

The U.S. Department of Energy's  
National Wind Technology Center (NWTTC)

# A Research Facility Providing Insight to the Future of Microgrids

Prepared for the IDEA Campus Energy Conference

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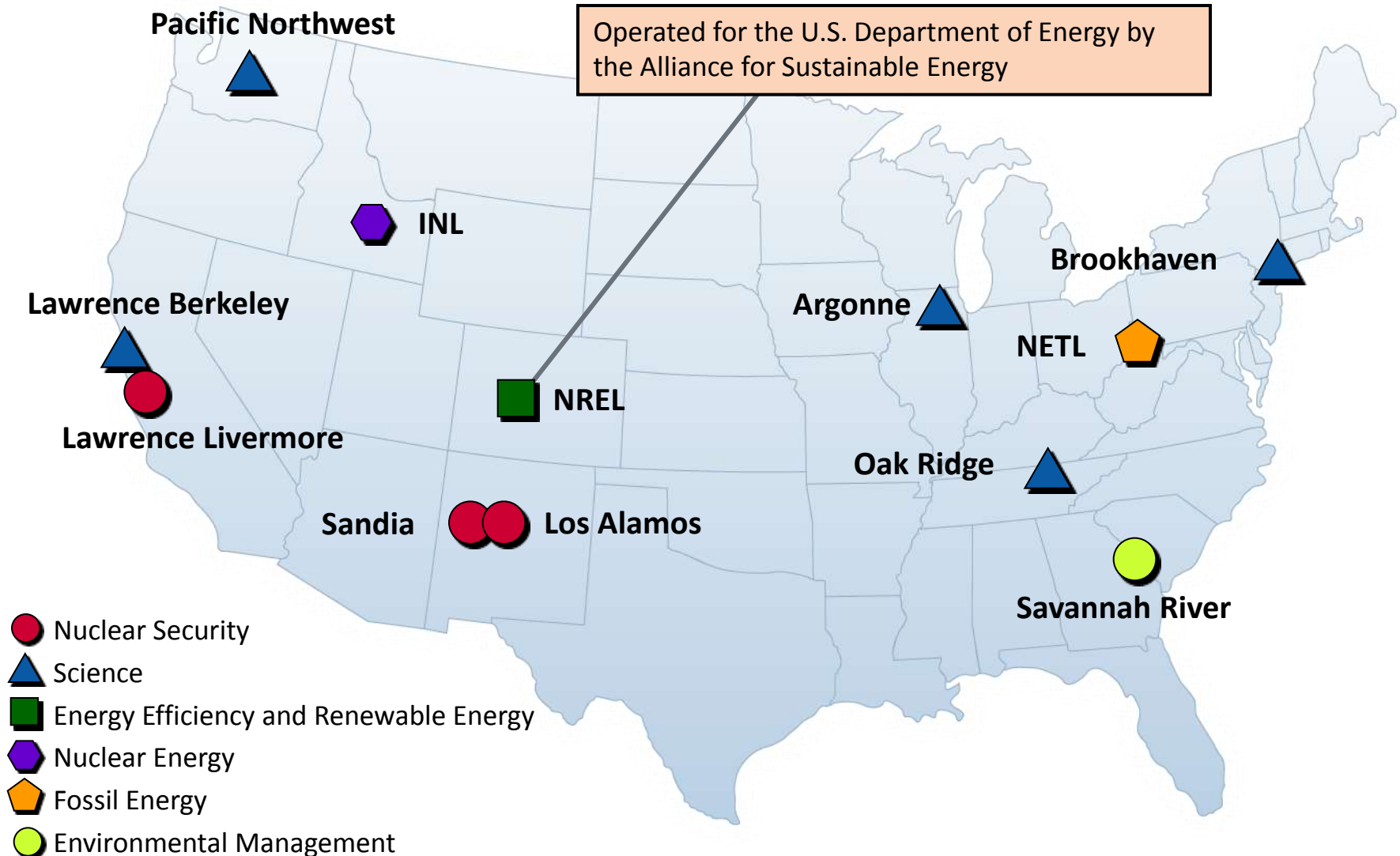
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# NREL Overview



# The U.S. DOE Laboratory System





# National Renewable Energy Laboratory Snapshot

## Dedicated Solely to Advancing Energy Efficiency and Renewable Energy

- Physical Assets Owned by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy
- Operated by the Alliance for Sustainable Energy under Contract to DOE
- 2400 staff and world-class facilities
- More than 350 active partnerships annually
- Campus is a living model of sustainable energy



