NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Up to Wind Speed

December 2011 Newsletter

Up to Wind Speed is a quarterly newsletter from the U.S. Department of Energy's National Wind Technology Center (NTWC) at the National Renewable Energy Laboratory (NREL).

For more than two decades, research conducted by NREL's Wind Program has helped industry advance wind energy technology, increasing reliability and lowering the cost of energy. Each quarter, the newsletter keeps you up to speed on what's happening in wind energy research and development and provides you with links to the NWTC's recent publications.

Articles in this issue:

NREL Leads Offshore Wind Research and Development

In support of DOE's offshore wind research and development strategic area, NREL is using its expertise to address the critical needs of the nation's burgeoning offshore wind industry, including:

- Developing and improving new computational tools and assessing turbine systems

NREL is developing a modular framework for its design tools. Modularizing the design tools and developing standardized interfaces enables the development of innovative, lower-risk, and higher-performing offshore turbine technologies. Data from several projects will be integrated into the tools.

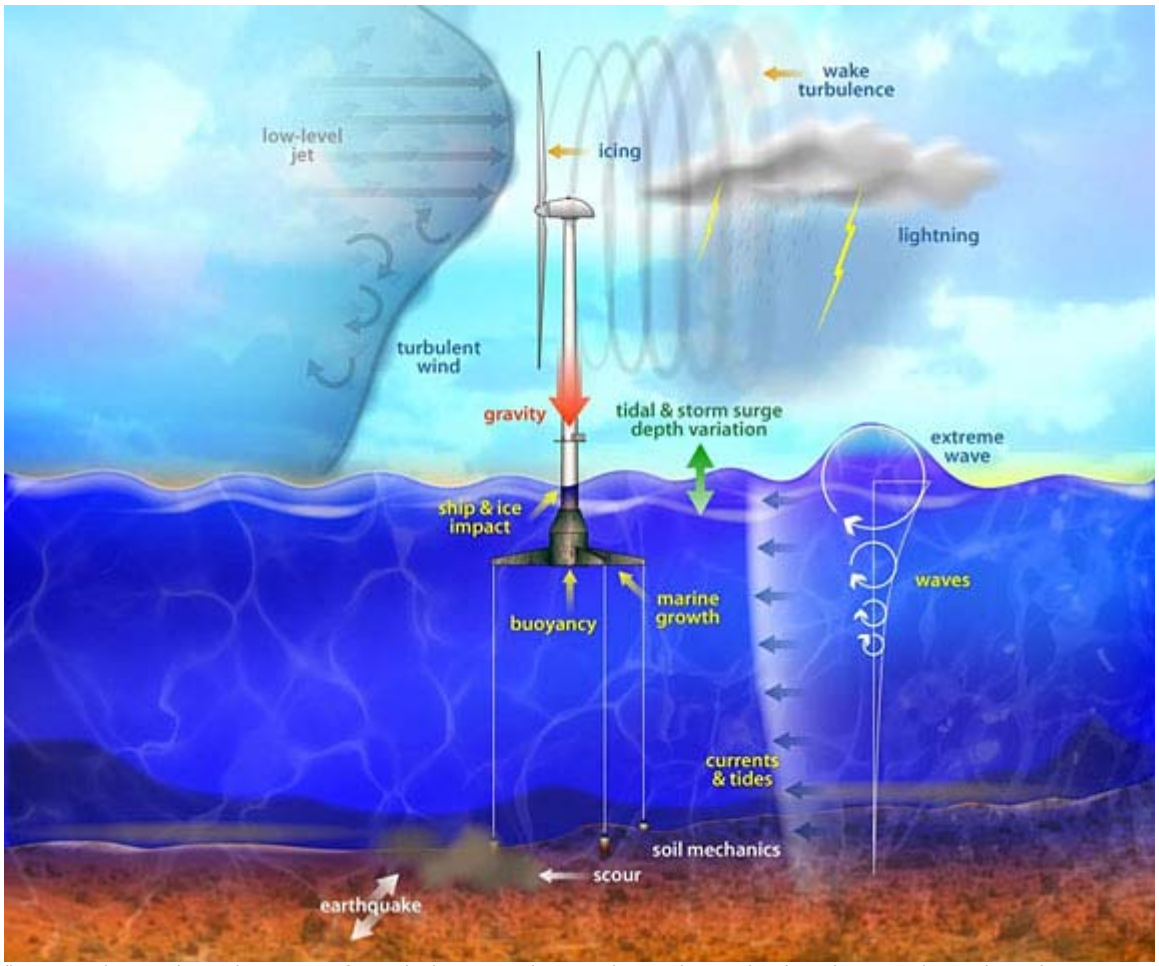


Illustration depicts the sophistication of aero-hydro-servo-elastic codes used in wind turbine design analysis. The codes incorporate wind-inflow, aerodynamic (aero), control system (servo), and structural-dynamic (elastic) models in the time domain in a coupled simulation environment. In recent years, some of these codes have been expanded to include the additional dynamics pertinent to offshore installations, including incident waves, sea current, hydrodynamics, and foundation dynamics of the support structure.

For example, NREL assessed the dynamic performance of six different floating wind platform designs. The results detailed the design trade-offs of different approaches for stabilizing a floating wind turbine, and assessed the increased loads seen in a floating wind turbine, as compared to a land-based one. The measurement data from tests are currently being used to validate the NREL-developed offshore wind turbine modeling tool, FAST. FAST uses Morison's equation to represent the hydrodynamic loading of waves on thin structures, an approach commonly used by many offshore hydrodynamic modeling tools. NREL is examining the effectiveness of this approach for estimating the wave load on multi-member structures.

In another project, NREL partnered with the University of Maine on the DeepCwind project, as part of its work assessing the feasibility of offshore turbine systems. The DeepCwind project will deploy the first floating wind turbine in the Western Hemisphere, and the first wind turbine on a tension leg platform deployed in the world.

- Participating in international projects to collect and analyze data

