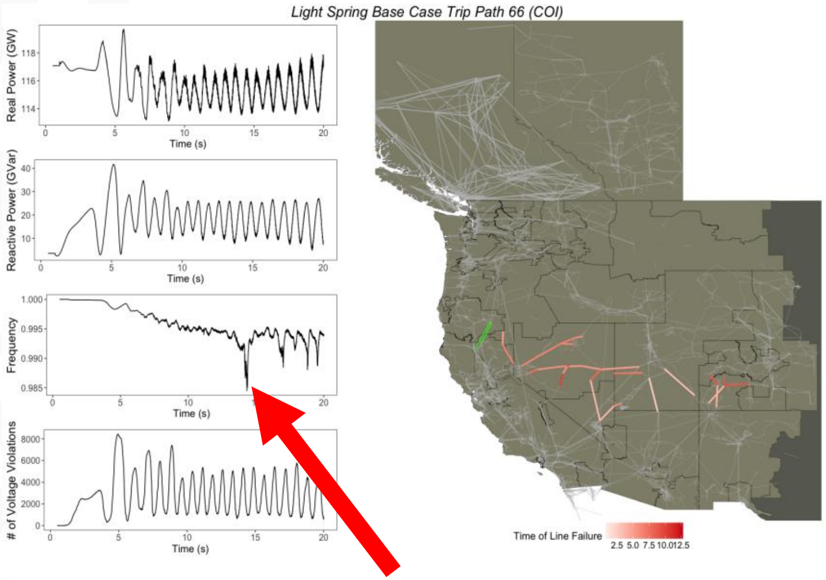


Source: Department of Energy, Office of Electrcity Delivery and Energy Reliability

- <u>Cascading and N-k modeling have large gaps</u>
  - Inadequate modeling
    - Reliability standards (NERC Standard TPL-001-4) challenging to meet with existing methods
  - Computational efficiency
    - Considerable speed up required for near term operations planning
- <u>N-k contingency analysis</u>
  - Existing k=3 analysis misses large-scale adversary attacks
  - Neglects high likelihood failures

Project Objectives

- ✓ Cascading tools that are 500x faster than existing packages
- ✓ Identify the worst k contingencies twice as fast
- ✓ Demonstration on a large-scale system



Frequency Event

Value Proposition

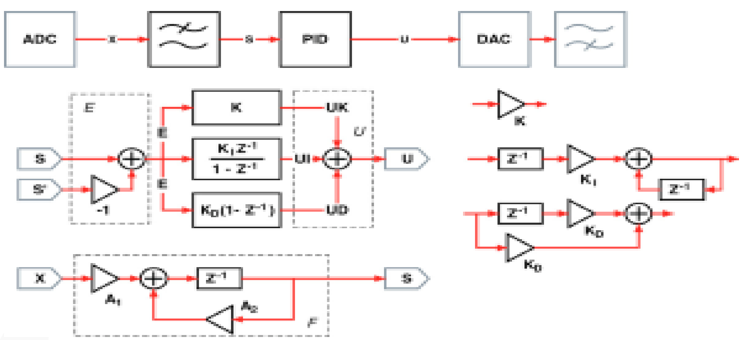
- ✓ Identify extreme event risk prior to event occurrence

System Operations, Power Flow, and Control

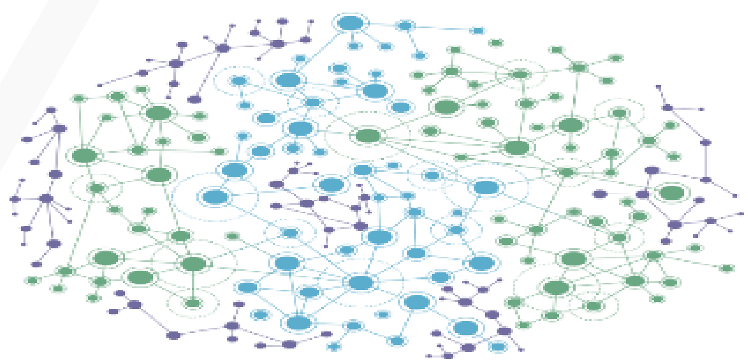
Objective: Develop advanced control technologies to enhance reliability and resilience, increase asset utilization, and enable greater flexibility of transmission and distribution systems

