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

WIND ENERGY TECHNOLOGIES OFFICE

Commercial Technologies and Products Supported by the Wind Energy Technologies Office

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Advanced Manufacturing and Supply Chain Automation

Commercial Technology

Support System Expands Manufacturing Capacity

Domestic production of wind turbines can yield high quality products for use in the growing U.S. wind power industry. Small turbine manufacturing in particular represents a market segment that could experience increased growth as domestic production cost decreases. However, producing high quality turbines often requires extensive assembly line testing, quality checks, and highly skilled workers. The combination of these requirements increases unit cost and decreases potential market growth.

Northern Power Systems, Inc. (NPS), with assistance from the Department of Energy's Wind Energy Technologies Office, as part of the Competitiveness Improvement Project (CIP), has developed a comprehensive manufacturing support system that reduces the turbine unit cost and improves manufacturing and production capacity. NPS's system improves many aspects of turbine manufacturing, ranging from vendor quality integration to product warranty support. This system was implemented at a test facility and has since been shared among NPS's manufacturing partners to reduce turbine cost and enable market growth.

A new NPS licensed product design begins with a NPS team of engineers and support staff who assist with transferring the new product design to manufacturing. This allows the manufacturing partners to reduce the time required for retooling and design changes to aid manufacturing. NPS then assists partners with optimizing the production process and maintaining product quality specifications at a minimum cost. Factory training and certification is available to partners who will be performing maintenance on NPS products. Training encompasses general maintenance, new installation procedures, and warranty-level services.



Northern Power Systems' NPS 100C

Overview

- Developed by Northern Power Systems, Inc.
- Commercialized in 2014.

Applications

Can expand manufacturing capacity of NPS partners and reduce the cost associated with product manufacturing.

Capabilities

- Allows partners to train employees to be certified in product installation and maintenance.
- Reduces product manufacturing time.
- Provides a support team to assist with implementation of the technology.

Benefits

Productivity

Optimizes the manufacturing process by providing support to manufacturing partners to implement new designs and reduce time to market.

Cost Savings

Reduces product cost by providing assistance from the introduction of a new product design to the manufacturing facility's production start-up.

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Advanced Methods for Predicting 3D Unsteady Flows Around Wind Turbines

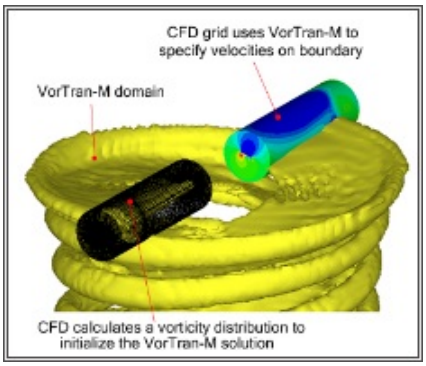
Commercial Technology

Turbine Modeling Software Increases Product Life and Efficiency

Adoption of renewable power sources is an important step to reducing U.S. dependence on fossil fuels and improving environmental conditions. Wind represents a prominent fraction of renewable energy with a total installed capacity of approximately 75 gigawatts in 2015.[1] Despite its large fraction of the renewables industry, wind power suffers from high long-term maintenance costs caused by unsteady loading and wake interactions, among other reasons. Both issues are identified as fluid structure interactions (FSI) and have yet to be characterized fully due to poor modeling of FSI. Failure to mitigate these issues or develop an FSI model in the future could lead to increased renewable energy costs or a cost-related depression of wind growth.

Continuum-Dynamics, Inc. (CDI), with industry partners and assistance from the Wind Energy Technologies Office, in the form of Small Business Innovation Research and Small Business Technology Transfer grants, has developed a 3D model to assist with the development of quieter, more efficient and durable wind turbines. CDI has applied their VorTran-M modular computational fluid dynamics (CFD) solver to resolve the numerical diffusion issues associated with unsteady Reynolds averaged Navier-Stokes (2D URANS) methods. The software analyzes wind turbine motion and resulting airflow to capture near-body wakes as well as FSI and noise by coupling computational structural dynamics (CSD) and acoustics modelling codes. VorTran-M is capable of resolving the fully-coupled structural and fluid dynamics equations to offer extended usability for turbine designers.[2] CDI's model incorporates fully unstructured Navier-Stokes (FUN3D) and includes features that allow VorTran-M to be coupled with other CFD methodologies, e.g. Large Eddy Simulation (LES), CSD and acoustics codes. Such coupling may reduce development time and internal resource costs for future projects.

CDI continues to develop their model, focusing on generalization of the FUN3D/VorTran-M coupling interface to support additional flow solvers, improving interface boundary conditions and parallel computation methods. CDI is also developing an interface that supports an arbitrary number of modeling grids and moving surfaces.



Schematic of VorTran-M-CFD coupling

Overview

- Developed by Continuum-Dynamics, Inc. and the Georgia Institute of Technology.
- Commercialized in 2014.
- Currently focused on extending, generalizing and hardening the numerical methods and coupling methodology.

Applications

Can be used to model FSI and assist with turbine development.

Capabilities

- Allows users to couple VorTran-M with URANS and LES methodology.
- Supports hybrid URANS-LES flow modeling.
- Improves design process for concept turbines.

Benefits

Cost Savings

Reduces cost by rapid coupling of VorTran-M with URANS or LES methodologies.

Productivity

Optimizes wind turbine design by providing tools with which to model FSI.

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[1] EERE WINDExchange Installed Wind Capacity
[2] Advanced Methods for Predicting 3D Unsteady Flows Around Wind Turbine Blades, Continuum-Dynamics, Inc., March 2011

DigitalClone®: Wind Turbine Health Monitoring Systems

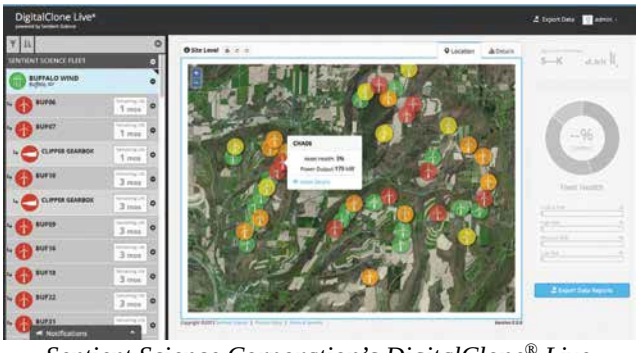
Commercial Technology

Digital Simulation Software Offers Predictive Maintenance Solution

Following the announcement of the U.S. Department of Energy (DOE) goal of 20 % wind energy by 2030[1], extensive government funding programs have been used to jumpstart the American wind industry. The result has been the development of a robust wind sector that has seen over 150 % growth since the 2008 DOE announcement and 2014.[2] Development of turbines has accompanied wind energy growth in the U.S. resulting in high efficiency wind towers that may enable DOE goals to be met. However, the costs and lifetime reductions caused by unrefined maintenance practices could prevent widespread success of the wind industry.

