

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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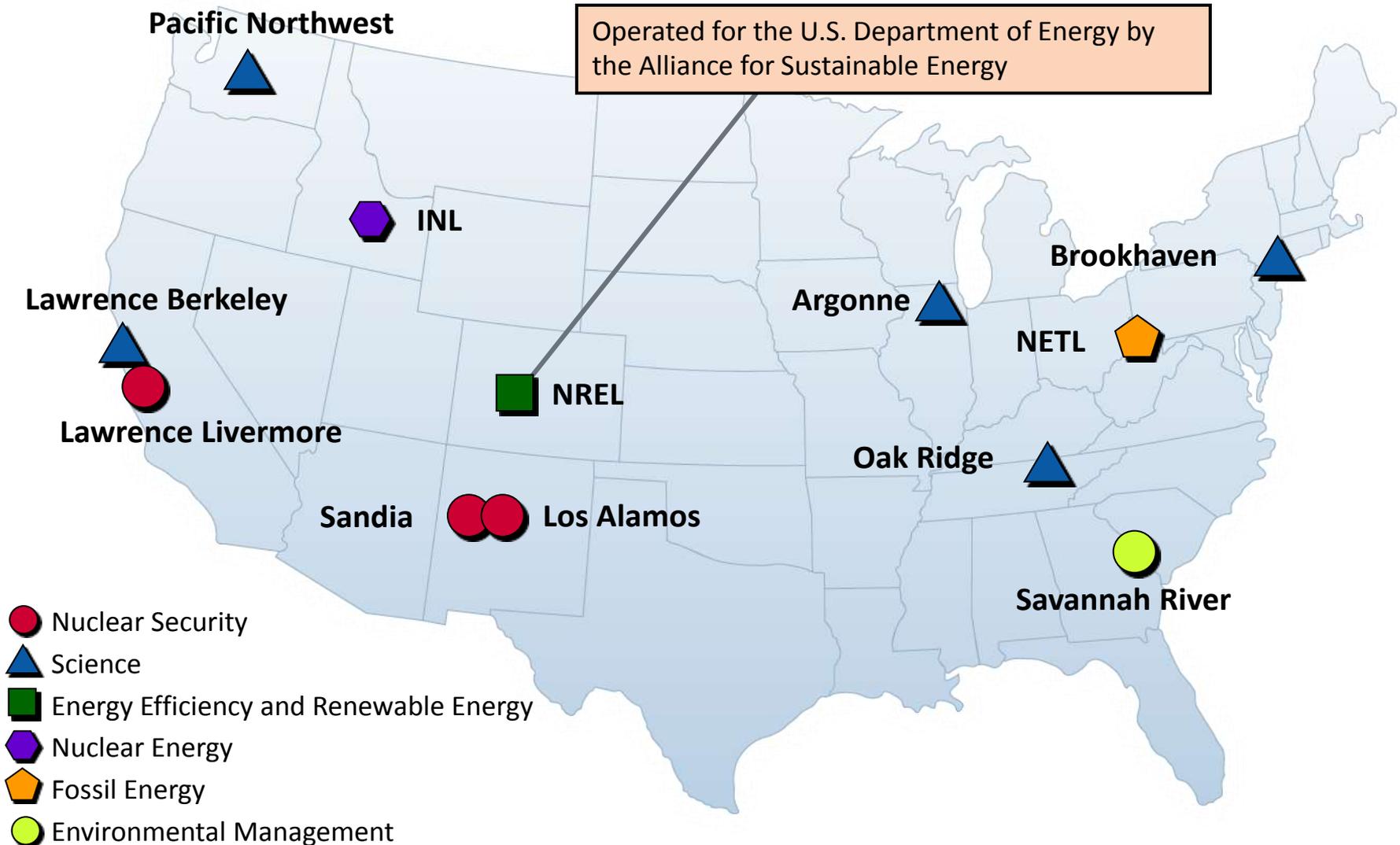
Electrical Engineer

