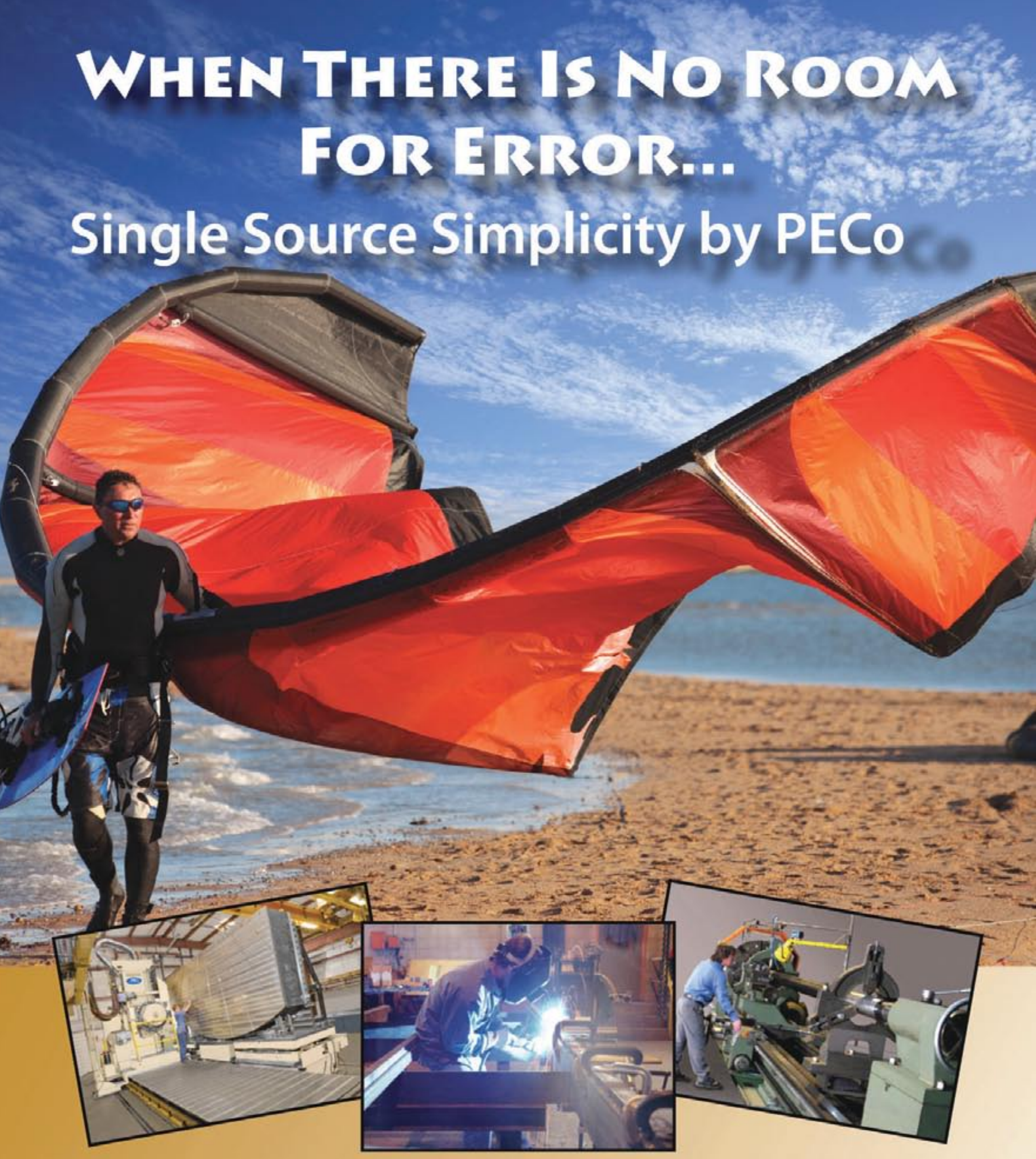
# WIND SYSTEMS

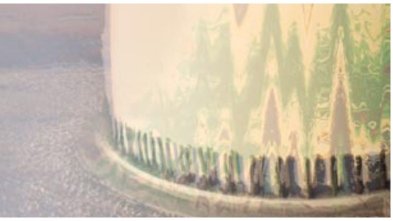
MAY/JUNE 2009

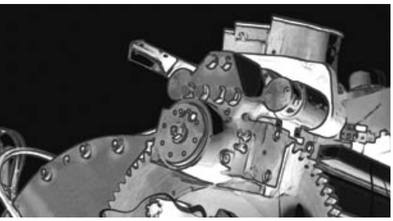


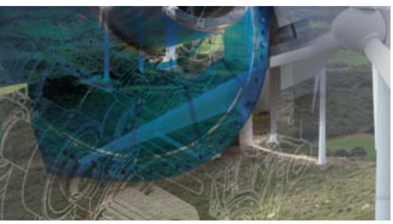

When There Is No Room
For Error...
Single Source Simplicity by PECo

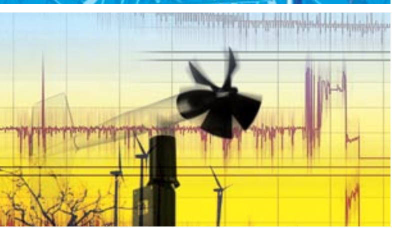
# FEATURES

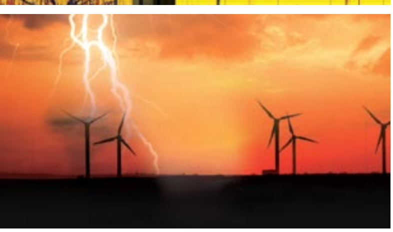
MAY/JUNE 2009











# DEPARTMENTS

VOLUME 1 NO. 1



# RESOURCES



*Wind Systems* magazine, published by Media Solutions, Inc., is printed entirely on Forest Stewardship Council certified Domtar Lynx paper. FSC certification ensures that this paper contains fiber from well-managed and responsibly harvested forests. The FSC logo also signals our commitment to improving the environment. *Wind Systems* paper is also Rainforest Alliance certified.

# EDLETTER

Welcome to the inaugural issue of *Wind Systems* magazine. As experienced publishers, we are delighted to have the opportunity to support—and report on—this fascinating and ever-evolving industry, and also to launch this exciting project at WINDPOWER 2009, presented by the American Wind Energy Association. Each issue of the magazine will address different aspects of the wind-energy field, focusing on construction, manufacturing, and maintenance. These articles will be written by experts from both industry and academia in order to provide a broad range of insights and expertise. In addition, articles exploring issues such as land management, energy storage, smart-grid initiatives, site location, and even meteorological and geographic concerns will be presented.

As for this issue's feature lineup, we're pleased to present "Vibration-Based Wind Tower Foundation Design" by Saif Hussain, S.E.—managing principal with the Encino, California, office of Coffman Engineers, Inc.—and structural engineer Mohamed Al Satari, Ph.D., P.E. David Clark, director of Turningpoint, has written "Monitoring for Maintenance," and Zachary Narrett conveys how Energy Storage and Power, LLC, can help the wind industry meet its full delivery potential using compressed air in "Maximizing Energy Storage." Jennifer Schlegel has penned "Achieving Excellence in Gearbox Design," and "Wind Resource Site Assessment," by Evan Lubofsky of the Onset Computer Corp., discusses the pros and cons of on-site vs. remote monitoring. In addition, Stephen Oaks, representing CommScope BiMetals, has contributed "Getting Grounded When Lightning Strikes."

In each issue of *Wind Systems* you will also find four columns written by industry experts. One, devoted to technology, is being written by Kathleen O'Dell of the National Renewable Energy Laboratory. The next, on construction issues, has been contributed by James D. Hussin of Hayward Baker, Inc. Michael Miller, of DC Power Systems, will be writing our column on small wind, and Parthiv Amin and Eckart Bodenbach, P.E., of Winergy Drive Systems will share maintenance tips from which you're sure to benefit. HPM America is our profile in this issue—many thanks to Gerry Sposato for his time—and Bob Connors, president of Gexpro Services, is our Q&A subject. We would like to thank everyone listed here for their important contributions to this industry, and also to our efforts toward making this publication a leading resource for wind professionals.

In closing I'd like to say a word about the format we've chosen. In developing the magazine we worked closely with our printer to establish a size and format that would result in zero paper waste, and we also decided to use materials containing recycled fibers. It is our desire to contribute to this industry's spirit of conservation and sustainability, and we look forward to working with you on upcoming issues of *Wind Systems*!

**Russ Willcutt, editor**
*Wind Systems* magazine
russ@windsystemsmag.com
(800) 366-2185

WIND SYSTEMS

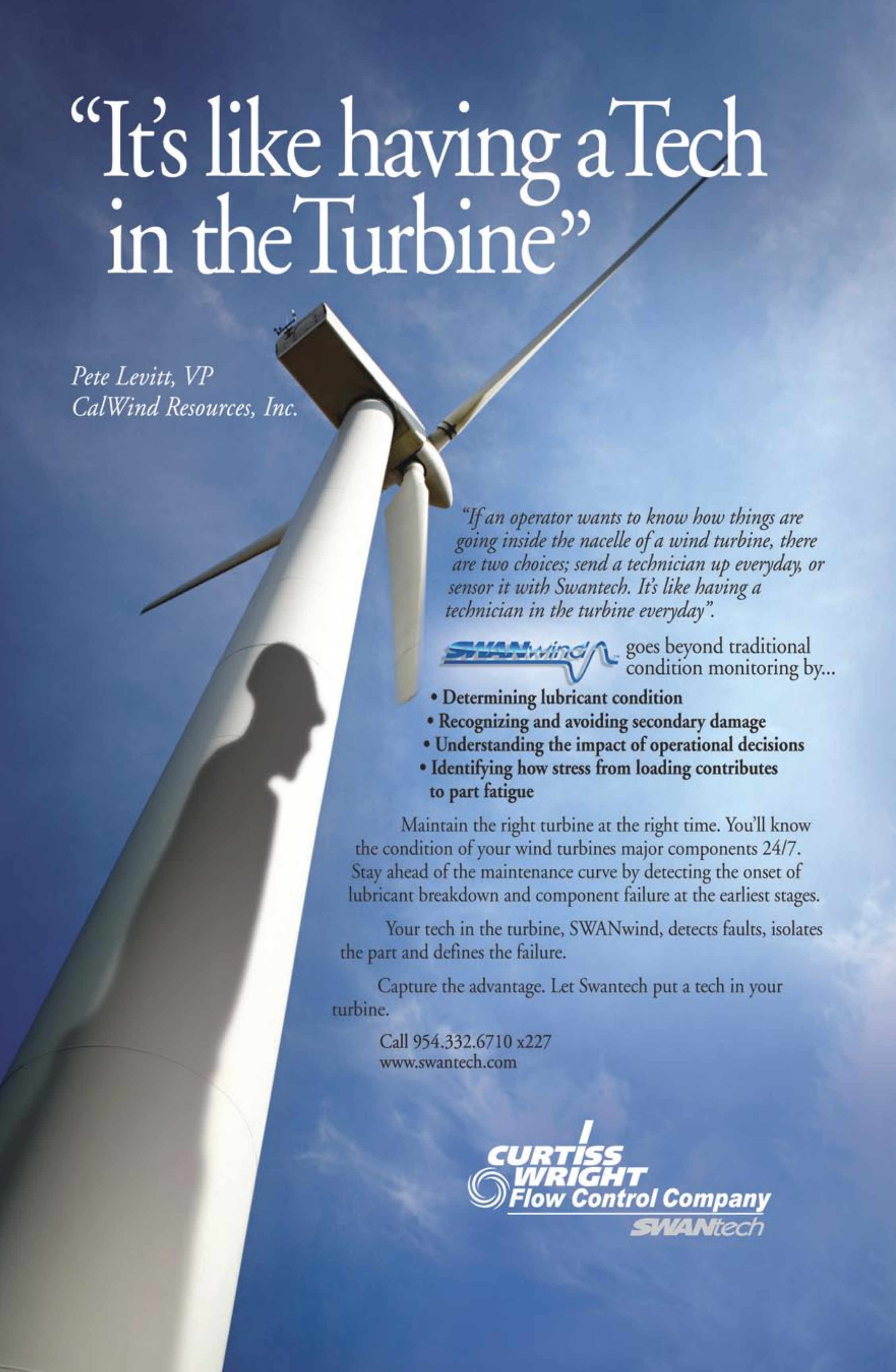


media solutions
PUBLISHED BY MEDIA SOLUTIONS, INC.
P. O. BOX 1987 • PELHAM, AL 35124
(800) 366-2185 • (800) 380-1580 FAX

David C. Cooper
President

Chad Morrison
Vice President

Teresa Hall
Operations


"It's like having a Tech in the Turbine"
Pete Levitt, VP
CalWind Resources, Inc.
"If an operator wants to know how things are going inside the nacelle of a wind turbine, there are two choices; send a technician up everyday, or sensor it with Swantech. It's like having a technician in the turbine everyday".
SWANwind goes beyond traditional condition monitoring by...
• Determining lubricant condition
• Recognizing and avoiding secondary damage
• Understanding the impact of operational decisions
• Identifying how stress from loading contributes to part fatigue
Maintain the right turbine at the right time. You'll know the condition of your wind turbines major components 24/7. Stay ahead of the maintenance curve by detecting the onset of lubricant breakdown and component failure at the earliest stages.
Your tech in the turbine, SWANwind, detects faults, isolates the part and defines the failure.
Capture the advantage. Let Swantech put a tech in your turbine.
Call 954.332.6710 x227
www.swantech.com
CURTISS WRIGHT
Flow Control Company
SWANtech

### TOUGH WIND TURBINE COUPLINGS FROM ZERO-MAX

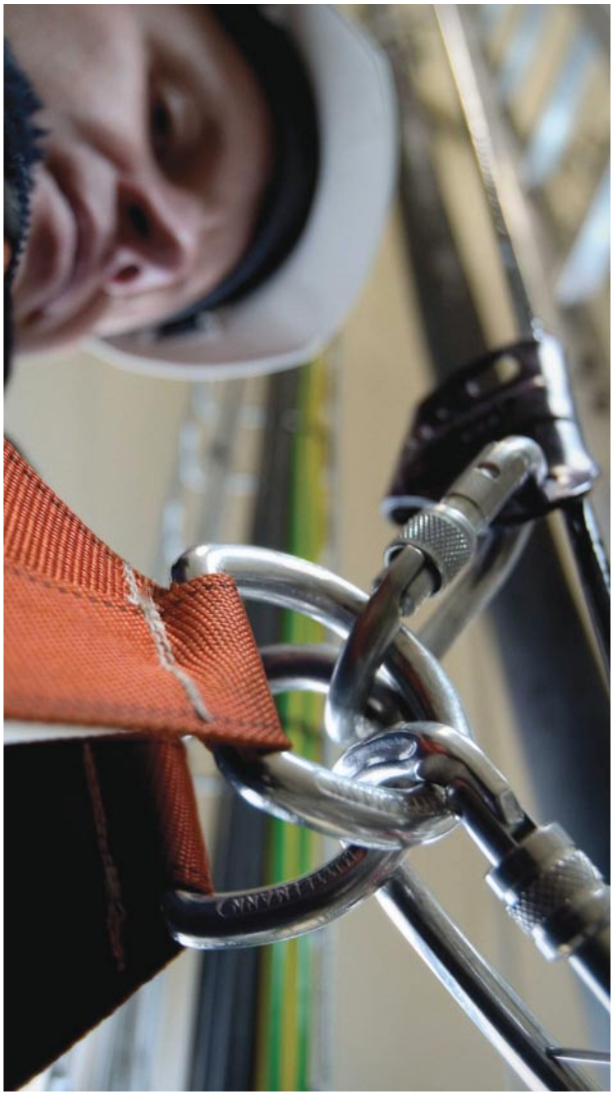
Zero-Max, Inc., an ISO 9001 certified design and manufacturing company, announces the introduction of its Composite Disc Couplings for the wind turbine industry. "These couplings withstand extreme misalignment while remaining torsionally stiff and have passed the 'hell hole' test at Tehachapi, California Wind Farm," according to James Motz, a member of the Zero-Max wind team.

"The couplings were tested under conditions simulating a 20-year load spectrum of continuous operation," he continues. "Once fatigue tested, the 'hell hole' location was selected for field testing in a wind turbine whereby the coupling would experience wind conditions in excess of 80 mph with continuous wind direction changes. The Zero-Max couplings survived these conditions that put over 50 wind turbines not using our coupling out of commission. The Zero-Max coupling continues to operate uninterrupted at this writing."

The Zero-Max wind turbine couplings are designed with composite disk packs at both ends of a center spacer. These patented designed disk packs provide the true strength and calculable flexibility of the coupling. The composite disk packs (flex elements) provide a distinct advantage over other coupling component designs by allowing a surplus of parallel and axial misalignment while remaining torsionally stiff through all harmonic ranges of the wind turbine's oscillating load. Depending on application, the Zero-Max's center spacers can be machined out of steel, composite glass fiber or 6061-T6 aluminum. Through the use of Finite Element Analysis (FEA), these center spacers can be engineered to withstand in excess of 70,000 Nm of torque depending on the material selected. For more information call (800) 533-1731, send e-mail to zero-max@zero-max.com, or go online to www.zero-max.com.

### AVANTI CLIMB ASSISTANCE EXPANDS IN OREGON

Avanti Wind Systems announces that 141 new wind turbines in Oregon are to have its climb assistance equipment installed. This system makes it easier for service technicians to climb up and down the ladders in wind turbines. The new turbines will be installed in Biglow Canyon for Portland General Electric. Construction of the first 65 wind turbines began in April this year, with the remaining 76 to be installed in 2010.



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.

In simple terms, Avanti climb assistant consists of an endless rope fastened to the technician's harness with a clamp of the same type used in mountain climbing. Giving a gentle tug starts a motor that pulls on the rope, thus facilitating climbing. The rope runs along the ladder, and the pull weight is set by the technician. The safety systems ensure that the user can stop the system at any time because the pull weight is set so that the technician only need stand still on the ladder and, after a few seconds without movement, the pull force stops. The weight is also lightened in a similar way on the way down.

Avanti Wind System is leading world market producer of service lifts and other personal security systems to wind turbine towers. In addition, the Avanti Training Program covers all training needs concerning the company's products, evacuation, fire precautions, rescue, health, and safety. The company's service lifts, ladders with build-in fall safety rail, and climbing assistance have been approved in accordance with official standards in the Unites States, the European Union, and Australia. Learn more by calling (262) 641 9101, sending e-mail to kp@avanti-online.com, or going to www.avanti-online.com.

### JOINT REPORT EXAMINES RENEWABLE ENERGY PROJECT FUNDING

Lawrence Berkeley National Laboratory (LBNL) and the National Renewable Energy Laboratory (NREL) are pleased to announce the release of a joint report titled "PTC, ITC, or Cash Grant? An Analysis of the Choice Facing Renewable Power Projects in the United States." This report was funded by the U.S. Department of Energy.

Signed into law one month ago, The American Recovery and Reinvestment Act of 2009 ("the stimulus bill") contains a number of provisions that could have a significant impact on how U.S. renewable power projects are financed over the next few years. Among these provisions is one that allows projects eligible to receive the production tax credit (PTC) to instead elect the investment tax credit (ITC). Another provision enables ITC-eligible projects, which now include most PTC-eligible renewable power projects, to instead receive a cash grant of equivalent value. Both of these provisions are in place for a limited time only.

The purpose of this report is to both quantitatively and qualitatively analyze, from the project developer/owner perspective, the choice between the PTC and the ITC, or equivalent cash grant, for a number of different renewable power technologies. Technologies analyzed include wind, open- and closed-loop biomass, geothermal, and landfill gas projects. The factors addressed in this report suggest that most wind, open- and closed-loop biomass, and landfill gas projects may benefit more from the ITC than they will from the PTC. Furthermore, based on qualitative considerations alone, it is reasonable to expect those projects that are placed in service or begin construction in 2009 or 2010 to elect the equivalent cash grant rather than the ITC itself. Geothermal projects, on the other hand, are likely to prefer the PTC, unless qualitative considerations overwhelm quantitative. The full report can be downloaded at eetd.lbl.gov/EA/EMP/reports/lbnl-1642e.pdf.

## GE ENERGY LAUNCHES NEW WIND TURBINE LAYOUT OPTIMIZATION SERVICE

Further expanding its suite of services for the global wind industry, GE Energy is introducing WindLAYOUT, which provides an opportunity to improve the economics of a wind plant through optimization of wind turbine layout. GE Energy, North America's leading supplier of wind turbines, continues to lead the wind industry by developing new technology to meet the growing demand for cleaner energy. "This new offering is another in GE's series of continuing technology advancements helping to move the wind industry forward," says Victor Abate, vice president-renewables.

