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# 225-kW Dynamometer for Testing Small Wind Turbine Components

## Preprint

J. Green

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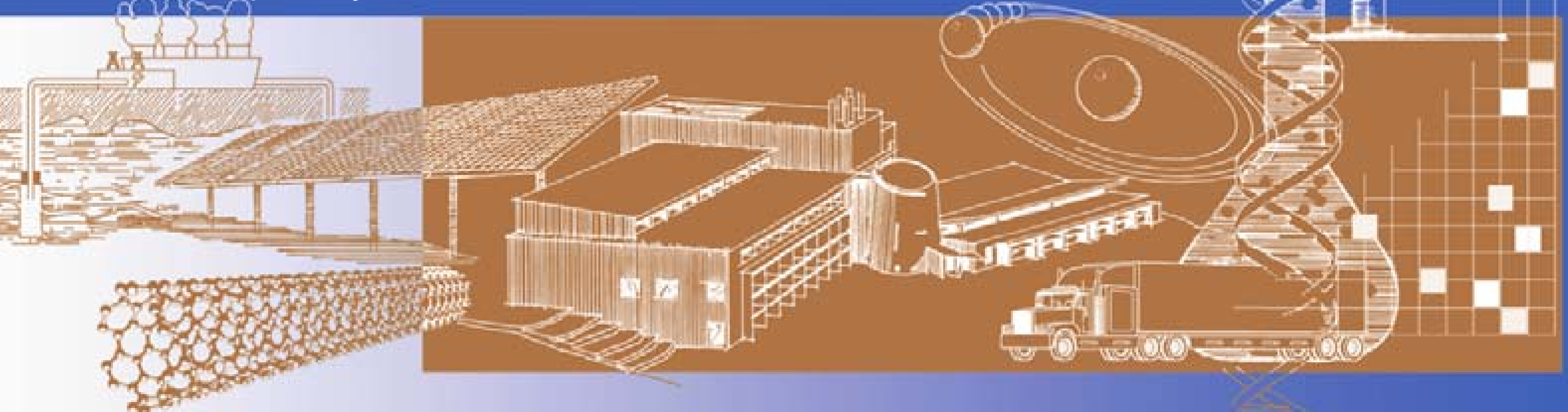

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# 225-kW Dynamometer for Testing Small Wind Turbine Components

Jim Green
National Wind Technology Center
National Renewable Energy Laboratory
Golden, Colorado

## Abstract
A 225-kW dynamometer has been commissioned at the National Renewable Energy Laboratory's (NREL's) National Wind Technology Center (NWTC) near Boulder, Colorado. Because both cost and reliability of small wind turbines continue to be barriers in the marketplace, new turbine designs are needed for low-wind-speed sites that will require development of advanced generators and power electronics. These developments can be facilitated and enhanced with this new dynamometer facility.

NREL's 225-kW dynamometer is suitable for testing a variety of components and subsystems, including generators, gearboxes, mechanical or electro-dynamic brakes, power electronics, control systems, and software. Test objectives might include performance, system integration (generator, power electronics, and grid), software development, or accelerated life testing. The facility is capable of 225-kW peak power and shaft speeds up to 4,140 revolutions per minute (rpm). Gear ratios as high as 41:1 can deliver maximum shaft torque of 51,000 Newton meters (Nm) or 38,000 foot-pounds (ft-lb). NREL is actively seeking industry partners to utilize this facility and advance the technology for small, distributed wind turbines.

This paper will provide an overview of the dynamometer layout and capabilities, including photographs, schematics, the torque vs. speed operating envelope, a description of control functionality, and an overview of data acquisition capabilities. Opportunities for industry partnership with NREL for use of the facility are also presented.

## Introduction
The U.S. Department of Energy's (DOE's) Wind Technology Program is committed to the goal of developing cost-effective distributed wind systems for lower wind speed, Class 3, wind regimes. Improved technology will be needed to effectively serve a growing market for grid-connected wind power for residences, farms, and small businesses. *The U.S. Small Wind Turbine Industry Roadmap* from the American Wind Energy Association (AWEA) identifies the high cost and low reliability of small wind turbines as barriers in the current market place (AWEA, 2002). The action items identified include new turbine designs for low-wind-speed sites and development of advanced generators and power electronics.

