



Wind Turbine Design Innovations Drive Industry Transformation

For more than 20 years, the National Renewable Energy Laboratory (NREL) has helped GE and its predecessors achieve market leadership through design innovations based on NREL research. But the path hasn't always been straightforward. Just as winds can be unpredictable, so too can the problems facing an industry seeking to harness wind power.

Tackling Turbine Blade Inefficiencies

In 1984, NREL researchers began investigating problems with wind turbine blade designs. Inefficiency was a significant barrier to lowering the cost of wind energy. Originally, turbine blades were adapted from aircraft propellers, and engineers were forced to compromise their efficiency to protect them from the stress of high-wind conditions. Those blades lost even more efficiency once their surfaces became roughened by airborne dirt.

NREL scientists invented specialized airfoils designed to withstand strong winds and dirt while operating at maximum efficiency. The result was three patented "families" of airfoils to handle blade sizes from 1 to 25 meters in length. These new airfoils were licensed by turbine manufactures to lower the cost and improve the reliability of their products.

There were other complications to overcome. In the early 1990s, the fledgling U.S. wind industry was struggling to find other ways to keep costs down and to ensure that the energy it was then developing at \$0.12/kilowatt-hour (kWh) could compete with the average \$0.04-\$0.06/kWh generated by fossil fuels. A major expense in those early wind machines was for repair and maintenance of gearboxes, along with supporting components such as shafts, generator, brakes, and lubrication system. This was a concern because the gearbox can make up about 35% of a typical turbine's price tag. Field tests showed that there were repeated gearbox failures related to wear and stress on the machines. However, there was no way to definitively test the effects of this stress on turbines under controlled conditions, making it difficult to correct recurring problems.

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 contributions in Market-Relevant Research through Deployment.



The 2.5-MW dynamometer test bed facility located at NREL's National Wind Technology Center PIX 08577



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.

Building the World's First Wind-Turbine Dynamometer

To address those issues, NREL proposed building a dynamometer at NREL's National Wind Technology Center (NWTC). With DOE backing, NREL designed and built the world's only wind turbine dynamometer, a 7,500-ft² facility that came online in the late 1990s.

The unique center allows engineers to conduct lifetime endurance tests showing 30 years' wear in a matter of months on a wide range of wind turbine drive trains and gearboxes at various speeds, using low or high torque. The tool has a powerful 3,350-horsepower (hp) electric motor coupled to a 2.5-megawatt (MW), three-stage epicyclic gearbox that can produce variable speeds from 0 to 146 revolutions per minute and run at torque levels up to 9.6 million inch-pounds to simulate the effects of various wind conditions.

In particular, early dynamometer testing led NREL researchers and GE engineers to develop the Highly Accelerated Life Test that has become GE's most rigorous proof test to date. Armed with this tool, NREL's team used the dynamometer to load test a 750-kW turbine that had shown damage to gear teeth after its mechanical emergency brake was applied. As a result, Zond, a turbine manufacturer whose assets GE later acquired, developed a better alternative to stop the turbines and reduce damage.



Tests conducted at the NWTC look at ways to arrest micropitting (flaking of surface layers) on wind turbine gear that can lead to serious operational problems. PIX 09992

Meeting the Micropitting Challenge

During that expansion era, NREL staff also tackled the recurring problem of "micropitting," the appearance of microscopic abrasions on turbine gears. High levels of micropitting contributed to early breakdowns, which in turn drove up costs. Using a combination of expertise and experience, the Wind Energy Program team systematically tested a variety of lubricants, including a then-novel type of synthetic oil. Tests showed that this new approach virtually eliminated the flaw. With this NREL-based discovery, Zond began using this synthetic lubricant fleetwide, and it eventually became standard in large turbines worldwide.

Zond and other wind power firms were purchased by Enron Wind Corporation, and in May 2002, GE Power Systems bought Enron's assets and expanded its presence in the turbine-building business. As part of this steady evolution, NREL researchers enabled the turbine builders to expand their options from a single-speed to variable-speed turbines, taking advantage of lower wind conditions. As with previous innovations—such as the NREL airfoil patents, which were licensed by GE and others—this variable-speed innovation allowed GE to continue refining its 1.5-MW turbines and build global market share.

Today, many incremental improvements have been combined so that GE and others can now deliver wind power at between \$0.05 and \$0.08/kWh, which is more than competitive with other fuels. And, even as GE expands and deploys its next-generation 2.5-MW installations, it turns to NREL. In 2009, GE installed its 1.5-MW turbine at the NWTC to continue its research and maintain industry leadership, no matter how hard the winds blow.

GE Gets \$1.4 Billion Contract for Largest U.S. Wind Farm

When GE announced a \$1.4 billion contract to supply 2.5-MW turbines for an Oregon project (said to be the largest U.S. wind farm) in December 2009, the company noted this success was built on the reputation and reliability of its 1.5-MW workhorse. The company could also have cited the foundation laid by NREL. GE's 1.5-MW turbine, the world's most widely deployed turbine with more than 12,000 installed, has benefited from collaboration with DOE's Wind Energy Program at NREL. The Oregon project, to be built in 2011 and 2012, is only the latest example of the company's leadership in the field. Today, GE Wind is the top turbine manufacturer in the United States, installing 3,657 MW of the total U.S. wind turbine capacity (8,558 MW) that came online in 2008.

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