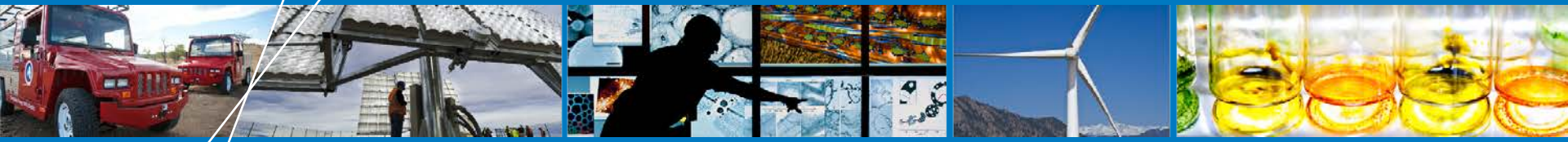
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

National Wind Technology Center Controllable Grid Interface



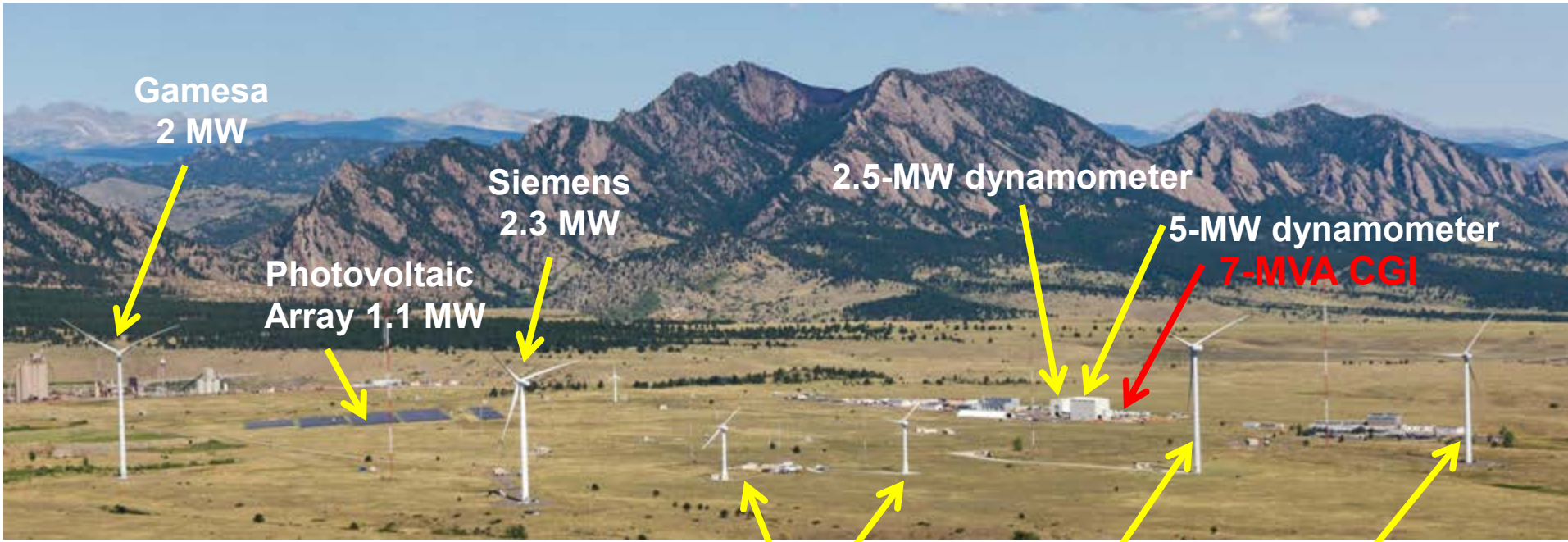
National Renewable Energy Laboratory

Vahan Gevorgian

March 6, 2013

NWTC Test Site

- Total of 11 MW of variable renewable generation currently at the National Wind Technology Center (NWTC) test site
- Many small wind turbines (less than 100 kW) installed as well
- 2.5-MW and 5-MW dynamometers
- 7-MVA controllable grid interface (CGI) for grid-compliance testing
- Multi-megawatt energy storage testing capability under development



Source: Dave Simms, NREL

CGI Facility Status

- Installed at NWTC test site in November 2012
- Commissioning and initial testing is scheduled from April to September 2013

