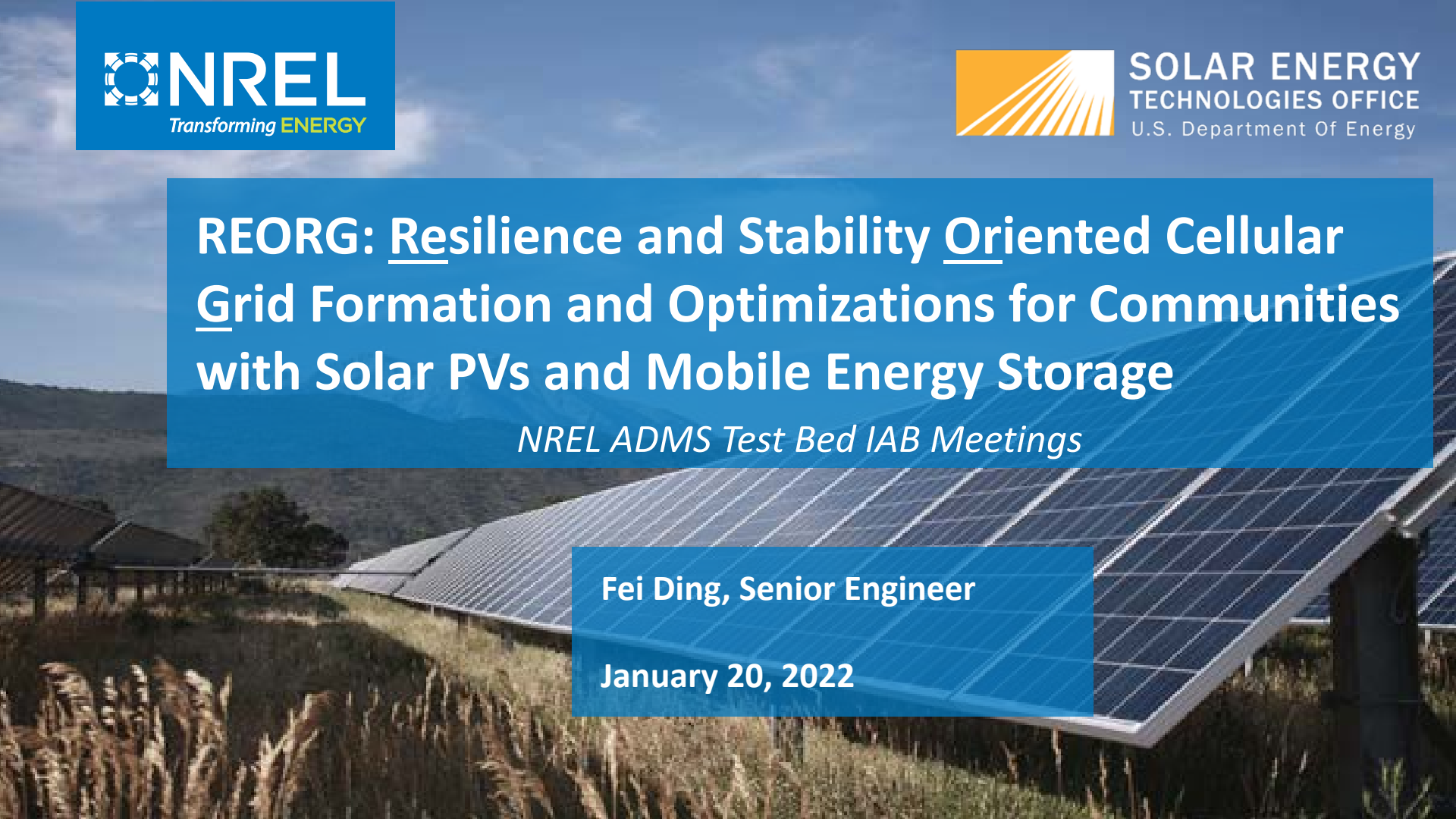

NREL Transforming ENERGY

SOLAR ENERGY TECHNOLOGIES OFFICE
U.S. Department Of Energy

REORG: Resilience and Stability Oriented Cellular Grid Formation and Optimizations for Communities with Solar PVs and Mobile Energy Storage

NREL ADMS Test Bed IAB Meetings

Fei Ding, Senior Engineer

January 20, 2022

Project Background

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Wildfire high risk areas identified by Holy Cross Energy

Pressing Need to Increase System Resilience

- Communities are asking for distributed clean energy solutions to realize community microgrids.

