MAY 2011

AWEA WINDPOWER SHOW ISSUE

WIND SYSTEMS

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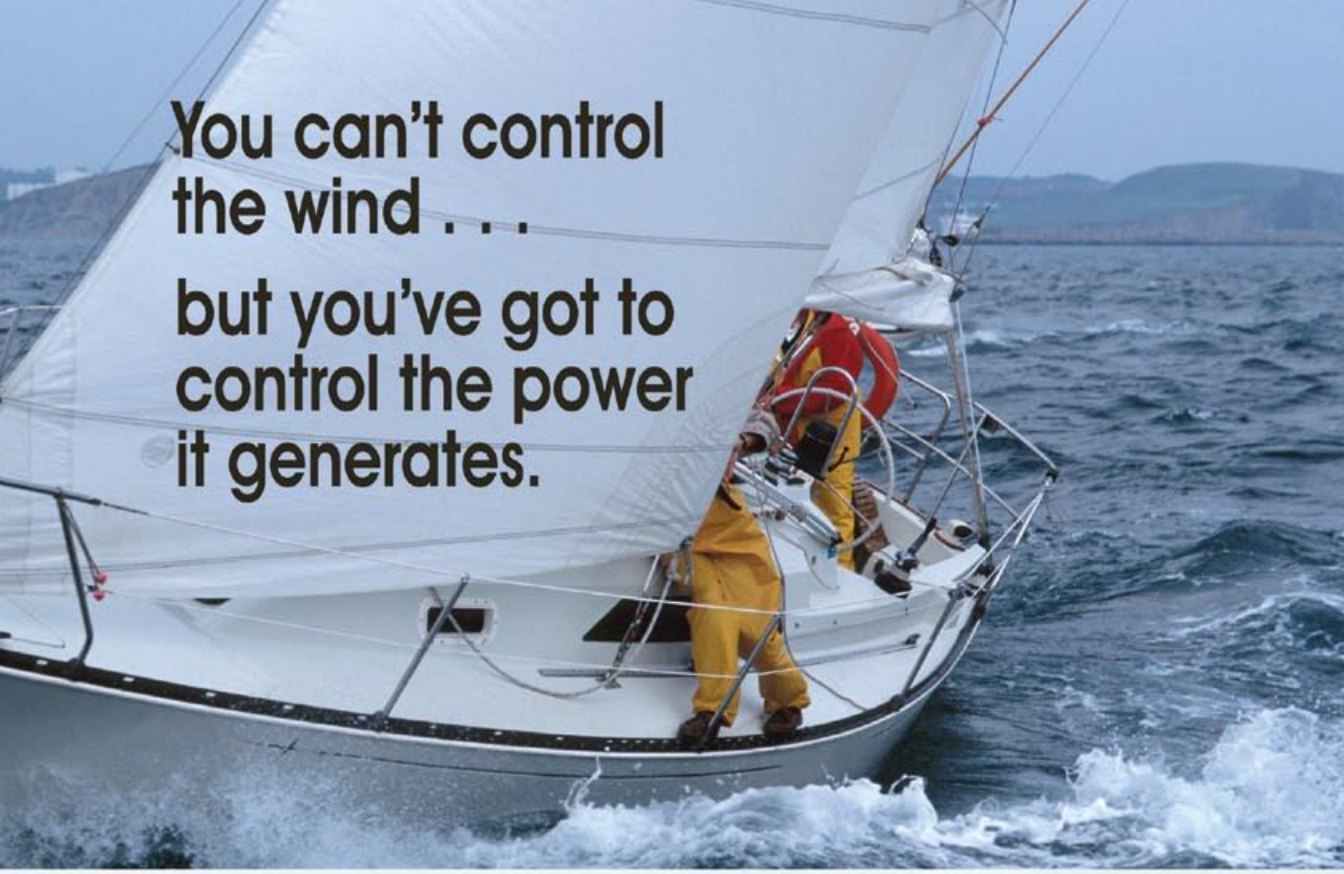

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Deer Island Wind Tower, *Massachusetts*
Caissons installed in glacial till to support a new wind tower.

Biglow Canyon Wind Farm, *Oregon*
Dynamic Compaction for seismic and liquefaction mitigation for new wind turbine pad footings.

SOLUTIONS FOR WIND TOWERS

SITE IMPROVEMENT FOR NEW FOUNDATIONS AND FOUNDATION REHABILITATION

Wind Farm, *Wyoming*
Dynamic Compaction for ground improvement and installed Driven Piles (shown) and Micropiles for construction of new foundations.

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Micropiles, installed in rock and designed for high cycle-fatigue loading, stabilized 30 existing wind tower foundations.

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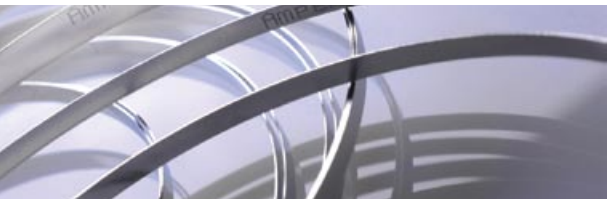

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The SeaTitan wind energy system by American Superconductor drives economies of scale for offshore wind development.

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EDLETTER

In the late eighties Terry Humphrey, wind aftermarket manager at Castrol Industrial, took a call from a man in Palm Springs, California, who said he needed about 10 gallons of oil for a gearbox. When Terry asked what the gearbox would be used for, the reply was "we're going to use it to make energy." This was his first exposure to the industry in which he is now such an active player, as you'll read about in this issue's Q&A feature. The North American wind industry has come a very long way since that time, as you'll see looking around you while attending the American Wind Energy Association's WINDPOWER 2011 Conference & Exhibition. Many of you will recall a time not so long ago when attendance numbered in the hundreds, rather than the tens of thousands of professionals gathered from around the world for the U.S. wind industry's premier event. We'd like to thank the entire AWEA staff for the hard work and professionalism from which we all benefit.

Knowing this is one of our most popular issues of the year due to the show, we've assembled a stellar cast of editorial contributors, beginning with "Best Practices for Turbine Manufacturers" by Dave Schaetz and Steve Ludwig of Rockwell Automation. Mike Moore of Shermco Industries has written "Predictive Maintenance Strategies," and David Somerville of Trelleborg Offshore discusses technologies such as distributed buoyancy modules in "Deepwater Wind Developments." Kailey Lord presents "The Cedar Point Case Study" in which RES Americas is involved, and Gary L. Doll, Ph.D., of Timken shares the secrets to "Building a Better Bearing." Lee Alnes of Second Wind encourages harnessing the full range of wind-sensing technologies in "Amassing Wind Information," and Martin Fischer of American Superconductor/AMSC Windtec describes the SeaTitan wind energy system in "Superconductors on the High Seas."

In addition, Sven Schmitz of Penn State's Wind Program discusses research into modeling the wake behind wind turbines in his technology column, and Trent Schon of Mortenson Construction concludes his two-part column on jobsite safety. Maintenance expert Merritt Brown of Rev1 Renewables advocates the use of mobile and wireless technologies in this month's installment, and Anne Puhalovich of the Professional Logistics Group explains how new trucking regulations will affect the wind market. I would like to thank Peter Duprey, president and CEO of Broadwind Energy, for taking the time to discuss the company's direction and capabilities with me for this month's profile, and John Segvich for his assistance during the production of this piece.

This is a pretty impressive lineup, you've got to admit, representing the intelligence and depth of expertise that is propelling this industry forward both here in the United States and around the world. We look forward to discussing how we can help you share your own knowledge with the wind energy industry at our booth #877. See you there!

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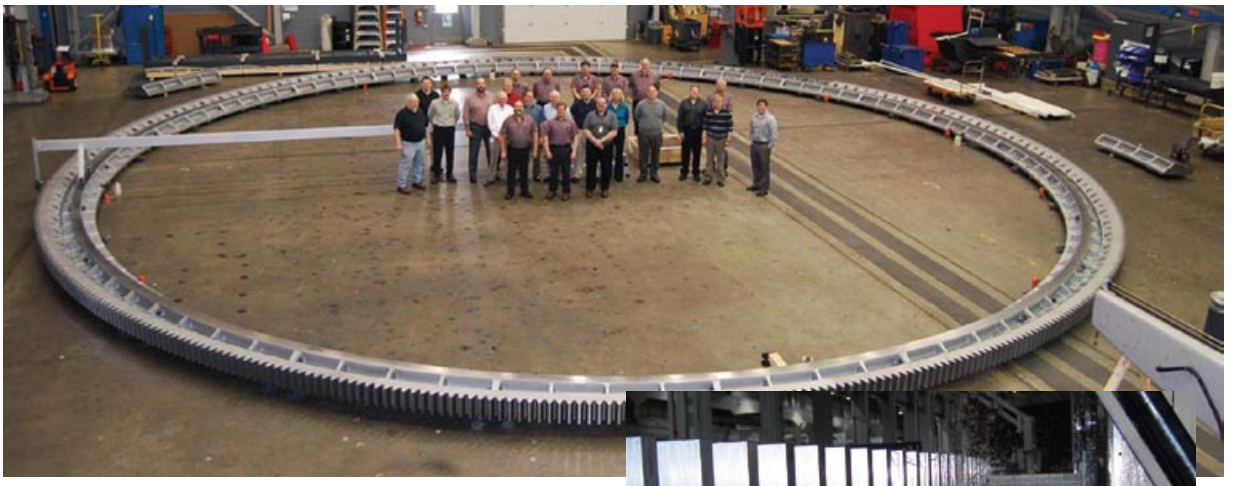

MAG DEVELOPS NOVEL PROCESS FOR PRODUCING GIANT GEAR

As proof that it can use machine tools as well as build them, MAG has developed a process that used a horizontal boring mill (HBM) and specially designed tools to cut 588 teeth in a 19-meter (62.5 ft) diameter gear assembly weighing 60 tons (54,836 kg).

The two-piece gear assembly, made of ASTM A290 steel, consists of a 24-section track that serves as the base and a 12-section upper gear rack. The MAG team designed dedicated fixtures for each operation and special tooling for cutting and finishing the gear teeth on an HBM. "We cut the gear teeth on an unconventional machine," according to Mark Huhn, project manager at MAG Fond du Lac. "In most cases the tooth involute would be generated by the machine itself, but we used a tool with the involute built into the cutter, which was accomplished by grinding the tooth form into the cutter first."

The gear teeth were manufactured to American Gear Manufacturers Association (AGMA) Gear Quality No. 6, and the gear was assembled to a pitch diameter concentricity of .8 mm (.031 in). The track, comprised of A148M Grade 620-415 castings, required a special cutter to produce a 2.127-degree surface angle. "The angle was circular interpolated onto the track surface and we designed a special cutter to cut the angle on one of our gantry-type machining centers," says Huhn.

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EATON INTRODUCES COMPACT MEDIUM VOLTAGE CIRCUIT BREAKER FOR WIND

With industry-leading environmentally friendly vacuum and solid insulation technology, Eaton's new 38 kV VCP-Wind medium voltage circuit breaker is designed to help customers manage power reliably, efficiently, and safely. They are engineered for wind farm collector substations and feature a reduced footprint. Maintenance requirements are minimized with the use of enclosed long-life vacuum interrupters, and the component arrangements allow for easy access. VCP-Wind's direct roll-in configuration simplifies handling and relocation of the breaker. Eaton's VCP-Wind medium voltage vacuum circuit breaker is rated up to 38 kV, 2000A (without fan cooling) and 31.5 kA.

Eaton's vacuum and solid insulation technology is free of SF6-gas that contributes significantly to the greenhouse effect and associated climate change. Through more than 80 years of innovation and experience, Eaton has developed environmentally friendly vacuum interrupters capable of reliably switching both normal load currents and high stress fault currents. In an effort to increase the dielectric strength

Companies wishing to submit materials for inclusion in this section should contact Russ Willcutt at russ@windsystemsmag.com. Releases accompanied by color images will be given first consideration.

of the circuit breaker, Eaton has also designed vacuum interrupters that are encapsulated in epoxy resin material. The VCP-Wind circuit breaker family utilizes this solid insulation technology that has been catering to a wide range of applications for years.

The VCP-Wind circuit breaker offers numerous safety features for maximum protection. Eaton's extensive innovation and experience in the electrical industry deliver world-class product reliability and quality. Go online to www.eaton.com.

NORDEX USA ENTERS JOINT VENTURE WITH MICHIGAN WIND FARM

Nordex USA, Inc., has entered into a joint venture with Beebe Community Wind Farm LLC, a Michigan project developer, for the co-development and construction of a wind farm in Gratiot County, Michigan. The project was initiated in 2007 by local resident Mark Hull, principal of Beebe Community Wind Farm LLC. Hull brought on Nordex last year to support project development as well as to supply 125 of Nordex' new N117-2.4 MW turbines, which are designed specifically for low wind sites and are derived from the established Nordex 2.5 MW class. The N117 boasts the longest rotor blade in its category, resulting in an average 15 percent yield increase over previous products. The turbines will be manufactured at Nordex' recently constructed plant in Jonesboro, Arkansas.

"We were initially interested in Nordex' turbine technology for our class-three wind site," says Hull, "but including them in the project team has considerably accelerated our development efforts. Wind projects require specialized expertise in several complex areas, so having Nordex on our side has been a true asset."

The partnership expands Nordex' track record for robust customer support offerings to the United States. "As a turbine manufacturer, we consider it important not only to provide reliable and efficient turbines, but also to support our customers in the course of project development," says Ralf Sigrist, president and CEO of Nordex USA. "Nordex has added value to developers in Europe through such partnerships for almost 10 years, and we are happy to bring this service now to our U.S. customers."

The Beebe Community Wind Farm takes a community-based approach that spreads economic benefit among local landowners through land leasing arrangements and to the greater community through tax revenue. More than 20,000 acres of land have been leased. The project has interconnection positions on a 345 kV line, and has been granted its "special use permit" from the county. Wind has been measured on the site for more than two years with met towers and SODARs, and continued environmental studies support the project's feasibility. Power sale discussions are ongoing with several potential off-takers. The start of phase

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one construction is targeted for 2012, with further phases slated for 2013 and 2014. Nordex has both completed and planned installations in several states, including Minnesota, Pennsylvania, Wisconsin, Maryland, Iowa, Idaho, and Colorado. The Arkansas facility will fill all future orders, shipping turbines to wind farms around the country. More information is available at www.nordex-online.com.

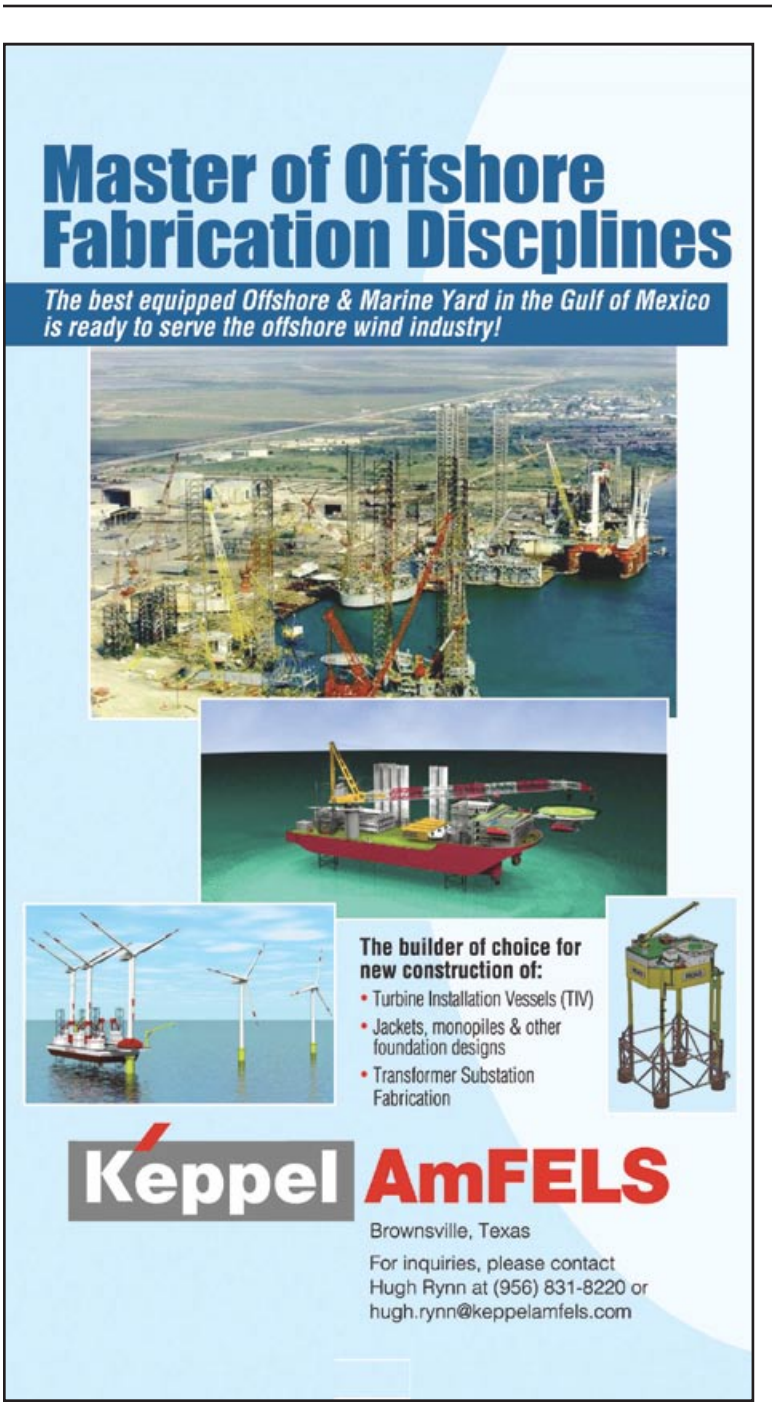
GE ENERGY FINANCIAL SERVICES HELPS FUND DEVELOPMENT OF ENERGY STORAGE SYSTEM

New Hampshire-based SustainX has received $14.4 million from GE Energy Financial Services and other investors to continue developing its technology for energy storage using compressed air. Through the GE Ecomagination Challenge's "Powering the Grid" program, in which SustainX is a partner, GE Energy Financial Services joins Cadent Energy Partners and prior investors Polaris Ventures and Rockport Capital in the new round of venture financing. The GE Ecomagination Challenge demonstrates GE's global commitment to accelerate the development and deployment of innovative power-grid technologies through open collaboration, while providing financial support to develop and commercialize innovative technologies.

Details of the financing were not disclosed. A total of $5.4 million in earlier financing for SustainX came from the Small Business Innovation Research program of the National Science Foundation and from the Energy Storage Program of the U.S. Department of Energy. AES Energy Storage, LLC, is working with SustainX to demonstrate a full-size system in the field, capable of storing enough energy to power 1,000 typical U.S. homes. "GE's backing, alongside that of other investors and the federal government, validates our efforts to develop and commercialize a cost-effective, grid-scale energy storage solution," says Thomas Zarrella, CEO of SustainX. "We are on schedule to develop a grid-scale prototype to be demonstrated at an affiliated AES site where we can showcase our transformative energy storage technology."

The present round of funding for SustainX represents the first time that both GE and Cadent Energy Partners have invested in the growing company. "We are pleased to be an investor in SustainX as we believe this company's energy storage solution has a global market with enormous potential," says Paul McDermott, managing partner of Cadent Energy Partners. "SustainX has set a remarkable pace in developing its product and establishing joint ventures to aid in the commercial production of its energy storage units. We look forward to participating in its continued success."

To store energy, SustainX compresses air by using electricity to drive pistons inside cylinders. The resulting high-pressure air is stored in above-ground



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vessels. To release energy later, the system uses stored air to drive the same pistons, which in turn drive an electric generator. SustainX technology keeps air at a nearly constant temperature during compression and expansion; this significantly improves efficiency and reduces the cost of compressed-air energy storage below that of other above-ground energy-storage options.

Independent experts estimate that the market for grid-scale energy storage will be $18 billion by 2015. Storage can improve the economics of wind and solar power, improve grid stability, store off-peak energy to be used during on-peak periods, improve the feasibility of microgrids in rural areas, and reduce emissions from the gas-turbine peaker plants presently used to keep electric supply precisely matched with demand. To learn more go to www.sustainx.com or www.geenergyfinancialservices.com.

BASF OPENS NEW EPOXY COMPOSITES APPLICATION LABORATORY

BASF Corporation announces the opening of their new epoxy composite laboratory at its technical center in Tarrytown, New York. The new laboratory brings together BASF's comprehensive technical capabilities for epoxy systems, under its Baxxodur® brand, to support the development of new epoxy composite applications. It offers a wide range of facilities for simulating customers' production processes with Baxxodur resin systems and the ability to develop tailored solutions for customer's specific process conditions. In addition, BASF has increased its technical support team with experts who provide on-site customer support. "This investment reinforces BASF's commitment to the wind energy market and will help us serve our customers better by providing fast and reliable technical support tailored to their needs," says Teressa Szelest, senior vice president of BASF's Chemical Intermediates Division.

Composites based on thermosetting epoxy resin systems have become an established material for the production of modern wind turbine rotor blades. Baxxodur epoxy systems can be processed significantly faster, over a wider temperature range than conventional systems, thereby increasing flexibility in production and allowing blade manufacturers to produce parts of higher quality in significantly reduced cycle times, offering up to 30 percent improvement in production efficiency.

The new laboratory provides excellent synergy with cluster of analytical services and application development resources of multiple BASF business units. This investment in North America is part of BASF's overall strategy to provide customers with a global network of technical support. BASF also has epoxy composite technical centers in Ludwigshafen, Germany, and Shanghai, China. To learn more about BASF's products for the wind energy market please visit www.windenergy.basf.com.