A key step in the development of a wind power project is the siting of wind turbines to achieve the highest possible level of energy production, while also addressing project costs and constraints. GE's new WindLAYOUT offering, part of the company's portfolio of Wind Plant Optimization products and services, utilizes GE's core power generation expertise to maximize energy capture without exceeding turbine design limits.

With GE's WindLAYOUT service, customers are able to make the best cost-benefit decisions regarding site development. The new offering includes features such as a wind turbine layout report detailing locations that maximize energy production estimates and due diligence on a wind resource assessment. The WindLAYOUT service is available for GE's 1.5-megawatt and 2.5xL wind turbines. The GE 1.5-megawatt machine is the world's most widely used wind turbine, with 12,000 now installed around the globe. The GE fleet of installed 1.5-megawatt wind turbines has exceeded 125 million operating hours.

In addition, GE has invested more than $100 million to launch its 2.5xL wind turbine technology and to enhance its production facilities in Salzbergen, Germany. The 2.5xL is designed specifically to meet the immediate needs of the European wind power industry, where lack of available land can constrain the size of projects. To learn more go to www.ge.com/energy.

## ADVANCED WIND BLADE PROTOTYPING FACILITY TO OPEN AT UMAINE

U.S. capacity for windblade research and development will take a giant leap forward this year with the construction of an Advanced Wind Blade Prototyping Facility at the University of Maine's AEWC Advanced Structures & Composites Center. Scheduled to open in December 2009, this new facility is unique in its capability for the design, manufacturing, and testing of large blades up to 70m.

The new facility will expand the AEWC Advanced Structures & Composites Center's laboratories to 70,000 ft2. Full-scale blade manufacturing is supported by the center's established expertise in the following areas: composites manufacturing, including VARTM, prepreg, fiber/tape placement; composites design, including FEA modeling, probabilistic mechanics and laminate analysis; joint design supported by expertise in fracture mechanics analysis; and material evaluation through static, fatigue, durability, impact, and non-destructive evaluation.

With 140 full and part-time faculty, scientists, and engineers, the AEWC Advanced Structures & Composites Center has 15 years of experience in large structures testing. It is well-known throughout the industry for its innovative product development and has won top ACMA awards for excellence in composites design and innovation in 2008 and 2009, as well as other research honors including SAMPE's best paper award in 2008. To learn more visit www.aewc.umaine.edu.

## TIMKEN EXPANDS SERVICE TO WIND MARKET

The Timken Company plans to expand production capacity at its Tyger River facility in Union, South Carolina, to serve the wind energy market. The investment is part of a strategy to strengthen Timken's position in serving growing global demand for highly engineered large-bore bearings that will help customers harness wind power.

Timken expects demand for large-bore bearings used in main-rotor shafts and gear drives in wind turbines to grow rapidly in the coming years as reliance on renewable energy increases. The Tyger River investment will allow the company to serve demand from North American customers and provide expanded capability to produce prototypes in support of new wind-turbine programs.

Expansion work at Timken's Tyger River location will begin this year, with production currently slated for 2010. It will be the company's second wind-related commitment of the past year, following formation of a joint venture with China's XEMC to build a new main-shaft bearing facility in Xiangtan, Hunan province. Construction of that new facility is scheduled to begin this year.

The Timken Company manufactures highly engineered bearings, alloy steels, and related components and assemblies. For more information please visit www.timken.com.

## CARBONE OF AMERICA AND NAWSA FORM DISTRIBUTION AGREEMENT

Two giants in the wind industry have joined forces to provide reliable, time-tested service and parts to the wind market. North American Wind Service Alliance (NAWSA) is the only North American distribution channel for Carbone of North America wind generator replacement graphite brushes, slip ring assemblies, and hub assemblies.

Carbone of North America, a leader in innovative material solutions involving graphite and other performance materials, has designed and developed replacement brushes specifically for the wind generator market. The electrographitic grades of materials in these brushes provide the best characteristics to improve performance and wear, extending lifecycles, and lowering replacement costs. It is now possible, with one call or e-mail to a NAWSA member, to arrange for the purchase and/or installation of these Carbone Lorraine components anywhere in North America. The NAWSA network of alliance members can ensure a local response to your need for quality performance products designed specifically for your wind generator needs. NAWSA's Web-based single point of contact for all wind generator concerns—from emergency response to diagnostics and repairs—has more than 50 tower-rescue trained technicians and fully trained support technicians based throughout the country to provide on-site evaluation, removal, installation, and support coordinated through NAWSA.

NAWSA's growth parallels the increasing demand for well-trained professional wind generator service across the country. With many units reaching an age where repair or replace decisions are vital for continued profitability, NAWSA has both the expertise and the flexibility to meet this demand within 48 hours of contact. To learn more send e-mail to info@nawsa.com or visit online at www.nawsa.com.

## AMERICAN WIND AND WILDLIFE INSTITUTE NAMES NEW PRESIDENT

The American Wind and Wildlife Institute (AWWI), a national organization committed to facilitating timely and responsible development of wind energy and the protection of wildlife and wildlife habitat, has announced the selection of Kraig Butrum to serve as its first president. He brings 25 years of experience in non-profit administration to AWWI. As a first priority he will hire a research director to prioritize and fund research so that developers can make informed siting decisions in relation to wildlife and conservation issues. Early in his tenure he will oversee the implementation and expansion of AWWI's research, mapping, mitigation, and outreach and education initiatives.

"The time is now for America to address global climate change, diversify its energy base, and lessen its dependence on foreign sources of oil," says Butrum. "I look forward to hitting the ground running in order to provide the research and information needed to meet our nation's goal to triple development of wind energy in the next few years while protecting biodiversity and critical habitat."

AWWI was founded in October 2008 by 20 of the nation's top science-based conservation and environmental groups and wind energy companies with the mission of facilitating timely and responsible development of wind energy while protecting wildlife and wildlife habitat. It does this through research, mapping, mitigation, and public education on best practices in wind farm siting and habitat protection. The institute's members include AES Wind Generation, Association of Fish and Wildlife Agencies, Babcock and Brown, BP Alternative Energy, Clipper Windpower, E.ON, Environmental Defense Fund, enXco, GE Energy, Horizon Wind Energy, Iberdrola Renewables, National Audubon Society, Natural Resources Defense Council, Nordic Windpower, NRG Systems, Renewable Energy Systems Americas, The Nature Conservancy, The Sierra Club, Union of Concerned Scientists, and Vestas America. To learn more, please visit www.awwi.org.

## CAPITAL SAFETY INTRODUCES FALL PROTECTION FOR THE WIND INDUSTRY

DBI-SALA, a Capital Safety brand, introduces a complete fall protection solution for the wind energy industry: the ExoFit™ Wind Energy Harness and Force2™ Wind Energy Lanyard. The products are uniquely designed for wind turbine construction, maintenance and inspection. With soft and lightweight, yet exceptionally durable materials, the ExoFit Wind Energy Harness maximizes worker comfort and productivity. The harness is constructed in the shape of an "x" for easy, no-tangle donning, and integrates a variety of premium features in both the standard model and a construction model.

Hardware on both the construction style and standard harness is PVC-coated to prevent scratches to the surface of the nacelle. Additional features of the

ExoFit Wind Energy harnesses include built-in lanyard keepers to prevent the lanyard from snagging or creating a tripping hazard, quick-connect buckles, a front D-ring for climbing or controlled descent, side D-rings for positioning, and a dorsal D-ring for fall arrest. Suspension trauma straps are also included on each model. In case of a fall, the suspended worker would connect the straps and step into them to relieve pressure.

The Force2 Wind Energy Lanyard features specialized components ideal for wind turbine construction and maintenance. Atop the nacelle, workers must tie-off at their feet, as overhead anchorage points are not available. This requires a shock-absorbing lanyard capable of resisting 12-foot free falls. The Force2 meets this requirement for individuals weighing up to 310 pounds, and has been tested for six-foot free falls for individuals weighing up to 420 pounds. The twin legs of the Force2 Wind Energy Lanyard allow for 100 percent tie off, a critical safety feature for working at height. For more information call (800) 328-6146, (651) 388-8282, or go to www.capitalsafety.com.

## NEW SLIP SYSTEMS FOR WIND TURBINE GENERATOR PROTECTION FROM CENTA

CENTA's wide-ranging global experience produces an enhanced version of its Torque Hub, the market-leading slip clutch that offers a simple and low-cost design for torque overload generator protection. In wind power plants, electrical circuit problems are known to cause short-term torque peaks. In this event slip clutches protect the costly gearbox against overload by slipping at a defined maximum torque in order to temporarily interrupt the drive. The slip process takes place not on the generator shaft surface, but inside the CENTA Torque Hub, which is mounted on the generator shaft in the coupling's clamping set.

CENTA's latest development in slip systems—the "CENTA Torque Set"—now positions the slip unit to the middle section of the shaft. By relocating the slip function, manufacturing tolerances at the generator shaft no longer cause variations in the slip torque, resulting in improved accuracy of the slip function. Another advantage of the new design is that the slip system is made to be pre-mounted as a complete unit. The maximum torque is set on a certified test bench according to the manufacturer's requirements and documented in a test report, eliminating the need for on-site adjustments. For more information contact Bob Lennon at (630) 236-3500 or bobl@centacorp.com. Go online to www.centa.info.

## WIND ENERGY TECHNICIAN PROGRAM TO OPEN

The first privately owned and operated instructional program and training center for wind energy technicians is scheduled to open in July 2009 in Vancouver, Washington, according to Arch Miller, founder of the parent company, International Air and Hospitality Academy. The Wind Energy Technician course is the first for alternative energy workers that will be taught in a separate division of the academy, called the Northwest Renewable Energy Institute (NW-REI). Training for other renewable energy technologies will follow.

Miller says the course is a direct response to the huge demand for wind power as a means of generating electricity in the United States. At the beginning of 2008 wind power accounted for just over one percent of the nation's electricity, or some 16,818 MWe. Last year, according to the American Wind Energy Association, the wind energy industry installed about 42 percent of all the new electric generating capacity in 2008 and created 35,000 jobs, primarily in construction and manufacturing.

"Currently there are some 85,000 Americans employed in the wind energy business in the U.S.," Miller says. "The U.S. Department of Energy reports that wind energy is capable of generating 20 percent of the nation's electricity by the year 2030. If we meet that goal the number of workers involved in wind power will grow from 85,000 today to 450,000 by 2030. That's a huge demand for new workers in this field, which today pays between $36,000 and $68,000 annually, depending on education and experience." To learn more call Colleen Piller at (360) 695-2500 or go to www.nwenergyinstitute.com.

## HEAVY-LIFT HOVERBARGE FOR OFFSHORE WIND WORK

Installing and maintaining offshore wind farms when faced with intertidal areas or shallow water can provide an interesting challenge. However, there could be an answer using an air cushion solution. The heavy-lift Hoverbarge, which Hovertrans engineers have been manufacturing for over 30 years, is an amphibious



SKF WindCon

SKF WindLub

marine barge capable of transporting a payload of hundreds of tons on a cushion of air.

The Hoverbarge system can be utilized to transport heavy equipment over shallow waters, mud flats, and sandbars unaffected by tidal ranges. The Hoverbarge could also eliminate the need for offshore jointing, transporting cable from the shore to deep water. The capability to move heavy equipment efficiently over such areas could reduce costs significantly because there is no need for dredging, constructing, or using quayside infrastructures. Hovertrans has seen an increase over the past month of interest from power and engineering companies looking to use the Hoverbarge system, potentially alongside traditional hovercraft for crew transfer.

The Hoverbarge has proven to minimize environmental impact. Dan Turner, managing and technical director of Hovertrans, says that "The Hoverbarge only exerts 1psi ground pressure compared to a human footprint of 8psi and can avoid the need for dredging. There appears to be great benefits from using a system that minimizes environmental impact when constructing wind farms."

For more information call + 44 23 8030 2035, send e-mail to Stuart Turner, general manager, at stu@hovertrans.com, or go online to www.hovertrans.com.

## DONALDSON TO SHOWCASE NEW GEARBOX FILTER AT AWEA SHOW

A leading manufacturer of innovative filtration solutions, Donaldson has engineered a revolutionary new gearbox filter to improve wind turbine performance. The company will showcase the new DT-1300R element at the AWEA WINDPOWER 2009 Conference & Exhibition in Chicago. The show, scheduled for May 4-7, is the largest annual event of its kind in the world, and features the latest industry developments, technologies, products, and more.

Gearbox wear and malfunction are two of the primary concerns in wind turbine maintenance. Donaldson's DT-1300R gearbox filter helps reduce those maintenance concerns, saving time and money. "The DT-1300R uses our new patented breakthrough in filter media, Synteq™ XP," says Marty Barris, director of engineering. "Synteq XP delivers absolute level efficiencies with contaminant-holding capacities beyond that of competitive filters. This increases performance and provides greater protection against wear, improving overall wind turbine performance and productivity."

Donaldson maintains the industry's largest inventory of many replacement elements, including the DT-1300R at their North American distribution center. "Keeping a product in stock translates into less overhead costs for our distributors and customers, quicker delivery, shorter lead times, and faster response to customer inquiries," Barris adds. "Donaldson is committed to customer service. Getting customers the products they need, when they need them, is something we've prided ourselves on for more than 90 years." To learn more go to www.donaldson.com.

## ELECTRICAL PROTECTION SOLUTIONS FROM FERRAZ SHAWMUT


Ferraz Shawmut has been a leader in circuit protection for industry and the electrical market for more than 100 years. Now the company is bringing its knowledge, innovation, and technical expertise for the second year in a row to the AWEA WINDPOWER 2009 Conference & Exhibition at McCormick Place in Chicago May 4-7, 2009. Ferraz Shawmut invites attendees to learn more about its complete line of problem-solving products for wind power electrical protection by stopping by booth #4536.

A worldwide supplier of current-limiting fuses and accessories for overcurrent protection, Ferraz Shawmut products ensure the security of electrical components, systems and the people who use them. A wide range of products are available for the nacelle, utility, and tower base, including finger-safe power distribution blocks (FSPDB), time-delay class J fuses (AJT), E-rated medium voltage current-limiting power fuses, and more. To learn more visit www.us.ferrazshawmut.com.

James D. Hussin
Hayward Baker, Inc.

## No structure can remain standing without a solid foundation. Read on for a primer in foundation types and ground-preparation techniques.

FOUNDATIONS HAVE BEEN A CRITICAL ASPECT of wind turbine tower design since the earliest days of the industry. Many early towers experienced foundation problems since the unique loading associated with these structures was not yet fully understood. As towers become taller, efficient foundation design is an increasingly significant component of the overall profitability of wind farm construction and operation.

Although wind turbine towers are not particularly heavy, by their very nature these tall, slender structures are subject to high lateral loading at a distance far above their base, resulting in a large overturning moment. In seismic areas, earthquake loading requires additional analysis, as the structural design of wind towers is quite sensitive to cyclic loading. Offshore wind turbine tower foundations pose additional foundation design and construction challenges, as wave and current loading, vessel impact, and scour must be addressed.

As with any foundation design, the first step is to perform a geotechnical exploration at the proposed site to identify the site characteristics and subsurface conditions. Field and laboratory tests should be performed to understand the subsurface conditions and the geotechnical parameters necessary for the design. Strength and deformation characteristics of the subsurface soil and rock govern the size and type of foundation system based on overall stability and tower deflection criteria. The overturning moment applied at the base of wind towers is a dynamic loading condition, varying with wind speed and direction. Therefore, geotechnical engineers must conduct appropriate laboratory and field testing that provides dynamic soil properties, in addition to static properties commonly provided for traditional structural design.

Both deep- and mat-foundation types have been used to support land-based wind towers. In the first category a single shaft is centered beneath the tower—this is often referred to as a "mono-pole" system—or a pile cap supported on a group of driven or drilled piles is used. The mat foundation is generally octagonal in shape, and it is sometimes referred to as an inverted "T" slab. The mat is often buried to provide resistance to overturning moments. In lieu of overburden surcharge, rock or soil anchors can be installed around the perimeter of the mat to resist uplift from overturning moments.

Ground improvement is the process of bolstering specific attributes of soil to increase its suitability for foundation support. On many construction projects the underlying soils pose various problems that can be addressed by ground improvement. Such improvements may focus on increasing the soil's shear strength and density to address stability issues, reducing compressibility, or altering permeability for groundwater control/consolidation. Some ground improvement techniques rely on the introduction of energy, whether by force or vibratory probes, to alter the characteristics of soils, while others mix or permeate the soils with a cementitious binder. Specialized structural elements may be introduced into the foundation soils, bypassing the problem soils altogether. Several different ground improvement methods may be used on the same site to achieve the desired results.

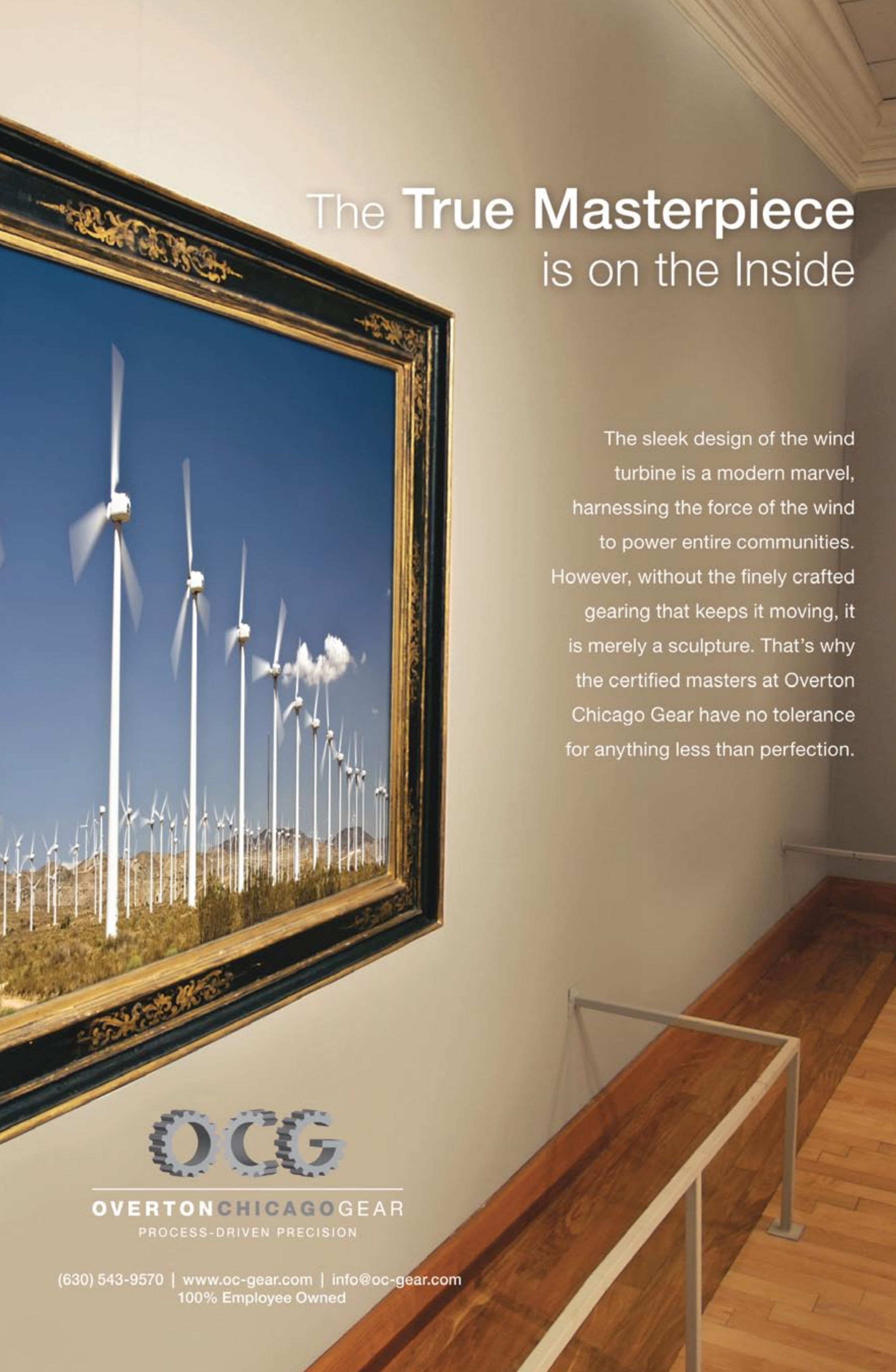
As an alternative to traditional deep foundations, ground improvement techniques are available to stiffen and strengthen existing soils, which enables the use of a mat foundation. Ground improvement methods for new tower foundations include grouting, aggregate piers/stone columns, dynamic compaction, vibro-compaction, and soil mixing. Existing site conditions and performance requirements will govern the selection and performance verification testing of the ground improvement type.

Offshore towers have additional loading related to currents, waves, and ice and ship impacts. They have been supported on driven mono-poles, gravity foundations (mats), and structural tripods supported by driven piles. Deep-water concepts consist of floating or partially submersed structures that are stabilized by anchored cables. A grounded deep-water concept (patented) has been developed that is similar to a lattice tower.

