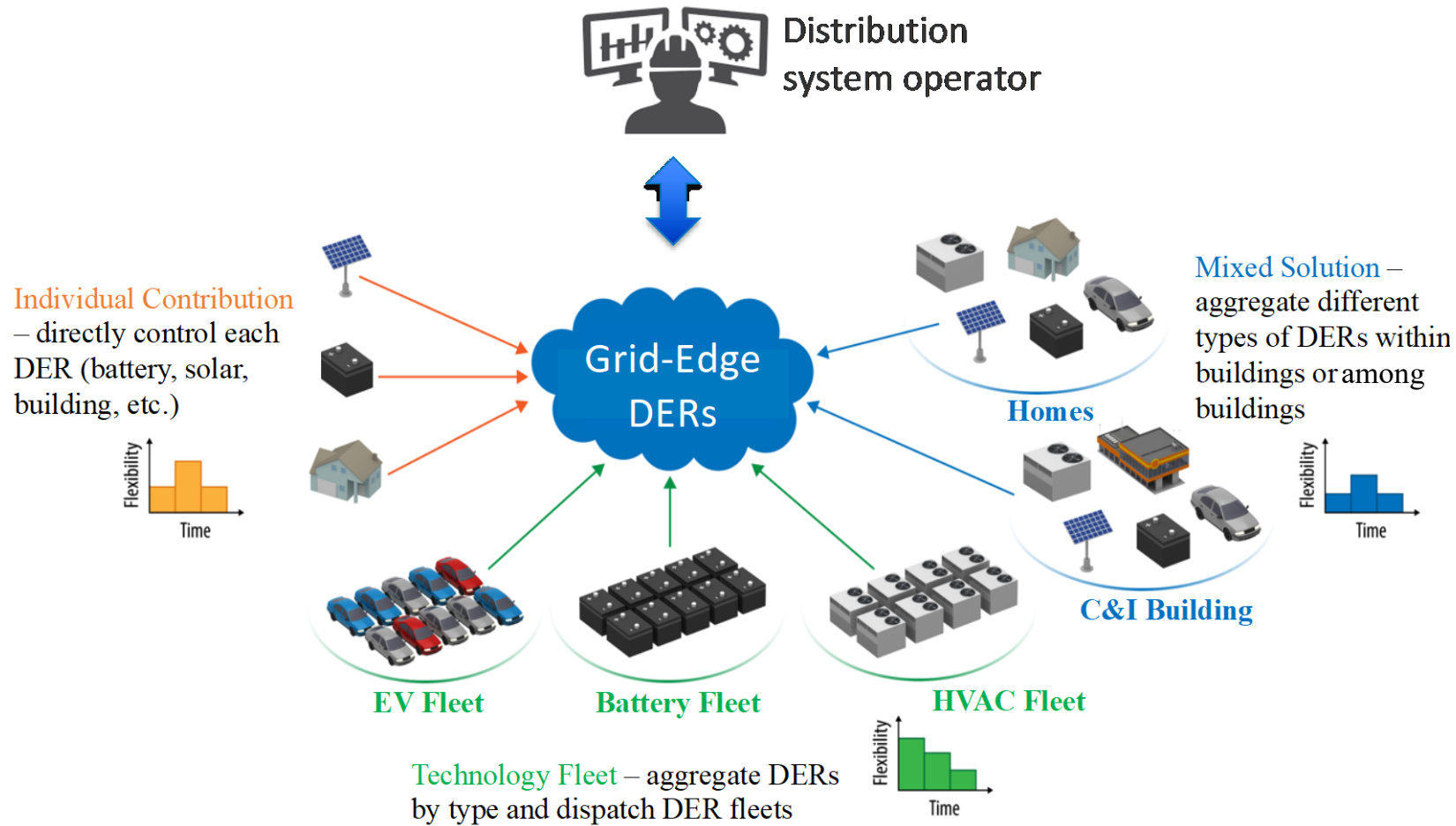




Test Bed and Control Solutions for Advanced Distributed Energy Resource Management

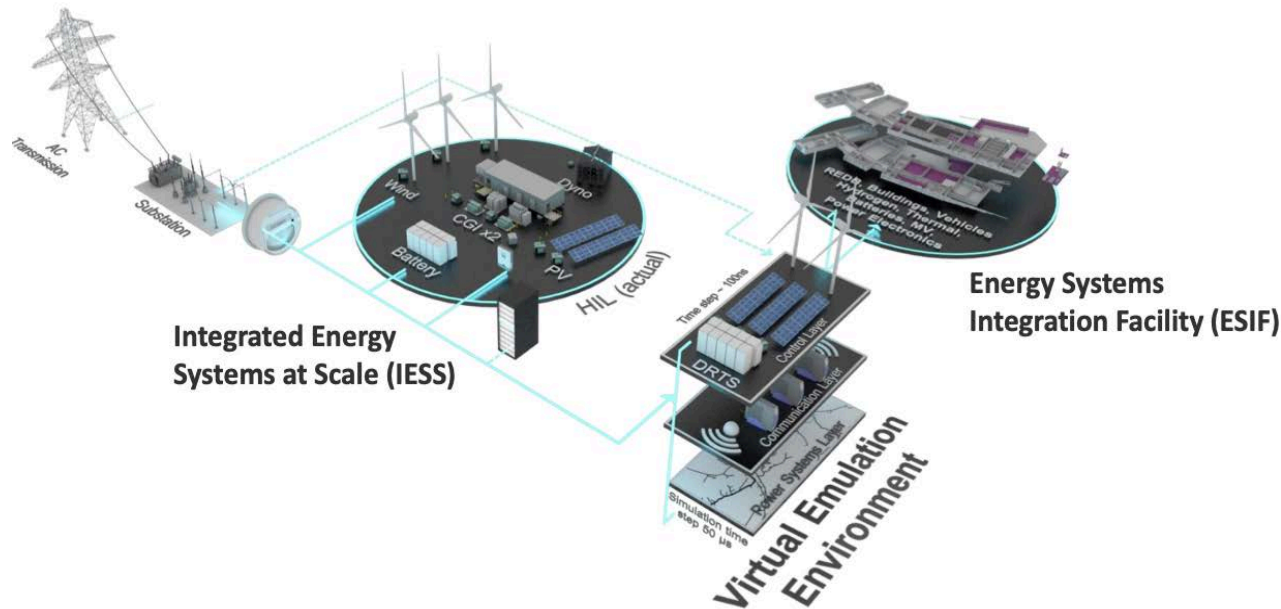
Fei Ding
Group Manager - Grid Automation and Controls
National Renewable Energy Laboratory
April 11, 2023

Grid-Edge Distributed Energy Resources



Advanced Research on Integrated Energy Systems (ARIES)