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STRENGTH THROUGH **COOPERATION**

Trent Schon
Mortenson Construction

While preventing the need for an emergency response is the primary goal, you must be prepared for any contingency, as this conclusion to a two-part series explains.

IN THE APRIL INSTALLMENT WE DISCUSSED key steps to emergency preparedness, including preparing a written plan and communicating it both on- and off-site, developing a quick reference checklist, and establishing a project response team. In dealing with local emergency services, whether comprised of volunteers or paid staff, you can help by providing them with a clearly labeled map of the project with street addresses and numbered wind turbines. Most counties have an emergency preparedness coordinator who is a great resource, so start by contacting that individual for help in assessing available resources and how best to distribute communications to the local emergency services.

Reliable on-site communication is critical. Handheld radios are by far the most-used communication device on a wind project and a very important tool during emergencies. However, protocol for radio use must be established to ensure that those needing assistance can be heard openly and without other interruptions. When emergency situations arise, radio channels should be cleared to allow the response team to react. This also means that work will probably slow or possibly halt on the project, so you may need to have a plan to manage those no longer working. In addition, the construction workforce must understand how to access it and when to use emergency numbers such as 911. A dedicated person in the office or trailer should be used as the center point of communication to avoid multiple phone calls to 911.

Training and drilling your workforce is critical. When determining whether your construction team is prepared to handle an emergency situation there are two primary questions to consider: is your staff trained, and do they know how to respond? A confident "yes" can only be accomplished through training and executing mock drills. At a minimum, emergency response teams should be trained in basic first aid, automated external defibrillator (AED), cardio pulmonary resuscitation (CPR), fall protection, tower rescue, fire extinguisher use, hazard communications, and blood-borne pathogens. Once this essential training is complete your company must set up drills to have your emergency response teams practice responding to various emergency scenarios. In order for these drills to be most effective they must occur during the life of a construction project at the peak of the civil work, and then again at the peak of the turbine erection stage. It is important to remember that many people do not think clearly during emergencies and the only way to address panic and respond confidently is to create realistic drills that test the team. After a drill or real emergency it is important to look for aspects of the response that did not occur as desired. A "lessons learned" analysis should be completed to identify improvement areas, and updates to your program should occur.

Because wind turbines are built vertically, a rescue at high heights requires additional focus and training. When it comes to tower rescue you must use the "Keep It Seriously Simple" (KISS) method, which ensures that emergency response is simple, precise, and focused. If your organization does not have the necessary experience to develop an in-house tower rescue program, there are many companies available that specialize in training workforces specifically on tower rescue. However, do your research prior to hiring any training company, and do your best to define what you want and need beforehand. Many of these companies seek to sell additional "bells and whistles" that are not necessary during a tower rescue. Above all, your tower rescue needs to be simple and clear. When drilling your emergency response team on tower rescue you should discuss the potential scenarios associated with the construction of most wind projects, identify the most effective approaches to deal with those scenarios, and then explain how to configure emergency equipment in a simple fashion. As mentioned above, you must repeatedly practice with tower rescue equipment in order to maintain competency among your workforce on every wind project. Always rely on the KISS approach.

While these two columns only scratch the surface of emergency preparedness, there are three basic ideas that should be applied to any emergency scenario you might experience on a wind project: make sure you define your plan and process, communicate the plan to all involved and, finally, train and drill your workforce. These three simple steps can mean the difference between life and death. Waiting until an issue arises is too late, and when it comes to worker safety all of us have an obligation to our wind power workforce to be sufficiently prepared for emergencies. It can be a long road when you're looking for help, so be prepared!

Trent Schon is director of safety for Mortenson Construction's Renewable Energy Groups, and a board-certified safety professional. Go online to www.mortenson.com.

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Rev1 Power Services, Inc.

The rise in mobile and wireless technology capability is the catalyst that the wind industry needs in order to keep pace with owner demands for real-time turbine status.

THOSE FAMILIAR WITH WIND TURBINE service documents—either having had to complete them as a technician uptower, or who are the recipients in the shop office—know all too well the delicate nature of these paper forms. Covered in grease, and sometimes torn or illegible, service reports continue to be the preferred method of communicating wind turbine maintenance despite the clear limitations this medium has in field applications. By the time such service information is placed in the hands of decision makers its value has been reduced to markings on a piece of paper, ineligible for cross-reference to other sources of data, rapid fleet-level review, or quick spare parts search to assure the project's high availability.

Regardless of whether a project site is using the most sophisticated electronic reporting system imaginable, or still using paper service reports, the purpose of visiting each turbine is not to create a record. The record is created to verify and document the turbine's service. It should be treated as historical evidence of all the work that was performed on the turbine, providing a benefit to the next service technician who will visit the unit and ensuring a well-documented response to maintenance issues. Unfortunately for most wind projects, mounds of historical service information is collected in paper format each year and shuffled away in a file drawer to be resurrected one day in a reactive approach to solving a major issue that has disabled a turbine. Except in rare cases, no intelligence or predictive data on turbine operation is ever developed from paper reports. A huge opportunity in equipment betterment has been lost because technology was not used to create information of value from collected data. Handheld devices such as PDAs, smart phones, and tablet or notebook PCs are no longer on the cutting edge of innovation. They are now commonplace tools of business and daily life. Use of handheld devices in business yields benefits by converting downtime to productive time, and their increased application drives business success by allowing simplification of processes as well as standardization of data. Though there are an infinite number of ways in which a maintenance or inspection process can be automated, software that offers open architecture will allow a service company's IT department to make changes and customize the program to fit the specific needs of the project. Without high cost, and being wedded to proprietary technology standards, project owners can easily build best practices into mobile applications by continuously improving upon the database structure, input devices, wireless capability, and query features. For example, making changes to an application system-wide can now literally be made to each mobile device over the Internet.

Considering that much of the work completed in the wind turbine O&M industry is performed remotely, instructions such as pop-up messages and training tips can be built into a mobile application. As example, consider the following scenario: A wind technician inspects a faulted wind turbine and identifies damage to the gearbox cooler radiator return hose. The technician correctly inputs this information into the handheld device. Based on the identified damage to the hose, the inspection application might bring up an additional set of questions: location of the damage, type of damage (tear, scrape, puncture, etc.), severity, type of hose (metal sheath, rubber, etc.), and serial markings on the hose. The technician may be asked to photograph the damage for the service report. For each of these questions a button is available to select for more detailed instructions on how to answer each question. This can be a powerful inspection training tool and will help to standardize all answers to ensure the most accurate service inspection possible.

To ensure the quality and consistency of a maintenance service, automating the exact way a process should be completed in every instance is an important value contribution. Mobile service applications can validate that the appropriate processes are done in the appropriate order. This is accomplished through a variety of means such as requiring specific information to be captured before moving to the next data field, requiring a digital photo of the as-found condition of a component, automatically capturing time and date stamps for work, and automatically checking inventory levels before replacing a part. These important data fields can be used proactively to assess the condition of a turbine prior to its next scheduled service or to serve as a maintenance timeline for responding to subsequent faults.

In today's age of technology, paper is an increasingly subordinate communication medium. In many respects, it survives only because we allow it to live. The rise in mobile and wireless technology capability is the catalyst that the wind industry needs in order to keep pace with owners' eager demands for real-time turbine status, particularly when MW-class turbines are at risk. Managing service data on an electronic platform will allow wind farm operators to maximize the use of historical information to optimize reliability and equipment longevity, minimize downtime, and improve the analysis of more comprehensive information. Until we are able to embrace digital technology in the service of turbines, we will continue to lose out on the full value of the data captured at the turbine by the service technician.

Merritt Brown is vice president of Rev1 Renewables, an energy services company supporting wind, solar, and biomass clients worldwide. To learn more call (866) 738-1669 or go online to www.rev1renewables.com.

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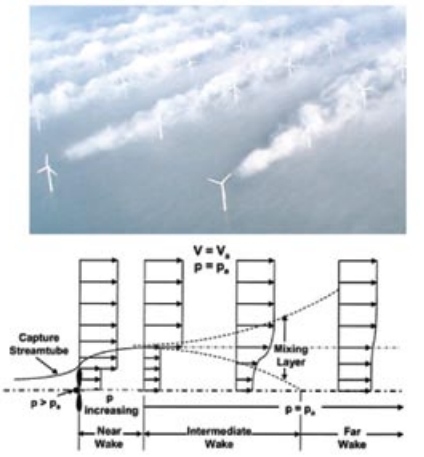
Sven Schmitz, Ph.D.
Penn State Wind Energy

In this installment the author discusses the past, present, and future of research into modeling the wake behind wind turbines.

THE WIND INDUSTRY FACES a number of challenges in developing wind farms, both onshore and offshore. Two that concern the aerodynamics of wind turbines are wind siting accuracy over complex terrain onshore and air/wave interaction offshore, and power forecasting for wind turbines to streamline transmission into electrical grid with minimal losses. These difficulties are even further amplified when wind turbine wakes interact directly with turbines located downstream in a turbulent atmospheric boundary layer (see figure). The accurate prediction of power extraction of wind turbine arrays such as in modern wind power plants is essential to the feasibility, reliability, and credibility of wind-produced energy.

A typical wind turbine wake is composed of three regions. One can identify a "near wake" that typically extends two to three rotor diameters downstream of the actuator disk and is governed by near-field viscous three-dimensional flow with wake expansion and an associated pressure increase. An "intermediate wake" where pressure and centerline velocity remain constant and a turbulent mixing layer reaches the centerline at the end of this wake region at about seven rotor diameters. A "far wake" region in which turbulent mixing now increases the centerline velocity recovery at approximately constant pressure. The fact that the pressure appears to remain constant in the intermediate and far wakes gave rise to assuming that downstream turbines do not affect the inflow of their upstream counterparts, thus leading to computationally more efficient "parabolized" methods.



Wakes downstream of HAWTs
Top: Wind Farm at Horns Rev, Denmark
Bottom: Structure of wind turbine wake

Today there are a number of wind turbine wake codes available that are primarily based on theory and standards developed in the 1980s. The very first models for wind farms considered wind turbines as distributed surface roughness elements in a logarithmic velocity profile model of the Atmospheric Boundary Layer (ABL). This concept was widely used in the early days of wind energy in the 1970s but is hardly used anymore today. However, these early approaches identified the two most important factors influencing wind turbine array efficiency, i.e. wind turbine location and atmospheric turbulence. Simple superposition of one-dimensional momentum deficits served as initial estimates. A more rigorous approach was pursued in the so-called "kinematic models," where a linear superposition of self-similar velocity deficit solutions based on models for co-flowing jets was utilized with the turbine thrust coefficient determining the initial velocity deficit. These kinematic models have their limitations and cannot include ground effects of complex terrain sites or interaction with sea waves offshore. More recent models are the "field models" based on the parabolized Navier-Stokes equations. A variety of closure models have been developed in RANS and LES to represent the behavior of the small scales. Different modeling issues here include the "inflow modeling" (ABL profiles from empirical methods and/or mesoscale weather prediction codes), the "wake modeling" (axi-symmetric, Gaussian velocity profile, Lagrangian vortex particle wake, RANS, etc.), and the "rotor modeling" (actuator disk, line, and surface methods that model the action of wind turbine blades on a RANS or LES flow with the use of the body-force concept).

Though significant advancements are currently being pursued, difficulties remain in a physically correct representation of actuating devices—i.e. the wind turbine blades—within a RANS or LES solver of the background ABL flow that satisfies the conservation laws of mass, momentum, energy, and circulation, or vorticity. Available field measurements show large data scatter that question the physical correctness of comparisons between data and predictions. There is the need for a hierarchical yet unified and general actuator blade model rooted in the physical conservation laws. We need some innovative modeler minds and hope that DOE's recent Funding Opportunity Announcement (FOA) will award new ideas that go beyond adjusting present predictive tools.

Sven Schmitz, Ph.D., is an assistant professor in the Department of Aerospace Engineering at The Pennsylvania State University and a member of its Wind Energy program. Call (814) 863-0778, e-mail sus52@engr.psu.edu, or go to www.wind.psu.edu.

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Anne Puhalovich
Professional Logistics Group, Inc.

Overland transport is a crucial link in the supply chain, so it's important to understand how new trucking regulations will affect the wind market.

THE FMCSA (Federal Motor Carrier Safety Administration) has implemented a new safety measurement program, referred to as CSA2010, intended to improve road safety and reduce highway accidents. The new measurement system is very complex and will affect the entire trucking industry, and it could impact industries that require heavy haul transport. The potential effects on the wind industry include a reduction in capacity and higher compliance costs.

The new rules create a fundamental change on how carrier safety is measured. Prior to CSA2010 carriers received a general pass/fail/conditional safety rating. The new Safety Management System (SMS) will use existing data sources to expand the rating criteria to six carrier safety fitness categories. In addition, the new measurements will drill down to the driver level detail to identify high-risk behavior. The intention of the new measures is for carriers to take more accountability over the safety of their drivers and their owner/operators.

CSA2010 will directly impact carriers. The more detailed ratings will more likely identify carriers with weak audit and compliance safety programs. To ensure compliance with the new rules and protect their safety rating, carriers will need maintain robust safety programs including investing in driver training, developing and documenting safe processes and procedures, and conducting in-house audits so that potential problems areas are addressed early. Carriers with these systems already in place may be minimally impacted by the new rules. Carriers with weak programs will experience increased compliance costs. Smaller or weaker carriers may be unable to meet all the requirements.

There is also legitimate concern that insurers will use the rating system to assess insurance qualification and rates. Since moving wind cargo is high risk by its nature, some carriers may choose, or be forced, to exit the wind business.

The new regulations will have an indirect effect on the pool of drivers. It is expected that carriers are going to be highly sensitive to the safety records of their drivers and will weed out the poor performers and refuse to hire drivers with bad safety records. Some estimate that up to 10 percent of the driver pool may unemployable. Driver safety records will remain part of the carrier's safety rating for two years, but because the records are time weighted the effect is more short term. So as the CSA2010 ramps up and the economy stays soft, it is highly probable that a shortage of drivers will occur. Carriers will be looking at a driver's past performance to see what risks they may taking when hiring the driver, and each company will set its own standards.

Fortunately, the heavy haul industry tends to have the most experienced and safest drivers, so the immediate impact of the new rules may be minimal. A greater threat to the wind industry is the ongoing depletion of qualified drivers due to retirements, the "boom/bust" nature of the industry, and occupational frustrations including many nights away from home. The new rules add a further risk factor for driver employment prospects and an additional barrier to the carrier's ability to attract new driver entrants. It takes many years to fully qualify as a heavy haul drivers and prospective new entrants may be unwilling to make the commitment due to high risk. The economic slowdown in the wind industry has led to driver exits. When the wind industry finally rebounds from its current levels, there will be fewer available drivers to handle the cargo.

The strongest companies will be motivated to hire and compensate the drivers with the best safety ratings. The competition for the best drivers will increase carrier costs, which eventually will be passed on to the shipper as higher rates.

The new SMS was tested in nine states in 2008 through 2010. Since April 2010, a preview of carrier data was available via the SMS system. In December 2010 the system was officially in effect, with full implementation expected by the first half of 2011.

CSA2010 is a big improvement toward improving overall road safety, but it still has its drawbacks. For one, it only addresses the commercial side of road behaviors. Secondly, the new requirements will add more cost in an industry already suffering from low margins. As demand for wind equipment increases along with the cost of operations, shippers are sure to see higher shipping rates. Finally, even though drivers are not directly affected by the rules, they will feel the pressure from their employers. A limited number of road side warning or citations may discourage drivers from entering the field and put more pressure on the availability of drivers.

Anne Puhalovich is project manager with Professional Logistics Group. For more information go online to www.prologisticsgroup.com.

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PROFILE

BROADWIND ENERGY, INC.

By Russ Willcutt

With expertise in manufacturing gears and towers—and providing crucial blade, gearbox, and O&M services—this company is poised to help carry the wind industry forward.

JUST AS A WIND TECHNICIAN'S adjustments ensure that a turbine is operating in top form, smart companies are constantly fine-tuning their operations as well. One that has paid particular attention to its structure and direction is Broadwind Energy, Inc., focusing on its strengths as a multi-faceted manufacturer and service provider for the global wind industry.

"Broadwind Energy is a collection of companies with longtime expertise in manufacturing gears and towers, and in providing O&M services," according to Peter Duprey, who became the company's president and CEO last December after stints with ACCIONA Energy North America and GE Energy, among others. "We acquired our tower business in 2006, our gearing business—Brad Foote Gear Works, which has been manufacturing high-precision gearing for the past 87 years—in 2007, and our services business in 2008, which provides blade and gearbox repairs and O&M services to the wind industry. We also opened a new multi-megawatt wind turbine drivetrain service center in Abilene, Texas, in February of this year, where one of our two tower manufacturing facilities is located."

Expected to eventually employ as many as 60 individuals, the service center will remanufacture gearboxes and repair blades, while also providing O&M services to the burgeoning Texas wind farm market and surrounding environs. The facility will also offer warranties on the repaired gearboxes, with significant savings compared to purchasing new. "I think we're at a point in the evolution of the wind industry, particularly in this country, where it makes sense to start paying more attention to the service side of things," Duprey says. "At the Abilene facility we'll take a used gearbox apart, put in new bearings and gears, and have it ready to replace a unit that's broken down. Part of our strategy is to be able to mobilize a team to go out in the field, pull the disabled gearbox and replace it, and then return the broken gearbox to our shop where it will be completely remanufactured and then run for up to eight hours on our test stand, which can handle gearboxes up to 3MW. We see the Abilene Wind Turbine Service Center as a great resource for the industry, and also a way of linking our gear manufacturing expertise with our O&M service capabilities. We'll also be able to repair cracks or flaws in blades, which we can repair uptower or, for more serious defects, bring down and repair in the shop. So we feel that a major business segment will involve performing these types of 'non-routine' repairs, and handling labor-intensive upgrades such as installing auto-lube systems."

As for its tower manufacturing operations, Broadwind Energy is applying its welding and metalworking expertise to designing and building the stronger, taller towers required by the larger turbines being produced. Evidence that the company is increasingly known for these complicated, thick-plated towers—it was the first in the country to produce a 100-meter tower, in fact—is found in Goldwind USA's decision to award Broadwind a contract to provide about 70 of its 85-meter towers for the Shady Oaks wind project in Illinois. More proof of its renown occurred earlier this year, when a certain individual toured the tower manufacturing plant in Manitowoc, Wisconsin, the morning after giving his State of the Union address.

"When we learned that President Barack Obama would be visiting, we decided to set the tour up in such a way that he would have the opportunity to observe every step of the tower manufacturing process, because it's a lot more complicated than simply bending metal plates into shape," Duprey explains. "The employees certainly loved it, and he was able to learn a little more about our industry as well."

Even more importantly, the President's visit made a larger point about the contribution the renewable energies industry is making to the U.S. economy. With companies such as Broadwind Energy building new facilities all across the country, creating new jobs to the benefit of the surrounding community, there is reason to hope for a resurgence of the manufacturing workforce throughout North America. "I think we can certainly bring hardcore manufacturing back to the United States," Duprey says, "and the wind industry is providing an excellent example of how to go about it."

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AMASSING WIND INFORMATION

Wind is a variable resource, but not an indecipherable one. Second Wind encourages harnessing the full range of wind sensing technologies that are available today.

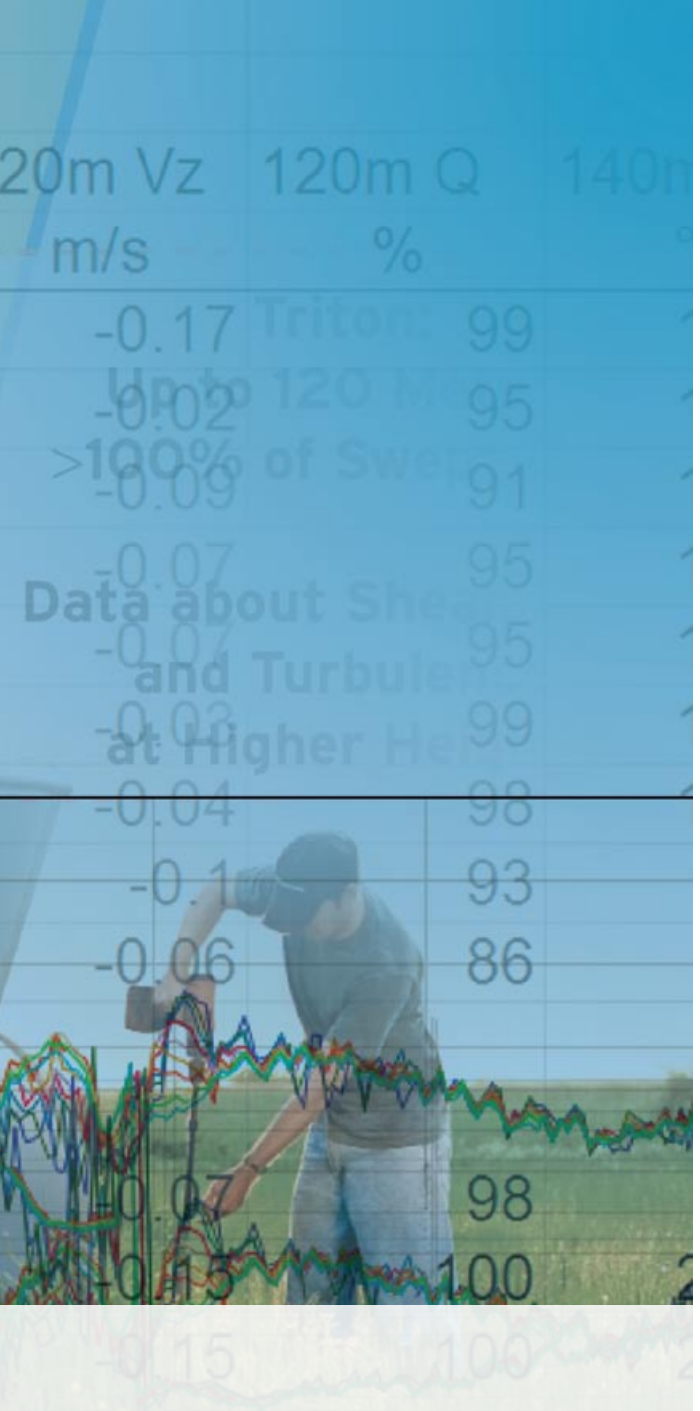
By Lee Alnes

Lee Alnes is director of business development for Second Wind, Inc. He can be reached at lee.alnes@secondwind.com. Go online to www.secondwind.com.