Expected Outcomes

- By 2020, deliver an architecture, framework, and algorithms for controlling a clean, resilient, and secure power grid
  - Leveraging advanced concepts, high performance computing, and more real-time data than existing control paradigms
  - Involving distributed energy resources as additional control elements
- Develop software platforms for decision support, predictive operations, and real-time adaptive control
- Deploy—through demonstration projects—new classes of power flow control device hardware and concepts
- Advance fundamental knowledge for new control paradigms (e.g., robustness uncompromised by uncertainty)



Conventional Controls



Distributed Controls

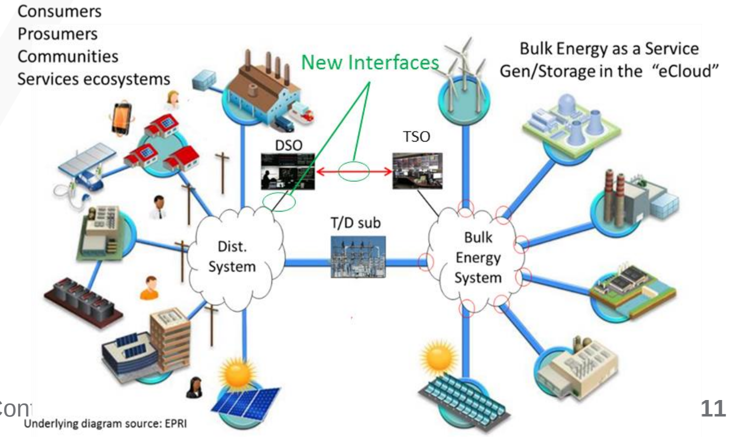
Grid Architecture

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Project Description
Grid architecture is the application of system architecture, network theory, and related disciplines to the whole electric grid. The purpose of this project is to re-shape the grid, remove essential barriers to modernization, redefine key grid structures, and identify securable interfaces and platforms.

Value Proposition
- ✓ Relieve essential constraints that impede grid modernization; define platforms and structures that provide resilience, functionality, security, and interoperability; manage complexity
- ✓ Proper structure (architecture) future-proofs grid modernization investments; poor structure results in high costs and low performance

Project Objectives
- ✓ Build stakeholder consensus around a DOE-convened vision of grid modernization, expressed as a new set of grid reference architectures
- ✓ Establish and win industry acceptance for the use of Grid Architecture work products and methodologies
- ✓ Supply a common basis for roadmaps, investments, technology and platform developments, and new services and products for the modernized grid



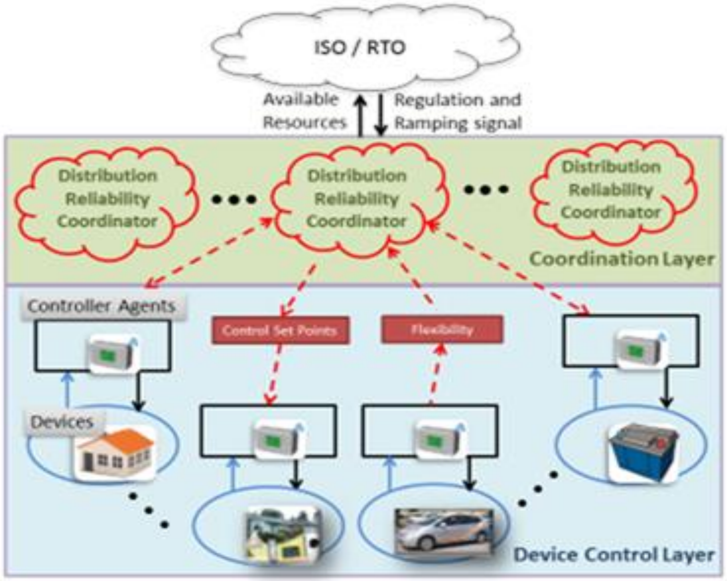
Control Theory

Project Description

Develop new integrated optimization and control solutions, including architectures, algorithms, and deployment strategies to transition to a large number of distributed energy resources (DERs) participating in grid control.

Project Objectives

- Ensure **architectural compatibility** of control theory and solutions.
- **Coordinate time scales** to enable tractable control of >10,000 DERs.
- **"Homogenize" diverse DERs.**
- **Incorporate power flow physics** and **uncertainty management.**



Value Proposition

- Large and diverse number of DERs that are not directly dispatched by the system operator.
- Traditionally used redundancy and reserve margins are insufficient for risk management due to growing uncertainty and complexity.

Multi-Scale Integration of Control Systems
High-Level Project Summary

Project Description

Create an integrated grid management framework for the end-to-end power delivery system – from central and distributed energy resources at bulk power systems and distribution systems, to local control systems for energy networks, including building management systems.