Occasionally, existing tower foundations require remediation to correct excessive deflection. Remedial options include: grouting for settlement reduction or structural releveling, micropiles for releveling and increased capacity, and anchors to increase overturning capacity. These techniques can be performed through an existing foundation or, in the case of micropiles or anchors, can also be installed adjacent to the existing foundation and structurally connected post-construction.

Wind tower mat foundations and traditional deep foundations are relatively common and well understood. However, many owners, engineers, and contractors are less familiar with ground improvement of poor soils to support a mat foundation or remediation of existing foundations. In future issues this column will provide information and guidance toward possible applications of ground improvement technologies within the wind tower construction industry.

James D. Hussin is a director with Hayward Baker, Inc., the leading specialty foundation and ground improvement contractor. He can be reached at jdhussin@haywardbaker.com. Go online to www.haywardbaker.com.


The True Masterpiece
is on the Inside
The sleek design of the wind turbine is a modern marvel, harnessing the force of the wind to power entire communities. However, without the finely crafted gearing that keeps it moving, it is merely a sculpture. That's why the certified masters at Overton Chicago Gear have no tolerance for anything less than perfection.
OCG
OVERTONCHICAGOGEAR
PROCESS-DRIVEN PRECISION
(630) 543-9570 | www.oc-gear.com | info@oc-gear.com
100% Employee Owned

Parthiv Amin and Eckart Bodenbach, P.E.
Winergy Drive Systems

## Ideally, gearboxes would run forever with no downtime, but repairs are required in the real world. Ask the following questions for improved outcomes.

**AS YOU KNOW, THE GEARBOX IS** a critical component of the wind turbine drivetrain. Should you encounter a problem with this unit, what should you do? Who can handle the repairs, what will they cost, and how long will it be down? All are valid questions, but one of the most important is whether the gear unit needs to be removed from the turbine at all.

Today's megawatt-class gear units are designed to allow repair work uptower. As a matter of fact, service professionals are involved in the design process of a Winergy gearbox. Part of the service team's responsibility is to ensure the ease of serviceability, design new tools, and develop procedures to exchange gears and bearings uptower. The serviceability of gear units should be a selection criterion for every turbine user, and one of the key questions asked during the turbine selection process.

After determining who will work on the gearbox, the next logical question to ask is how it will be repaired. What repair processes are being used, how is the unit being disassembled, how will damage be avoided during disassembly, and how will the parts be stored until reassembly? Like all major suppliers, Winergy has developed both assembly and disassembly instructions. This addresses these questions while reassuring the customer that the unit will be tested as well as approved. Don't forget to make sure these reports are comprehensible, however. A good disassembly and inspection report with a drawing of the gear unit in question and a detailed description of the findings, as well as illuminated and focused pictures, should be the norm.

And what about the different types of parts, both new and reworked, that are going to be used? All gears are not made equally. The gear unit OEM has drawings, specifications, and more documents to insure that every part is made to the same standard as those made for a new gear unit, and new parts cannot be fashioned accurately without the original dimensions.

The same gear-cutting machines, heat-treat ovens, and grinding machines are used for new production and service parts alike. Both parts are sometimes made side by side, with the manufacturer determining only then which will be used in the new gear units, with the others designated for repairs. Gear units are manufactured to highly precise DIN standards and equivalent to aircraft quality, except for weighing several tons more. This goes for the steel that is used, as well. Shop quality is a good thing to consider, too. Is a supplier audit possible, and how big is its quality department? To what quality standards are the units repaired, and what certifications and documents are available on demand? These are all fair and important questions.

Will the unit just be repaired, or improved as well, and what upgrades are available? Gear unit design is constantly changing, and there is more interaction between the drivetrain, turbine, and gear unit than in times past. What was good five years ago might not be acceptable today. Only the OEM is capable of improving an existing gear unit, since all of the original design information is at their fingertips. Let's face it, the design of gear units is their daily concern, and OEMs spend sizable resources monitoring their fleet, developing new designs, improving the reliability of gear units, developing better lubrication systems, implementing new bearing concepts, and improving the tooth corrections on the geared parts, etc. All of these factors play into the improvement of repaired gear units over original parts.

Also, how are you going to test the gear unit? How can one trust a simple spin test? Today's production gear units are loaded up to 100 percent of load and speed to ensure the highest degree of quality and reliability. It provides a "run-in" period and ensures that the product is performing well before uptower installation. The OEM has the test bench that allows full load test of some repaired gear units, or at least a load test with compromises—partial load, for example—for others.

One last question involves cost, which is an important criterion in determining the value you're receiving. You need some idea of how long the service work will last—note: it should last as long as the original design—what warranty provision will be provided, and whether the OEM will stand behind the problem and provide uptower work, if needed. The best course is to design, manufacture, and maintain gearboxes that are reliable and don't require service. Should problems arise, however, asking these questions will help assure a positive outcome.

Parthiv Amin is president of Winergy Drive Systems, and Eckart Bodenbach, P.E., is service manager. Call (847) 531-7400 or visit www.winergy-ag.com.

Kathleen O'Dell
National Renewable Energy Laboratory

## You'll be amazed by the wind-industry support capabilities of NREL's wind energy research facility, at the foot of the Colorado Rockies.

**"YOU MAKE 'EM, WE'LL BREAK 'EM"** could be the motto of the National Renewable Energy Laboratory's (NREL's) National Wind Technology Center (NWTC). Located just south of Boulder, Colorado, it is the U.S. Department of Energy's premier wind energy research facility. At the NWTC researchers work with industry partners, testing full-scale wind turbines and their components to their limits to identify and resolve reliability issues and validate the performance of new designs before manufacturers risk millions of dollars on commercial production. The goal of this research is to assist U.S. industry in developing cost-effective, high-performance wind turbine technology that will compete in global energy markets. To that end NREL researchers work closely with industry partners to research, design, build, test, and refine advanced wind turbine designs.

Located at the foot of the Colorado Rockies, the location is ideal because it experiences two distinct wind patterns. First, strong westerly winds sweep across the continental divide during the fall and winter. These winds accelerate as they blast over the ridges and down through the canyons along the Colorado Front Range, occasionally reaching speeds exceeding 120 miles per hour and providing the severe testing environment needed for validating wind turbine reliability and performance. The second wind pattern occurs in late winter and spring, when smooth stable easterly and northeasterly winds blow in from the Great Plains. These winds are equally important because they are ideal for validating wind turbine performance under typical Midwest conditions.

As the only facility in the United States accredited through the American Association of Laboratory Accreditation (A2LA) to perform several critical tests, the NWTC provides the high quality testing required by wind turbine certification agencies, financial institutions, and other organizations throughout the world. Tests accredited by A2LA to International Electrotechnical Commission (IEC) Standards include wind turbine noise, power performance, power quality, and several structural safety, function, and duration tests.

The NWTC has multiple test sites that manufacturers can use to evaluate prototype machines under extreme conditions. In 2009 the center will begin working with Siemens to install and test its 2.3-MW late-stage prototype. The new machine's rotor spans 101 m and features a novel blade design that captures more of the wind's energy, but should not force any more load onto the turbine's moving parts and control systems. The turbine will be heavily instrumented to produce a constant stream of data.

*Dynamometer Test Facilities:* The NWTC's 225-kW and 2.5-MW dynamometer test facilities provide industry with a way to conduct a range of system tests that can't be duplicated in the field. These tests include gearbox fatigue, wind turbine control simulations, transient operation, and generator and power system component efficiency and performance tests. A few months of endurance testing on the 2.5-MW dynamometer can provide engineers with an equivalent of 30 years of use and a lifetime of braking cycles to help them determine which components are susceptible to wear.

*Blade Test Facilities:* NREL works with industry partners to verify new blade designs and materials. As wind turbines grow in size and their blades become longer and more flexible, it becomes more difficult to test the blades for endurance. To test the new, larger blades, NREL installed a larger blade test stand capable of testing blades up to 50 m in length. The tests include fatigue and ultimate static strength, as well as several nondestructive techniques such as photoelastic stress visualization, thermographic stress visualization, and acoustic emissions. NREL is working with consortiums in Massachusetts and Texas to develop two new blade test facilities capable of testing blades up to 80 m.

As today's utility-scale wind turbines become taller and more flexible, researchers at the NWTC are investigating ways to mitigate system fatigue by gaining better control of the way the components interact and move. By studying conventional turbine component controls such as blade pitching, twist-coupled blades, and advanced devices such as micro-tabs, researchers are developing innovative rotor control strategies to mitigate unwanted aerodynamic loads at the rotor hub and improving design codes. Current research will lead to future innovations that incorporate LIDAR to monitor and actively "fly" large rotors for load control.

The researchers at NREL have worked with wind industry partners for more than 25 years to advance both large and small wind energy technologies. We look forward to sharing news of our activities in upcoming issues of *Wind Systems* magazine.

Kathleen O'Dell is a communications specialist with NREL. Call (303) 384-6957, e-mail kathleen.odell@nrel.gov, or go to www.nrel.gov.

# Energy storage to enable clean, reliable power.

## The right technology, at the right time, with the right team.

Compressed air energy storage (CAES) is the missing piece of the puzzle for a green, affordable and reliable electric grid for the 21st century. Energy Storage and Power's CAES technology can effectively manage the timing and improve the economics of wind and other renewable generation. Two leaders in the energy industry, PSEG and energy storage pioneer Dr. Michael Nakhamkin have now come together to offer this improved process to others.

## An advanced process to manage intermittent renewable generation.

Energy Storage and Power's patented CAES technology stores low cost off-peak energy in the form of compressed air in an underground reservoir. The air is then released during peak load hours and heated with the exhaust heat of a standard combustion turbine to produce electricity when clean power is needed.

Contact us today to see how this second generation CAES technology with the advantages of multi-source standard components, lower capital costs and improved reliability will give you the power to harness your power.

"Clearly, compressed air energy storage (CAES) has significant potential as a near term, viable, large scale energy storage technology."

— *Dr. Arshad Mansoor,*
*Vice President of Power Delivery and Utilization, Electric Power Research Institute*

866.941.CAES (2237)

EnergyStorageAndPower.com

**Energy Storage and Power LLC**

Michael Miller
DC Power Systems

## For those with creative minds and spirits, small wind offers an amazing opportunity for designing systems to fulfill a growing market demand.

IN THE SMALL WIND INDUSTRY you will often encounter the sentiment that you should buy the biggest tower you can afford in order to maximize the total energy harvested from the system. This is true, in a sense, and I personally believe that every homeowner with enough space and wind should be allowed to erect as tall a tower as they require to get into good wind, free of the approval processes required in most parts of the country.

Of another mind are the proponents of a new batch of wind turbines designed to harvest wind energy from atop much smaller towers. These are small home-size systems, typically sold on shorter, tilt-up monopole towers, and offering a slew of new technologies designed to harvest energy from previously discounted potential sites such as urban rooftops, commercial centers, or anomalous micro-topographies that allow for the harvest of canyon flows or other natural wind tunnels. I advocate this type of growth in small wind, even though I realize the limitations that short towers and turbulent sites place on any given project's total production due to certain realities. These include the amount of power available in the wind, and the inefficiencies of the systems converting that power into useful energy.

As an advocate of small wind, I believe that it can truly make a difference, but I also choose to maintain a healthy sense of skepticism whenever I learn of new methods for harvesting wind power. Some seem incredibly outlandish at first, such as the possibility of using roof-mounted turbines. This has actually been studied, and it can be done with vibration and noise remaining within tolerable limits, but energy production will suffer. The energy produced is all that really matters, and each project has a different measure of success, making the classical payback scenario a secondary consideration for some.

In the ideal case, every small wind turbine should be mounted on a tilt-up, monopole, hydraulically-operated tower that is designed to work specifically with the turbine to which it is mated, and the whole rig should be installed and regularly maintained to the manufacturer's specifications by properly trained and qualified personnel. The turbine owner should have a reasonable expectation of energy production going into the project, as well as a means of assessing actual production in real time once it is commissioned. Most importantly, it should be easier than it now is to obtain zoning approval.

While there are legitimate concerns about safety that drive some of these zoning laws, today's small wind power systems are safer and more reliable than ever before. As long as the systems are purchased from a reliable manufacturer/representative, and then mounted and maintained by a certified professional, they should continue to provide clean, safe electricity from a free fuel source for decades.

The reality, though, is that there's a large market demand for personal wind power, even in areas where the ideal is difficult to reach. Do we ignore this segment of the market while steadfastly focusing on the ideal? It gets more challenging when we add to the equation restrictive zoning laws, "not in my backyard"—or NIMBY—property owners, and sometimes-litigious environmental groups. Yet demand continues to rise.

Small wind is here to say, and in the coming years we'll see it being used in ways and places never before considered. This will be achieved by better blade and equipment designs, R&D efforts, lighter and more-durable materials, and the ingenuity of the professionals who mount, service, and maintain these systems. We will probably see some models that are doomed to failure along the way, but the end result will be improved small-scale power production for residential and other applications.

At present small wind turbines are available from a number of manufacturers, and via widely differing distribution networks. They come in all sizes, and with tower heights ranging from 20 to more than 150 feet. The market is currently hungry for more options, lower costs, and increased reliability, so designers are rushing to fill that demand. In addition to the power independence these systems provide to end users, this situation also offers great opportunity to those capable of dreaming up the next big thing in small wind equipment design. I plan to share more insights into this exciting emerging industry in future installments of this column.

Michael Miller is wind division sales manager for DC Power Systems. Call (707) 395-3173, e-mail mmiller@dcpower-systems.com, or go to www.dcpower-systems.com.

# HPM AMERICA

By Russ Willcutt

With its beginnings in apple orchards, this company has returned to its green roots by machining large parts for the wind-power industry.

**IT'S BEEN SAID THAT WHEN ONE DOOR CLOSES,** another often opens, and the smart businessperson is constantly searching for that first light of opportunity to shine through the crack. Such was the case nearly three years ago, when a major wind turbine OEM was looking for a source to machine its hubs and contacted HPM America, according to Gerard Sposato, the company's vice president of sales and marketing.

"Since around 2001 U.S. die casting has really slowed down," he says, "going from some 3,000 companies in North America to about 300, and dealing with automotive companies and suppliers has led injection molding to experience the same downturn as well. A lot of that has to do with outsourcing the work to other countries, but it's also because of the changing structure and needs of the automotive industry based upon the current economic downturn. So when we were contacted by this OEM we realized that we had the ability, the people, the equipment, and the infrastructure in place to perform this work, so we decided to diversify our product offering and enter the wind-power energy market, and it's ended up being a perfect fit. Wind has really turned this company around."

Serendipity has long played a role in this company's history, beginning with its founding in 1877 when Augustus Q. Tucker—an owner of apple orchards around Edison, Ohio, who was also a student of mechanical engineering—developed a hydraulic press for making cider. Such were the beginnings of the Hydraulic Press Manufacturing Co., or HPM, which also developed the first American-made injection molding machine in 1931. Today the company is headquartered in Mount Gilead, Ohio, with three additional locations in Brazil and India.

According to Sposato, HPM America has two business segments: an OEM side, which manufactures injection molding, die-cast, extrusion, and hydraulic press equipment; and its contract manufacturing operations, which includes its machining capabilities for wind and other industries, such as mining. These activities are conducted in a 400,000 square-foot facility so vast that it has its own rail spur entering an assembly bay, and it's also able to utilize its own in-house heavy haul trucking group, resulting in the ability to ship directly and economically to any site in North America.

"We offer single-source responsibility to our customers," he explains. "On the contract manufacturing side we can purchase castings and steel directly from the foundries and truck them here to our facility, machine the castings and fabricate parts, assemble them if necessary, and then paint the completed machine parts in one of our four down-draft paint booths. We can then check the part in our state of the art inspection station and ship the order to a destination of the customer's choosing, either by road or rail. We feel that's a pretty powerful package."

And a package that helps keep costs down, he adds, since any time a process can be completed in-house the price of shipping to a subcontractor is saved. "Every time you send a part somewhere it can cost you two- or three-thousand dollars, depending on the part size and weight, so we try to do everything that we can right here at HPM. We can do as much or as little as a customer wants, depending on their needs."

The same is true for its OEM capabilities, where many clients call for a turnkey package, contracting with HPM to build the machine, ship it to the customer's facility, and install it using its own highly experienced personnel. The company also keeps an extensive inventory of spare parts on hand—about a million at any one time—and on the contract manufacturing side it keeps full inspection reports on file for 20 years, all of which can be accessed by the customer online, should they need them. "We do all of this because we're not taking a 'hit and run' approach to sales," Sposato says, "we want to partner with our clients for a long, long time. It's often easiest to make that first sale, but the second, third, and fourth one is harder. But if you can't perform on the first one, you won't get the chance to work on the others."

As for its wind-specific activities, HPM's Contract Manufacturing Unit can produce a number of parts for the nacelle, including the hub, bases, front support, generator frames, and pitch plates, among many other component parts. The company has a full engineering staff in the States as well as in India, and those services can be contracted on a stand-alone basis. "We've worked with a number of companies on that basis globally," Sposato says, "where they'll contract our engineers to complete a project at either our facility in Ohio or in India, or we will send an engineer directly to the client's location to perform the work, whichever scenario is best for them."

At a time when the wind-power industry is gaining substantial traction in the United States, HPM America is poised to play a prominent role in its continued development, offering a singular slate of capabilities to its current and potential customers. "We want to be the company that people can count on. Our goal is to exceed our customer's expectations in terms of quality and delivery, and we also want to be an environmentally conscious member of our community and world," he says. "We want to set the benchmark that other manufacturing operations are held to."

**Call (419) 946-0222, send e-mail to sales@hpmamerica.com, or go online to www.hpmamerica.com.**

# VIBRATION-BASED WIND TOWER FOUNDATION DESIGN

Wind towers must sustain continuous vibration-induced forces throughout their operational life, so how can you engineer a cost-effective design for structural integrity? Coffman Engineers provides one answer.

By Saif Hussain, S.E., and Mohamed Al Satari, Ph.D., P.E.

Saif M. Hussain, S.E., is managing principal with the Encino, California, office of Coffman Engineers, Inc. Mohamed Al Satari, Ph.D., P.E., is a structural engineer, formerly with the company. Visit www.coffman.com. The authors would like to thank the following staff for their contributions to this project: Steve Cegelka, Logan Haines, Ben Momblow, Scott Thompson, Paul Van Benschoten, and Will Veelman. Formatting assistance by Jonathan Wirthlin, P.E., LEED AP.

THIS IS A CASE STUDY OF MULTIPLE wind turbine towers located in different villages in Alaska where severe arctic weather conditions exist. Initially, a reinforced concrete (RC) mat foundation was utilized to provide vertical and lateral support. Where soil conditions required it, a pile foundation solution was devised utilizing a 30” thick RC mat containing an embedded steel grillage of W18 beams supported by 20”-24” grouted or un-grouted piles. The mixing and casting of concrete in-situ has become the major source of cost and difficulty of construction at these remote Alaskan sites. An all-steel foundation was proposed for faster installation and lower cost, but it was found to impact the natural frequencies of the structural system by significantly softening the foundation system. The tower-foundation support structure thus became near-resonant with the operational frequencies of the wind turbine leading to a likelihood of structural instability or even collapse. A detailed 3D Finite-Element model of the original tower-foundation-pile system with RC foundation was created using SAP2000. Soil springs were included in the model based on soil properties from the geotechnical consultant. The natural frequency from the model was verified against the tower manufacturer’s analytical and the experimental values. Where piles were used, numerous iterations were carried out to eliminate the need for the RC and optimize the design. An optimized design was achieved with enough separation between the natural and operational frequencies to prevent damage to the structural system, eliminat-

ing the need for any RC encasement of the steel or grouting of the piles.

## INTRODUCTION

Wind towers have to sustain continuous vibration-induced forces throughout their operational life. The operating frequency of the three-blade turbine could potentially cause dynamic amplification of these forces, significantly posing a threat to the overall structural integrity. Sufficient separation of the structural system's natural frequency from the turbine operational frequencies is key to avoiding potentially catastrophic failures. The turbine operating frequency is typically lower than the structural system natural frequency, but could approach it as higher turbine output is obtained. Idealized assumptions of fixity at the base of the tower are un-conservative; a more realistic analysis accounting for foundation flexibility yields lower estimates of the natural frequency for the system. In such cases, soil-foundation-structure interaction needs to be considered.

## STRUCTURAL DESCRIPTION

The owner, Alaska Village Electric Cooperative (AVEC), desired to purchase new or used towers to provide wind generated energy in concert with its diesel systems in the Alaska villages of Hooper Bay, Chevak, Gambell, Savoonga, Mekoryuk, Kasigluk, and Toksook Bay, as well as others. The tower models differ in height (23-46m), weight, and wall thickness. Furthermore, the three-bladed turbines vary in weight (7812-7909kg), blade diameter (19-27m), and power output (100-225kW). Towers were from a variety of manufacturers and suppliers. The turbine and tower packages ultimately utilized were supplied by Northern Power Systems of Barre, Vermont. Figure 1 shows some of the installed towers.