To address maintenance issues Sentient Science Corporation, with assistance from the Wind Energy Technologies Office, the National Aeronautics and Space Administration (NASA), in the form of Small Business Innovation Research (SBIR) grants, and the State University of New York at Buffalo (SUNY Buffalo), has developed DigitalClone®. DigitalClone is a predictive model used to anticipate maintenance issues and allow engineers to find solutions to forecasted issues without running physical tests. This allows engineers to anticipate when and where products will fail and generate solutions and plan accordingly to rectify these problems. Digital testing allows several thousand tests to be performed over the course of a few days rather than currently spending considerably longer to only get a few data points. DigitalClone allows real-time tracking of hardware operating conditions and suggests improvements to equipment conditions based on component wear forecasting. Validation by NASA, Boeing, the Department of Defense, and British Petroleum has indicated that DigitalClone is able to accurately predict component wear including component interactions with the entire system.

Sentient Science was awarded a 2014 SBIR Tibbetts Award in recognition of their achievements. DigitalClone has been successfully deployed to eight of the major wind operators in the U.S., was used on the Hubble Telescope, and was used to develop several aircraft for the Air Force and Navy. Sentient Science has partnered with SUNY Buffalo to provide either one time services or extended licensing to clients using SUNY Buffalo's 8K processor cloud-oriented server infrastructure.



Sentient Science Corporation's DigitalClone® Live.

Overview

- Developed by Sentient Science Corporation, NASA, and SUNY Buffalo.
- Commercialized in 2013.
- Currently expanding market efforts to other industries.

Applications

Can be used to predict and resolve maintenance issues digitally.

Capabilities

- Allows prediction of product life, maintenance cost, lubrication requirements, and life span.
- Provides a reliable low-cost testing option for new part designs.

Benefits

Cost Reduction

Reduces testing time and cost by up to 90 % using digital modeling.

Efficiency

Allows product designers to analyze potential designs without manufacturing a prototype.

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[1] 2014 Wind Vision, U.S. DOE, April 2015
[2] Predicting Wind Power with Greater Accuracy, LLNL, April 2014

Distributed Wind Research, Development and Testing

Commercial Technology

Distributed Wind Research Reduces Small Turbine Costs

The U.S. energy grid is continuously experiencing rapid growth in wind energy use with the first quarter of 2016 representing the strongest growth of wind power installations since 2012.[1] Roughly a third of these installations, by megawatt, were contracted by either government agencies or large corporations. While wind power growth is strong in these sectors, small turbine sector growth is prevented because of a lack of available technology, which increases installation cost for small scale turbine owners. In an effort to encourage small to medium wind turbine use in the U.S., the Department of Energy (DOE) has initiated a program to increase the number of certified small turbines from zero to forty by 2020.

In collaboration with small businesses and with assistance from DOE's Wind Energy Technologies Office, as part of the Competitiveness Improvement Project (CIP), the National Renewable Energy Laboratory (NREL) is supporting the development and certification of new small wind turbines. To improve the development of these turbines, NREL has established four testing centers to form the Small Wind Region Test Center whose results can used by the Small Wind Certification Council. Each of the four regional centers is used to provide standardized testing for new turbine designs to allow manufactures to communicate accurate information to consumers, utilities, lenders, and policy makers. The certification council provides accredited third party verification of testing results based on internationally-adopted technical standards. This support capacity is coupled with a competitiveness improvement project (CIP) that reduces direct turbine development cost.

NREL's CIP expands U.S. wind capabilities by providing funding to domestic small businesses and encouraging new developments that reduce the cost of new turbines. Annual CIP awards help reduce high development costs and have contributed to the development and testing of turbines by more than five small businesses. CIP funded research has resulted in improvements that lead to annual energy production increases of 15 % and



Pika Energy's Injection Molded Blades developed with support from NREL's Competitiveness Improvement Project.

Overview

- Developed by several private companies with NREL support.
- Commercialized in 2013.

Applications

Can reduce levelized energy and turbine development costs.

Capabilities

- Provides standards for small turbine performance.
- Offers levelized cost reduction in small turbine costs of at least 20 %.
- Increases the variety of small turbines available on the U.S. market.

Benefits

Cost Savings

Reduces costs associated with the development of new wind turbines. By offering funding assistance for new development projects.

Standardization

Allows certification of the safety and performance of individual turbine models using an accredited internationally-accepted system.

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[1] For more information see: U.S. Wind Industry First Quarter 2016 Market Report
[2] For more information see: Distributed Wind

Distributed Wind Site Analysis Tool (DSAT)

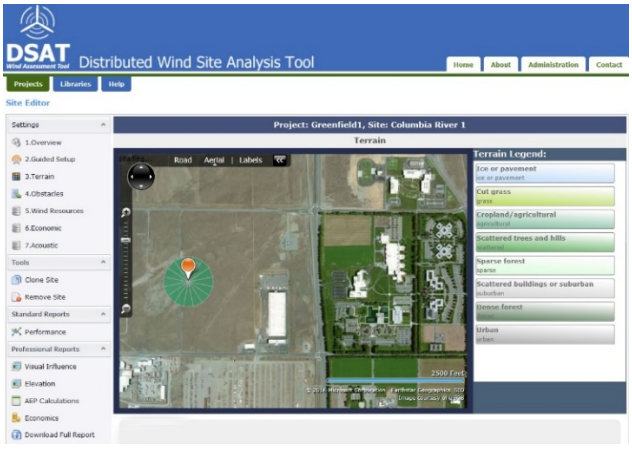
Commercial Technology

Online Assessment Tool Provides Single Turbine Site Analysis

Wind power continues to experience heavy growth and continues to represent an increasingly accessible source of clean energy. As of the first quarter of 2016, there has been over 10,000 MW of new wind site construction, surpassing the 9,000 MW reported at the end of 2015[1], yet the distributed wind market has remained limited with cumulative installed capacity at 934 MW at the end of 2015.[2] While extensive wind maps and models are available to assist with the location of beneficial siting for utility-scale projects, the same tools are not readily available for distributed wind, resulting in a time consuming and expensive process to identify potential sites. Reducing the difficulty of site evaluation could increase wind power accessibility for smaller- scale operators who lack the resources of utility-scale operators.

