U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Wind Program Newsletter

October 2014 Edition

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Three Offshore Wind Advanced Technology Demonstration Projects Receive Phase 2 Funding

The U.S. Department of Energy (DOE) awarded additional funding to three of the seven projects from the Offshore Wind Advanced Technology Demonstration Funding Opportunity. Dominion Virginia Power, Fishermen's Energy of New Jersey, and Principle Power, Inc. will each receive up to $46.7 million over the next 4 years to advance their projects in the second phase of the funding opportunity.

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Three DOE Reports Analyze U.S. Wind Energy Growth

The U.S. Department of Energy (DOE) recently released three reports that provide a detailed analysis of the markets for utility-scale land-based and offshore wind technologies and distributed wind technology: the *Offshore Wind Market and Economic Analysis* produced by Navigant Consulting, Inc., the *2013 Wind Technologies Market Report* produced by the Lawrence Berkeley National Laboratory, and the *2013 Distributed Wind Market Report* produced by the Pacific Northwest National Laboratory.

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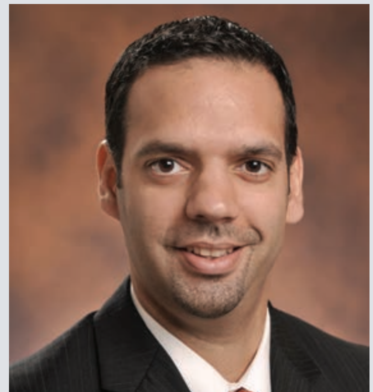
Letter from the Wind Program Director



Jose Zayas, Director,
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This fall edition of the Wind Program Newsletter comes at an exciting time for the program.

Advancements in next-generation wind energy technologies are allowing the Wind Program to reach new heights and push the boundaries of innovation further than ever before. This past May, I had the opportunity to announce the recipients of funding that will help establish some of the country's first grid-connected offshore wind projects by 2017. These projects, located off the coasts of New Jersey, Oregon, and Virginia represent the pinnacle of Wind Program research and development that will help establish our nation's clean energy future for generations to come. Knowing that proper research best informs future success, we recently released two new reports that assess the feasibility of offshore wind grid connectivity and highlight the offshore wind industry's progress throughout the past year.

Although the Wind Program's offshore wind projects represent some of the next "big" things in wind energy, we are also working to expand the role of smaller, distributed wind systems as an integral part of the country's wind energy framework. As the Wind Program works to enhance our existing grid infrastructure, the more than 72,000 turbines in distributed applications have allowed wind energy to reach some of the furthest corners of the country, bringing renewable energy to schools, homes, and businesses.

Adding to our existing project portfolio, the Wind Program—through various funding opportunities—has initiated new efforts this past year to enhance wind energy systems, increase hub heights, and improve forecasting and modeling capabilities, and is working to support America's land-based and emerging offshore wind industries.

I look forward to celebrating future wind energy success and hope to engage with all of the participants at this year's American Wind Energy Association Offshore WINDPOWER 2014 Conference & Exposition. Come by the Department of Energy Booth (#200) for an opportunity to learn more about our ongoing initiatives!

Sincerely,
Jose Zayas

Study Finds 54 Gigawatts of Offshore Wind Energy Capacity Technically Possible by 2030

According to a new study funded by the U.S. Department of Energy, the United States has sufficient offshore wind energy resources to legitimize the installation of at least 54 gigawatts (GW) of offshore wind capacity by 2030. The National Offshore Wind Energy Grid Interconnection Study (NOWEGIS) focuses on two DOE objectives: reducing the cost of offshore wind energy and reducing the timeline of deployment. NOWEGIS was conducted by a team of leading energy organizations, including ABB, the National Renewable Energy Laboratory (NREL), Duke Energy, AWS Truepower, and the University of Pittsburgh Swanson School of Engineering.

Using NREL's Regional Energy Deployment System (ReEDS) model for electricity generation and transmission, the study surveyed appropriate locations (excluding military zones, shipping lanes, and other necessary locations) and calculated timelines for deployment that could result in 54 GW of offshore wind. NOWEGIS modeling also suggests that 5 GW of offshore wind power could be produced within a decade. In addition, the report points out that far more wind power could be generated if current exclusion zones, such as commercial shipping lanes, could be utilized.

Presentations and Posters by DOE Wind Program at Offshore AWEA WINDPOWER 2014

TUESDAY October 7

Welcome and Opening General Session
9:00 a.m.–10:10 a.m. Location: Hall A
Jose Zayas, Director of Wind and Water Power Technologies Office, U.S. Department of Energy (DOE)

Partnering to Reduce Cost
10:15 a.m.–11:45 a.m. Location: Hall A
Gary Norton, Senior Advisor, Offshore Wind Program, U.S. Department of Energy
DOE – Partnering to Reduce Offshore Costs

Designing Offshore Foundations for U.S. Conditions
3:45 p.m.–5:15 p.m. Location: Room 201
Rick Damiani, Senior Engineer, National Renewable Energy Laboratory
Hurricane Design Guidance for U.S. Waters: Engineering Offshore Wind Systems to Survive Hurricanes

Networking Poster Reception
5:15 p.m.–6:15 p.m. Location: Hall B
Baseline Design of a Hurricane-Resilient Wind Turbine, by R. Damiani, A. Robertson, S. Schreck and B.Maples, National Renewable Energy Laboratory
Delineating the Navigation Risk to Commercial Shipping Around Offshore Wind Farms, by A. Copping, Pacific Northwest National Laboratory
Operational Impacts of Large Deployments of Offshore Wind, by Eduardo Ibanez, National Renewable Energy Laboratory

WEDNESDAY October 8

Closing Session
3:00 p.m.–4:30 p.m. Location: Hall A
Gregory Matzat, PE, Senior Advisor, Offshore Wind Technologies
U.S. Department of Energy U.S. Department of Energy Advanced Technology Demonstration Project Initiative

According to NOWEGIS, bringing this amount of power ashore is possible using existing collection and interconnection technologies; both alternating current and direct current methods show promise in transporting offshore electricity to the land power grid.