Value Proposition

✓ The current grid operating systems were developed over the last three to four decades using a piecemeal approach, within narrow functional silos.

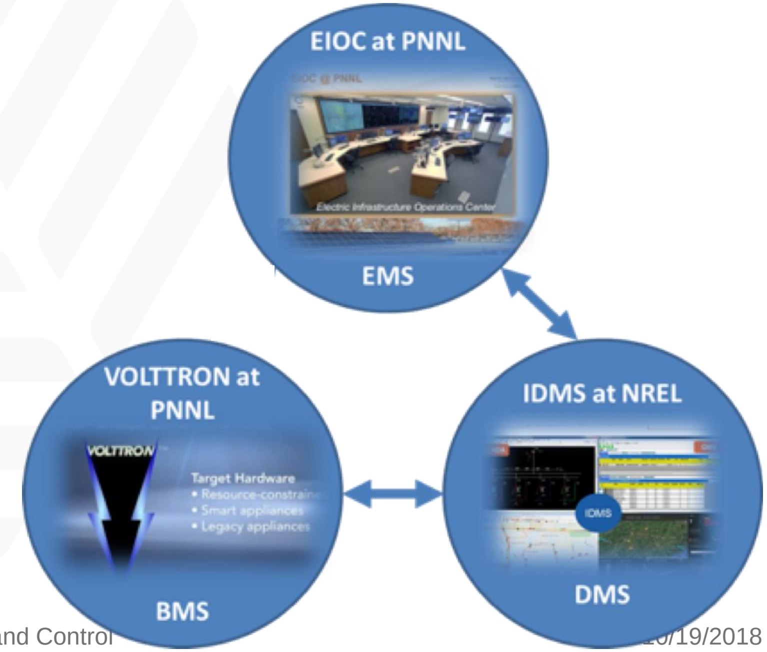
✓ The rapid growth of DERs and the increased need to integrate customers with the power system are rendering the current generation of grid operating systems obsolete.

Project Objectives

✓ Develop an open framework to coordinate EMS, DMS and BMS operations.

✓ Demonstrate the new framework on a use case at GMLC national lab facilities.

✓ Deploy and demonstrate new operations applications on that framework.

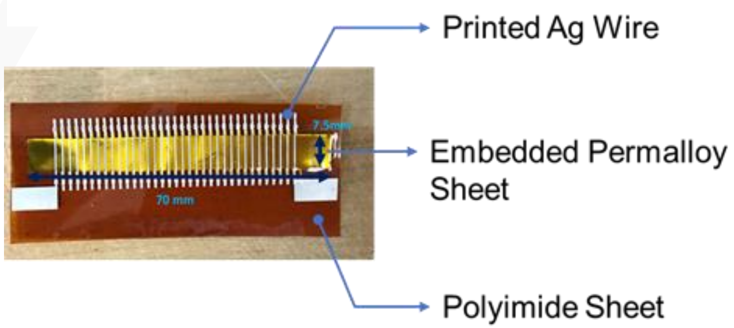


Sensing and Measurements

Objective: Create sensor development and deployment strategies to provide complete grid system visibility for system resilience and predictive control

Expected Outcomes

- Advance and integrate novel, low-cost sensors to provide system visibility
- Develop next-generation, low-cost sensors that are accurate through disturbances to enable closed-loop controls and improved system resilience
- Develop real-time data management and data exchange frameworks that enable analytics to improve prediction and reduce uncertainty



Sensing & Measurement Strategy

Project Description

- A cohesive strategy to develop and deploy sensing & measurement technologies for the modern grid is lacking.
- Project focuses on such a strategy to define measurement parameters, devices for making measurements, communications to transfer data, and data analytics to manage data and turn it into actionable information.

Value Proposition

✓ Grid is undergoing a major transformation (integration of new devices, major shift in generation mix, aging infrastructure, added risk of extreme system events (both manmade and climate).

✓ A need exists to characterize the state of the grid at much higher fidelity/resolution to maintain system reliability and security.