The RMH Group

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

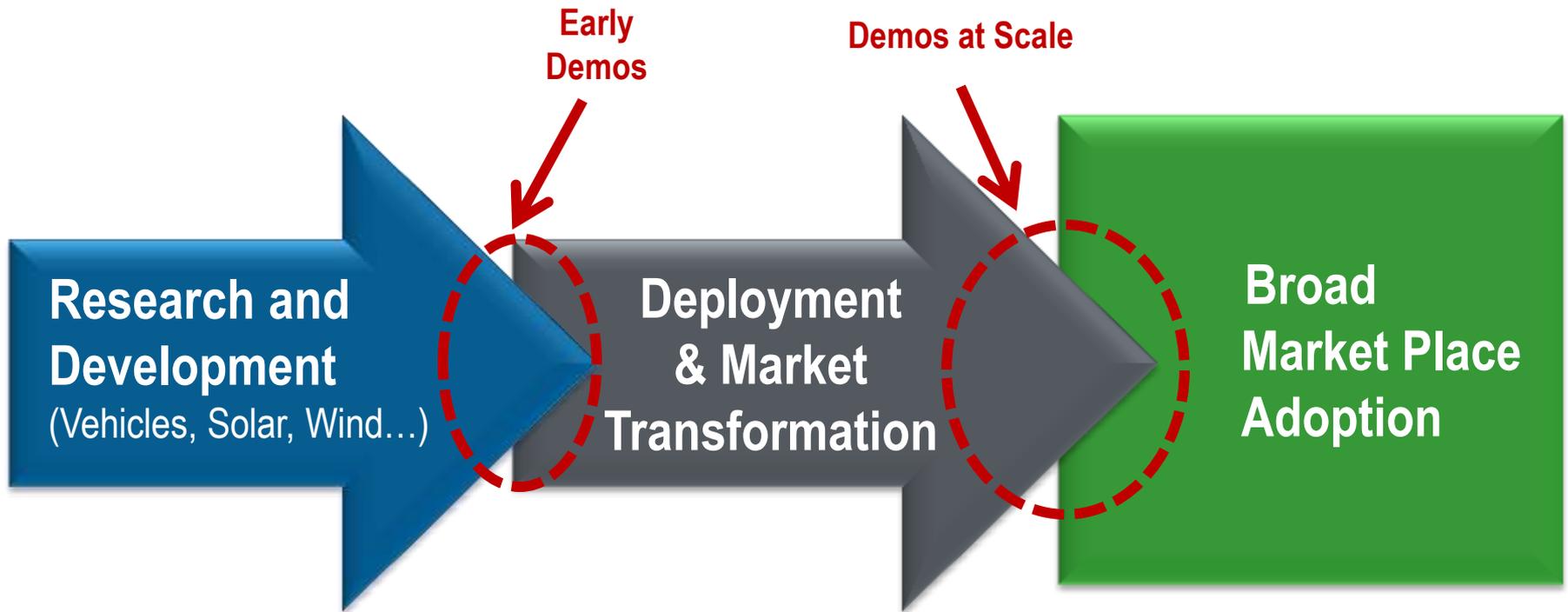
Grid Infrastructure
Distributed Energy
Interconnection
Battery and Thermal Storage
Transportation