The Cadmus Group, Inc., with assistance from DOE's Wind Energy Technologies Office, the National Renewable Energy Laboratory (NREL), and a team of industry partners has developed a Distributed Wind Site Analysis Tool (DSAT). DSAT is an online tool that provides valuable insight regarding the environmental and energy impacts of turbine installation. The program uses an array of U.S. meteorological and geological survey data with proven algorithms to provide an in-depth analysis of the suggested turbine placement. Analysis provided by DSAT makes use of high resolution wind maps, wind tunnel testing, computation fluid dynamics modeling, and real world performance data to accurately predict the performance of distributed wind projects.

DSAT is available from Cadmus Group through their website and offer a free basic version. A series of advanced modules were developed to offer professional level reporting, visual impact and terrain analysis, and unlimited simulation storage. These advanced modules are offered along with the standard DSAT program for a nominal subscription fee.



DSAT Site Location & Setup User Interface

Overview

- Developed by The Cadmus Group, Inc., Building Research Establishment (U.K.) Loughborough University, Encraft, and NREL.
- Commercialized in 2012.
- Available through The Cadmus Group.

Applications

Can be used to analyze site performance, including environmental impact and energy benefit for single turbine installations.

Capabilities

- Provides performance modeling and simulation of wind turbine sites.
- Offers analysis of turbine impacts on surrounding visuals and terrain.
- Includes capabilities for urban and building mounted siting.

Benefits

Accuracy

Supports turbine performance analysis in complex environments using flow modeling derived from wind tunnel testing and has been validated on 89 installations.

Cost Savings

Reduces siting analysis costs by providing an online tool that performs most site analyses in an easy to use package.

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[1] For more information see: 1Q2016 AWEA Market Report
[2] For more information see: 2015 Distributed Wind Market Report

eGRID: Electric Grid Research, Innovation and Development

Commercial Technology

Flexible Testing Platform Reduces Product Standard Test Times

To spur acceptance of wind based power technologies, products that are new to the market must be thoroughly tested and characterized to allow quick and simple integration. The relatively young wind power market lacks standard test protocols, limiting the pace at which new products can be developed. Current testing is done by individual companies and is often tailored to specific units which make testing new technologies a time intensive process due to constant setup changes. A ubiquitous and easily accessible testing platform that is capable of performing a wide range of tests could alleviate the moderate time to market caused by non-standardized testing.

Clemson University, with assistance from the Wind Energy Technologies Office and a team of industry partners, has developed a 15 MW capable grid simulator (eGRID) for wind turbine testing as part of the Duke Energy South Carolina Electric & Gas Energy Innovation Center.[1] eGRID allows testing of both direct drive and geared units at 50 and 60 Hz under real-world conditions (low or zero load). eGrid also can perform harmonic testing and power hardware-in-the-loop studies. The test rig uses telemetric data collection to allow the use of specialized measurement signals. Data acquisition is performed by a 750 channel high speed system developed by the Savannah River National Lab (SRNL). Data can be streamed from the unit but may also be stored by a removable redundant array of independent discs (RAID 5) system. Transmitted data is protected by a National Security Agency approved Suite B virtual private network (VPN) connection between the center of operations and the client.

Clemson continues to improve the capabilities at eGRID to offer greater speed, flexibility and applicability to not only wind power but also solar, energy storage, micro-grid and other technologies.



Clemson University's Duke Energy eGRID

Overview

- Developed by Clemson University, Duke Energy, SRNL, Scana Corp., Underwriters Laboratories, Santee Cooper, and TECO-Westinghouse.
- Commercialized in 2013.
- Currently marketing eGRID to turbine manufacturers and other technology innovators.

Applications

Can be used to perform turbine testing on a simulated electrical grid up to 15 MW.

Capabilities

- Provides flexible testing support turbines up to 15 MW on a simulated electrical grid.
- Allows automated testing for individual component noise and vibration optimization.
- Supports specimens up to 13 m x 20 m weighing up to 400 tons.

Benefits

Cost Savings

Reduces cost by allowing most turbines to be tested on a single universal system.

Productivity

Optimizes turbine testing by providing a reliable, low maintenance, long service life platform with easy specimen interchange accessibility.

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[1] SCG&E Energy Innovation Center

Enhancing Short Term Wind Forecasting for Improved Utility Operations

Commercial Technology

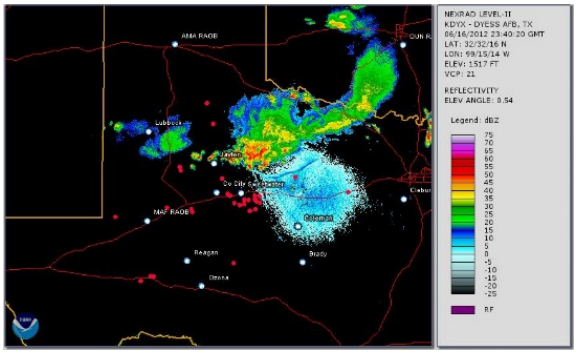
Wind Forecasting Service Offers Enhanced Grid Stability and Efficiency

DOE's target of 30 % grid reliance on wind power by 2030 necessitates an increase in current wind energy reliance by up to 26 % over current levels.[1] Such an increase in wind power penetration means greater variability in the U.S. power grid due to the variable nature of wind power. While there have been many studies on wind forecasting at the day or week level, there has been relatively little research in short-term (0 – 6 hour) wind forecasting which may lead to grid stability and integration cost issues. To ensure that the U.S. grid remains stable and domestic power costs remain low, it is necessary to develop, implement and continue enhancement of short-term wind forecasting for wind farms.

AWS Truepower (AWST), LLC collaborated with DOE's Wind Energy Technologies Office and the National Oceanic and Atmospheric Administration (NOAA) to lead the southern portion of the Wind Forecast Improvement Project (WFIP). This public-private partnership project sought to improve the accuracy of short-term wind power forecasting capabilities through numerical weather prediction model advancements, application of advanced machine learning methods and the assimilation of atmospheric data from the targeted deployment of a network of in situ and remote sensing instruments into the weather models. In addition, the economic benefits of higher accuracy forecasts were assessed in collaboration with NREL.