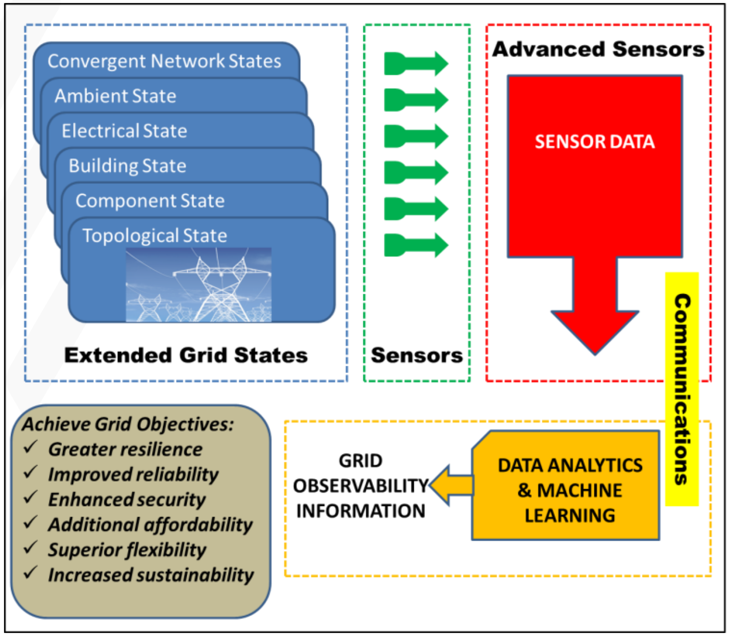
Project Objectives

✓ Create extended grid state model.

✓ Develop a sensor technology roadmap.

✓ Develop a sensor placement optimization tool (SPOT).

✓ Outreach to technical & standard groups.



Advanced Sensor Development
Project Summary

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Project Description:
Focus on key challenges previously identified in industry roadmaps and DOE programs that are critical to increased visibility throughout the energy system. The proposal is organized around three major segments: end-use, transmission and distribution (T&D), and grid assets health monitoring

Expected Impact:

Increased visibility throughout the future electric delivery system.

Increased accuracy and fidelity of detection of faults, failures and other events.

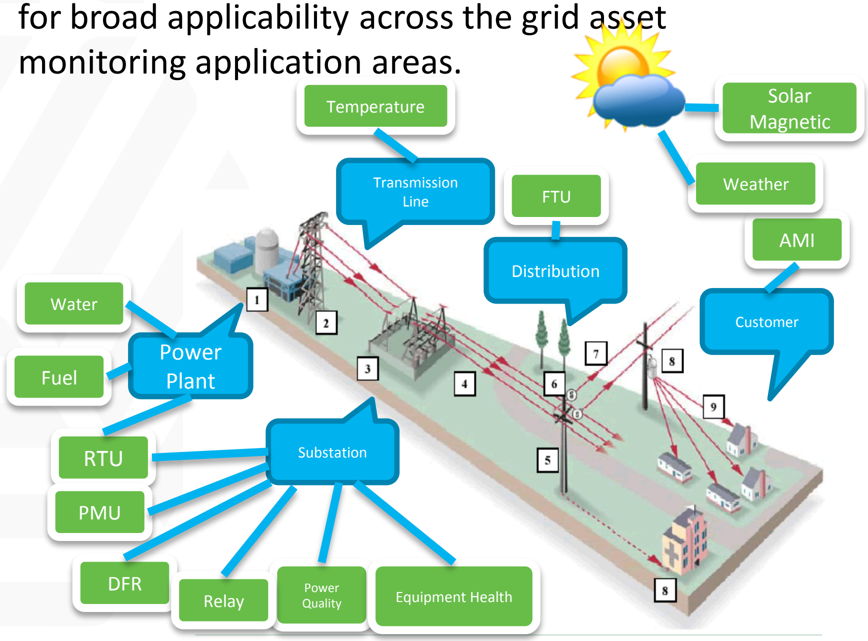
Demonstrate approaches to data analysis, including machine learning, for baseline operation and anomaly recoverie(s)

Objective

End-use: (1) develop low-cost sensors to monitor the building environment

T&D: extend the resolution of transmission grid visibility

Asset Monitoring: sensing platforms with attributes for broad applicability across the grid asset monitoring application areas.



Modified from Duke Energy
https://www.progress-energy.com/florida/home/safety-information/storm-safety-tips/restoration.page?