# Scope of Mission



## Energy Efficiency

Residential  
Buildings

Commercial  
Buildings

Personal and  
Commercial  
Vehicles



## Renewable Energy

Solar

Wind and Water

Biomass

Hydrogen

Geothermal



## Systems Integration

Grid  
Infrastructure

Distributed  
Energy

Interconnection

Battery and  
Thermal Storage

Transportation



## Market Relevance

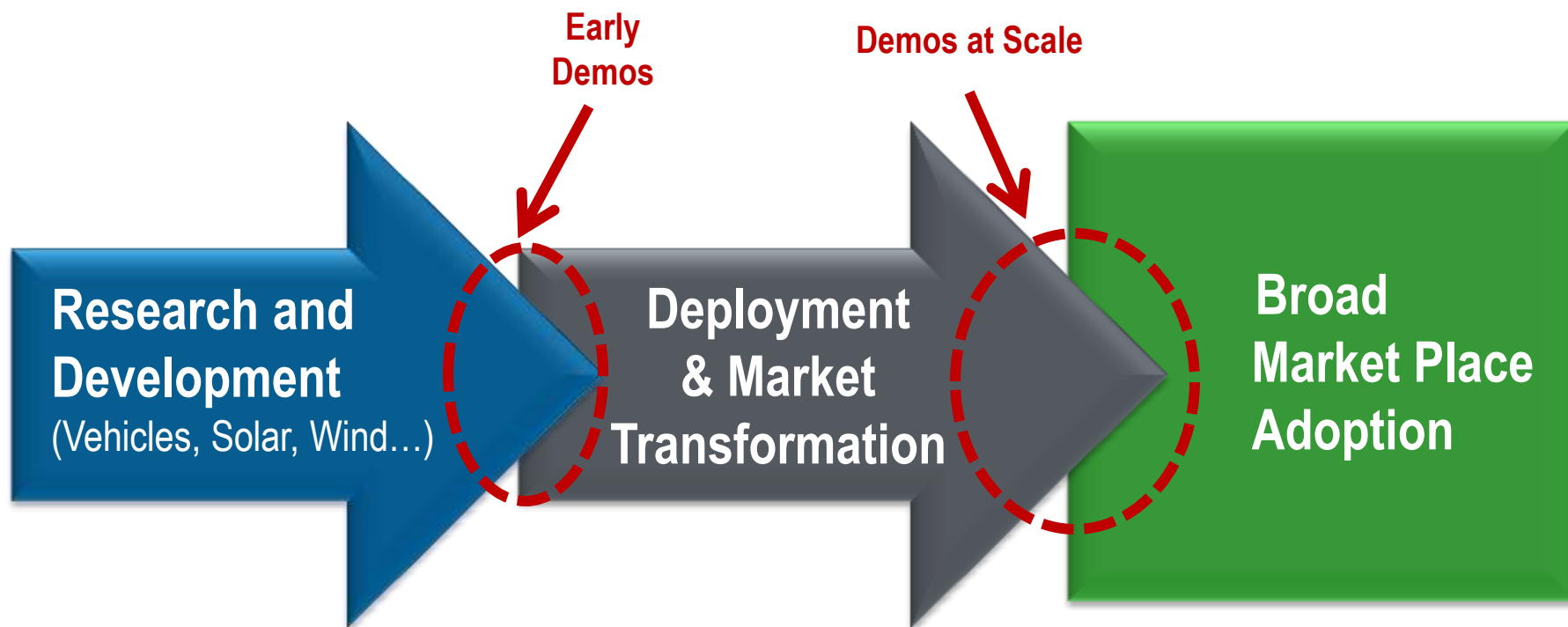
Industry

Federal Agencies

State and Local  
Governments

International

# Full Spectrum - *Research to Market Adoption*



# Energy System Integration Capabilities

## Energy System Research and Development Across Technologies



### Solar and Wind

- RE integration
- Power electronics
- Building integration
- Thermal and PV system optimization



### Grid Planning and Operations

- Transmission and distribution systems
- Smart Grid technologies
- Microgrids
- Standards



### Energy Storage

- CSP thermal storage
- Utility-scale batteries
- Distributed storage



### Buildings

- Sensors and controls
- Design and integration
- Modeling and simulation
- Big data warehousing and mining
- System integration



### Fuel Cells and Hydrogen

- H<sub>2</sub>/electric interfaces
- RE electrolyzers
- Storage systems
- Standards
- Fuel cell integration
- Fueling systems



### Advanced Vehicles

- Plug-in-hybrids and vehicle-to-grid
- Battery thermal management
- Power electronics

