Driving economic growth, innovation, and workforce development

Duke Energy eGRID

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Transforming the Electric Grid
Introduction
High-Speed Motor
3.4 MW Wind Turbine
5 MW Transformer
The eGRID Center Team Members

Meredyth Crichton  Executive Director of the Energy Innovation Center
Gokhan Ozkan, PhD  eGRID Research Faculty
Moazzam Nazir, PhD  eGRID Lab Leader
Russell M. Moore  Research Engineer
Jeremy Jones  Data Systems Engineer
Jonathan Dobson-Lewis  Data Systems Engineer
Travion Simmons  Data Systems Technician

Graduate Students:
3 PhD Students

Dominion Energy Innovation Center
Where We are in Technology Development Cycle

- **Design and Development**
  - Simulations
  - Functional Testing
  - Controls Algorithms

- **Independent Certifications**
  - Equipment Safety
  - Basic Functionality

- **Demonstration Projects**
  - Complete Systems
  - Controls Verification

- **Commercial Deployment**
  - Operations Training
  - Technician Training

- **Prototype Testing**
  - Standards Testing (UL, IEC, IEEE)

- **Hardware-in-the-Loop Testing**

- **Academics and Education**
Dominion Energy Innovation Center

Main Facility Electrical Bus (23.9 kV)

15 MW Test Bench

Harmonic Filter

15 MW HIL Grid Simulator

Building Power

Hydraulic System

7.5 MW Test Bench

M1

M2

LAU

Full Nacelle Under Test

Harmonic Filter

Variable 23.9 kV (50/60 Hz)

15 MW Test Bench Recirculation Bus

Simulated Grid Experimental Bus

7.5 MW Test Bench Recirculation Bus
### The 20 MVA HIL Grid Simulator

#### Three Independent Test Bays

<table>
<thead>
<tr>
<th>Overall Electrical Capabilities</th>
<th>Main Test Bay</th>
<th>Small Test Bay 1</th>
<th>Small Test Bay 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Voltage</td>
<td>24 kV (50/60 Hz)</td>
<td>4160 V (50/60 Hz)</td>
<td>4160 V (50/60 Hz)</td>
</tr>
<tr>
<td>Nominal Power</td>
<td>20 MVA</td>
<td>5 MVA (4 MW @ 0.8 PF)</td>
<td>5 MVA (4 MW @ 0.8 PF)</td>
</tr>
<tr>
<td>Frequency Range</td>
<td>45 to 65 Hz</td>
<td>0 to 800 Hz</td>
<td>0 to 800 Hz</td>
</tr>
<tr>
<td>Sequence Capabilities</td>
<td>3 and 4 wire operation</td>
<td>3 and 4 wire operation</td>
<td>3 and 4 wire operation</td>
</tr>
<tr>
<td>Overvoltage capabilities</td>
<td>133% Continuous Overvoltage</td>
<td>133% Continuous Overvoltage</td>
<td>133% Continuous Overvoltage</td>
</tr>
<tr>
<td>Fault Simulation</td>
<td>Yes (includes Reactive Divider)</td>
<td>Limited to Converter Only</td>
<td>Limited to Converter Only</td>
</tr>
<tr>
<td>Hardware In the Loop</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

#### Diagram

- **Utility Side Step-Down Transformers**
- **Simulated Grid Side Step-Up Transformers**
- **Reactive Divider Network Room (Fault Ride-Through Testing)**
- **Simulated Grid Experimental Bus**

**Key Points**
- **TWMC Power Main Test Bay**
  - Nominal Voltage: 24 kV (50/60 Hz)
  - Nominal Power: 20 MVA
  - Frequency Range: 45 to 65 Hz
  - Sequence Capabilities: 3 and 4 wire operation
  - Overvoltage capabilities: 133% Continuous Overvoltage
  - Fault Simulation: Yes (includes Reactive Divider)
  - Hardware In the Loop: Yes

- **Small Test Bay 1**
  - Nominal Voltage: 4160 V (50/60 Hz)
  - Nominal Power: 5 MVA (4 MW @ 0.8 PF)
  - Frequency Range: 0 to 800 Hz
  - Sequence Capabilities: 3 and 4 wire operation
  - Overvoltage capabilities: 133% Continuous Overvoltage
  - Fault Simulation: Limited to Converter Only
  - Hardware In the Loop: Yes

- **Small Test Bay 2**
  - Nominal Voltage: 4160 V (50/60 Hz)
  - Nominal Power: 5 MVA (4 MW @ 0.8 PF)
  - Frequency Range: 0 to 800 Hz
  - Sequence Capabilities: 3 and 4 wire operation
  - Overvoltage capabilities: 133% Continuous Overvoltage
  - Fault Simulation: Limited to Converter Only
  - Hardware In the Loop: Yes
The 20 MVA Power Amplifier Units

4 Power Amplifier Units (PAUs)

8 Slices Per PAU

3 Cubes Per Slice
2.5 MW Controlled DC Supply

- Modify a single PAU cabinet set to create a DC supply without changes to the control scheme
- Aimed at solar testing with Maximum Power Point Tracking and 2D PV field simulation
- Limited bi-directional power flow (dynamic braking resistors) allows for tight regulation

### DC Supply Module Specifications

<table>
<thead>
<tr>
<th></th>
<th>1 Module</th>
<th>6 Modules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage Range</td>
<td>200 – 1000 V</td>
<td>200 – 1000 V</td>
</tr>
<tr>
<td>Current Rating</td>
<td>420 A (1000 V)</td>
<td>2500 A (1000 V)</td>
</tr>
<tr>
<td>Short Circuit Current</td>
<td>835 A</td>
<td>5000 A</td>
</tr>
<tr>
<td>Ripple Frequency</td>
<td>2400 – 4800 Hz</td>
<td>2400 – 4800 Hz</td>
</tr>
<tr>
<td>Reverse Power Flow</td>
<td>67 kW (1000 V)</td>
<td>400 kW (1000 V)</td>
</tr>
</tbody>
</table>
Controller Design Validation with Controller Hardware-In-the-Loop Experiments

- Controller Hardware-In-the-Loop (CHIL) experiments are designed to evaluate the controllability and stability of performing fault ride-through evaluations with the Hybrid Method.
- The RTDS system simulates the Grid Simulator physical system model and the DUT models.
- A scale version of the Interface Controller is used to validate the control algorithms.

![Block Diagram of the CHIL experiments for the Hybrid Method](image-url)

[Image of National Instruments Interface Controller]

[Image of Real-Time Power System Simulator RTDS®]

[Image of Digital Real-Time Simulator SpeedGoat®]
High Speed Dynamometer

» Dyno testbed developed as part of DOE AMO Next Generation Electric Machines program

» Partner: TECO Westinghouse Motor Company (TWMC) designed HS motor and SiC drive
3.4 MW Wind Turbine

» Zero voltage ride through testing for type 3 wind turbine

Zero Voltage Ride Through for 1 sec (point 1)
3.4 MW Wind Turbine

- IEEE 2800-2022 Consecutive voltage deviations ride-through capability
- 4x0.8 seconds and 2x1.6 seconds with 70pu voltage ride-through
5 MVA Transformer test IEEE 1547
Low voltage ride through, voltage regulation, power quality
eGRID Founding Partners

Large Solar PV Converters

Micro-Grid Applications

EV Charging Stations

Utility Scale Energy Storage

Wind Energy

Traditional Distributed Generation (Diesel, NG, etc.)

Smart Grid Technologies

Aerospace

eGRID Market Applications
Thank You