Integrated Multi-scale Data Analytics and Machine Learning for the Grid

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Project Description

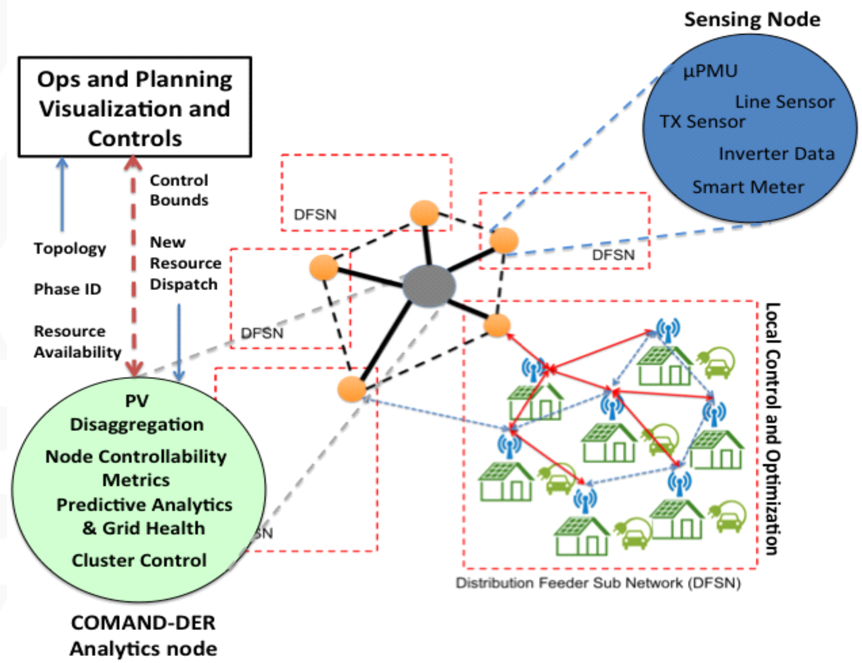
Develop and demonstrate distributed analytics solutions to building-grid challenges, leveraging multi-scale data sets, from both sides of the meter. Evaluate and demonstrate the application of machine learning techniques to create actionable information for grid and building operators, and derive customer benefits from disparate data

Value Proposition

- ✓ Solving fundamental challenges for transitioning ML and data analytics into the grid industry
- ✓ Enabling the transition from data to actionable information at the building to grid interface
- ✓ Increased revenue streams for resource utilization for customers
- ✓ Proactive and efficient asset management for operators/planners

Project Objectives

- ✓ Enable local nodal information exchange and high-performance, distributed algorithmic analysis
- ✓ Deploy local analytics integration at the grid edge, with a bridge to supervisory grid layers
- ✓ State-of-the-art distributed analytics strategies to thrive in an evolving distribution system
- ✓ Improve grid health and data utilization



Devices and Integrated Systems

Objective: Develop and update interconnection and interoperability methods, protocols, standards & test procedures

Focus Areas

- Work across DOE Program offices to develop technologies that provide a **range of grid services**
- Develop and **update interconnection and interoperability methods**, protocols, standards & test procedures
- Conduct technology and **integrated system testing and validation**

Expected Outcomes

- Develop new grid interfaces to **increase ability of new technology to provide grid services** for reliability, resilience and increase utilization of infrastructure
- Coordinate and support the development of interconnection and interoperability standards and test procedures for provision of grid services **across all element of the grid**
- Validate secure and reliability grid operation with **all forms of energy** at multiple scales (microgrids to transmission systems)

Standards & Test Procedures for Interconnection & Interoperability

Project Description

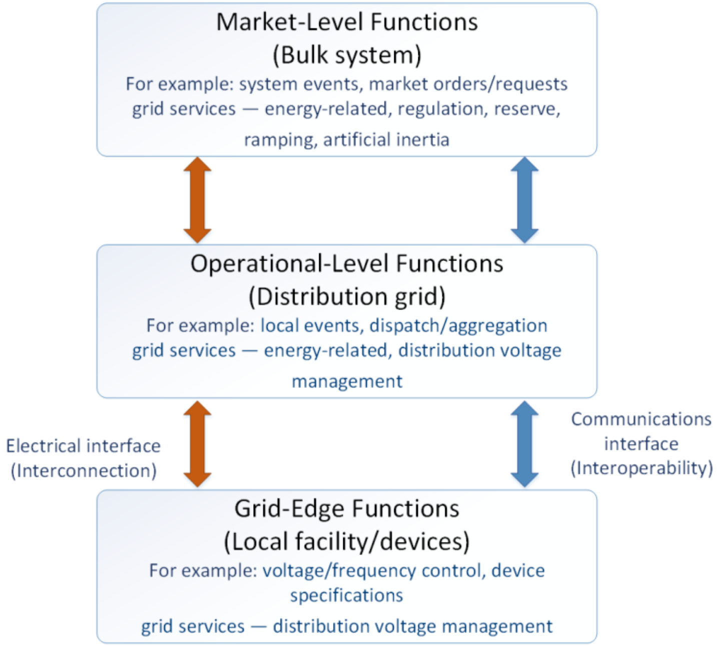
- **Accelerate** the development and validation of interconnection and interoperability standards
- Ensure **cross-technology compatibility** & harmonization of requirements for key grid services