Photo by Mark McDade, NREL

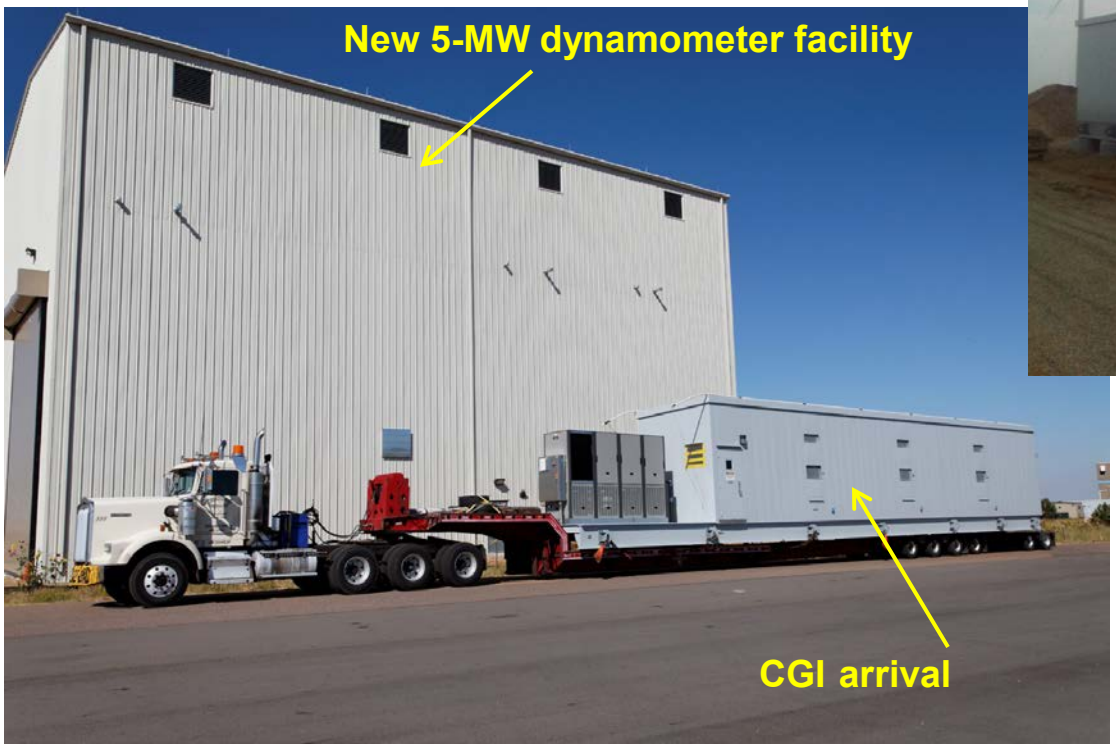


Photo by Mark McDade, NREL

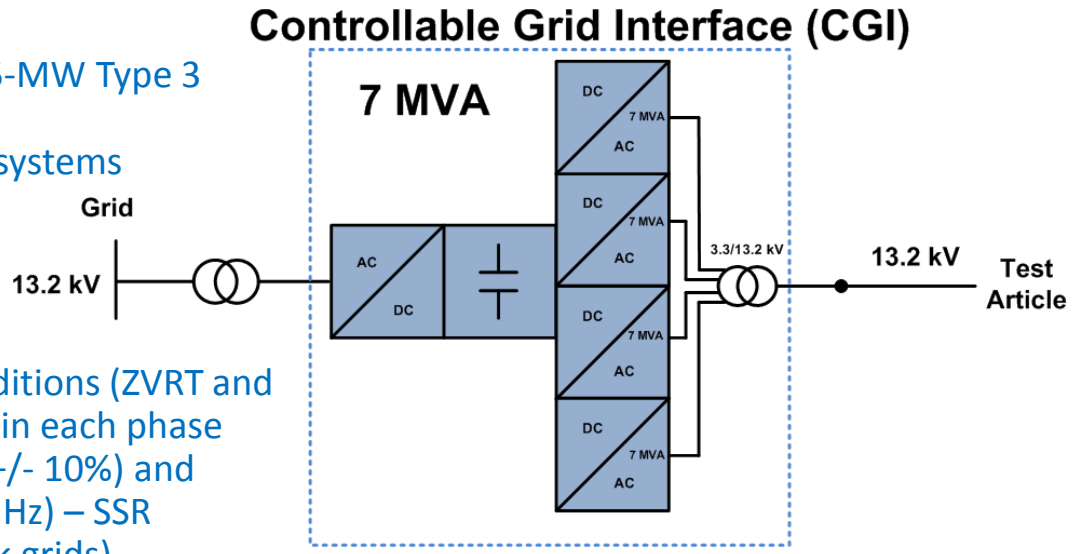
CGI Main Technical Characteristics

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

Possible test articles
- Types 1, 2, 3, and 4 wind turbines
- Capable of fault testing world's largest, 6.15-MW Type 3 wind turbine
- Photovoltaic (PV) inverters, energy storage systems
- Conventional generators
- Combinations of technologies

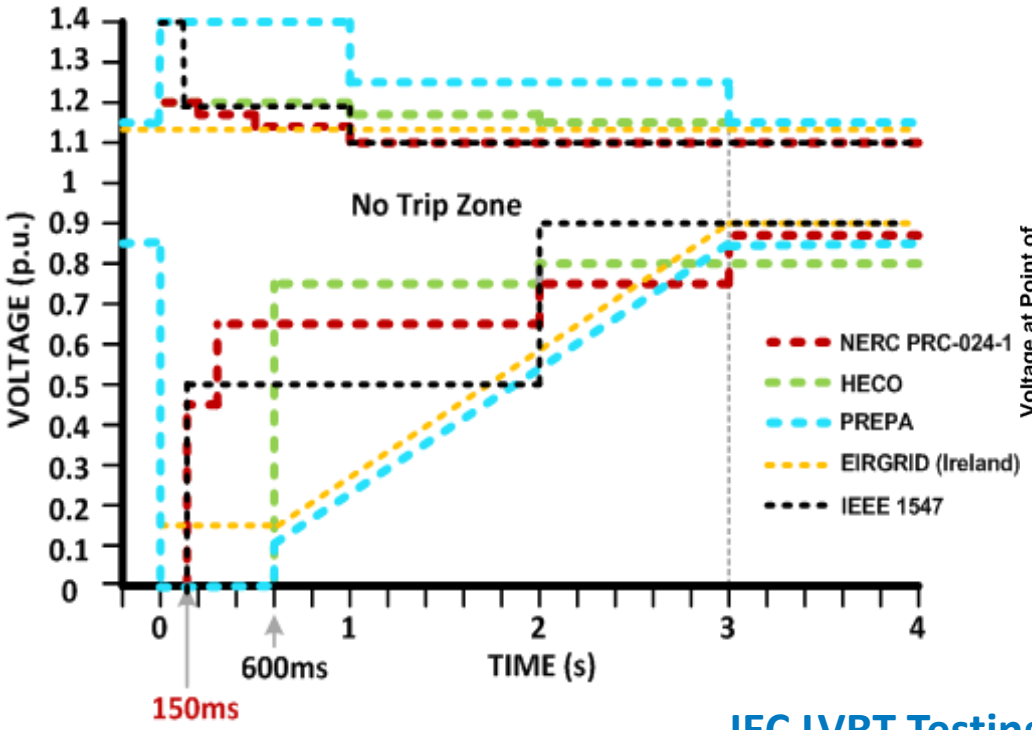
Voltage control (no load THD <5%)
- Balanced and unbalanced voltage fault conditions (ZVRT and 130% HVRT) – independent voltage control in each phase
- Long-term symmetrical voltage variations (+/- 10%) and voltage magnitude modulations (0 Hz to 10 Hz) – SSR
- Programmable impedance (strong and weak grids)
- Programmable distortions (lower harmonics 3, 5, 7)

Frequency control
- Fast output frequency control (+/- 3 Hz)
- 50-Hz/60-Hz operation
- Simulate frequency response of various power systems
- RTDS/HIL capable