The AWST portion of the study resulted in more accurate wind power forecasts for domestic wind producers located in the Electricity Reliability Council of Texas (ERCOT) system. Project results prove that forecasts provided by AWST outperformed the existing forecasting methods used by ERCOT. Improvements in the physics-based and statistical wind grid prediction models provided significant improvements in wind power ramp prediction of 20 % or better. Further, inclusion of the remotely sensed atmospheric observations demonstrated a 6 % improvement over forecasting methods where the data was withheld.

AWST currently offers short- and long-term wind power forecasting services to wind farm owners, utilities and balancing areas, and reliability focused ISOs and RTOs.



Radar imagery of a thunderstorm complex near Sweetwater, TX June 2012

Overview

- Developed by AWS Truepower, NOAA, WindLogics, and NREL.
- Available through AWS Truepower.

Applications

Can be used to provide accurate predictions of future wind power in both the short- and long-term.

Capabilities

- Enhanced short-term wind power forecasts from numerical weather prediction model advancements and assimilation of real-time in situ wind measurements.
- Improves the stability of grids with high wind penetration.

Benefits

Reliability

Reduces the risk of instability due to ramp events by providing advanced warning of all sudden increases or decreases in wind speed.

Cost Savings

Advanced knowledge of wind power variability allows for optimized electricity grid operation resulting in lower costs.

Higher Penetration of Wind

Accurately scheduling the variable nature of wind generation allows wind farms to become a trusted source of firm generating capacity for the grid.

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[1] 2014 Wind Vision, U.S. DOE, January 2014

Large Wind Turbine Blade Testing

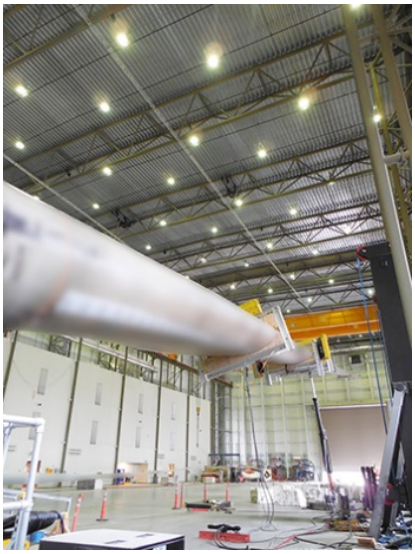
Commercial Technology

Testing Services Enhance Wind Turbine Development

With the U.S. Department of Energy (DOE) maintaining a goal of 20% reliance on wind power by 2030[1], wind turbine and blade testing has become even more critical to keep the cost of wind-based power competitive with non-sustainable sources. Current testing is often limited to the manufacturer's test capabilities which can restrict the level of testing available for large wind turbines. Enhanced testing centers allow faster and more robust testing of new and existing designs against accepted international standards.

Massachusetts Clean Energy Center, with assistance from the Wind Energy Technologies Office and the National Renewable Energy Laboratory (NREL), as part of the American Recovery and Reinvestment Act, has built the Wind Technology Testing Center (WTTC). WTTC offers a suite of certification tests for turbine blades up to 90 meters and is equipped with test stands that can accommodate up to 100 tons. The center offers a variety of tests ranging from blade material testing to lightning protection testing and is able to perform static and fatigue tests that satisfy the IEC 61400-23 structural testing standard for wind turbine rotor blades. WTTC's blade testing engineering services are supplemented by NREL engineering support and expertise to ensure proper testing of the test materials.[2]

WTTC is able to perform the latest test methods for blades including both horizontal and vertical testing. The facility performs accelerated fatigue testing to simulate the > 20 year life span that is expected of most blade designs in only a few months. WTTC makes use of NREL's patented resonant test and a ground-based resonant test developed at WTTC for fatigue testing. Testing includes a 21-meter tip-to-tip displacement test which is monitored continually for the duration of the process. Bi-axial testing of the blade can be done concurrently to reduce time and cost.



The Wind Technology Testing Center

Overview

- Developed by the Massachusetts Clean Energy Center and NREL.
- Testing services commercialized in 2011.
- Currently working on design certification goal of 40 certifications by 2020[2].

Applications

Can be used to provide testing and certification for turbine blades up to 90 meters in length.

Capabilities

- Allows static testing up to 84 mega Newton meters.
- Offers horizontal tip displacement up to 32 meters.
- Offers bending moment tracking to ultimate failure.

Benefits

Efficiency

Allows bi-axial testing to reduce testing cost and time without sacrificing thoroughness.

Quality

Uses fatigue test procedures developed jointly by WTTC and NREL personnel to provide high quality blade testing services.

Reliability

Allows blade design certification via internationally accepted testing methods.

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[1] 2014 Wind Vision, U.S. DOE, April 2015
[2] For more information see: Wind Technology Testing Center & WTTC Fact Sheet

Next-Generation Wind Turbine

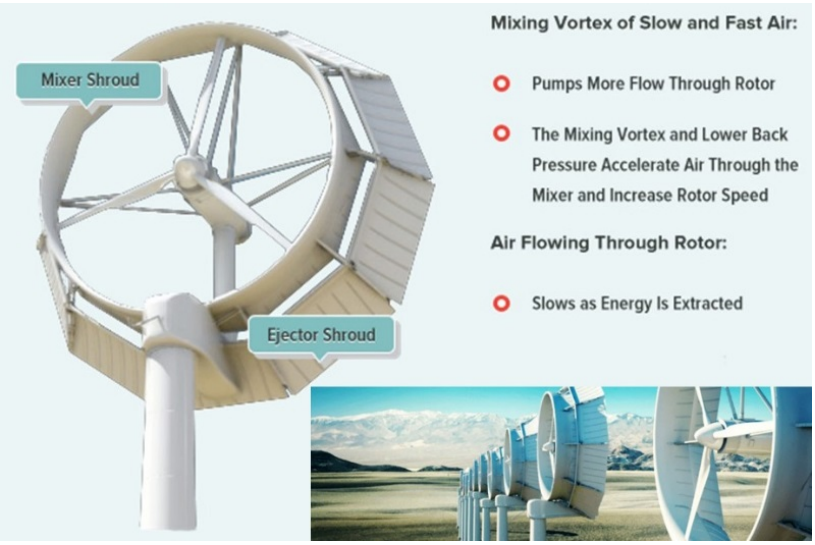
Commercial Technology

Aerodynamic Turbine Shroud Increases Efficiency and Reduces System Size and Cost

As the U.S. transitions to distributed energy resources, wind power is becoming one of the favored sources for low-cost renewable energy. The continued growth of distributed wind is contingent on the availability of reliable, high-efficiency, cost-effective wind turbine options.[1]

Ogin, Inc., with assistance from the Department of Energy's Wind Energy Technologies Office (WETO) has developed the Ogin™ wind turbine technology. Ogin's proprietary shroud technology, after further development, was used on the Ogin OE20 150 kW wind turbine to increase the wind energy captured over traditional wind turbines of comparable size. Field testing is ongoing to verify the Ogin turbine's aerodynamic coefficient of performance.