## Informatics and Analysis

**Full systems interface evaluation for integration of electricity, fuel, thermal, storage, and end-use technologies**



# NREL's Energy Systems Integration Facilities

**NREL ESIF - A unique national asset for energy systems integration R&D, testing, and analysis at various scales**

**ESIF**  
**1kW-2MW**



**DERF**  
**1kW-200kW**



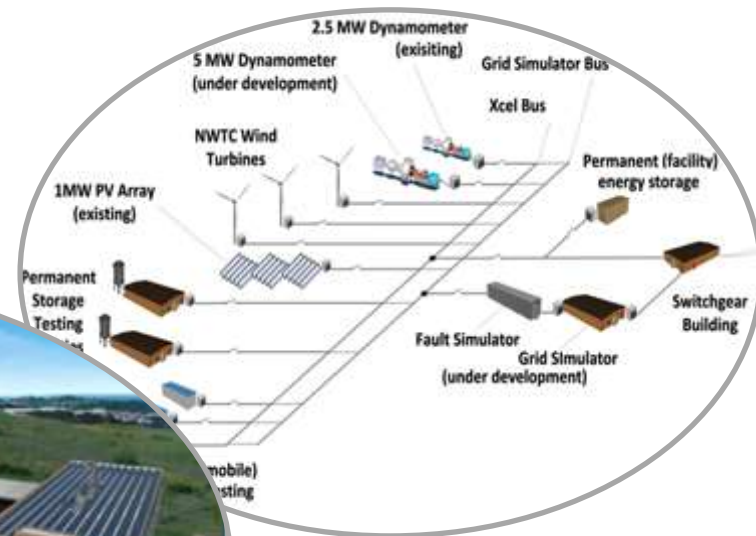
**TTF**



**VTIF**

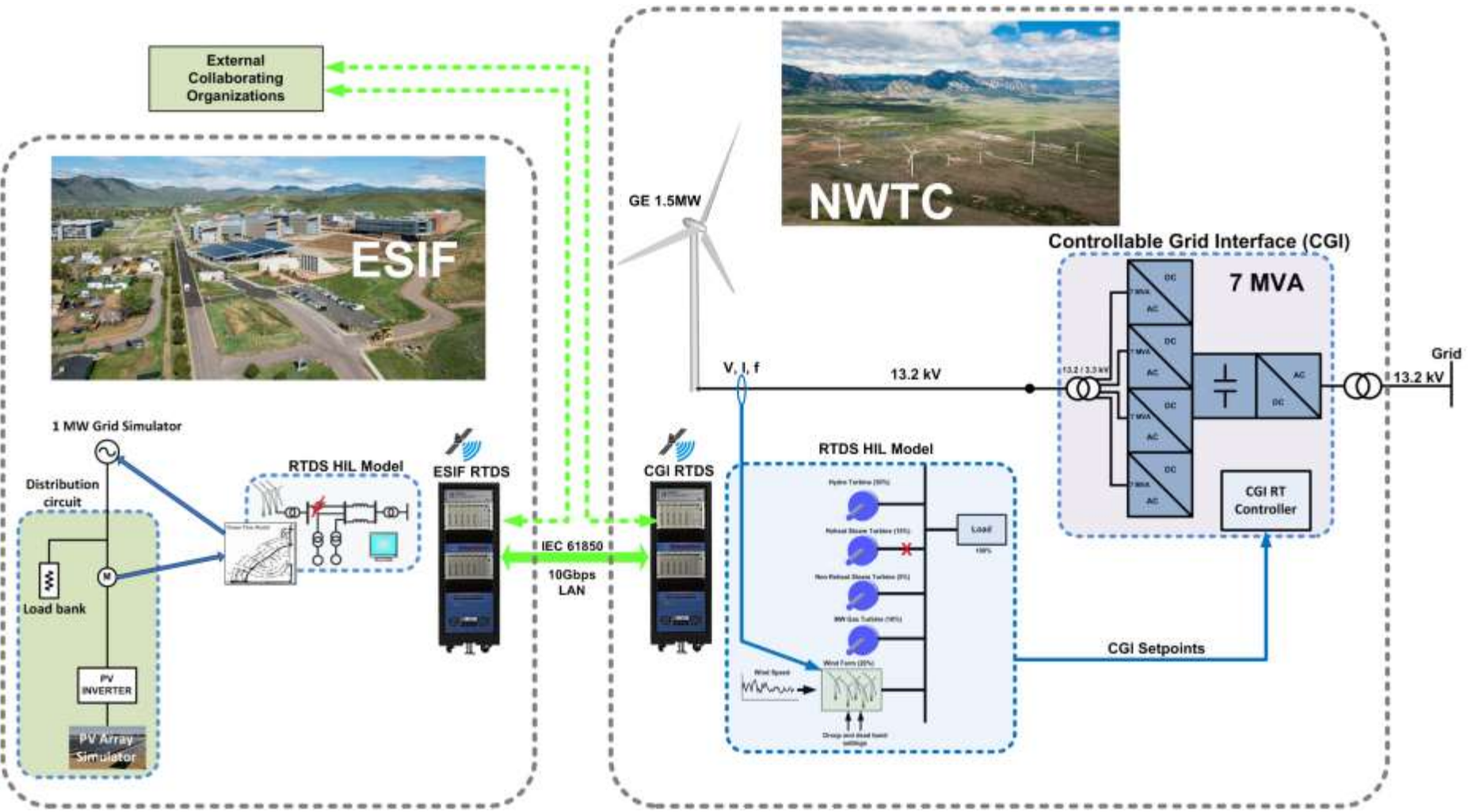


**NWTC – 2MW+**



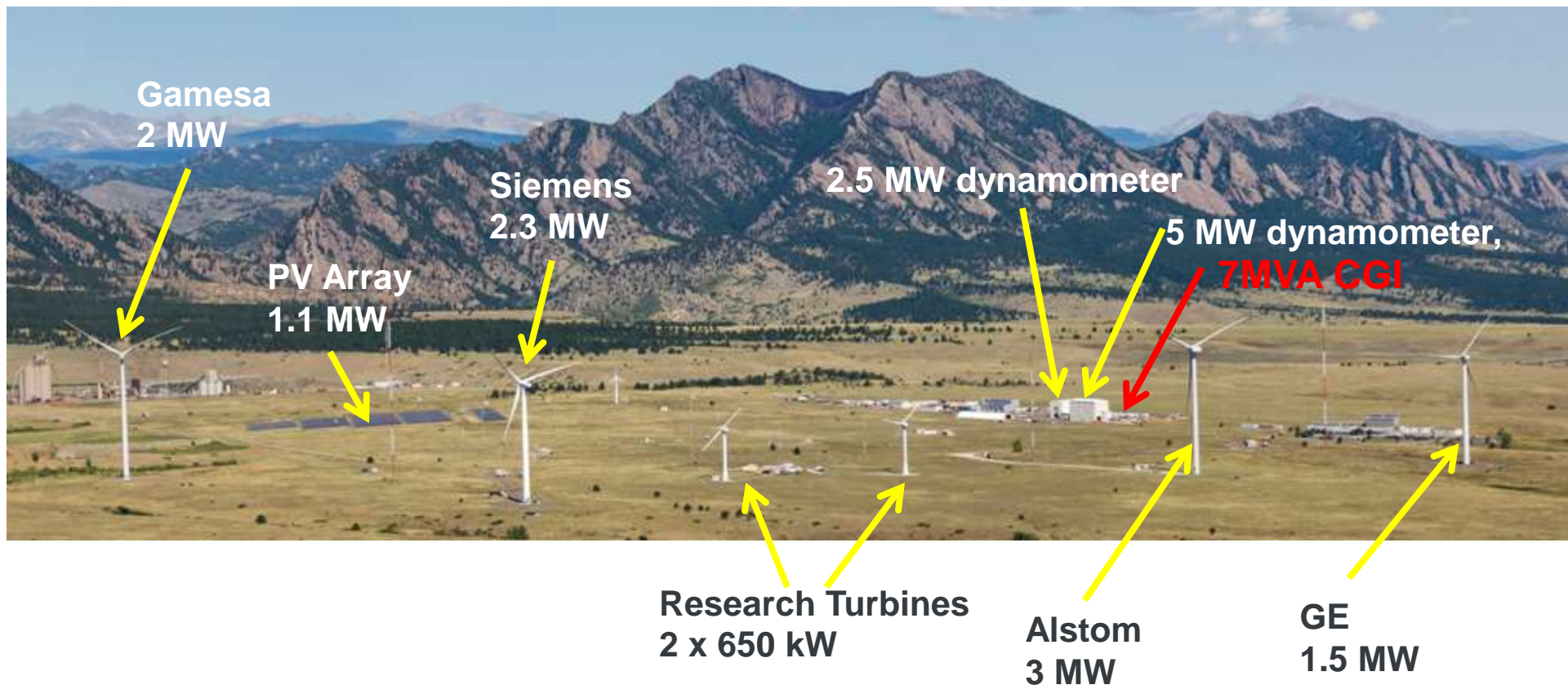


# NWTC/ESIF Real-time Interconnection



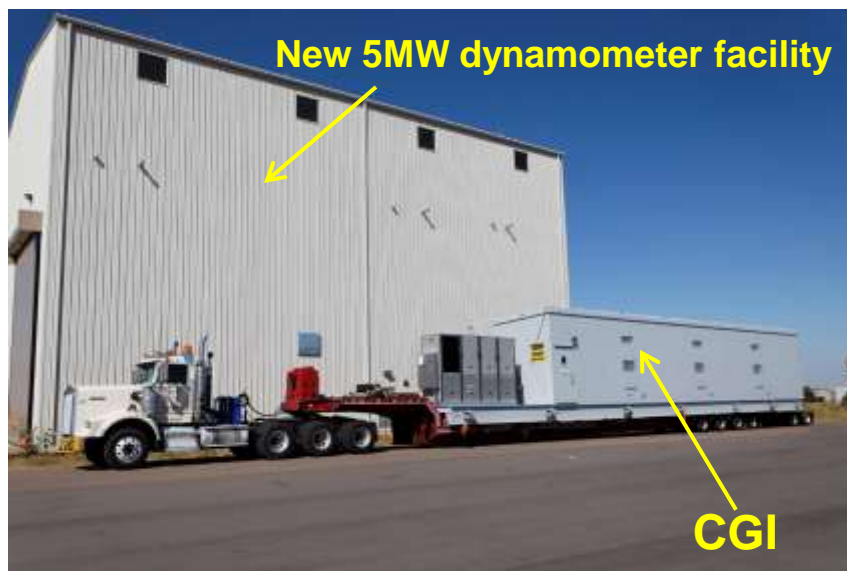
# NWTC Test Site

- Total of 11 MW variable renewable generation currently at NWTC test site
- There are many small wind turbines (under 100 kW) installed as well