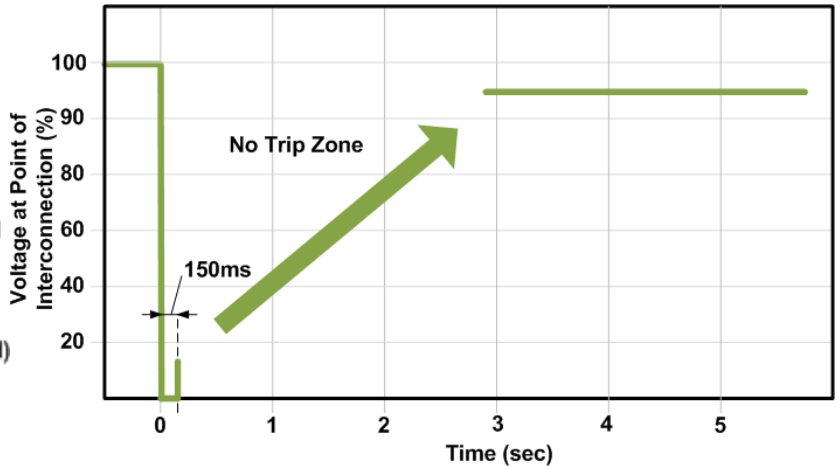


Power electronic grid simulator based on three-level VSC VFD technology (ABB ACS 6000 modules – same hardware used in NWTC 5-MW dynamometer)

Wind Turbine Voltage Fault Ride Through Testing Requirements



FERC LVRT requirements (order 661-A)



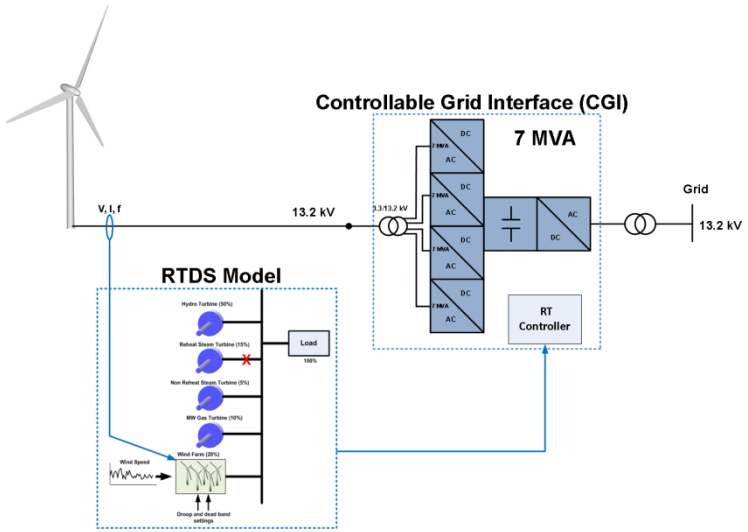
IEC LVRT Testing

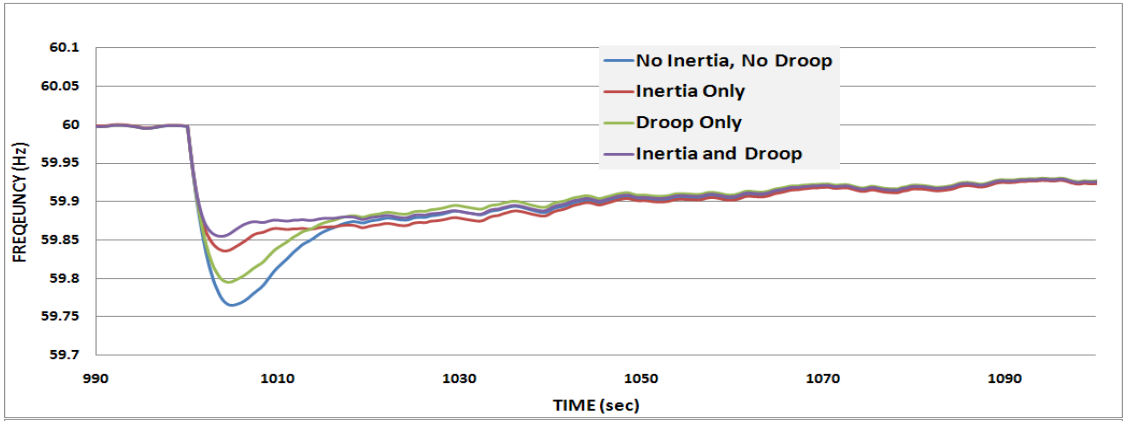
Fault Type	Voltage drop (fraction of nominal L-to-L voltage)	Fault Duration (ms)
Three-phase, balanced	0.9	500
Three-phase, balanced	0.5	500
Three-phase, balanced	0.2	200
Two Line-to-Line (L-L), unbalanced	0.9	500
Two Line-to-Line, unbalanced	0.5	500
Two Line-to-Line, unbalanced	0.2	200