NREL recently initiated two new partnerships for international demonstration projects. NREL is working with Principle Power, who deployed the WindFloat project in Portugal. WindFloat is a floating support structure for offshore wind turbines designed for turbines that have a rated capacity of 3-10 MW. The design dampens wave and turbine induced motions, enabling wind turbines to be sited in previously inaccessible locations where water depth exceeds 50m and wind resources are superior. NREL is partnering with SWAY in Norway. Plans are underway to build the world's largest turbine standing 533 feet tall, with a rotor diameter of 475 feet, a gearless generator system, and a rated capacity of 10 MW. SWAY deployed a 1/5 scale prototype in Norway. Under both collaborations, NREL will

help collect and analyze test data.

- Developing cost and economic models to help evaluate new technology, such as floating systems

Through a shared resources CRADA, NREL and the University of Delaware authored the report, *Pricing Offshore Wind Power*. The report is an important reference for agencies and policymakers who seek to understand market conditions for offshore wind projects. The paper highlights the interaction of costs, incentives, and policy programs, and the requirements for financial viability. The report is published in the journal, *Energy Policy*.

- Providing published strategic and collaborative R&D reports that inform policy decisions

NREL produced the report, A National Offshore Wind Strategy: Creating an Offshore Wind Energy Industry in the United States, which examines the goals for offshore wind deployment and cost reduction outlined in DOE's National Offshore Wind Strategy. The Offshore Code Comparison Collaboration (OC3) for IEA Task 23 Offshore Wind Technology and Deployment, was published by NREL, under the now completed IEA Wind Task 23 OC3 project.

NREL's research and collaborations will advance the industry's ability to verify and validate wind turbine dynamics codes, document model benefits and deficiencies, and identify needed improvements.

Eastern Grid Integration Studies — What's Next?

The Eastern Wind Integration and Transmission Study (EWITS) results will be leveraged for further investigation in the Eastern Renewable Generation Integration Study (ERGIS).

Geographic area of the earlier EWITS project. The Eastern Interconnection provides power to more than 70% of the U.S. population.

ERGIS will evaluate approaches for system planning and operations in the face of generation and transmission uncertainty, the potential impact of greater inter-regional cooperation, the use of demand response technologies (e.g., plug-in vehicles and storage), as well as the impact of geographic diversity and inter-hour scheduling.

ERGIS topics will include reserves analysis, regional and inter-regional impacts, mitigation strategies (e.g., demand response, storage, curtailment), and sensitivity analysis (e.g., transmission, emissions, fuel cost). These will be addressed under three separate tasks.