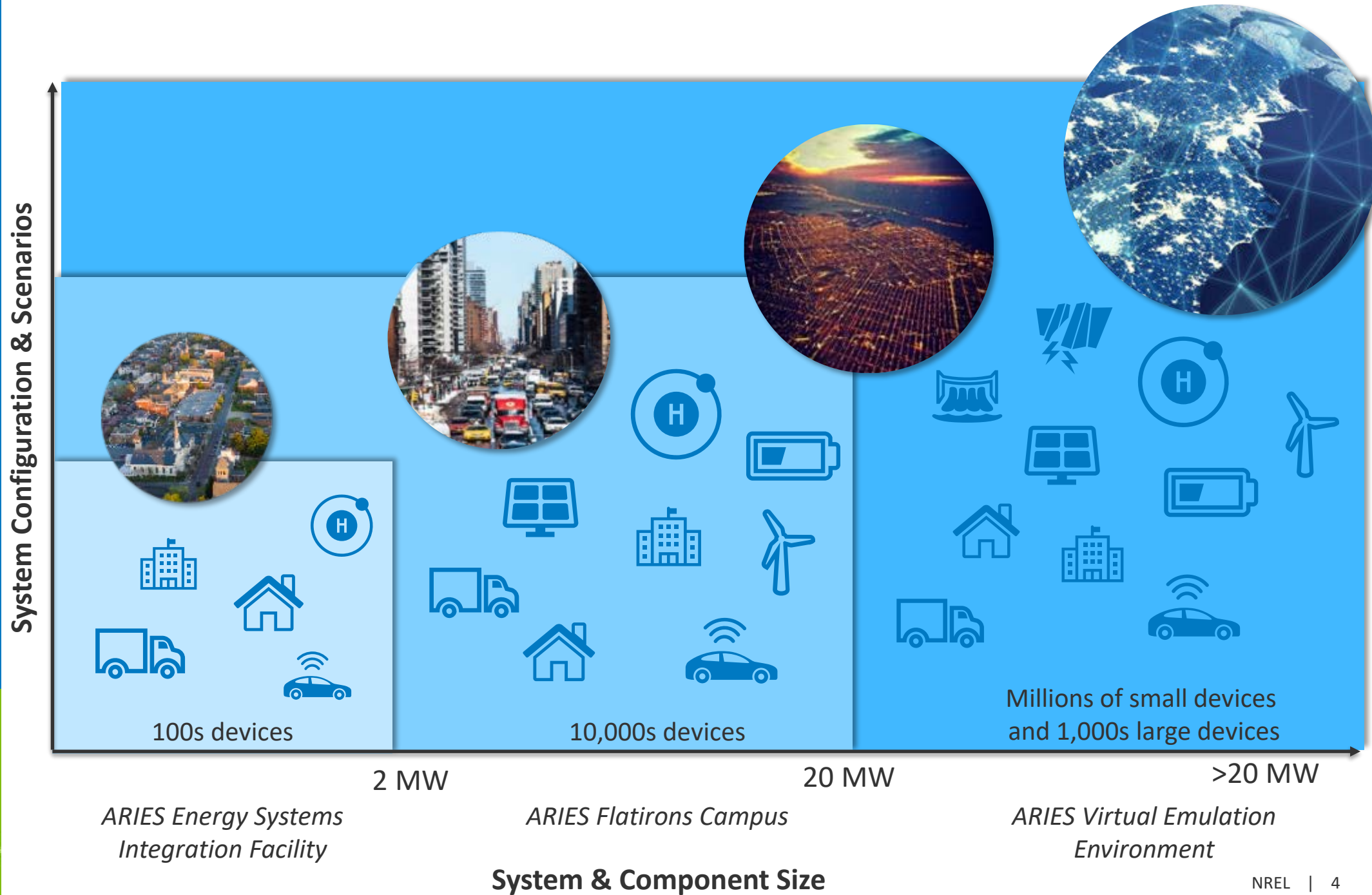
- ❑ ARIES platform integrates multiple lab facilities, software and hardware devices, physical and cyber networks and their emulations at NREL.
- ❑ ARIES can be used to validate and demonstrate different DER use cases.



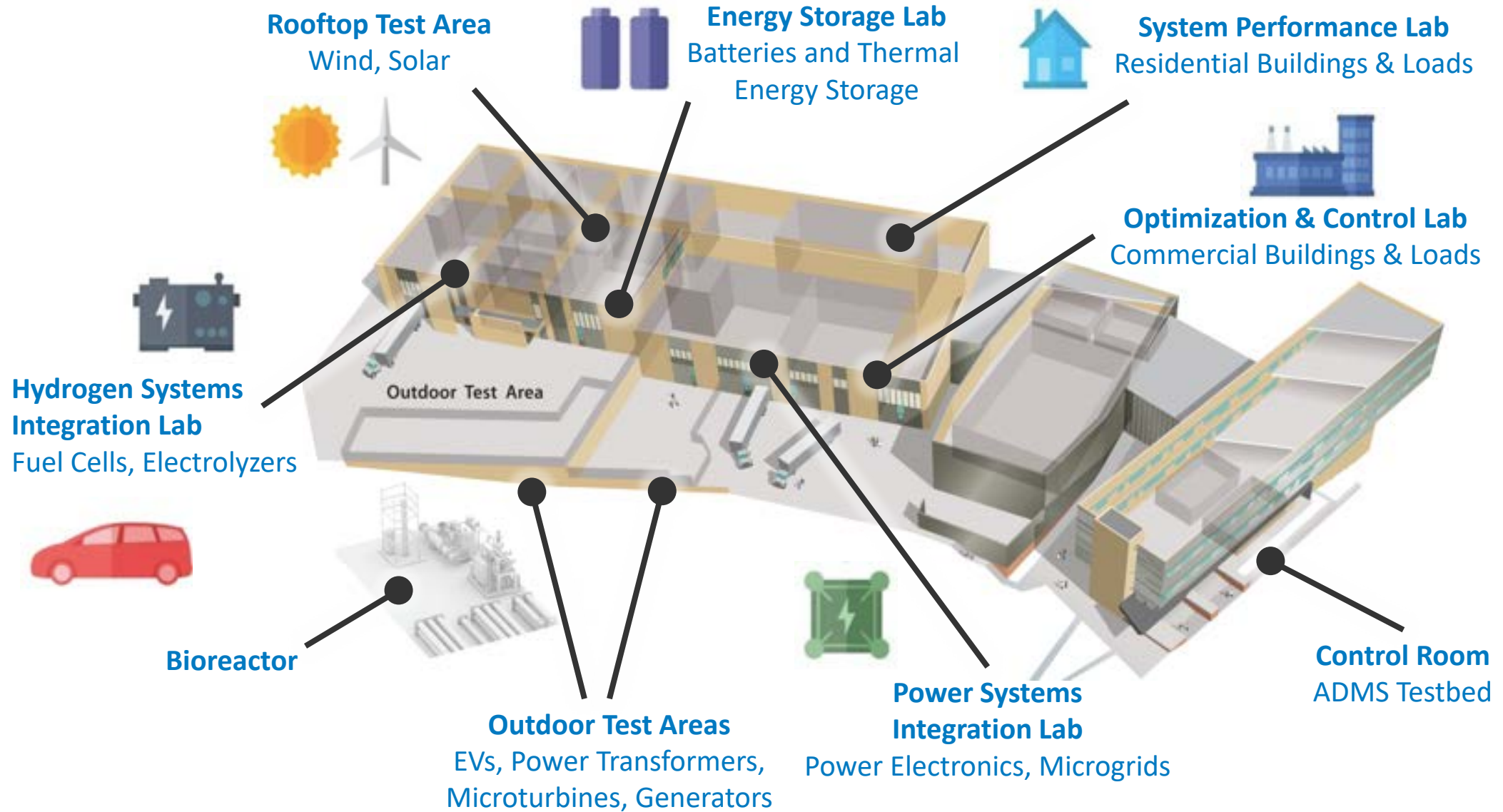
Some Example facilities available from ARIES:

