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'Smart turbine blades' to improve wind power

WEST LAFAYETTE, Ind. - Researchers have developed a technique that uses sensors and computational software to constantly monitor forces exerted on wind turbine blades, a step toward improving efficiency by adjusting for rapidly changing wind conditions.

Jonathan White
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The research by engineers at Purdue University and Sandia National Laboratories is part of an effort to develop a smarter wind turbine structure

"The ultimate goal is to feed information from sensors into an active control system that precisely adjusts components to optimize efficiency," said Purdue doctoral student Jonathan White, who is leading the research with Douglas Adams, a professor of mechanical engineering and director of Purdue's Center for Systems Integrity.

The system also could help improve wind turbine reliability by providing critical real-time information to the control system to prevent catastrophic wind turbine damage from high winds.

"Wind energy is playing an increasing role in providing electrical power," Adams said. "The United States is now the largest harvester of wind energy in the world. The question is, what can be done to wind turbines to make them more efficient, more cost effective and more reliable?"

The engineers embedded sensors called uniaxial and triaxial accelerometers inside a wind turbine blade as the blade was being built. The blade is now being tested on a research wind turbine at the U.S. Department of Agriculture's Agriculture Research Service laboratory in Bushland, Texas. Personnel from Sandia and the USDA operate the research wind turbines at the Texas site.

Such sensors could be instrumental in future turbine blades that have "control surfaces" and simple flaps like those on an airplane's wings to change the aerodynamic characteristics of the blades for better control. Because these flaps would be changed in real time to respond to changing winds, constant sensor data would be critical.

"This is a perfect example of a partnership between a national lab and an academic institution to develop innovations by leveraging the expertise of both," said Jose R. Zayas, manager of Sandia's Wind Energy Technology Department.

Research findings show that using a trio of sensors and "estimator model" software developed by White accurately reveals how much force is being exerted on the blades. Purdue and Sandia have applied for a provisional patent on the technique.

Findings are detailed in a paper being presented Monday (May 4) during the Windpower 2009 Conference & Exhibition in Chicago. The paper was written by White, Adams and Sandia engineer Mark A. Rumsey and Zayas. The four-day conference, organized by the American Wind Energy Association, attracts thousands of attendees and is geared toward industry.

"Industry is most interested in identifying loads, or forces, exerted on turbine blades and predicting fatigue, and this work is a step toward accomplishing that," White said.

A wind turbine's major components include rotor blades, a gearbox and generator. The wind turbine blades are made primarily of fiberglass and balsa wood and occasionally are strengthened with carbon fiber.

"The aim is to operate the generator and the turbine in the most efficient way, but this is difficult because wind speeds fluctuate," Adams said. "You want to be able to control the generator or the pitch of the blades to optimize energy capture by reducing forces on the components in the wind turbine during excessively high winds and increase the loads during low winds. In addition to improving efficiency, this should help improve reliability. The wind turbine towers can be 200 feet tall or more, so it is very expensive to service and repair damaged components."

Sensor data in a smart system might be used to better control the turbine speed by automatically adjusting the blade pitch while also commanding the generator to take corrective steps.

"We envision smart systems being a potentially huge step forward for turbines," said Sandia's Rumsey. "There is still a lot of work to be done, but we believe the payoff will be great. Our goal is to provide the electric utility industry with a reliable and efficient product. We are laying the groundwork for the wind turbine of the future."

Sensor data also will be used to design more resilient blades.

The sensors are capable of measuring acceleration occurring in various directions, which is necessary to accurately characterize the blade's bending and twisting and small vibrations near the tip that eventually cause fatigue and possible failure.

The sensors also measure two types of acceleration. One type, the dynamic acceleration, results from gusting winds, while the other, called static acceleration, results from gravity and the steady background winds. It is essential to accurately measure both forms of acceleration to estimate forces exerted on the blades. The sensor data reveal precisely how much a blade bends and twists from winds.

The research is ongoing, and the engineers are now pursuing the application of their system to advanced, next-generation turbine blades that are more curved than conventional blades. This more complex shape makes it more challenging to apply the technique.

In 2008 the United States added 8,358 megawatts of new wind-power capacity, which equates to thousands of new turbines since the average wind turbine generates 1.5 megawatts. The new capacity increased the total U.S. installed wind power to 25,170 megawatts, surpassing Germany's capacity as the world's largest harvester of wind power.

"Our aim is to do two things - improve reliability and prevent failure - and the most direct way to enable those two capabilities is by monitoring forces exerted on the blades by winds," Adams said.

The research is funded by the U.S. Department of Energy through Sandia National Laboratories. Sandia is a multiprogram laboratory operated by Sandia Corp., a Lockheed Martin Co., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Writer: Emil Venere, 765-494-4709, venere@purdue.edu

Sources: Douglas Adams, 765-496-6033, deadams@purdue.edu

Jonathan R. White, 765-449-4809, JonWhite@purdue.edu

Mark Rumsey, 505-844-3910, marumse@sandia.gov

Jose R. Zayas, 505-284-9446, jrzayas@sandia.gov

Purdue News Service: (765) 494-2096; purduenews@purdue.edu

Note to Journalists: An electronic copy of the research paper is available from Emil Venere, 765-494-4709, venere@purdue.edu

PHOTO CAPTION:
Purdue doctoral student Jonathan White holds a cross section of a wind turbine blade like the one used in research to improve the efficiency of turbines and prevent damage to blades from high winds. The researchers, from Purdue and Sandia National Laboratories, have developed a technique that uses sensors and computational software to constantly monitor forces exerted on wind turbine blades. Such sensors could be instrumental in future turbine blades that have control surfaces and flaps like those on an airplane's wings to change the aerodynamic characteristics of the blades for better control. (Purdue University photo/Andrew Hancock)

A publication-quality photo is available at http://news.uns.purdue.edu/images/+2009/adams-turbineblade.jpg

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ABSTRACT

Operational Load Estimation of a Smart Wind Turbine Rotor Blade

*Jonathan R. White*a, Douglas E. Adamsa,*
Mark A. Rumseyb, Jose R. Zayasb

aPurdue University, 1500 Kepner Drive,
Lafayette, Ind.

bSandia National Laboratories, P.O. Box 5800, Albuquerque, NM

A key technology to improve the efficiency of wind turbines is smart rotor blades, which can monitor the physical loads being applied by the wind and then adapt the airfoil for increased energy capture. For extreme wind and gust events, the airfoil could be changed to reduce the loads to prevent excessive fatigue or catastrophic failure. Knowledge of the actual loading to the turbine is also useful for maintenance planning and design improvements. A prototype smart blade is presented that captures flap deflection and torsional deflection shapes to estimate the loading of the wind over the entire blade. DC-type accelerometers are utilized in order to estimate the loading and deflection from both quasi-steady-state and dynamic events. Modal properties were measured for the turbine blade in free-free, cantilevered, and assembled boundary conditions to develop a model for use in estimating the operational forcing functions. Experimental results showed that blade displacement and rotation could be estimated from steady-state loading using DC accelerometers. Dynamic loading to the turbine blade was also estimated through the use of modal filtering. The results demonstrated that a DC accelerometer sensor array could be used to estimate loads and deflections, which are needed to reduce maintenance costs and enable adaptive control of the blade. Passive and active damage detection methods applied to a previous fatigue to failure test are also covered as well. In-plane measurements are shown to be sensitive to damage and transverse measurements are useful load estimation. The active method was capable of compensating for temperature changes and then producing an indicative estimate of the damage.

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