After completing the WETO assisted program work, Ogin began commercialization by certifying their OE20 wind turbine design which amassed over 56,000 operating hours during prototype field testing. Subsequently, they completed two pilot manufacturing cycles and implemented improvements based on the field tests to refine and qualify their manufacturing and suppliers. Ogin believes they are now prepared for commercial scale manufacturing and to serve growing market demand. Ogin continues to optimize their designs to remain competitive and broaden product application to distributed, residential, hydrokinetic, and airborne wind energy.



Ogin™ Wind Turbine

Overview

- Developed by Ogin, Inc.
- Commercialized in 2013.
- Several installations operating since 2011, and design commercial scale manufacturing ready in 2016.

Applications

Can be used in distributed wind applications for a broad range of wind speeds.

Capabilities

- Produces 10 % to 60 % more energy than traditional turbines of comparable size and provides a broad range of sizes from sub-kW to 200 kW.
- Higher turbine efficiency enables the option of lower hub heights thus minimizing visual impact.

Benefits

Cost Savings

Smaller, less expensive turbines can be used to generate the same amount of energy as a traditional wind turbine.

Customer Value

Produces more energy than traditional wind turbines where capacity is constrained, positively impacting return on investment.

Environment

Rotor shroud reduces impact on native avian populations and reduces shadow flicker.

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[1] 2014 Wind Vision, U.S. DOE, April 2015

PelaStar™: Innovative Offshore Wind Plant System Design

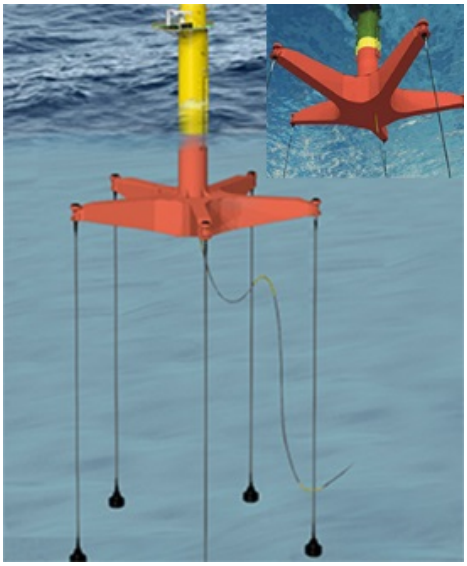
Commercial Technology

Tension Leg Platform Enables Deep Water Turbines At Reduced Cost

Offshore wind energy represents an opportunity to produce low-cost renewable energy close to dense, urban load centers that do not have the land or wind resource available to site large wind farms. Offshore wind arrays, because of the installation cost, are often placed in shallow regions near the coastline using foundations that are anchored to the seabed. Unfortunately, many sites that offer stable levels of available wind remain undeveloped because of the high cost of constructing foundations anchored to deep-water sea floors. Development of lower cost foundations for deep-water installations could enable development in previously prohibitive regions.

Glosten Associates, Inc., with assistance from the Department of Energy's Wind Energy Technologies Office and industry partners has developed PelaStar ™, a tension leg deep-water turbine foundation. PelaStar provides a stable platform for a wide range of potential turbines that experiences minimal motions from water movement. To reduce installation cost, the foundation was designed to be manufactured at a harbor and can be assembled using standard marine manufacturing equipment. After assembly, the turbine can be towed to the desired location and anchored using a lightweight tendon system that uses vertical load anchors rather than a seabed foundation. The installation process can be completed with a single barge and doesn't require the use of jack-up crane vessels, further reducing installation cost.

In addition to their low cost turbine foundation, Glosten also offers National Renewable Energy Laboratory (NREL) developed site installation and optimization software, which can be used to minimize installation cost for given depths and ocean conditions. The software is able to perform fully coupled, six degrees of freedom, non-linear, time domain analysis for



PelaStar Floating Turbine Foundation and Underwater View

Overview

- Developed by Glosten Associates, Inc., NREL, and industry and research partners.
- Commercialized in 2013.
- Currently installing turbines in the Celtic Sea off the coast of Cornwall, U.K.

Applications

Can be used to allow construction of wind arrays in deep water at a competitive cost.

Capabilities

- Provides foundations in deep-water areas using a stable tension leg platform.
- Reduces the cost of installing turbines in 60 meter and deeper water compared to seabed foundation methods.
- Allows construction without the expense of using offshore cranes.

Benefits

Cost savings

Reduces costs by allowing total turbine assembly at the quayside using easily manufactured modular sub-assemblies.

Easy Installation

Allows easy transportation by using high strength low weight tendons rather than a bottom fixed foundation for final anchoring.

Quality

Constructed using a certified 25 year fatigue life design.

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[1] For more information see: PelaStar Brochure

Production Scale-Up of Nanoengineered Lubricant Additive

Commercial Technology

Nanoengineered Lubricants Improve Wear Resistance, Reliability, and Energy

Friction is one of the major reasons for failure of vital engineering components in systems such as pin-joints, engines, power generators, undercarriages in mining equipment, parts used in aerospace systems, bearings, camshafts, pumps and gears in wind turbines.[1] The annual cost of friction and wear-related energy and material losses is estimated to be a few percent of the gross national product of industrialized nations. In addition to equipment failure, tribological issues at impacting surfaces cause excessive friction and accelerated wear, which reduces energy efficiency. The reliability of wind turbine gearboxes is one of the major challenges to delivering an efficient wind energy platform and new methods are needed to improve mechanical system lubrication; novel nanoengineered lubricants could increase reliability and energy efficiency in lubrication applications.