## OPERATIONAL ISSUES

As the wind turbine blades start to rotate from rest, their circular speed increases, and the induced vibration frequency increases. Depending on its power output capacity, the turbine blades rotate at maximum rotational (circular) speeds that range from 45 to 60 rpm, corresponding to 0.75 to 1.00 Hz. These operational frequencies are very close to the range of natural frequencies of the entire soil-foundation-tower-turbine system.

If more output power is desired, higher rotational speeds have to be accommodated. A poor design decision would involve a maximum rotational speed that is very close to the natural frequency of the structural system, resulting in a high likelihood of resonant amplification causing structural instability. Another poor design would have a rotational speed not very close to yet higher than the natural frequency of the structural system. In such cases the structure would have to endure violent near-resonance vibrations as the operational frequency approaches the natural frequency while speeding up to and down from the maximum speed. This situation would result in very high dynamic forces, which could cause immediate damage to the structure. Even if these dynamic forces do not exceed the structure's strength capacity, fatigue-induced failures could also be encountered.

A sound design would avoid allowing the operational frequency to approach the vicinity of the natural frequency by a certain safety factor. A safety factor of 15 percent of the natural frequency was recommended by the turbine vendor and adopted by the authors for this project.

## DESIGN OBJECTIVE

In order to develop a sound overall structural system that meets the structural performance requirements of the wind towers, the dynamic interaction of the sup-

Fig. 1: Operational wind towers.

porting soil, foundation, and superstructure needs to be considered. Since the tower and turbine are prefabricated and manufactured, once selected for a certain installation location only the foundation can be designed and fine-tuned in accordance with the site soil conditions and desired system frequency.

Depending on the soil conditions, the optimum foundation system needs to be selected (spread footing, deep piles, micro-piles, etc.). Additionally, the foundation must have adequate stiffness in order to maximize the system's natural frequency within practical limits. A suitably stiff soil-foundation-structure system will allow for higher power output generated by the turbines.

## FOUNDATION DESIGN

Based on the geotechnical conditions at the different sites, two types of foundations were selected; large spread foundation, and deep piles. A 5' deep, 12'x12' reinforced concrete (RC) spread footing was utilized to provide the system with vertical and lateral support, as well as damping and stiffness. Where soil conditions necessitated it, a pile foundation solution was devised utilizing a 30" thick mat of RC foundation embedded with a steel grillage of W18 beams founded on 20" grouted piles.

After some installations were made, it was determined that the mixing and casting of concrete in-situ is the major source of cost and difficulty of construction. An all-steel foundation was proposed for faster installation and lower cost, but such a foundation system impacted the natural frequency and significantly softened the system. Consequently, the foundation design was driven by the system's natural frequency. Multiple solutions combining different pile sizes, grouted and un-grouted, and different beam sizes were devised. The optimum design was selected for each location based on the highest practically obtainable natural frequency and cost effectiveness of the design.

## MODELING AND ANALYSIS

A detailed 3D Finite Element Analysis (FEA) model of the tower-foundation-pile system was created using

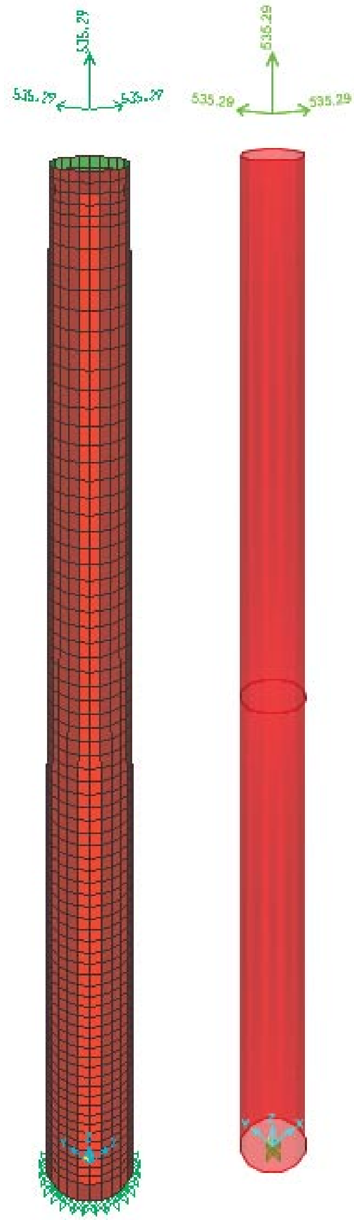


Fig. 2: Meshed shell element model (a) and tapered frame element model (b).

SAP2000. The tower was modeled using a fine mesh of thin shell elements, while the steel grillage and piles were assigned the appropriate cross-sectional properties. Thick plate elements were utilized to model the RC foundation. In order to capture the soil-foundation-structure interaction, compression-only springs were devised to mimic the soil around the piles. Soil damping properties were conservatively neglected and the turbine mass was lumped at the hub height above the top of the tower. The natural frequency from the model was verified against the tower manufacturer's analytical and the experimental values.

Discretization of FEA elements into sub-elements is not as straightforward a task as some may believe. Unfavorable discretization can give rise to subsequent numerical difficulties. In vibration analysis, for example, abrupt changes in element size should be avoided, as such changes tend to produce spurious wave reflec-

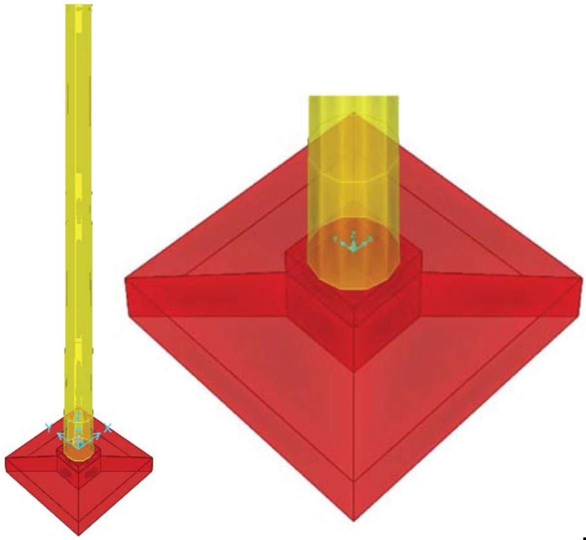


Fig. 3: Tapered frame model on RC spread footing (a) and close-up of the 3D footing element (b).

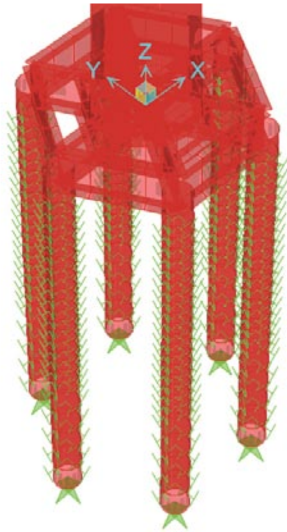


Fig. 4: Steel tower support on top of piles that are laterally constrained by soil springs.

# WE'VE EXPANDED WITH A NEW LOCATION.

## OUR NEW GEAR GRINDING AND MANUFACTURING FACILITY HOUSES ONE OF THE LARGEST GRINDERS IN NORTH AMERICA.


KAPP NILES

The ZP 40 grinding machine features the ultimate in design construction with true hydrostatic guideways and rotary table. The work table is direct drive. Nodular cast iron is used for the machine beds, columns, and all sub-assembly housings, for stability. The machine accuracy is therefore assured for a long lifetime.

The ZP40 is designed to profile grind spur and helical external and internal gears using dressable corundum or sintered grinding wheels. An integrated measuring device further increases machine's flexibility. The ZP machine can be set up to accommodate application-specific requirements for maximum flexibility, high precision and optimum productivity.

It is specifically designed to accommodate shaft pinions,

tions and numerical noise [4]. Consequently, a simplified tapered frame element was devised to model the tower instead of the thin-walled shell elements. Negligible deviations of the results from the two modeling techniques were observed. Thus, all design optimization runs utilized the tapered frame element. Figure 2 shows the two different modeling techniques.

The piles were modeled using frame elements, meshed into 1' segments. The large spread footing, on the other hand, was modeled using a 3D solid element with RC properties (fig. 3). The solid element was meshed into sub-elements using an intelligent algorithm consistent with the object-based FEA modeling of the SAP2000 program. Figures 4-6 show the discretization of the piles and footing with the application of the soil springs to the meshed surfaces.

| Savoonga | |
|---|---|
| Tower Height | 29m |
| Turbine C.G. | 1.28 m (50") above top of tower |
| Combined Turbine and Blades Mass | 7812 kg-mass (535.292 slugs) |
| Foundation Beams | W36X170 |
| Pile Section | 24" steel pipe, 3/4" thickness |
| Number of Piles | 6 |
| Point of Fixity | Varies; 18-11 ft below soil surface |
| Modulus of Horizontal Subgrade Reaction | Varies with depth; 19-319 kip/in |
| System Natural Frequency | 1.128 Hz |
| Recommended Maximum rpm* | 57 rpm |
| **Mekoryuk** | |
| Tower Height | 29m |
| Turbine C.G. | 1.28 m (50") above top of tower |
| Combined Turbine and Blades Mass | 7812 kg-mass (535.292 slugs) |
| Foundation Beams | W36X170 |
| Pile Section | 24" steel pipe, 3/4" thickness |
| Number of Piles 6 | |
| Point of Fixity | 30 ft below soil surface |
| Modulus of Horizontal Subgrade Reaction | Varies with depth; 19-1070 kip/in |
| System Natural Frequency | 1.148 Hz |
| Recommended Maximum rpm* | 58 rpm |
| *The recommended rpm incorporates a 15% safety factor. | |

Table 1: Design summary for Savoonga and Mekoryuk villages.

## RESULTS

Where piles are used, numerous iterations were carried out to eliminate the need for the RC and optimize the design once a comfort level with the modeling technique was reached. The foundation system design was optimized through a parametric sensitivity-based approach in which the radius of the pile group, grillage beams, and pile sizes were varied to produce comparable alternatives. It was found that the radius of the pile group had the most impact on the system frequency. A favorable radius was selected

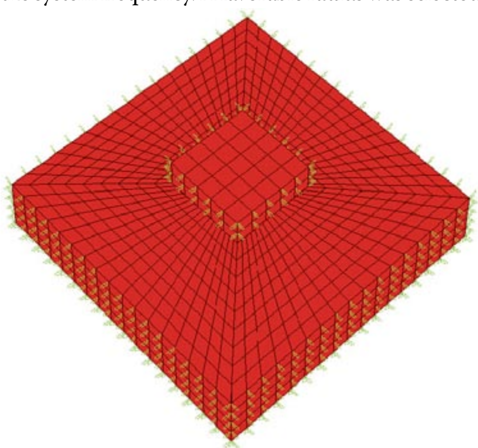


Fig. 5: Meshed 3D solid element with vertical and horizontal compression-only soil springs.

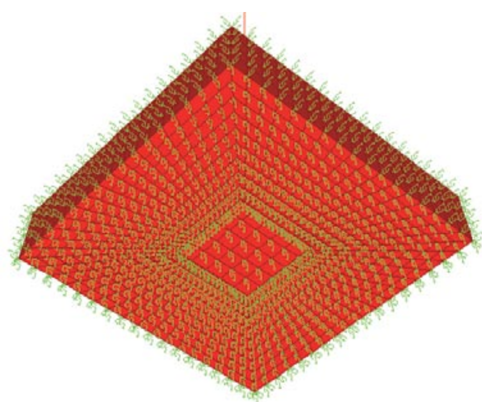


Fig. 6: Underside view of foundation.

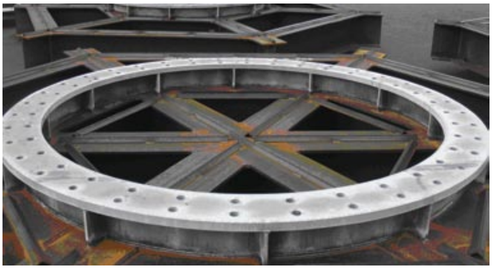


Fig. 7: Steel tower support.

using a set of typical grillage beam and pile sizes. A series of further variations to the beam/pile sizes and different combinations yielded an optimized foundation design for each site. The optimized designs were achieved with enough separation (15 percent) between the natural and operational frequencies to prevent damage to the structural system. The optimization eliminated the need for any RC encasement to the steel foundation or grouting to the piles, in many cases.

In most cases, an optimized foundation system design for a particular site was also found to be satisfactory for other locations. Thus, a small library of universally applicable standard designs was compiled in an effort to keep the fabrication cost low. Table 1 summarizes the final design for two of the tower locations and demonstrates how one optimized design is adequate in two locations with different geotechnical conditions. Figure 7 shows one of the optimized all-steel tower support foundations.

## CONCLUSIONS

The foundation system design was controlled by the natural frequency of the soil-foundation-structure system rather than by strength or serviceability considerations. Taking into account the soil-foundation-structure interaction yielded a more realistic estimate of the natural frequency. Had a fixed-base-tower assumption been adopted, significantly under-designed systems would have been incorporated.

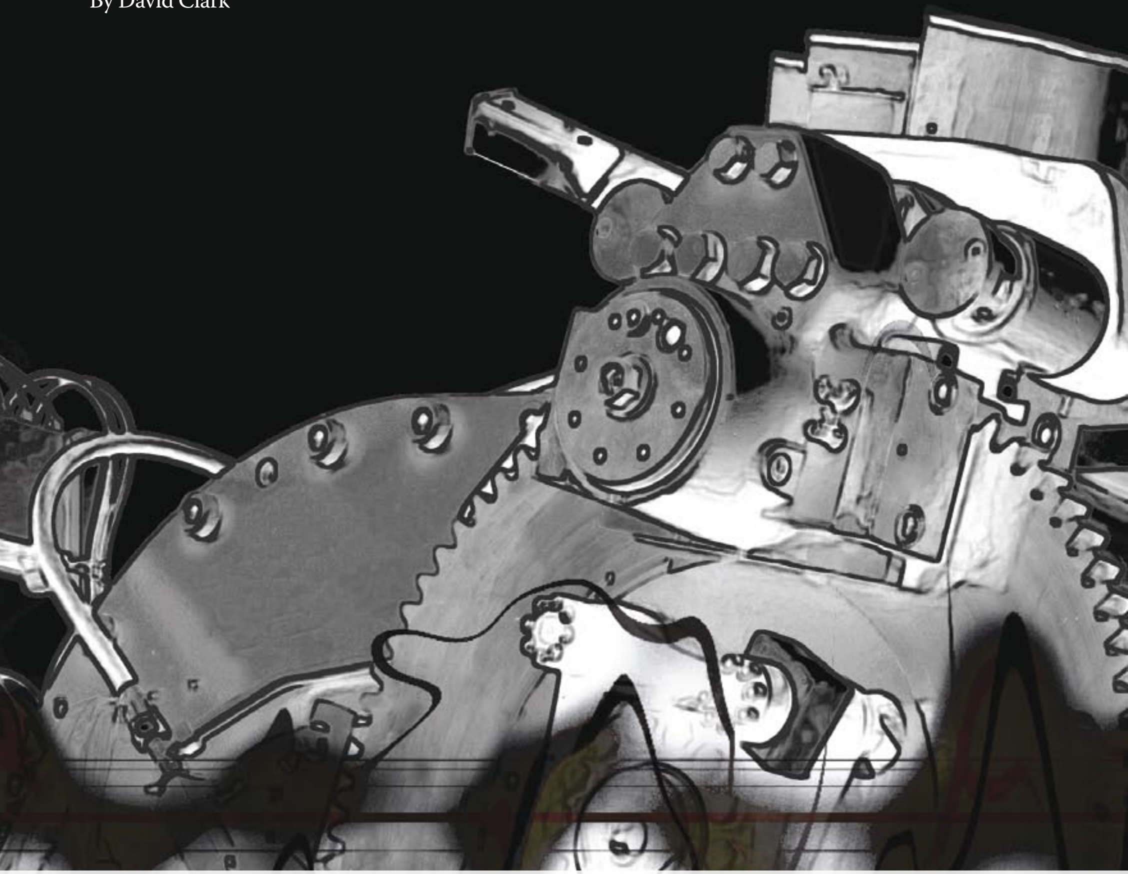
## REFERENCES:

1) American Concrete Institute. (2004), ACI 351-04 Foundations for Dynamic Equipment, Farmington Hills, Michigan.
2) J.P. Saylor & Associates, Consultants Ltd. Vestas V27-225kW Specifications and Technical Data, Des Moines, Iowa.
3) Golder Associates, Inc. Geotechnical Reports, Anchorage, Alaska.
4) R.D. Cook, D. S. Malkus and M. E. Plesha. (1989), Concepts and Applications of Finite Element Analysis, John Wiley & Sons, New York, New York, pp. 553-582.

# MONITORING FOR MAINTENANCE

The experts at Turningpoint explain why you can think of vibration condition monitoring as an MRI for your wind-tower gearbox, helping predict and schedule maintenance in advance.

By David Clark



David Clark is director of Turningpoint. He can be reached at (530) 677-9785 or david@turningpointwind.com. Go online to www.turningpointwind.com.

IN A RECENT REPORT COVERING the last quarter of 2008 in Europe, 54 gearbox failures attributed to either wear or failure equaled 8,177 hours of downtime. This downtime includes the actual repair, lost production, and crane costs. Since a catastrophic gearbox failure on an average megawatt class wind turbine costs somewhere between $225,000 and $300,000 to remediate, more and more people are looking for maintenance methods to address costly gearbox issues.

No matter the industry, it seems that maintenance practices fall into three basic categories:

- Wait until it breaks;
- Maintain at an interval;
- Predict maintenance.

The approach that we are focusing on in this article involves using vibration analysis to predict maintenance. There are many tools for predictive maintenance, with vibration being one of the most prolific. While predicting mainte-

nance using vibration is widespread in other industries, for various reasons—and despite some challenges—the wind industry is quickly adopting a predictive maintenance culture.

## INSPECTION INFO

It is generally accepted that most things fail in a “bathtub” type failure curve. It has a higher probability of failing early in its service life, or later in life as it wears (fig. 1). It stands to reason that testing of gearboxes needs to occur during assembly, commissioning (both early stages), and during the life of the wind turbine to catch the other end of the failure curve. In addition, gearbox rebuilders as well as manufacturers would be wise to adopt vibration acceptance testing prior to sending gearboxes out into the field (fig. 3). The reasoning is simple, really—Do you want to change a bearing or gear in your repair facility or up tower?

In the table labeled fig. 2 you can see how the common wind turbine inspection methods compare. This table was created with help from Don Roberts, project engineer with DNV Global Energy Concepts, Inc. DNV/GEC is a company that, among many other services, provides these types of inspection. While there are exceptions, this table holds true for many of the most-common gearboxes in wind when using these inspection techniques. What we are trying to illustrate is an understanding as to how these inspection techniques compare in this application. You can see that an open inspection leaves most of the gearbox unseen. A bore scope inspection is better, but on average leaves large gaps in detection.

Vibration detects all of the meshing and bearing fault frequencies. What it does not do, however, is specifically identify which of the three planetary bearings is failing. Vibration will simply tell you that one of the three bearings is at fault. Not that this is a bad thing, because the end result is the same. Furthermore, vibration will detect conditions that are not seen by a camera or the human eye. These are issues such as imbalance, misalignment, mechanical looseness, and resonance conditions.

## VARIOUS VIBRATIONS

Vibration analysis is as easy as you want to make it. With that said, in wind turbines it is difficult to get right, which is probably why so many get it wrong. Let’s opt for easy, though grossly under-explained, just for explanation’s sake. The peaks indicate in frequency specifically where a problem is occurring. In fig. 4 it is the planetary gear mesh frequency. The amplitude (height) of the peaks indicates the severity of damage at that specific location. In this image the problem is at the planetary section, and at the early stages based upon the amplitude. So, with vibration, not only do you know where, but relatively how bad. Again, the frequency indicates where and the amplitude indicates how severe.

Gear Mesh Frequency (GMF) is a vibration signal that occurs when two gears mesh together. The higher in amplitude the signal, the more severe the damage, and the further it has progressed. A very basic explanation involves the following equation:

Gear (tooth count) x RPM = GMF

In a vibration signature that is displayed in a "spectrum," a gear with eight teeth running at 15 rpm would have a GMF at 120 rpm. This is the basic math of why we see peaks in vibration at GMF. This is greatly oversimplified and not completely accurate for planetary gearboxes, but it provides a basic understanding of what generates GMF. Two gears meshing together times the speed. Of course, you don't need a calculator to determine GMF because these calculations are likely in a wind turbine vibration monitoring software program (fig. 5). The point is that vibration analysis does detect gear issues specifically. And again, the frequency indicates where, and the amplitude indicates how severe.