WHEN IT COMES TO WIND INFORMATION, much attention is focused on the choice of wind measurement technology and data collection practices in wind resource assessment and project design. Right now, wind data plays a limited role in the day-to-day operations and maintenance (O&M) of a wind farm once it is built. As wind measurement technology evolves and adoption of new methods increases, the same new technologies that are being used in the pre-development phases of a wind farm will also hold promise for improving productivity of wind farms after they are built.

WIND INFORMATION LIFECYCLE

Wind information has a lifecycle, with phases corresponding to the development and operational stages of a wind farm. Collection and maintenance of high quality wind information throughout the project lifecycle can be a vital part of your ongoing O&M strategy and useful for future planning purposes. Consider that a typical power purchase agreement is usually 15-20 years or more, and wind land leases can be 50-100 years in length. Twenty years from now when your turbines have reached end of life and more efficient turbine and blade technologies



are available, you will be well prepared to calculate financial returns on various re-powering alternatives if you have collected and archived in-depth information about the local wind resource. We don't know what wind turbines of the 2030s will look like, but turbine hub heights have nearly doubled over the last two decades, and the increase in height is projected to continue.

WIND INFORMATION AND O&M

The foundation for successful wind turbine monitoring and plant optimization begins with wind data collected during the pre-construction phases. Analysis of turbine rotor height data collected during the wind farm design phase of project engineering can aid in development of optimal operating strategies. For example, turbulence and inflow angle can be seen with wind measurements taken prior to construction. Once in the operations phases, turbulence and wake effects can be measured with portable wind profilers and mitigated though smart wind sector management approaches that dictate when some wind turbines might have to be switched off if they are operating in the wake of a neighboring wind turbine.

Profitability during the operations phase depends on maximizing power production and minimizing ongoing maintenance, especially unscheduled maintenance events associated with equipment breakdown. Since the cost of maintaining a wind turbine goes up with age—averaging about 10 percent of total wind farm operating costs during the early years and approaching 35 percent of operating costs as the turbine nears the end of its useful life—minimizing repair costs by improving operational practices can substantially increase wind farm profitability. So how can wind data contribute to improved production and reduced maintenance over the life of the wind farm?

Ongoing wind monitoring traditionally involves a handful of meteorological masts equipped with cup anemometers mounted at or near hub height, but recent increases in turbine height to 100 meters and higher makes this impractical. The number of masts used typically decreases between the assessment/design stage and the operations stage, meaning less data to inform decisions during operations. Increasing hub heights drives up the cost of hub-height monitoring, and makes larger guyed masts harder to incorporate into wind farm layouts.

Until recently reliable collection of turbine-height wind speed and direction data has been tedious at best, and prohibitively expensive in many cases. Historically, field measurement solutions employed 80-meter lattice-construction met masts equipped with numerous weather sensors. These towers cost on the order of $100,000 to erect, take many months to secure permitting, require Federal Aviation Administration (FAA) and Air Force approval in the United States and other types of permitting in most other countries, and need a steady power supply to operate the signal beacons.

Hub-height met masts and mechanical sensors are prone to failures caused by icing, windstorms, tornados, and other severe weather, and they have significant ongoing maintenance costs, resulting in a five-year lifecycle cost of as much as $200,000 to $250,000 each.

More recently, modern "remote sensing" wind profilers employing Sodar (Sonic Detection and Ranging)

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or Lidar (Light Detection and Ranging) technology are being used to get accurate data at hub height and beyond. These relatively new devices have the ability to accurately measure wind speed and direction across the entire rotor sweep and can detect inflow angles, turbulence, and wake effects. Remote sensing systems have a small footprint compared to a mast and are highly portable for temporary placement around a wind farm. When connected to an operations team with near real-time communications, remote sensing data collection has the potential to support four essential functions: power curve testing, load analysis, condition monitoring, and forecasting.

POWER CURVE TESTING

A turbine purchase contract typically includes a guaranteed power curve which warrants expected energy output at given wind speeds at that site. When the turbine doesn't deliver the expected power, warranty service and/or financial compensation may be in order. Formal power curve testing is usually administered according to International Electrotechnical Commission (IEC) standards that still require traditional anemometers, and is normally conducted while the wind farm is under construction because wake effects from neighboring turbines will affect the results. The assumption that a single-point hub-height wind speed is representative of the wind over the entire turbine rotor worked for small wind turbines, but is not applicable to modern turbines with 80- or 100-meter rotors.

Wind shear (speed changes that vary with height), veer (directional changes that vary with height), and turbulence caused by terrain or weather conditions require a more accurate wind measurement across today's turbine rotor. Proven accuracy, rapid deployment, and portability make remote sensing technology the logical choice for future power curve testing, and field tests are taking place now.

LOAD ANALYSIS

The wind industry is continually working to better understand the actual operating loads that affect today's massive turbines. Wind turbine load testing and analysis determines how turbines withstand the forces they're subjected to. Wind turbines and supporting structures are subjected to an almost constant barrage of wearing forces. Wind shear, veer, and turbulence take a constant toll on turbine gears, shafts, bearings and housings; performance in the field has not always matched that which can be modeled in a computer. Some standards have been created to allow the industry to design turbines with improved reliability, but the lack of good wind data has limited improvements. Turbine blades still crack, main shafts flex too much, bearings overheat, and gearboxes lose teeth. Knowing the wind conditions that cause these failures is critical to determining viable operating strategies.

The question for wind plant operators is whether the wind loads hitting the turbine are within its design envelope, and whether potential wear and tear on the machines outweighs the value of the electrical production. Taking turbines offline in certain damaging wind conditions may prove to be far more cost-effective than leaving them operating. However, knowing when to make this tradeoff requires reliable, accurate wind information.

CONDITION MONITORING

New hardware and software solutions for wind turbine condition monitoring can help indicate changes in turbine performance and allow operators to measure and record a wide range of turbine operating parameters. However, typical condition monitoring makes no correlation between turbine operation at any given moment and the wind forces hitting

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the rotor at that same moment. Although most wind turbines are designed to withstand a 100-year occurrence, at some sites turbines can be subject to conditions like that several times a month. Those extremes put enormous stress on the turbine components; accurate wind information allows operators to make operational decisions that can either improve performance or minimize equipment damage.

Most turbines now have heat and vibration sensors that trigger alerts when gearboxes are getting too hot or the equipment is vibrating too much. While these sensors are helpful, they don't enable proactive turbine management; they're akin to the "check engine light" in the average car. By the time the alarm trips, extreme conditions could have already damaged the turbine.

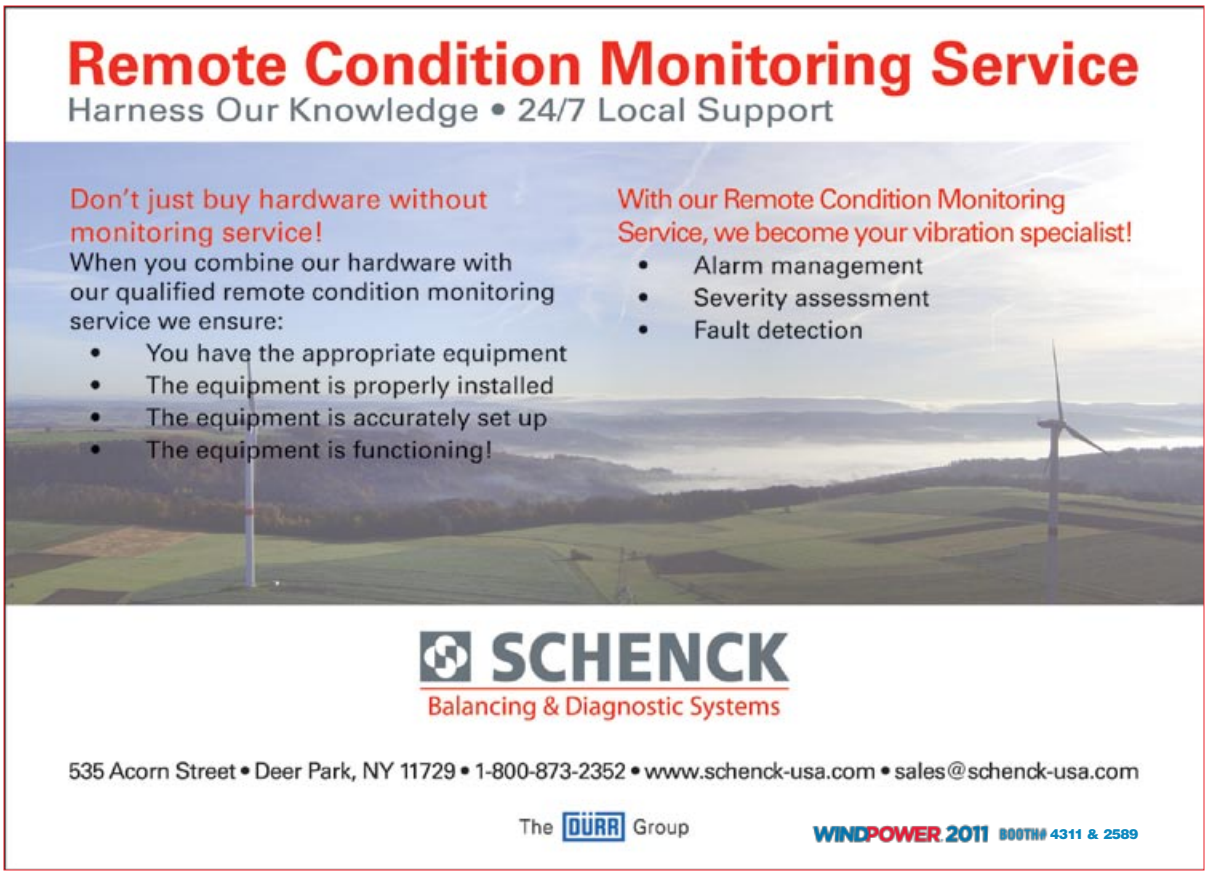
Wind data that reveals how the damaging conditions were created increases the value of condition monitoring. What wind forces were hitting the turbine blades? What pitch were the blades at when the gearbox started to heat up? What direction was the wind blowing? What was the yaw angle? How much shear was there? Operators need a greater base of recorded wind data so they can correlate conditions with actual wear and tear on the turbines. With that information in hand, operators can develop operating strategies that may prevent serious gearbox and rotor damage, which often means lengthy downtime and loss of revenue.

FORECASTING

To meet its full potential, wind energy must be integrated into utility systems where reliability is critical. Wind forecasting tools have been proven to minimize costs and ensure reliability, but their accuracy in near-term forecasting has suffered from lack of real-time wind data. Several studies are currently underway that show it may be possible to dramatically improve forecast results by accurately collecting and reporting actual turbine height wind speed and direction measurements and providing them to forecasters in near real-time. These measurements can be taken on-site or near-site and even regionally to get a look ahead at what wind conditions are approaching a wind farm. Accurate near-term forecasting of wind energy is heavily reliant on observed data because the timing of rapid weather changes such as thunderstorms is very difficult to predict without good quality field observations.

Numerical weather models are typically initialized with National Weather Service gridded data sets that are by nature at least one hour old by the time they can be accessed, ingested, and processed by the modeling software. Thus, forecasting in the hour-ahead timeframe may be improved with wind observations, both at and around a wind farm.

Early detection of weather fronts and other severe



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storm events is critical to predicting so-called "ramp events." A ramp event is a period of rapid change in wind farm production caused by rapid change in wind speed. There is no clear industry definition of how much change or what timeframe constitutes a ramp event. In fact, the amount of wind speed change required to cause concern will vary depending on the grid system in question. One thing is certain, ramp events are of interest to independent system operators because they must have operating strategies in place to deal with any impact the events may have on generation capacity and system reliability.

High quality observed wind data is particularly useful to assist human forecasters—still the best way to determine the timing of weather fronts—as input to computational learning systems, and for rapid assimilation into custom high-resolution numerical weather prediction models.

The same handful of met masts on wind farms that are used for ongoing wind monitoring are used to enhance wind forecasts, and the same shortcomings apply. The number and placement of towers on-site may not reflect wind conditions across the site, and sensors below hub height are missing most of the productive winds that the turbine sees. Remote sensing can provide measurements at hub height and above, with easier upwind placement and added data like inflow angle that is difficult to measure with mast-based sensors.

LOOKING AHEAD

The wind industry is experiencing a period of rapid evolution. Innovations in turbine technology have brought improvements in the amount of power that can be extracted from a given amount of land, but have created the need for more innovative wind measurement applications and wind data collection practices. The measurement technologies and data management systems that are today being deployed in pre-development applications hold great promise for the operations side of the wind information lifecycle. As wind information technologies, practices, and applications evolve to meet the needs of operating wind farms, wind farm operators must move to an integrated infrastructure that uses wind data—both current and historical—to make wind farms more productive and profitable.

Wind is a variable resource, but not an indecipherable one. Wind farm operators can improve turbine performance while minimizing wear and damage by employing the full range of wind sensing technology available today in an integrated infrastructure that informs monitoring and optimization. That process begins with treating wind data as a living asset that documents a site's historic wind patterns and adds value to its future.

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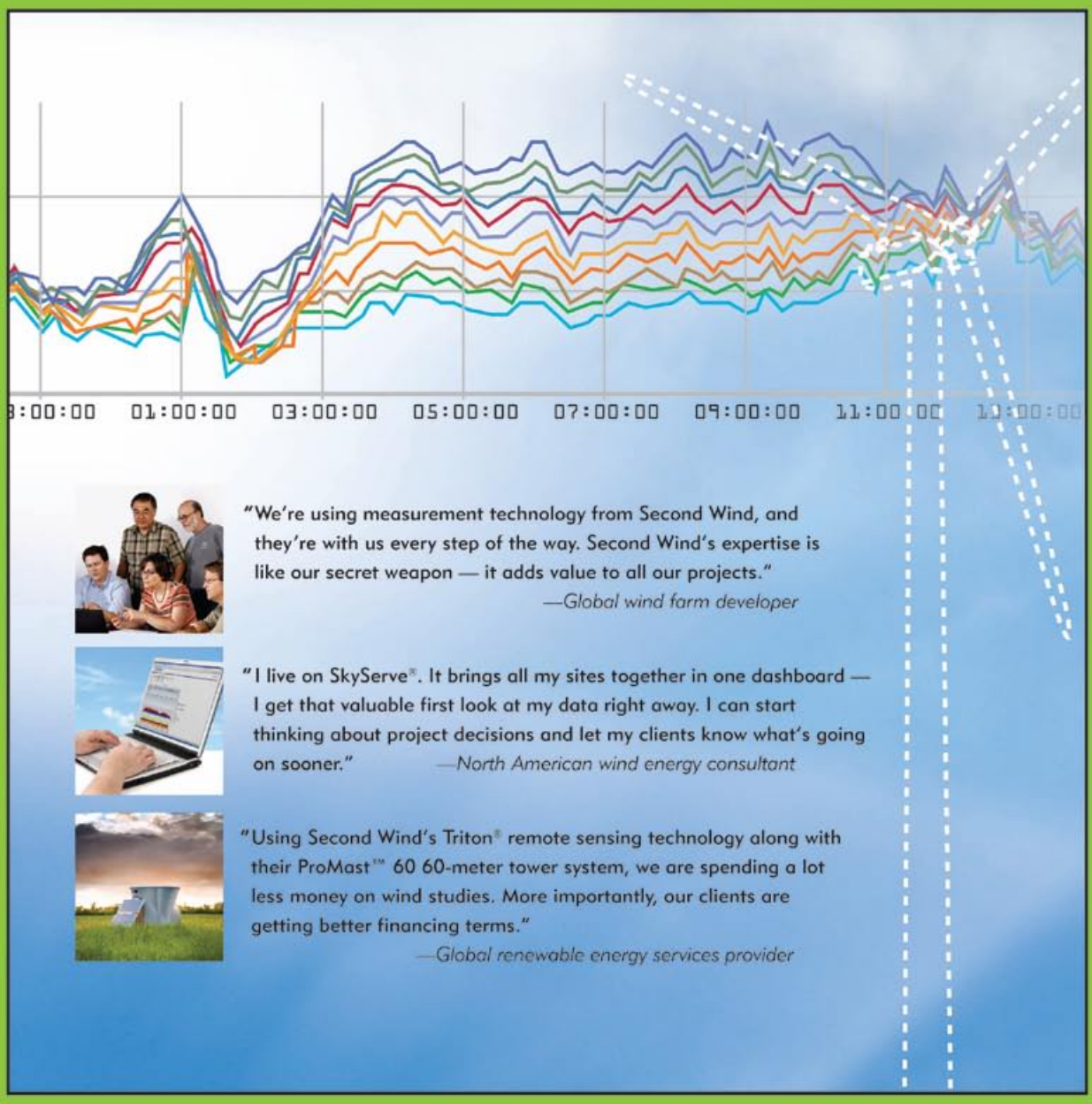

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PREDICTIVE MAINTENANCE STRATEGIES

Following predictive maintenance strategies implemented by the industrial sector will increase reliability throughout your turbine system. Shermco Industries provides details.

By Mike Moore

Mike Moore is vice president of sales for Shermco Industries. He can be reached at mmoore@shermco.com. For more information visit www.shermco.com.

WHEN THE SOUTHWESTERLY WINDS BLOW

out here in Texas—which is all day, every day—taking a planned outage to maintain your 120 megawatt wind farm is probably not going to happen. During the summer months, when the demand for electricity is at its highest and the demand for the reliability of these machines is even higher, planning a maintenance program to increase or even just maintain minimum levels of reliability and safety with a "No Outage Allowed" set of rules in place becomes quite complex very quickly.

So what is the wind farm O&M electrical engineer to do? Fortunately, there's a fairly simple answer: Develop a detailed no-outage maintenance plan based on good national consensus standards that have tried and true, recognized industry practices utilizing qualified and certified testing personnel.

MAINTENANCE TERMINOLOGY

Developing an "online" or "predictive maintenance" program isn't easy. Finding the right folks to safely work in the program is even harder. Keeping up with data and understanding data trending, machine/equipment failure

Fig. 1: Results of wind operator overspeed.

modes, and changing how often you should test based on all the above can be a stressful situation indeed. Development of the predictive program will be based on key components:

Reliability centered maintenance: RCM is the establishment of safe, cost-effective, minimum levels of maintenance, changes to operating procedures and strategies, and the establishment of capital maintenance regimes and plans. RCM typically utilizes predictive maintenance routines that constantly monitor conditions, typically performed when the equipment is online, or in service. RCM also concentrates on the monitoring and correction of root causes to equipment failures, also known as "root-cause-analysis."

Predictive maintenance: PdM is the process of evaluating the condition of equipment by performing periodic or continuous (online) equipment condition monitoring. Basically, predictive maintenance differs from preventive maintenance by basing the maintenance need on the actual condition of the machine rather than on a preset schedule. PdM is typically performed when the equipment is online or in service.

SAFETY IS CENTRAL

For the wind industry, money has always been tight and budgets squeezed. In recent years, however, wind has expanded at a rapid pace, and for the electrical construction contractor and the new generation of wind farm electrical workers things were exciting, and oftentimes chaotic. Most of these workers had never been exposed to the hazards that the wind turbine and collector system present, and most of them still have very little knowledge of the toxicity of electricity. In the last several years the wind industry has found value with proper engineering on the front end of a project, including acceptance testing and commissioning of the electrical power system components prior to initial energizing. Complete acceptance testing and commissioning of wind farms ensures a smooth startup and reduces the number of problems that can keep the site from coming—and staying—online. Many studies have shown that routine maintenance, including testing of electrical distribution equipment, has increased reliability and minimized downtime for commercial and industrial facilities, and these same philosophies hold true for wind farms.

The same can be said about protecting electrical workers who operate or work on energized electrical equipment, as we now can calculate that the incident energy produced by an arcing fault is proportional to its operating time. This aspect of incident energy means that proper maintenance and testing of the over-current protective devices (OCPD) is not only an operational issue, but also a safety issue. With this said, the very nature of maintaining an operational wind farm has some unique hazards typically not found in the commercial or industrial workplace.

PLANNING MAINTENANCE

When developing a reliability based maintenance program the consideration of equipment condition, environment, loading, criticality, and reliability must be determined. Other factors including long-term trending, auditing, and staying abreast of changes in standards. Methods of testing and evaluation must be considered as well.

One should develop these programs based on national consensus standards to bring credibility to the program. Suggested sources are the IEEE STD 902-1998 (Yellow Book): IEEE Guide for Maintenance, Operation and Safety of Industrial and Commercial Power Systems; NFPA 70B: Recommended Practice for Electrical Equipment Maintenance; or the InterNational Electrical Testing Association (NETA) MTS-2007: Standard for Maintenance Testing Specifications for Electrical Power Equipment and Systems. The NETA testing standard also offers guidelines for the frequency of maintenance tests within "Annex B" of the document.