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

- H₂/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



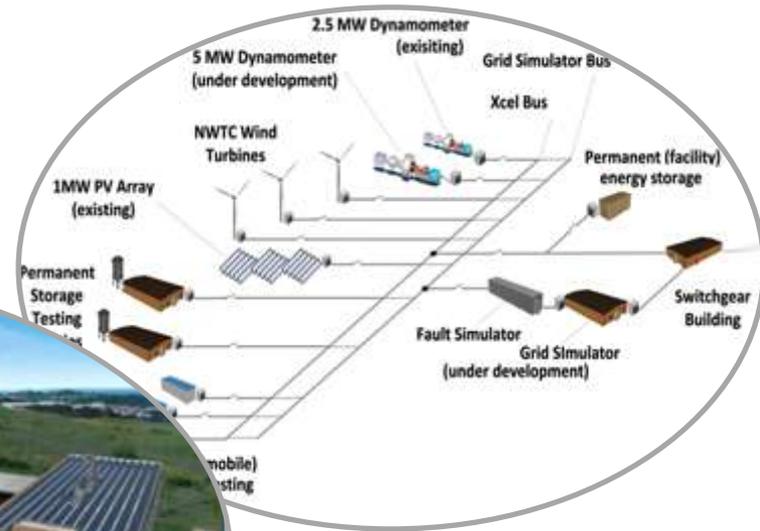
TTF



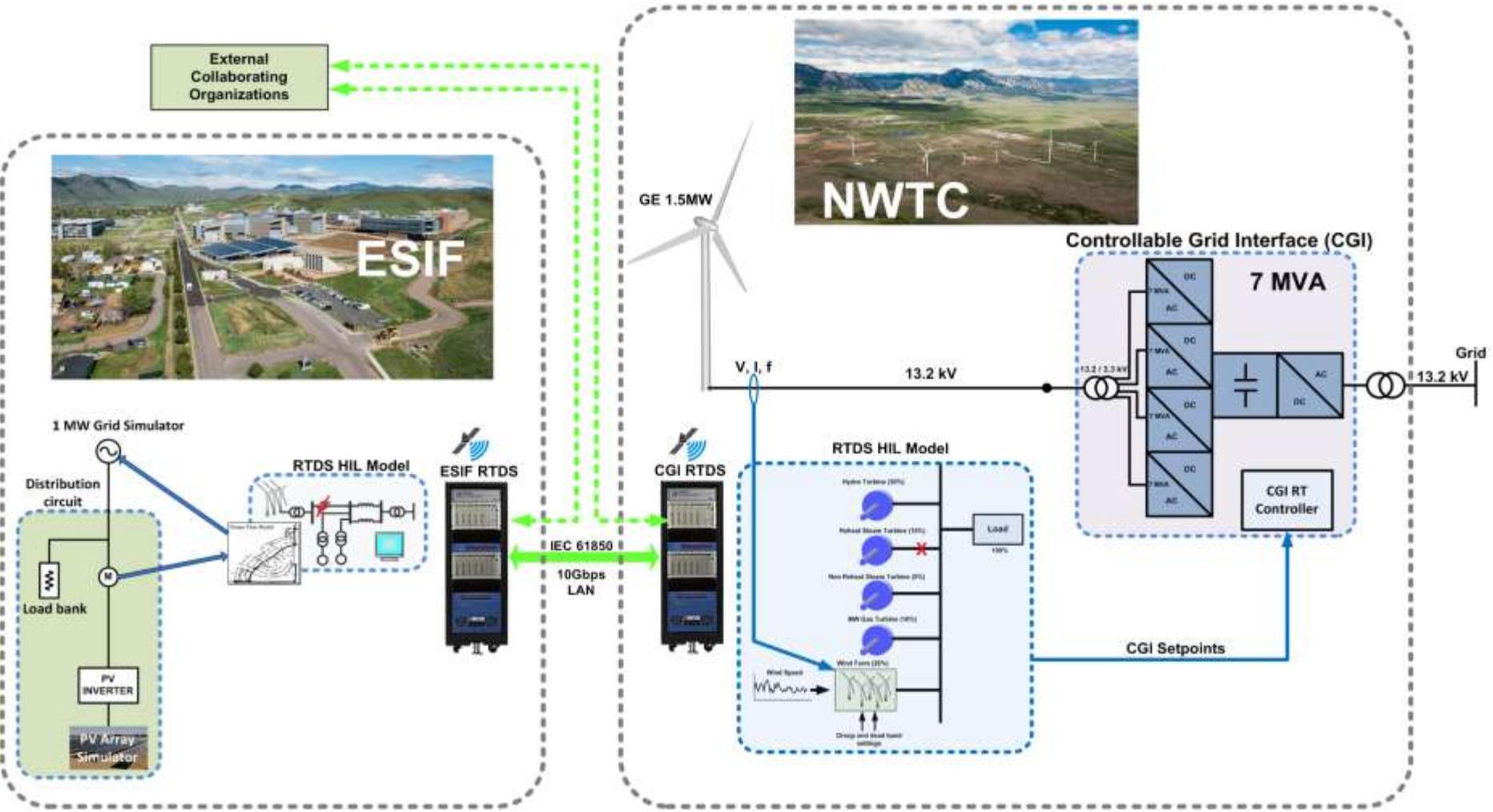
VTIF



NWTC – 2MW+

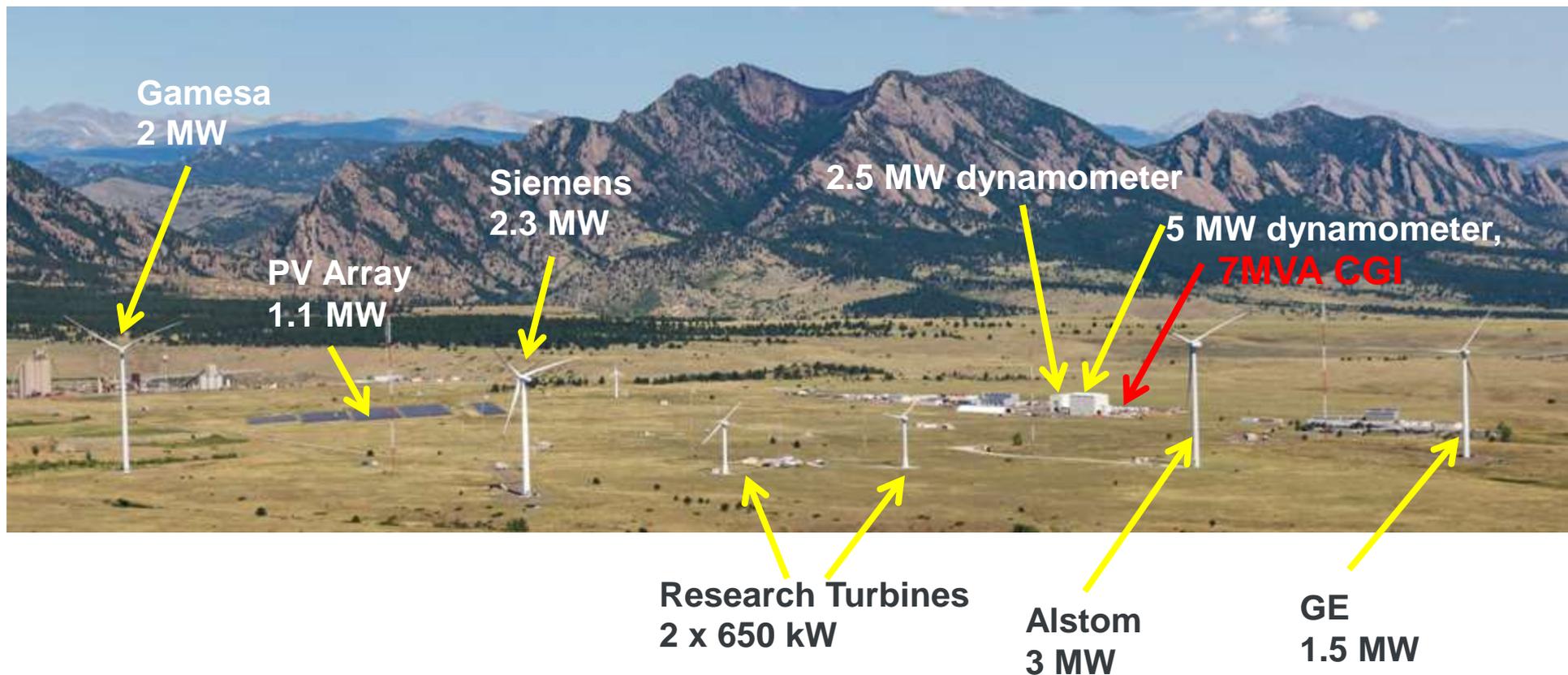