- **Advanced Distribution Management System (ADMS) Test Bed** that emulates utility distribution grid operations
- **Real-time Analytics for Grid (RTAG)** that emulates bulk grid operations
- **Cyber Range** provides holistic cyber-physical emulation platform for **cybersecurity** research work
- **Power Electronic Grid Interface (PEGI)** platform for studying the future predominant way generation sources and loads connect to the power grid
- **Hybrid Energy Real-Time Emulation Hub (HERTH)** that enables at scale HIL and CHIL experiments to study multi-technology energy systems using a near-real-world environment
- **Buildings Research Infrastructure** for studying commercial and residential grid-interactive buildings load flexibility

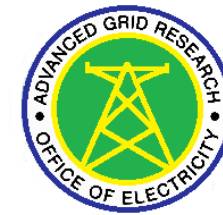
ARIES Scale



Energy System Integration Facility at a Glance



Advanced Distribution Management System (ADMS) Test Bed



Advanced Grid Research

OFFICE OF ELECTRICITY
US DEPARTMENT OF ENERGY

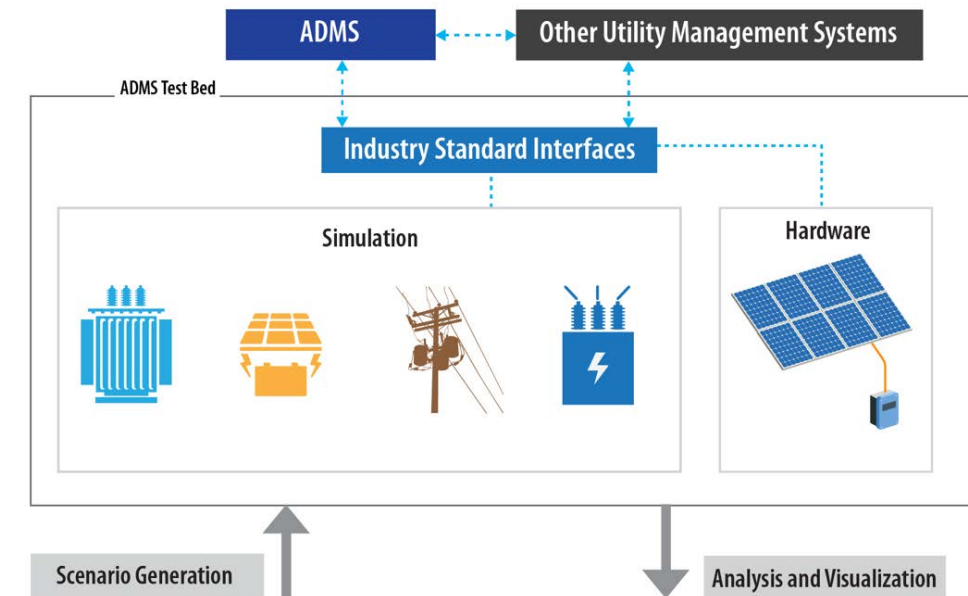
Build a vendor-neutral test bed to evaluate existing and future advanced distribution management system (ADMS) functionalities in a realistic setting.

Goal: Accelerate industry adoption of ADMS to:

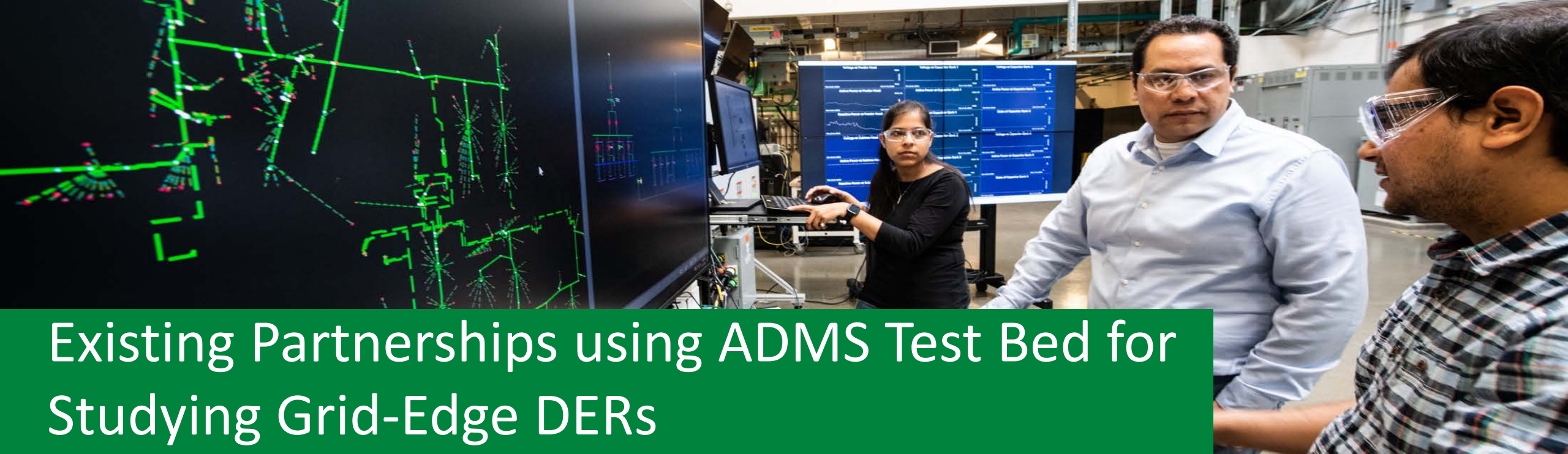
- Improve normal operations with high levels of distributed energy resources (DERs).
- Improve resilience and reliability.

Approach: Partner with utilities and vendors to evaluate specific use cases and applications to:

- Set up a realistic laboratory environment.
- Simulate real distribution systems.
- Integrate distribution system hardware.
- Use industry-standard communications.
- Create advanced visualization capability.