Some of the more common PdM tasks with the wind industry involve very cost-effective and simple tasks performed on a monthly or quarterly basis. Though performing these services online can present additional risks and hazards that must be accounted for, the overall impact to operations is minimal, and typically outages and downtime are not required.

Many PdM tasks are simple to implement, and PdM routes and routines are fairly straightforward to develop and sustain. In order to have a successful PdM program you must have the ability to compare the current readings to either a previously collected set of readings, or develop to a set of alarm limits. We want to see how the heat, motor signatures, vibration, and oil data patterns have changed from previously obtained data.

Technicians performing electrical tests and inspections should be trained and qualified to understand the hazards associated with operating, switching, and maintaining electrical power equipment. These individuals shall also be trained, experienced, and capable of conducting the cable testing and evaluating the test data, and they must be able to make an informed judgment on the continued serviceability or non-serviceability of the equipment under test.

Utilizing an independent third-party testing contractor is the only method of determining the long-term usage of the electrical equipment and its suitability for the intended purpose. Selection of a qualified contractor with an industry recognized "electrical testing accreditation," such as InterNational Electrical Testing Association (NETA) accreditation, will help to ensure that a qualified and competent testing organization will perform the cable testing. Regardless of who you use, proper due diligence to the testing contractors capabilities and qualifications is essential.

MAINTENANCE METHODOLOGIES

Infrared scanning: Infrared scanning (IR) accurately identifies the presence of abnormal heat in electrical and mechanical systems, which can help predict equip-

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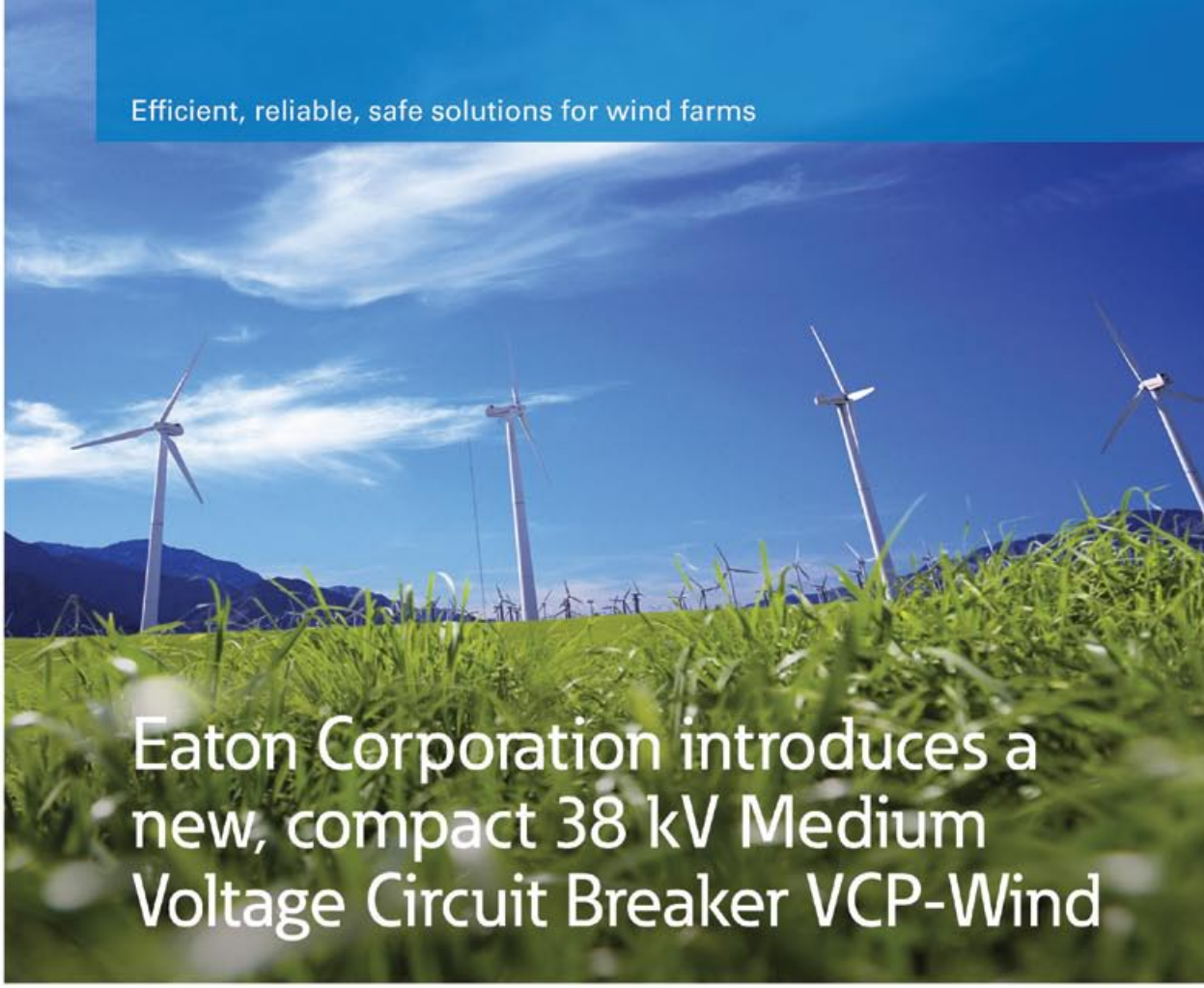

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ment trouble. The infrared (thermographic survey) process gives you a detailed thermal and photographic record of any problems detected, so you can take action before breakdowns occur. Typical inspection routines discover issues with roller and ball bearings, shaft/coupling alignment, loose cable and control wire terminations, generator core iron, windings, electrical connections, electrical insulation, and commutator/brush assemblies. The same technology and methodology used in the turbine is also used in the collector system to identify thermal issues in electrical components as well as the step-up transformer insulating oil flow/level, collector cabling connections/terminations, and generator circuit breaker connections.

Infrared cameras have significantly come down in cost over the last few years that many sites are purchasing their own camera for the routine scanning of the equipment and to troubleshoot heating. Their use for the daily maintenance routines is simple. Training and qualifying the part-time thermographer is easier than ever and usually performed by the manufacturer's representative in a few hours. Infrared scanning of these machines and collector equipment at least on an annual basis is extremely important. If the demand for reliability is higher than average an increase if frequency to twice annually, or even quarterly is justifiable.

Several factors can render an infrared camera unable to see electrical corona, which is the ionization of the air surrounding a high voltage component. They include conductor voltage, shape and diameter, and surface irregularities such as scratches, nicks, dust, or water drops, all of which can affect a conductor's electrical surface gradient and its corona performance. The corona camera can detect insulation and connection issues associated with the higher voltage equipment in the collector substation and the interconnection substation.

An annual frequency of scanning the collector substation for corona is an acceptable practice. Corona scanning, combined with any ultrasound and partial discharge analysis, could yield valuable data about the health of the insulation system.

Since some extreme electrical hazards exist on the wind farm, some planning and documentation must be put into place on dealing with high hazard and high risk electrical work. It is extremely important that the qualifications of the testing contractor or employee be qualified to perform the task.

Prior installation of "infrared windows" will greatly reduce the risk of any exposures, and expedite the online testing program. These

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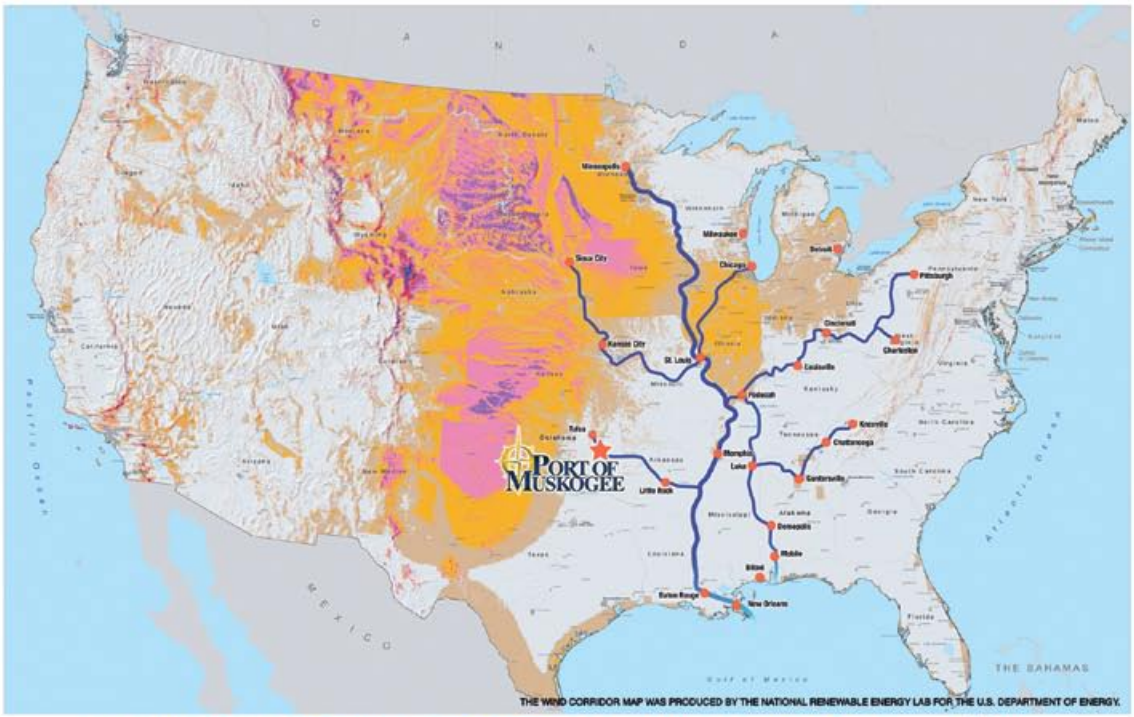

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windows will allow the passage of the IR light, maintaining emissivity, and if correctly installed limit any reason to enter the equipment enclosure and exposing live buses for routine inspections, which in turn greatly reduces and/or eliminates the electrical hazard exposure.

Online generator analysis: Online testing offers an analysis on the entire circuit path from the generator T-leads to the stator for phase-to-phase resistance, inductance, impedance, and current imbalance which is used to determine if turn or phase shorts are present, as well as faulty connections. The test can also identify cracked or broken rotor bars, porosity, and high resistance connections on the end rings through motor current signature analysis, and a rotor influence check. Many mechanical issues such as bowed shafts, cocked end rings, and degraded bearing journals create magnetic imbalances that can be detected, as well.

Since this methodology calls for the direct interaction of personnel with an energized and operating generation system, it is extremely important that the testing contractor or employee be qualified to perform the task. Prior installation of motor test access panels (MTAPS) will reduce the risk of any exposures and expedite the online testing program. These boxes allow the routing of the leads from the coupling capacitors and sensors to be brought outside the equipment. This will mitigate exposure to the electrical hazards and offers a low risk environment to perform the sampling. Typical frequencies for this activity are usually performed on an annual basis, but should be performed quarterly to offer the results and reliability, since this is one of the larger costs associated with your predictive

Vibration analysis: Vibration on rotating apparatus can be very destructive. These vibrations can be caused by imbalances on the rotating parts, the meshing of gear teeth, bearing loading, coupling alignment, and footing issues.

Very few of the turbines currently installed have permanently mounted online vibration monitoring systems. This means that almost all of the vibration data collection and analysis that is performed used a portable data collector, and the data is entered into a database program. This program, though effective and a great solution for preventing bearing failures, does provide for some challenges due the large number of points to be monitored each period. This means that an average 80-turbine site could have as many as 400 or more vibration points. When you consider taking vertical and horizontal readings at each bearing and one axial reading on each machine case, the numbers add up quickly.

Lubrication grease and oil analysis: Sampling and

analyzing bearing greases and oil lubricants determine the properties of the lubricant for additives, base oil composition, and issues such as contaminants and debris from premature gear or bearing failures. Tracking oil analysis sample results over the life of a particular machine can be trended to eliminate costly repairs.

Lubrication sampling, testing, and analysis is one of the least expensive line items in the maintenance budget, but is the most underutilized methodology of the predictive technologies. The standard practice for sampling of the lubricants is annually, but increasing the frequency to two or even three times a year will offer a premium return on the reliability of rotating apparatus.

Transformer insulating oil sampling and analysis: The majority of power transformers in operation at wind farms are filled with mineral oil. The primary function of the oil is to provide a high dielectric insulating material and an efficient coolant to dissipate heat.

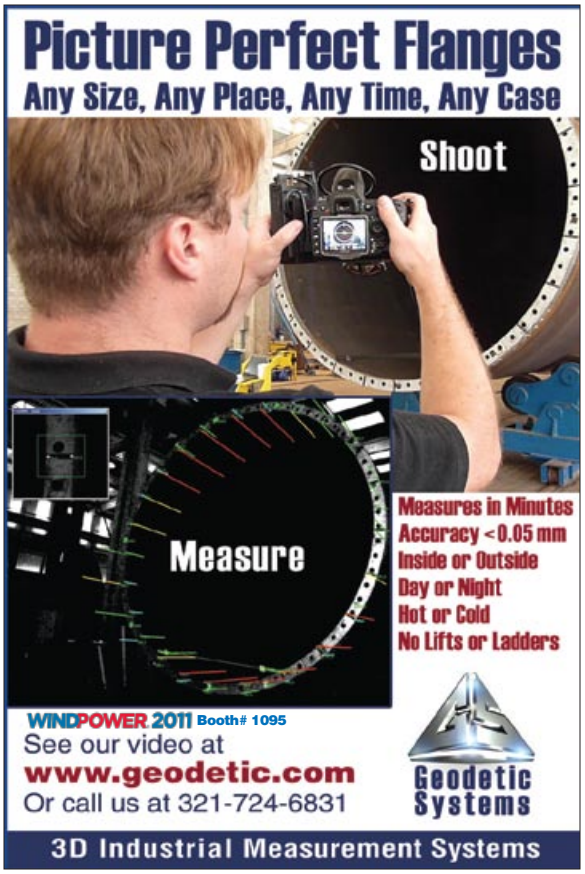
The effectiveness of the oil as an insulating material is reduced as the moisture level increases, while cooling is reduced as the oil oxidizes. The paper insulation will also absorb moisture from the oil. An analysis of the levels and ratios of dissolved combustible gases in electrical insulating fluids is a very effective tool to diagnose potential problems in the transformer caused by loose connections, overloading, arcing, hot spots, and case or seal leaks that let moisture or atmosphere enter the unit.

Transformer insulating oil sampling, testing, and analysis is another one of those inexpensive line items in the maintenance budget. Average costs typically range from $150-$250 for an oil quality and dissolved gas-in-oil test. The prices differ based on the desired battery of tests included in the program. The collector transformers should be sampled on an annual basis, while the collector substation transformers could stand an increase in frequency to twice annually, and possibly three times per year based on the number of load tap changer operations. The more critical the component, the more often you should test.

COLLECTOR SYSTEM

Partial discharge sampling and analysis: PD is a localized electrical discharge that only partially bridges the insulation between conductors. PD is a phenomenon that occurs inside cable insulation within imperfections, resulting from cable aging such as thermal, mechanical, and electrical stresses.

Because a significant percentage of cable failures are associated with partial discharge, cable systems are typically tested after installation for craftsmanship and



other related problems that can cause partial discharge. Online PD testing provides crucial information on the integrity of an electrical system. Partial discharge can be located, measured, and recorded, helping to identify cables, switchgear, and transformers that are close to failure.

Online partial discharge testing: PD or online testing is performed while the equipment is energized at normal operating voltages with a snapshot in time sample pulled and sent to a third party laboratory for analysis. The testing is conducted during real operating conditions, under typical temperature, voltage stresses, and vibration levels. It is a nondestructive test and does not use over voltages that could adversely affect the equipment. "Online partial discharge testing" is relatively inexpensive compared to offline testing that requires interruption of service and production. This methodology detects and locates some accessory and a few cable defects, but can detect failures in other areas; i.e., switchgear and bus.

Similar hazards exists as discussed earlier in the online generator testing discussion. When direct interaction of personnel with an energized and operating generation system may occur, it is extremely important that they are qualified to perform the task. Prior installation of "PD boxes" or cable/equipment test access panels will reduce the risk of exposure and expedite the online testing program. These boxes allow the routing of the cable/equipment shields or RF current transformers leads outside the equipment and mitigating exposure to the electrical hazards, and creates a low risk environment to perform the sampling.

SUMMARY

As many of these wind farms come out of their warranty periods, maintenance is a must, but finding qualified employees and contractors to perform these routine tasks is becoming evermore difficult due as the aging workforce and the lack of the younger workers moving in to replace retiring workers exacerbates the problem.

For the wind farm, following predictive maintenance strategies implemented by the industrial sector will offer a higher level of reliability, along with protecting the company's assets. Predictive and preventive programs can also help address the compliance requirements with NERC/FERC regulations. Follow-up with a regimented routine preventive testing and inspection program and further enhance the predictive maintenance program. Develop a well-defined and regimented predictive and preventive maintenance plan with reporting and trending capabilities, and improved reliability will follow, as well as less worry and enhanced peace of mind.

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DEEPWATER WIND DEVELOPMENTS

With the development of technologies such as Distributed Buoyancy Modules, Trelleborg Offshore is expanding the reach of deepwater wind development.

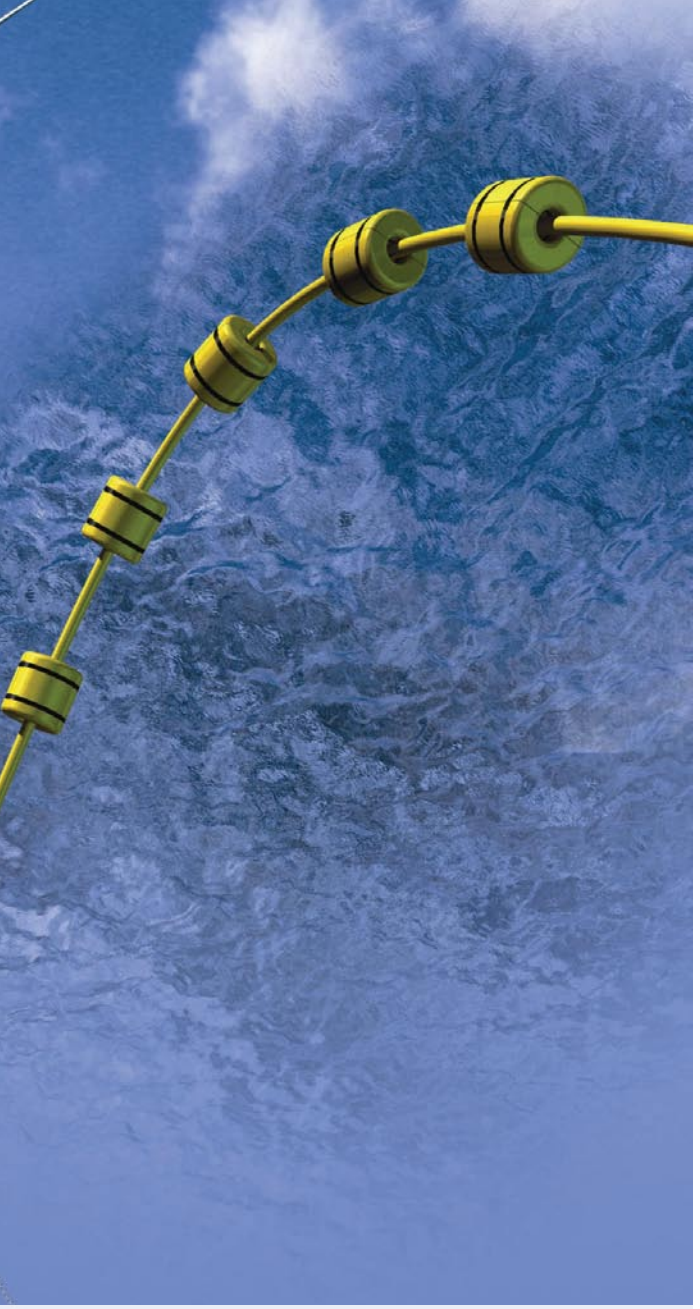
By David Somerville

David Somerville is principal renewables engineer at Trelleborg Offshore Renewables Solutions. For more information contact Gary Howland at gary.howland@trelleborg.com or visit www.trelleborg.com.

WHILE THERE IS NO SHORTAGE of wind in coastal locations around the globe, the process of effectively capturing wind for power generation isn't always as easy as you might think. Offshore wind power generation has traditionally been reserved for shallow water locations as, to date, wind farm technology has concentrated on seabed fixed platforms. These tend to be monopile or tubular jacket platforms, which are only suitable for shallower waters and can't be used in deepwater environments. In places such as Norway, which have comparatively little shallow water, traditional wind turbine technology can't be utilized, despite the abundance of North Atlantic wind.

Not surprisingly, Norway isn't alone, as other marine locations in the world face similar difficulties. However, where coastal offshore wind farms are not appropriate—in coastal marine reserves, for example—deepwater installations offer an alternative option. The deployment of the Statoil offshore wind turbine, Hywind, 10 km off South West Norway, provides a glimpse into the future of wind power generation.

With the increasing need for renewable energy



sources, it was vital to enable the exploitation of offshore wind power in deepwater locations. The requirements for inshore and offshore wind turbines are quite different requiring alternative technology to enable the effective utilization of wind power in all environments. The degree of buoyancy required for the cable, for example, was a key requirement for this offshore wind turbine and something that would have been unrecognizable in shallow water projects.

