



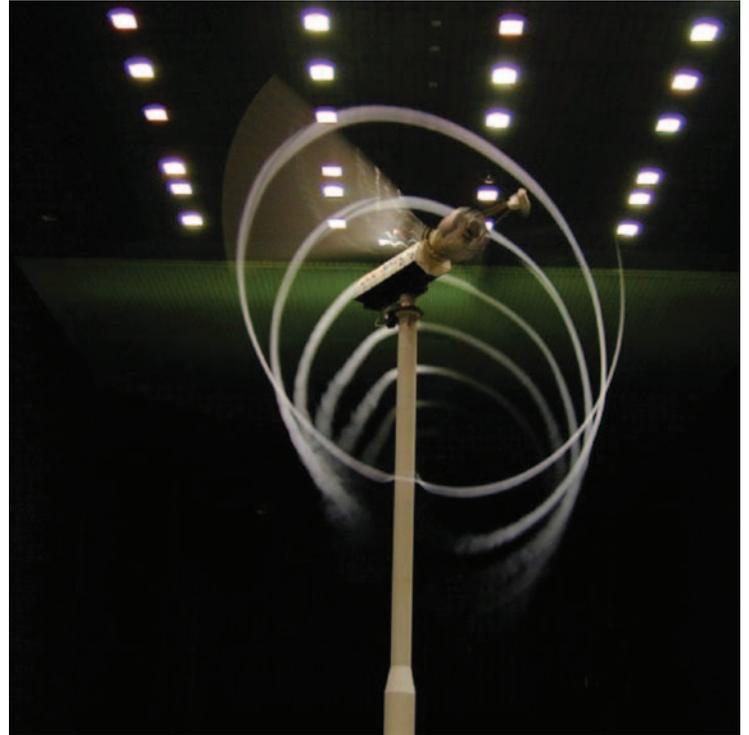
Systems and Controls Analysis and Testing

Harvesting more wind energy with advanced controls technology

As today's utility-scale wind turbines become taller to reach wind resources found at greater heights, their structures are becoming more complex and their components more flexible and lighter weight. As the components become more flexible, it is imperative to control the way they move and interact to prevent damage and possible system failures.

Many large commercial turbines still use classical controllers based on a single input and a single output. While adequate for controlling the "stiff" machines of the past, these methods are inadequate for stabilizing future multimegawatt turbines. The challenges facing today's wind turbine designers is to capture the maximum amount of energy with minimal structural loading for minimal cost.

To meet these future challenges, researchers at NREL's National Wind Technology Center (NWTC) are studying conventional turbine component controls such as blade pitching, new components such as twist-coupled blades, and advanced devices such as micro-tabs to develop innovative rotor control strategies to mitigate unwanted aerodynamic loads at the rotor hub.



Flow visualization tests conducted in the NASA Ames wind tunnel using smoke emitted from the tips of the turbine helped researchers determine the extent of the wake under a limited set of conditions. NREL/PIX 09996



NWTC researcher works in the hub of the 3-bladed Advanced Controls Wind Turbine at the NWTC. Photo by Lee Jay Fingersh, NREL/PIX 14902

Design of control algorithms for wind turbines must account for multiple control objectives. Wind turbines are complex, nonlinear, dynamic systems forced by aerodynamic, gravitational, inertial, centrifugal, and gyroscopic loads. Turbine rotors are subjected to a complicated 3-D turbulent wind inflow field with embedded coherent vortices that drive fatigue loads and reduce the turbine's lifetime. Multimegawatt turbines require active control and damping systems that mitigate fatigue loads, maintain stability, and allow maximum energy capture in a complex environment.

Controls Advanced Research Turbines (CART)

The test facilities at the NWTC include two controls advanced research turbines (CARTs). Testing new control schemes on these machines is a critical step before new control systems can be implemented in commercial machines.

The two turbines are horizontal-axis Westinghouse WTG-600 models that were formerly deployed in a commercial wind farm

in Hawaii for 10 years. After the turbines were shipped to the NWTC, engineers installed modifications that enabled them to use the turbines to test new control schemes for reducing loads on wind turbine components.

Modifications include:

- A new pitch system: The original hydraulically actuated pitch system was replaced with a high-speed electromechanical pitch system that enables high bandwidth independent pitch control of the blades.
- A new generation system: The new generation system incorporates power electronics that make it possible to control the turbine in either full variable-speed mode or as a constant-speed machine. The new control system allows almost complete flexibility in the type of control that can be implemented.
- Added custom instrumentation: A variety of instrumentation was added to allow a high degree of flexibility in the type of control algorithm that can be implemented.
- A three-bladed rotor: The two-bladed rotor on one machine was replaced with a three-bladed rotor to allow researchers to test new control schemes applicable only to three-bladed machines.

For more information, contact the National Wind Technology Center at 303-384-6900.

Helpful Web Sites

The National Wind Technology Center

www.nrel.gov/wind

Department of Energy Wind and Hydropower
Technologies Program

www1.eere.energy.gov/windandhydro



An aerial photo of the two NWTC Controls Advanced Research Turbines (CART).

Photo by Lee Jay Fingersh, NREL/PIX15736

National Renewable Energy Laboratory

15013 Denver West Parkway, Golden, Colorado 80401 • 303-275-3000 • www.nrel.gov

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