NanoMech Corporation, with assistance from the Wind Energy Technologies Office, in the form of Small Business Innovative Research grants (as part of the American Recovery and Reinvestment Act), has optimized and scaled-up a patented process for nanomanufacturing advanced lubricant additives using an open architecture and macromolecular approach. These nanoengineered lubricant additives consist of multi-components and work with a range of greases and oils. The additives provide advanced lubrication in the following ways: (1) by supplying nanoengineered lubricating agents that reduce friction and wear at the intricate asperity-to-asperity contact zone, (2) by enabling strong tendency for uniform surface adsorption, and (3) by reacting with the surface to form a durable lubricating film that can sustain high loads and reduce friction and wear. These water-based additives are more environmentally friendly than additives currently in use for these applications.

Scaling up production to industrial scale was achieved in collaboration with a leading lubricant manufacturer who identified the required performance and cost targets as well as process routes. The pilot production facility demonstrated commercially-viable production output which when tested performed consistently for reduced friction, wear reduction, corrosion reduction and increased lubricant lifetime. The first critical application of



NanoMech's Award Winning, Patented Nanoengineered Lubricants

Overview

- Scale up and nanomanufactured by NanoMech Corporation.
- Commercialized in 2013.
- Currently investigating applications in renewable energy sector, electric vehicles, industrial products, military, transportation, aerospace, oil and gas.

Applications

Nanoengineered lubricants for gears, bearing, compressors, rail curves, valves, ball-joints and many other mechanical components.

Capabilities

- Provides reduced friction, wear and corrosion by several orders of magnitude.
- Enhances load carrying capacity at the mating interface.
- Provides compatible drop-in additive to enhance the performance of existing hydrocarbons and non-hydrocarbons.

Benefits

Durability

Nanoengineered lubricants extend the life and performance by reducing boundary friction and extending durability of mechanical parts.

Energy Savings

Reduced friction across a multitude of mechanical applications will reduce energy consumption and improve the durability, performance and sustainability of the mechanical components.

Environmental

Nanoengineered lubricants are more environmentally friendly than what is currently in use for these applications.

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[1] 2014 Wind Vision, U.S. DOE, April 2015

Ramping Uncertainty Tool: Grid System Operations

Commercial Technology

Prediction Tool Improves Balancing Authority Efficiency and Confidence

In an effort to curb reliance on fossil fuels and reduce the impact of energy generation on the environment the U.S. Department of Energy has set goals to promote and increase the use of clean energy from renewable sources.[1] These goals will enable using variable sources to provide enough power to satisfy load requirements. These variable sources are subject to small random deviations from predicted power outputs and often require balancing from other energy sources.[2] Many current Balancing Authorities (BAs) use deterministic models which do not take random events into account and cannot predict random variations such as problems associated with reliability. A modelling tool that is capable of accounting for random variations could help increase U.S. grid performance and reliability.

Pacific Northwest National Laboratory (PNNL), with assistance from the Wind Energy Technologies Office and a team of industry partners, has developed an uncertainty ramping tool to predict variations in the renewable energy supply. The prediction tool is an online analysis and visualization tool that is capable of providing resource predictions for both wind and solar power. The predictions provide an estimate of power shortfalls at the day and hour time-scale. The tool can dynamically adapt to changing environmental conditions and analyze the effect of these changes on the expected power requirements. By predicting deficiencies between produced power and demand, the tool is able to reduce costs associated with power lost and can dampen price-spikes in the energy market.

PNNL developed a probabilistic algorithm to power its uncertainty tool that incorporates multiple uncertainty sources, including forecast errors, outages, and generator failures. A user submitted confidence level is used to provide predictions for a worst case scenario. The tool is currently being used by the California Independent System Operator (CAISO).



PNNL's Ramping Uncertainty Tool Dashboard

Overview

- Developed by PNNL, AWS Truepower, and industry partners.
- Commercialized by CAISO in 2012.

Applications

Can be used to balance power grids that use variable sources.

Capabilities

- Predicts supply deficiencies for a given confidence level.
- Provides estimates for required capacity, ramp rate, and ramp duration.
- Predicts price spikes in the real-time energy market.

Benefits

Cost Savings

Reduces cost associated with generation shortfalls by predicting deficiencies, allowing other resources to be brought online.

Efficiency

Allows greater use of renewable sources without compromising power grid stability by helping balancing authorities to account for random variation.

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[1] For more information see: 2014 Wind Vision, U.S. DOE, April 2015.
[2] For more information see: CIASO Ramp and Uncertainty Prediction Tool.

Simple Modular Technology (SMarT) Tower Systems for Free-Standing Small Wind Turbines

Commercial Technology

Modular Wind Tower Offer Low Cost and Simple to Install Distributed Power Option

To facilitate the U.S. Department of Energy (DOE) 2030 goal of 20% grid reliance on wind energy, current wind power production must increase from approximately 75 GW to 224 GW.[1] Wind towers can require large foundations that are both time and skill intensive to install. Shipping, welding, and erecting a tower necessary for a wind turbine further increases the difficulty of wind power installation for small wind turbine owners. A technology that simplifies the construction process of small wind turbines is necessary to encourage adoption of wind turbines in the U.S. residential generation market.

AnemErgonics, LLC, with assistance from the Wind Energy Technologies Office and the National Renewable Energy Laboratory (NREL), in the form of Small Business Innovation Research grants, has developed a small wind turbine tower based on Simple Modular Technology (SMarT). SMarT Towers® offer simplified alternatives to both problems associated with small turbine installation. The SMarT Foundation® negates the need for mat and pier steel reinforcement and can be installed using only fiber reinforced concrete. SMarT Foundations can be installed in 2 - 4 hours after site excavation is completed. SMarT Foundations are equipped with a Gin Pole to allow the wind tower to be tilted up or down, simplifying the construction process. The Gin Pole negates the need for a crane or high lift and allows the tower to be tipped down for maintenance after construction. AnemErgonics's SMarT Towers are constructed from high strength fiberglass with ductile cast iron components. Each tower can be constructed without welding to further lower the cost of construction.

To facilitate market adoption of SMarT systems, AnemErgonics makes the tower available through multiple vendors and ships components through FedEx. SMarT Towers are designed to be easily compatible with all small turbines up to 5 kW but are designed specifically for the Xzeres Skystream and Pika T701 turbines.



AnemErgonics SMarT Wind Tower and Foundation

[1] 2014 Wind Vision, U.S. DOE, April 2015

Overview

- Developed by AnemErgonics and NREL
- Commercialized in 2008.
- Over 1500 SMarT Foundations and 25 towers sold.