At the national level, the NOWEGIS estimates that 54 GW of offshore wind energy could reduce the national annual electricity production costs by approximately $7.68 billion—corresponding to approximately $41 per megawatt-hour of offshore wind added to the grid—helping justify the high initial investment of offshore wind projects. (Note that this represents operations costs and does not include capital costs.)

Nevertheless, deployment of large quantities of offshore wind technology will depend on state policies, federal permitting processes, and technology improvements. State policies can encourage offshore wind deployment by creating demand for this resource through renewable portfolio standards that establish requirements for the purchase of offshore wind as part of a renewable energy portfolio based on state needs. Additionally, further technical improvements by government, industry, and academia in technologies such as cables, offshore platforms, and high-voltage direct-current converters would contribute to accelerated commercialization and deployment of offshore wind power.

Read the full report at *energy.gov/eere/downloads/national-offshore-wind-energy-grid-interconnection-study-nowegis*

An illustration of the twisted-jacket foundation technology that will be used by both Dominion Power and Fishermen's Energy for their offshore wind demonstration projects. *Image by Joshua Bauer, NREL.*

Three Offshore Wind continued from page 1

The second phase will include follow-on design, fabrication, and deployment to achieve commercial operation by 2017.

Dominion Power will install two 6-megawatt (MW) direct-drive wind turbines off the coast of Virginia Beach on twisted jacket foundations designed by Keystone Engineering of Louisiana. Fishermen's Energy will install five 5-MW turbines on twisted jacket foundations off the coast of Atlantic City, New Jersey, that will act as a laboratory for researchers to learn about offshore wind, and Principle Power will install five 6-MW turbines on semisubmersible platforms off the coast of Coos Bay, Oregon.

With roughly 80% of the U.S. electricity demand originating from coastal states, offshore wind is a crucial renewable resource to be incorporated in the country's clean energy mix. Designed to reduce the cost of offshore wind energy through the development and deployment of innovative technologies, DOE's down-selected Offshore Wind Advanced Technology Demonstration Projects will contribute towards the United States having offshore wind systems ready for commercial operation in domestic waters by the end of 2017.

Read more about DOE's Offshore Wind Advanced Technology Demonstration Projects at *energy.gov/eere/wind/offshore-wind-advanced-technology-demonstration-projects*

Three DOE Reports continued from page 1

The Offshore Wind Market and Economic Analysis Report noted that although the United States currently has no offshore wind installations, two projects—Cape Wind and Deepwater's

Block Island project—are now in initial stages of construction. In total, 14 projects with 4.9 gigawatts (GW) of total potential capacity are now in advanced stages of development, defined in the report as having either been awarded a lease, conducted baseline or geophysical studies, or obtained a power purchase agreement.

The report also states that although the offshore wind industry in the United States made significant progress in 2013, there are three high-level barriers that can impede future progress: cost competitiveness, lack of infrastructure, and uncertain and lengthy regulatory processes. Because offshore wind is driven by upfront capital costs, investment support policies such as cash grants, low-interest loans, and tax breaks are needed to increase cost competitiveness.

Infrastructure challenges include the lack of purpose-built ports and vessels, lack of domestic manufacturing and experienced labor, and insufficient offshore transmission. Regulatory challenges include uncertain site selection and leasing processes, fragmented permitting processes, and public resistance related to uncertain environmental impacts.

The continued development of innovative offshore technologies will also help to reduce cost and stimulate needed infrastructure development. In 2014, DOE announced that Fishermen's Energy, Dominion, and Principle Power were each selected for up to $46.7 million in federal funds for the final design and construction of pilot projects off the coasts of New Jersey, Virginia, and Oregon, respectively.

The *2013 Wind Technologies Market Report* found that the total wind power capacity in the United States grew to 61,110 megawatts (MW) in 2013. Regarding this increase, a number of states in particular stood out: California installed 269 MW, whereas nine other states generated more than 12% of their power through wind.

The report also found considerable progress in wind generation technology, specifically turbine nameplate capacity, hub height, and rotor diameter have all increased significantly. In addition, costs of wind power installations have fallen, leading to an improvement of wind competitiveness in 2013. As for the international outlook, U.S. exports of wind-powered generating sets have increased steadily since 2007, reaching $421 million in 2013.

Although the wind power growth in 2013 was smaller than that of 2012, the report points out that the production tax credit, a primary source of federal support for wind projects, has now been extended, which is expected to spur wind deployment in 2014–2015.

According to the *2013 Distributed Wind Market Report*, 2013 saw the addition of 30.4 MW of distributed wind capacity, leading to a cumulative distributed wind capacity of 842 MW. Domestic manufacturers dominated the small wind market, with 93% of 2013 domestic small wind sales (on a unit basis) coming from U.S. suppliers. Domestic manufacturers also increased exports by 70%, from 8 MW in 2012 to 13.6 MW in 2013. In addition, 76% of small wind sales from U.S. manufacturers were to non-U.S. markets, compared to 57% in 2012.

Despite the modest additions to installed wind capacity in 2013, the American Wind Energy Association reported that more than 12,000 MW of capacity was under construction at the end of 2013. Up to 130 MW of that energy may be distributed wind, which could increase the cumulative capacity in the near future.