Another generalization is that a gearbox is a box with gears and bearings. It is similar in math as in determining gear problems, but instead of teeth bearings have rolling elements. So if there are 14 rolling elements in a bearing, RPM paired with an equation is used to locate the fault in a vibration signature in a bearing. And while there are four parts to a bearing—rolling elements, cages, and inner and outer races—they are similarly detected in the vibration signature using RPM. Most major wind turbine vibration software companies should have thousands of bearings in a library, making identification of a bearing or its subcomponents easy (fig. 7).

It really is overkill to detect all of these subcomponents since one likely doesn't care which one is bad and just needs to know that a bearing should be replaced. While this is correct, if a trend is noticed in a specific part of the bearing failing, it may actually point to another root cause altogether. An example would be if several inner races in the same bearing across several gearboxes were failing. This might point to either the incorrect bearing fitment or improper installation.

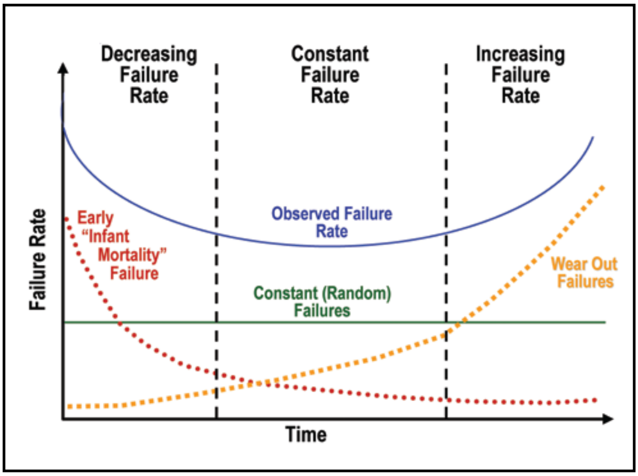



Fig. 1: A "bathtub" type failure curve.

| WIND TURBINE GEARBOX COMMON INSPECTION TECHNIQUES | | | |
|---|---|---|---|
| Component detection percentages on a typical gearbox | | | |
| | VISUAL INSPECTION | BORESCOPE INSPECTION | VIBRATION ANALYSIS (HFE INCLUDED) |
| High Speed Pinion | 100% | 50% | 100% |
| Intermediate Wheel & Pinion | 100% | n/a† | 100% |
| Low-Speed Wheel | 100% | n/a† | 100% |
| Sun Gear | No | 30%§ | 100% |
| Planetary Gears (3) | 10% | 30%§ | 100% |
| Ring Gear | 20% | 30% | 100% |
| High Speed Bearings (3) | No | 100% | 100% |
| Intermediate Bearings (2-3) | No | 50%‡ | 100% |
| Low Speed Bearings (2) | No | 50%‡ | 100% |
| Planetary Carrier Bearings (2) | No | 30%§ | 100% |
| Planetary Gear Bearings (6 drCRB) | No | 30%§ | 100% |

† Clearly visible during visual inspection by removal of inspection cover

‡ Depends upon gearbox make/model, oil level and bearing configuration

§ Requires several rotations of rotor and to inspect 100%, adding several hours to inspection

Fig. 2: Comparison of techniques for wind-turbine gearboxes.

## WHY ONLINE?

A traditional handheld vibration instrument is not viable for many reasons in wind turbines. Safety, variability of wind—or no wind—and infrequency of measurements are just the start of why a traditional portable is not feasible. There are at least a dozen more legitimate reasons and challenges to a portable approach, although such a unit is fine for test stands in rebuild shops for this industry.

An installed online vibration monitor is a far better approach because it doesn't involve visiting the site or climbing the towers. Also, you can corral vibration information from several farms remotely. As many negatives as there are to portables, there are just as many positives to an installed condition monitoring system.

One trend to consider involves European insurance companies that feel so strongly about condition monitoring they make

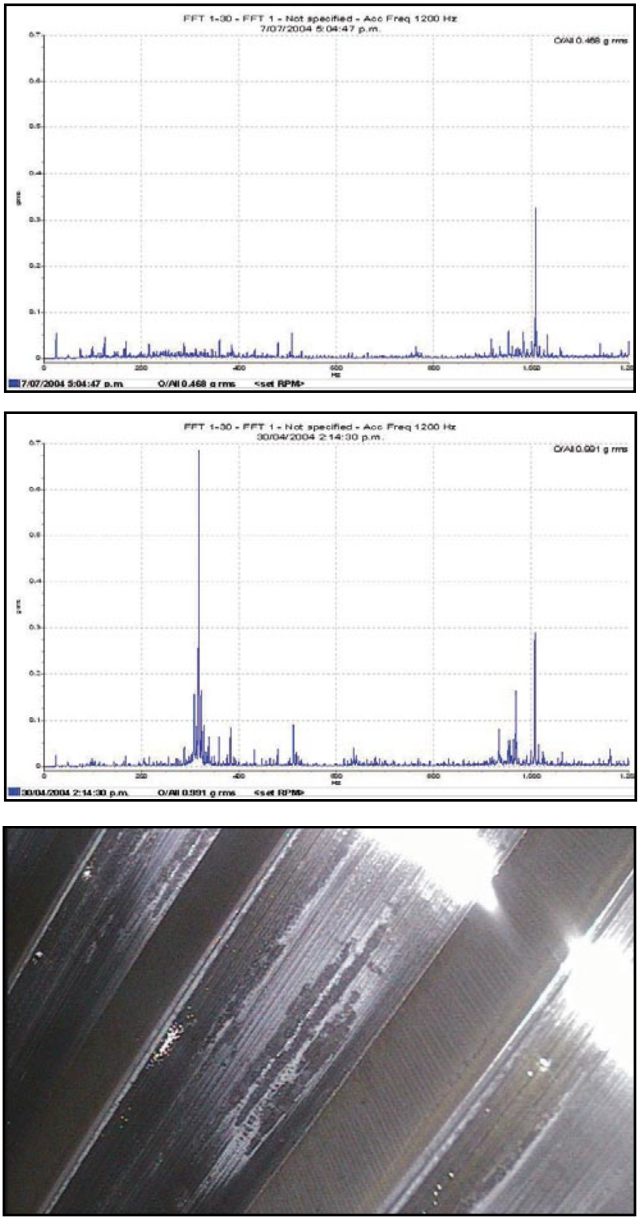



Fig. 3: A good gearbox as seen with vibration (top), a bad gearbox (middle), and the borescope image showing the actual damage (bottom, thanks to Don Roberts, GEC).

it part of the policy requirement. Basically, either you use vibration condition monitoring or you rebuild the gearbox about every five years. The choice is yours… if you want their insurance, that is. One would imagine that, in the United States, similar condition monitoring requirements are not far off. Besides safety, the demand for production, reliability for investors, and PPAs are but a few reasons why an insurance company would dictate similar condition monitoring requirements in the States.

## COST JUSTIFICATIONS

To provide an example, over the 20-year design life of a wind turbine let us assume that one gearbox failure occurs during that period on half the farm. Over a typical 100-unit wind farm project, this means 50 gearboxes will fail over the life of the project in this particular example. In a second example we will use the European insurance suggested interval, which is at about the five-year interval. This assumes that, over the 20 years, there will be a gearbox failure every five years. Again, on average, and across half the assets, this adds up to 200 rebuilds in the second example.

So, per 100 turbines, the range on gearbox failures over 20 years would be 50 gearboxes in the first example and 200 in the second. If you take the number we discussed earlier, which is about $250,000 per average catastrophic event, the expense costs on 100 turbines would be $12,500,000 in the first example and $50,000,000 in the second.

This only assumes a gearbox failure. We can add in generators and main bearings failures and the numbers jump measurably. Considering that the current cost of an online wind turbine vibration monitoring system is in the $6,000-$15,000 range per turbine, the cost of predicting maintenance far outweighs the maintenance costs even when using the most expensive system in the best-case scenario. To add a finer point, remember that this justification was just for gearboxes, excluding main bearings and generators.

Furthermore, the cost of one gearbox failure alone would cover the cost of outfitting somewhere between 16 high-cost and 41 low-cost system turbines with condition monitoring for the life of the asset. An online system such as this would also monitor not only the gearbox, but also the other common high-cost repairs such as the main bearing and generator.

Another perspective on this approach to maintenance is to look at the cost of a system spread over the life of a wind turbine. The cost of a wind turbine vibration monitoring system over the usable 20-year life ranges from less than a dollar to about two dollars a day. Again, systems cost between $6,000-$15,000 per turbine, which means that the prorated cost of installation is less than a daily cup of coffee. Put into these

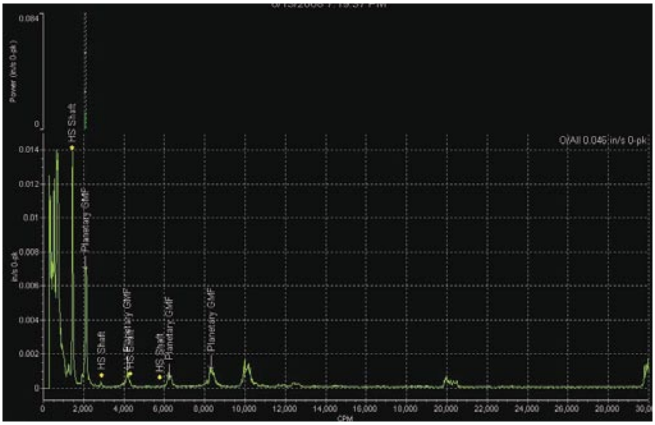



**Fig. 4:** A gearbox with component fault frequencies labeled.

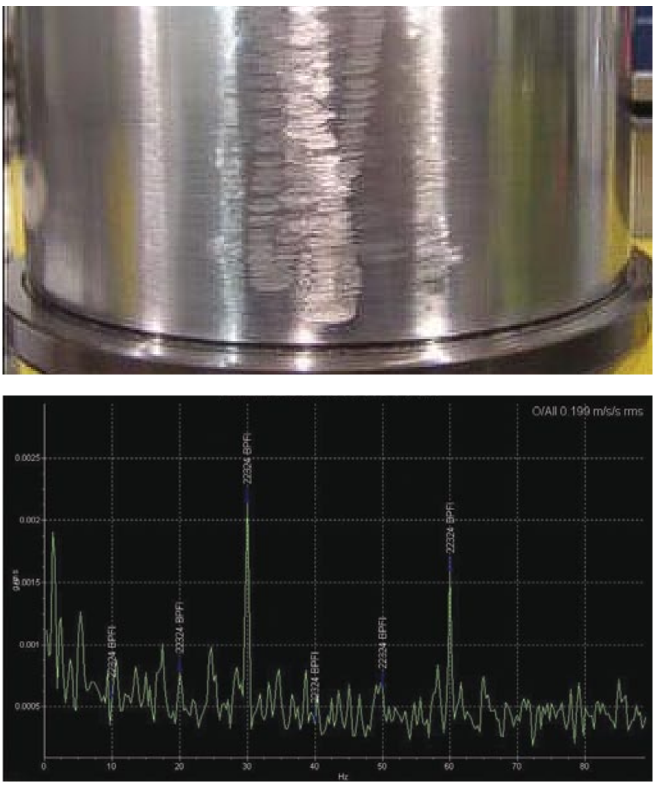



**Fig. 5:** Bearing defect (top, Don Roberts, GEC) detected in the inner race of the bearing (bottom).

terms, it's easy to see how this affordable monitoring system will pay for itself many times over its service life.

## AVOIDING CATASTROPHE

Some will say that, if the gearbox is failing, what are you really saving? It will surely fail anyway. Most of the gearbox problems caught using vibration monitoring involve up-tower repairs because they are detected early, before catastrophic failure occurs. As a common example, a high-speed shaft repair can be up-tower when detected early. Other detected conditions—such as misalignment, for instance—are also reversible before damage results. It is common to see months of downtime when problems aren't caught in advance by using vibration analysis in gearboxes.

Secondly, with long lead times for repair parts, having several months' notice to have them delivered, along with cranes and other necessary equipment, provides a definite production edge. Maintenance decisions such as these can revolve around wind season, other repairs, or when the repair would be most advantageous. And don't forget due diligence inspections for newly purchased sites.

## CONCLUSION

By using the tools available to the wind-power industry, one has the ability to run maintenance on their own terms. That's really at the core of what predictive maintenance provides. For wind this translates into knowing what needs to be fixed before it fails. It also means that crane callouts can be grouped for multiple repairs. Also, parts can be ordered in anticipation of making repairs. And, finally, repairs can be scheduled around wind season to maximize production and minimize downtime. Predicting maintenance is like predicting production, in that reliability *equals* production.

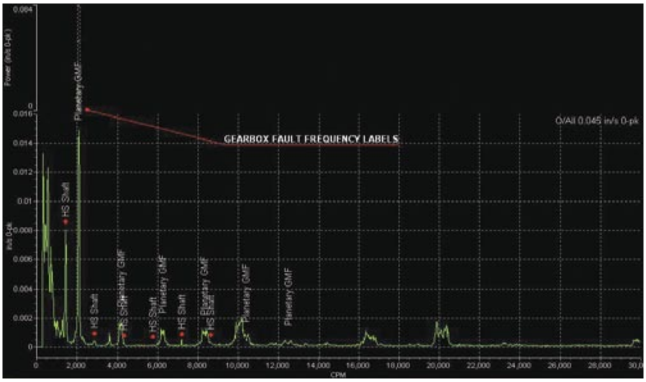


Fig. 6: RPM factors into identifying vibration sources.

# ACHIEVING EXCELLENCE IN GEARBOX DESIGN

Industry giants LMS and Moventas join forces to increase testing efficiency and shorten customer turnaround time in developing wind turbine gearboxes.

By Jennifer Schlegel

Jennifer Schlegel is a copywriter and publications manager for LMS International in Belgium. For U.S. representation call (248) 952-5664, send e-mail to info.us@lmsintl.com, or go online to www.lmsintl.com. Learn more about Moventas at www.moventas.com.

**BUSINESS IS BOOMING** at Moventas, a leading tier-one supplier of gearboxes for wind turbines. Company sales increased 40 percent last year, reflecting tremendous growth of this alternative resource in the face of sky-high energy prices. According to the World Wind Energy Association, global installed wind turbine capacity has grown tenfold in the last 10 years and has increased 25 percent just in the past year. Predictions from the association indicate that the 74 gigawatts of current worldwide wind-powered electrical generation will more than double by 2010, when levels are expected to reach 160 gigawatts.

To meet this growing demand, more wind turbines—and ever-larger units—are needed quickly. Speeding up development is a daunting task, however, given the increasing complexity of the designs and the need for machines to oper-


Modal testing of major subsystems such as the gearbox is a critical step in the development of massive wind turbines to ensure that no damaging resonances are excited in the structures.

ate reliably for decades in adverse weather conditions. These issues all come down to considerably more tests to be performed on each of the custom-designed units. Jari Toikkanen, manager of the Research and Test Group at Moventas, has seen the number of noise and vibration tests quadruple in the last five years, with many projects requiring same-day turnaround.

"In addition to greater product development efforts for these units, wind turbine OEMs are demanding more vibration tests that measure behavior in greater detail than ever before," says Toikkanen. "Tests are done primarily to improve product reliability and meet strict demands from regulatory agencies such as the AGMA (American Gear Manufacturers Association) and European ISO standards."

## STUDYING GEARBOX RESONANCES

He notes that particular attention is focused on studying vibrations of the wind turbine's massive gearbox, which uses a combination of planetary and helical gearing to step up rotor speed 100-fold for driving the electrical generator. Another major component of interest is the torque arm connecting the gearbox to the turbine framework. For large three-megawatt rated models made by Moventas, the gearbox weighs around 30 tons and measures two meters in diameter and two-and-a-half meters in length. The torque arm is four meters wide from bushing to bushing, a half meter thick, and weighs another five tons.

Engineers perform extensive modal impact testing to ensure that resonances of these components do not match the excitation frequencies of the

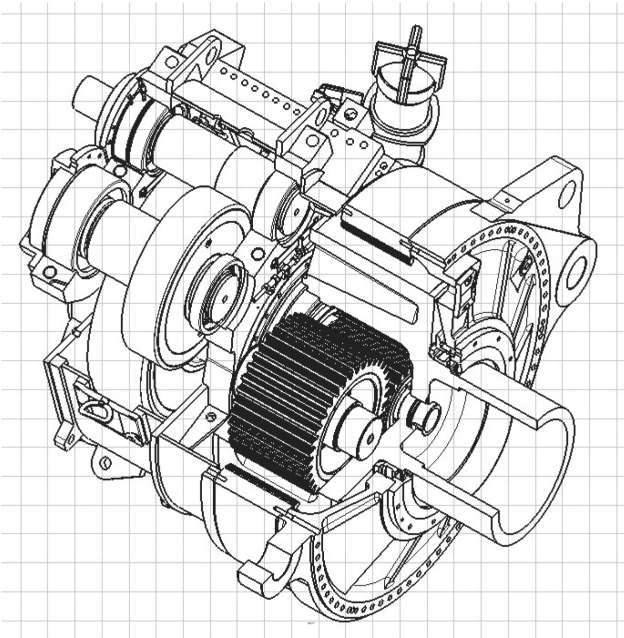


Fig. 2: Using a combination of planetary and helical gearing, wind turbine gearboxes step up rotor speed 100-fold for driving electrical generators. Moventas uses LMS Test.Lab for modal analysis in studying resonances created by gear-tooth meshing in these units.

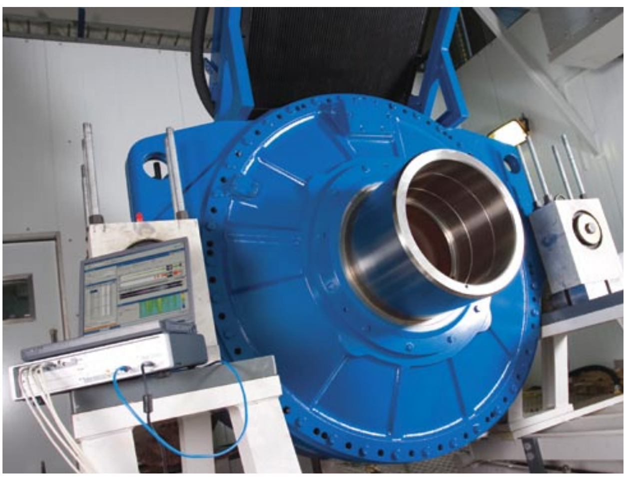


Fig. 3: LMS SCADAS Mobile has an integrated suite of vibration analysis all in a lightweight, portable laptop-size unit that Moventas engineers can easily carry between test rigs.

surrounding structure or gear mesh frequencies, thus exciting potentially damaging vibrations in the framework, rotor blades, drive shafts, and the huge tower, the tallest of which is over 120 meters. Generally, the goal is to avoid the modal frequency range of 80 to 250 Hz for the torque arm and 400 to 800 Hz in the rest of the housing structure. When resonances are identified within or near these ranges, engineers shift the modal frequencies by modifying the geometry of the gearbox components and torque arm, typically optimizing stiffness properties by changing part thicknesses and shapes.

Toikkanen notes that the process is complicated by the variable gearing frequencies that excite gearbox and torque arm vibration modes at different rotor blade speeds, from an input rotation of a few rpm for a light breeze to a maximum of 10 times that for gale-force winds. Further, Moventas is also performing additional tests and studies of torsional vibration beyond the scope of their current resources.

## BOOSTING TEST PRODUCTIVITY

The former test solution at Moventas presented challenges in completing work in a timely manner. Test equipment was awkward to move between test rigs, test setups were typically lengthy ordeals, and engineers had to spend time on multiple test runs because only two channels were available for modal analysis. Also, measurement data had to be post-processed before results could be viewed, thus requiring tests to be completely re-run if sensors were not properly connected, for example, or if more detailed study was needed to troubleshoot unexpected problems.

These limitations were overcome when Moventas implemented the LMS Test.Lab software with an LMS SCADAS Mobile data-acquisition system that has eight channels, enough to take all modal analysis measurements in a short time. The system contains an integrated suite of tools Moventas engineers need for modal analysis—test set-up, control, measurement, signal conditioning, result analysis, data management, and report generation—all in a lightweight, portable laptop-size unit.