With these technology development needs in view, the National Renewable Energy Laboratory's (NREL's) National Wind Technology Center (NWTC) near Boulder, Colorado, has developed a new 225-kW dynamometer. Upgraded from a former 75-kW facility during 2005, the dynamometer is now available for use.

## Test Capabilities

The 225-kW dynamometer can be used in a wide range of technology testing and development activities focusing on drive train components, power electronics, and controls used in small wind turbines. These include:

Generator/Alternator Testing

- Efficiency
- Cogging torque
- Equivalent circuit parameters
- Thermal characteristics
- Vibration
- Defect testing (infant mortality)
- Insulation life testing

Gearbox Testing

- Efficiency
- Thermal characteristics
- Lubrication flow
- Tooth contact patterns
- Vibration
- Endurance or fatigue

Power Electronics Testing

- Efficiency
- Thermal characteristics
- Control and stability
- Power quality
- Defect testing (infant mortality)
- Control systems and software testing
- System integration (generator/power electronics/grid)
- Software development and testing

## Operating Envelope

The NWTC 225-kW dynamometer will be suitable for testing small wind turbine components from the smallest turbines up to turbines with nearly 200-kW ratings. Some headroom between the component rating and the dynamometer rating is typically needed to adequately cover over-speed and over-torque conditions that turbine components encounter in real applications. Maximum available shaft speed is 4,140 revolutions per minute (rpm) and the maximum available shaft torque is 37,000 foot-pounds (ft-lb) or 51,000 Newton meters (Nm). Losses in bearings and gearboxes will somewhat reduce the available torque delivered to components under test. The operating envelope for this facility is shown in Figure 1. For comparison, this figure also shows the range of expected values of power vs. rpm for typical small wind turbines.

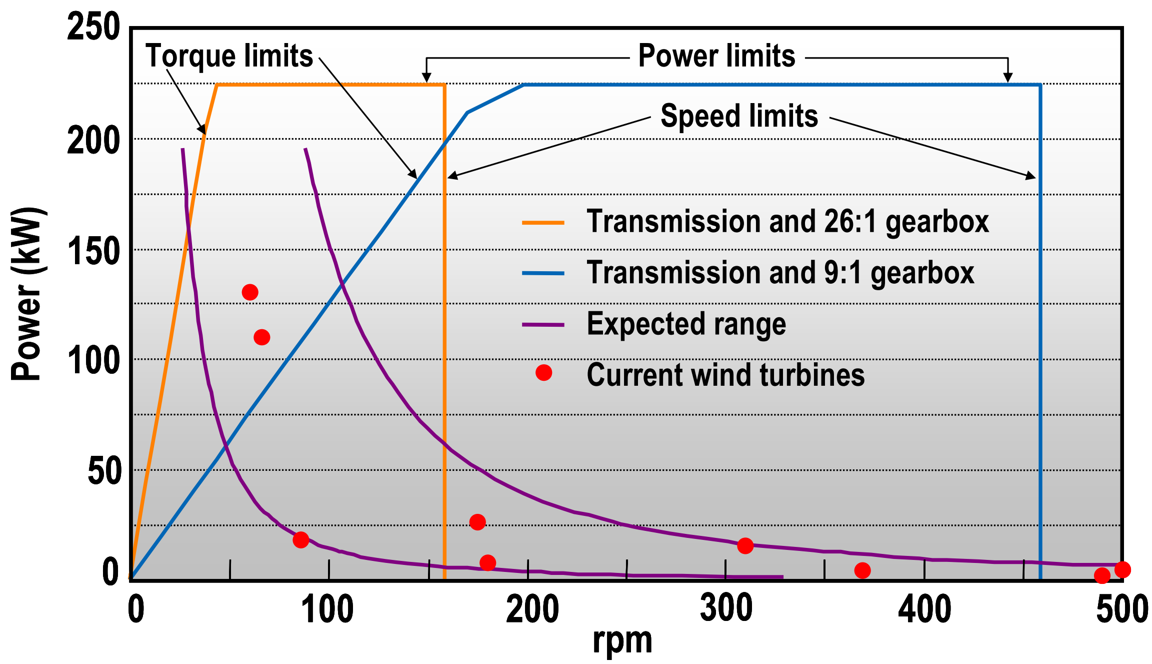


Figure 1. NWTC 225-kW Dynamometer
(Operating Envelope 0-500 rpm)