Read the *Offshore Wind Market and Economic Analysis* at *energy.gov/eere/downloads/2014-offshore-wind-market-and-economic-analysis*

Read the *2013 Wind Technologies Market Report* at *energy.gov/eere/wind/downloads/2013-wind-technologies-market-report*

Read the *2013 Distributed Wind Market Report* at *energy.gov/eere/wind/downloads/2013-distributed-wind-market-report*

DOE Offers Conditional Commitment to Cape Wind Offshore Wind Generation Project

The U.S. Department of Energy (DOE) recently announced the first step toward issuing a $150 million loan guarantee to support the construction of the Cape Wind offshore wind project with a conditional commitment to Cape Wind Associates, LLC. The project could be the first commercial-scale offshore wind facility in the United States, with a capacity of more than 360 megawatts (MW) of clean energy off the coast of Cape Cod, Massachusetts.

"(This) announcement of a conditional commitment to the Cape Wind project demonstrates our intent to help build a strong U.S. offshore wind industry," said Energy Secretary Ernest Moniz.

The proposed Cape Wind project would use 3.6-MW offshore wind turbines that would provide a majority

Urban Green Energy's Vision Air 5, 3.2-kilowatt wind turbine at the National Wind Technology Center at the National Renewable Energy Laboratory (NREL). *Photo from NREL*

Northern Power Systems 100-kilowatt wind turbine. *Photo from Northern Power Systems, NREL 26782*

of the electricity needed for Cape Cod, Nantucket, and Martha's Vineyard, and would create approximately 400 construction jobs and 50 operations jobs.

Under the proposed financing structure for the Cape Wind project, DOE would be part of a group of public and private lenders. This co-lending arrangement will help build private sector experience with offshore wind projects in the United States while reducing taxpayer exposure.

Read the full article at *energy.gov/articles/energy-department-offers-conditional-commitment-cape-wind-offshore-wind-generation-projec-0*

NREL Announces Two New Competitiveness Improvement Project Awards

In July, the U.S. Department of Energy's (DOE's) National Renewable Energy Laboratory (NREL) announced two new Competitiveness Improvement Project (CIP) awards. Northern Power Systems of Barre, Vermont, and Urban Green Energy of New York City, New York, will receive a portion of the $1.27 million allocated to the CIP in support of the DOE's Clean Energy Manufacturing Initiative. The CIP aims to help U.S. manufacturers of small and mid-sized wind turbines with rotor swept areas up to 1,000 m^2 improve their turbine design and manufacturing processes to reduce costs, improve efficiency, and eventually earn certification that shows they have met performance and safety requirements.

Northern Power Systems is currently focused on a broad range of component improvements aimed at reducing total system cost and increasing performance of its 100-kilowatt (kW) wind turbine. Under its award, the company plans to develop and deploy an innovative blade designed for low wind speed applications and model and test an advanced control method that will help increase the amount of energy produced by its turbine.

Under its award, Urban Green Energy will subject its 1-kW vertical-axis wind turbine to extensive third-party testing to be performed by the regional test center managed by Intertek. Successful completion of the testing will lead to certification, ensuring that the turbine meets the American Wind Energy Association's safety and performance standards.

The two new awards will bring the total number of awards under this second round of CIP funding to five—Pika Energy of Westbrook, Maine, received two awards in April, and Endurance Windpower of Spanish Forks, Utah, recieved an award in March.

Under its awards, Pika will upgrade its manufacturing processes and improve core wind turbine components. The company will focus on reducing manufacturing costs of key turbine components and will use experience gained from the injection molding process developed for its blades under a Round 1 CIP award. Pika will also scale up the turbine's blades, alternator, inverter, and tower to enable more energy production at a reduced end-user cost.

Endurance Wind Power will conduct testing on its prototype turbine with an expanded rotor that allows for a larger wind-swept area, leading to a more efficient turbine.

2011 DOE-Funded Offshore Wind Project Updates

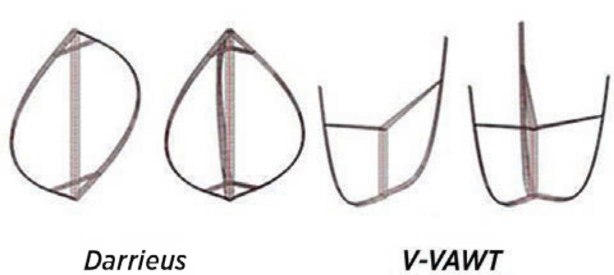
For the past few years, much of the U.S. Department of Energy's (DOE's) Wind Program research and development efforts have been focused on accelerating the development and deployment of offshore wind energy technology. In 2011, DOE awarded $43 million to 41 projects across 20 states to speed technical innovations, lower costs, and shorten the timeline for deploying offshore wind energy systems. Nineteen of those projects were focused on addressing technical challenges and providing the foundation for a cost-competitive offshore wind industry in the United States. Although many of these projects are not scheduled for completion until the 2016–2017 timeframe, research results are starting to trickle in. This section of the Wind Program Newsletter includes updates, information, and results from those projects. Project updates in this edition of the newsletter include the vertical-axis offshore wind turbine study by Sandia National Laboratories and the Simulator for Offshore/Onshore Wind Farm Applications (SOWFA), a computer-aided engineering tool developed by the National Renewable Energy Laboratory (NREL).

