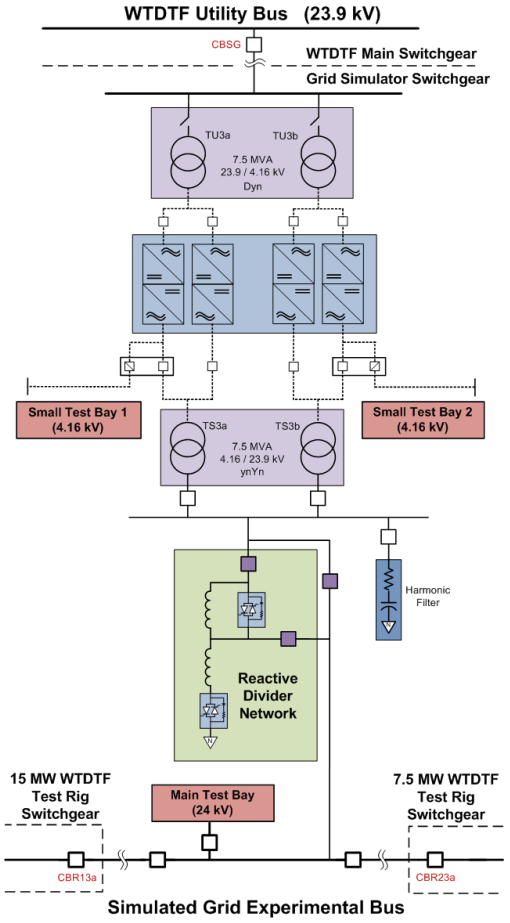
15 MW Hardware-In-the-Loop Grid Simulator Facility

CLEMSON UNIVERSITY

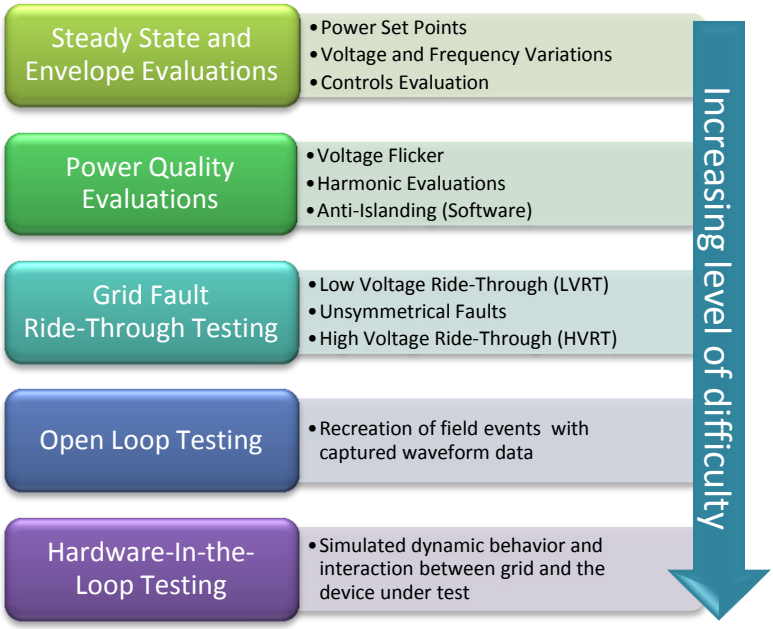
www.ClemsonEnergy.com

Main Test Bay	
Nominal Voltage	24 kV (50/60 Hz)
Nominal Power	15 MVA (20 MVA Installed)
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 (limit 1 HIL total)
Small Test Bay 1	
Nominal Voltage	4160 V (50/60 Hz)
Nominal Power	3.75 MVA (3 MW @ 0.8 PF)
Frequency Range	45 to 65 Hz
Sequence Capabilities	3 and 4 wire operation
Overvoltage capabilities	133% Continuous Overvoltage
Fault Simulation	Limited to Converter Only
Hardware-In-the-Loop	Yes (limit 1 HIL total)
Small Test Bay 2	
Nominal Voltage	4160 V (50/60 Hz)
Nominal Power	3.75 MVA (3 MW @ 0.8 PF)
Frequency Range	45 to 65 Hz
Sequence Capabilities	3 and 4 wire operation
Overvoltage capabilities	133% Continuous Overvoltage
Fault Simulation	Limited to Converter Only
Hardware-In-the-Loop	Yes (limit 1 HIL total)