NWTC/ESIF Real-time Interconnection



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

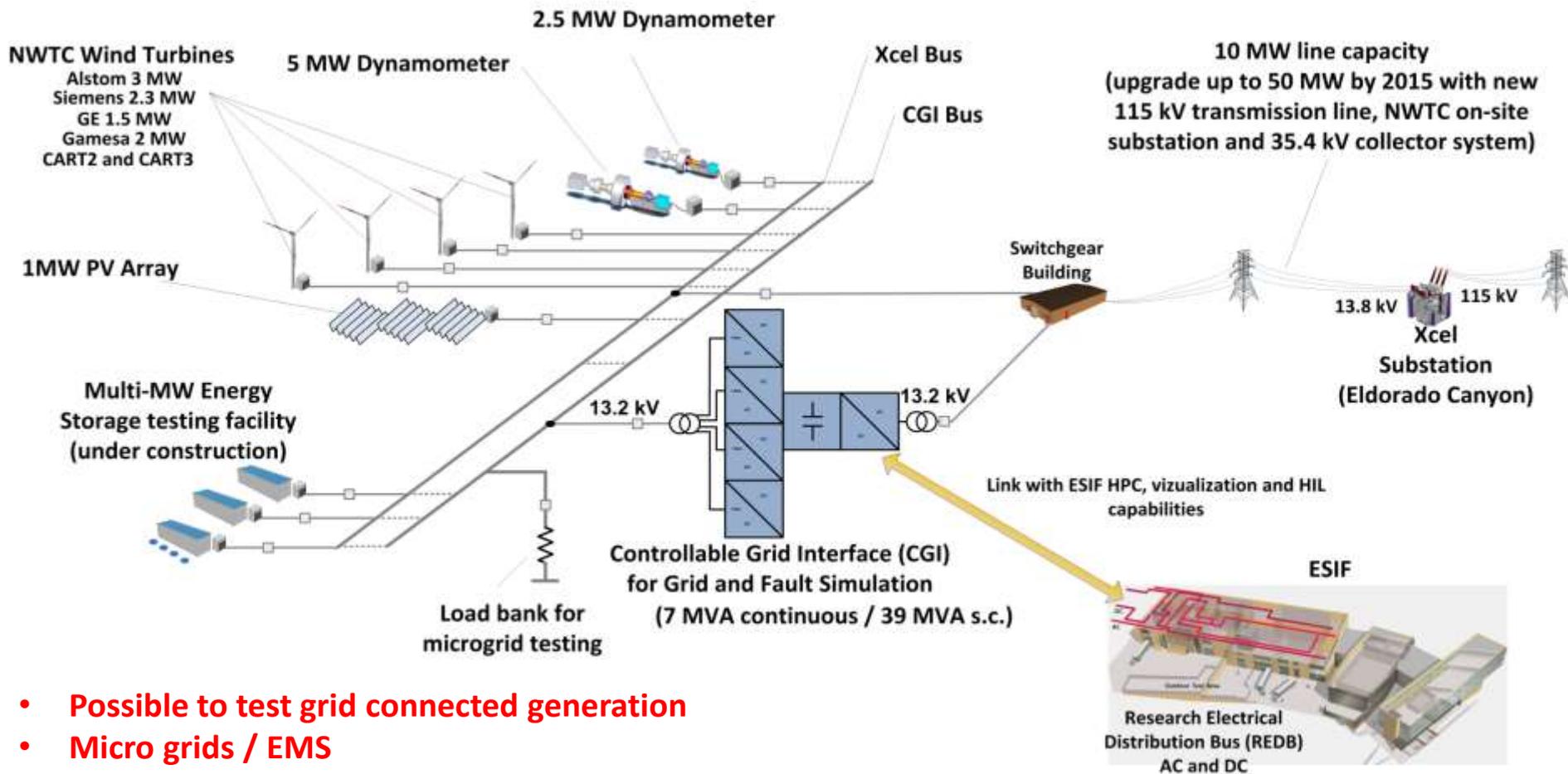
Storage Test Pads

- 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



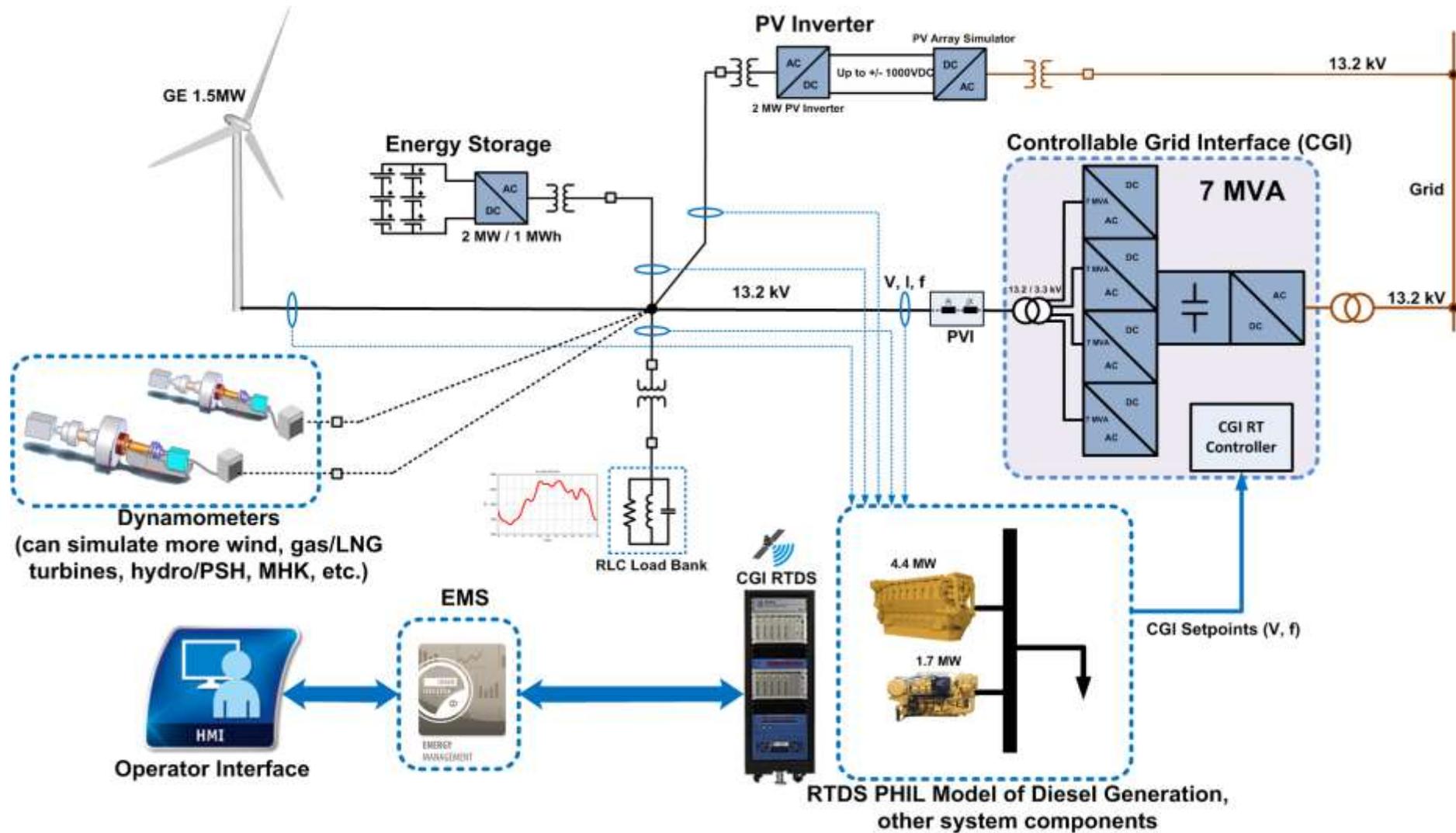