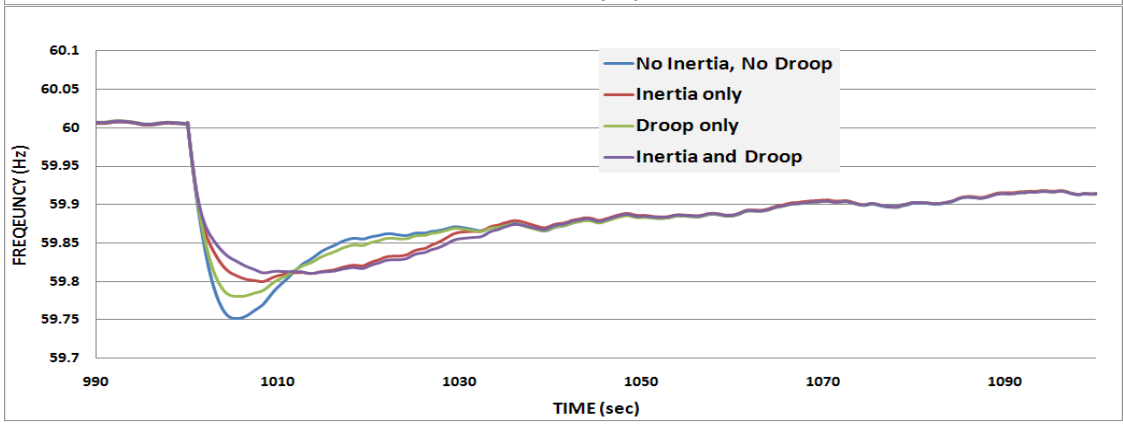
Testing Wind Power to Provide Frequency Response

CGI is a useful tool for testing wind, PV, and storage to provide inertial and primary frequency response