Project Objectives

✓ **Harmonize requirements** among standards development organizations

✓ **Minimize conflicting requirements** across technology domains

✓ **Streamline** conformance test procedures to the fullest extent possible



Value Proposition

✓ **Improve coordination** of modern energy generation & storage devices with the grid

✓ **Enable market expansion** through improved interoperability

✓ **Reduce barriers** to deployment through improved standards

**Multi-Year Project Plan*

Definitions, Standards and Test Procedures for Grid Services from Devices

Project Description

- **Develop and test high-resolution models of distributed energy resources** (DERs) with a **standardized interface** in the form of a **battery-equivalent (BEq) representation**, for
- Ready access by planning and operational tools in assessing DERs' ability to provide operational flexibility in the form of valuable grid services
- At the bulk system and local distribution levels.

Project Objectives

✓ **High-resolution models explicitly model** engineering, operational, & human constraints

✓ **Standard battery-equivalent model interface** applicable to all device classes

✓ **Prototypical "drive cycles" for** devices providing a **wide variety of grid services**

✓ **Trial analysis** using models & drive cycles **to exemplify device potentials**

Value Proposition

Common BEq representation/interface allows:

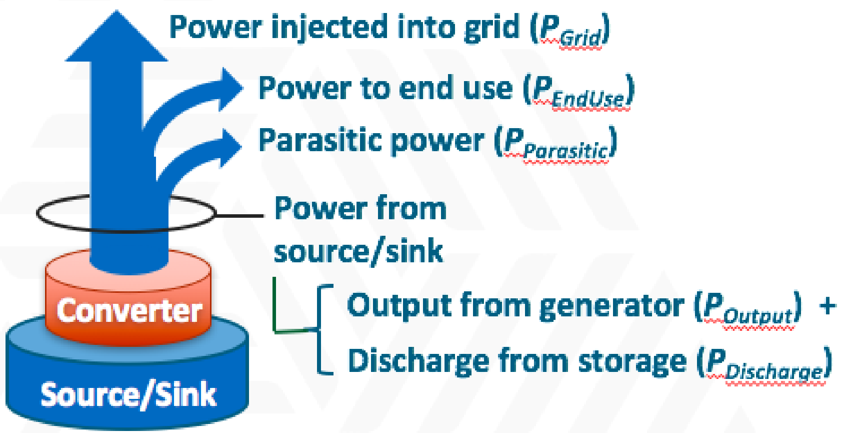
✓ Grid operations & planning models easily & accurately assess DERs

✓ Contributions of DER classes to be "summed"

✓ Grid control & optimization methods to be shared across DER types

✓ Consideration of BEq as a grid flexibility metric

✓ Level-playing field for evaluating DERs

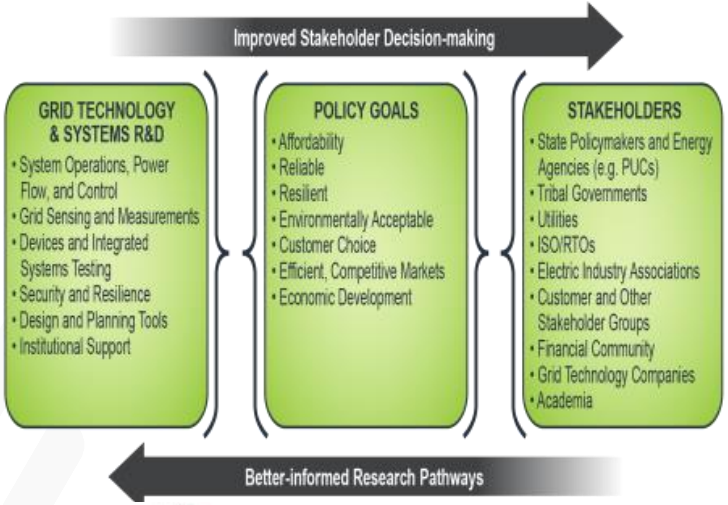


Institutional Support

Objective: Support and manage institutional change in a period of rapid (and potentially disruptive) technological innovation

Expected Outcomes

- Address high-priority grid modernization challenges and needs identified by electric power industry stakeholders, with particular emphasis on state policymakers and regional planning organizations
- Convene key grid stakeholders as an honest-broker for collaborative dialogues on grid modernization
- Create an overarching suite of grid-related "institutional" analysis, workshops, and dialogues to highlight challenges and explore options for transforming the grid, focusing on key policy questions related to new technologies, regulatory practices, and market designs