<https://www.nrel.gov/grid/advanced-distribution-management.html>



Existing Partnerships using ADMS Test Bed for Studying Grid-Edge DERs

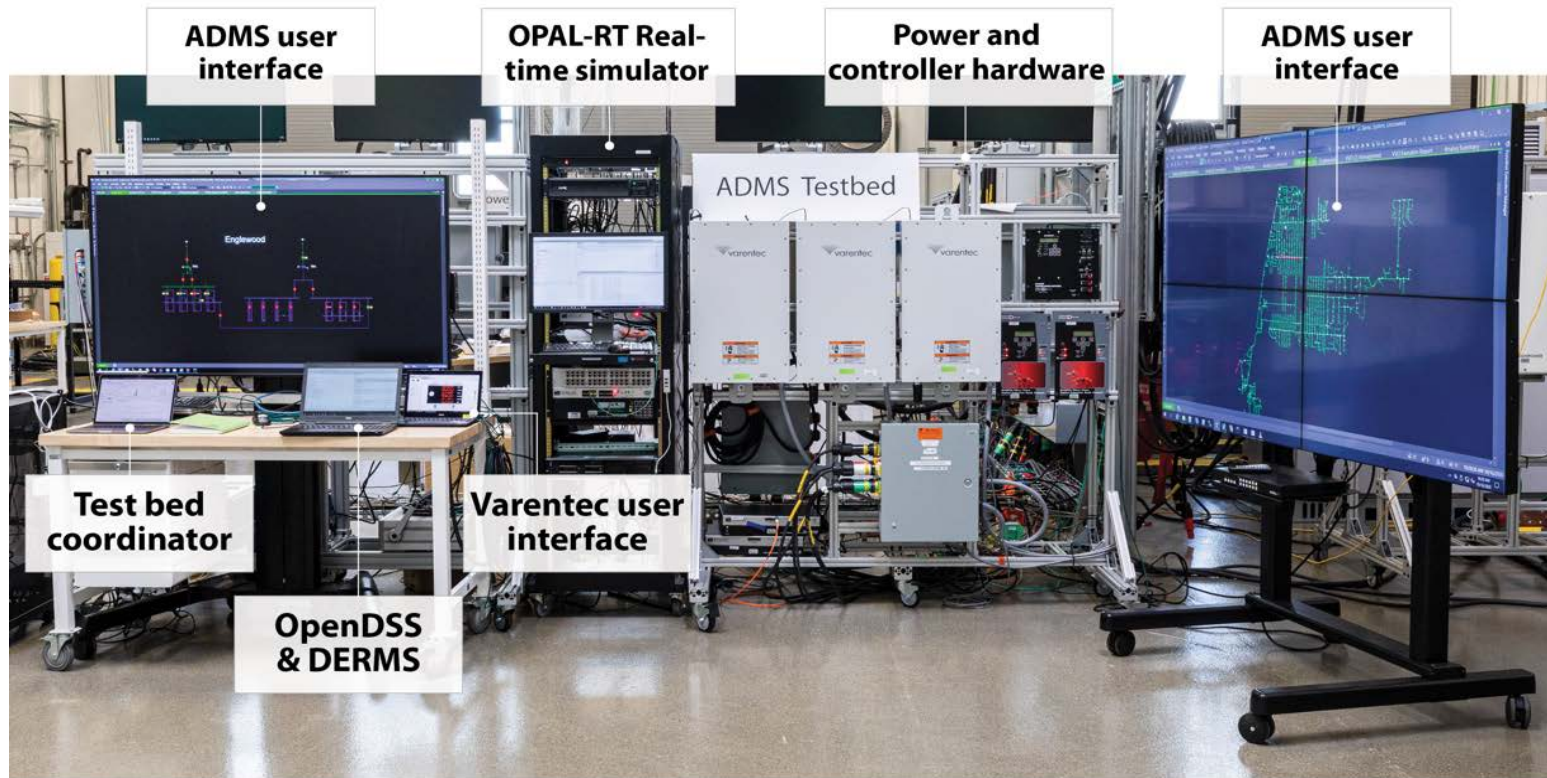
For the ADMS Test Bed use cases, we have partnered/are partnering with:

- Xcel Energy, San Diego Gas & Electric Company (SDG&E), Southern Company, Holy Cross Energy, and Central Georgia EMC
- GE, Schneider Electric, Survalent, Oracle, and Opal-RT
- National Rural Electric Cooperative Association (NRECA) and Electric Power Research Institute (EPRI)
- Pacific Northwest National Laboratory (PNNL; GridAPPS-D) and Argonne National Laboratory.

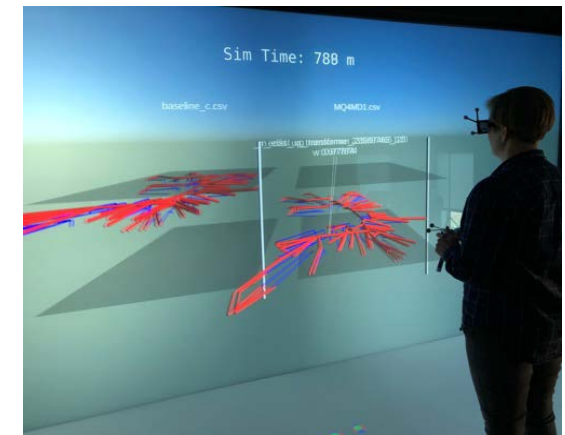
We have worked/are working with additional partners on other projects, including:

- Hawaiian Electric, Pacific Gas & Electric Company, Detroit Energy, Cobb EMC
- Open Systems International (OSI), Minsait ACS
- Lawrence Berkeley National Laboratory (LBNL), Oak Ridge National Laboratory (ORNL)
- University of Connecticut, University of North Carolina at Charlotte (UNCC), Iowa State University

ADMS Test Bed



2D real-time visualization



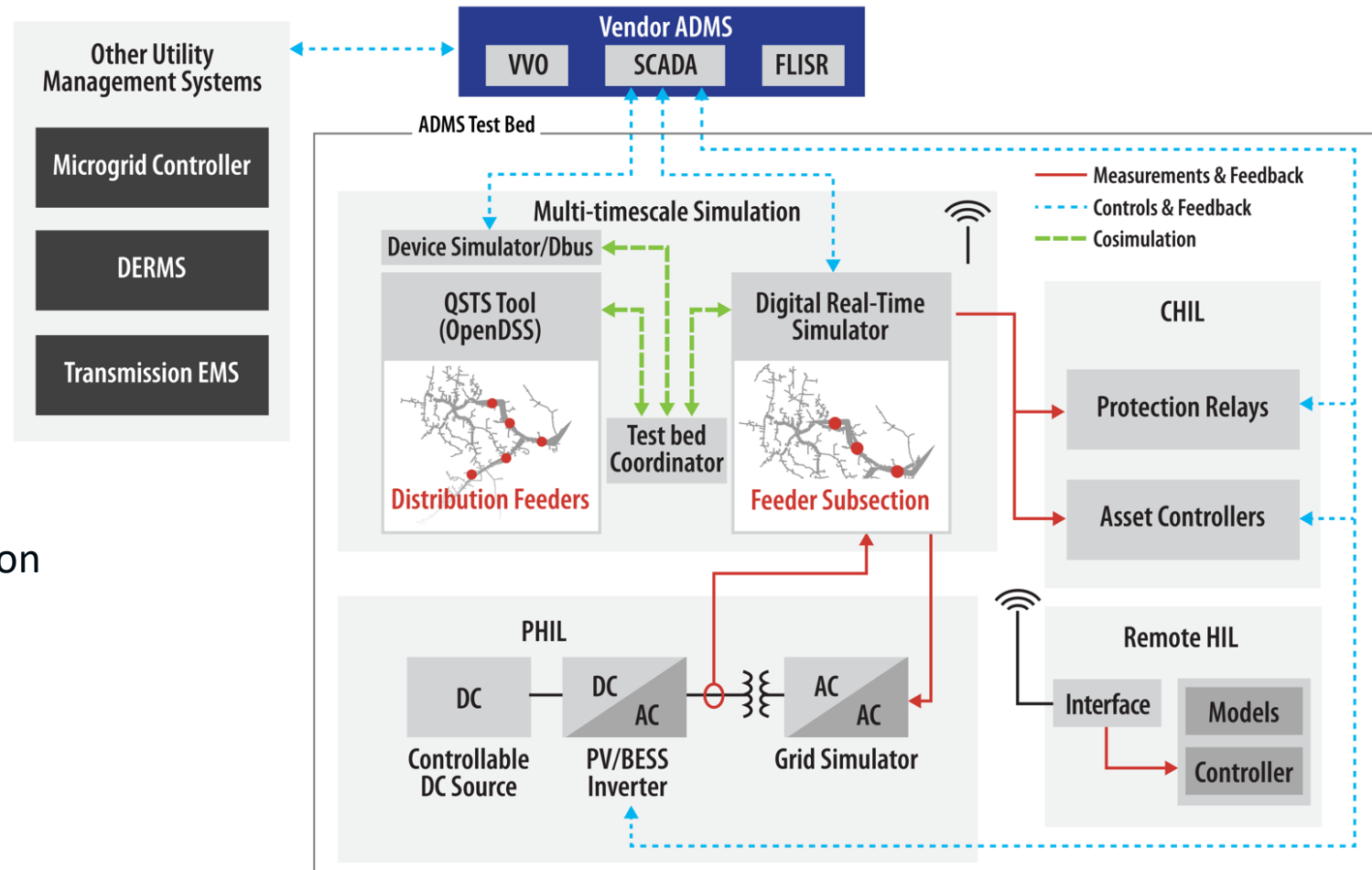
3D visualization

Photos by NREL

A Realistic Co-Simulation Test Bed for Grid Edge Technology Development and Evaluations

ADMS Test Bed capabilities include:

- Multi-timescale co-simulation using HELICS (OpenDSS/OPAL-RT/RTDS)
- Co-simulation of transmission and distribution grids, buildings, transportations
- Hardware integration
- Communications interfaces
- Data collection and visualization.