Task 1 of the ERGIS project will engage stakeholders to identify the desired study scenarios (e.g., renewable penetration levels) and develop the necessary wind, load, and potentially solar, databases. Aspects of this task will include specifying the number of analysis scenarios and study year, updating EWITS wind forecasts and actuals, development of solar data for the Eastern integration, identifying base load growth and other assumptions, identifying renewable generation penetration levels, and defining zones, regions, and balancing areas.

Task 2 of the project includes significant new analysis of operating and reserve strategies not previously addressed. It will investigate various reserve strategies and ramping requirements via statistical analysis, and examine the impact of cooperation and reserve sharing on different types of reserve requirements. This task also includes an evaluation of the impact of renewable generation aggregation on the overall ramping requirements in different time frames, as well as the impact of sub hourly scheduling.

The last task will place additional emphasis on planning and operating the Eastern Interconnection in an uncertain future, building on the original EWITS, rather than replicating it. This requires the enhancement of operational flexibility, evaluating sensitivity cases, and ensuring the capability to perform additional analysis in the future. To meet this need, the study will use a new model on the Plexos software platform, including the development of Plexos production simulation databases, analysis, and capabilities. The new platform offers production simulation analysis to further examine the impact of high levels of renewable generation on various reserve sharing approaches, regional results, system robustness, and mitigation strategies (e.g., demand response and storage).

ERGIS is co-funded by the DOE Office of Electricity Delivery and Energy Reliability (OE) and the EERE Wind and Water Technologies Program, and will include stakeholder engagement to identify the desired study scenarios, the investigation of various reserve strategies and ramping requirements via statistical analysis, the examination of the impact of cooperation and reserve sharing on different types of reserve requirements, and an evaluation of the impact of sub hourly scheduling.

5 MW Dynamometer Ground Breaking

The dedication ceremony for the new 5 MW dynamometer upgrade facility took place at the National Wind Technology Center on September 16. When complete, the new facility will more than double the wind turbine drivetrain testing capacity (in terms of rated power) at the NWTC.

Ground breaking ceremony for the 5-MW Dynamometer Upgrade held at the NWTC on September 16, 2011. Shown left to right: Fort Felker, Mike Derby, Robert Hawsey, and Jim Green.

The upgraded dynamometer will be able to test the largest wind turbine drivetrains used in land-based markets. Its capability to simulate wind loads in six degrees-of-freedom will provide the most complete simulation of wind turbine operating conditions available in North America. In addition, the new facility will have the ability to simulate the grid connection to test low-voltage ride-through capability, and response to faults and other abnormal grid conditions. This upgrade is a $9,950K American Recovery and Reinvestment Act project, which has been underway since FY2009. Construction and commissioning of the facility will be completed in June of 2012.

NAWEA Scoping Workshop

The first organizational meeting to form the North American Wind Energy Academy (NAWEA) was held in November. The academy will be a virtual organization bringing together expertise and experience not found in a single institute. NAWEA's vision is to be the world leader in wind energy scientific research and education for high penetration wind technology development and deployment. NAWEA's role will include facilitating a national effort for comprehensive long term, high risk, multidisciplinary, multi-institutional research and education for wind energy.

Under the joint sponsorship of NREL, NOAA, NCAR, Renewable and Sustainable Energy Institute (RASEI-University of Colorado Boulder), with participation by industry and other universities from across the country, this scoping workshop had the goal of defining an organization that can bridge institutional, and governmental dividing lines to facilitate the large-scale deployment of wind generating capacity in the United States.

The workshop also examined opportunities for crosscutting research in the areas of turbine and wind farm technology, grid integration, atmospheric science, social acceptance, policy, and wind energy education. The workshop tapped the experience of the attendees to craft the organizational goals, mission, structure, and operational model for NAWEA.

2011 Wind Turbine Condition Monitoring Workshop

The 2011 Wind Turbine Condition Monitoring workshop, held September 19-20 in Broomfield, CO, explored current wind turbine drivetrain condition monitoring (CM) techniques and structural health monitoring (SHM) for wind turbine drivetrains, blades, and primary support structures. The workshop's objective was to pinpoint future research and development areas.

Exploded view of the GRC test gearbox used for the CM round robin project.

Areas of primary interest were failure modes, sensing, diagnostics, prognostics, data mining, and asset management techniques. More than 46 presenters discussed the science and commercial wind industry application of:

- Current CM practices
- European perspective
- Drivetrain monitoring
- Lubricant conditioning and monitoring
- SHM of wind turbines
- R&D in CM & SHM
- CM practices in other industries

Workshop speakers and more than 150 participants represented a broad range of entities and expertise, including governmental agencies, consulting companies, owners and operators, condition monitoring equipment or solution suppliers, maintenance service providers, filtration system suppliers, lubricant sensing and analyzing parties, wind farm developers, and universities and research institutes in the United States, Europe, and Australia.