- 2.5MW and 5 MW dynamometers
- **7 MVA Controllable Grid Interface (CGI) for grid compliance testing**
- Multi-MW energy storage testing capability under development





# GE 2.75 MW installed in NREL Dynamometer



New 5MW dynamometer facility

CGI

# NWTC 7-MVA Controllable Grid Interface



- Installed at NWTC test site in Nov 2012
- Commissioning and characterization testing – end of 2013
- Row 4 / turbine bus connection – FY14
- Energy storage site connection – end of 2014



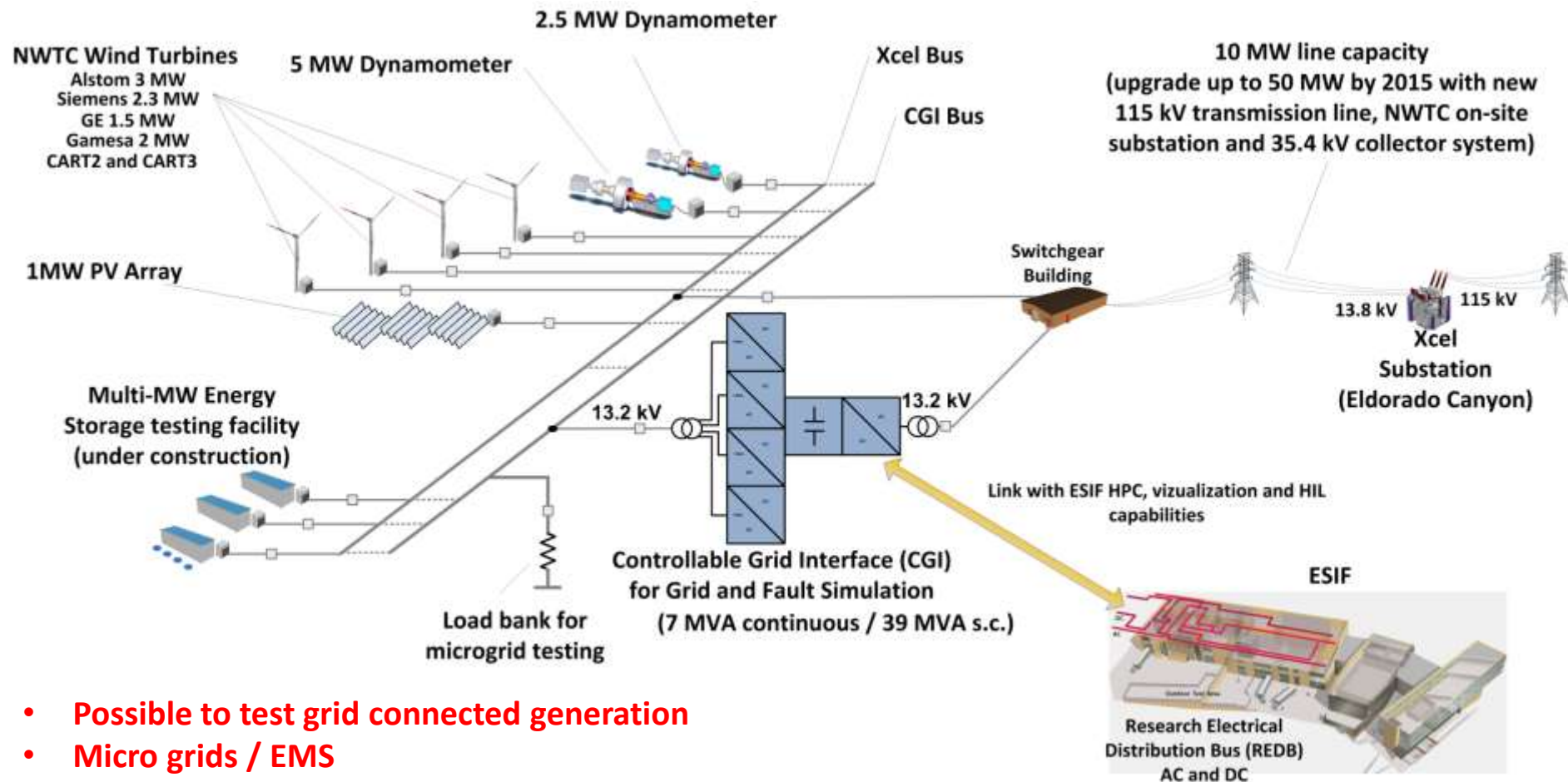
# Storage Test Pads

- Two pads each rated for 4 MW
- Each pad can be connected to the real grid or NWTG Grid Simulator
- Containerized storage solutions – up to 110ft ISO containers
- Pre-wired, MV switchgear / protection installed
- Fiber-optic / Ethernet