Unsolved Key Challenges:

- Lack of methods to partition grids for distributed control applications
- Inaccurate system models and limited communication networks during prolonged outages
- Need to maintain microgrid stability under various conditions

Our Solution

Organize the distribution system into community microgrids using dynamically reconfigurable cells

- Resilient and stable cell-based microgrid operations
- Adapt to time-varying system conditions

Project Overview

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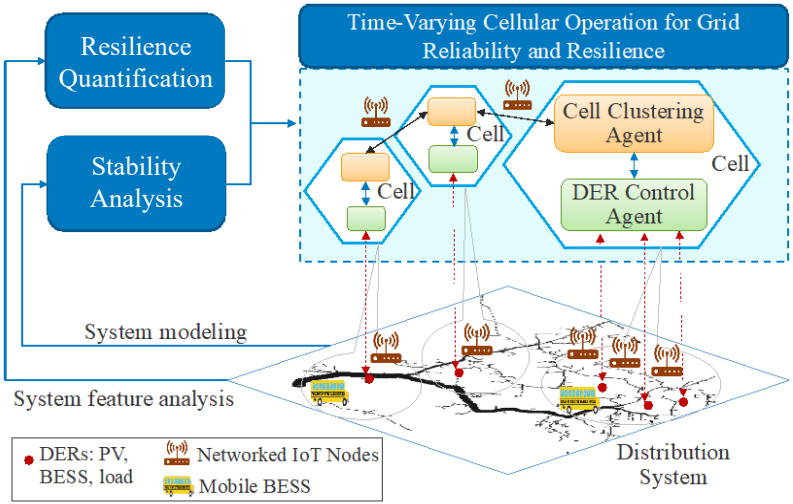
Objectives: Develop and validate a cellular community microgrid formation and optimization approach to achieve resilient, stable, scalable operations for distribution feeders with PVs and mobile battery energy storage systems (BESSs). Demonstrate the technology at a community located at Aspen, CO served by Holy Cross Energy.

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 IoT platforms
- **Impact**
  - Use solar PVs and other synergistic DERs to address an electric co-op's wildfire mitigation need
  - Provide a national scalable approach for operating community microgrids and increase system-wide resilience

Team: NREL, Holy Cross Energy, University of Connecticut, Minsait ACS, NRECA

Project Duration: 2021.04 – 2024.03

Technical Approach: Form Cells

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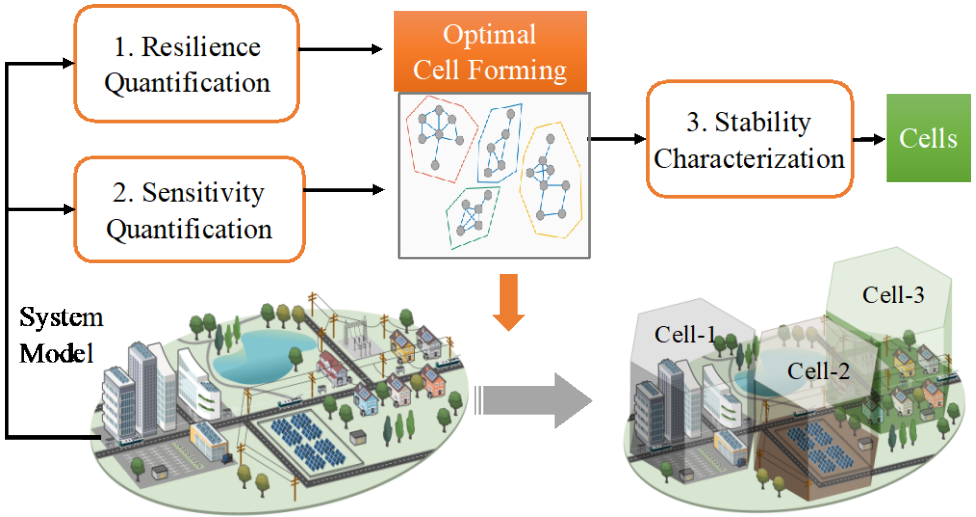
A ***Cell*** is a group of interconnected PVs, BESSs, and buildings that makes up the smallest subset of the grid capable of operating independently using its own resources.