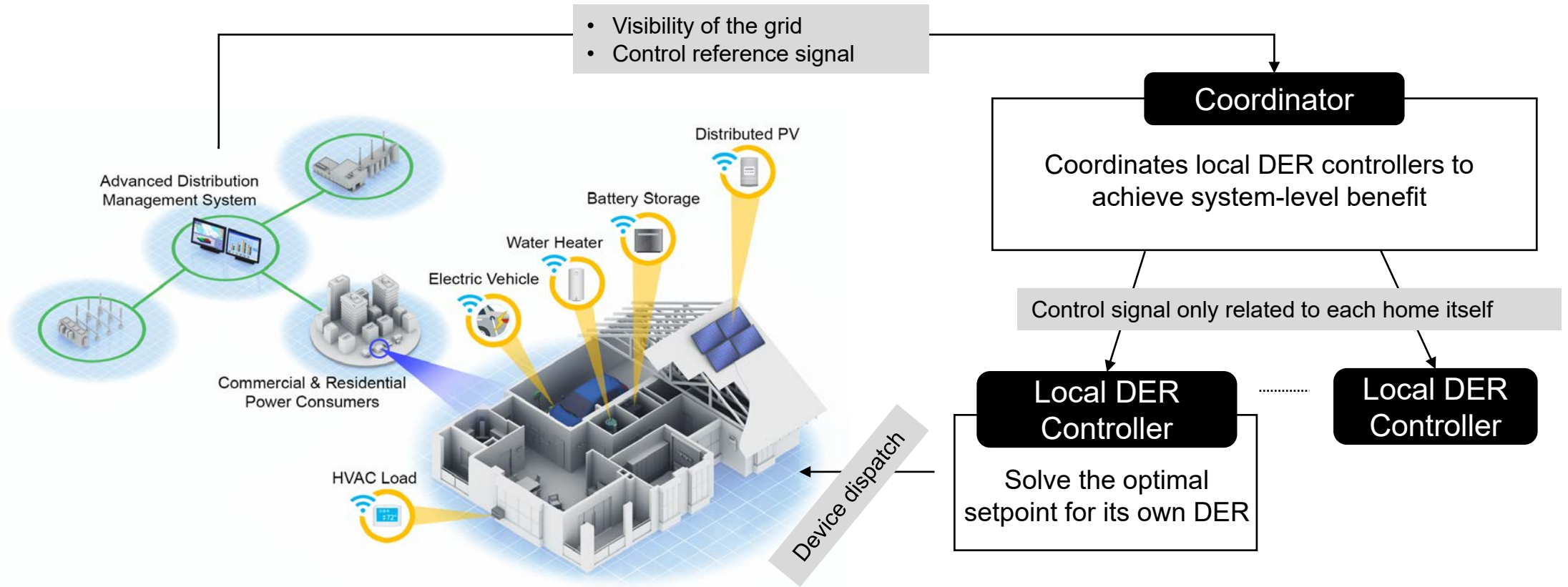


Grid-Edge Control Solutions & Applications

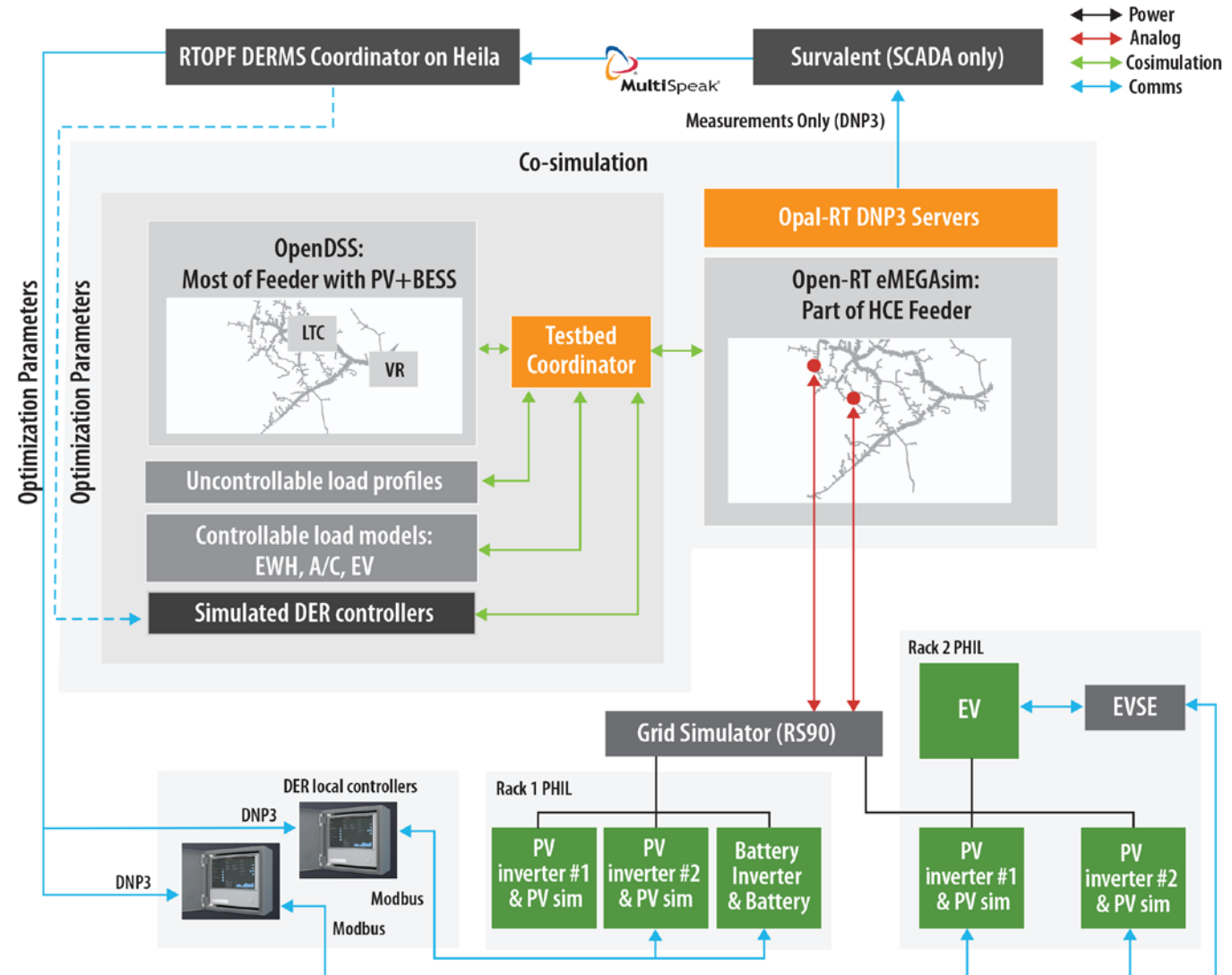
1 **Distributed Control of DERs**

2 **Resilience-Oriented Dynamic Microgrid Operations**

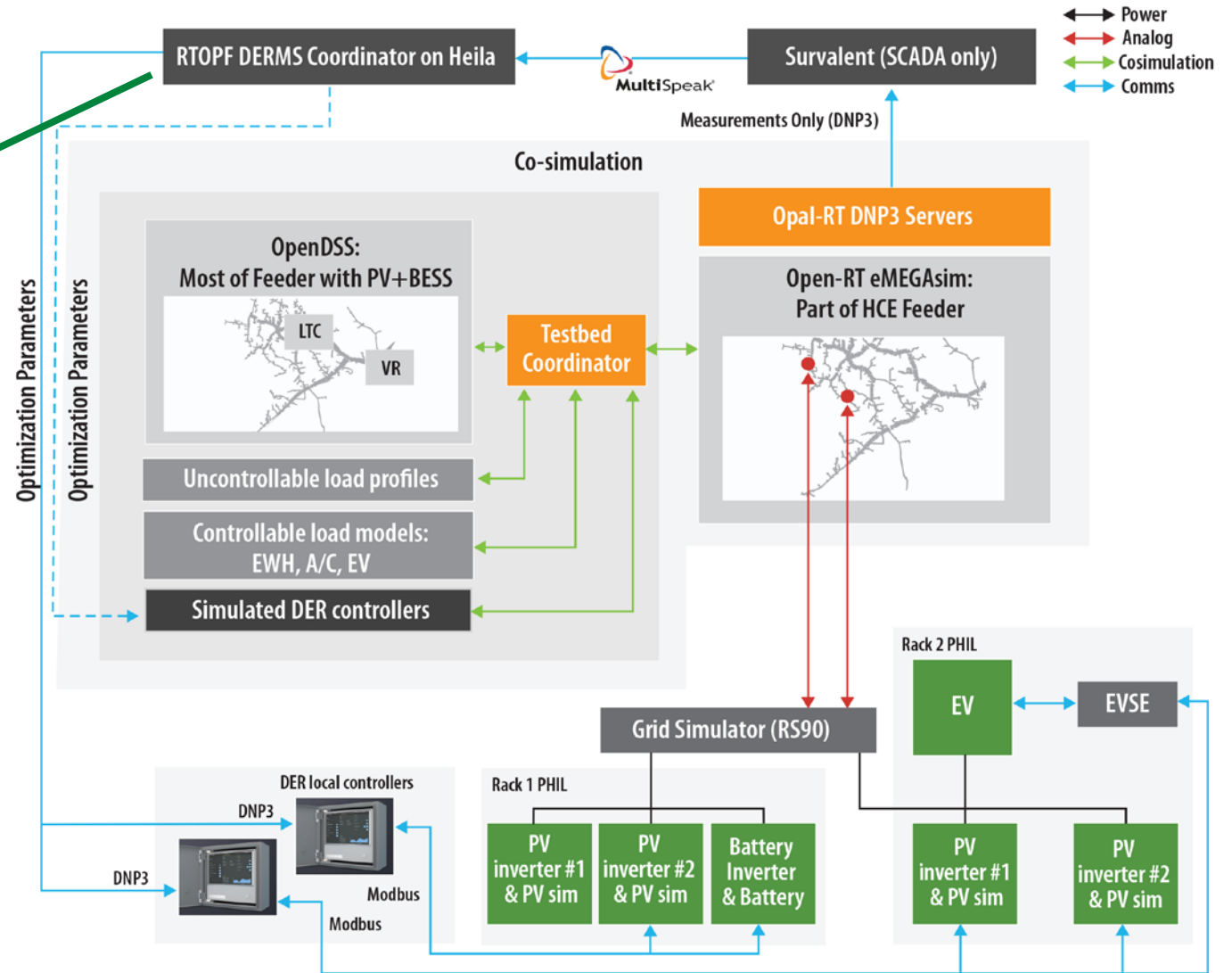
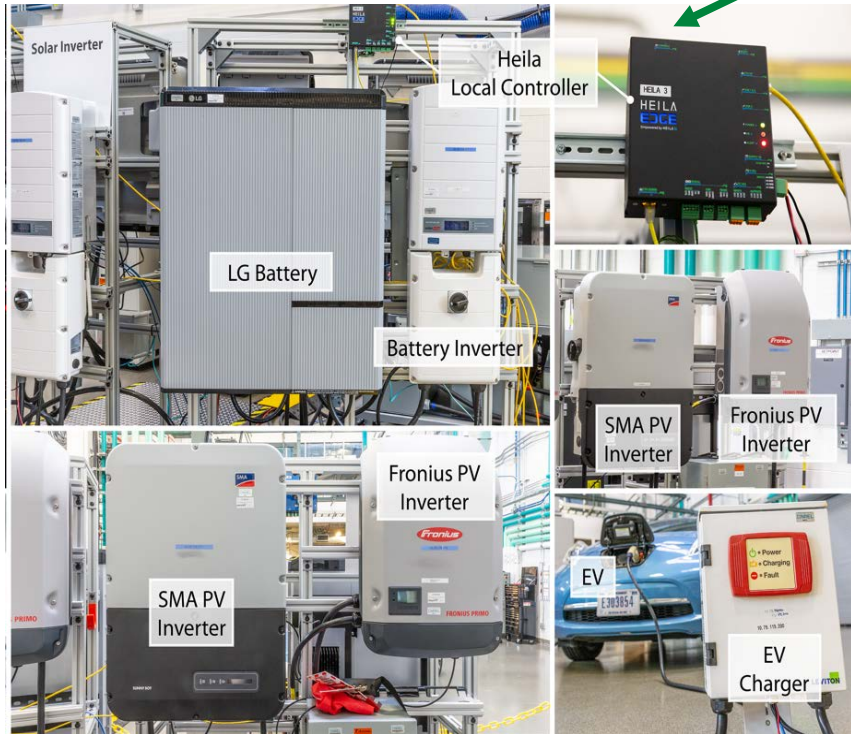
Coordination between ADMS and Grid-Edge Control



Validation using ADMS Test Bed



Validation using ADMS Test Bed



Basalt Vista Field Pilot Study



- Basalt Vista is an affordable housing community in Colorado, constructed for local schoolteachers. It has 12 duplex/triplex buildings with a total of 27 all-electric, net zero energy homes.
- Deployed 20 controllers at four homes and proved the concept of “autonomous homes”.