Facility Single Line Diagram



Electrical and Grid Integration Evaluations



Project Partners

Duke Energy

Santee Cooper

SCANA

TECO-Westinghouse Motor Company

Savannah River National Laboratory

Underwriters Laboratory

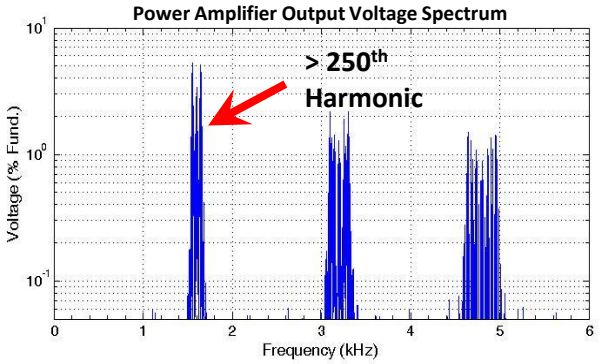
US DOE EERE

AEC/Idom Engineering

Hi Line Engineering (a GDS Company)

Choate Construction

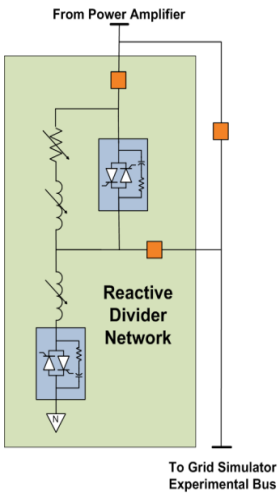
TECO-Westinghouse Motor Company 20 MVA Power Amplifier



- Modular design that is easily reconfigurable for various voltage and power levels
- Installed amplifier power of 20 MVA in four sections of 5 MVA each with a nominal voltage of 4160 V
- Output voltage range from 480 V to 13,800 V (manual reconfiguration required)
- The multi-level architecture and PWM strategy greatly reduces the harmonic noise in the output voltage created by the amplifier
- Custom communication allows for reference voltage sampling at rates up to 12 kHz

The Reactive Divider Network

- Electrically isolated for 100 MVA
- Thermally designed for over 35 MVA for a 3 second duration with a 10 minute duty cycle between faults
- Combines fixed and tapped air core reactors to provide thousands of possible fault combinations
- Precise timing through the use of semiconductor based switches
- More robust representation of fault events than using the power amplifier alone

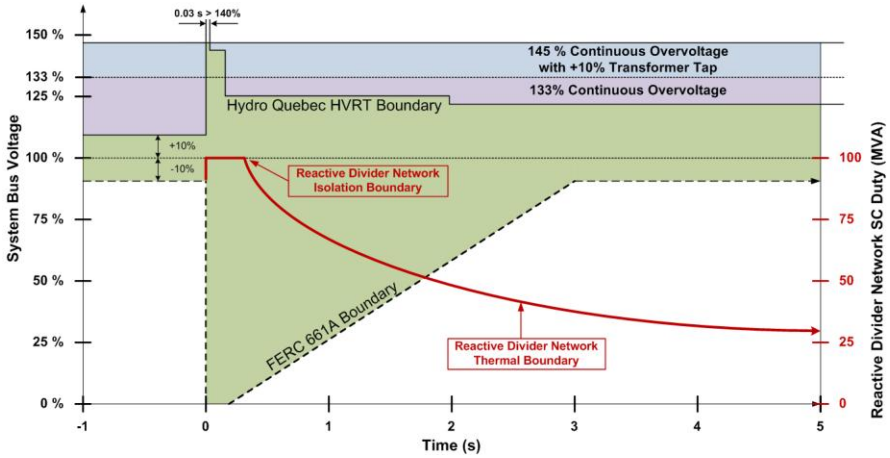


Real Time Digital Simulator (RTDS®)

An expandable parallel computer that solves electromagnetic transients associated with power system models in real-time and an extensive software library of components and controls.

Targeting 3 racks for a total of 144 three phase system buses.

Low and High Voltage Ride-Through Capabilities



- Power amplifier has 133% built-in continuous over-voltage without modulation index saturation
- 145 % over-voltage possible with +/- 10 % output transformer taps
- Coupling of LVRT and HVRT allows for the emulation of more realistic events (i.e. Fault Induced Delayed Voltage Recovery)

Interface Control and Data Acquisition System

- National Instruments PXIe based real-time systems with onboard FPGAs computational capabilities
- Uses high speed, low latency GE Reflective Memory for remote I/O
- Custom high speed serial fiber optic communication between the interface control and the power amplifier
- Locally wired connections to the RTDS® system for Hardware-In-the-Loop applications