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 disconnected from the grid.

Technical Approach: Operate Cells using ML

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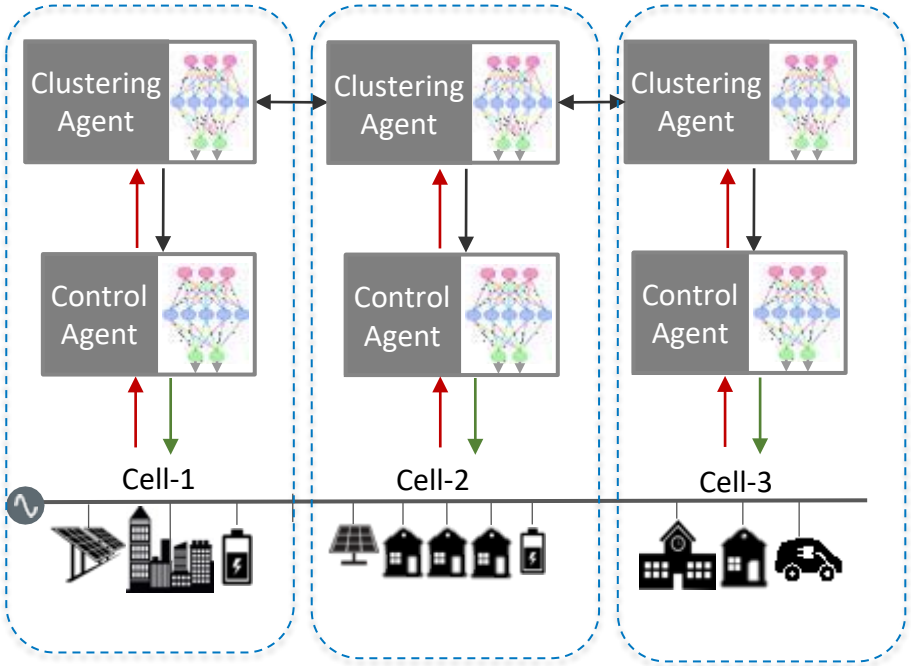

Use **Multi-Agent Deep Reinforcement Learning (MADRL)** to design a 2-Level Control Strategy for managing DERs in coordination with network reconfiguration for both normal grid-connected and resilient microgrid operations:

- **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 model and massive communication

