National Wind Technology Center
Controllable Grid Interface

Vahan Gevorgian

June 13, 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
2.5-MW Dynamometer Facility

Photo by
New 5-MW Dynamometer

Drive Motor

High-Speed Shaft

Gearbox

Non-Torque Loading System

Adaptor Flange

Low-Speed Shaft

Auxiliary Hydraulic Equipment

Test Article Bed Plates
CGI Facility Status

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

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 (LVRT, 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
- Real Time Digital Simulator/hardware-in-the-loop (HIL) capable

Power electronic grid simulator based on three-level VSC VFD technology (ABB ACS 6000 module – same hardware used in NWTC 5-MW dynamometer)
CGI Design Allows Testing for All Fault Ride-Through Requirements

IEC Low-Voltage Ride-Through Testing

<table>
<thead>
<tr>
<th>Fault Type</th>
<th>Voltage drop (fraction of nominal L-to-L voltage)</th>
<th>Fault Duration (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three-phase, balanced</td>
<td>0.9</td>
<td>500</td>
</tr>
<tr>
<td>Three-phase, balanced</td>
<td>0.5</td>
<td>500</td>
</tr>
<tr>
<td>Three-phase, balanced</td>
<td>0.2</td>
<td>200</td>
</tr>
<tr>
<td>Two Line-to-Line (L-L), unbalanced</td>
<td>0.9</td>
<td>500</td>
</tr>
<tr>
<td>Two Line-to-Line, unbalanced</td>
<td>0.5</td>
<td>500</td>
</tr>
<tr>
<td>Two Line-to-Line, unbalanced</td>
<td>0.2</td>
<td>200</td>
</tr>
</tbody>
</table>
Recreation of Frequency Events

Eastern Interconnection

Electric Reliability Council of Texas

Western Interconnection

Island System
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.
Large overcurrent capacity is needed for some wind turbine topologies and conventional generation low-voltage ride-through (LVRT) testing.

Multiple inverters for short term overcurrent capacity (2 sec @ 39 MVA)

Voltage is controlled at this point (130% overvoltage is possible)

RMS Current Ratings
Nominal @ 7 MVA continuous - 306 A
Short term @ 22.8 MVA for 10 sec - 1000A
Short term @ 39 MVA for 2 sec - 1725A

Voltage Dip

Current Response of Type 3 Wind Turbine

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

Link with Energy Systems Integration Facility (ESIF) for advanced HIL testing

ESIF HPC

Visualization

High Performance Model for Transmission and Distribution Operations

Grid 13.2 kV

RTDS / HIL

CGI Controller

Type 3 Wind Turbine

Energy Storage

CGI

6.3 MVA

DC

AC

7 MVA

DC

AC

7 MVA

DC

AC

3.3/13.2 kV

13.2 kV

Load bank

INVERTER

ESIF 1 MW Grid Simulator

Power Flow Model

CGI for Wind Turbine, Energy Storage, and PV Inverter Testing
Proposed Electrical and Facility Infrastructure for Grid Energy Storage (GES) Test Pads and Row 4 Turbine Interconnection to CGI

Notes:
- Graphical infrastructure depiction only, not to scale – locations shown are approximate; final siting should be based on cost/practical considerations
- GES test pads sized to house customer-supplied GES test articles (pictured) plus customer-supplied transformer and other equipment
- Translucent items depicted are optional depending on budget; plan and install as much as possible/practical anticipating future expansion
- The 5-MW Dyno, Control Room or the Site 3.1 Data Shed (partial N area) could serve as a client facility for GES test control/DAS/customer use
NWTC’s Unique Role in Energy Storage Testing

- CGI-connected tests for storage inverter LVRT testing, frequency response testing
- Utility connected tests in parallel with real megawatt-scale wind and PV resource variability
- Ideal conditions to test energy storage for frequency regulation and ramp limiting applications

NREL’s unique niche in energy storage testing area
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

Controllable Grid Interface (CGI)

Possible secondary voltages: 480/575/690 VAC

Example of Inverter/Transformer Integrated System

NATIONAL RENEWABLE ENERGY LABORATORY
Most components are already in place. Switchgear upgrade is underway.

*Permanent storage facility concept is under evaluation
NREL’s ESIF

- HIL 1-MW power electronic grid simulator
- High-performance computing data center
- Data analysis and visualization

Photo by NREL