The final day of the three day workshop focused on the CM round robin project, which was launched by NREL in early 2011. The main objective of this project is to evaluate different vibration analysis algorithms used for vibration-based wind turbine CM and determine whether the typical practices used by the CM community are effective. Another objective is to assess vibration-based CM capabilities and to establish a baseline from which improvements can be measured. Under this project, research partners from three continents analyzed vibration data collected by NREL from a damaged gearbox. Set up as a blind study, partners analyzed the same gearbox data using their techniques. Then, they received the actual failure information from the test gearbox. Many of the partners presented their analysis algorithms and results at the workshop. See the workshop presentations on the 2011 Wind Turbine Condition Monitoring Workshop website.

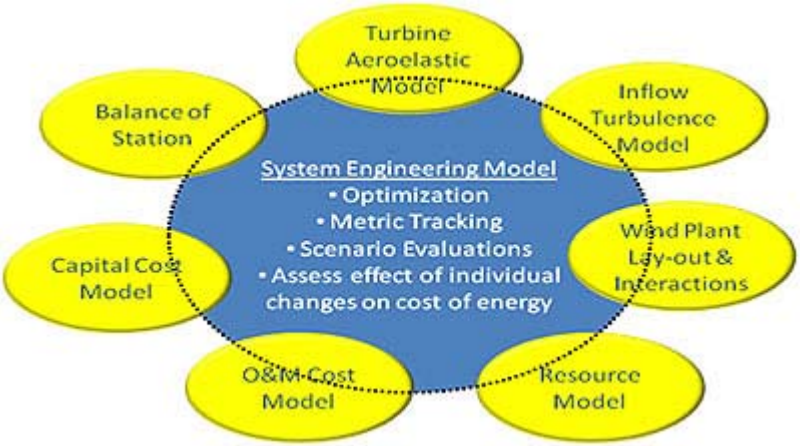
An NREL report details Wind Turbine Drivetrain Condition Monitoring during GRC Phase 1 and Phase 2 Testing.

Applying a Systems Engineering Approach to Wind Energy

A soon-to-be published NREL white paper, Applications of Systems Engineering to the Research, Design, and Development of Wind Energy Systems, details the benefits of a systems engineering approach to wind turbine RD&D.

The white paper reviews the set of design drivers that traditionally are considered when looking at wind plant cost of energy including all of the turbine's components, individual

wind turbines, and the interactions between them, as well as balance of station and operations and maintenance. Using a systems engineering approach, the paper incorporates design objectives and methods related to the entire wind energy system — including grid interaction, and community and environmental impacts. It surveys the landscape of systems engineering methods and catalogues existing system design tools. Then, it provides an overview of how the existing set of design tools, and known future tool extensions, may be coupled together within a systems engineering design and development framework.



The paper concludes that Systems Engineering shows significant potential for addressing wind plant and wind turbine system design challenges. It will be a useful framework and tool for guiding and coordinating wind energy research and design activities.

Gamesa Installs 2 MW Wind Turbine at NWTC

At a hub height of 90 meters and a rotor diameter of 97 meters, the Gamesa turbine installed at the NWTC is part of an agreement between NREL and Gamesa to conduct research, development, and testing.

The September installation of the 2 MW Gamesa G97 wind turbine brings the number of multimegawatt turbines at the nation's premier wind testing facility to four.

Cranes installed the Gamesa wind turbine rotor at the NWTC in September. *NREL/PIX 19777.*

Recent NWTC Publications

- Aerodynamic and Performance Measurements on a SWT-2.3-101 Wind Turbine
- Allocating Reserve Requirements (Presentation). NREL (National Renewable Energy Laboratory).
- Alstom 3-MW Wind Turbine Installed at NWTC (Fact Sheet). NREL Highlights, Research & Development, NREL (National Renewable Energy Laboratory). (2011).
- Building a New Energy Future with Wind Power (Fact Sheet). Wind and Water Power Program (WWPP).
- Capacity Value of Wind Plants and Overview of U.S. Experience (Presentation). NREL

(National Renewable Energy Laboratory)