Distributed and Adaptable Cell Management System using Minsait Software Platform

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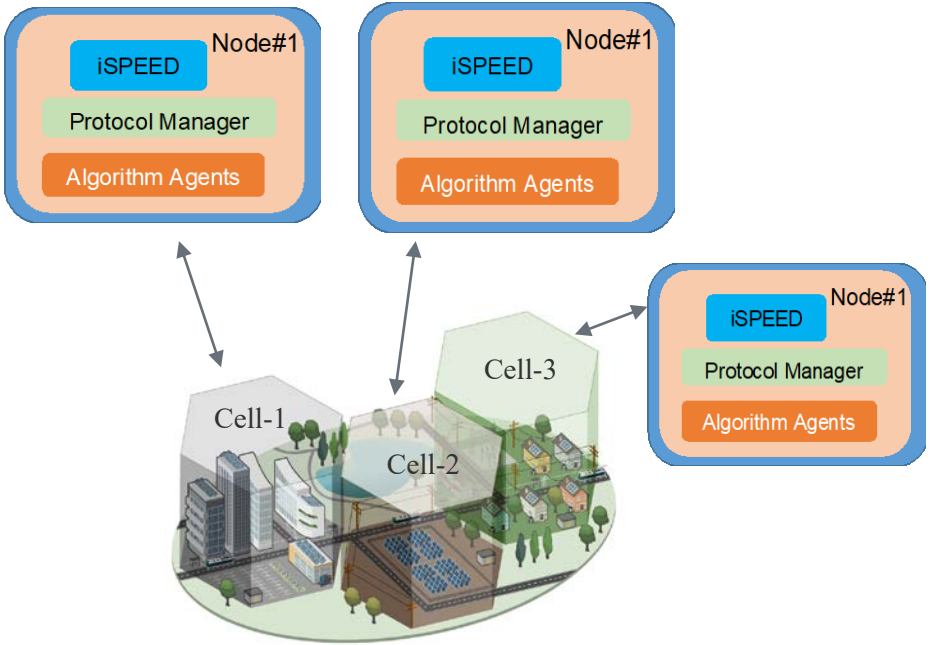
The dynamic nature of clustering cells and the distributed control require a software architecture able to act as a **distributed and adaptable Cell Management System**.



- Collect, process and store data **locally** in every node
- **Modular and highly reproduceable** node software architecture
- In coordination with:
  - edge sensors and IoT devices
  - utility metering infrastructure and system
  - controllable switches, protection relays

Testing and Demonstration

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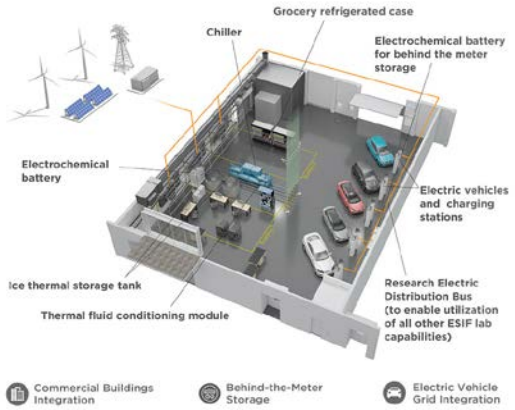
NREL's Energy Systems Integration Facilities will be used to conduct **hardware-in-the loop experiments** for validating the REORG approach.

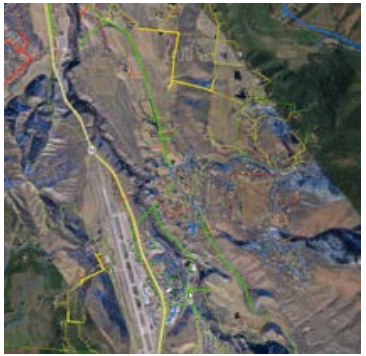
Hardware devices to integrate:

- Grid-forming and grid-following inverters
- Batteries and PV emulators
- EV supply equipment
- Load banks



Selected Field Pilot Community at Aspen CO with 100% PV Penetration:

- 760 residential and 379 commercial customers, with 4.5 MW peak demands and 400 kW distributed PVs
- A recently installed 5 MW PV farm and planned >10MWh energy storage systems
- Aspen Airport Business Center, Colorado Mountain College, Comcast service center, Conoco fueling station
- **Critical loads:** Aspen Pitkin Airport, Roaring Fork Transportation Authority, waste-water treatment facility



Project Schedule

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Year-1 (15 months: 4/1/21-6/30/22):
Technical Approach Development