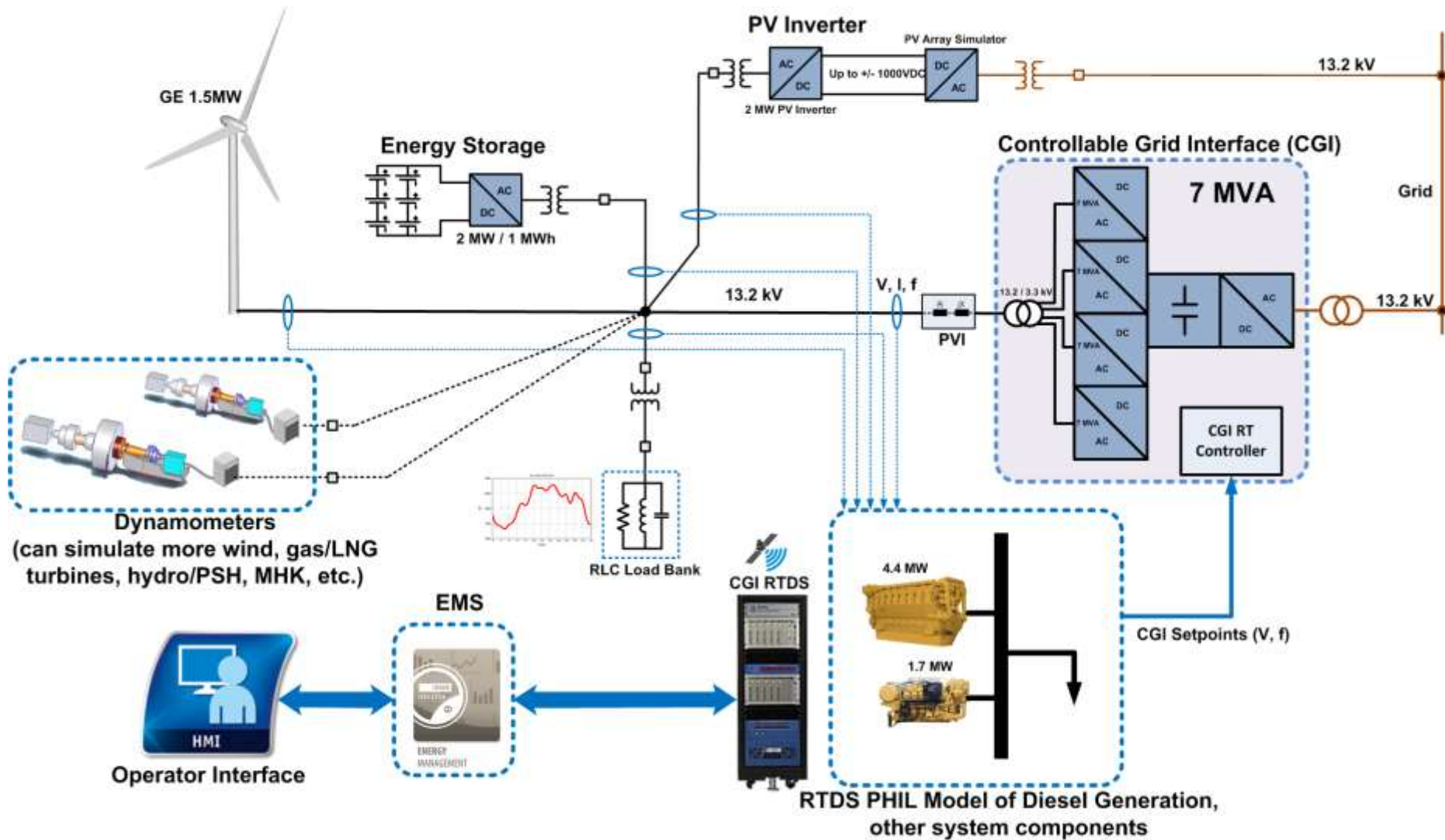
# NWTC Dual-Bus Test Setup

- Highly flexible and configurable system level multi-MW testing/demonstration platform
- Most components in place and operational
- Energy storage testing facility to become on-line by the end of March 2015

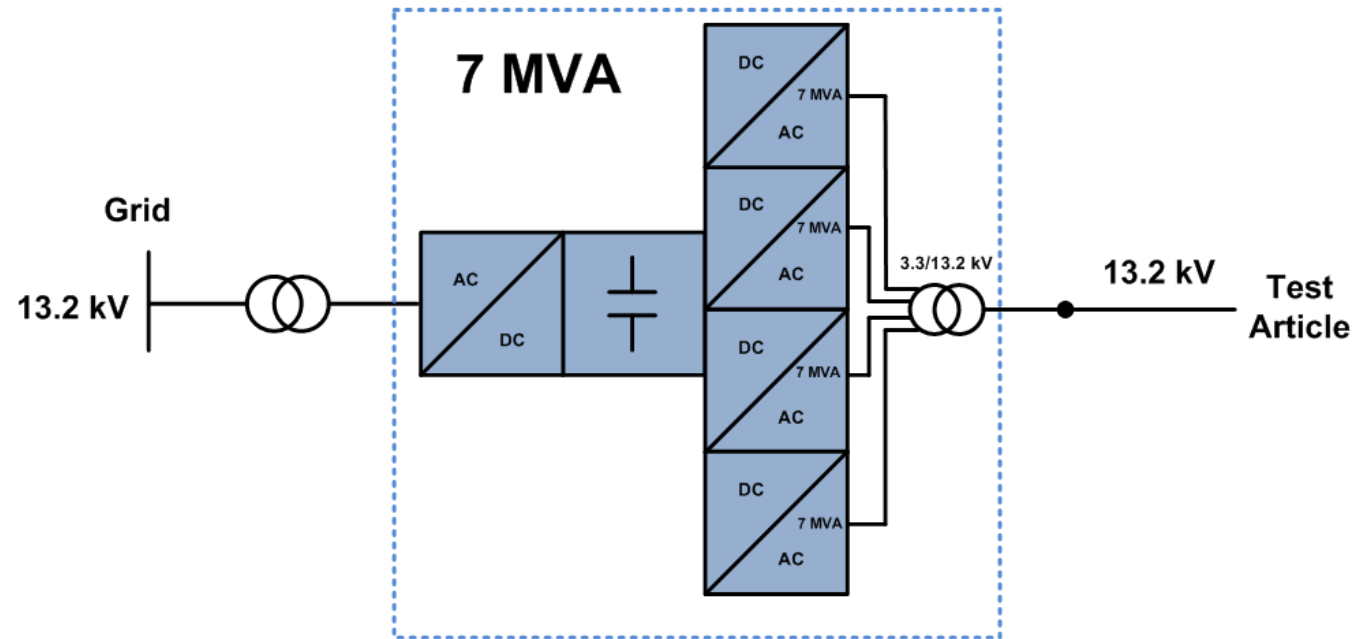


- Possible to test grid connected generation
- Micro grids / EMS
- Combination of technologies / Advanced controls