## Electric Loads

Three types of electric loads are available for units under test on the dynamometer. The first is single-phase service at 120/240 volts alternating current (VAC), 60 Hertz (Hz), with up to 50 kilovolt-ampere (kVA) capacity. This load simulates the typical 100- or 200-ampere (A) utility service available to most homes, small farms, and small businesses. The second load is three-phase service at 480 VAC, 60 Hz, with up to 250 kVA capacity. This simulates utility service for farms and businesses that have larger power requirements, up to 250 kW. Other service voltages as well as 50 Hz operation are possible but will require enhancements to the facility. For testing off-grid systems designed to charge batteries, the dynamometer includes battery bank simulation via a voltage-controlled direct current (DC) bus with capacity up to 20 kVA and voltages up to 216 volts DC.

## Dyno Components

The drive system for the dynamometer consists of a drive motor coupled to one or more speed-reducing gear boxes selected to deliver the requisite torque and shaft speed for a given test program. These components are installed on concrete and steel pedestals with a drive shaft extending over a rigid steel table as shown in the example configuration in Figure 2. This table is on jack screws such that its height can be changed to allow alignment of various test article input shafts with the dynamometer drive shaft. At its lowest available height, the table is about 5 ft or 1.5 meters (m) below the dynamometer drive shaft, providing room for installation of test articles with diameters up to about 8-10 ft (2.4-3.0 m).

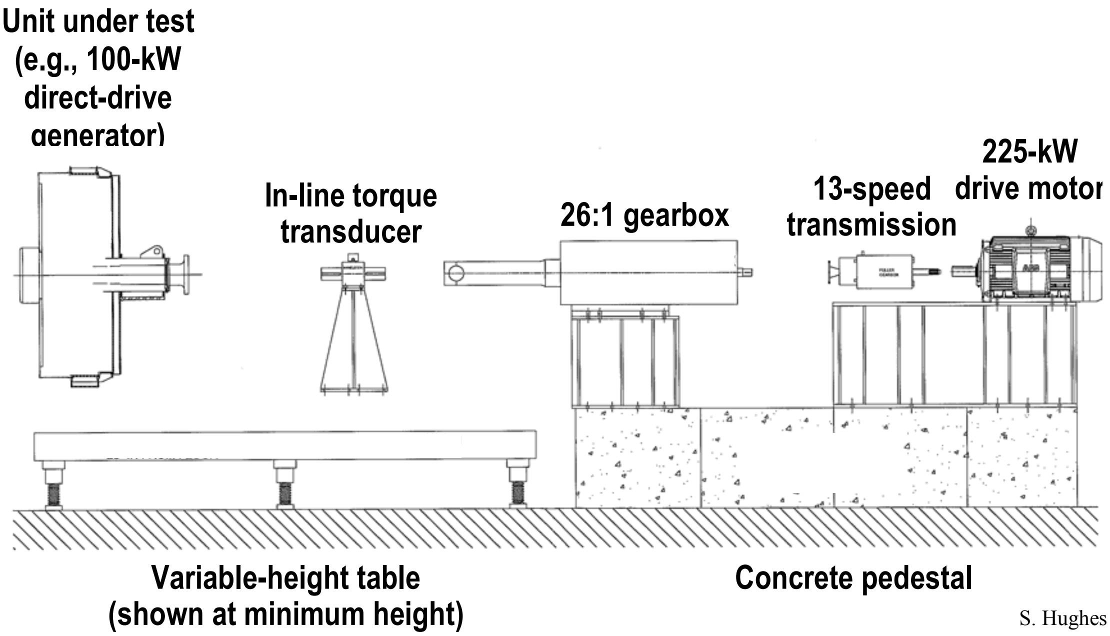


Figure 2. NWTC 225-kW Dynamometer configuration concept for a 100-kW direct-drive generator.