"We can easily carry the unit between test rigs at our facility,

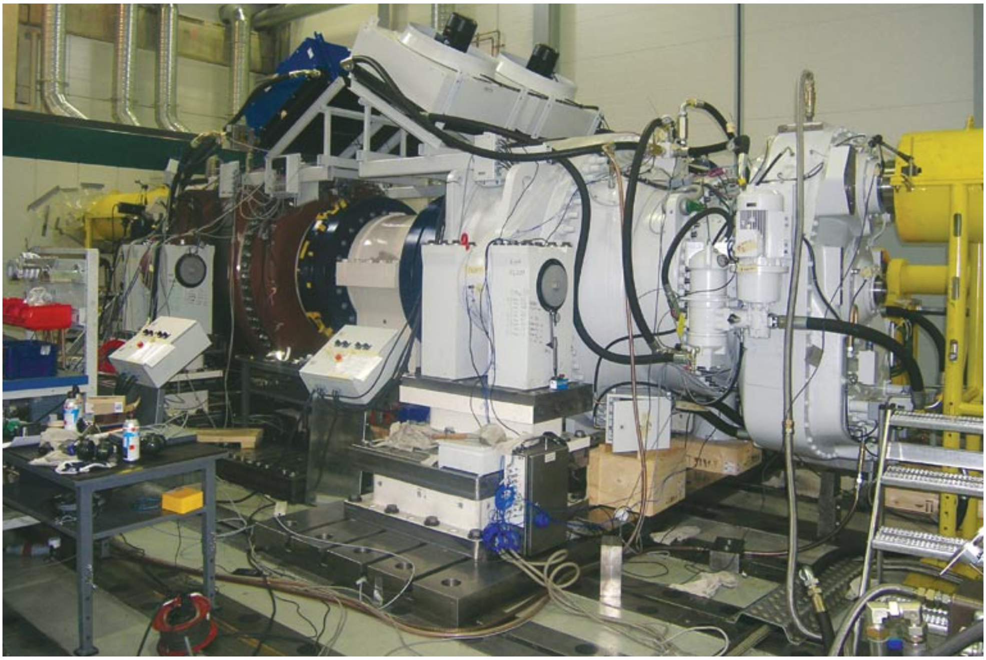


Fig. 4: Setup of LMS Test.Lab is done quickly and easily at Moventas with tools such as the Geometry Workbook that shows the locations of accelerometers as colored boxes superimposed on a 3D wireframe representing the basic geometry of the gearbox.

Fig. 5: Visualization is especially helpful to Moventas engineers with the animated mode shapes displayed together on the same screen with plots such as frequency response functions (FRFs).

and if necessary our engineers can go at a customer or end-user site very quickly to provide support or troubleshooting," says Toikkanen. "Also, the system is extremely convenient to set up. Built-in workbooks and prompts show us step-by-step where to enter parameters and how to proceed through the process. Templates even fill in values we've used in the past that aren't likely to change. Geometry models showing the placement of accelerometers on the gearbox housing are especially useful and easy to configure. From start to finish, setups with LMS Test.Lab are very fast and easy, so we're ready to take measurements in a few minutes rather than several hours."

Another capability of LMS Test.Lab that greatly improves testing productivity is online monitoring. "We can see results immediately as measurements are being taken instead of waiting hours for post-processing," says Toikkanen. "With real-time visualization we can verify the test on the spot, see firsthand how the structure deforms with every hammer impact, and readily identify the root cause of any unexpected resonances."

Visualization is particularly helpful to Moventas engineers with the animated mode shapes displayed together on the same screen with plots such as frequency response functions (FRFs) showing vibration amplitude versus frequency at key locations on the gearbox. This enables engineers to see immediately how the gearbox housing bends and twists at various frequencies so they can readily identify which bearings are transmitting vibrations and determine critical gear-mesh harmonics.

When testing is done, report generation features allow Moventas engineers to efficiently create the necessary documentation, complete with LMS Active Pictures that show live test data, including mode shape animations, in Microsoft Word documents as well as PowerPoint presentations. "LMS Test.Lab report generation with Active Pictures lets us quickly create reports that clearly show our designers, customers and regulatory agencies the modal behavior of the gearbox," says Toikkanen.

"With its mobility, test setup, online monitoring, visualization, and report-generation capabilities, LMS Test.Lab boosts our test productivity immensely," he adds. "Now we can complete routine tests in a few days instead of weeks. When faster turnaround is needed, our team can run an entire battery of modal tests in the morning and have results analyzed and documented that afternoon."

## FAST-RESPONSE ENGINEERING PROJECTS

In addition to implementing LMS Test.Lab, the company has worked closely with LMS Engineering Services on projects requiring additional calculation resources; projects where fast response was needed to meet requirements for key wind-turbine manufacturer customers. Defining the scope and specifications of durability analysis calculations for these projects was coordinated in conjunction with Petri Lahtinen, chief structural analyst at Moventas.

In one such project, LMS Engineering Services was called upon to provide critical fatigue life analysis needed by Moventas and a wind turbine manufacturer for certifying a wind turbine. The study was to verify that two critical wind-turbine gearbox cylindrical components—a torque arm and gear planet carrier—would withstand expected loads over a 20-year operational lifetime. LMS engineers created finite element models of the components and applied unit load cases to determine the stress-time series on each part. This stress-time series together with the complete load time histories for the components were then used with LMS Virtual.Lab durability simulation software to determine fatigue life prediction for the base material. Results were provided within two weeks from the start of the project, thus enabling Moventas to give a fast response in verifying that cumulative damage values were well within the safety factor of the designs.

In a project for another wind-

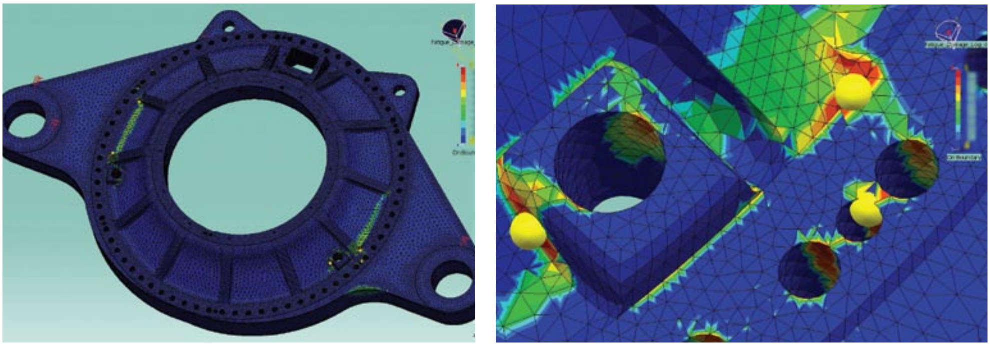
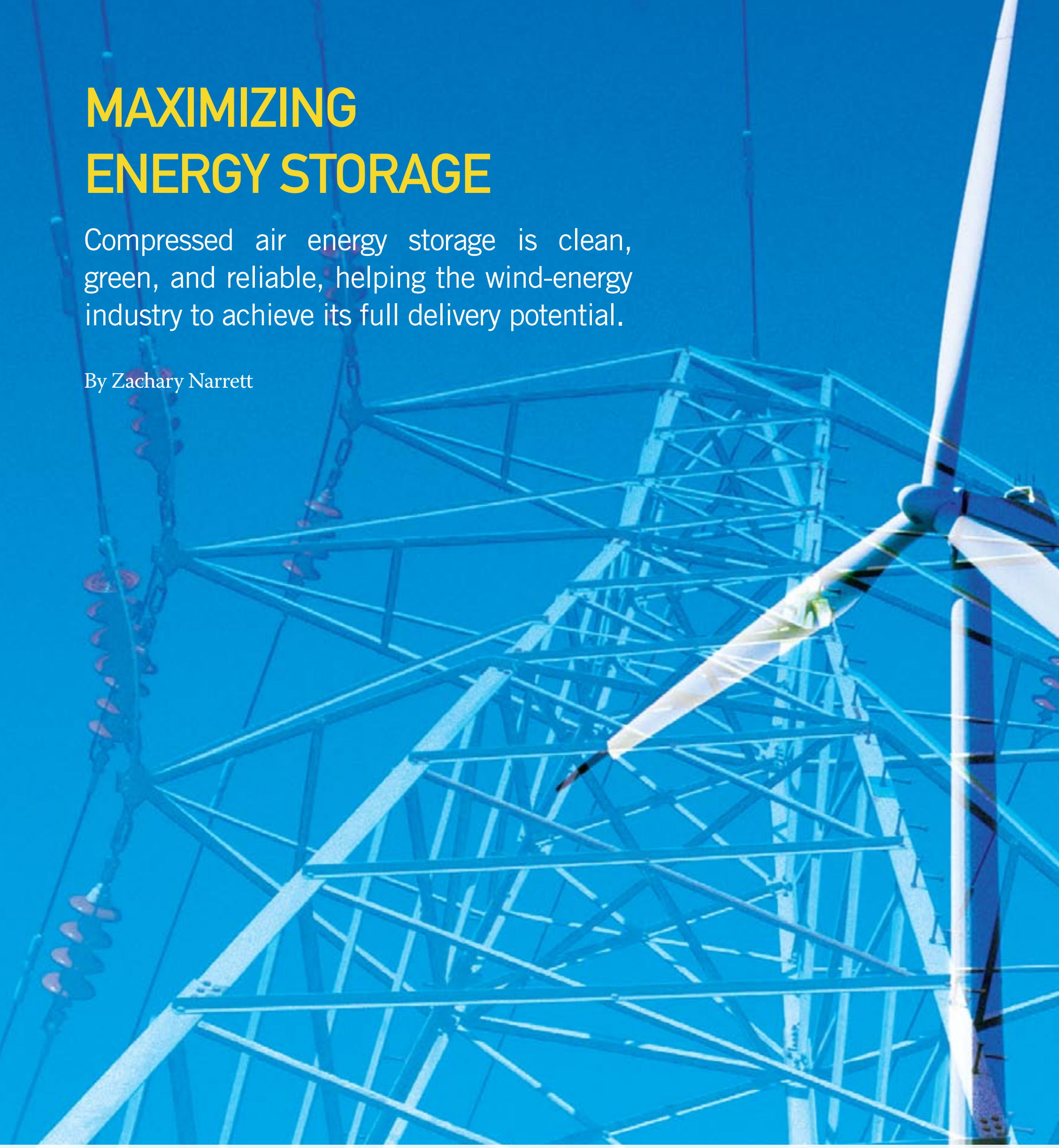


**Fig. 6:** Two screen captures from the LMS software showing results.

turbine manufacturer, Moventas contracted LMS Engineering Services to measure gearbox rotational vibration on the low-speed input and high-speed output shafts. Signals from accelerometers mounted directly on the low-speed shaft were fed into LMS Test.Lab for analysis. Signals for the high-speed shaft were obtained from a laser vibrometer system measuring rotational velocity. A series of operating response color maps accurately identified rotational vibration and related resonances for both shafts. In less than one week Moventas was provided valuable data needed by the wind turbine manufacturer in simulating the dynamic performance of the entire drivetrain.

"The collaboration with LMS Engineering Services demonstrates that LMS goes far beyond selling hardware and software," says Toikkanen. "Their industry-wide expertise in performing this work and fast response in providing exactly the right data made us look good in the eyes of our customers and made a lasting impression that has immeasurable business value for us."



# MAXIMIZING ENERGY STORAGE

Compressed air energy storage is clean, green, and reliable, helping the wind-energy industry to achieve its full delivery potential.

By Zachary Narrett

To learn more about Energy Storage and Power, LLC, call (866) 941-2237, e-mail info@energystorageandpower.com, or go to www.energystorageandpower.com. Zachary Narrett is senior writer with PSEG. Visit online at www.pseg.com.

**INCREASINGLY, THE ENERGY FUTURE** is blowing in the wind. Clean wind energy is America's fastest-growing energy source, expanding by a record 8,300 megawatts in 2008, but a number of challenges must be met to ensure wind achieves its full promise, with intermittency representing one of the biggest obstacles. By its nature wind is a variable resource that isn't so easy to integrate with the grid in large quantities. The wind blows when it will and generally picks up at night, while electric demand peaks during the day. These basics have profound implications for the economics of wind energy. In today's volatile energy markets, wind energy producers can find themselves sometimes having to pay to sell their power, or suddenly curtailed as a result of transmission congestion or other factors.

Given such issues, there has been a search for technical solutions that involve storing energy for use when it is most needed, with the goal of

better integrating renewable energy into the grid and improving its economic viability. In this way renewables can become more manageable, predictable, and profitable resources.

"Anything that does commercial-scale energy storage is huge," says John Gardner, Ph.D., associate vice president of Energy Research, Policy, and Campus Sustainability at Boise State University. "It can completely change the economic prospects of a wind farm."

Enter CAES 2, the second generation of compressed air energy storage technology. CAES 2 technology stores low-cost, off-peak energy for release when needed, which is generally during peak hours when the energy has more value. In situations where there is a sudden loss of renewable generation, CAES 2 can come to the rescue by providing power almost at a moment's notice. It also can serve as a standalone intermediate generation resource for capturing energy arbitrage, capacity payments, and ancillary services.

## A GREEN TECHNOLOGY

CAES 2 is designed not only to be an efficient solution to support wind power, but an environmentally sound one as well. As renewables become a larger and larger part of U.S. energy supply, compressed air energy storage with CAES 2 will be important to help wind energy achieve its full promise and value.

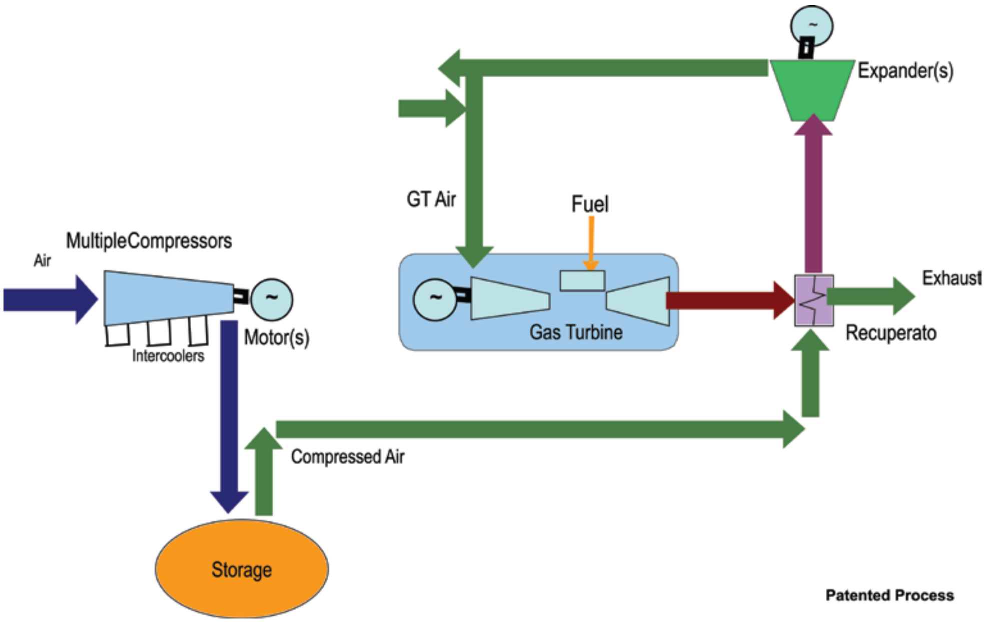
"Energy storage is the missing piece of the puzzle for a green, affordable, and reliable electric grid for the 21st century," says Roy Daniel, CEO of Energy Storage and Power, which developed and delivers the patented second-generation CAES units. "CAES 2 is an enabling technology for efforts to provide more clean, renewable power, fight climate change and move our nation toward energy independence."

While not new, the technology behind CAES has significantly improved. Almost 20 years ago Michael Nakhamkin, Ph.D., designed the nation's only CAES plant, which was a 110-megawatt facility in McIntosh, Alabama. While the plant continues to operate successfully, Nakhamkin has taken the technology to another level by using multi-sourced components to reduce costs, enhance reliability, and improve environmental performance. "It's a simple concept, using a proven standard based on off-the-shelf components," he adds.

The key is the process used by CAES 2 to store compressed air and transform it cleanly and efficiently back into electricity. The first step is to use off-peak energy to run a compressor train and create compressed air, which is usually stored in an underground cavern. During peak hours the air is released and heated to power an expansion turbine/generator (a modified steam turbine) to produce electricity. Heating the air is necessary because stored air cools as it is expanded in the turbine.

CAES 2 technology has an integrated recuperator and air expander that makes use of exhaust heat from the combustion turbine, eliminating the need for a separate burner. This advance significantly reduces the natural gas used in the process to lower costs and emissions. It is estimated that a CAES 2 storage unit would use approximately 60-percent less fuel than an open cycle combustion turbine, and 40-percent less fuel than a combined cycle

## Second Generation Compressed Air Energy Storage Unit (CAES 2) Layout




unit. Moreover, the air storage cycle is totally green during regular operations to further benefit the environment. Ambient air is stored, and ambient air released.

## FLEXIBILITY, SCALABILITY

Other improvements add to the attractiveness of CAES 2 as a practical energy storage solution and grid integration tool. Perhaps the most important is the flexibility to match generation to load. A CAES 2 unit is designed to start in less than 10 minutes and offers exceptional operating flexibility. "This technology covers the whole spectrum, from load leveling and ramping to frequency control, so you can have what you need to have in terms of load-matched generation," Daniel observes. "CAES units can be instrumental in managing renewable energy output to create a highly valuable, firm, dispatchable product."

In addition, CAES 2 units are scalable, and can range from 15 megawatts to 430-plus megawatts without significantly altering their operational qualities. In fact, the respective size of the CAES 2 unit is primarily based on the size of the combustion turbine. For example, an 80 MW combustion turbine can be used to produce a 230 MW CAES 2 unit. Combustion turbines can be existing or new.

Larger CAES units can be accommodated with underground compressed air storage in a relatively tidy footprint. For example, a 300-megawatt unit would require some 22 million cubic feet of space, or about a third the size of a football stadium. At full capacity, a reservoir of this size could produce enough electricity to power around 200,000 homes for eight hours. According to the Electric Power Research Institute (EPRI), the geology of most of the United States is suitable for storing compressed air underground.

Smaller versions of the technology using above-ground storage provide cost-effective alternatives to utility-scale batteries and other electronic systems for energy storage. These CAES 2 units offer utilities a low-cost, low-carbon option for reinforcing their transmission systems and providing distributed generation coupled with energy storage.

## MULTIPLE APPLICATIONS

Wind is not the only resource that CAES 2 technology can benefit. It is suitable for solar and other renewable energy developers, independent power producers, electric utility companies, and transmission owners. One innovative use of CAES 2 is as a bolt-on for an existing combustion turbine. Green compressed-air power adds to the combustion turbine's output but not to its emissions for a better environmental profile, while providing additional megawatts of stored energy for load management.

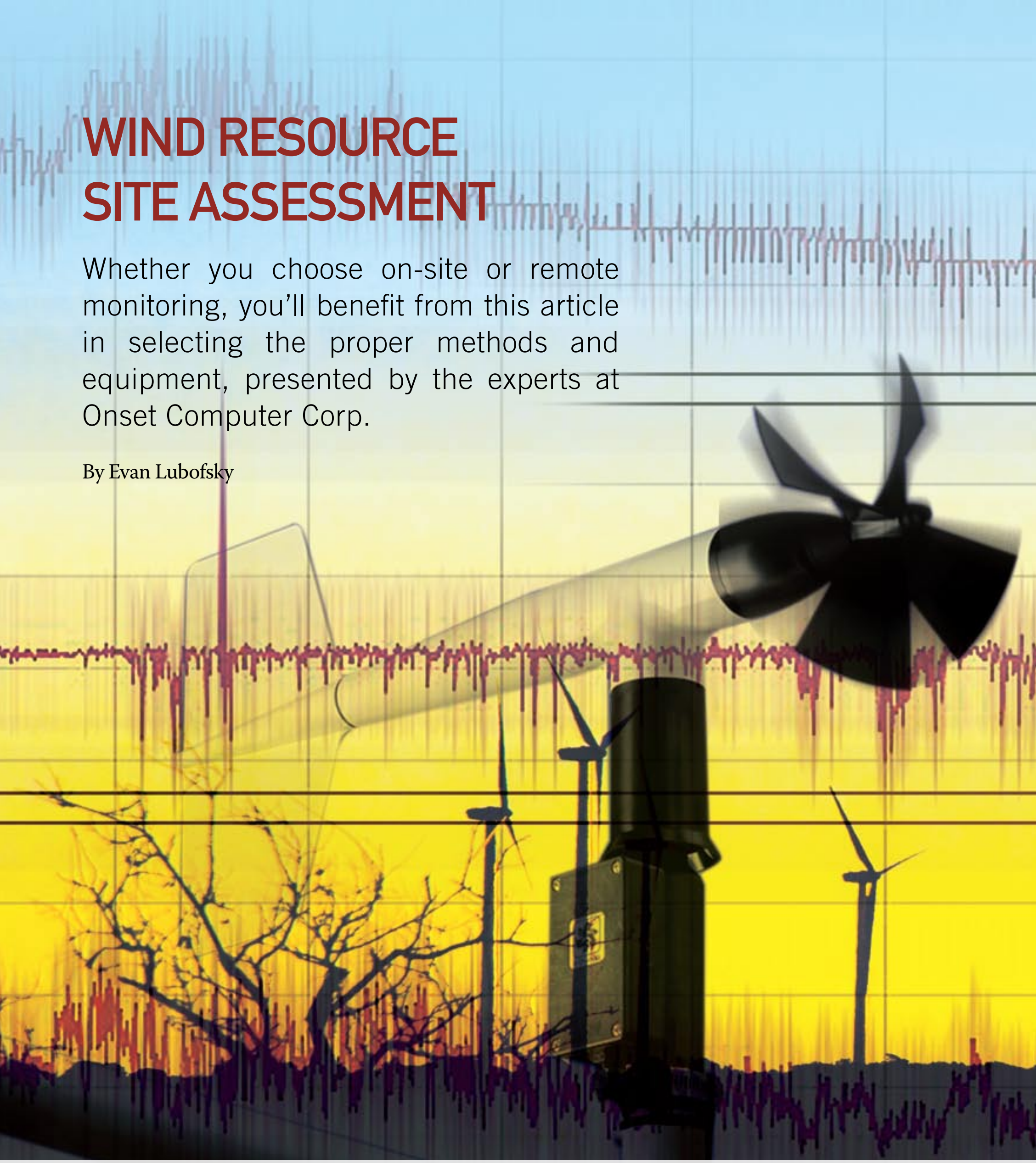
Compressed-air storage could have an important role as a supplement to baseload resources, such as carbon-free nuclear power, according to Arshad Manshoor, EPRI's vice president of power delivery and utilization. "Nuclear is an inherently stable source of power, so stable that we don't want to ramp it up and down," he explains in *The Energy Daily*. "Nuclear will need storage at night, when demand is low, and we really are looking at hundreds of megawatts of storage to meet that need.