- Challenges in Simulation of Aerodynamics, Hydrodynamics, and Mooring-Line Dynamics of Floating Offshore Wind Turbines
- Department of Energy Awards $43 Million to Spur Offshore Wind Energy, Wind Program Newsletter, September 2011 Edition (Brochure). Energy Efficiency & Renewable Energy (EERE). (2011)
- Deployment Barriers to Distributed Wind Energy: Workshop Report -- October 28, 2010. (2011).
- Dynamic Models for Wind Turbines and Wind Power Plants
- Establishment of Small Wind Turbine Regional Test Centers (Presentation). NREL (National Renewable Energy Laboratory).
- Flexibility Reserve Reductions from an Energy Imbalance Market with High Levels of Wind Energy in the Western Interconnection
- Gearbox Reliability Collaborative Bearing Calibration
- Gearbox Reliability Collaborative - Phase 1 and 2 Overview (Presentation). NREL (National Renewable Energy Laboratory).
- Impact of High Wind Power Penetration on Hydroelectric Unit Operations: Preprint.
- Investigation of a FAST-OrcaFlex Coupling Module for Integrating Turbine and Mooring Dynamics of Offshore Floating Wind Turbines: Preprint.
- Investigation of Various Wind Turbine Drivetrain Condition Monitoring Techniques (Presentation). NREL (National Renewable Energy Laboratory).
- Jobs and Economic Development Impacts (Postcard). Wind Powering America (WPA), Energy Efficiency & Renewable Energy (EERE). (2011).
- Loads Analysis of Several Offshore Floating Wind Turbine Concepts
- LIDAR Wind Speed Measurement Analysis and Feed-Forward Blade Pitch Control for Load Mitigation in Wind Turbines: January 2010—January 2011
- Market Design Simulations with Variable Energy Resources (VERs) (Presentation). NREL (National Renewable Energy Laboratory).
- NREL Computer Models Integrate Wind Turbines with Floating Platforms (Fact Sheet). The Spectrum of Clean Energy Innovation, NREL (National Renewable Energy Laboratory). (2011).
- NREL Gearbox Reliability Collaborative: Comparing In-Field Gearbox Response to Different Dynamometer Test Conditions: Preprint.
- NREL Triples Previous Estimates of U.S. Wind Power Potential (Fact Sheet). The Spectrum of Clean Energy Innovation, NREL (National Renewable Energy Laboratory). (2011).
- NREL Variability Analysis for the Western Interconnect (Presentation). NREL (National Renewable Energy Laboratory).
- Offshore Renewable Energy R&D (Fact Sheet). National Wind Technology Center (NWTC), NREL (National Renewable Energy Laboratory)
- Operating Reserve Implication of Alternative Implementations of an Energy Imbalance Service on Wind Integration in the Western Interconnection: Preprint.

- Operating Reserves and Variable Generation. A comprehensive review of current strategies, studies, and fundamental research on the impact that increased penetration of variable renewable generation has on power system operating reserves.
- Stakeholder Priorities in Wind Energy (Presentation). NREL (National Renewable Energy Laboratory)
- State of the Art in Floating Wind Turbine Design Tools
- Structural Design of a Horizontal-Axis Tidal Current Turbine Composite Blade
- Transmission Considerations for Market Operation: U.S. Design (Presentation). NREL (National Renewable Energy Laboratory).
- Use of SCADA Data for Failure Detection in Wind Turbines
- Western Renewable Energy Zones (Presentation). NREL (National Renewable Energy Laboratory).
- Wind Economic Development (Postcard). Wind Powering America (WPA), Energy Efficiency & Renewable Energy (EERE). (2011).
- Wind Energy Forecasting: A Collaboration of the National Center for Atmospheric Research (NCAR) and Xcel Energy
- Wind Energy Ordinances (Postcards). Energy Efficiency & Renewable Energy (EERE). (2011).
- Wind Integration Study Methods (Presentation). NREL (National Renewable Energy Laboratory).
- Wind Turbine Drivetrain Condition Monitoring - An Overview
- Wind Turbine Drivetrain Condition Monitoring During GRC Phase 1 and Phase 2 Testing
- Wind Turbine Drivetrain Condition Monitoring (Presentation). NREL (National Renewable Energy Laboratory)
- Wind Turbine Generator System Power Quality Test Report for the Gaia Wind 11-kW Wind Turbine.