NWTC Dual-Bus Test Setup

- 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

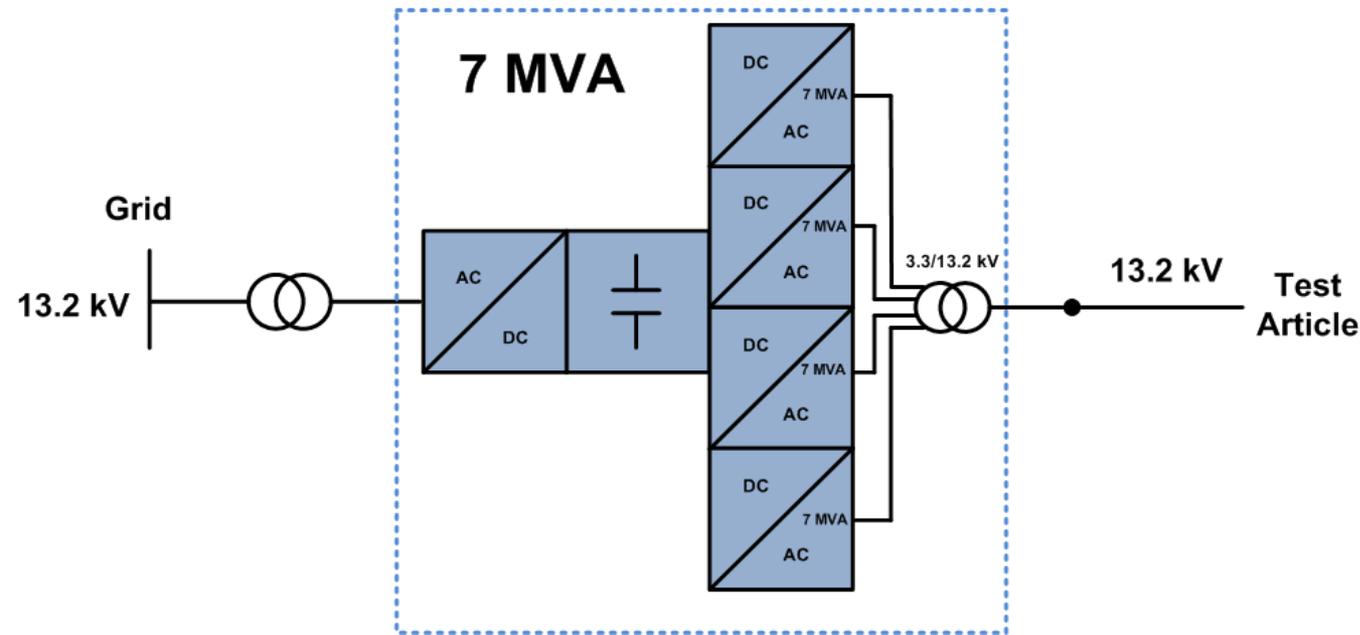


- Possible to test grid connected generation
- Micro grids / EMS
- Combination of technologies / Advanced controls