Sandia National Laboratories and Partners Complete Phase I of a Vertical-Axis Deepwater Offshore Turbine Study

Sandia National Laboratories and partners from the University of Maine, Technical University of Delft, Iowa State University, TPI Composites, and Texas A&M University have completed the first phase of a project to explore the feasibility of large-scale vertical-axis wind turbines (VAWTs) for deepwater offshore locations. The results of this conceptual study showed the potential for a significant cost of energy reduction in the deepwater offshore environment for VAWTs. Component cost models were developed to perform a levelized cost of energy (LCOE) analysis, which was then employed to gain a better understanding of opportunities for cost reduction and tradeoffs in the design space for offshore VAWTs.

The major accomplishments of this project included:

- Development of design codes for floating offshore VAWT systems



This figure shows several of the rotor configurations considered in the preliminary design studies conducted by Sandia National Laboratories. *Photo from SNL*

- Identification of driving wind and wave design conditions and standards
- Studies for floating VAWT system design concepts
- Innovations and analysis to mitigate technical challenges.

The initial phase of the work also produced new developments for large-scale deepwater offshore VAWT technology in the following areas:

- VAWT design codes (Updated set to include structural, aerodynamic, aeroelastic, and hydrodynamic/mooring)
- Rotor structural dynamics and platform design studies
- Novel VAWT airfoil design
- Aeroelastic stability tool development and stability estimates
- Balance-of-station cost reduction
- New approaches for storm survival and load alleviation.

Cost and performance tradeoffs between various rotor configurations and floating platform options were examined in the initial project phase.

Currently, plans are being made for the next phase of the work, which include enhancements to the suite of VAWT codes developed in Phase I as well as detailed design studies and up-scaling of rotor and platform concepts. In addition, promising LCOE reduction pathways identified in the initial phase will be explored in the design studies.

Computer-Aided Engineering Tools Model Offshore Wind Turbines, Substructures, and Wind Farms

Several of the research projects funded by DOE's Offshore Wind Technology Development Funding Opportunity are contributing to the development of computer-aided engineering tools that the wind industry is using to advance the development of offshore wind technologies. NREL recently released one of these new tools—SOWFA.

SOWFA is a unique simulation framework that allows users to investigate the effects of weather patterns, turbulence, and complex terrain on the performance of wind farms as well as individual wind turbines. It combines various open-source software programs, including a weather researching and forecasting model, a computational fluid dynamics model, and the FAST wind turbine performance simulator into a package that produces both high- and medium-fidelity wind farm simulations. SOWFA's high-fidelity mode requires a high-performance computing cluster and considerable expertise to run. It allows researchers to examine select situations in great detail to understand complex wind farm physics. SOWFA's medium-fidelity mode requires only a laptop to run. Developers can use it for a less detailed examination of the wind farm environment by switching out the wind farm atmospheric simulation (OpenFoam) module for a dynamic wake meandering and TurbSim module. The dynamic wake meandering model simulates the wakes of the wind turbines so that developers can study the interaction between multiple turbines in a wind farm. TurbSim models the atmospheric turbulence and inflow.

SOWFA enables engineers and developers to understand the causes of wind plant underperformance and how to increase power output and decrease the effects of loads to minimize wear on turbine components, all of which would contribute to significant decreases in cost for both offshore and land-based wind energy development. It also enables wind turbine manufacturers to study wind turbine 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 it's built, greatly reducing the risks of development and deployment.

SOWFA is available to wind technology developers free of charge on NREL's Computer-Aided Engineering Tools page at *wind.nrel.gov/designcodes/simulators/sowfa/*

New Superconducting Magnet Will Lead to Next Generation of Wind Turbine Generators

AML Superconductivity and Magnetics, in conjunction with the U.S. Department of Energy's (DOE's) Argonne National Laboratory, recently announced that their superconducting magnet system passed a landmark reliability test, demonstrating its potential suitability for wide-scale commercial applications. This innovative superconducting magnet will help establish a new generation of turbine generators that are roughly half the size and weight of those currently in operation.

In 2012, DOE funded AML's design for a superconducting generator for large-scale, high-efficiency offshore wind turbines. AML worked with its partners, Emerson Electric Corporation, Creare Inc., DNV USA, and DOE's Argonne National Laboratory to develop the design for a 10-megawatt (MW) direct-drive fully superconducting generator. According to AML's Vice President of Development, Vernon Prince, the design has been thoroughly vetted and validated by DOE and is ready for a full-scale demonstration project and volume manufacturing.

Key potential advantages of the AML direct-drive generator include improved scalability, reduced weight, and coils that are free of rare-earth materials. AML's design does not require a gearbox, which may lead to improved reliability and reduced maintenance costs. Although this may also be true for contemporary, gearbox-free direct-drive generator designs, the AML generator makes a magnetic field using superconducting windings that are more powerful and compact than copper-based alternatives. They are also constructed of more readily available and lower-cost materials than permanent-magnet-based generators, which are sensitive to cost fluctuations in the volatile rare-earth magnet market. In addition, AML calculates that its generator will weigh up to 50% less than a comparable permanent-magnet rare-earth generator with a 10-MW power rating. A lower generator mass has major system benefits, including a lighter—and thus less expensive—tower, and reduced installation costs through the use of smaller cranes and offshore vessels.

New Version of FAST Released

The U.S. Department of Energy's National Renewable Energy Laboratory (NREL) recently released a more robust version of its FAST software under a modularization framework that represents a generational change in how computer-aided engineering (CAE) tools are developed. NREL's FAST has evolved over the past three decades into one of the most powerful and flexible CAE tools available through open source to wind technology developers today. FAST models the coupled aerodynamics, hydrodynamics, controls and electrical drives, and structural dynamics of land-based and offshore fixed-bottom and floating wind turbines.