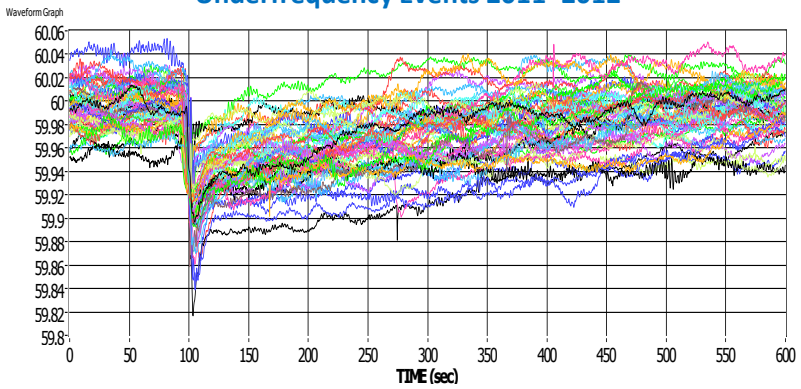
Example of Island Grid HIL Testing







Western Electricity Coordinating Council Underfrequency Events 2011–2012



NWTC Energy Storage Testing Facility

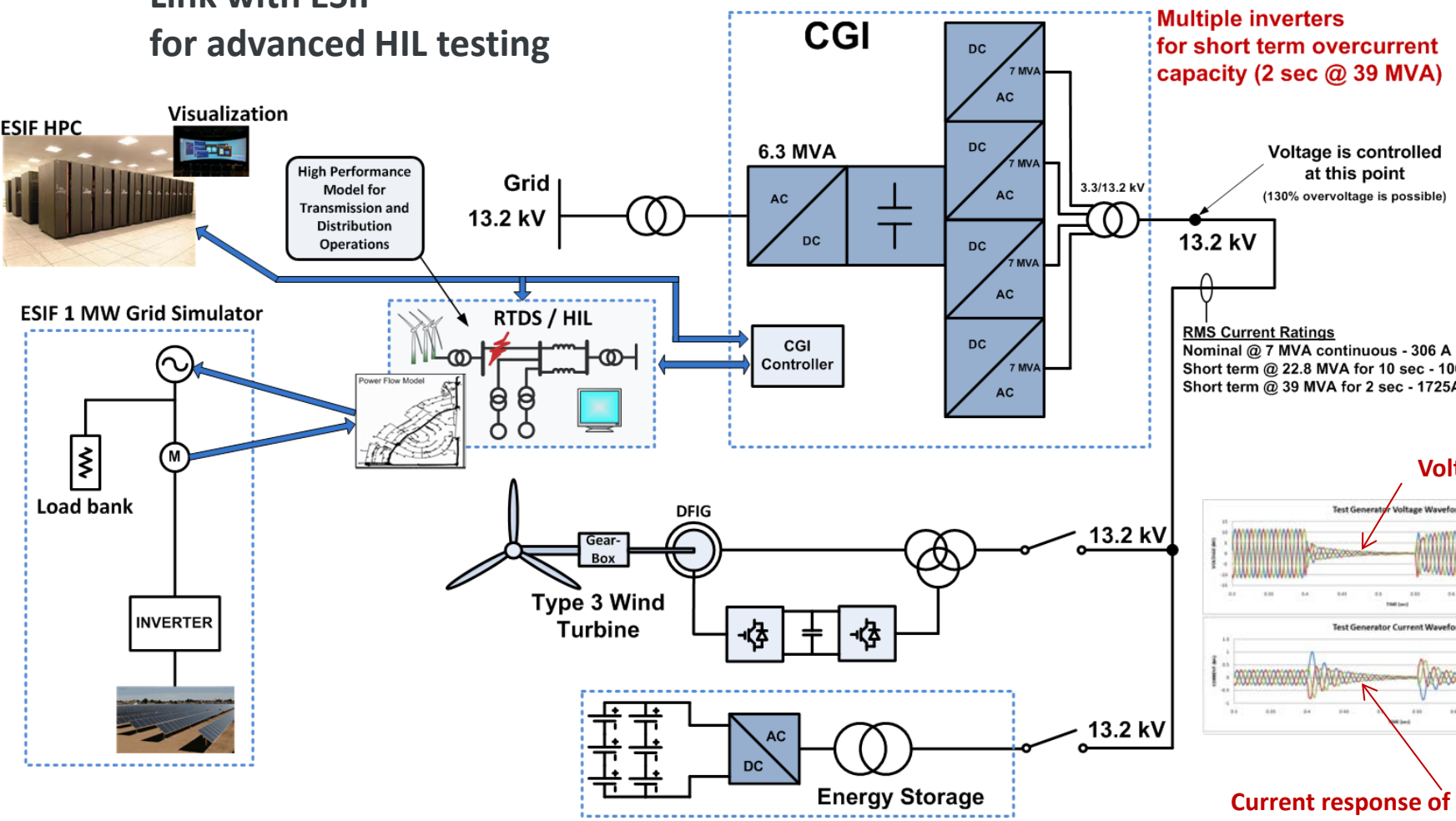
- Fully funded project. Scheduled for completion by October 1, 2013
- Will enable testing of wind, PV, and storage systems connected to XCEL grid or CGI