The dynamometer drive motor is a 225-kW (300-horsepower [hp]) rated, variable-speed, induction motor. It was obtained from ABB with a matched variable-speed drive and harmonic filter. The motor reaches rated power at 1,800 rpm and has a top speed of 3,600 rpm. The motor installation is shown in Figure 3.

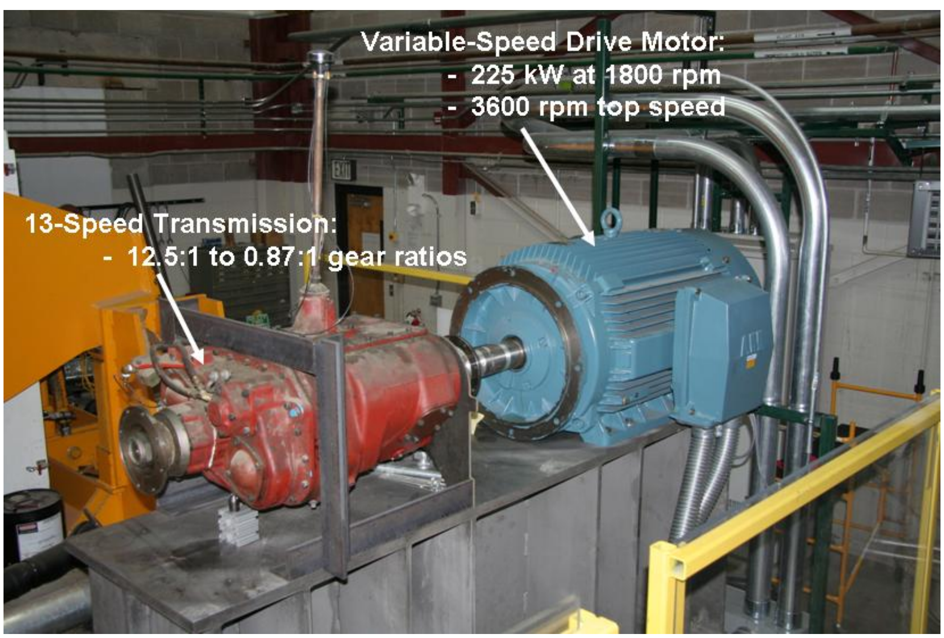


Figure 3. Dynamometer drive motor and 13-speed transmission.

Three speed-reducing gearboxes are available for the dynamometer. The first, coupled to the drive motor, is a 13-speed transmission with gear ratios ranging from 12.5:1 up to an overdrive gear at 0.87:1. It is anticipated that this transmission will be used for all dynamometer operations. This transmission will be coupled directly to the unit under test or to one of two fixed speed gear boxes to reduce shaft speed and increase torque. These gear boxes have ratios of 9:1 and 26:1. Gearbox specifications are shown in Table 1.

Table 1. NWTC 225-kW Dynamometer Gearbox Specifications

| **Device** | **Brand** | **Gear Ratios** | **Torque Limit** |
|---|---|---|---|
| Transmission | Fuller | 13 ratios<br>12.5:1-0.87:1 | 1,250 ft-lb<br>1,700 Nm |
| Fixed-Ratio Gearbox | Byrne | 9:1 | 8,750 ft-lb<br>(11,900 Nm) |
| Fixed-Ratio Gearbox | Flender | 26:1 | 37,600 ft-lb<br>(51,000 Nm) |

## Control/Data Acquisition Capability

Control and data acquisition for the dynamometer will be done using personal computers (PCs) connected to National Instruments hardware for signal input and output. The concept for system control and data acquisition is shown in Figure 4. Operation will be either manual or automated at the discretion of the operators. Either speed and/or torque control of the dynamometer drive motor are available in either closed- or open-loop modes. Operating modes will include ramps and steady state, simulated wind inputs, and programmable cycles. The control PC will also be used to monitor operating temperatures and alarm conditions.

A second computer will be used to record data independent of the dynamometer control function. Measurement parameters will be selected to meet the objectives of each test. The most commonly measured parameters are likely to be:

- Shaft rpm and torque
- Power, voltage, and current from generator to inverter
- Power, voltage, and current from inverter to grid.