"We asked the question 'if we need bulk storage in our portfolio in the next five to 10-year timeframe, what technologies are available?' There are lots of options," he says, "but we need options that are cost effective and deployable in that timeframe. The only answer we were left with is compressed air."

Nakhamkin sees CAES 2 as ready to provide wind and other energy producers with a range of market benefits including higher utilization, stability, and power quality. "We have learned a lot about the logistics of compressed air energy storage, and I believe the time is right technically, environmentally, and economically for a large-scale deployment of CAES 2 technology," he says. "The technology has evolved to the point where it can be critical to helping this nation meet its growing energy needs while decreasing carbon emissions from the electricity sector."

## CONCLUSION

Technology that improves the reliability of wind or other intermittent renewable energy resources fits with efforts to green America's energy picture and improve energy security. Indeed, it can be a key to reducing dependence on fossil fuels and imported energy. Clean, efficient energy storage with CAES 2 can accelerate wind energy's continued growth and success to speed the arrival of America's green, sustainable future.



# WIND RESOURCE SITE ASSESSMENT

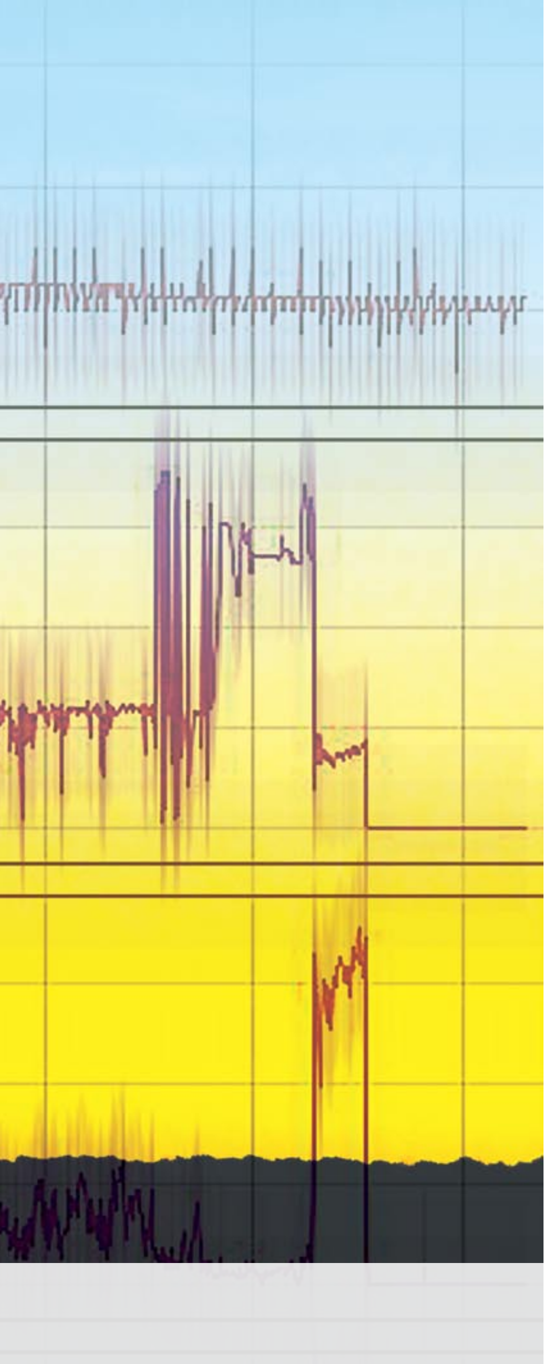
Whether you choose on-site or remote monitoring, you'll benefit from this article in selecting the proper methods and equipment, presented by the experts at Onset Computer Corp.

By Evan Lubofsky

Evan Lubofsky is director of marketing for the Onset Computer Corporation. To learn more call (800) 564-4377 (800-LOGGERS), send e-mail to sales@onsetcomp.com, or go to www.onsetcomp.com.

AS INTEREST IN HARNESSING WIND ENERGY grows in the United States and around the world, several trends and events are converging in support of that interest. They include a desire to lessen dependency on petroleum products, rising energy prices, and a recognition that environmentally sustainable building management practices can be environmentally responsible while resulting in cost savings, as well. Building owners and managers can take steps toward the U.S. Green Building Council's LEED® certification and take advantage of federal and state tax incentives that will help save money in the long run.

Whether the focus of a wind project is to supply power for greenhouses on a farm or to install turbines for larger-scale commercial energy sup-



ply, proper turbine siting is crucial for optimal performance and return on investment, despite the scale of the project.

Once a site is determined to be an appropriate candidate for a wind turbine—through consultation of local and regional wind resource maps, meteorological data, and existing studies—a thorough, on-site wind assessment must be carried out that measures wind speed and direction at heights appropriate for the project, and at locations suitable to represent the project. While appropriate permits and permissions are being obtained for the test site or sites, you will need to select monitoring equipment.

The intent of this article is to provide project managers working on small- to moderate-scale wind energy projects with information about how data loggers fit into wind resource site assessment. This article examines sensor, data logger, and communications options, with advice on what to look for in selecting such equipment. Then you will find information about equipment mounting hardware to help ensure optimal performance during your project's monitoring period. This information will help simplify the equipment selection process, while also helping you save time and money for your site assessment project.

## CENTRAL COMPONENTS

The main components of a site's wind resource assessment are wind speed and wind direction sensors that plug into a data logger, all of which are mounted on an appropriately sized tower. Knowing a bit about sensors and loggers will help you choose the right devices for your budget and ensure that you collect data reliably and accurately.

## SENSORS

Sensors for a wind assessment project are often mounted tens of meters off the ground and must measure environmental parameters accurately and consistently for at least a year, across all the seasons. In addition to doing their job of measuring wind parameters, sensors must withstand rain, snow, ice, and humidity. When evaluating sensors, check the manufacturer's specifications regarding:

- Operating temperature—What happens during freezing temperatures?
- Response time—Will short gusts be recorded?
- Connection to logger and deployment—Is there any wiring required, or does the sensor simply plug into the logger?
- Durability—What are the sensor components made of? Are the moving parts strong?
- Expected lifetime—For how long will the sensor operate?
- Accuracy and Resolution

Factors to consider for each type of sensor include the anemometer. Wind speed is the most important measurement in your assessment. Cup-style anemometers are the most common for wind power projects, consisting of several cups that rotate around a vertical shaft.

The anemometer should be sturdy enough to withstand sustained winds and winds gusts of up to at least 100 mph, depending on your location. Keep in mind that wind speed increases with vertical distance from the ground. Check into the manufacturer's specifications for maximum wind speed, starting threshold, response time—often referred to as distance constant, this describes how responsive the anemometer is to changes in wind speed—expected lifetime, and materials for the shaft, cup, and bearings.

Ideally, anemometers are placed at three locations on a tower: the proposed turbine's hub height, the height of the highest blade tip, and the height of the lowest blade tip. Often, however, towers are used that are shorter than the proposed turbine hub; there are numerical models that allow the input of data from lower heights to be applied. Budgetary restrictions may also limit data collection. In any case it's a good idea to mount two anemometers at each tower height for data replication, or in case of sensor failure.

Another important consideration is wind direction. Wind vanes are often part of the anemometer unit, but they may also be available as stand-alone devices. Most important is to check the resolution of the vane to make sure the data output is in small-enough units for you to use it effectively in your assessment. Also consider maximum wind speed—especially whether the vane is designed to withstand typical and maximum wind speeds at your site—expected lifetime, and the materials of which the fins and shaft are constructed.

Other sensors can monitor temperature, relative humidity, and barometric pressure. It may be useful to be able to link temperature, RH, and barometric pressure to wind speeds and direction, though it is not strictly necessary for all site assessments. If there are meteorological stations nearby you may opt to omit these sensors, depending on your project requirements and resources.

## DATA LOGGERS

All data logging systems for measuring wind parameters consist of multiple sensors that connect to a data logger, which records and stores all data at prescribed time intervals. When evaluating data loggers, keep simplicity and flexibility in mind as you consider the following points.

***Housing:*** The logger will be outside for a year or more, so check if the enclosure is strong and weatherproof enough to withstand wind, rain, and curious animals, and that the electronic components will stay dry.

***Data channels:*** There is usually a limit to the number of sensors that can be plugged into a logger. Does the logger have enough data input channels? Can more be added?

***Power:*** If there is a battery, will it last the full duration of your study? If not, how easily can new batteries be swapped in? Will the data be safe during a power outage? Check about solar and rechargeable battery options, as well. Specific power options may be recommended for certain data download options.

***Configuration:*** Some sensors require programming for deployment, while others simply plug in and are immediately recognized by the logger. Can you configure sensors in the field with or without a laptop, or do you need to set everything up in the office beforehand?

***Flexibility:*** You may decide to add other sensors sometime during the monitoring process, or at a future date for another application. Can the logger accept a wide variety of sensor inputs, including third-party sensors?

***Cable length limitations:*** Towers can be very tall, and you must ensure that the logger can handle all the cables necessary to reach the sensors. In some cases you may need to use multiple loggers.

Today's data logging systems include a wide variety of data retrieval options, from cellular remote communications to on-site laptop computer download. The next section describes the different options available.

## DATA COMMUNICATIONS OPTIONS

There are several options for downloading data from your wind resource monitoring system, and they essentially break down into two categories: manual download, and remote communications. Each has its strengths, and you'll be better prepared to assess them if you first consider the following:

- **Monitoring period**—How often would you like to download data? You'll be monitoring wind parameters at the site for a year or more, so how often would you like to check in? How many parties are interested in the data?
- **Maintenance**—How often will you do routine maintenance checks to be sure that the logger, sensors, and tower are in good working condition and repair? Such checks require staff and travel time.
- **Location**—Where is the station located? Is it in a vandalism-prone area, many miles from roads, or right on the edge of the project owner's property?
- **Budget**—What's your budget? Some communications options are more costly than others at the outset, but they may save money in labor and travel costs over the life of the project.
- **Future applications**—Will you reuse the equipment for future wind resource assessment projects?

## MANUAL ON-SITE DOWNLOAD

In light of these questions, let's consider the difference between manual on-site downloads and those conducted from a remote location. Data shuttles are small, handheld devices that plug into a data logger and retrieve data. They are usually designed for field conditions and are simple to operate, often involving a single-button download. Alternatively, you can use a laptop computer equipped with the appropriate software and interface cable.

This is often the most inexpensive option, though it does have some limitations. Technicians must visit the logger to download data, and there may be no way to know about malfunctions until data has been examined.

## REMOTE DATA DOWNLOAD

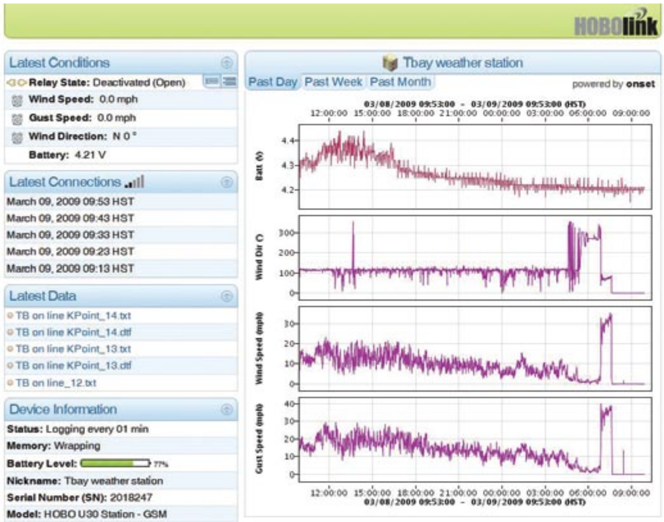
Remote communications allow for real time Internet-based access to data. Rather than going out into the field, the user simply logs onto a Web site to view and download data, thus saving time and money on travel and labor and minimizing the chance of data gaps due to equipment failure.

Operators can easily and frequently monitor sensor and battery status or make adjustments to logging intervals, right over the Internet. It is easy to check that sensors and loggers are working properly, and cellular phone and e-mail alarm notifications can even be set for when sensor parameters are out of a set range, if equipment fails, or if battery power is low. The sooner you know about a system malfunction the faster you can get out to the site, fix the problem, and continue collecting uninterrupted data.

Two data communications systems available today are cellular and Wi-Fi. Cellular systems require a cellular data contract, and the logging system must be within provider range. With Wi-Fi, data transfer is accomplished via a Wi-Fi network or router connected to the Internet. There is no need to pay for cellular service, but your installation does have to be within range of a Wi-Fi router. Users can set notification alarms that transmit to cell phones and e-mail addresses with either system.

## MOUNTING TIPS FOR DATA LOGGING SYSTEMS

In addition to the sensors and data logger you'll need to select hardware and other accessories for mounting and connecting the devices, and to ensure that system components are




Wind site evaluation data.

installed properly. Once it's up and running animals, weather conditions, and vandals may act upon your monitoring system, and periodic field visits and/or logger alarms are required in order to ensure smooth operation.

You will need to attach your sensors and logger securely to your chosen tower in a fashion that allows for optimal data collection. Sensor manufacturers usually provide a selection of hardware options, so check around to see what's available before you consider spending money and time to design or make your own. In most cases equipment should be mounted on sturdy metal arms and brackets, with several anchor points. You should consult the manufacturer's recommendations for placement distances, but here are some factors you'll have to consider:

***Sensors:*** Mount anemometers and vanes far enough away from the tower structure and other sensors to avoid interference. Each sensor should have its own individual boom that holds the sensor well away from the tower, so consult your manufacturer for details. Temperature and humidity sensors require solar radiation shields, and you should make sure that they are designed to shed water and operate in freezing conditions.

***Cables:*** Sensors connect to the logger via cables, so order enough of the proper length to reach from sensors to logger. Wrap cables along the tower from the sensors to the logger and secure them with UV-resistant tape or ties, allowing enough slack in chafe-prone areas.

***Logger:*** Make sure the logger is securely housed inside a weatherproof, locked, tamper-resistant structure. Mount it high enough so that animals can't reach it from the ground, and close any gaps to deter birds. Make sure the enclosure is properly sealed, carefully following the manufacturer's instructions and, if applicable, mount the solar panel so that it will receive adequate sunlight throughout the day and through the seasons. Again, your sensor, logger, and tower manufacturers will have detailed guidance specific to the equipment you have selected.

## CONCLUSION

Site-specific wind resource assessment is one of the most time-consuming and important steps of a wind energy project. This article will hopefully help make you aware of the data-collection and communications options available to you so that you can make the best choice for your site, project, and budget.

# GETTING GROUNDED WHEN LIGHTNING STRIKES

Reliable grounding solutions from CommScope BiMetals will help protect your investment from the ever-present danger lightning presents to wind towers.

By Stephen C. Oaks

Stephen Oaks is managing partner of Pacific Management Partners, Ltd., and a consultant to CommScope BiMetals, which can be reached at (704) 883-8015, bimetals@commscope.com, or www.commscope.com.

MOST OF US UNDERSTAND THAT WIND turbines are ideal lightning attractions, and that grounding turbine systems is critical to avoiding catastrophic damage. Lightning is such a threat to wind turbines that it likely isn't a matter of if one will be struck, but when. The cost of replacing circuits in the nacelle, transformer, and elsewhere is hard on O&M budgets. But what grounding solution makes the most sense for wind farm developers and turbine makers focused on material cost reductions and reliability? Solid copper wire has long been deployed because it is known as an excellent electrical conductor. However, it isn't always the only or most appropriate answer. Substantial price swings and problems

with theft can make copper a liability. That's why some wind turbine and wind farm developers are exploring the benefits of less expensive bi-metal copper clad grounding wire/cable.

Material cost reductions and reliability continue to be a concern for wind farm developers and turbine makers. Most engineers are familiar with solid copper grounding wire/cable, which has been used around the world for many decades as the primary choice in grounding conductors. In increasing numbers utilities, municipalities, and electrical co-ops are switching to BiMetal copper-clad cable for grounding their towers, substations, and foundations. The utilities have experienced industry-wide problems with solid copper wire/cable theft, resulting in substantial maintenance costs going beyond the replacement cost of the wire/cable. Additionally, when the solid copper cable is cut from its site/tower, not only do service personnel risk severe injury, but system reliability is jeopardized as well.

Solid copper wire and cable has been used as grounding, or "earthing" wire for power, telecommunications, wind turbines, solar panels, gas lines, buildings, bridges, homes, and many other structures needing to dissipate lightning strikes to the ground. Solid copper wire has long been known to be an excellent electrical conductor, and the operative word here is "long," referring to timing, but not necessarily the most suitable. Copper has experienced significant demand and price fluctuations on the open market in the past decade, and it is a highly tradable commodity used in products from printed circuit boards to wire to jewelry and many other places.

There are other choices in grounding wire material types that can lead to cost reductions while ensuring long-term circuit/equipment protection. Solid copper has experienced substantial price swings, over 200 percent in the past year alone. Such price volatility can be minimized and cost savings applied to the installation of grounding wire/cable throughout the wind plant, from blades, to trenches, to wind farm substations.

Some careful buyers have learned that there are alternatives to solid copper grounding wire. "Why pay for 100-percent copper when 40 percent conductivity will work just as well due to skin effect?" asks Bruce Hammett, president of WECS Electrical Supply, Inc., and a 25-year veteran of the wind power industry.

Metallurgically bonded copper to steel, sometimes called copper clad, has been used in telecom, cable TV, and in electric utilities for grounding wire. Utilities today are most concerned with thieves climbing onto their property, cutting the solid copper away and taking it to scrap dealers for cash. While this is not yet a well-known problem for wind turbines or wind farms, that doesn't mean the thieves won't find them to be a good supply source in the future. As the copper on utility power poles and substations gets converted to copper-clad grounding wire, expect the thieves to find it in wind turbines next.

There are a few companies that have been producing copper-cladded wire and cable for several years. A recent addition to this list is CommScope, a U.S. telecom accessories manufacturer now reaching out to the wind and utility industries that has named a division, BiMetals, as a reference to the metallurgically bonded copper-clad wire/cable it produces. Some companies try to copper-plate the wire. This lacks the purity of a metal bonding environment to provide a highly bendable and durable copper skin. Due to the long-term vibration, fatigue or bending requirements of most of the cable used in turbines and wind farms, it is best to stay away from a plated copper wire/cable.

Today's copper-clad wire is metallurgically bonded to a steel or aluminum core. The aluminum core is the same material used for power cable—center conductor. However, the power cable is for a different application than discussed in this article. The optimum strength, "bend-ability," and fatigue capability of copper-cladded grounding wire is achieved with heat-pressure bonding in an inert gas environment under highly controlled heating and cooling operations. Examples of fatigue and bend test comparisons can be seen in fig. 1.

There are some issues, however, such as size, weight, and flexibility that require adaptation or acceptance when compared to solid copper. In order to accomplish the same current carrying capability, there may be small size increases when using copper-cladded steel wire vs. solid copper. For example, copper solid grounding wire, a 2/0 7W at 0.365" diameter will require a size 7 strand #7 AWG copper clad steel 40 percent conductivity at 0.433" diameter, or a 16 percent increase in diameter. Examples of conversion can be seen in fig. 2.