Applications

Can be used to support small wind turbines up to 5 kW.

Capabilities

- Simplifies the wind tower construction process.
- Provides support for tilt-up towers up to 75 feet high.
- Can achieve cost savings up to 20 % for materials and 60 % for labor on 55 foot towers.

Benefits

Cost Savings

Reduces the labor required to construct the tower to between two and four hours and reduces construction materials required for assembly.

Efficiency

Allows construction without steel mat and pier foundation.

Productivity

Enables maintenance work to be performed at ground level by tipping the tower down when necessary.

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SWT 2.3-108: Siemens Advanced Rotor Systems

Commercial Technology

Large Scale Wind Turbine Testing for Enhanced Performance

With recent developments concerning environmental stability and energy security emphasizing the need for new energy sources, wind power represents a growing energy segment capable of alleviating both concerns. To accomplish this, new and innovative turbine designs are needed to satisfy the growing demand for cost competitive renewable electricity. However, testing new turbine designs is costly and establishing test sites that are well-equipped and well-staffed can be difficult. Partnerships between government and private organizations offer cost-sharing and enable more utility-class wind turbine testing.

Siemens Wind Power (SWP), in cooperation with National Renewable Energy Laboratory (NREL) and the Wind Energy Technologies Office, formed a Cooperative Research and Development Agreement (CRADA) partnership to provide an in depth evaluation of utility-scale wind turbines. This partnership tested two utility class Siemens turbines, with rotor diameters over 100 meters, at NREL. SWP and NREL collaborated on the analysis of the detailed measurements and validated the operation and performance in intense turbulence and high altitude at NREL's National Wind Technology Center (NWTC). Data collected from rotor testing resulted in greater understanding of aerodynamic and structural interactions. Design innovations were implemented to enable passive load shedding while maintaining load capture. Test results will allow future turbine development by using the expansive test data gathered by NREL and SWP. This testing wrapped up development of a new wind turbine that was designed to be more efficient at moderate wind speeds than previous models. The SWT-2.3-101 turbine, a member of Siemens 2.3 MW family, benefited from this research and is available from Siemens.

A contract extension between Siemens and NREL allowed the partnership to test a Siemens design improvement to their B49 blade. The newer larger B53 blade is able to operate in lower wind speeds, has a cut in speed of 3-4 m/s, and reaches rated speed at 11-12 m/s.[1] An enhanced design makes the B53 more efficient at low speeds than predecessors while also making it lighter and more durable. Siemens offers the new B53 blade on their SWT-2.3-108 turbine.



Siemens 2.3 MW turbine with 108 m rotor, sited at the NWTC

Overview

- Tested by Siemens under a CRADA partnership with NREL.
- Commercialized in 2014.
- Available through Siemens.

Applications

Can be used to provide cost-competitive renewable energy at low wind speeds.

Capabilities

- Provides 2.3 MW at rated conditions and can provide power at wind speeds as low as 3 meters per second.
- Testing center environment and measurement protocols enable physics based modeling and design of new turbine blades.

Benefits

Cost Savings

Produces power at low wind speeds, enabling cost competitive wind energy production at a broad range of deployment sites.

Design Engineering

Exploits NREL expertise to develop a comprehensive database for future engineering development, design, and blade validation.

Product Development

Allows innovative blade design and validation using extensive testing of rotor aerodynamic responses.

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[1] For more information see: SWT-2.3-108

TYCOR®: Reducing Cost and Weight of Wind Turbine Blades Using an Engineered Core Material

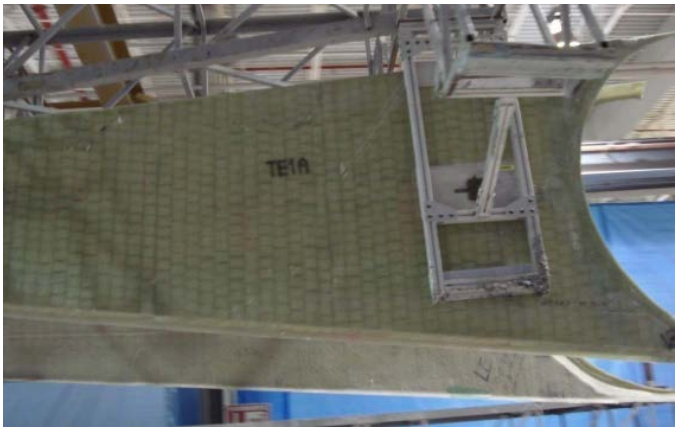
Commercial Technology

Fiber Reinforced Core Reduces Blade Weight and Cost

To support the growing use of wind power on the national grid, the wind industry has increased the efficiency of wind turbines and their capacity to capture energy from low speed winds. As a result of this endeavor, turbine blade lengths have increased over fifteen years from a maximum of 33 m to 75 m. Currently there are attempts to extend blade length to 125 m or longer for offshore operations. A limiting factor to recent increases in turbine performance is weight - the weight of a turbine blade is proportional to the cube of its length. To ensure the viability of turbines with longer blades, it is necessary to find a method for reducing their weight.

Milliken and Company, with assistance from the Wind Energy Technologies Office, in the form of a Small Business Innovation Research Xlerator grant, has developed TYCOR®, a line of lightweight fiber-reinforced sandwich cores for turbine blades. TYCOR improves on traditional cores by being ideally suited to modern manufacturing processes. While balsa and structural foam can have issues with resin uptake in the vacuum-assisted resin transfer molding (VARTM) process, increasing their cost, TYCOR is able to undergo the process without issue. The sandwich core used in TYCOR is molded through the VARTM process and obtains 95 % of its strength from fiberglass webs.[1] The foam used in the process is low cost and lightweight, meaning TYCOR fills the performance gap between structural foam and balsa cores in both strength and cost. TYCOR is designed for optimum conformability, simultaneously removing the need to cut the material to use it in curved blade shells and reducing the weight of material needed in the finished product.

Milliken and Company makes core products for blades under the name TYCOR W. TYCOR has been approved by the international certification body Det Norske Veritas - Germanischer Lloyd (DNV-GL) for use in wind turbines and allows turbine designers to select a design that is uniquely suited to their weight and cost needs. Milliken and Company offers TYCOR W in four standard core products and also provides modified cores to meet custom specifications.



Shear Webs with Milliken's TYCOR W Core.

Overview

- Developed by Milliken and Company.
- Commercialized in 2008.
- Marketed as TYCOR W fiber reinforced cores.