The new version of FAST (FAST v8) offers many features requested by the wind engineering community, including the analysis of wind turbines installed on multimember offshore substructures and improved documentation to support proper application of the tool. FAST v8 also includes an improved coupling approach with enhanced numerical robustness and efficiency as well as new modules for offshore surface ice loading.

FAST v8 resolves many of the problems associated with the first release and sets the stage for future development, including coupling of the BeamDyn nonlinear blade structural-dynamics module and the transformation from a turbine-centric tool to a tool capable of modeling turbine-to-turbine interaction (wake/array effects and control) within wind plants.

FAST v8 and its documentation are available on NREL's Computer-Aided Engineering Tools page at *wind.nrel.gov/designcodes/simulators/FAST8/*

A Minnesota Blizzard Provides Insight into Utility-Scale Wind Turbine Wakes

Jiarong Hong can hardly wait for Minnesota's harsh winters to return. That's because the University of Minnesota's mechanical engineering assistant professor and St. Anthony Falls Laboratory researcher uses blizzard conditions to help visualize wind turbine wakes.

Starting in 2012, Hong and other researchers tried placing spotlights downwind from the 2.5-megawatt (MW) wind turbine at the U.S. Department of Energy-funded EOLOS Wind Energy Research Field Station in Rosemount, Minnesota.

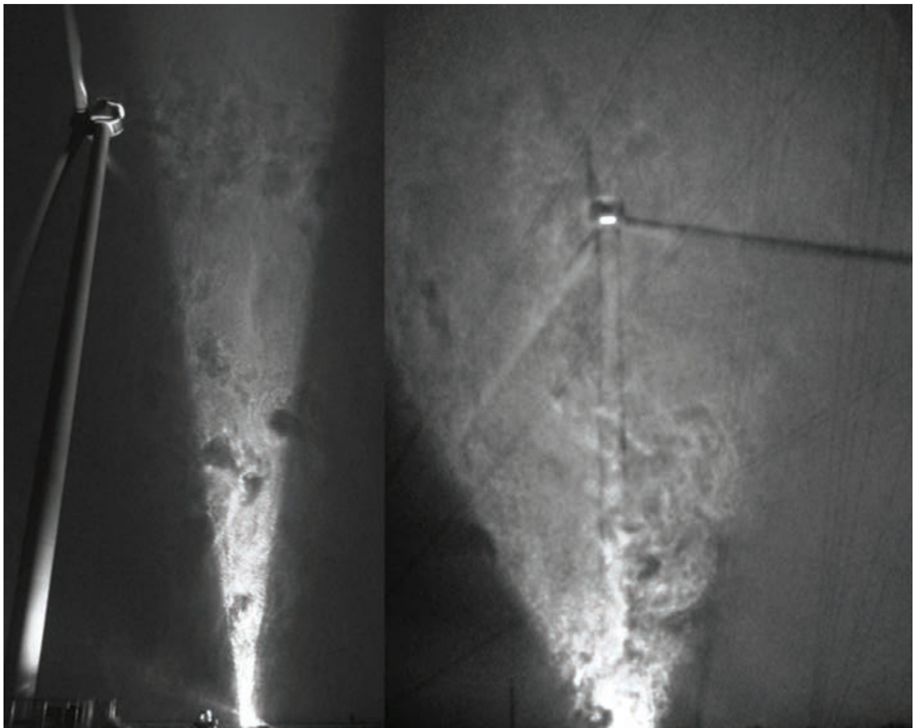
The research team was attempting to study turbulent airflow around a turbine in the field. "You need to find tracers to put in the airflow," Hong said. "It is very easy to do in the lab, but very difficult—if not impossible—to do at the 50- or 100-meter scale."

In a controlled situation, researchers add tracers and photograph the tracers' flow through miniature turbines. Under those conditions, researchers can compare two consecutive images to get an idea of how air travels and impacts other turbines downwind.

But Hong wanted a way to measure the flow from a real turbine. That's when difficulties mount. For example, to be successful, researchers would have to figure out how to inject a large volume of tracers in a way that did not disturb the currents—furthermore, the tracers would need to be environmentally friendly.

"I started thinking about the weather," Hong said. "Minnesota has a lot of snow. Maybe there would be a way to use natural snow." Gradually, after a number of trials and errors, his team figured out a way to characterize airflow motion using snowflakes.

Then he encountered another problem: the uncertainty of weather forecasts. Sometimes a predicted snowfall never arrived as the team waited for



Traces of rich coherent flow structures behind a 2.5-megawatt wind turbine at the EOLOS Wind Energy Research Field Station in Rosemount, Minnesota, are visualized by the snowflakes illuminated in a light sheet parallel (left) and perpendicular (right) to the wind direction. These flow structures include tip vortices and trailing sheet vortices generated from the rotating turbine blades, and the vortices shed from the turbine hub and tower. *Photo by Jiarong Hong and Michele Guala*

up to 6 hours—or came in insufficient quantities to measure. Finally, early in the morning of February 22, 2013, a true blizzard roared in—and the researchers were ready. They had positioned a large searchlight with reflecting optics designed to create a light sheet reflecting off snow particles in an area that was 36 meters wide and 36 meters high.

As the wind drove the snow, researchers videotaped patterns created as the blades of the wind turbine rotated. The turbulent airflow measurements were synchronized with the turbine operational and loading information obtained from the sensors embedded in the EOLOS turbine. "We looked at the video of the snow's motion, and correlated the frames, which showed how the snow was placed and moved in the air," Hong said. "We were able to quantify the turbulence in unprecedented detail at such scale." The team's results were published in the scientific journal *Nature Communications*.

