Grid Simulator for Testing MW-scale Wind Turbines at NREL

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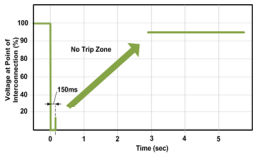
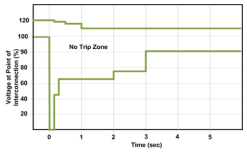
Introduction

In order to understand the behavior of wind turbines experiencing grid disturbances, it is necessary to perform a series of tests and accurate transient simulation studies. The latest edition of the IEC 61400-21 standard describes methods for such tests that include low voltage ride-through (LVRT), active power set-point control, ramp rate limitations, and reactive power capability tests. The IEC methods are being widely adopted on both national and international levels by wind turbine manufacturers, certification authorities, and utilities. On-site testing of wind turbines might be expensive and time consuming since it requires both test equipment transportation and personnel presence in sometimes remote locations for significant periods of time because such tests need to be conducted at certain wind speed and grid conditions. Changes in turbine control software or design modifications may require redoing of all tests. Significant cost and test-time reduction can be achieved if these tests are conducted in controlled laboratory environments that replicate grid disturbances and simulation of wind turbine interactions with power systems. Such testing capability does not exist in the United States today. An initiative by NREL to design and construct a 9-MVA grid simulator to operate with the existing 2.5 MW and new upcoming 5-MW dynamometer facilities will fulfill this role and bring many potential benefits to the U.S. wind industry with the ultimate goal of reducing wind energy integration costs.

FERC–LVRT Requirement



NERC–PRC-024 LVRT/HVRT Requirement

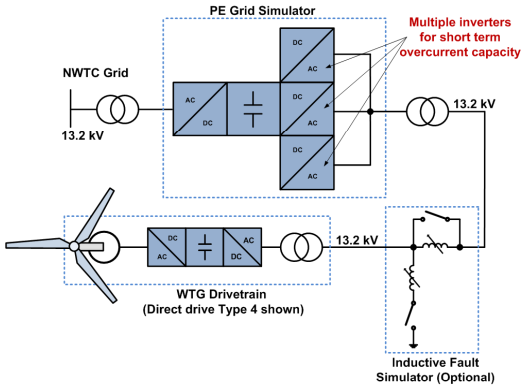


IEC–LVRT Test Requirement for Wind Turbines

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

9-MVA Grid Simulator Configuration

The proposed grid simulator is a combination of hardware and real-time control software for simulating grid disturbances on wind turbine terminals and estimating impacts of turbine response on the grid. Also, the performance of wind turbine drivetrain components (both mechanical and electric) can be tested and quantified under such conditions.



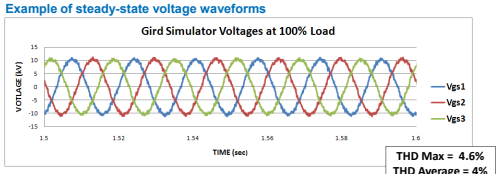
Why power electronics solution?

Power electronics vs. rotating grid simulator comparison

	PE converter	VFD/ Generator
Frequency variations	●●	●●
Simulate waveform distortions	●●	●●
Fast response	●●	●●
Strong and weak grids	●●	●●
Complexity of control	●●	●●
Immunity to short-term over-voltage, over-current	●●	●●
Filtering requirements	●●	●●
Mechanical stress on components	●●	●●
Cost	●●	●●

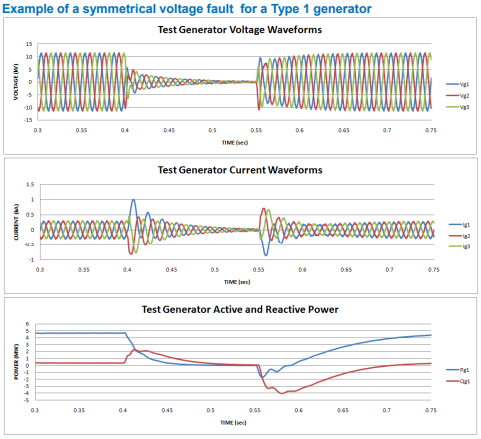
Simulation Results

Example of steady-state voltage waveforms



THD Max = 4.6%
THD Average = 4%
THD Min = 3.7%

Example of a symmetrical voltage fault for a Type 1 generator



Main Specifications

Output loads:

- Type 1 wind turbines
- Type 2 wind turbines
- Type 3 wind turbines
- Type 4 wind turbines
- PV inverters
- Energy storage inverters

Power rating:

Line side - 9 MVA (with 125% overload capacity)

Generator side – 27 MVA (with 125% overload capacity)

Other specifications:

Output Frequency: 50/60 Hz (±3 Hz)

Programmable impedance

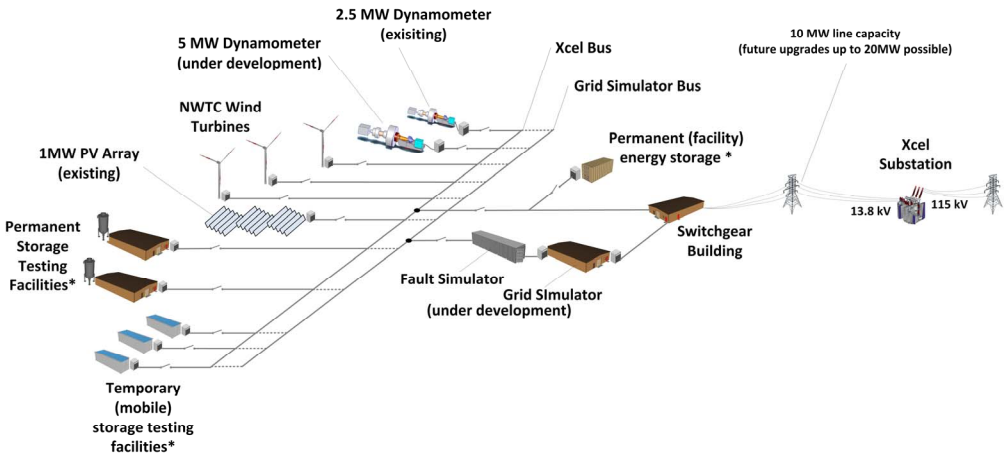
Symmetrical voltage variations (±10%)

IEC–LVRT tests, NERC–LVRT/HVRT tests

Voltage magnitude modulations: 0-10 Hz

NWTC's New Test Grid Concept

The NWTC Grid and Fault Simulator as a New Unique Testing Capability



*Storage testing concept is being evaluated

NWTC Grid and Fault Simulator will allow testing of many grid integration aspects for multi-MW utility-scale variable renewable generation (wind and solar) and storage technologies.

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