Source: Dave Simms, NREL

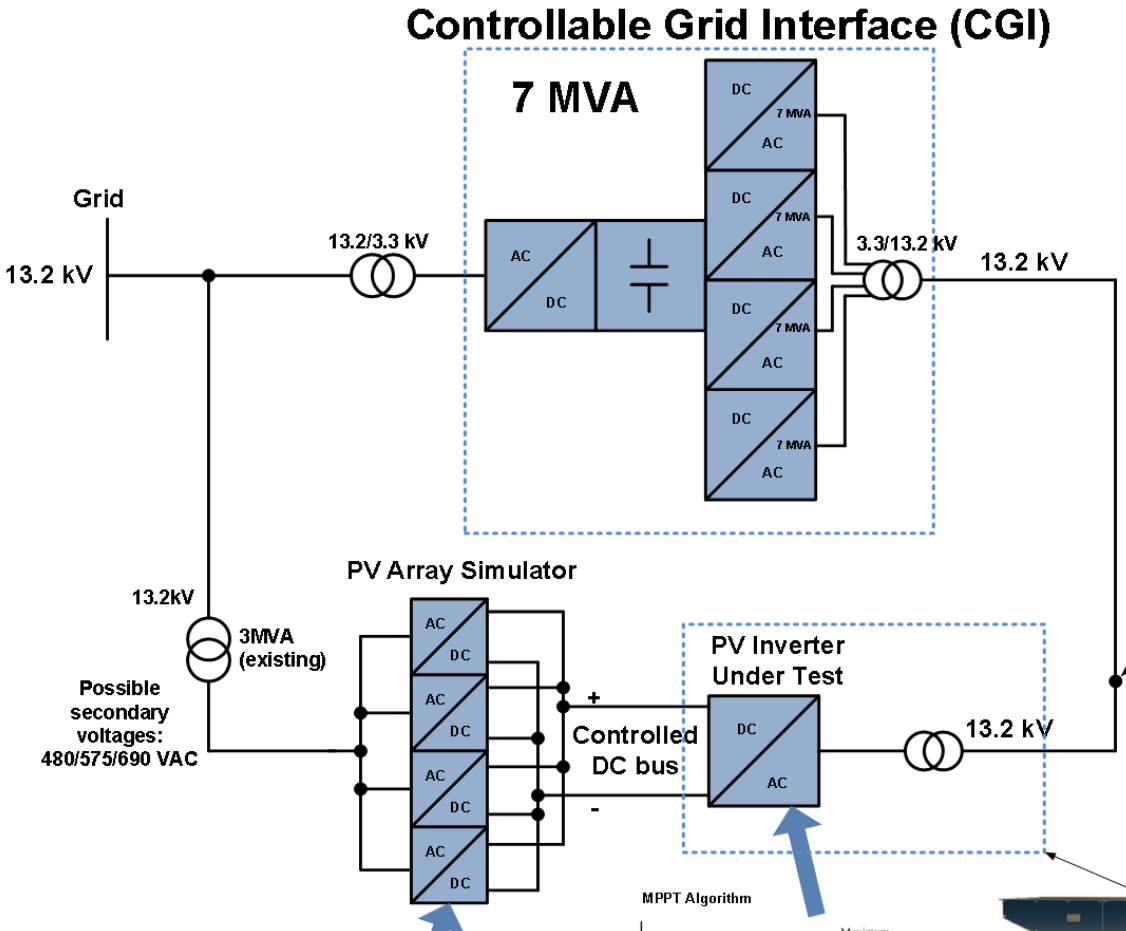
CGI for Wind Turbine, Energy Storage, and PV Inverter Testing

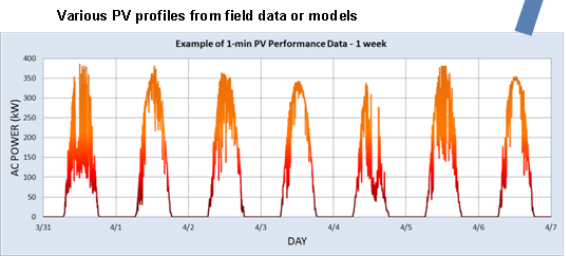
Large overcurrent capacity is needed for some wind turbine topologies and conventional generation LVRT testing