However, a wide range of proven technologies originally developed for deepwater oil and gas extraction, such as deepwater riser buoyancy and protection, can be transferred to offshore wind power generation applications, such as the Hywind project. Solutions such as Trelleborg Offshore's syntactic foam-based Distributed Buoyancy Modules (DBMs), required for the management of the power offtake cable connecting the offshore generator with Norway's national grid, are based on technology used in the deepwater oil and gas industry.

TURBINE TECHNOLOGY

The construction of the Hywind floating wind turbine is based on a proven deepwater floating platform design. This comprises a tall cylinder containing flotation tanks partly submerged 100 meters / 330 feet below the surface. It is ballasted at one end to ensure that it remains upright in the water, and secured to the seabed creating a comparatively small footprint. Located on top of this is the wind turbine generation unit.

The Hywind design is suitable for deployment where the seabed is between 120 and 700 meters/ 394 and 2296 feet deep. While the heavy structure, at over 5,000 tons, is incredibly stable, it operates in a very dynamic ocean environment. The buoy itself may be virtually static, but the energy behind the movement of ocean currents at different depths can impose heavy loads on the power cable, for example even though the depth at which it is deployed from the cylinder is below the influence of the waves.

CABLE BUOYANCY PROTECTION

Hywind is currently moored in 220 meters/721 feet of water with in excess of 100 meters/330 feet of power cable weighing about a ton per 10 meters/33 feet. The cable must be able to accommodate all movement and loading from the ocean in relation to the static platform, as well as its own weight, and therefore has a different performance specification than the cable used in static shallow water wind farms.

A proven method of reducing load on the cable from fixed and floating offshore structures is to provide midwater suspension of the cable by means of controlled buoyancy. In this way, the full weight of the cable doesn't threaten the security of the connection with the structure above.

Global cable company Nexans, which has extensive experience in supplying cable and fittings for oil and gas platforms, supplied the almost 14 km of power cable reaching back to shore. Trelleborg Offshore worked closely with Nexans to develop a solution to support the 10.6 tons of cable at a depth of around 150 meters/492 feet.

The proven Trelleborg Offshore syntactic foam Distributed Buoyancy Modules provided an ideal solution to support the cable. The DBMs were carefully posi-

tioned to create what is known as a "lazy wave" formation, where a section of cable between the platform and ocean floor floats horizontally mid water to accommodate any changes in tension on the cable.

CUSTOM-BUILT BUOYANCY

Trelleborg Offshore designed and manufactured 45 DBMs for the Hywind project. Made from syntactic foam, the DBMs have a final buoyancy weight of 235kg/518lbs. The final buoyancy weight provides the rating for the end of design life of the DBMs and cable, it allows for some compression of the foam and the very small amount of water infiltration over the 30-year design lifetime of the solution.

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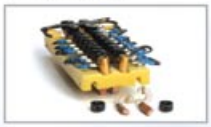

*Vestas is a registered trademark of Vestas Wind Systems A/S.
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Fig. 1: The Statoil offshore wind turbine, Hywind, 10 km off Southwest Norway.

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Fig. 2: Trelleborg Offshore's syntactic foam Distributed Buoyancy Modules (DBM).

The DBMs consist of two half rings with a syntactic foam core rated to a depth of 220 meter/721 feet, encapsulated within a tough protective polyethylene shell. A three-part clamp is located at the center of the ring to fix the two halves to the cable, with a restraining band around the exterior.

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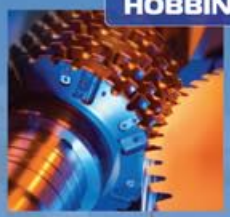

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ponent, as it is designed to resist the crushing pressure that would reduce normal flexible or rigid foams to a non-buoyant thickness. Trelleborg Offshore used its widely specified Evasyn™ grade of foam, which consists of a mixture of gas-filled macrospheres and microspheres held within a foam resin matrix. The formulation is precisely calculated to deliver the required buoyancy, as a mixture with a high compression resistance and low density.

The use of macrospheres and microspheres, distributed throughout the resin, impart the desired compression resistance. The glass walled microspheres, with an average diameter of 0.05-0.1mm/0.00195-0.0039 inches, are used as a buoyant filler around the thermoplastic resin macrospheres. The high-grade macrospheres, unique to Trelleborg, are injection moulded to a range of diameters to meet the buoyancy and compressive resistance requirements of the application.

DESIGN FOR A MARINE LIFETIME

With more than 50 years of experience and development in manufacturing and formulation of a variety of syntactic foams to meet different physical requirements, Trelleborg Offshore provides bespoke solutions to match marine, offshore, aeronautical, and naval requirements. The foam core is light and dimensionally stable, but very rigid, while the use of different materials for the macro and microspheres enables a wide range of precise specifications to be met.

The polyethylene (PE) shell provides a protective and highly visible surface, which helps resists abrasion, impact damage, and marine growth. The molded shape of the shell also enables easy handling, which ensures the on-ship deployment of the cable can be done quickly and effectively. As the DBMs are fastened into position on the cable while at sea, easy handling is vital.

An essential part of the DBM is the clamp that allows each module to be fixed accurately in position on the cable for a precise distribution of buoyancy and optimum control of the cable configuration in the water. The clamp includes machined nylon segments lined with compressible rubber fingers, which produce a secure grip on the cable surface.

The clamp segments are designed to bolt together until they contact each other, giving a simple and clear installation method. The clamping pressure is achieved by the compression of the rubber fingers, which also provide flexibility to accommodate the effects of diametric variations and bending of the power cable. All components are resistant to corrosion in seawater, ensuring structural integrity for the whole service life.

SAFETY IS CENTRAL

For deepwater applications such as DBMs, the foam and PE shell are hydrostatically batch tested to ensure they meet the requirements for buoyancy and compression resistance, using Trelleborg Offshore's own test facilities. The results of the tests enable verification of the materials for the task required.

As well as the buoyancy tests, geometric tests are also carried out, ensuring that all the components fit together before the DBMs are shipped out. The clamp functionality test is also done to verify that the clamp will withstand the design axial loads on the cable without slipping or damaging the cable.

The DBM is designed to ensure that it can be easily attached to the cable as it is lowered into the sea from the after deck of a cable-laying vessel. As well as having just a short "safe" weather window to perform these tasks, it is also important that the DBMs can be fastened securely under motion at low temperatures and while wearing gloves. The entire installation is carried out from onboard the ship, avoiding the cost and risk associated with the use of divers or ROVs (remotely operated vehicles).

With the ability to design, manufacture, test, and verify all aspects of offshore buoyancy and protective products for surface and subsea applications from plants in Skelmersdale and Barrow in the U.K., and Houston and Boston in the United States, Trelleborg Offshore ensures complete quality control.

Other product applications developed initially for offshore oil and gas work, but relevant to both shallow and deepwater wind turbine installations, include bend restrictors and stiffeners, protective ducting to minimize the effects of impact and abrasion, and vortex induced vibration suppression systems that reduce current induced cyclic stress on flexible cables and pipelines.

POWER GENERATION FOR THE FUTURE

The world of wind turbine energy generation is entering an exciting new era with the deployment of the Hywind turbine. It provides an additional dimension in the race to create lower cost energy resources, to complement existing land and inshore technologies. Although it's a new field, it is reassuring that a large proportion of the technology has previously been well tried and tested in other demanding offshore environments, such as the oil and gas industry.

It's essential that all available avenues of renewable energy are explored and utilized. The Hywind project demonstrates that deep offshore wind power generation is a genuinely viable source of power generation for the future, and that tried and tested methods are available to combat the issues presented by deeper-water locations.

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BEST PRACTICES FOR TURBINE MANUFACTURERS

The experts at Rockwell Automation have developed six principles for building cost-effective wind turbine generators in new markets, which they share with you here.

By Dave Schaetz and Steve Ludwig

Dave Schaetz is industry technical consultant, alternative energy, and Steve Ludwig is safety programs manager at Rockwell Automation. Visit online at www.rockwellautomation.com.

AGGRESSIVE FEDERAL GOALS TO REDUCE THE nation's dependence on non-renewable energy resources continue to drive expansion of the U.S. wind turbine manufacturing industry. The state of Colorado, for example, is aiming for 30 percent of its energy to come from renewable energy sources including wind power by 2020. Seeing this growth potential, wind turbine manufacturers around the world, including those in Europe and China, have their sights set on expanding operations in the U.S.

But a wind turbine manufacturer's path for expanding in new markets is not without obstacles. Challenges include establishing and managing an effective supply chain, identifying and complying with relevant standards, improving the safety of workers, and remaining competitive with time-to-market cycles.

Following are six best practices for wind turbine manufacturers looking to expand in the growing U.S. market by delivering cost-effective, safer solutions that are compliant with appropriate standards.

UNDERSTAND SAFETY STANDARDS

As wind turbine generator (WTG) manufacturers expand

operations globally, they must adhere to local and regional safety standards to help ensure the safety of workers and equipment in those regions. By following appropriate international safety standards, WTG manufacturers can streamline production processes globally, and gain access to customers all over the world. As an added bonus, incorporating safety standards into the wind turbine design process can increase productivity and profitability for both manufacturers and operators of wind turbines. Some of the newest safety standards that are reshaping how designers approach wind turbine safety projects include:

International Organization for Standardization (ISO) 13849-1/2 and International Electrotechnical Commission (IEC) 62061. These international safety standards were recently mandated by the European Commission's Machinery Directive, and were issued in part to guarantee the free movement of goods and services across a single European market. They also are considered among the most rigorous machine safety standards in the world. Any WTGs shipped into or out of Europe must comply with the appropriate standard after the final withdrawal of EN 954-1 in 2011. The international standards add two very important elements to the definition of the reliability of the machine's safety function: time and risk. These two elements help machine builders take advantage of a more methodical approach to safety system design.

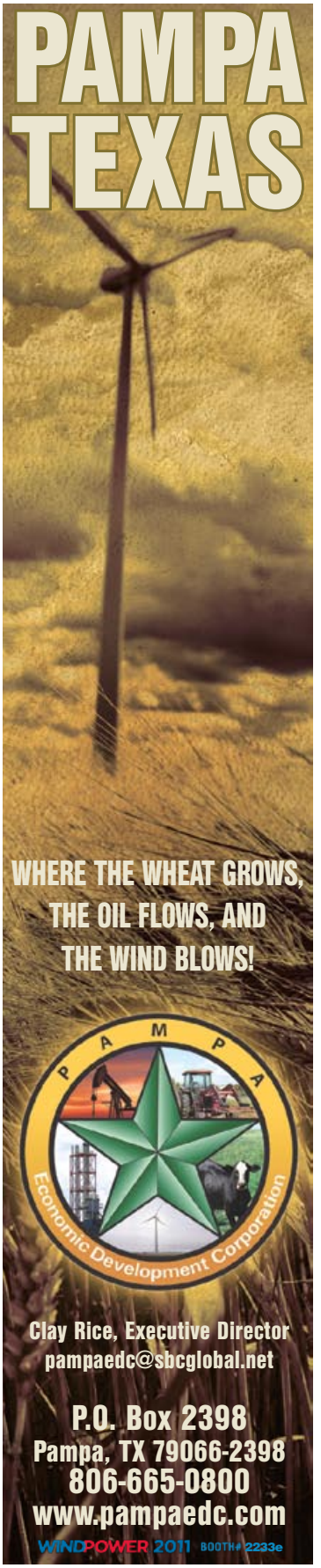
Both international standards require WTG manufacturers to identify and document the potential hazards associated with machine operation and the risk levels hazards present to users. The safety system is then designed to the level of risk associated with the hazards present on the machine. This allows the designer to design the safety system to the correct functional level. Appropriate documentation proves a machine's level of safety, designers can better justify a need for a safety system upgrade, and operators can be more confident in the reliability of a machine's safety system.

Product Directives. Many product directives have been issued in Europe as part of an effort to create a unified European market. Limited to "essential requirements," which are general in nature and primarily focus on health protection, these directives are compulsory for any product put into circulation and so apply to wind turbines and their subassemblies.

GL Guideline for the Certification of Wind Turbines (Edition 2010). The latest edition of this guideline makes specific references to the EN ISO 13849-1: 2006 Functional Safety Standard and requires that WTG manufacturers conduct a risk assessment to determine the maximum permitted probability of failure. By providing numerical evidence of the probability of failure, WTG manufacturers can help justify a customer's investment in new safety systems.

Underwriters Laboratories, Inc. (UL) Standards. Large and small WTGs are evaluated according to UL Subject 6140-1, UL's "Outline of Investigation for Wind Turbine Generating Systems." The systems are evaluated for risk of fire and shock, including safety related control system electrical performance and utility grid-interconnect performance for utility interactive models. While these standards apply in North America, they do not align directly with many of the European IEC standards, making it difficult for European WTG manufacturers to conform to standards when expanding to the U.S.

Tackling the many often-complex standards can be daunting. WTG manufactures should leverage the expertise of certified safety consultants from a global supplier to



navigate requirements and design an acceptable safety system.

START WITH A SAFETY AUDIT

Machine safety is critical for protecting people and the capital investment in a WTG. The diameter of wind turbine blades has become significantly larger in recent years and is now larger than the wingspan of a Boeing 747 jumbo jet, increasing the potential amount of wind energy each WTG is capable of producing. In turn, protecting assets becomes increasingly important for wind turbine manufacturers.

Uncontrollable hazardous weather conditions like high wind speeds create unique safety challenges for wind turbine manufacturers. For example, the turbine must be capable of being brought to a stop quickly and safely in the event of high wind speeds to prevent the turbine from tearing apart. WTG safety system designers are also challenged with a mix of high and low voltages, depending on the section of the WTG (e.g., tower, nacelle, or hub), requiring different considerations based on what is present in a particular area. Within each area, there may be low voltages, high voltages, or a combination of the two. The voltage dictates the safeguarding mechanisms necessary to mitigate risks in each area of the WTG.

For example, personnel must be protected against rotating parts in the nacelle and hub, and WTG designers may need to use physical guarding or special access requirements to stop the WTG from rotating prior to personnel entering the area. Other examples of effective safeguarding include employing a safe-speed monitoring relay to detect over speed of the rotor, vibration monitoring sensors to detect excess vibration, switches to control the opening of control cabinet doors, and/or medium voltage switchgear used in the lower portion of the tower to detect and suppress arc flash hazards.

Performing a safety audit before control system design helps engineers chart the course for an effective safety solution, and evaluate and investigate risks early in the development process. This saves critical time and helps machine builders get their equipment to market faster. In addition, the machine's end users gain optimized production, thanks to an automation system that helps operate machinery and processes in the most efficient way. A safety audit identifies potential hazards and the required safety control system integrity level, and helps guide the selection of the overall control architecture to achieve the optimum level of safety.

Where hazards cannot be removed through design, machine builders typically will install a fixed physical barrier that helps protect users from the hazard. When frequent access to the hazardous area is required, non-fixed guards are used, such as removable, swinging, or sliding doors. In areas where non-fixed guards are impractical, guarding solutions that monitor the presence of the operator rather than the status of the gate can be used.

USE INTEGRATED SAFETY SYSTEMS

The evolution of safety standards and economic factors are driving the evolution of safety systems from hardwired to contemporary, highly integrated configurations. Using an integrated platform for safety and standard control eliminates the need for electromechanical or hardwired controls. The more designers integrate the standard and safety control functions of a system, the better the opportunity to reduce equipment redundancies, and improve productivity and minimize costs.

This integrated control functionality reduces the number of unique components in use as part of the WTG control system, which in turn reduces inventory costs, as well as maintenance team training requirements. End users also benefit from less waste with fewer parts to maintain and replace throughout the WTG life cycle. In addition, integrated control systems, having broader intelligence regarding machine operation and status, reduce nuisance

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shutdowns and prolonged restarts, further improving machine efficiency and productivity.

Safety controllers provide this integrated control functionality and offer significant benefits in multistep shutdown or ramp-down sequences because they provide the necessary logic through software rather than the hard-wired logic of relays. An integrated safety controller is an ideal solution for any application requiring advanced functionality, such as zone control. Being able to safely monitor and control access to what is active on each level of the WTG is critical due to the size and height of the decks within a WTG tower design. With properly designed safety controls and guarding, designers reduce access time, helping make machines safer and more efficient.

Along with eliminating the need for a separate safety controller, integrated safety systems also use a single programming software package. This can eliminate the need to write and coordinate multiple programs on different controllers, which in turn can simplify application programming, and help reduce training and support costs.

Safe-speed control solutions provide a great example of effective control integration. With safe-speed control, safety input devices, such as guard-locking switches and emergency stop pushbuttons, connect directly to the speed-monitoring core of the control solution. This eliminates the need for a separate, dedicated safety controller. Extending use across multiple platforms, safe-speed control solutions help reduce overall system cost and improve flexibility because they allow operators to perform maintenance and other tasks while a machine is in motion. Safe-speed control also helps increase uptime and decrease energy costs because a machine need not be completely shut down and then restarted.

Networking offers another way to integrate safety and standard controls. The introduction of networks to industrial environments helps increase productivity, reduce wiring and installation, improve diagnostics and ease access to facility data. Using an existing network to include safety information extends those same benefits, allowing seamless communication of the complete automation process on one standard network with one set of hardware and wiring. Diagnostics from smart devices that are networked together also can simplify designs and reduce integration costs.

ENSURE COMPLIANCE WITH FUTURE GRID CODES

WTG manufacturers need to keep in mind the emergence of new grid codes around the world, as these codes have important implications for the network connection requirements of wind farms to the grid. Recently, utilities have expressed interest in a harmonized grid code compliance standard that would specify the response time for wind farms that support the electrical grid during faults in the system. One suggested stan-

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dard would require wind farms to supply reactive power within 20 milliseconds of fault detection, a reaction time many struggle to deliver today due to legacy, and often proprietary, communication protocols that make it difficult to coordinate a complete wind farm. Some farms utilize more than one WTG manufacturer, and each one may utilize a unique communication protocol it has developed internally, making it difficult for a wind farm to standardize on one protocol throughout the farm.

Wind farm management systems designed with EtherNet/IP network connectivity are capable of meeting or exceeding this proposed reaction time. EtherNet/IP, the world's leading industrial network, is an open standard that uses Ethernet TCP/IP technology. EtherNet/IP manages standard and safety control on a single network and allows convergence of the WTG with the business enterprise, providing access to diagnostic data and allowing more accurate and informed decisions. This connectivity also allows for deterministic data exchange at fast intervals and reduces the infrastructure required to support system management activities.

Using a wind farm management system with the EtherNet/IP network connectivity provides wind farm management companies with remote-monitoring capabilities. The ability to remotely monitor and control equipment from a distant location helps reduce fuel usage and related emissions. It also reduces associated travel time and costs of sending maintenance personnel to the WTG location.

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PARTNER WITH A GLOBAL SUPPLIER

WTG manufacturers expanding operations in a new market may encounter several supply chain challenges, including how to manage costs, inventory and vendor relationships. Working with a single global supplier, manufacturers benefit from one local point of contact for all supply chain considerations, freeing up internal resources to focus on its core competency and lowering the total cost to design, develop and deliver new turbines.

A global supplier with broad industry experience also can help the manufacturer implement a successful production management system based on industry best practices. As a result, WTG manufacturers can better respond to spikes in customer demand, increase productivity, and lower their time to market. One global supplier also eliminates the need to contact multiple vendors for support and troubleshooting issues, and is also a resource for regional standards compliance.

LEVERAGE PANEL BUILDING SERVICES

Engineering the control panel is easily one of the most time-consuming and cost-intensive aspects of the WTG design and development process. Knowing this, many WTG manufacturers work with third-party panel builders to streamline the process. However, the actual design and documentation are usually the responsibility of the WTG manufacturer. And, as business grows in new markets, working with multiple panel builders can become quite arduous, often resulting in the need for increased engineering staff resources.

Rather than working with multiple panel builders, manufacturers can work with a global automation supplier that provides panel-building services to develop complete power and control panels for all new projects, regardless of location. This single point of contact through design, prototyping and ongoing deliveries can help a WTG manufacturer increase production capacity without increasing its internal workforce, freeing up existing resources that would be needed for engineering, procurement, inventory management, testing, standards compliance and troubleshooting support.

A single global supplier with experience assisting WTG manufacturers in globalization efforts can also help adapt to regional electrical standards for panel building. WTG manufacturers need to ensure panels are compliant with UL standards in the U.S. and CE standards in Europe and other countries.

Working with a single global supplier, the WTG manufacturer can also standardize component selection and panel design across all locations worldwide, simplifying spare part inventory, training and staff-

ing practices. Reducing the number of control platforms also helps serve end customers; since the manufacturer's staff is trained on one platform, there is always a knowledgeable technician available for customer support.

Thanks to advancements in technology and globalization of safety standards, WTG manufacturers can expand to new markets and help customers improve worker safety and protect equipment and assets. By enlisting the help of global suppliers, WTG manufacturers can ensure a smooth expansion to new markets and continue growing as the wind energy industry expands.