Applications

Can be used to provide lightweight high-strength cores for large turbine blades.

Capabilities

- Achieves a shear modulus of up to 130 MPa.
- Reduces core resin usage by up to 55 %.
- Reduces blade core weight by up to 45 %.

Benefits

Cost Savings

Reduces the cost of large turbine cores by reducing the amount of resin used in the VARTM process.

Efficiency

Provides a lower weight option than balsa, allowing blades to have high shear modulus while reducing losses from blade weight.

Environment

TYCOR is produced with environmentally clean manufacturing methods.

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[1] For more information see: TYCOR Fiber Reinforced Cores

UltraBattery™: Advanced Energy Storage for Wind Power and Grid Regulation Services

Commercial Technology

Advanced Battery Provides Intermittency Protection for Renewable Energy Sources

Renewable resources are projected to account for a large percentage of U.S. energy production by 2030[1]. The majority of the energy generated by these renewables is expected to be produced by either wind or solar power. Both power sources provide moderate amounts of power but suffer from intermittency which could lead to grid instability or power shortfalls during instances when intermittency overlaps with periods of peak loading. Currently, this is not a problem as natural gas can be rapidly scaled to account for loading changes and the combination of coal and nuclear power account for base loading needs. However, this risk must be mitigated before widespread acceptance of renewables can replace fossil sources like natural gas and coal.

To address the issue of supply intermittency East Penn Manufacturing, with assistance from the Wind Energy Technologies Office, Ecoult, and the Commonwealth Scientific and Industrial Research Organization (CSIRO) has developed the UltraBattery™ for largescale energy storage. The UltraBattery is a hybrid energy storage solution that is produced by combining an asymmetric ultra-capacitor with a lead-acid battery in a single cell. Combining the two technologies offers the cost benefits of a lead-acid battery with the lifecycle and recyclability benefits of an ultra-capacitor. The containerized UltraBattery provides up to 3 MW of frequency regulation and can provide up to 1 MW of stable power for up 4 hours. System sizing allows the battery to maintain reserve power between 70 % and 30 % for a maximum 40 % depth of discharge.

East Penn Manufacturing has completed development of the initial UltraBattery model and is marketing it as the DEKA UltraBattery for advanced power storage.



East Penn Manufacturing's UltraBattery

Overview

- Developed by East Penn Manufacturing, Ecoult and CSIRO.
- Commercialized in 2012.
- Currently marketing the product through Ecoult as DEKA Ultrabattery™.

Applications

Can be used to offer intermittency protection for renewables powered grids.

Capabilities

- Stores power for use during intermittency or maintenance down times.
- Offers backup power from a few kilowatts to tens of megawatts for up to 4 hours.

Benefits

Cost Savings

Reduces cost of wind integration providing a low cost and high efficiency energy storage option.

Efficiency

Optimizes renewable energy grids by offering a high capacity storage solution to maintain continuous backup power.

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[1] 2014 Wind Vision, U.S. DOE, April 2015

Wind-Diesel Hybrid Power: Alaska Energy Authority

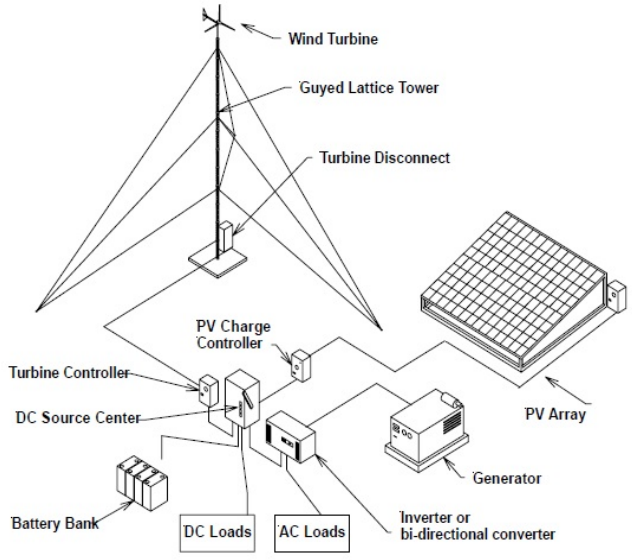
Commercial Technology

Hybrid Power System Uses Less Fossil Fuel

Wind systems can offer sustainable and clean energy sources for small grid power networks. To ensure stability, wind can be used to provide power when available, with regular grid power filling in the down times. In low access areas this becomes a problem as there may not be a municipal grid available to provide backup or additional power to cover peak loading. Many Alaskan settlements suffer from this issue as terrain and sparse populations prohibit the creation of large scale power grids and require the use of diesel-powered generators. Unfortunately, many towns use only diesel generators because a renewable power source is not available in less developed areas. A renewable and reliable power source is needed in these areas to reduce dependence on diesel fuel.

The National Renewable Energy Laboratory (NREL), with assistance from the Department of Energy's Wind Energy Technologies Office and the Alaska Energy Authority, has demonstrated hybrid wind-diesel systems as an effective means of providing a constant source of power to secluded micro grids. The system is designed to reduce reliance on diesel fuel, storage requirements and the environmental impacts of diesel fuel use in these areas. Installed systems are based on an AC bus configuration that simultaneously implements both wind and diesel power generation. This setup allows areas with good wind resources to shutdown diesel fuel based generation when wind power is high and turn on during lulls in wind power generation. Integration of short term storage batteries allows areas with strong wind to maintain stability by switching to battery power during periods of wind intermittency.

NREL has successfully assisted several local municipalities with wind-diesel hybrid system implementation. Successes have resulted in many participant towns becoming less reliant on diesel fuel and achieved annual fuel savings of up to 45,500 gallons in some towns.[1]



NREL's Hybrid Community System

Overview

- Developed by NREL and the Alaska Energy Authority.
- In use in several Alaskan towns since 2005.

Applications

Can enable towns in secluded areas to scale back diesel use while maintaining grid stability.

Capabilities

- Reduces reliance on diesel engines for power production in secluded areas.
- Offers fuel savings of up to 20 % in smaller communities with the potential for higher savings in larger well-established communities based on quantity of fuel used.

Benefits

Cost Savings

Reduces costs associated with the purchase, transport, and storage of diesel fuels.

Emissions Reductions

Allows complete replacement of diesel power use in some areas and reduces the safety hazards and environmental risks associated with diesel fuel storage.

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[1] Wind/Diesel Power Systems Basics and examples, NREL, April 2008

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