"These measurements are extremely important in our efforts to improve the efficiency of wind energy and develop and validate high-fidelity computational models for optimizing wind farms," said Fotis Sotiropoulos, co-author of the study and director of the St. Anthony Falls Laboratory and the Eolos Wind Energy Research Center. "Who would have ever thought we'd use a Minnesota blizzard to help fight global warming?"

"This research is at a very early stage," Hong said, adding that the team has repeated the study a half dozen times so far, most recently on April 3, 2014. He hopes this research idea can be implemented not only in Minnesota, where snow in May is common, but elsewhere where meteorological conditions are suitable. This method could produce a range of valuable data on turbulent air flows around utility-scale turbines and contribute to better layouts and control strategies of modern wind farms. Such data could also increase energy production and decrease turbine component fatigue from wakes.

As for waiting long hours in the cold only to be disappointed, Hong remains positive: "We're getting more and more experienced," he said. And when the deep freeze returns, he'll be ready for another round of winter—and research.

Sandia National Laboratories Develops Tool for Evaluating Wind Turbine-Radar Impacts

The U.S. Department of Energy (DOE) and Sandia National Laboratories (SNL) are continuing to work toward better integrating new wind turbines with their local environment. One barrier to wind energy installations has been the concern that wind turbines may impact the National Air Space (NAS) radar system. This concern has led to a blanket rejection of several wind farm developments in areas close to NAS radar systems. In an effort to improve the siting and permitting process for wind energy developers looking to build projects within the vicinity of radar systems, SNL is working with BEM International and Peak Spatial Enterprises to develop a Tool for Siting Planning and Encroachment Analysis for Renewables (TSPEAR) toolkit.

The TSPEAR toolkit supports energy developers that wish to design, analyze, and track the progress of wind energy projects. Initially designed to support wind energy development by assessing the interaction between turbines and constraining factors, such as the NAS radar systems, TSPEAR is partially populated with information from existing databases and can integrate custom models and tools used throughout the development process.

TSPEAR includes a graphical user interface that allows developers to combine commercial planning/management capabilities with a model that contains common air route surveillance radars within the contiguous United States (CONUS), airport surveillance radar within the CONUS, and a line-of-sight analysis tool. Combining these resources, TSPEAR allows a developer to evaluate the impacts their proposed project may have on radar systems prior to submitting specific plans for development to government agencies for approval.

SNL is working with the Massachusetts Institute of Technology Lincoln Laboratory to validate the results of TSPEAR against the Interagency Field Test and Evaluation experimental campaigns that measured radar performance over and around several wind farms.

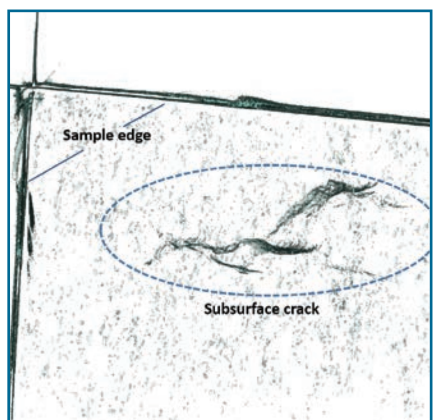
Additionally, SNL plans to further develop TSPEAR to include models of a suite of mitigation technologies for projects that are found to have an impact on a nearby radar system to enable them to evaluate potential options for moving forward with development.

Argonne Researchers Shine 'Light' on Origins of Wind Turbine Bearing Failures

Researchers at the U.S Department of Energy's (DOE's) Argonne National Laboratory (ANL) are investigating the root cause of failures to wind turbine drivetrain components, such as bearings and gears. One of the leading causes of drivetrain reliability issues is a complicated mode of bearing failure known as white-etching cracks (WECs). This failure is characterized by the formation of altered material microstructure near the contacting surface of the bearing raceway that results in cracks and pits that end the useful life of the bearing. Currently, there is no consensus on the cause of WECs and appropriate mitigation methods are still under debate.

ANL researchers are working to "shine some light" on this issue. In fact, they are using one of the brightest light sources in the world to do so.

Aerial photograph of the Advanced Photon Source at Argonne National Laboratory.
Photo from Argonne National Laboratory



A single slice of the three-dimensional subsurface crack network found in a bearing using x-ray micro-tomography (length scale to be added at later date).
Photo from Argonne National Laboratory

ANL's Advanced Photon Source (APS) is the brightest synchrotron x-ray source in the western hemisphere, and is ANL's largest and most heavily used scientific user facility supported by DOE's Office of Science. Of the many measurement techniques available at the APS, x-ray micro-tomography can be used to image internal defects in a part, similar to how a CT scan is used to examine a human body in a doctor's office. However, the APS source is powerful enough to look through hard bearing steel.

Using this micro-tomography capability, ANL researchers have examined several failed bearing pieces provided by their industrial collaborator, the SKF Group, a leading bearing manufacturer. Currently, they have successfully mapped entire subsurface crack networks in three dimensions, which previously could only be done through a destructive two-dimensional serial cross-sectioning technique. The information gained through this examination will provide insights into how the WECs are generated and the cause of their formation. In collaboration with their industrial partners, ANL scientists will apply these results toward identifying and developing appropriate mitigation methods to prevent WEC-related bearing failures.

The results of this work will be presented at the DOE-sponsored Wind Turbine Tribology Seminar, hosted by ANL and co-organized by the National Renewable Energy Laboratory's Gearbox Reliability Collaborative, October 29–31, 2014.