SESSIONS DAY 1: SUNDAY MAY 22

8:30 a.m.-3:45 p.m.:
- Wind Development for Professionals-Turning Ideas into a Wind Generation Asset

9:00 a.m.-4:00 p.m.:
- "Careers in Wind" Summit (separate registration required)

12:30 a.m.-3:30 p.m.:
- How Wind Energy Works in Electricity Markets Today
- Fundamentals of Worker Environmental Health & Safety
- Wind Energy 101: Introduction to Wind Energy

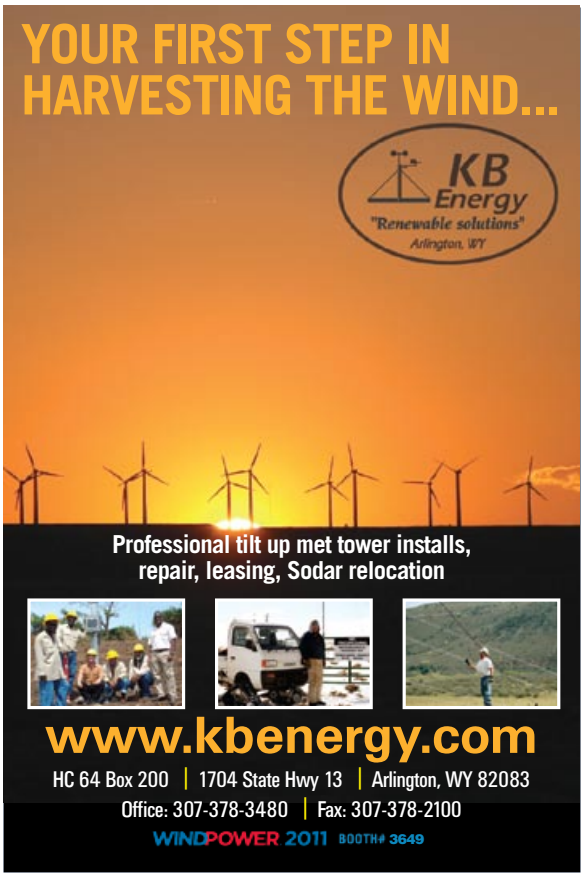
SESSIONS DAY 2: MONDAY MAY 23

AWEA WINDPOWER CONFERENCE & EXHIBITION 2011
Anaheim, CA May 22-25

10:30 a.m.-12:00 p.m.:
- Key Topics Track: Long Term Market Prospects for the U.S. Wind Market (1A)
- Project Development Track: California-Challenges to Renewable Leadership (1B)
- Wind 101/Transmission Track: Wind 101-The Business of Wind Power (1C)
- Resource Assessment Track: The Future of Resource Assessment-What's New and Emerging
- Wind 101/Performance Track: Wind 101-Laying the Technical Foundation

1:30 a.m.-3:00 p.m.:
- Key Topics Track: Decisive Policy-Expanding the U.S. Wind Energy Industry (2A)
- Project Development Track: Nuts and Bolts-Tools for Project Developers (2B)
- Wind 101/Transmission Track: Transmission in the Western U.S. (2C)
- Resource Assessment Track: Estimate Wind Correctly-How Much, How Strong (2D)
- Wind 101/Performance Track: Wind Facility Safety-Secure and Protect (2E)

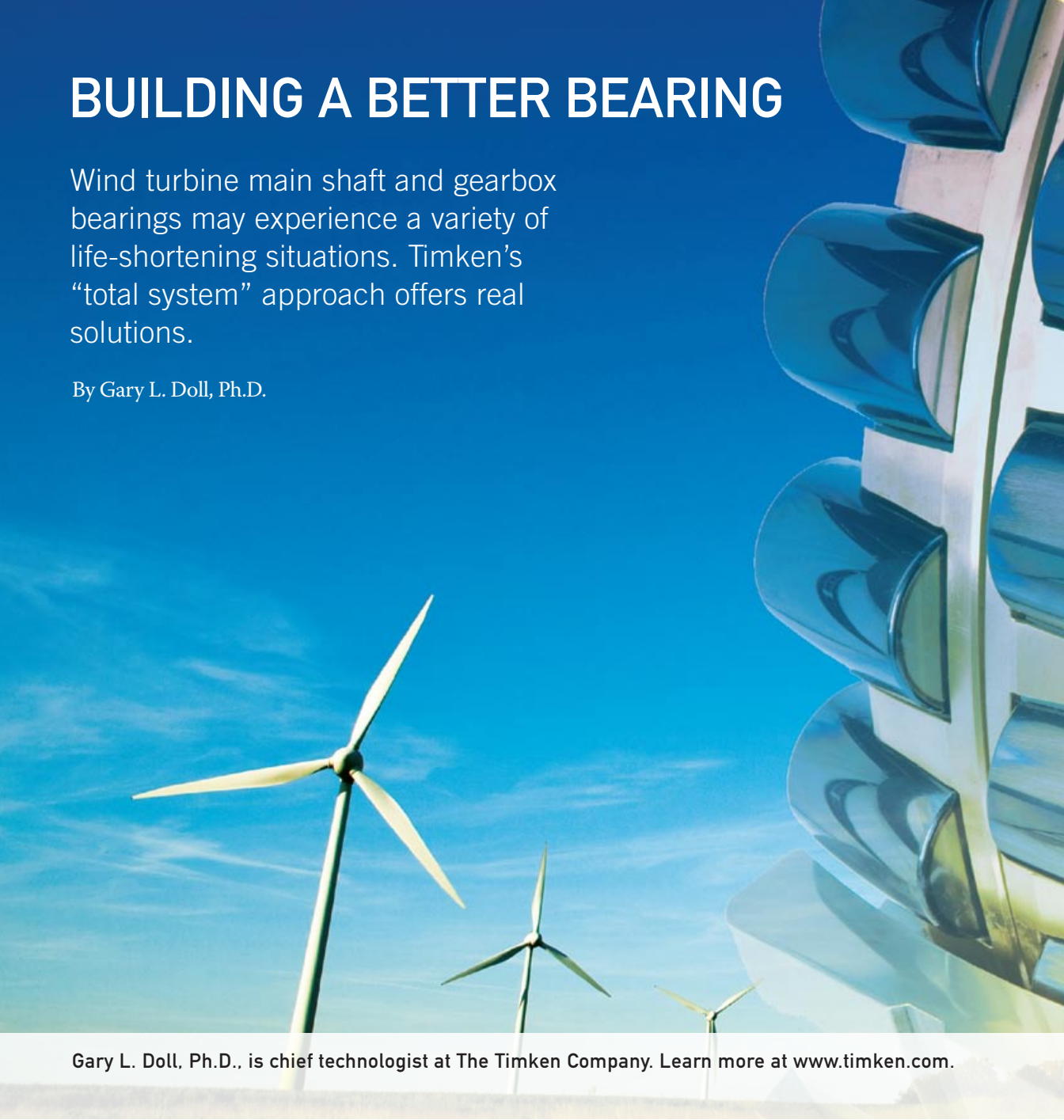
3:30 a.m.-5:00 p.m.:
- Key Topics Track: Wind is Good-Economic Benefits to Wind Development (3A)
- Project Development Track: Wind Energy and Radar-Assessing for Compatibility and Realizing Solutions (3B)
- Wind 101/Transmission Track: Transmission in the Eastern U.S.-What Should Get Built, What May Actually Get Built (3C)
- Resource Assessment Track: Resource Assessment-Scientific (3D)
- Wind 101/Performance Track: Increase Wind Project Profitability per KWh (3E)



BUILDING A BETTER BEARING

Wind turbine main shaft and gearbox bearings may experience a variety of life-shortening situations. Timken's "total system" approach offers real solutions.

By Gary L. Doll, Ph.D.



Gary L. Doll, Ph.D., is chief technologist at The Timken Company. Learn more at www.timken.com.

AT WIND FARMS, MAINTAINING MAXIMUM uptime is critical. However, as bearings perform their mission-critical function inside wind turbines, challenges related to dynamic and unpredictable stresses have made this goal difficult to achieve. In particular, the most significant areas of concern are associated with main shaft spherical roller bearings and gearbox spherical and cylindrical roller bearings. Many of these bearings are wearing prematurely, leading to increased turbine maintenance costs, and could lead to sudden, expensive turbine breakdowns. In this article we will look at common main shaft and gearbox bearing reliability concerns, their causes, the impact on performance, and suggested remedies.

MICROPITTING: CAUSES AND EFFECTS

Spherical roller bearings have been and are being used to support the main shaft primarily because of their ability to accommodate misalignment between the shaft and the bearing housing. If everything works as envisioned with a spherical-based design, it can be an effective arrangement. However, if these bearings experience large amounts of wear, they must be prematurely removed from service.

The most significant wear problem facing main shaft spherical roller bearings is micropitting, a type of surface-initiated fatigue wear. Micropitting is caused by interaction of the raceway and roller asperities, leading to high stresses in the contact. The normal stress alone is not typically sufficient to cause a crack to initiate at or very near the surface early in the lifecycle of a bearing. However, the addition of frictional shear stress increases the bulk contact stress values and brings the maximum values closer to the surface, allowing these localized stresses under the asperity contacts to become significant. This type of interaction typically occurs when the lubricant film is insufficiently thick to separate the contacts and when there is relative sliding between the two contacting surfaces.

Analyses of typical radial and thrust forces on a 230/600 main shaft spherical roller bearing with the radial clearances inherent in the bearing design indicate that the entire load is supported by the downwind row of the bearing, while the upwind row is essentially unloaded. This uneven load distribution results in higher loads on the downwind row, as well as a full 360-degree loaded arc of rollers. The fully loaded arc of rollers increases the number of stress cycles occurring on a point on the inner raceway for every shaft revolution.

Main shaft bearings typically rotate at slow speeds in the 10-20 rpm range, which does not generate a substantial lubricant film thickness even with higher viscosity lubricants. Consequently higher loads, more stress cycles, and thinner lubricant films are present on the downwind row increasing the risk of micropitting, especially if roller/raceway sliding is present.

In bearings, micropitting is a degenerative condition. As it continues more raceway material wears away, causing the loss of profiles in the center and high stress concentrations at the edges of the wear track. High stress concentrations can cause early raceway fatigue, which may result in erosion of the raceway, commonly referred to as "spalling," and a reduction of the useful life of the bearing. Unfortunately, because micropitting is a wear process, its existence is not always readily apparent. In fact, thousands of hours of operation may be required to generate observable wear on bearings.

TO SMEAR OR NOT TO SMEAR?

In rolling element bearings, the friction caused by large amounts of roller/raceway sliding can generate local temperatures in the contact zone that are high enough to melt the surfaces of the rollers and raceways, generating a "smeared" appearance on the raceway surface. Sometimes, FeO is found in the smeared region, which means that the local temperature in the contact zone exceeded ~500 degrees Celsius. Smearing is usually a sudden occurrence as opposed to an accumulated wear process, and is known to occur in lightly loaded large bearings and in bearings subjected to high accelerations or rapid speed changes, conditions that are common to wind turbine gearbox bearings.

WHAT IS BRITTLE FLAKING?

The phenomenon of micropitting is not exclusive to main shaft bearings. It happens to bearings inside wind turbine gearboxes, too. Gearbox bearings can experience two other problems: the aforementioned smearing, and brittle flaking. Like micropitting, smearing is caused by roller/raceway sliding in thin film lubricant conditions. The origins of brittle flaking are less understood.

Before we examine brittle flaking it should be noted

Fig. 1: Addressing reliability problems with Timken's new wear-resistant upgrade bearing.

that, due to micropitting and smearing problems in spherical roller bearings fewer, if any, wind turbine gearboxes are being designed and manufactured with this type of bearing. Cylindrical and tapered roller bearings are much more commonly used in newer turbine gearbox designs.

So, what causes brittle flaking? Several studies have suggested that the diffusion of hydrogen from the lubricant into the bearing's steel might be a factor. However, studies that are more recent suggest that large surface shear stresses that cause cracks to initiate at non-metallic inclusions are the more likely cause. The cumulative effect of cyclic shear stresses is believed to nucleate cracks that propagate toward the surface. As the cracks get closer to the surface they reduce the load bearing capability of the steel, and fracturing occurs. Thus, small flakes of steel can become dislodged.

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Fig. 2: In debris-laden environments, Timken testing shows that new wear-resistant tapered roller bearings exhibit 60 percent longer life than standard tapered roller bearings (at left). In low lambda conditions testing shows that the wear-resistant tapered roller bearings have up to 350 percent longer life than standard tapered roller bearings (right).

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Brittle flaking appears to be more common in cylindrical roller bearings that have a through-hardened Bainetic microstructure. Analysis of bearings that have experienced brittle flaking wear in wind turbine gearboxes indicates that crack initiation frequently occurs at the tiny but numerous sulfide and nitride inclusions in the Bainetic steel rings. To remedy this problem, Timken recommends using case-hardened bearing rings instead of through-hardened Bainetic rings.

Fig. 3: Timken's wear-resistant material is applicable to a wide range of bearing rollers to increase life and performance.

How does one address possible gearbox micropitting and smearing? There are at least two options. One potential way is to minimize roller/raceway sliding by using preloaded tapered roller bearings as opposed to cylindrical roller bearings. A second method is to engineer the surfaces of the rollers to reduce or eliminate the consequences of roller sliding in cylindrical bearings. For gearboxes that cannot be adapted to use preloaded tapered roller bearings, surface engineering should be employed to mitigate such micropitting and smearing wear.

SURFACE ENGINEERING

Surface engineering involves altering the chemical and/or topographical properties of a component's surface. One surface engineering technique that is being tried in some circles to mitigate micropitting and smearing is the chemical conversion of roller and raceway surfaces from steel to black oxide.

For many years, black oxide has been used on bearings to inhibit corrosion and, in some cases, help break in rollers and raceways that do not have adequate surface finishes. However, black oxide surface treatments wear away rap-

idly once the bearing is in operation. For this reason, black oxide surface treatments may not provide an effective defense against micropitting. Moreover, several studies have shown that black oxide surface treatments are more prone to smearing damage than nascent steel rollers and raceways. Obviously, a more advanced engineered surface is required for wind turbine bearings to attain their designed lifetimes.

A combination of two engineered surface (ES) technologies—super-finishing and a durable, wear resistant coating applied to rollers—provides extended protection against micropitting and smearing. The super-finishing process produces smooth roller surfaces that decrease the opportunity for roller/raceway asperity contact. Timken's new diamond-like carbon coating is deposited on top of the super-finished rollers. Like other diamond-like carbon coatings, Timken's coating consists of nanocrystalline WC precipitates dispersed in an amorphous hydrocarbon matrix. However, unlike these other coatings, Timken's coating has been specifically designed to endure the high stress cycles of roller bearings.

For example, in roller bearings operating at 150 percent of their rated load, Timken's new coating remains intact on the rollers long after the bearings have exceeded their designed life. While the coating remains intact on the rollers, it reduces then shear stresses between the rollers and the raceway that cause low cycle micropitting and smearing wear. Tapered, cylindrical, and spherical roller bearings that use rollers with these two engineered surfaces are called "wear-resistant bearings." Rollers in wear-resistant bearings boast several attributes that make them extremely effective at preventing micropitting and smearing.

For one, the coating has a friction coefficient that is about 25 percent that of steel. Therefore, the frictional heating that causes smearing and the shear stress responsible for micropitting are about 75 percent lower than that of untreated rollers. Secondly, since the coating is about twice as hard as the raceway, rollers with this coating dynamically polish the raceway surfaces to roughness values well below those that can be achieved with bearing manufacturing processes. For example, at the conclusion of full-scale bearing testing, the raceways of wear-resistant bearings were measured to be more than 10 times smoother than they were at the beginning of the testing. Finally, once the ultra-smooth raceway finishes are created by the ES-treated rollers, less lubricant film thickness is required to separate fully the surfaces of rollers and the raceways.

MAIN SHAFT SOLUTIONS

For main shaft applications, Timken has developed the Timken® Wear-Resistant spherical roller bearings that incorporate the new, durable coating and super-finished sur-

faces on their rolling elements. These two elements work in tandem to address the root causes of low-cycle micropitting.

In addition to addressing the life-limiting wear of micropitting, the advanced ES treatments on the rollers yield other benefits. The ratio of the lubricant film thickness to the roughness values of the raceway and roller is called the lambda value. Because the super-finished rollers and the highly polished raceways have very small roughness values, the effective lambda value will become much higher than it would be otherwise. The benefits? A higher lambda value can lengthen bearing life and reduce rolling torque losses, resulting in increased efficiency.

HOPE FOR GEARBOX BEARINGS

Wind turbine gearboxes experience load reversals and rapid accelerations and decelerations in daily operation. For several reasons, these transient conditions cause the rollers in cylindrical roller bearings to skid on the raceways, elevating the risk and occurrence of micropitting and smearing.

ES-treated rollers in wear-resistant cylindrical roller bearings significantly reduce the magnitude of the raceway shear stresses from skidding rollers that cause micropitting just as they do in the main shaft spherical roller bearings. Since the ES-treated rollers also reduce the frictional heating from rollers skidding on raceways, wear-resistant cylindrical roller bearings also protect against smearing wear. Recently, tests that were designed to generate the application conditions that produce smearing on wind turbine gearbox cylindrical roller bearings were conducted. Although standard and black oxide-treated cylindrical roller bearings exhibited smearing wear during every test, smearing did not occur in wear-resistant bearings with ES-treated rollers. As long as the coating remains intact on the rollers, smearing wear on raceways will be prevented. Unlike the black oxide surface treatments, Timken's new coating is designed to be extremely durable on bearing rollers.

Besides addressing the micropitting and smearing problems of gearbox cylindrical bearings, wear-resistant bearings with ES-treated rollers provide several other important benefits to gearbox reliability. Firstly, wear-resistant cylindrical roller bearings operate with significantly less torque during the run-in period and about 15 percent less torque during normal operation compared to bearings with untreated rollers. This provides a measurable increase in the overall efficiency of turbines.

Secondly, wear-resistant bearings are exceptionally tolerant to debris damage. Bearings in turbine gearboxes frequently display signs of debris damage, even in gearboxes with well-filtered oil. As ES-treated rollers in wear-resistant bearings polish the raceways, they can also remove the raised edges around debris-generated dents that are

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responsible for reducing bearing life. Extensive laboratory testing has revealed that the fatigue life of debris-damaged bearings with ES-treated rollers is about two times greater than bearings without treated rollers.

Finally, testing has shown that wear-resistant bearings with ES-treated rollers have about a 3.5 times greater fatigue life than standard bearings under low lambda conditions. Examination of the ES-treated rollers at the conclusion of the tests indicated no visual coating wear.

TOTAL SYSTEM APPROACH

Like other complex, highly engineered bearings, wind turbine bearings do not operate in a "vacuum." Measures can and should be taken to maximize bearing life and performance, even during the bearing installation stage. Unfortunately, it is all too possible to damage or shorten the service life of a bearing before the bearing even becomes operational. Some installation methods like oil baths can increase the chance of bearing contamination. Other methods, such as stationary heating ovens, are cumbersome and can require changes to a facility's layout.

Heating is another concern. One of the primary causes of bearing failure is overheating. Uneven heating of the bearing can be just as harmful. The solution to these problems is even, controlled heating. Timken offers induction heaters that warm up bearings in an even, balanced manner. This is possible due to the heater's internal electromagnet, through which a middle frequency alternating current passes.

Keeping bearings correctly lubricated during their lifecycle is important. Knowing how much and how often lubricant should be applied to the critical contact areas of a bearing is crucial. A common practice in two-row main shaft bearings is to provide a single grease injection inlet between two bearing rows. Over time this practice can cause uneven lubrication of each row due to the accumulation of old grease around the grease inlet. Such accumulation forces grease to follow a path of least resistance, which could starve grease to one of the bearing rows.

A better method is to use a low-pressure, centralized lubrication system, such as Timken's Injector-Based Wind Energy Lubrication System. This system contains a central pump that automatically delivers lubricant through a supply line to multiple banks of injectors. Each injector bank operates independently to lubricate each bearing row. Meanwhile, old grease is pulled to a waste container.

Monitoring bearing conditions after installation is another important piece of the puzzle. Online monitoring systems, such as Timken's Online Intelligence System, gather data on speeds, temperatures, loads, and vibration. This can alert turbine operators to developing mechanical problems before the loss of power generation occurs. By being mindful of bearing requirements before and during operation, and taking a "total system" approach, wind farm operators can help minimize system damage and preserve valuable uptime.