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

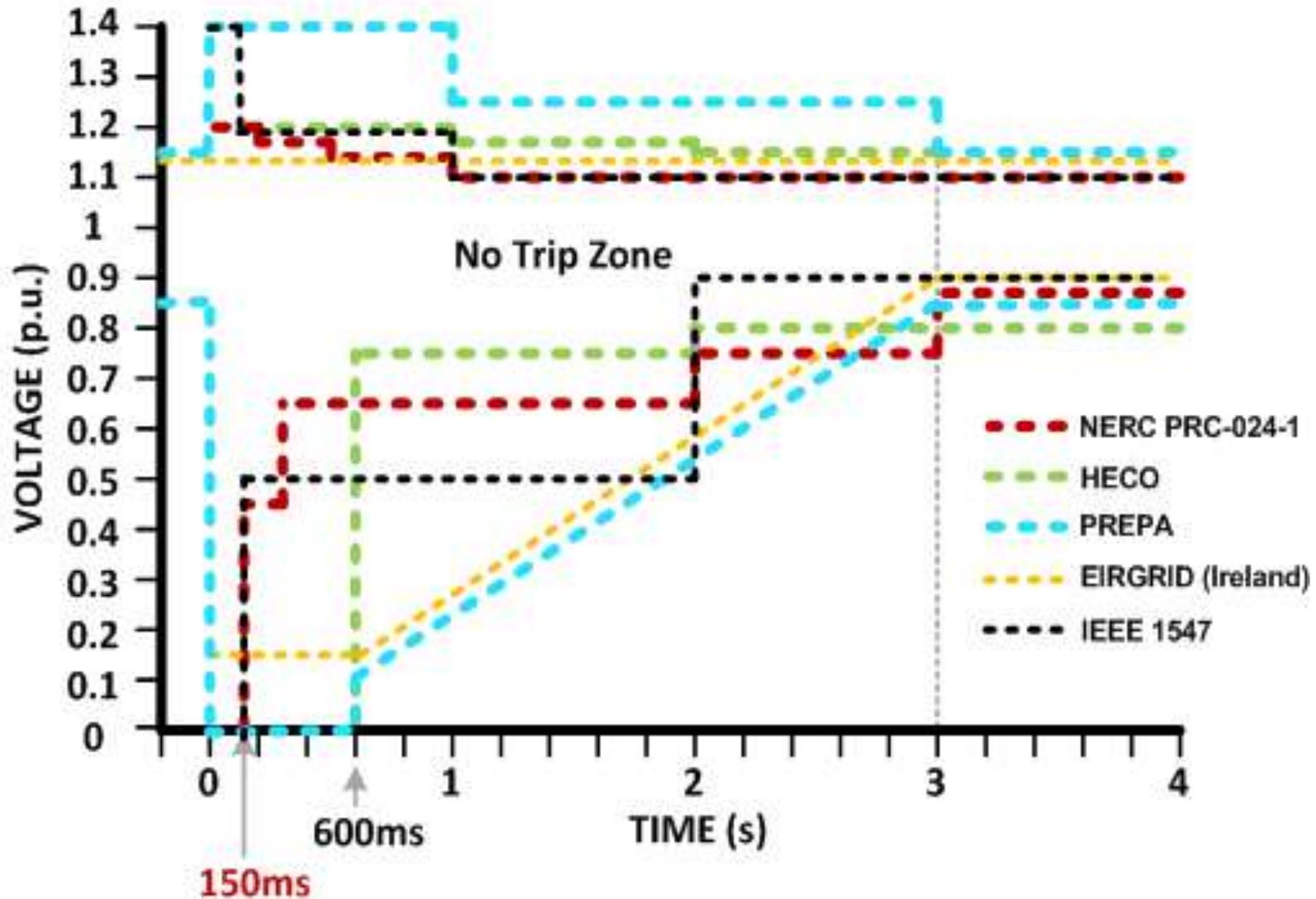
Voltage control (no load THD <5%)