Year-2 (7/1/22-6/30/23):
Technology Validation and Control Platform Development

Year-3 (7/1/23-3/31/24):
Field Pilot Demonstration

Distributed Cell Management System

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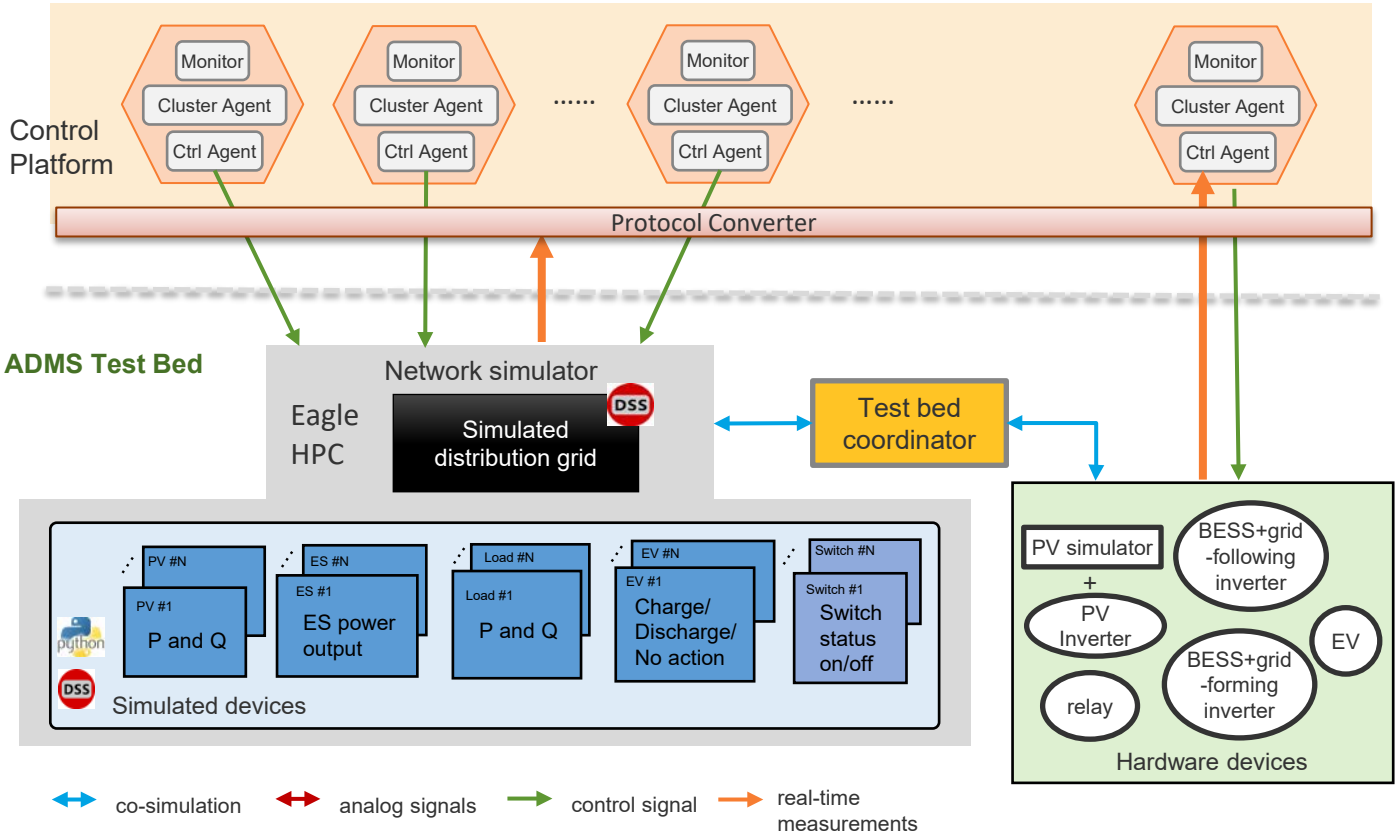

A distributed ADMS solution with extensive DER control capability

- Cloud solution for lab experiment
- Edge solution for field pilot

Thank You

Contact: fei.ding@nrel.gov

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