

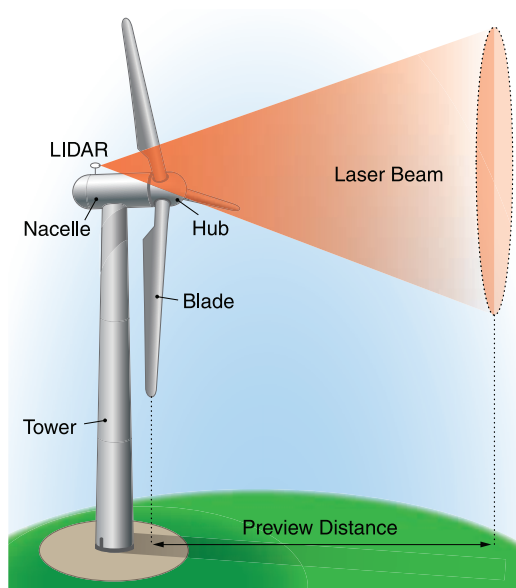
NREL Develops New Controls that Proactively Adapt to the Wind

Until now, wind turbine controls that reduce the impacts of wind gusts and turbulence were always reactive—responding to the wind rather than anticipating it. But with today’s laser-based sensors and new controls developed by researchers at the National Renewable Energy Laboratory (NREL) and their industry partners, the wind speed can be measured ahead of the turbine, thereby improving performance, reducing structural loads, and increasing energy capture. The world’s first field tests of these controls are currently underway at the National Wind Technology Center (NWTC) at NREL.

As utility-scale wind turbines become more sophisticated, their components become bigger, lighter, and more flexible. Turbine rotors are also subjected to complex turbulent winds that can cause fatigue damage and reduce the turbine’s lifetime, so turbine designers strive to reduce structural loading while capturing the maximum amount of energy at the lowest cost. To protect these light, flexible turbines from damaging winds, sophisticated control algorithms change the pitch of the wind turbine blades to prevent structural damage and possible system failures. Unfortunately, the effectiveness of these controls is limited, because they react to the winds once the winds are already hitting the turbine.

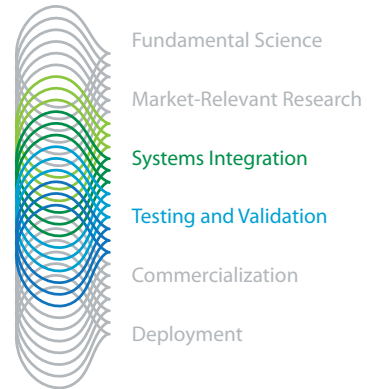
Looking Ahead Using LIDAR

Today, wind turbine designers have a new tool that provides a look-ahead capability, allowing the turbine to effectively “brace itself” for a wind gust before that gust actually arrives. Known as a Light Detection and Ranging system (LIDAR), this new tool emits laser beams that reflect



Using special eye-safe laser technology, the LIDAR measures wind speed approximately 50 to 100 meters ahead of the turbine.

Illustration by Al Hicks, NREL



Through deep technical expertise and an unmatched breadth of capabilities, NREL leads an integrated approach across the spectrum of renewable energy innovation. From scientific discovery to accelerating market deployment, NREL works in partnership with private industry to drive the transformation of our nation’s energy systems.

This case study illustrates NREL’s innovations in Systems Integration through Testing and Validation.



NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

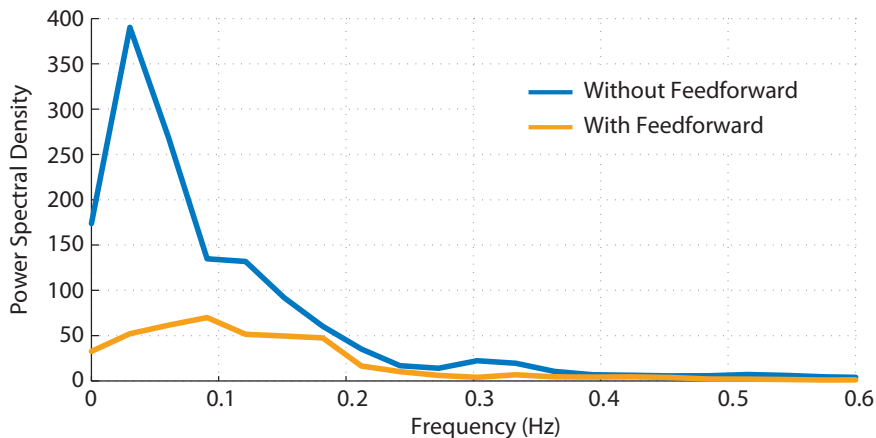
off of particulates in the atmosphere, and the reflected laser light is processed by the LIDAR system to calculate wind speed and direction. NREL researchers are now developing and testing new advanced control algorithms for wind turbines, using a turbine-mounted LIDAR system to measure wind speed upwind of the turbine. Basically, this “look-ahead,” or “feedforward,” information prepares the turbine’s pitch actuators to respond to the wind before it reaches the blades, thereby reducing the impact of strong wind gusts and turbulence.

In collaboration with commercial partners, such as Blue Scout Technologies, Inc. and Michigan Aerospace; universities, including the Colorado School of Mines, the University of Colorado-Boulder, and the University of Stuttgart; and other laboratories, such as DTU Wind Energy, NREL researchers are conducting field tests on these advanced control systems and related technologies at the NWTC at NREL. Test facilities include two 600-kilowatt Controls Advanced Research Turbines (CARTs): the two-bladed CART2 and the three-bladed CART3. Each turbine is equipped with a different type of LIDAR, allowing researchers to perform a side-by-side comparison. And because the turbines are relatively small, field tests are more cost-effective to perform.

Both NREL and its partners benefit from this collaboration. By using the LIDARs, NREL can verify and improve the performance of the algorithms. And by using the algorithms, the LIDAR manufacturers can refine their instruments to gather more accurate information for use in these control algorithms.

During recent field tests, a LIDAR measurement was used by the blade pitch controller to regulate wind turbine rotational speed at high wind speeds. The power spectral density of turbine speed was calculated with and without the LIDAR feedforward control enabled. The initial research results indicate that there was a reduction in power spectral density, which demonstrates that the LIDAR-based feedforward control improves speed regulation compared to the baseline feedback-only control.

Extensive testing still needs to be completed before the new control systems can be applied to commercial machines. As a result, NREL is continuing to conduct field tests and working with a number of LIDAR manufacturers to test their systems on the CART turbines. NREL is also working with several turbine manufacturers to implement LIDAR-based controls on their turbines, with the intent to provide dynamic, advanced feedforward controls for larger turbines and to offer those controls to the wind industry.



This figure shows the power spectral density of turbine speed with and without the LIDAR feedforward control enabled. The reduction of power spectral density at lower frequencies indicates that the LIDAR-based feedforward control regulates turbine speed better than the baseline feedback-only control. Illustration by Alan Wright and Stacy Buchanan, NREL

A World-Class Wind Facility

Just miles from the Rocky Mountains, the National Wind Technology Center (NWTC) at NREL is located on the Great Plains near Boulder, Colorado. The flat terrain and limited obstructions provide excellent conditions for testing wind turbines. More importantly, the strong wind resource and the technical expertise of the staff is what makes the site a world-class wind turbine research facility.

Many turbine manufacturers work with NREL to field test their machines. This includes turbines manufactured by Atlantic Orient Corporation, Bergey Windpower, Southwest Wind Power, Northern Power Systems, Endurance Wind Power Inc., Gaia-Wind Ltd., Entegritty Wind Systems Inc., Abundant Renewable Energy, Global Energy Concepts (formerly Advanced Wind Turbines), Siemens, General Electric, Gamesa, and Alstom.



Small, midsize, and utility-scale wind turbines are field tested at the NWTC. Photo by Dennis Schroeder, NREL/PIX 19898

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