Frequency control

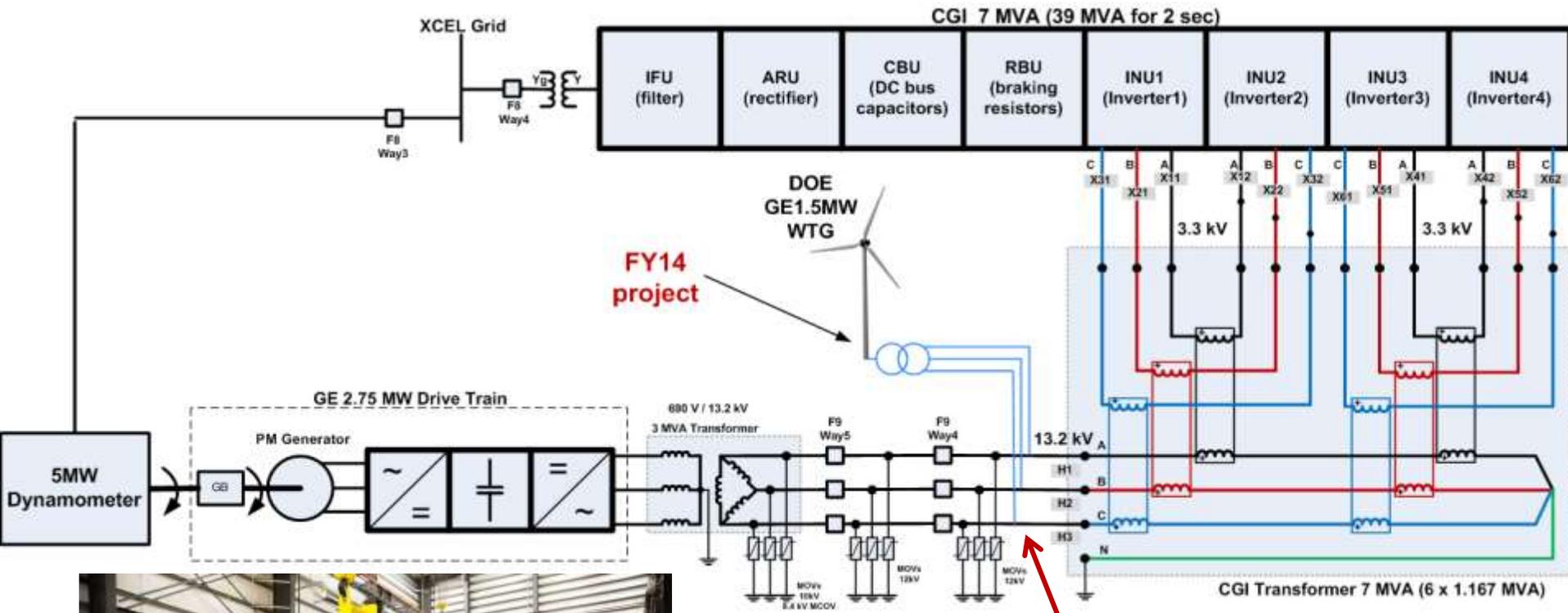
Capabilities

- 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



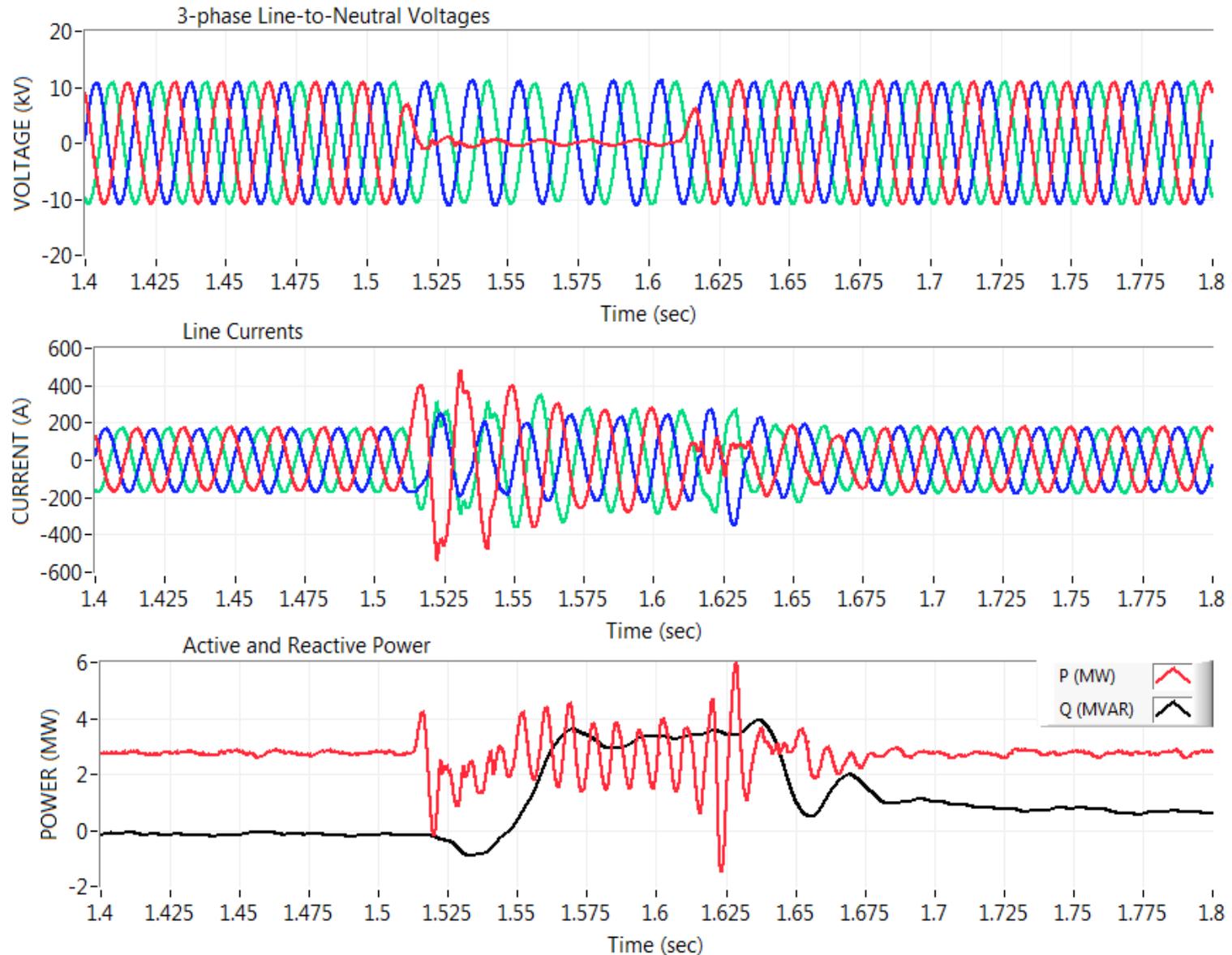
Type 4, ~3MW Turbine Operation with CGI



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

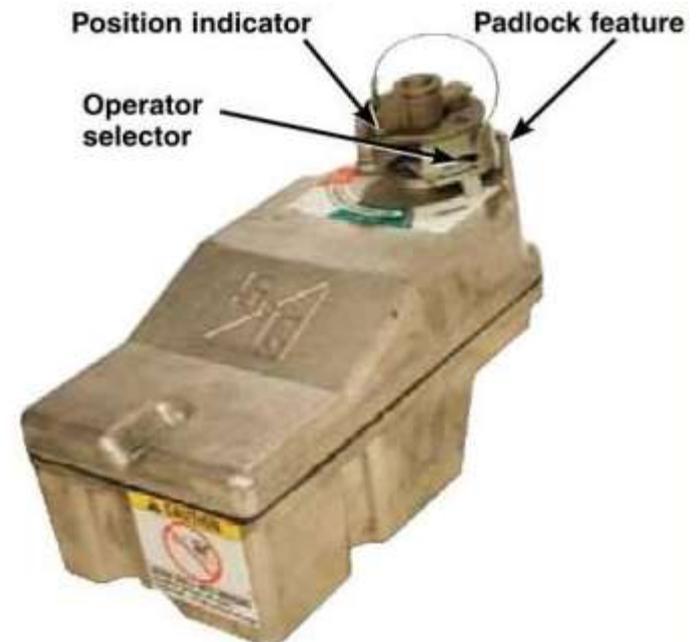
Site Power Plan - Overview

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



Site Safety Concerns

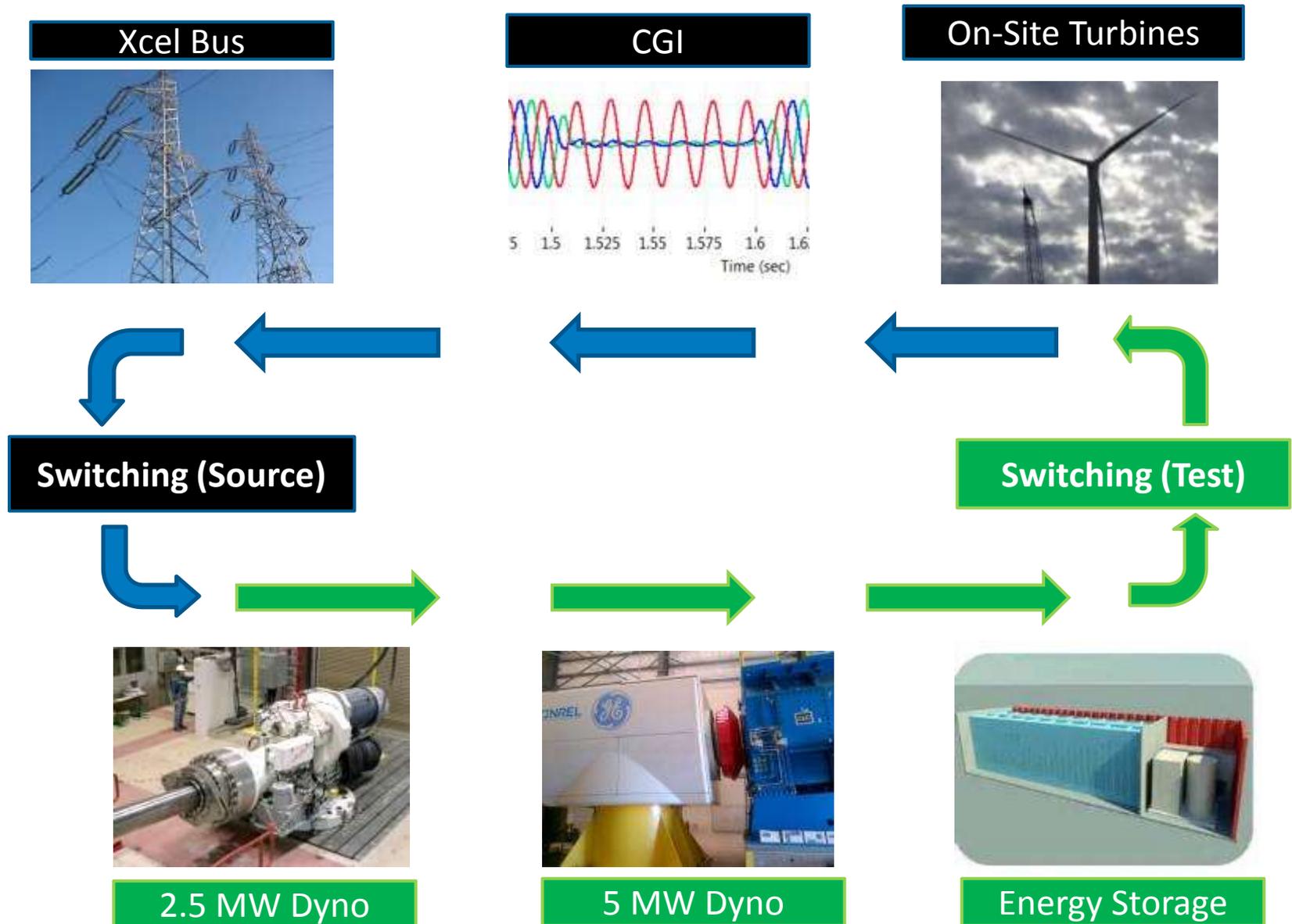
- **Components typical of microgrids**
 - Switching interlocks for two and three source circuits
 - Utility, renewables, energy storage
 - System is capable of remote switching
- **Above and beyond typical microgrid**
 - Equipment specified to withstand test conditions
 - Monitoring of circuits is essential



Site Power Distribution

- **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

- **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?