# NWTC CGI for Microgrid Testing



# CGI Main Technical Characteristics



## Power rating

- 7 MVA continuous
- 39 MVA short circuit capacity (for 2 sec)

## Possible test articles

- Wind Turbines
- PV inverters
- Energy storage systems
- Conventional generators
- Combinations of technologies

## Voltage control (no load THD <5%)

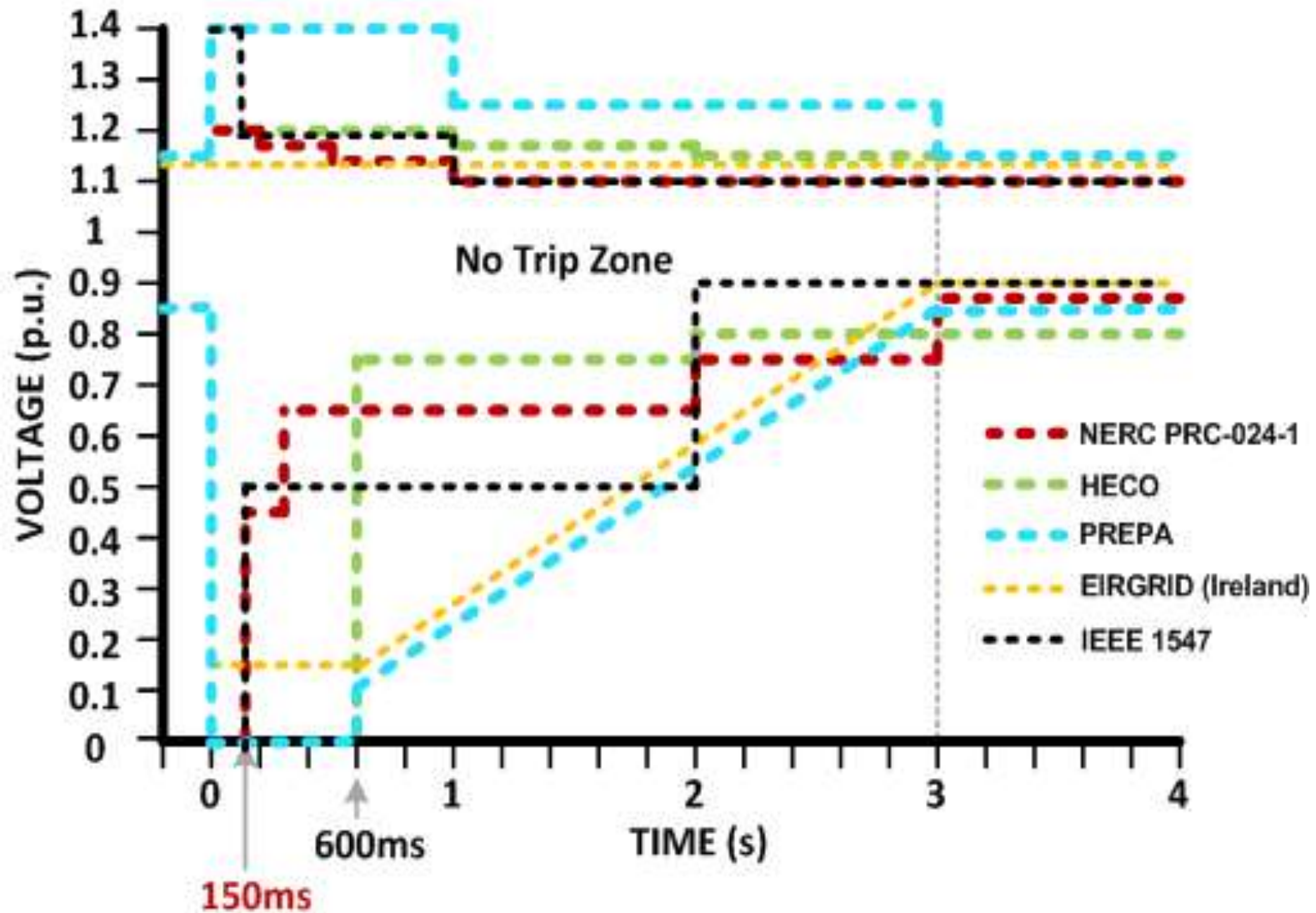
## Frequency control

## Capabilities

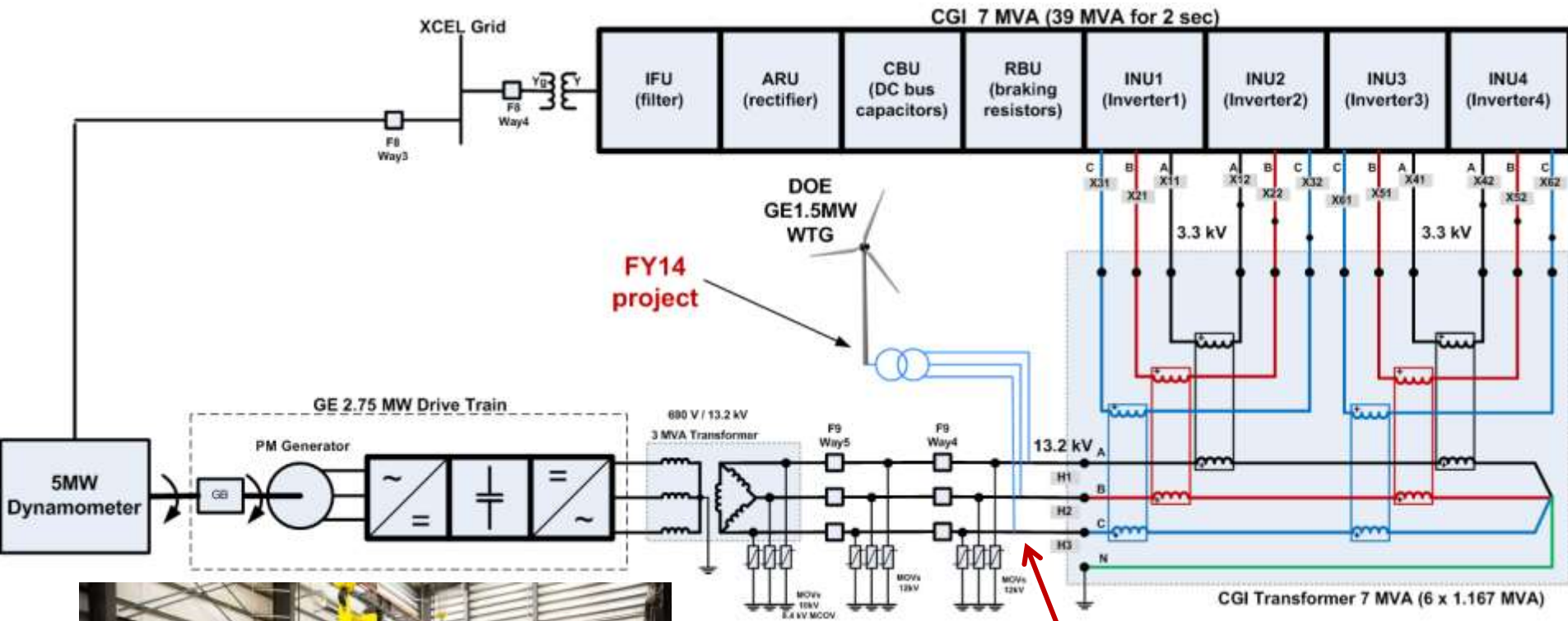