SESSIONS DAY 3: TUESDAY MAY 24

8:30 a.m.-10:00 a.m.:
– General Session (open to all attendees)

10:30 a.m.-12:00 p.m.:
– International Opportunities/Supply Chain Track: Large Wind Turbine Manufacturer Forum (4A)
– Project Development Track: Wind Energy and Wildlife-The Environmental Impact (4B)
– Finance/Legal Track: Finance-The Latest Twists in Raising Capital for Wind Projects (4C)
– Utility Track: Long-Term Wind Power Contracts and State Policies (4D)
– Scientific Track: Scientific Track-Opening Session (4E)

1:30 p.m.-3:00 p.m.:
– International Opportunities/Supply Chain Track: International Wind Energy Update (5A)
– Project Development Track: Impact of Wind Energy Development-Perceptions and Realities (5B)
– Finance/Legal Track: Get a Greater ROI in Wind Project Development Today (5C)
– Utility Track: Utility Resource Planning-How Utilities are Adding Wind Power (5D)
– Scientific Track: Improve Turbine and Plant Performance (5E)

3:30 p.m.-5:00 p.m.:
– International Opportunities/Supply Chain Track: Export Opportunities for the U.S. Wind Energy Industry (6A)
– Project Development Track: Public Relations-Understanding and Leveraging Wind Energy's Broad Support (6B)
– Finance/Legal Track: The Legal Side of Wind Project Development (6C)
– Utility Track: Utility Strategies for Wind Power-Case Studies (6D)
– Scientific Track: The Science Behind Condition Monitoring-Solutions for the Future (6E)

SESSIONS DAY 4: WEDNESDAY MAY 25

8:30 a.m.-10:00 a.m.:
– Supply Chain Track: The Future Wind Turbine Supply Chain (7A)
– Wind Deployment Track: Risks and Rewards in Offshore Wind Project Development (7B)
– Grid Track: Meeting Grid Interconnection Requirements (7C)
– Technical Track: Wind Turbine Stress Relievers (7D)
– Scientific Track: Wind Turbine Structures, Dynamics, Loads, and Control (7E)

10:30 a.m.-12:00 p.m.:
– Supply Chain Track: Transportation & Logistics Opportunities and Challenges (8A)
– Wind Deployment Track: Who Owns Community Wind? (8B)
– Grid Track: Wind Energy Integration-Challenges and Solutions (8C)
– Technical Track: Ensure Reliability with Component Certification (8D)
– Scientific Track: Delivering Competitive Energy Costs from Offshore Wind Power (8E)

1:30 p.m.-3:00 p.m.:
– Supply Chain Track: Project Construction-Best Practices and Challenges (9A)
– Wind Deployment Track: Community Wind-Power for People (9B)
– Grid Track: How to Apply Electrical Code Requirements for Large Wind Power Plants (9C)
– Technical Track: New Technology in Blade Design (9D)
– Scientific Track: Advanced Tools and Techniques for Wind Integration Studies (9E)

3:30 p.m.-5:00 p.m.:
– Supply Chain Track: Workforce Development and Training-Moving the Industry Forward (10A)
– Wind Deployment Track: Small Wind Policies and Technology (7B)
– Scientific Track: Research on Forecast Ensembles, Boundary Layer Observations & Seasonal Forecasting (10E)

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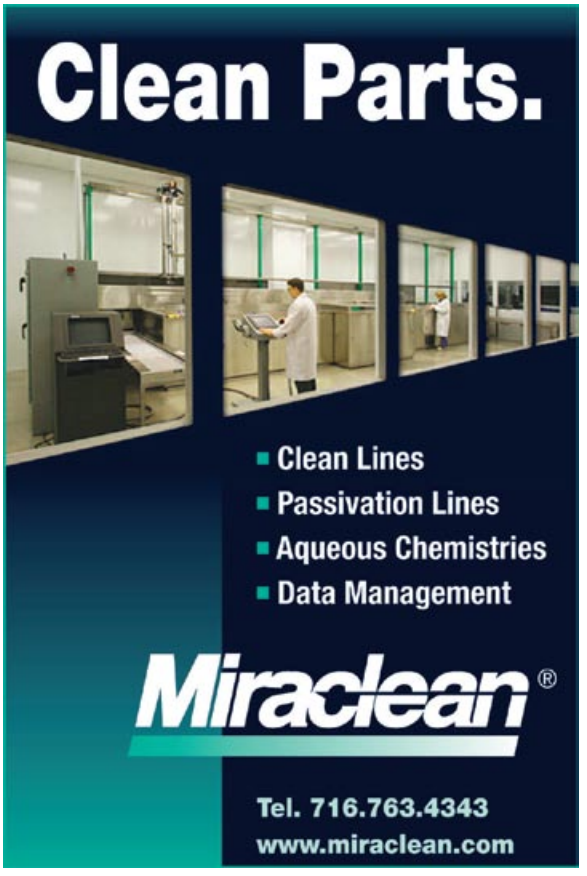
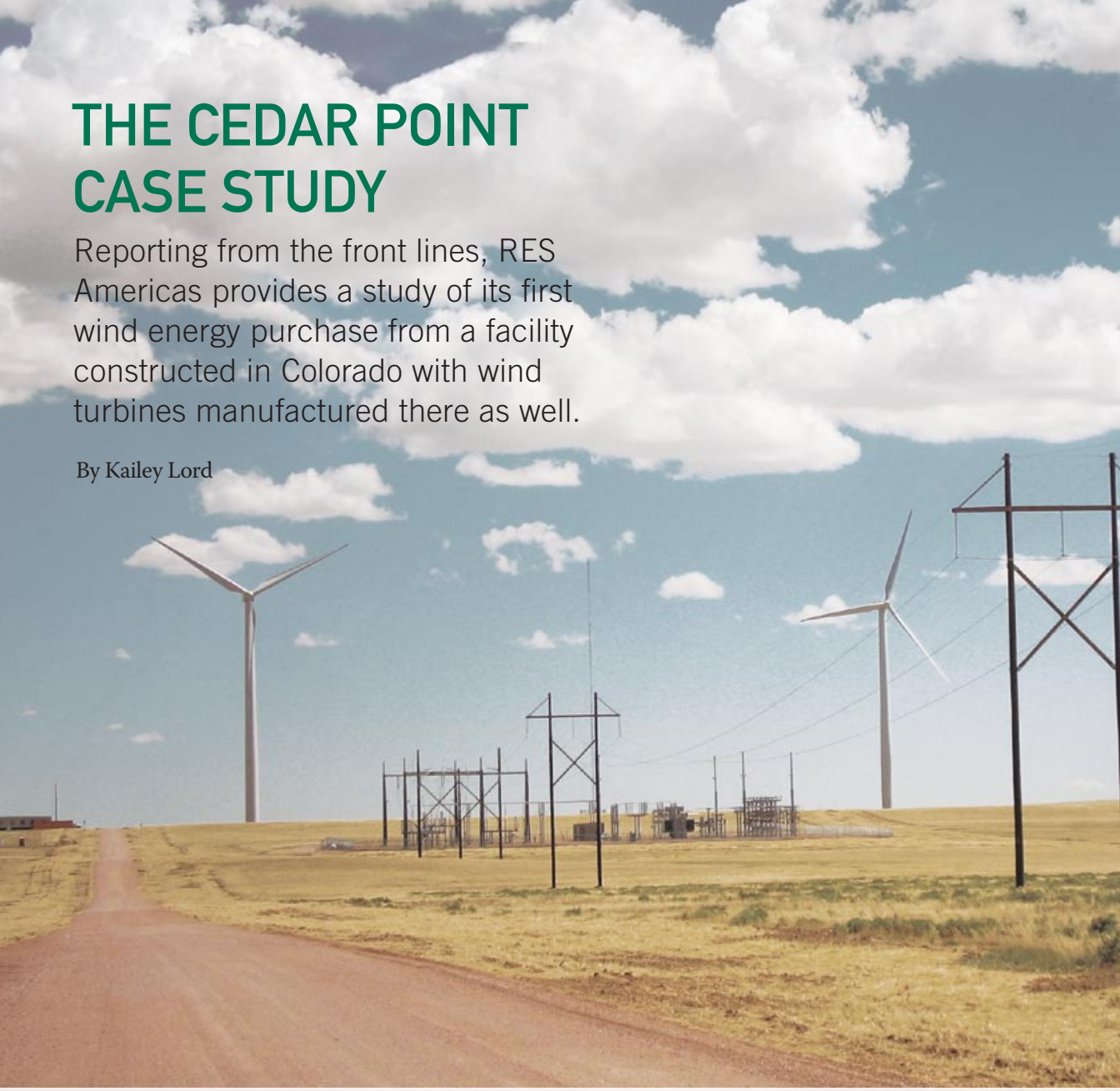


THE CEDAR POINT CASE STUDY

Reporting from the front lines, RES Americas provides a study of its first wind energy purchase from a facility constructed in Colorado with wind turbines manufactured there as well.

By Kailey Lord



Kailey Lord represents RES Americas. Learn more at www.res-americas.com.

WIND INDUSTRY PROJECT DEVELOPMENT is a dynamic business. One of the key challenges is identifying and securing project sites. What makes a site attractive can vary from state to state. Good wind is essential, of course, but access to transmission, ease of permitting, and community support can also be important factors. This case study examines the development of one project that is currently under construction: Cedar Point Wind.

LOCATION, LOCATION

In 2004 Renewable Energy Systems Americas, Inc. (RES Americas), worked diligently to analyze wind resources and identify wind project sites in Colorado. The company's in-house experts, a team of experienced wind analysts, focused on a ridgeline running through Lincoln and Elbert counties in northeastern Colorado.

Eastern Colorado is a sparsely populated area. The plains experience extreme weather throughout the year, ranging from whiteout blizzards to hailstorms and tornadoes. The land is fertile and has yielded generations of cash crops for family-owned farming operations. It is also a region of blustery winds. This, combined with

Fig. 1: Cedar Point is located in Eastern Colorado, a sparsely populated area that experiences extreme weather throughout the year.

its proximity to the Denver load center, made it an attractive prospect.

RES Americas, a company that takes risk assessment very seriously, had to ensure the Cedar Point Wind Project had all these attributes: a strong, consistent wind resource, available transmission capacity, and a welcoming community with available land. The Cedar Point site passed with flying colors. Four years of wind data and research confirmed the reliability of the power generating resource, but the biggest challenge ahead would be leasing 20,000 acres of private property from multiple owners, some whose families had lived in the area for generations.

A TOPOGRAPHIC JACKPOT

The tipping point for RES America's quick move to develop Cedar Point was the geographic characteristics of the land; it was unique, even in renewable-friendly Colorado. RES Americas estimated that the site could accommodate 139 turbines, or roughly 252 megawatts (MW).

Kara Cubbage, lead developer for the project, says that "Cedar Point was a distinctive opportunity. It was a topographic jackpot. Our wind data was great and created an enormous amount of internal excitement and support for the project. Approaching the landowners and residents of the tri-county area would be the next major obstacle in getting this project off the ground and headed in the right direction. Early stage development was competitive in the region. We had to make our case to this community that Cedar Point was a candidate for successful and timely development."

Fortunately for Cubbage and RES Americas, residents in the area embraced the project from the onset. Initial leasing began in 2003, and within a year most of the land for the project was under contract. By 2007, all leasing was complete. The flat land, primarily utilized for agricultural operations, was determined to be more than suitable to host turbines and transmission facilities.

COMMUNITY RELATIONS

RES Americas made a commitment at the onset of project development to community relations. The company understood that winning over local residents and the business community in the area was as important as having landowner partners.

Through a series of open houses and other public

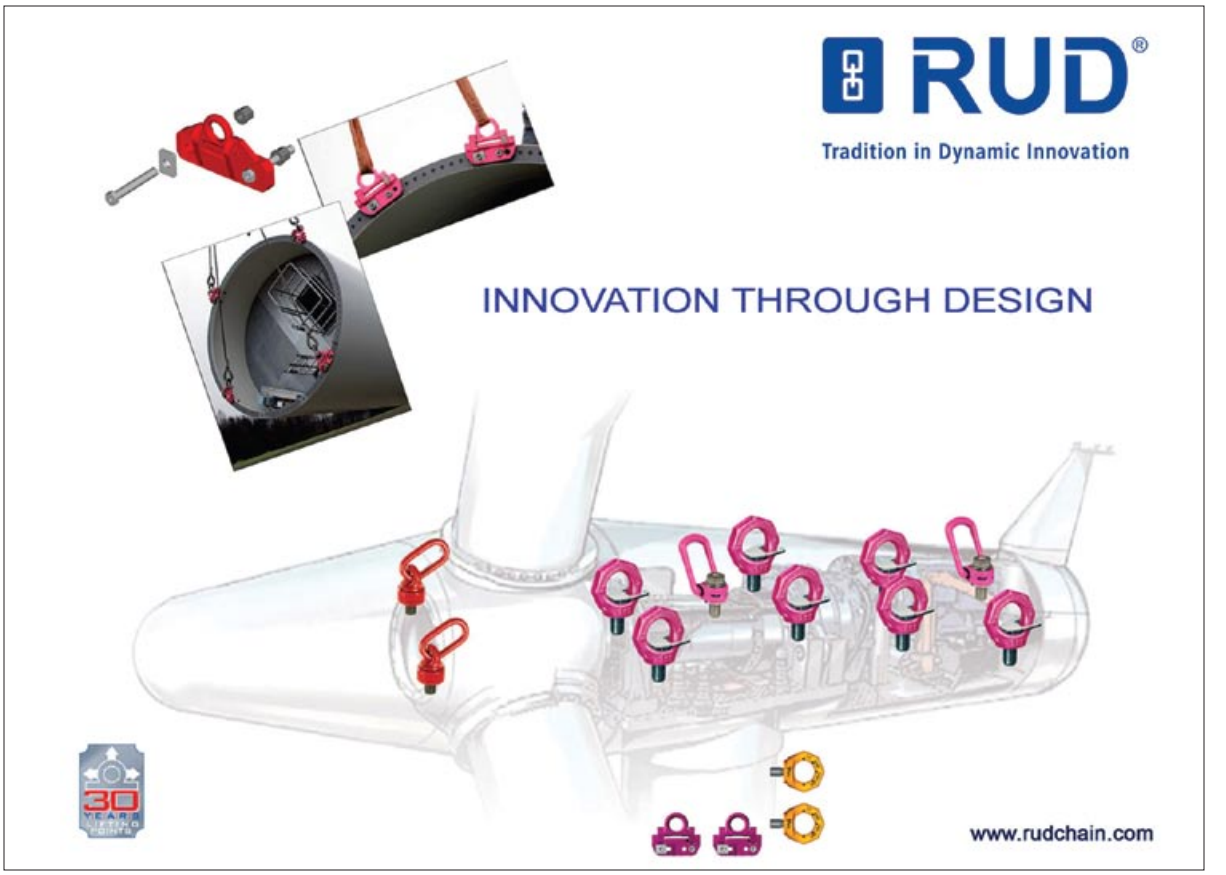
Fig. 2: Towers begin dotting the landscape at the Cedar Point Wind Farm.

meetings, largely led by Cubbage herself, the project saw little to no resistance in the community or through the complex permitting process. Area residents recognized the community benefits immediately. They learned that construction alone would bring 100-200 temporary jobs to local contractors, and up to 12 full-time jobs after the site was operational. The area tax base would enjoy expanded revenue to benefit local schools and promote economic development in surrounding communities. Pat Vice, executive director of Lincoln County Economic Development, says that "The generation of electricity from wind produces revenue for farmers and ranchers and benefits rural communities by the creation of new jobs during construction, for ongoing maintenance, and as tax revenue supporting local schools and hospitals."

TRANSMISSION AND OFFTAKE

Like most states, Colorado is diligently working on the expansion of transmission capacity to carry much-needed power from generators—whether renewable or fossil fuel—to load centers where it will be used. Windy sites are not always right next to substations or other points of interconnection to the electrical grid. This was the case with Cedar Point, and it posed a significant hurdle.

The RES Americas team faced a great challenge in identifying a spot on the grid where power could be delivered upon project completion without additional grid construction, which could be a very costly endeavor. After further analysis it was determined that the project would be able to connect to an existing Public Service Company (PSCo) 230k transmission line at the Missile Site Substation, just north of Deer Trail. In order to gain access, RES Americas would need to construct 42 miles of private transmission to link the project to the grid. A majority of the path for this proposed line follows the



right of way path for a previously proposed line, the Eastern Plains Transmission Project, making the daunting task a much easier assignment. Nonetheless, it took several months to secure the rights of way for 42 miles of easements.

By 2010 it appeared that Cedar Point was well on its way to becoming a reality. The wind resource had been confirmed through years of measurements. The leasing agreements were finalized. Rights of way had been obtained, and permitting was nearly complete to begin construction of the project and transmission line. However, the project wouldn't be built until there was a buyer for the power to be generated.

Through a national movement spurred by the American drive to free our country from foreign energy sources and to make use of our renewable energy assets, states have adopted renewable standards for utilities servicing their state. Colorado has been a leader in adopting such standards.

Cedar Point was a project of significant size that would have value to a utility working to reach the required renewable standards of 30 percent by 2020. Cedar Point, along with two other projects, won the 2009 renewable power procurement process run by PSCo.

In March of 2010, RES Americas executed a 20-year PPA with PSCo under which the utility agreed to buy

Fig. 3: Tower sections are delivered to the construction site.

Fig. 4: Foundations being poured at Cedar Point.

Fig. 5: Trenching begins, connecting turbines to the grid.

Fig. 6: Blades are lifted into place at the Cedar Point Wind Farm.

252.2 MW of clean power from Cedar Point. "The Cedar Point Wind power purchase agreement is the first to be completed from the 2007 Colorado Resource Plan by Public Service Company of Colorado, an Xcel Energy company. The project will expand the utilization of Colorado's desirable wind resource into another region of the state to deliver this clean wind energy to our customers," said Tom Imbler, Xcel Energy vice president for commercial operations, at the time the PPA was announced. "Not only will this project help us to meet our renewable energy standard for Colorado, it will be our first wind energy purchase from a facility constructed in Colorado with wind turbines manufactured in Colorado."

SELLING POINT

RES Americas made the strategic decision to sell the project to a new owner while retaining engineering, procurement, and construction rights. This would allow the company to realize value from the project while freeing resources to focus on other projects in its development portfolio.

Once the PPA was finalized, the bidding process to own the project intensified. RES Americas reviewed a number of bids from several prospective owners. Ultimately, the $500 million project was sold to Enbridge, Inc., a Canada-based energy company with American affiliates.

"Renewable energy aligns very well with our objective to profitably grow our energy infrastructure business," according to Al Monaco, executive vice president, major projects and green energy at Enbridge. "The investment in Cedar Point bolsters our already strong portfolio of green energy projects and establishes a beach head for future investment into the growing U.S. green energy market. We expect to continue to grow our renewable portfolio, particularly in states such as Colorado that support green energy development."

BREAKING GROUND

The Cedar Point Wind Project officially broke ground on August 25, 2010, more than seven years after the early stages of development had begun. RES Americas is serving as the engineering, procurement, and construction contractor for the site, and on completion it will operate the project for at least two years.

Just over nine months into construction, RES Americas is poised to deliver ahead of schedule. In this part of Colorado, harsh winters and weather can play a significant role in construction. RES Americas understood this variable in the construction timeline and planned accordingly. "Luckily the weather has been very cooperative, so much so that the transmission line was completed ahead of schedule and the turbine deliveries began almost a month ahead of time. We are continuing

to stay focused on the tasks at hand and stay ahead of schedule," says Jason Zingerman, vice president of construction at RES Americas.

During the early part of the construction phase all efforts were focused on infrastructure, excavation, and foundations. Each foundation was comprised of nearly a half-million tons of concrete and rebar, requiring an immense amount of earthmoving and backfilling with aggregate material.

Tower installation and erection started in March of 2011 as the winter season began to fade and electrical infrastructure neared completion. All the wind tower components for Cedar Point are being manufactured in Colorado by Vestas Wind Systems.

Local subcontractors were heavily engaged during excavation and road construction; nearly 100 local jobs were created to complete these tasks. "We're excited about being part of this community," says Zingerman. "Really, this is the community's project and everyone has been very supportive during the construction phase."

THE FUTURE

RES Americas and Enbridge expect that the project will begin commercial operation in November of 2011. Once completed, Cedar Point will consist of 139 1.8 MW Vestas V90 turbines, two onsite project substations, an operations and maintenance building, and over 42 miles of an electrical transmission line. It will be the second largest wind project in Colorado and is contributing to the state's economic development.

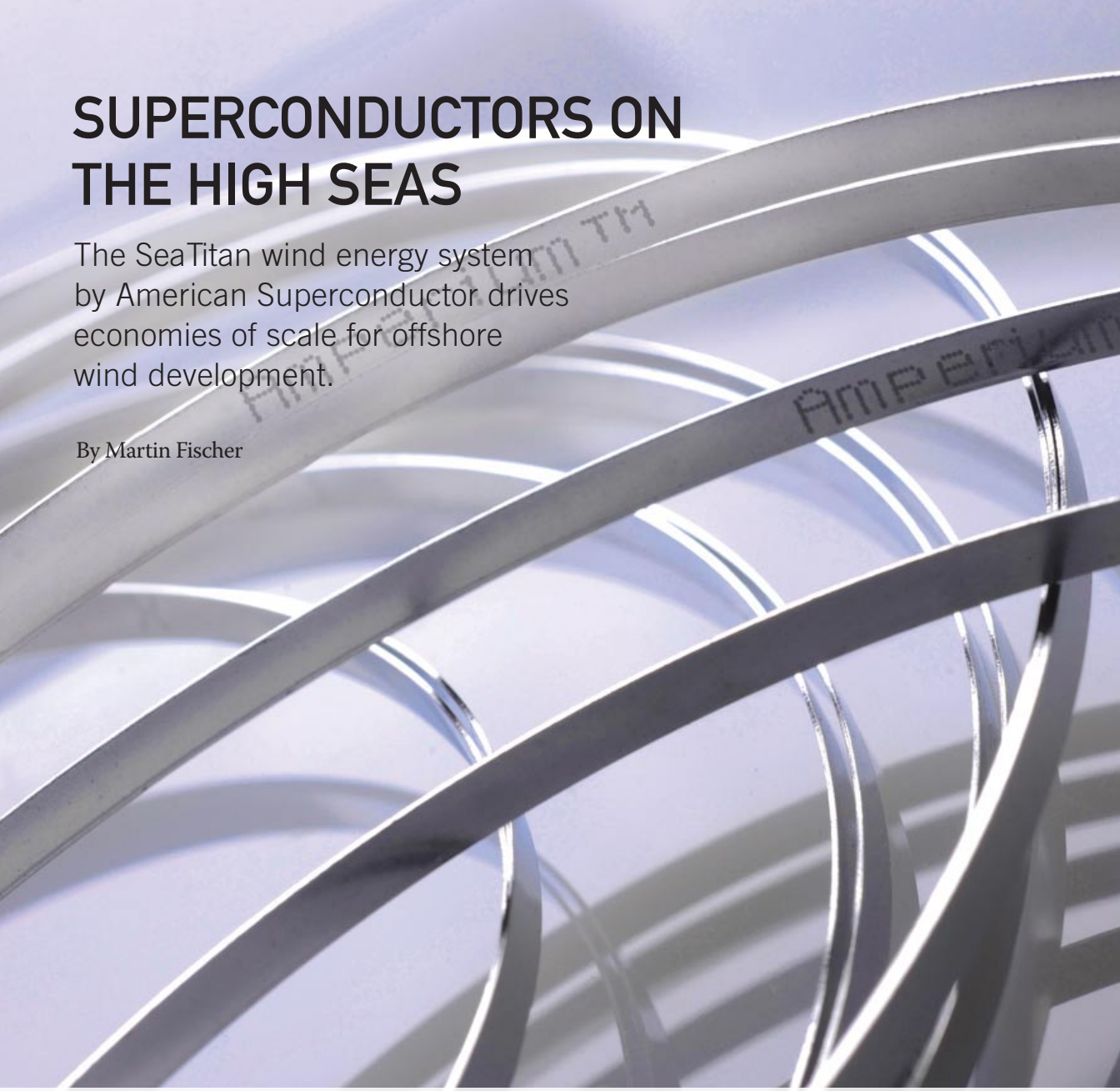
Vestas has recently announced plans to hire more than 1,000 people in Colorado by the end of 2011, largely due to projects like Cedar Point. Colorado is one step closer to reaching the renewable standards goals designated by former Governor Ritter and the landmark legislation requiring 30 percent renewable by 2020. Cedar Point will yield approximately 875,000 MWh, roughly the annual energy consumption of around 80,000 Colorado households. The project will displace fossil generation, keeping approximately 710,000 tons of CO2 per year out of the atmosphere.