For more information and to register for the 2014 Wind Turbine Tribology Seminar, visit *dis.anl.gov/WTT2014/*

Pacific Northwest National Laboratory Assesses Risks for Marine Vessel Traffic and Wind Energy Development

The nationwide demand for energy is fueling development of sustainable offshore wind resources. To reach the strong and steady offshore wind resources, the Bureau of Ocean Energy Management (BOEM) will lease the seabed on the outer continental shelf for offshore wind farms. But the prospect of offshore wind turbines anchored to the seafloor in the Atlantic Ocean has raised questions about potential risks to commercial shipping traffic as vessels maneuver around the installations. Sponsored by BOEM, and in close coordination with BOEM and the U.S. Coast Guard, the Pacific Northwest National Laboratory (PNNL) has developed an assessment of navigation safety risks, by:

- Processing and filtering transponder data (Automated Identification System [AIS] data) from all commercial shipping on the Atlantic
- Geospatially analyzing the AIS data to determine historical shipping routes
- Developing a data-driven numerical model to predict vessel movements in the presence of offshore wind farms
- Enlisting maritime expertise from an experts' panel of pilots, ship captains, industry experts, and federal agencies
- Assessing the marginal increased navigation risk to ships from the presence of offshore wind farms.

The AIS data set for shipping in the United States is very large (several billion points) and represents a significant challenge to handle and analyze. PNNL researchers extracted information for each of the 20,000+ vessels, including the tonnage, dimensions, horsepower,

Anholt Offshore Wind Farm, Siemens 3.6 MW Offshore Wind Turbines, The Kattegat Strait, Denmark. *Photo by Soren Kjeldgaard, NREL 27891* displacement, and routes travelled by the ship over a 3-year period. Beginning with methodologies developed for wind farms and shipping in the United Kingdom, PNNL developed new geospatial analytical tools to determine the commonly traveled routes among the 28 major ports on the Atlantic, displaying them as geographic information system layers. Using the AIS data and geospatial routing, a numerical model was developed that moves ships in a realistic manner for the base case (present conditions with no wind farms) and the future case (with planned wind farms). Each case was also run as scenarios with confounding conditions, such as hurricanes or Nor 'Easters, with loss of propulsion of one or more ships. For the base case, the model maneuvers ships around other vessel traffic, existing hazards, and moves them in and out of ports. The future case with wind farms adds maneuvering of ships around the wind farms, as well as avoiding other ships funneled into the same waters. The rules of road, as practiced by mariners, are incorporated into the model to enable the ships to behave as they would in the real world.

The Atlantic fleet of commercial vessels was parsed into three major categories: cargo, tankers, and tug/towing. Each vessel type has individual characteristics for routing in and out of ports and individual challenges when maneuvering around wind farms. Cargo and tanker vessels cannot change course or slow rapidly, and they need deep draughts for entering harbors. Tugs and towing vessels come in many different configurations that include large articulated tugs, strings of several barges towed by catenary wire by one tug, and "wing and ground" configurations of tugs pushing perpendicular to barges. The model generally sends tug and towing vessels inshore to avoid wind farms, while cargo and tanker vessels go further out to sea.

PNNL researchers are continuing to refine the model, improving the realism of ship routing and encounters. The preliminary study results indicate that the presence of wind farms on the Atlantic coast could increase the risk of vessels coming within one half mile of one another (an "encounter") by approximately 12% and groundings caused by avoidance of wind farms could increase by less than 1%. It is likely that the increased risk of encounters between ships will drop as further refinements are added to the model, including improved route planning, as would be expected by large shipping companies, and more detailed bathymetry of the coastal areas. These improvements will raise confidence in the predictive capability of the model and allow it to act as a better tool for evaluating the safety of wind farm installations.

International Effort Advances Offshore Wind Turbine Design Codes

For the past several years, the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) has teamed with the Fraunhofer Institute for Wind Energy and Energy System Technology (IWES) in Germany to lead an international effort under the International Energy Agency's (IEA's) Task 30 to improve the tools used to design offshore wind energy systems.

The computer-aided engineering tools used to design offshore wind systems are based on the same design tools used for land-based wind turbines. Land-based design tools use aero-servo-elastic codes, which incorporate aerodynamic (aero), control system (servo), and structural-dynamic (elastic) models; however, because offshore wind turbines are installed in marine environments, they require modeling tools that can also consider the hydrodynamic loads on a variety of substructure types as well as their mooring systems. To design these systems, engineers need design codes that can simulate incident waves, sea current, hydrodynamics, foundation dynamics of the substructure, and mooring loads and dynamics. The complex nature of the design codes required for these systems underscores the need to verify and validate their accuracy.

The purpose of the IEA Task 30 Offshore Code Comparison Collaboration Continuation (OC4) project is to verify the accuracy of these design codes through code-to-code comparisons. For the last phase of the OC4 project, the research teams ran analyses using a reference model based on a 5-megawatt turbine on a floating semisubmersible foundation. Twenty-one organizations from 11 countries submitted results using 19 different simulation codes for this phase. In June, NREL hosted a meeting in conjunction with the Ocean, Offshore, and Arctic Engineering Conference in San Francisco, California, to present the final results of the OC4 project and launch the next phase of this important research effort. Thirty-two people from around the world, representing universities, laboratories, and commercial companies, attended the meeting.

Although the results of the code-to-code comparisons contribute to a greater understanding of the dynamics of offshore floating wind energy systems and the techniques used for modeling them, the code comparisons only identified differences—they did not determine which solution is the most accurate. To address this limitation, IEA launched an extension of the OC4 project: Offshore Code Comparison Collaboration Continuation, with Correlation (OC5). The focus of this project is to validate offshore wind modeling tools through the comparison of simulated responses to physical response data from actual measurements. This project will examine three structures using data from both floating and fixed-bottom systems, and from both scaled tank testing and full-scale, open-ocean testing.