The dynamometer facility is equipped with four shaft-mounted torque transducers that range in capacity from 83-16,700 ft-lb (112-22,600 Nm). Their accuracies are between 0.1 and 0.5%. The NWTC also has a portable data system for recording power quality in compliance with the International Electrotechnical Commission (IEC) standard for measuring the power quality of wind turbines (IEC 2001).

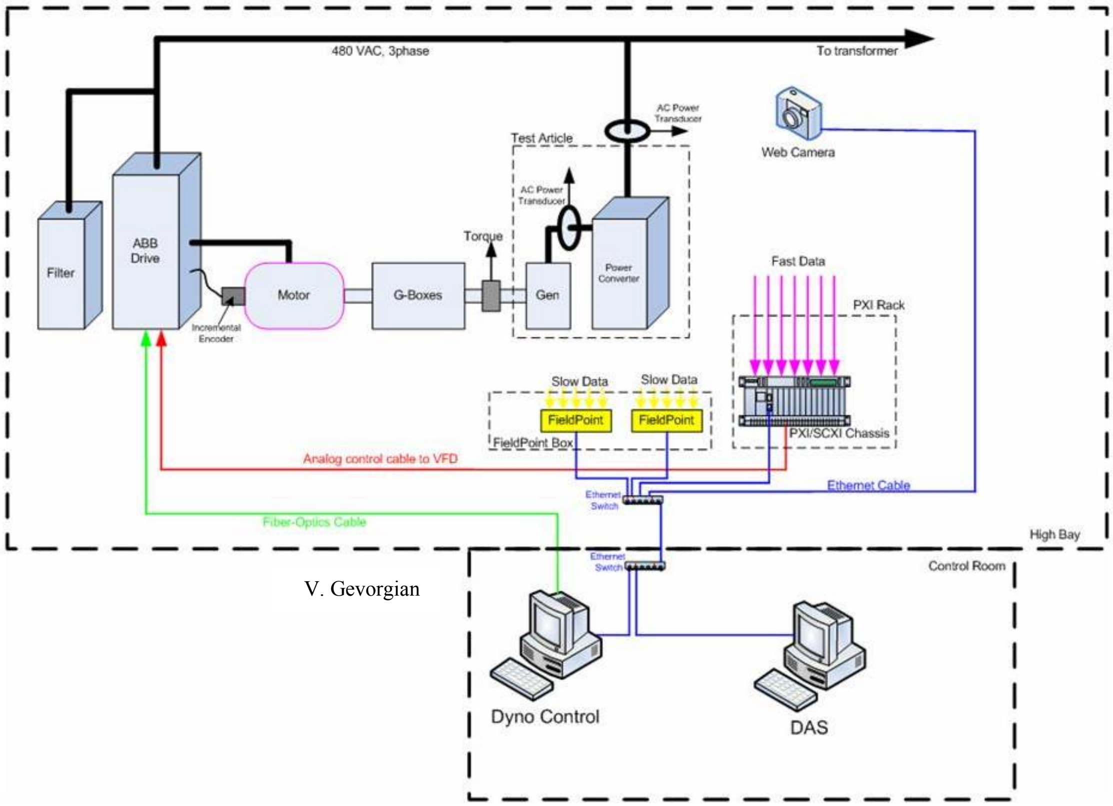


Figure 4. NWTC 225 kW Dynamometer
control and data acquisition concept

## Partnerships with NREL

The NWTC is seeking opportunities to collaborate with industry partners in the use of the 225-kW dynamometer for small wind turbine technology development. For more information, refer to the NREL Technology Transfer Web page: http://www.nrel.gov/technologytransfer/partnering.html#crada, or contact the author:

Jim Green
National Wind Technology Center
National Renewable Energy Laboratory
1617 Cole Blvd., MS 3811
Golden, CO 80401

jim_green@nrel.gov
303-384-6913

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This paper describes NREL's new 225-kW dynamometer facility that is suitable for testing a variety of components and subsystems for small wind turbines and discusses opportunities for industry partnerships with NREL for use of the facility.

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