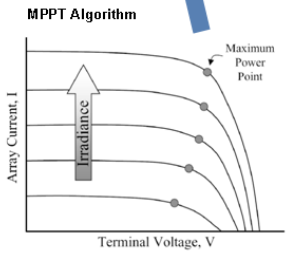
Link with ESIF
for advanced HIL testing

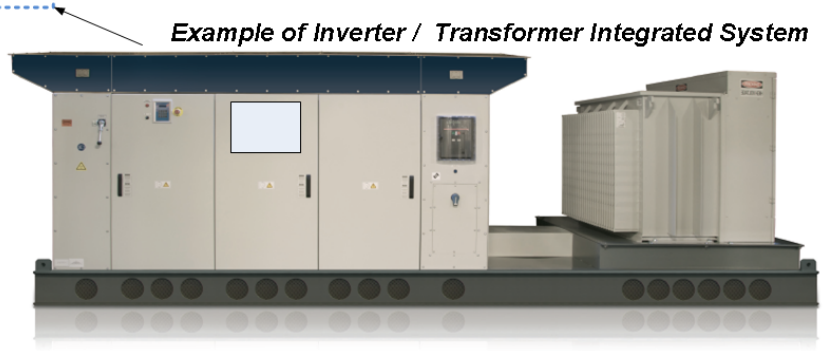


PV Inverter Testing Concept Using NWTC CGI







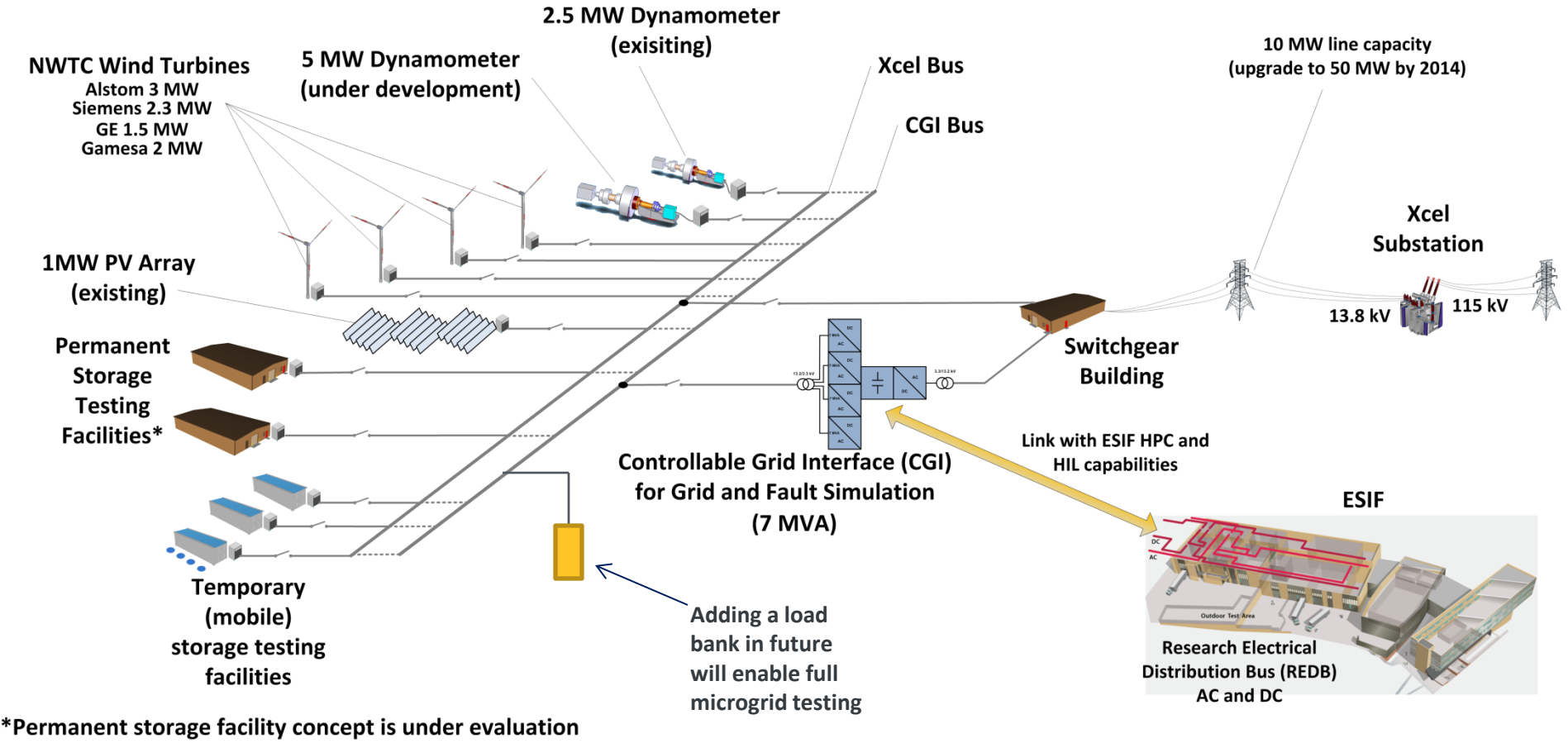


Possible tests

- MMPT algorithms
- 50-Hz/60-Hz operation
- Voltage fault tests
- Advanced testing
  - Operation with reserves
  - Frequency response
  - Voltage control
  - Testing with energy storage
    - Toshiba Super Charge Ion Battery

NWTC Two-Bus Test Site Concept

Most components are in place already. Switchgear upgrade is underway.



*Permanent storage facility concept is under evaluation