Metrics Analysis

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Project Objectives

Work directly with *strategic* stakeholders
to confirm the usefulness of *new and enhanced existing* metrics
that will guide grid modernization efforts
to maintain and improve:

- **Reliability,**
- **Resilience,**
- **Flexibility,**
- **Sustainability,**
- **Affordability, and**
- **Security.**

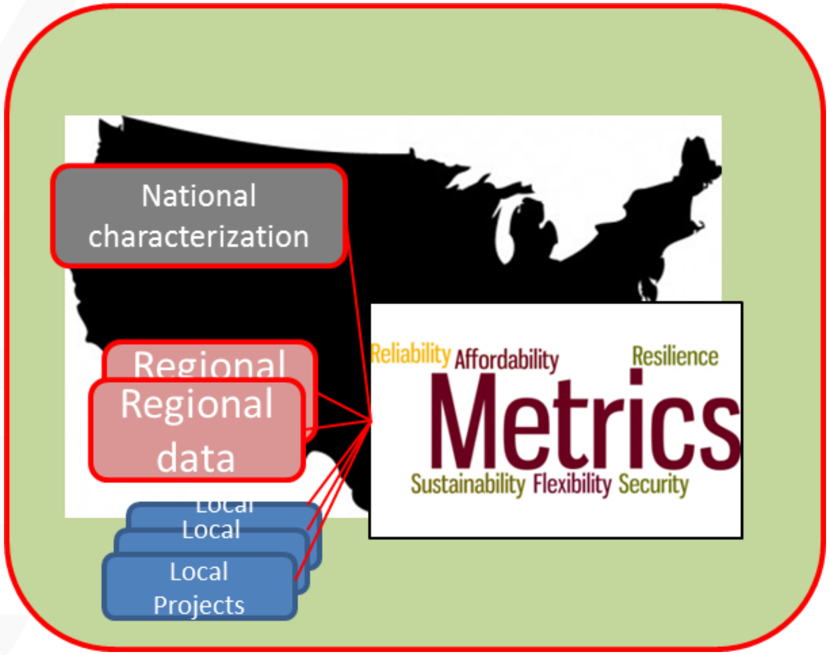
Value Proposition

✓ Ensuring that all stakeholders understand how grid modernization investments will affect and benefit them

✓ Audiences: grid modernization technology developers and investors; utility and ISO technology adopters or sponsors; federal, state, and municipal regulatory or oversight authorities; **and electricity consumers** (i.e., the ratepayers**)**

Expected Outcomes

✓ Definition, Validation, and Adoption of metrics and analysis approaches by leading industry stakeholders and regional partners



Distribution System Decision Support Tool Development and Application

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Project Description

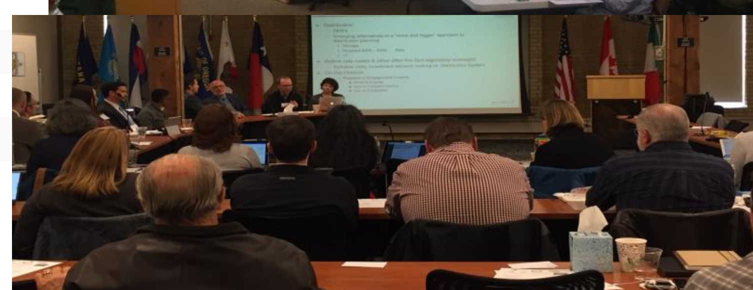
Identify strategies and provide technical assistance to state regulators and utilities that focus on advanced electric distribution planning methods and tools, with a focus on incorporating emerging grid modernization technologies and the significant deployment of DER

Project Objectives

- ✓ Provide technical assistance to state regulators in partnership with NARUC
- ✓ Identify gaps in existing and emerging planning practices & approaches
- ✓ Compile information on existing planning tools, identify gaps and necessary functions
- ✓ Provide technical assistance to electric utility industry and associated stakeholders

Value Proposition

- ✓ Electric distribution systems are aging and in need of expensive upgrades
- ✓ Large amounts of DERs are being integrated to distribution systems in U.S.
- ✓ PUCs and decision makers have asked for assistance in understanding the distribution systems, planning and prioritizing upgrades

