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NWTC Researchers Field-Test Advanced Control Turbine Systems to Increase Performance, Decrease Structural Loading of Wind Turbines and Plants

Researchers at the National Renewable Energy Laboratory's (NREL's) National Wind Technology Center (NWTC) are studying component controls, including new advanced actuators and sensors, for both conventional turbines as well as wind plants. This research will help develop innovative control strategies that reduce aerodynamic structural loads and improve performance. Structural loads can cause damage that increase maintenance costs and shorten the life of a turbine or wind plant.

Today's utility-scale wind turbine structures and plants are more complex than ever—and their components are more flexible and lighter weight than previous generations of wind turbines. As components become larger and more flexible, it is imperative to control the way they move and interact to prevent damage and possible system failures. The challenge facing wind turbine designers and wind plant developers is to capture the maximum amount of energy, with minimal structural loading, for minimal cost.

Algorithms designed to control the dynamic systems of wind turbines and plants must account for multiple complex nonlinear objectives that are driven by aerodynamic, gravitational, inertial, centrifugal, and gyroscopic loads. Turbine rotors are subjected to complicated, three-dimensional, turbulent wind inflow 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.

Validating new control schemes is a critical step before new control systems can be implemented in commercial machines and wind plants. Research facilities at the NWTC include two Controls Advanced Research Turbines (CARTs): the two-bladed CART2 and the three-bladed CART3. Both turbines are used to field-test advanced control systems and related technologies.

The NWTC's experimental wind turbines, a three-bladed Controls Advanced Research Turbine (CART3) and a two-bladed CART2. Both are used to validate new control schemes and equipment for reducing loads on wind turbine components.
Photo by Lee Jay Fingersh, NREL 21664

CART2/3 Features

- Hub height = 36.6 m
- Rotor diameter = 42.6 m
- Power rating = 600 kW
- 2 or 3 blades
- Extensively instrumented:
  - Dedicated meteorological mast
  - Strain gauges
  - Accelerometers.

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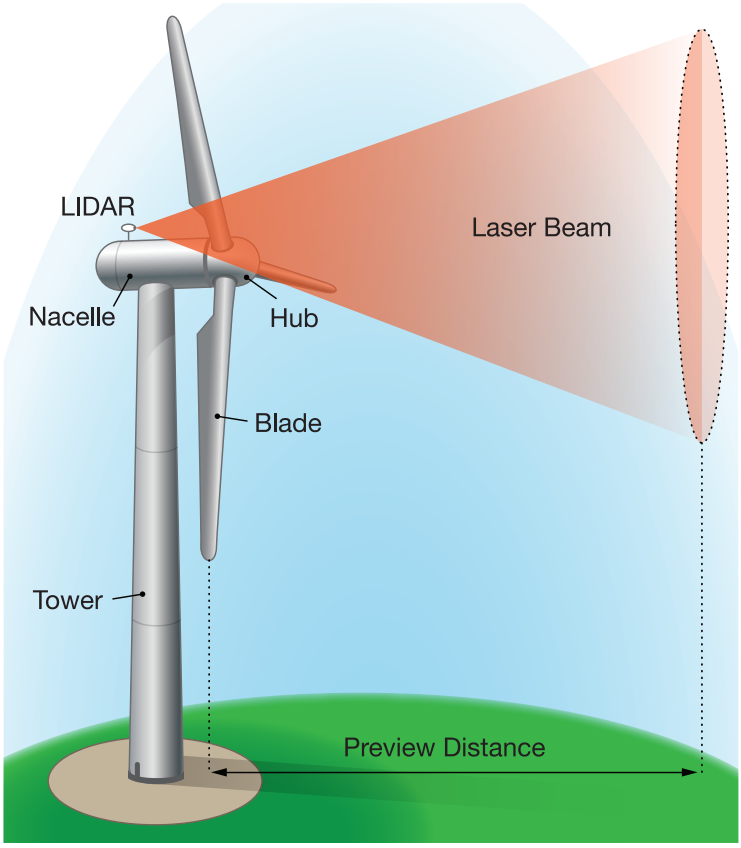
The CARTs are horizontal-axis Westinghouse WTG-600 models on which NWTC engineers modified the turbines to research and test new control schemes for reducing loads on wind turbine components and increase energy capture. Modifications include:

- 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.
- 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.
- 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.
- 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.

Feedforward Algorithms and Lidar Also Advance Controls Research

NWTC researchers developed a feedforward controller that is able to regulate turbines and wind plants by "looking ahead" at incoming wind conditions and eliminating the delayed control response time that currently exists when the controller senses a wind gust and the mechanical adjustment to the rotor torque responds.



Using laser technology known as a light detection and ranging system, or lidar, NWTC researchers can provide a look-ahead capability. The lidar allows the turbine to effectively "brace itself" for a wind gust before that gust actually arrives, measuring wind speed approximately 50 to 100 meters ahead of the turbine. *Illustration by Al Hicks, NREL*

To validate this advanced controller, NWTC researchers use lidars—lasers that measure wind speed and direction—looking ahead of the two CARTs. The lidars transmit data to a CART controller, which then controls the wind turbine. Field research shows that feedforward controls provide better rotor regulation than existing feedback setups.

Until recently, wind turbine controls that reduce the impacts of wind gusts and turbulence were always reactive—responding to the wind rather than anticipating it. Now, NWTC researchers and their industry partners, have shown that wind speed can be measured ahead of the turbine, thereby improving performance, reducing structural loads, and increasing energy capture.

Partner With Us

The NWTC's CARTs are available for researching and developing new controls capabilities. For more information, please contact Alan Wright, *Alan.Wright@nrel.gov*.

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