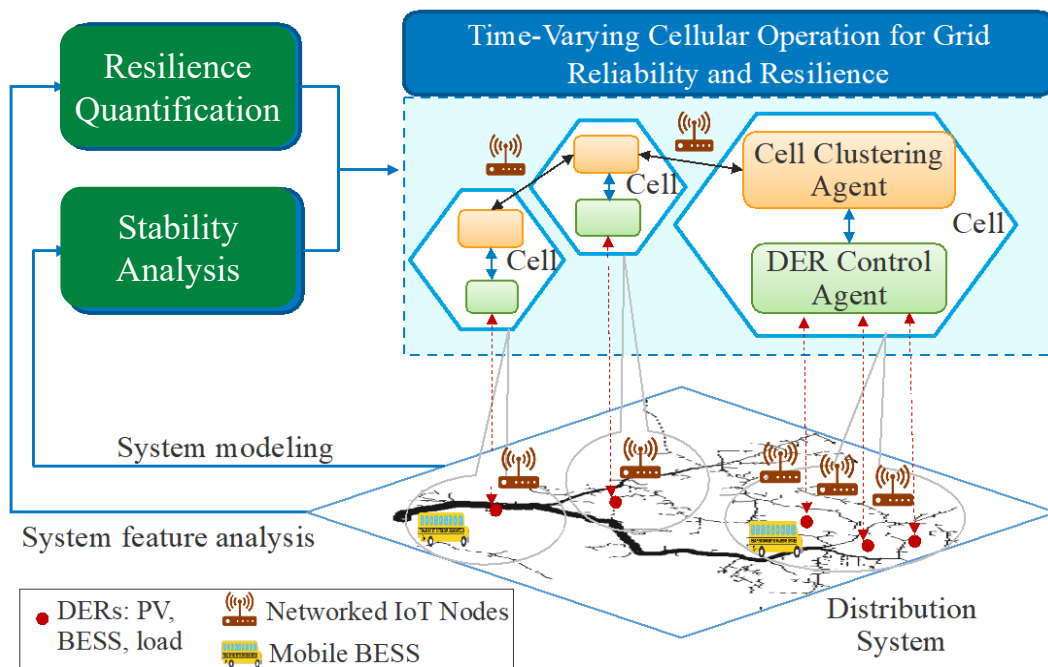


Photo credit: Anna Stonehouse
<https://habitatroaringfork.org/pages/basalt-vista>

Resilience-Oriented Dynamic Community Microgrid Operations

Objectives: Develop and demonstrate a cellular community microgrid formation and optimization approach to achieve resilient, stable, scalable operations for distribution feeders with photovoltaics (PVs) and mobile battery energy storage systems (BESS).

Technical approach:



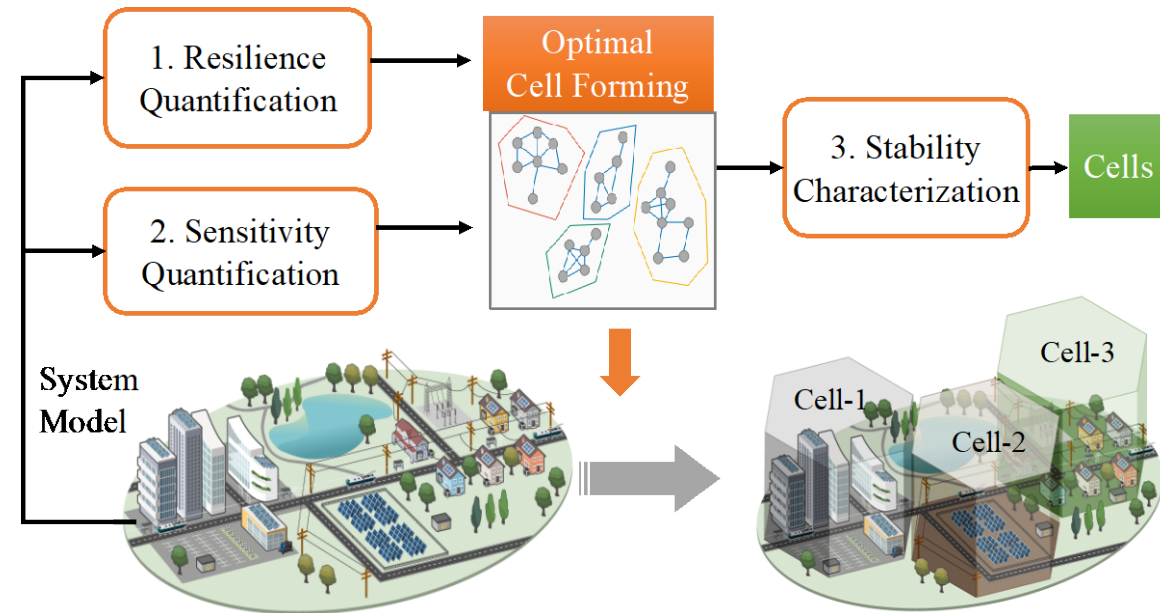
Outcomes:

- ❑ **Innovation:**
 - Resilient and stable cell microgrid organization scheme using machine learning and advanced stability designs
 - Distributed and adaptable cell management system realized using modern Internet of Things platforms.
- ❑ **Impact:**
 - Use solar PV and other synergistic distributed energy resource (DERs) to address an electric co-op's wildfire mitigation need.
 - Provide a national scalable approach for operating community microgrids and increasing system-wide resilience.

Technical Approach: Form Cells

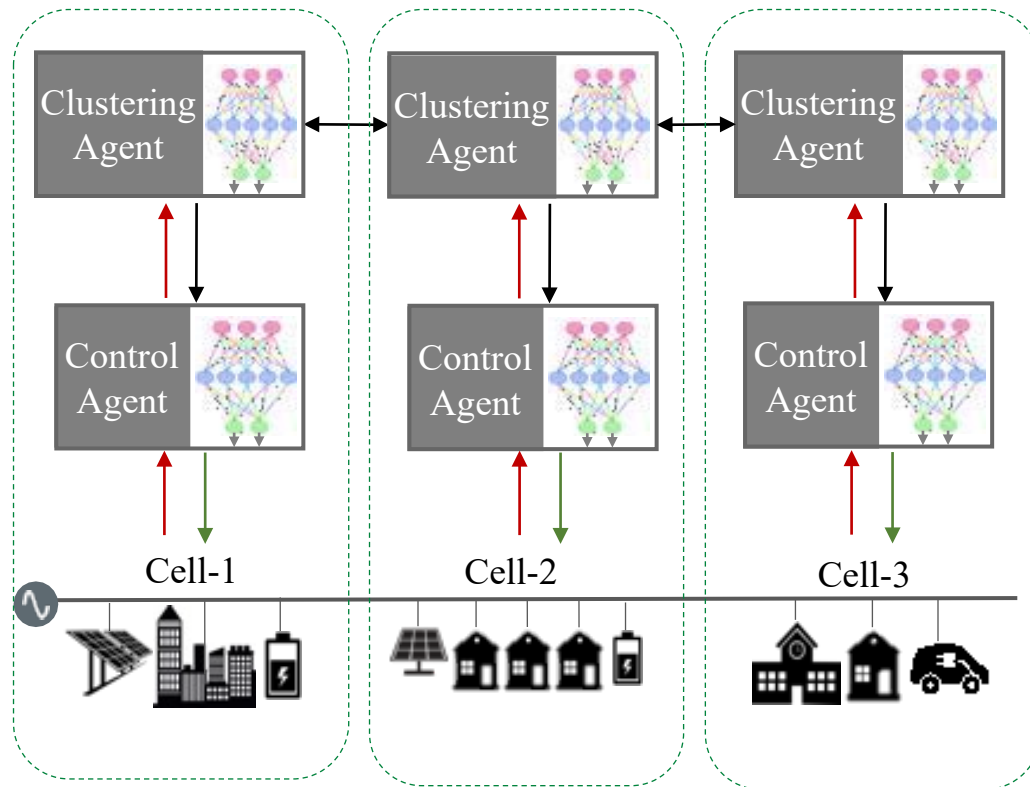
A **cell** is a group of interconnected PV, BESS, and buildings that comprises the smallest subset of the grid that is capable of independently operating by using its own resources.

1. Resilience quantification to preliminary identify resilient cells
2. Sensitivity analysis to obtain “loosely connected” cells
3. Stability analysis to guarantee cell stability in islanded mode.



Each identified cell has integrated resilience over a desired threshold and can achieve stable operation when it is disconnected from the grid.