- Balanced and unbalanced over and under voltage fault ride-through tests
- Frequency control
- Voltage control (0-130%; no load THD <5%)



# Testing to **All** Interconnection Requirements and Grid Codes



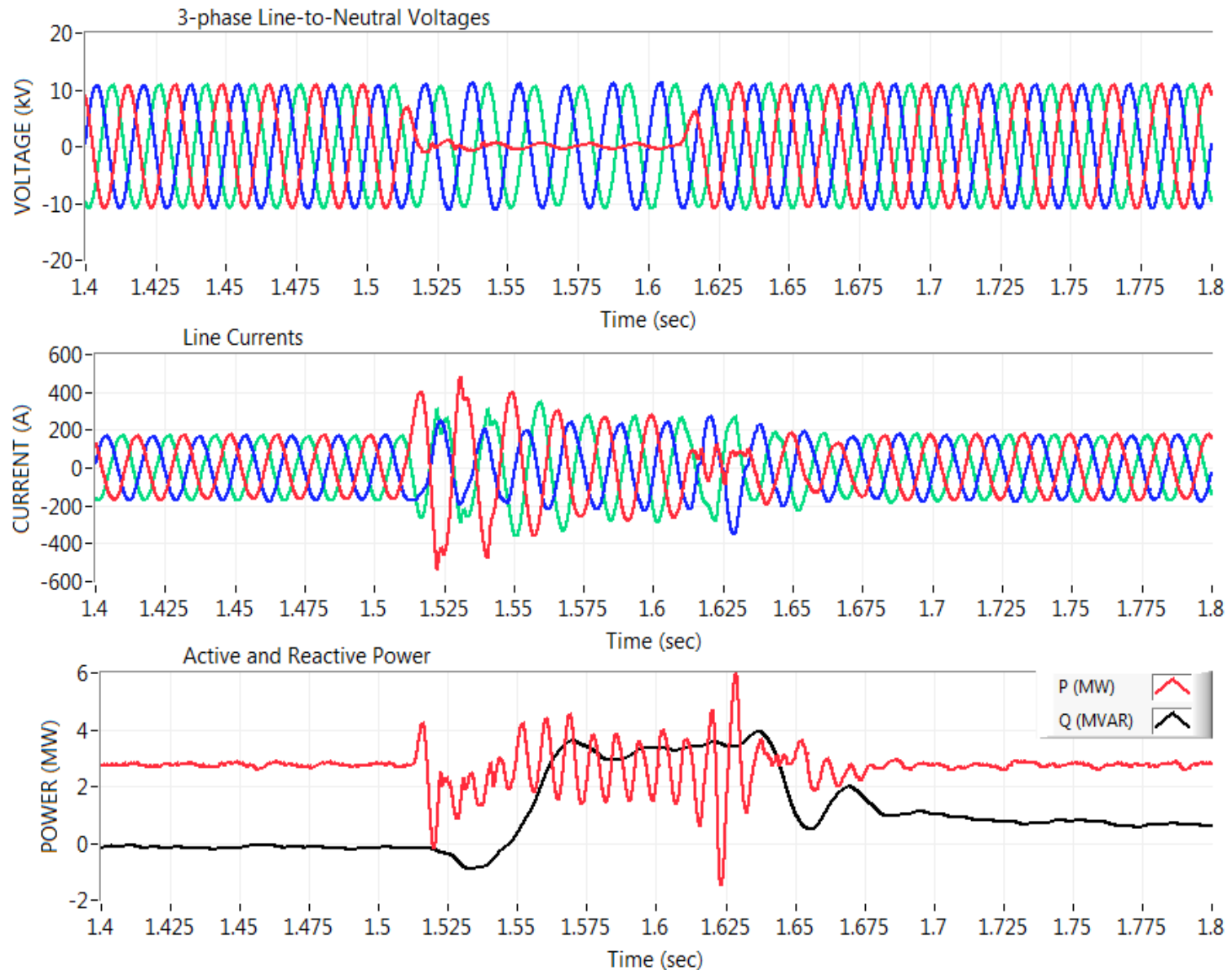
# Type 4, ~3MW Turbine Operation with CGI



Voltage amplitude, frequency, phase angle and harmonic content are controlled on CGI terminals