Read more about the results of the OC4 code-to-code comparison effort in Offshore Code *Comparison Collaboration Continuation Within IEA Wind Task 30: Phase II Results Regarding a Floating Semisubmersible Wind System* at *nrel.gov/docs/fy14osti/61154.pdf*

Sandia National Laboratories Releases Updated Wind Plant Modeling Guidelines

Sandia National Laboratories (SNL), in collaboration with the Western Electricity Coordinating Council's (WECC's) Renewable Energy Modeling Task Force (REMTF), has released an updated version of the *WECC Wind Plant Dynamic Modeling Guidelines* for the second generation of generic wind turbine generator models. These positive-sequence power flow and dynamic models are routinely used for simulation and planning of power system networks. The North American Reliability Corporation, the nation's electric reliability watchdog, has stated that developing and improving access to validated, nonproprietary models is a prerequisite for large-scale integration of variable generation.

The second generation of generic wind turbine generator models was developed and approved by the WECC Modeling and Validation Working Group. The new versions of the models incorporate a modular approach. That is, the models are made up of smaller modules that are truly generic and usable for any appropriate renewable generation system. This format allows for additional versions to be developed for each module as changes are deemed necessary in the future. These models have been implemented in General Electric's Positive Sequence Loadflow software, Siemens Power Technologies International Power Transmission System Planning software, and PowerWorld's power system simulation software.

SNL has been actively involved in the development of these models through the REMTF, is the current chair of the task force, and is an active participant in a similar ongoing effort by the International Electrotechnical Commission.

Read the updated *WECC Wind Plant Dynamic Modeling Guidelines at www.wecc.biz/library/WECC%20Documents/Forms/DispForm.aspx?ID=3388*

National Renewable Energy Laboratory Identifies Research Needed to Address Power Market Design Challenges

A new report by the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) identifies research opportunities to improve the ways in which wholesale electricity markets are designed, with a focus on how the characteristics of variable generation from wind and solar power can affect those markets. The report states that because power systems are planned and operated so that they are closely tied to market designs, improvements in the designs of wholesale electricity markets could also improve the reliability and efficiency of the power system.

Evolution of Wholesale Electricity Market Design with Increasing Levels of Renewable Generation identifies a number of potential market impacts caused by increasing penetrations of variable generation. In North American market design, energy is sold in day-ahead markets and balanced in 5-minute real-time markets. The team reviewed several historical approaches to meeting two of the most critical and complicated market design challenges: 1) revenue sufficiency for long-term reliability; and 2) providing incentives for short-term operational flexibility. The team also looked at how those approaches have evolved in recent years. According to the report, this evolution is due, in some part, to increased penetrations of variable generation.

Most in the electric power industry agree that these challenges must be met. Although there are regional differences, there is a general standardized market design for the nine independent system operator and regional transmission operator market regions in North America; however, there is much debate about the way in which each market has met the challenges and whether or not additional modifications to the market designs are necessary to ensure that the challenges will continue to be met. Within the United States, each market is evolving differently. Some markets have undergone significant changes. Other markets have remained relatively unchanged, possibly because the current design has been determined to have already met these challenges sufficiently. These differences may exist because each system is so different, with various generating portfolios, economies, transmission networks, and regulatory philosophies.

The report examines the ways in which the industry has historically or recently been making changes to wholesale electricity market designs to meet the challenges of revenue sufficiency and flexibility incentives. From this analysis, the team came up with a number of suggested research areas the industry should focus on to improve the ways in which the markets are designed to meet these challenges.

Although the report presents the two challenges independently from one another, it also states that they are linked. Flexibility may become the more significant factor for ensuring power system reliability in future systems, and linking reliability requirements between the short term and the long term is crucial. In addition, the way in which revenues and incentives are designed in the short-term markets can dictate how they must be designed in the long-term markets. Maintaining a link between the short-term and long-term incentives and reliability needs, the report says, must be considered when performing this research.

Read the full report at *nrel.gov/docs/fy14osti/61765.pdf*

Wind Events

American Wind Energy Association Offshore WINDPOWER 2014 Conference & Exhibition

Atlantic City Convention Center

Atlantic City, New Jersey—October 7–8, 2014

awea.org/Events/Event.aspx?EventID=18548

Utility Variable Generation Integration Group Fall Technical Workshop

San Antonio, Texas—October 15–17, 2014

variablegen.org/events/#!/6019/fall-technical-workshop

Distributed Wind All-State Policy Summit and Strategies for Manufacturers Advancing Research and Technology Wind Launch

Albany, New York—October 15–16, 2014

energy.gov/eere/wind/events/distributed-wind-all-state-policy-summit-and-strategies-manufacturers-advancing-research

American Wind Energy Association Wind Energy Finance & Investment Seminar

New York, New York—October 20–21, 2014

awea.org/events/event.aspx?eventid=27119

Wind Turbine Tribology Seminar

Argonne National Laboratory

Argonne, Illinois—October 29–31, 2014

dis.anl.gov/WTT2014/

Women of Wind Energy Leadership Forum

San Diego, California—November 18, 2014

womenofwindenergy.org/leadership-forum.html

AWEA Wind Energy Fall Symposium

San Diego, California—November 18–20, 2014

awea.org/Events/Content.aspx?ItemNumber=6607

Photo front cover: Principle Power's WindFloat Prototype (WF1)

Principle Power's floating foundation, WindFloat, provides siting of offshore wind turbines in water depths greater than 40 m and without the use of heavy-lift vessels. *Photo from Principle Power, NREL 23116*

Stay current on important wind energy events around the United States by subscribing to the Wind Program Newsletter by email. *wind.energy.gov/subscribe.html*

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