Technical Approach: Operate Cells using Machine Learning



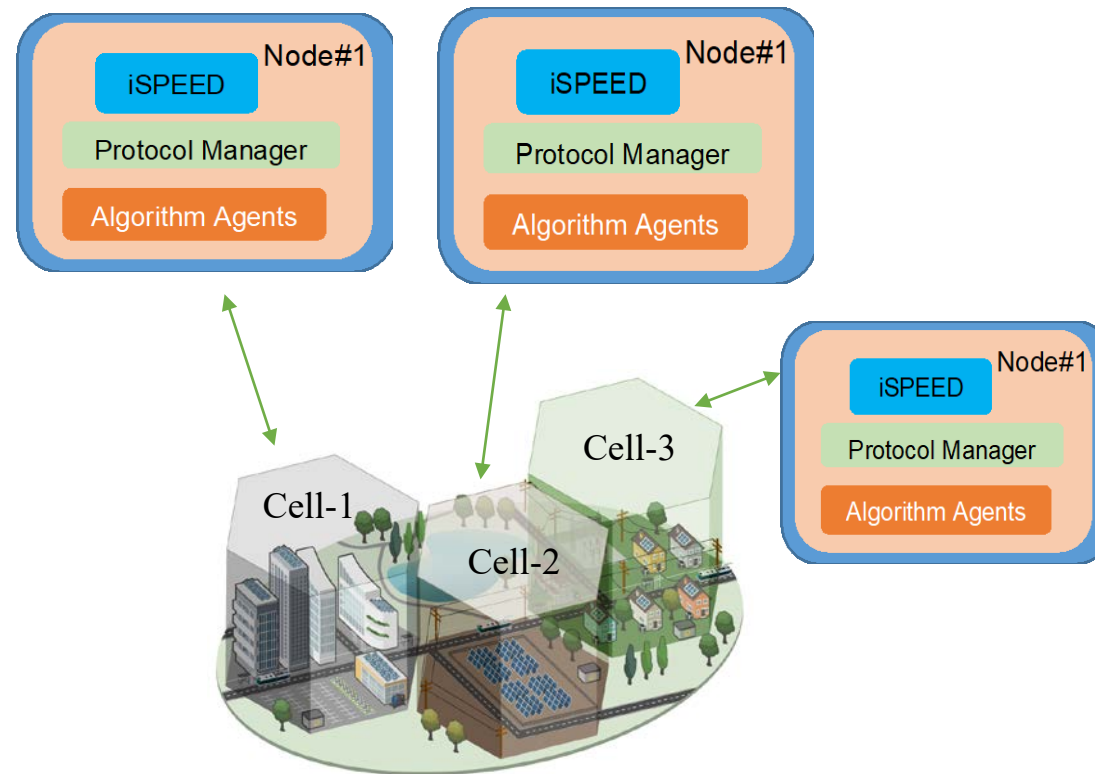
Use **multi-agent deep reinforcement learning (MADRL)** to design a two-level control strategy:

- **Cell control agent:**
 - Control DERs inside the cell.
- **Cell clustering agents:**
 - Coordinate with other cells for network reconfiguration and service restoration.

Use machine learning to reduce the reliance on accurate system models and massive communications.

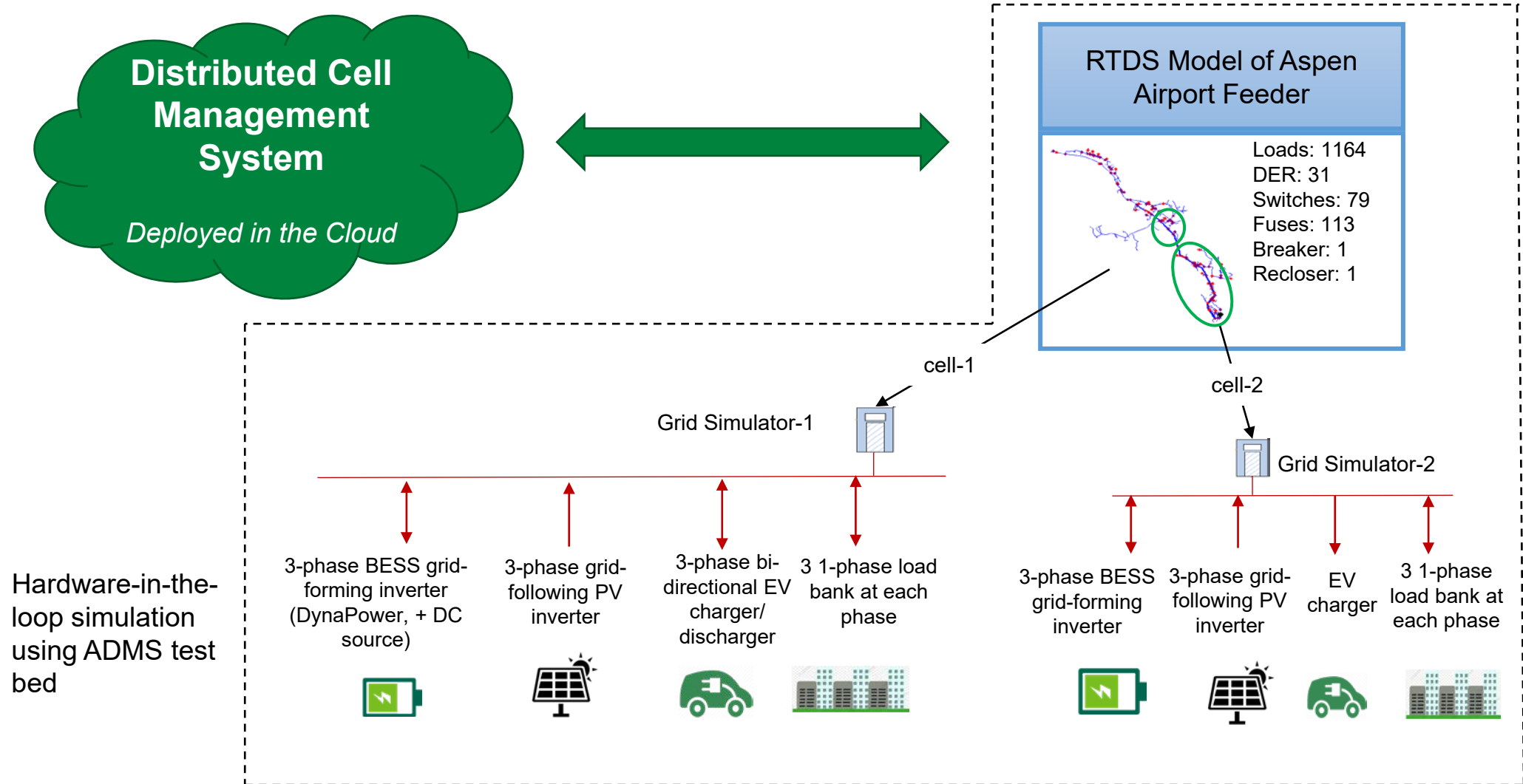
Distributed Cell Management System

The dynamic nature of clustering cells and the distributed controls require a software architecture that can act as a **distributed and adaptable cell management system**.



- Collect, process, and store data **locally** in every node.
- **Modular and highly reproducible** node software architecture
- In coordination with:
 - Edge sensors and Internet of Things devices
 - Utility metering infrastructure and system
 - Controllable switches, protection relays.

Validation using ADMS Test Bed





Thank You!

fei.ding@nrel.gov

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