The Cedar Point Wind Project is a great accomplishment for both Enbridge and RES Americas. The project will bring the RES Americas constructed/under construction portfolio to over 5,200 MW and is the company's first large project in Colorado. Cedar Point is Enbridge's seventh wind power facility and brings the total generating capacity of their green energy projects to 810 MW. More importantly, it is a significant accomplishment for Colorado. It is a project that was born in state, developed in state, constructed in state, and will operate in state to benefit Coloradoans.

SUPERCONDUCTORS ON THE HIGH SEAS

The SeaTitan wind energy system by American Superconductor drives economies of scale for offshore wind development.

By Martin Fischer



Martin Fischer is vice president of American Superconductor and general manager of AMSC Windtec. Call +43 (0) 463 444604-0, e-mail seatitan@amsc-windtec.com, or go online to www.amsc-windtec.com.

IN ITS NASCENT STAGES TODAY, the offshore wind power market is expected to enter a period of rapid and prolonged growth beginning within the next several years. The development of higher capacity wind energy systems will be required to fully capitalize on this vast clean energy resource.

Total installed offshore wind power capacity rose to approximately 3 gigawatts (GW) by the end of 2010, according to latest reports by the European Wind Energy Association. That figure, which is up from approximately 2GW at the end of 2009, does not include the more than 32GW of offshore capacity currently planned, but not yet fully consented, in the United Kingdom. While there currently are no offshore wind farms in North America, several projects are in development in the United States. Reflecting the scope of the growth expected for this market, industry research firm IHS Emerging Energy Research currently projects that global offshore installed capacity will increase to approximately 20GW by 2015, and rise sharply to 104GW by 2025.

Until now, among the greatest challenges to developing larger wind turbines for both onshore and offshore

use have been the practical size and weight limitations of the wind turbine generator. The power density advantage of superconductors, however, is now being applied to wind turbine generators to maximize the "power per tower" of multi-megawatt turbines, while at the same time overcoming size and weight barriers and reducing overall project costs. Utilizing superconductor direct-drive generators, SeaTitan™ wind turbines are being designed to produce 10MW or more of power, which would make them the world's largest and most powerful wind turbines.

OFFSHORE SUPERCONDUCTOR TURBINES

American Superconductor (AMSC) is developing the SeaTitan wind energy system by combining the company's wind turbine engineering experience with its leadership in the superconductor arena. The superconductor generators to be used in SeaTitan wind turbines are based largely on proven superconductor ship propulsion motors and generator technology developed by AMSC for the United States Navy. The unique power density of superconductors will enable a 10MW SeaTitan wind turbine to be similar in weight and size to a conventional 5MW system. This breakthrough wind turbine will significantly lower offshore wind development and maintenance costs and create a path forward to wind generator power ratings of 10MW and beyond.

Offshore wind energy has many advantages compared to onshore, including higher wind speeds with less intermittency and greater availability of space. In addition to offering aesthetic advantages, offshore sites also are typically located in closer proximity to high power demand population centers.

While the size of the world's offshore resource is huge, the costs of capitalizing on this market currently are about 50 percent higher compared to onshore wind development on a first-cost basis. Part of this added cost premium is due to less than optimal "adaptation" of conventional technology with ad hoc design modifications such as sealed nacelles and special access platforms for maintenance purposes. Because the majority of costs associated with offshore wind are related to installation and the subsea support structures, the most effective way to reduce costs is by maximizing the amount of power per tower produced by each turbine such as achieved by utilizing superconductor generators.

SUPERCONDUCTOR POWER DENSITY

Wind turbines being employed today for the offshore market are currently limited to power ratings of approximately 5-6MW in capacity, partly due to the fact the drivetrains for these conventional multi-megawatt turbines are very heavy and have unresolved reliability issues. Allowance for tolerances and deformations in large generators reduce the effectiveness of Permanent Magnet (PM) generators. What is needed to fully capitalize on the opportunity presented by offshore wind is the design of special purpose machines with inherent high efficiency and lower maintenance requirements. The generator developed by AMSC achieves this by utilizing the company's Amperium™ high temperature superconductor (HTS) wire, which is capable of conducting more than 100 times the electrical current ("amperage") of copper wire of the same dimensions. The resulting power density of these systems compared to conventional generators using copper wire will break this existing power rating barrier and enable these

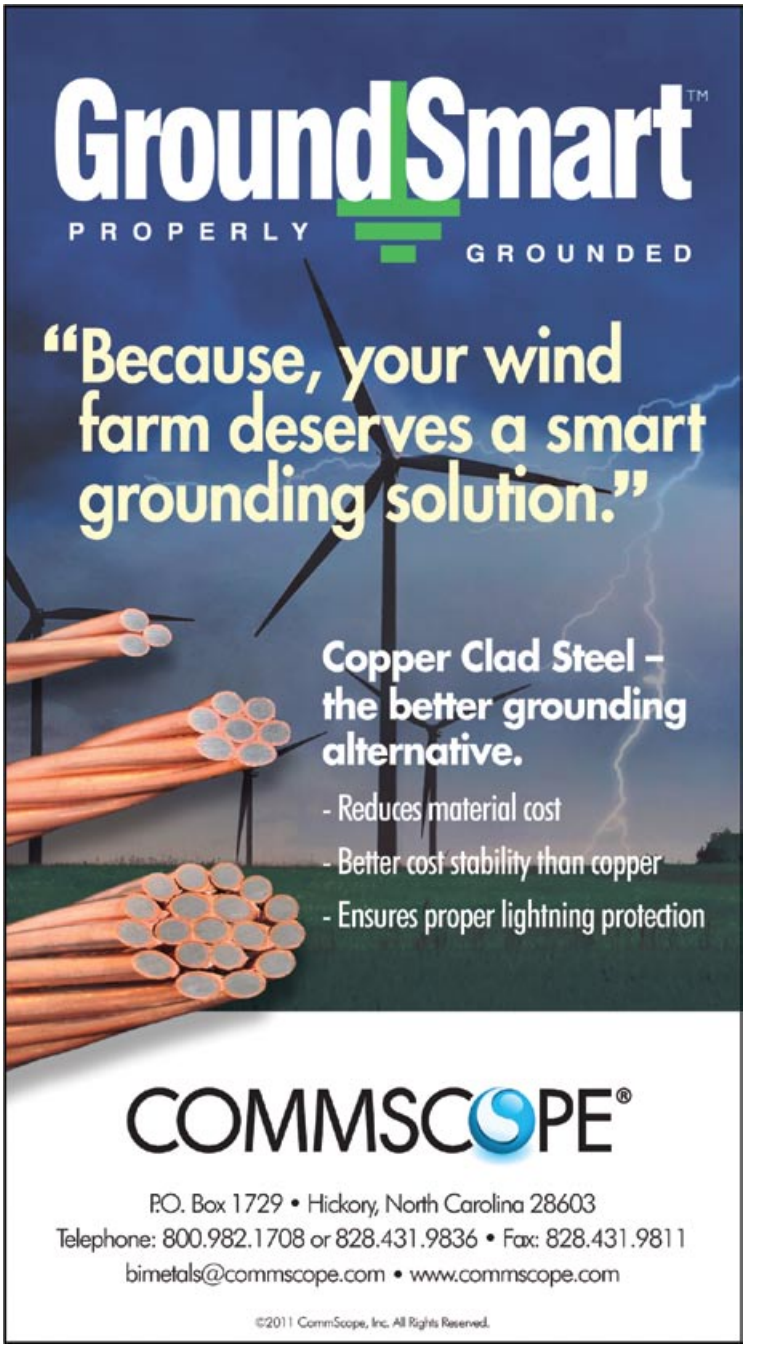
smaller-sized turbines that are capable of producing more power per tower.

By eliminating copper in the turbine rotor and instead using superconductor rotors, the wind generator is not only much smaller and lighter but more efficient and less expensive than conventional large-scale wind turbine generators. Efficiency is further enhanced—and manufacturing and maintenance costs reduced in the SeaTitan wind turbine design—by using a direct drive generator, thus eliminating the complex turbine gearbox, which tends to be the most maintenance intensive wind turbine component. Superconductor technology has already been proven numerous times in many applications, including large-scale power cables and rotating machine platforms such as large ship propulsion motors. In fact, a 36.5MW superconductor ship propulsion motor designed and manufactured by AMSC for the U.S. Navy successfully completed the Navy's full-load power testing in January 2009. These machines are now ready for deployment.

The weight savings attributable to HTS technology allows the SeaTitan wind turbine generator to be placed directly above the tower. This enables improved mainframe design and direct load transfer from the hub to the tower offering. In most existing offshore wind turbines, a major failure mode is caused by the deflections of the rotor shaft. To reduce damage the housing of the gearboxes or generators could be decoupled from the mainframe, but only in a complex way. This is not needed for the superconductor generators because their large air gap can absorb all deflections, allowing the generator housing to be directly integrated in the wind turbine mainframe. This factor, combined with the significantly small generator diameter, is the primary contributor to the strength, light weight, and small size of the SeaTitan wind turbine design. Further, the SeaTitan wind turbine requires only one main bearing configuration.

NEW TECHNOLOGY PARADIGM

The SeaTitan wind turbine additionally incorporates a number of design solutions that ensure redundancy of its operation. For example, the cryogenic cooling system for the HTS generator achieves high reliability by employing n+1 modular, single-stage Gifford McMahon (GM) coolers and long-life seals in its helium transfer coupling. In fact, in AMSC's experience with cooling transfer systems in both HTS transmission and large rotating machines, the reliability of this component has proven to be excellent. The SeaTitan wind turbine design, which is equipped with more than one cryogenically cooled surface, also promotes efficiency and eases maintenance. Having more than one cryogenically cooled surface in series allows each of these surfaces to work less to lower the temperature of the



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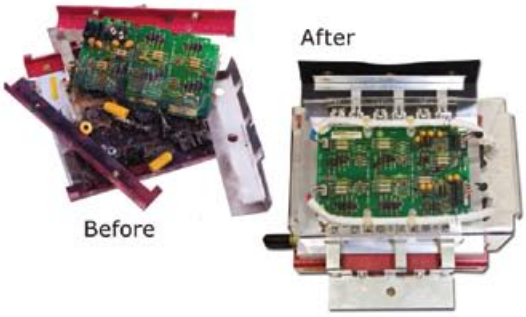

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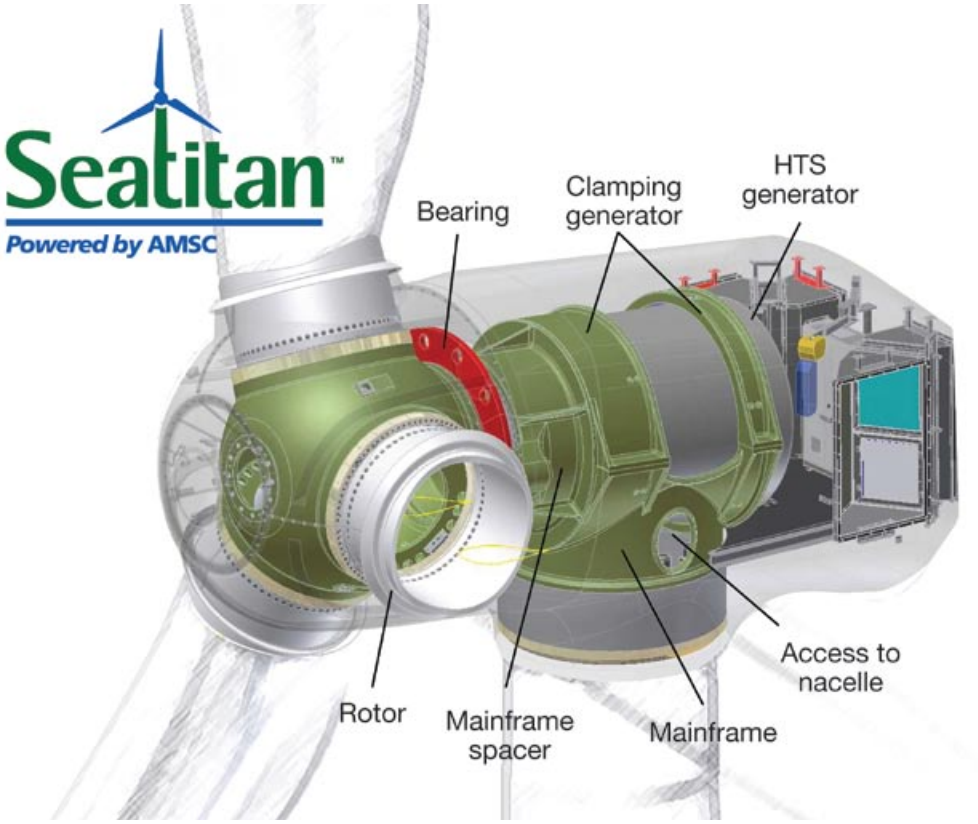

Fig. 1: A schematic diagram of the SeaTitan wind turbine.

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Fig. 2: Amperium high temperature superconductor (HTS) wire.

cryogenic fluid. Also, if one cryogenically cooled surface malfunctions, the redundancy in the system will be able to overcome the loss. The refrigeration system additionally has no unusual environmental requirement or impact due to the required cryogenic cooling components for an HTS generator. In fact, most serviceable components are placed at the bottom of the tower for easy access. These accessible components include power converters, compressors for cryogenic cooling, the control cabinet, and switchgear.

PROTOTYPE SUPERCONDUCTOR TURBINES

In addition to the SeaTitan wind turbine, as part of its Windtec™ product line, AMSC provides a variety of licenses and customized designs for onshore and offshore turbines. More than a dozen wind turbine manufacturers today are utilizing the company's suite of conventional wind turbines with power ratings up to 6MW. The company also provides extensive customer support services through manufacturing scale up as well as advanced electrical control systems for each wind turbine that its customers produce.

The SeaTitan wind turbine will have an initial design capacity of 10MW with a 190-meter rotor. AMSC recently acquired a 25 percent stake in UK-based Blade Dynamics Ltd, which has developed wind turbine blade technologies designed to increase the efficiency and performance of multi-megawatt wind turbines while also re-

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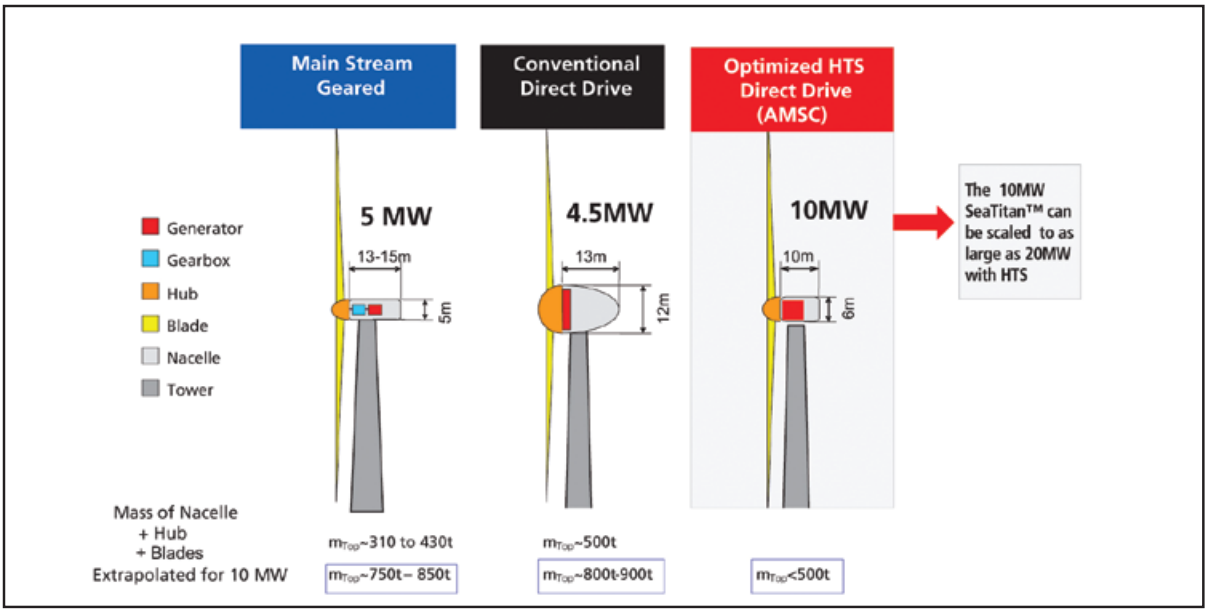

Fig. 3: A comparison of the SeaTitan to other turbine designs.

ducing costs. In addition to providing AMSC wind turbine design licensees with a differentiated blade offering, Blade Dynamics' unique technology will also provide a compelling blade platform for the SeaTitan wind turbine. The tower can rest on conventional jacket foundations and deepwater foundations of various types.

AMSC expects to select its first SeaTitan wind turbine licensee in the months ahead. It will then work with this customer to establish a full supply chain for this wind turbine, including a manufacturer for the SeaTitan generator. AMSC expects that its licensees will enter full-volume production by mid-decade.

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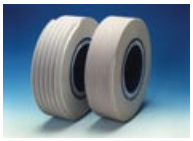

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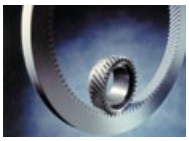

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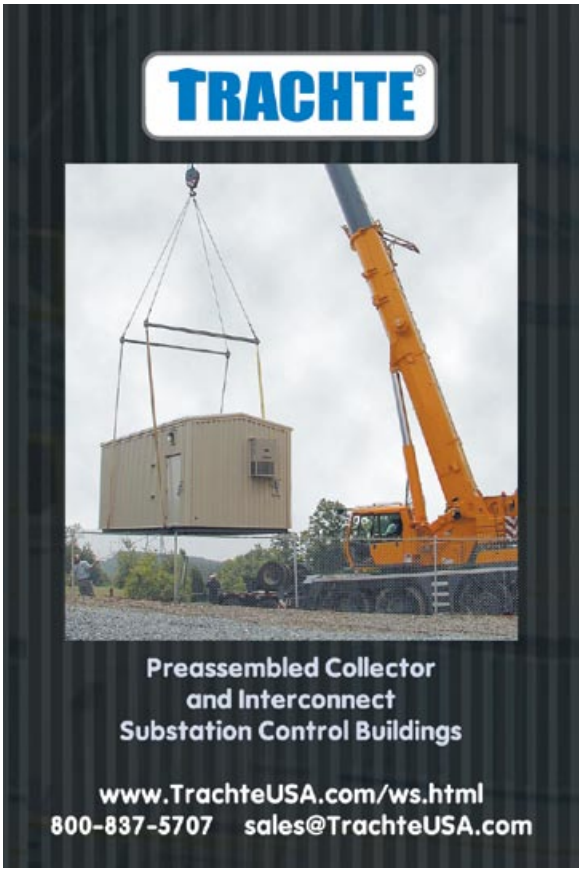

Terry Humphrey
wind aftermarket manager/Castrol Industrial

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SPEAKING OF LEARNING, I UNDERSTAND THAT PART OF YOUR WORK INVOLVES CONDUCTING TRAINING SESSIONS FOR WIND PROFESSIONALS.

That's right, we do. Some of the classes we offer are scheduled in advance, with wind technicians traveling to attend at a centrally located site. At other times we'll hold the session at our customer's facility, meeting with O&M specialists and company tribologists to provide our viewpoint on managing their lubrication issues. What we want to do is share the knowledge we've amassed during our years spent developing specialty lubricants for the wind energy market, working closely with OEMs, wind farm owner/operators, O&M service companies, and research institutions such as the National Renewable Energy Laboratory, with whom we have a longtime and very close working relationship. This experience is based on our activities both here in North America and through our colleagues in Europe. The central message we want to convey is that we're in this for good. We believe in the important role wind power will play in providing clean energy in the future, and as we accrue data we will continue incorporating those findings into our lubrication formulations. And although it may sound like a pipe dream, our ultimate goal is to develop a one-time fill that's good for the life of the gearbox. We now have automotive transmission lubricants that are rated at 100,000 miles, and there was a time when that was unthinkable. So keep your eyes open, we just might get there!

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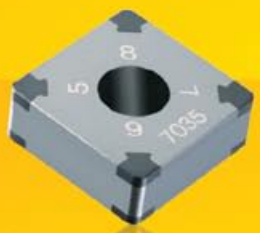

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