# Example test result: Single-phase fault emulated on MV terminals of 2.75 MW wind turbine



# Site Power for the CGI

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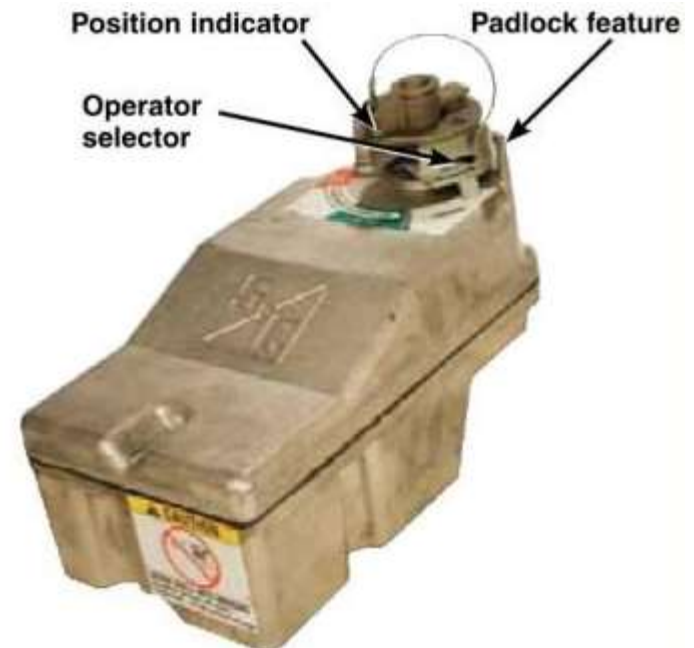
# Site Power Plan - Overview

- **Campus type distribution**
  - Safety through design
  - Outdoor installation
    - Underground conductor routing
  - Centrally monitored & controlled distribution system



# Site Safety Concerns

- **Components typical of microgrids**
  - Switching interlocks for two and three source circuits
  - Utility, renewables, energy storage
  - System is capable of remote switching
- **Above and beyond typical microgrid**
  - Equipment specified to withstand test conditions
  - Monitoring of circuits is essential

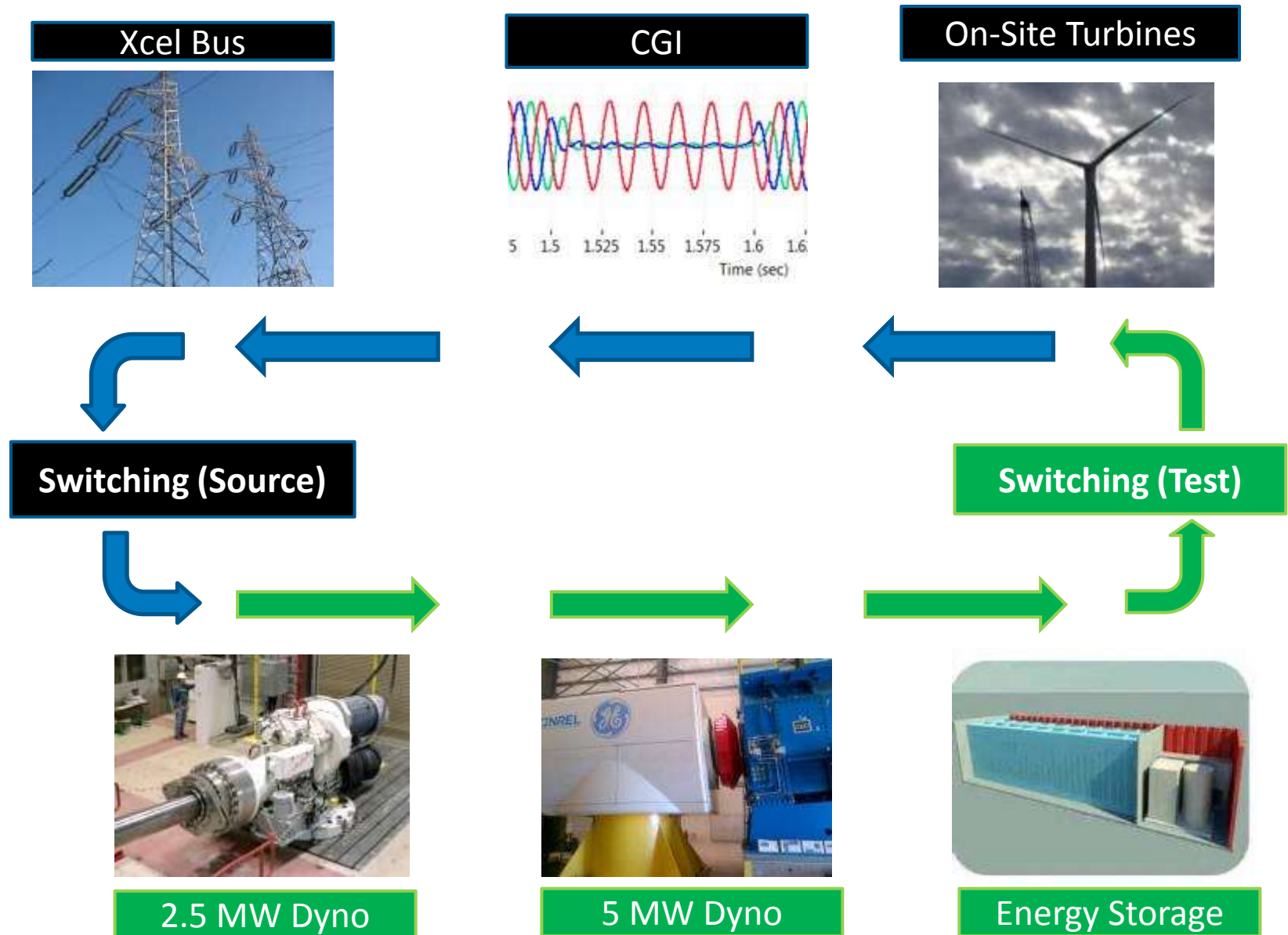


# Site Power Distribution

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- **Component layout in a campus-style environment**
  - Equipment consists of standard power distribution equipment wherever possible.
  - Similar to real world applications
- **Many networks integrated for control of the power distribution system**
  - EtherCat for status and hardwire controls used for trip & alarm breaker control

# Site Power Flow





# Summary

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- **NREL is dedicated to energy efficiency and renewable energy**
- **NWTC is a unique site for microgrid testing**
- **Site power distribution designed for safety and constructability**
- **Site power flow organizing sources and test articles for flexibility in configuration**

# QUESTIONS?