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NWTC Aerodynamics Studies Improve Energy Capture and Lower Costs of Wind-Generated Electricity

Flow visualization tests conducted in the NASA Ames wind tunnel using smoke emitted from the tips of the turbine helped NWTC aerodynamics engineers determine the extent of the wake under a limited set of conditions. *Photo by Lee Jay Fingersh, NREL 09996*

Researchers at the National Wind Technology Center (NWTC) at the National Renewable Energy Laboratory (NREL) have expanded wind turbine aerodynamics research from blade and rotor aerodynamics to wind plant and atmospheric inflow effects. The energy capture from wind plants is dependent on all of these aerodynamic interactions, which impact the cumulative fatigue damage of turbine structural components that ultimately effect the useful lifetime of wind turbines. This work also is essential for understanding and maximizing turbine and wind plant energy production. Both turbine lifetime and wind plant energy production are keys to determining the cost of wind-generated electricity.

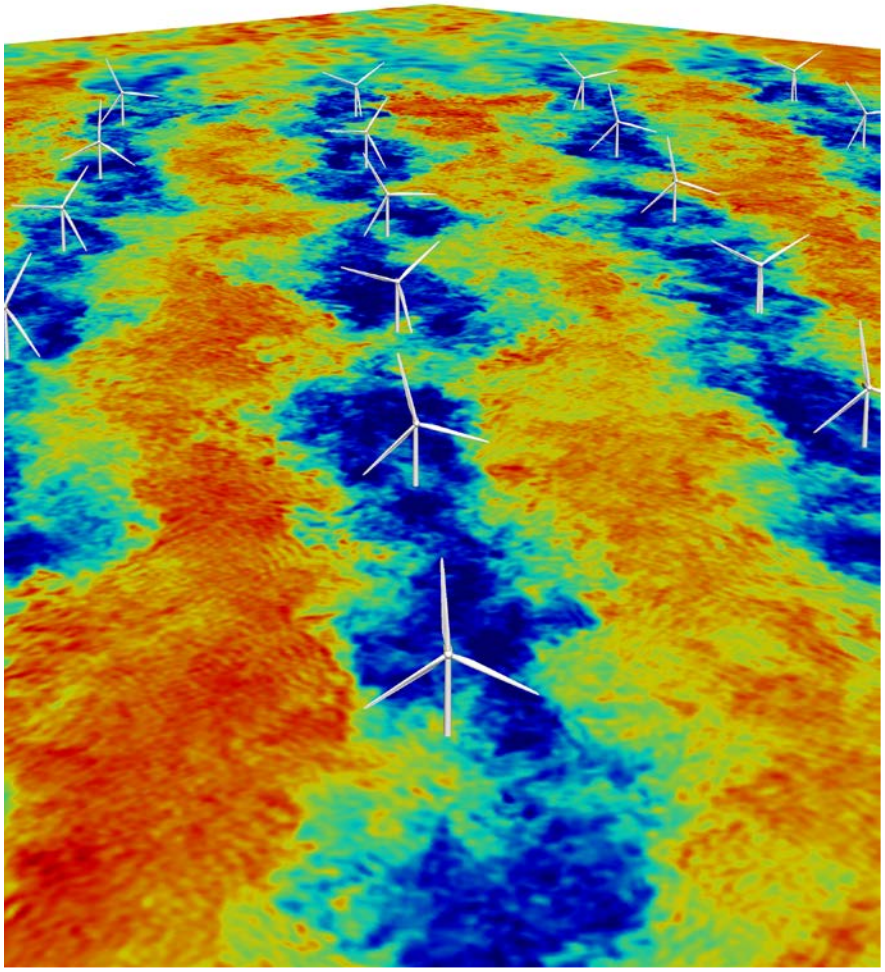
The NWTC works with manufacturers and wind plant developers to study the aerodynamic properties affecting wind power—from individual blades or turbines to entire wind plants—for optimal performance. Understanding wind turbine blade aerodynamics can enhance the accuracy and reliability of aerodynamic force predictions in engineering models used to design wind turbines. These advances improve machine operability, life span, energy capture, and power quality, all of which ultimately enable continued cost reductions.

In addition, NWTC engineers have developed multiple modeling and simulation software tools that are capable of modeling and analyzing aerodynamic effects at multiple levels—from the wind flow of individual blades to the performance of entire turbines to the wake interactions of multiturbine arrays in a wind plant system.

Aerodynamics Challenges

Aerodynamics research and development challenges for wind plants include:

- Behavior of the atmospheric boundary layer within which the array of turbines resides—this can have a large impact on turbine performance and loads.
- Turbine wake interaction—researchers believe this may be a major cause of lower energy capture and increased failure rates in wind plants. The close proximity of turbines in wind plants can cause many of them to operate in the wake of upstream turbines. Operating within a wake causes a decrease in power output and an increase in mechanical loading, which translates to less energy and higher maintenance costs.
- Terrain and vegetation—wind speeds increase at the tops of ridge lines, which is why wind turbines are often placed at these locations. But the downwind impacts of terrain or vegetation on potential wind sites remain unknown and could be significant.



A SOWFA simulation of the Lillgrund Wind Farm off the coast of Sweden shows wind turbine wake interactions throughout the array. *Graphic by Matt Churchfield, NREL*

NASA Ames Wind Tunnel Aids Research

In conjunction with the National Air and Space Administration (NASA), the NWTC has analyzed more than 1,700 different wind turbine conditions using the NASA Ames wind tunnel, providing a valuable resource for research into wind turbine aerodynamic codes, aerodynamic force predictions, and turbine designs. NWTC researchers studied turbine blade rotational augmentation and dynamic stall, resulting in better understanding, more accurate predictions, and improved turbine design.

Modeling Performance of Wind Plants

The Simulator fOr Wind Farm Applications (SOWFA), developed at the NWTC, is a coupled open-source software tool that allows users to investigate effects of weather patterns, turbulence, and complex terrain on the performance of wind turbines and plants. SOWFA simulates fluid dynamics on scales from regional weather to turbine wakes, and the impact of these dynamics on turbine structural and system response.

SOWFA helps engineers and developers of both land-based and offshore wind energy technology improve the performance of an entire wind plant by researching the causes of plant underperformance, increasing power output, and decreasing the effects of loads to minimize wear on turbine components. SOWFA also features a Super Controller that lets users simulate coordinated, multiturbine control of wind plants. These capabilities enable turbine manufacturers to study designs before they are manufactured and installed in the field—and wind plant developers to study the performance of turbines on a proposed site before construction—all of which reduces the risks of development and deployment. SOWFA and other NWTC software can be downloaded at *https://nwtc.nrel.gov/software*

Partner With Us

The NWTC welcomes collaborators in aerodynamic research and development. A variety of partnerships, contracts, and research agreements are available for those interested in working with us.

Past partnerships include:

- Manufacturers of turbine systems and components
- Wind plant developers, owners, and operators
- Universities and other research institutions
- Government agencies
- Other national laboratories.

Contact

Patrick Moriarty, *Patrick.Moriarty@nrel.gov*

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National Renewable Energy Laboratory
15013 Denver West Parkway • Golden, CO 80401
303-275-3000 • www.nrel.gov

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