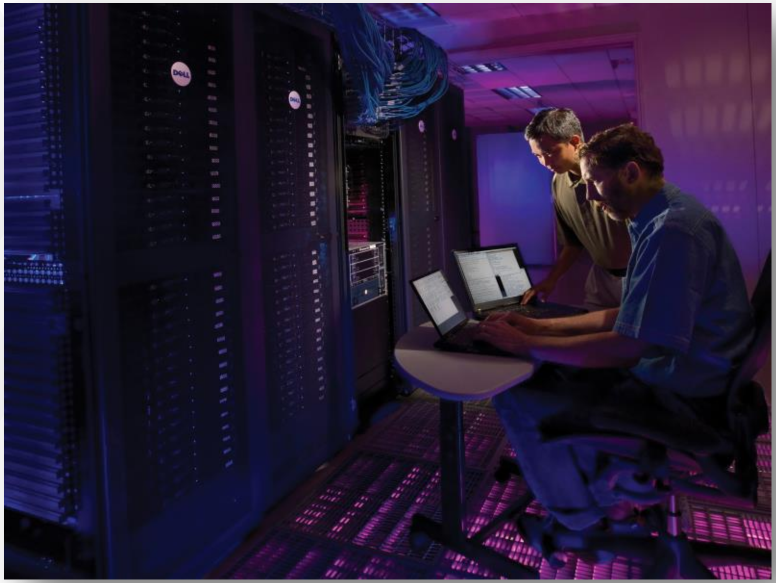


Security and Resilience

Objective: Provide a pathway to comprehensive multi-scale security and resilience for the nation's power grid

Expected Outcomes

- Holistic grid security and resilience—from devices, to microgrids, to systems
- Inherent security designed into components and systems, not security as an afterthought
- Security and resilience addressed throughout system lifecycle and covering the spectrum of legacy and emerging technologies



CleanStart DERMS

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Project Description

Develop and implement a DER Management System integrated application, which provides a separate communications, analytics and control layer, purely for a black-start and restoration application

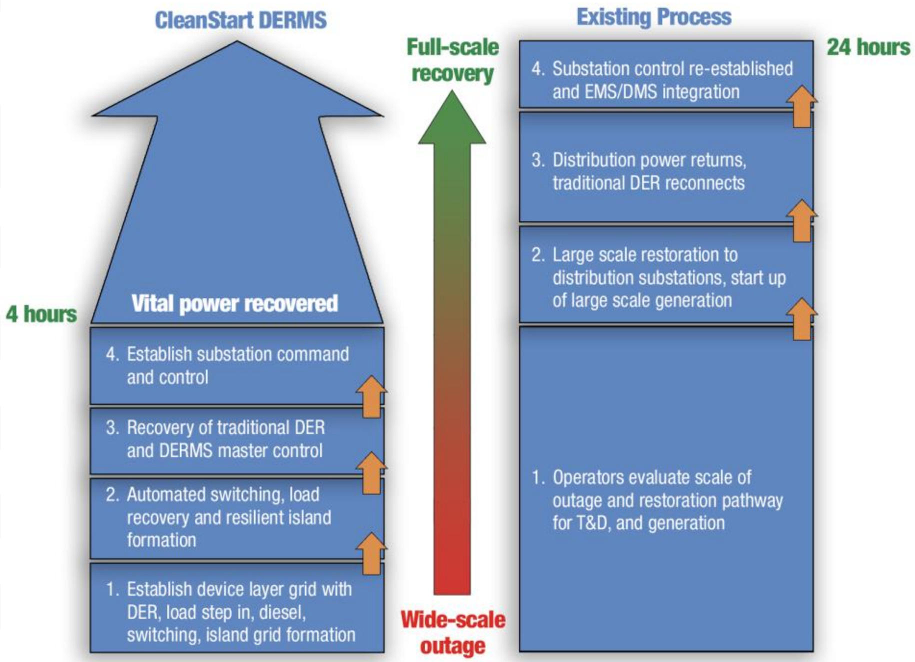
Solution will demonstrate the start of a microgrid following an outage (cyber or physical)

Project Objectives

- ✓ Minimize the outage time for the maximum number of customers using the greatest contribution from distributed and clean energy resources
- ✓ Implement methods for coupling and validation of predictive analytics and advanced controls for resilience
- ✓ Provide support services from DER back to the transmission system during critical outages

Value Proposition

- Black start and restoration at present is a centralized bulk system driven solution whereas DER is by nature decentralized
- Key innovations
  - DER controls as a mechanism for black start and restoration
  - Cross utility coordination and effective useful information/resource transfer
- Product will be transformational to utilities experiencing a rapid DER influx, considering both controlled and uncontrolled resources as part of the resilient resources to be utilized in widescale events



Thank You

Contact us at gmi@hq.doe.gov

Visit us at https://energy.gov/gmi