To the degree change can be implemented, this copper-clad technology is available now. To change standards and begin using copper-cladded steel for grounding wire, engineers should check the DC resistance and fusing currents to select the proper size of wire compared with solid copper. Figs. 3-4 show fusing

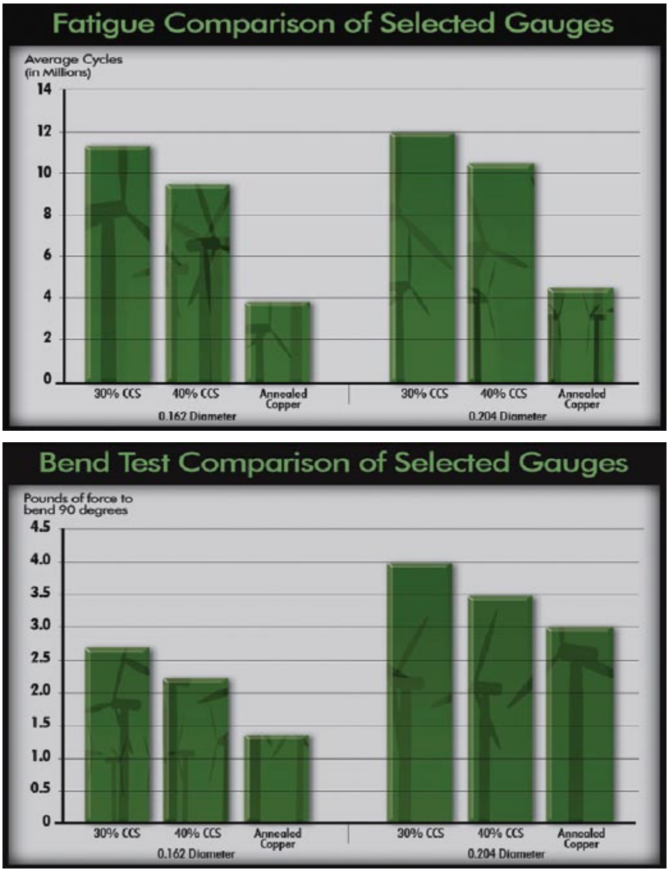



Fig. 1: Examples of fatigue and bend test comparisons.

| Copper Solid | | Copper Clad Steel 40% DSA | |
|---|---|---|---|
| Size | Diameter(in) | Size | Diameter(in) |
| #2 7W | 0.292 | 7 #10 | 0.306 |
| 1/0 7W | 0.325 | 7 #8 | 0.385 |
| 2/0 7W | 0.365 | 7 #7 | 0.433 |
| 3/0 7W | 0.410 | 7 #6 | 0.486 |
| 4/0 7W | 0.460 | 19 #9 | 0.572 |

Fig. 2: Conversion examples.

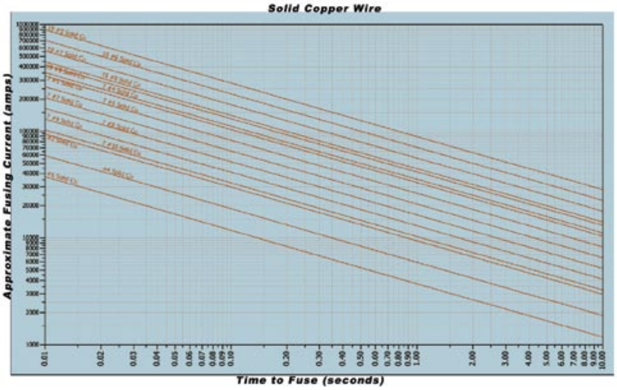



Fig. 3: Fusing data, solid copper wire.

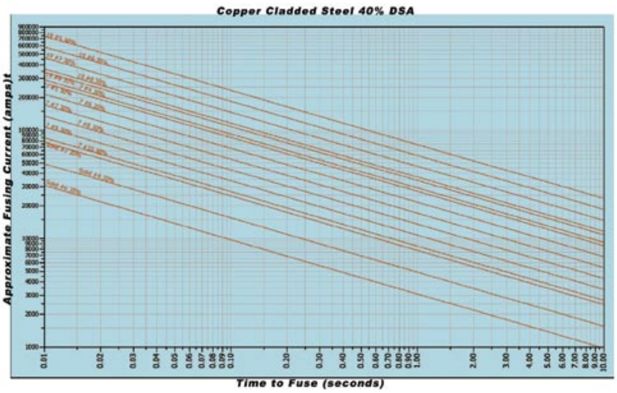
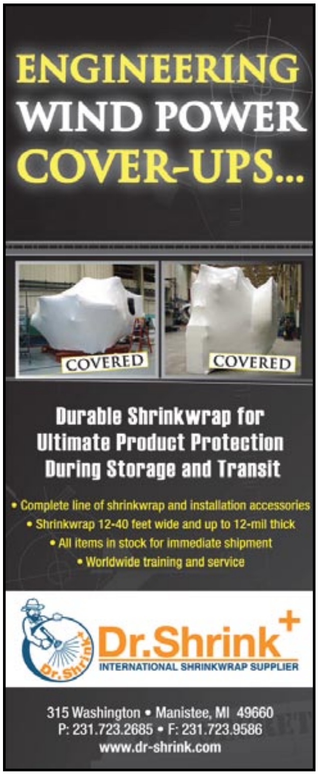



Fig. 4: Fusing data, copper-cladded steel.

current comparisons of solid copper wire and copper-clad wire from one manufacturer.

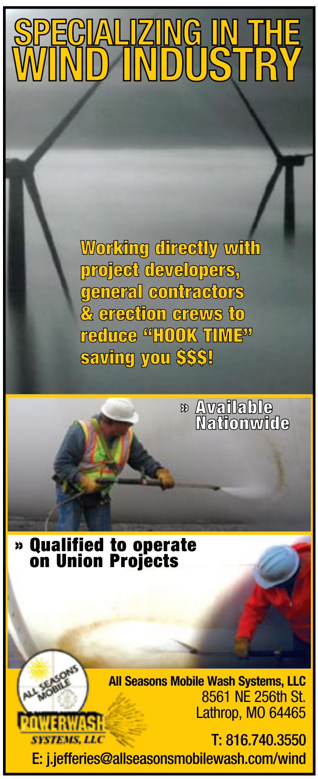
There is one other important point contributing to cost controls. The purchase cost of copper-clad wire is likely to be less for equivalent quantities, as there is less copper in such wire, which is acceptable due to the "skin effect" phenomena. Costs of specialty metals are likely to remain volatile, and one of the best ways to safeguard against theft losses and the high costs of purchasing copper wire is to use copper-cladded steel for grounding applications. Last year, as copper prices increased along with other commodities, the absolute dollar savings with copper clad grounding wire became substantial. Copper prices have moderated in the past six months, along with other commodities, but have already begun increasing this year and are expected to increase further. The cost benefits of using copper-clad grounding wire exist with both the initial purchase stage as well as the O&M costs related to theft and longevity. With so many concerned with making harvesting wind energy as cost-efficient as possible, maybe it's time for you to consider a change in grounding wire/cable.


GEAR BASICS
for the
WIND POWER INDUSTRY
Finally! A Basic School
for Non-Experts!
Do you have people who are new to GEARS?
Do your production or maintenance
people need to know more about GEARS?
Cole Manufacturing Systems, Inc.
offers a beginning gear training
course designed to your
exact needs.
• Terminology of Gears
• Gear Functions and Basic Formulae
• Manufacturing & Inspection Methods
• Interpretation of Inspection Data
• Applying Inspection to Correct Problems
THE COURSE CAN BE ON-SITE IN YOUR PLANT
OR TRAINING FACILITY, OR OFF-SITE AT A
NEARBY FACILITY. WE COME TO YOU!
(248) 601-8145
FAX (248) 601-0505
Email: dsmith@colemfgsystems.com
www.colemfgsystems.com


ENGINEERING
WIND POWER
COVER-UPS...
COVERED
COVERED
Durable Shrinkwrap for
Ultimate Product Protection
During Storage and Transit
• Complete line of shrinkwrap and installation accessories
• Shrinkwrap 12-40 feet wide and up to 12-mil thick
• All items in stock for immediate shipment
• Worldwide training and service
Dr.Shrink
INTERNATIONAL SHRINKWRAP SUPPLIER
315 Washington • Manistee, MI 49660
P: 231.723.2685 • F: 231.723.9586
www.dr-shrink.com

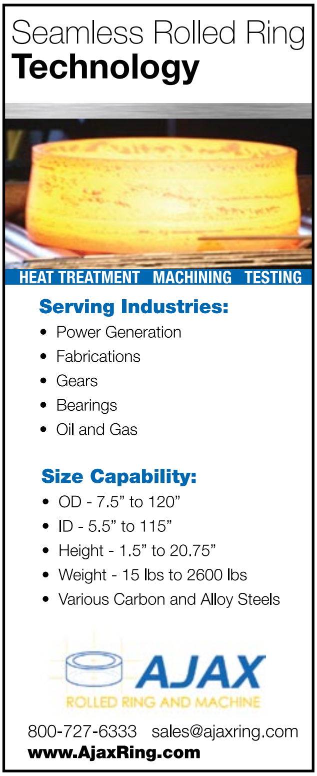

PROTECT
YOUR BOLTS
YOUR FOUNDATIONS
ARE NOT COMPLETE
WITHOUT PROTECTING
THE ANCHOR BOLTS WITH
IRONCLAD™ BOLT CAPS
NORM TOOMAN
CONSTRUCTION, INC.
THE STANDARD OF
THE INDUSTRY.
IRONCLAD BOLT CAPS
800.359.0372
NORMTOOMANCONST.COM


EXCEL GEARS...
AND MUCH MORE
Precision gears, high-speed spindles, CNC gimbal heads, even gearbox assemblies for battleship gun turrets. That's the breadth of design, build and testing capabilities Excel brings to your company for high speed and high power, with smooth and quiet operation. Gear grinding to AGMA 15 (DIN 2) at 60" external diameters, gear hobbing to 70" maxi-mum pitch diameter.
All with our personalized service and guaranteed performance. You CAN have it all! Talk to us for your next project.
EXCEL GEAR, INC.
A TOTAL SERVICE COMPANY
excelgear.com | 815.623.3414

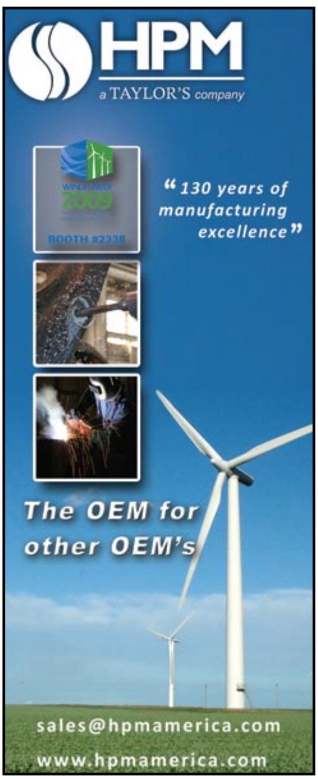

SPECIALIZING IN THE
WIND INDUSTRY
Working directly with
project developers,
general contractors
& erection crews to
reduce "HOOK TIME"
saving you $$$!
» Available
Nationwide
» Qualified to operate
on Union Projects
ALL SEASONS MOBILE
POWERWASH
SYSTEMS, LLC
All Seasons Mobile Wash Systems, LLC
8561 NE 256th St.
Lathrop, MO 64465
T: 816.740.3550
E: j.jefferies@allseasonsmobilewash.com/wind


Gearbox
Repairs & Overhauls
We are well-equipped to support you with any emergency breakdown, schedule repair or preventative maintenance services.
• 24 x 7 availability
• Complete gearbox, cylinder
& mechanical overhauls
• Repair journals, housings, shafts, linkages, etc.
• Fabricate replacement parts
• Since 1967
MACHINE WORKS, INC
PAMCO
EST. 1967
(626) 358-8288
pamcomachine.com

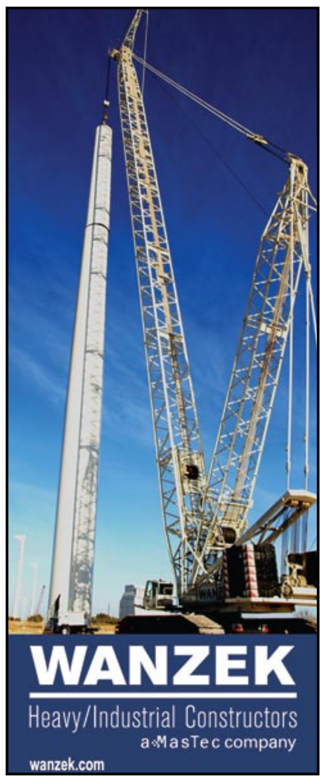

MAXIMUM
STORAGE
in minimum
space
USA
Stor-Loc
Modular Drawer System
STOR-LOC MODULAR DRAWER SYSTEM
880 N. Washington Ave. Kankakee, IL 60901
Toll Free: 1.800.786.7562 • Fax: 1.800.315.8769
email: sales@storloc.com
www.storloc.com

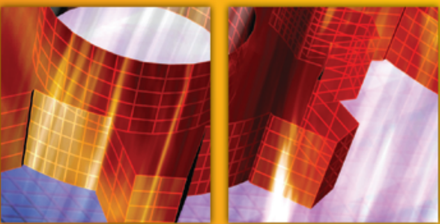

Seamless Rolled Ring
Technology
HEAT TREATMENT MACHINING TESTING
Serving Industries:
• Power Generation
• Fabrications
• Gears
• Bearings
• Oil and Gas
Size Capability:
• OD - 7.5" to 120"
• ID - 5.5" to 115"
• Height - 1.5" to 20.75"
• Weight - 15 lbs to 2600 lbs
• Various Carbon and Alloy Steels
AJAX
ROLLED RING AND MACHINE
800-727-6333 sales@ajaxring.com
www.AjaxRing.com


LAPP GROUP
Lapp provides products and solutions for wind turbines from the nacelle down through the tower.
Large selection of UL-2277 Wind Turbine Tray Cables (WTTC)
888-456-3539
www.lappusa.com


HPM
a TAYLOR'S company
"130 years of manufacturing excellence"
The OEM for other OEM's
sales@hpmamerica.com
www.hpmamerica.com


"WHEN IT HAS TO BE RIGHT"
THE GEAR WORKS
Wind Turbine Gearbox Repair Services
· Custom Wind Gear Manufacturing
· Large Gear Grinding to 2.6m
· Gear Metrology Laboratory
· Large Gearbox Assembly to 20 Tons
· Gearbox Testing
· 50 Years of Gearbox Repair Experience
· 24 Hour Factory Operation
· ISO-9001 Registered
THE GEAR WORKS
THE GEAR WORKS – SEATTLE, INC.
500 S. PORTLAND STREET · SEATTLE, WA 98108-0886
PHONE: 206.762.3333 · FAX: 206.762.3704
EMAIL: SALES@THEGEARWORKS.COM
THEGEARWORKS.COM


WANZEK
Heavy/Industrial Constructors
a MasTec company
wanzek.com



# ADINDEX

## CAN YOU GIVE US AN OVERVIEW OF WHAT GEXPRO SERVICES PROVIDES?

I think the most succinct description would be that Gexpro Services provides global supply chain management services such as global sourcing, value engineering, quality control, inventory management , and IT solutions for industrial OEMs. We were acquired by Rexel, which is the largest global electrical distributor in the world, in late 2006 as part of their acquisition of GE Supply. Gexpro Services offers powerful supply chain management solutions with and for the customer, and our affiliation with Rexel has only strengthened our position and capabilities in the United States at more than 2,500 locations around the globe. We support five vertical segments—technology, transportation, consumer/industrial, aerospace, and energy—and we're particularly involved in the wind-power industry, for which we provide C-part component hardware as well as electrical and fabrication supplies.

## IF I WERE A WIND-INDUSTRY OEM, WHAT WOULD YOU BE ABLE TO DO FOR ME?

We can provide products and services for their nacelle, blade, and tower applications, to begin with. That includes bolts, fasteners, brackets, ladders, platform assemblies, and a lot of other large-diameter hardware for the tower internals. Electrical supplies would include power cables and trays, lighting fixtures, receptacle kits, and cable harnesses and assemblies. So we offer a vast array of products, but one thing in particular that our clients really appreciate is our global quality and sourcing capabilities, because a strong global supply chain drives competitive costs. We have quality and sourcing resources in Asia, for example, who are constantly seeking the highest-quality products at the best available price, which allows our customers to be very competitive in their manufacturing operations. Beyond supplies, however, we can help manufacturers streamline their assembly lines by overseeing and managing their inventory. We utilize Kanban systems to monitor stock levels and trigger supply shipments as well as kitting programs, where we gather all of the individual component parts necessary to assemble a particular bill of material and ship them complete to the customer's facility or to a job site, depending on their requirements. We actually become an extension of our client's supply chain operation, scanning their bins using our Oasis Pro software every day so that we know what components are progressing and regressing in real time. For instance, if we see a unit manufacturing schedule ramping up, or know that a new product is being introduced, we'll work with our customers to make the necessary adjustments to inventory levels so they have just what they need, exactly when they need it.

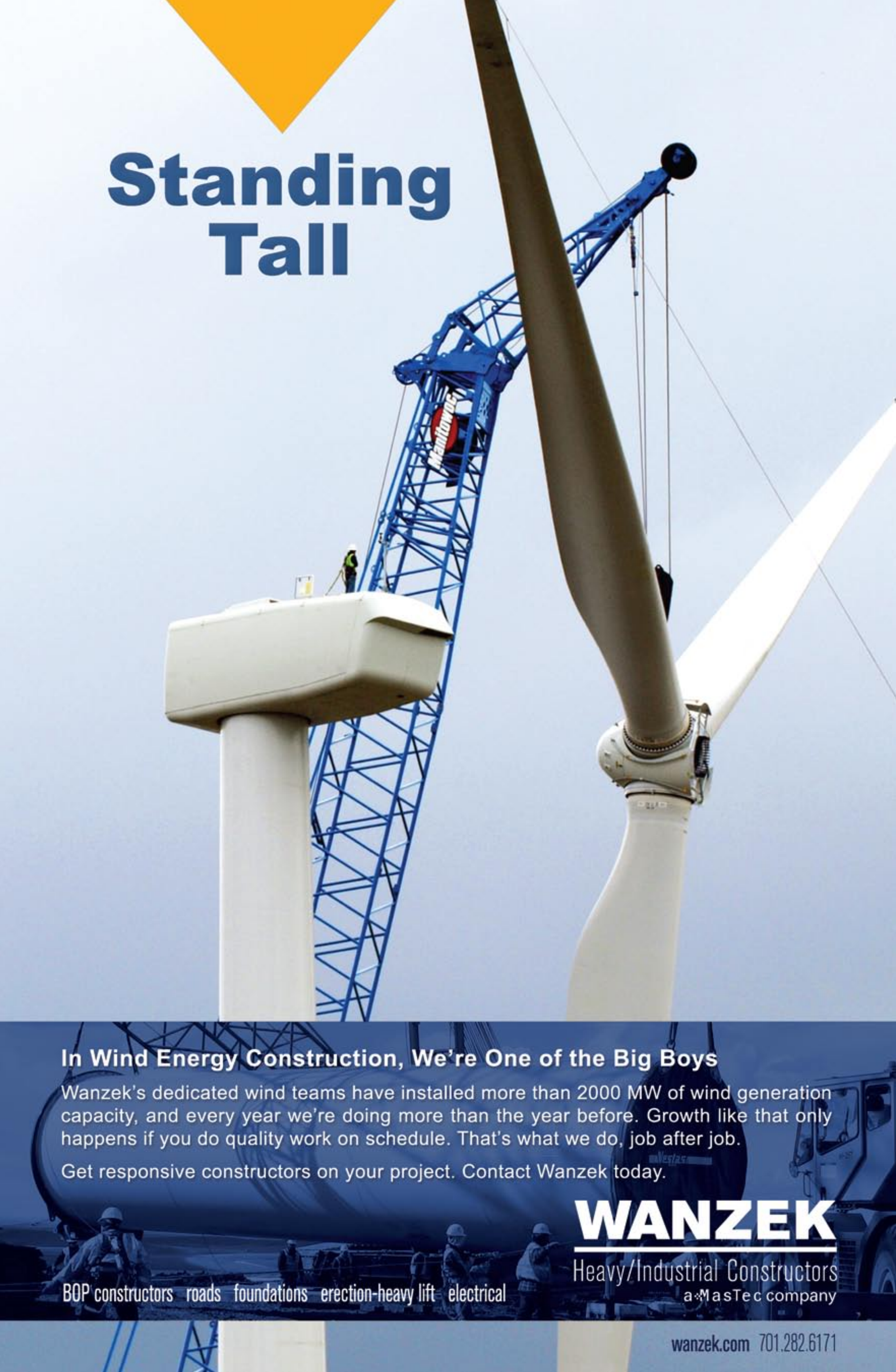
## SOUNDS LIKE YOU'RE IN A POSITION TO FREE UP A LOT OF YOUR CLIENT'S RESOURCES.

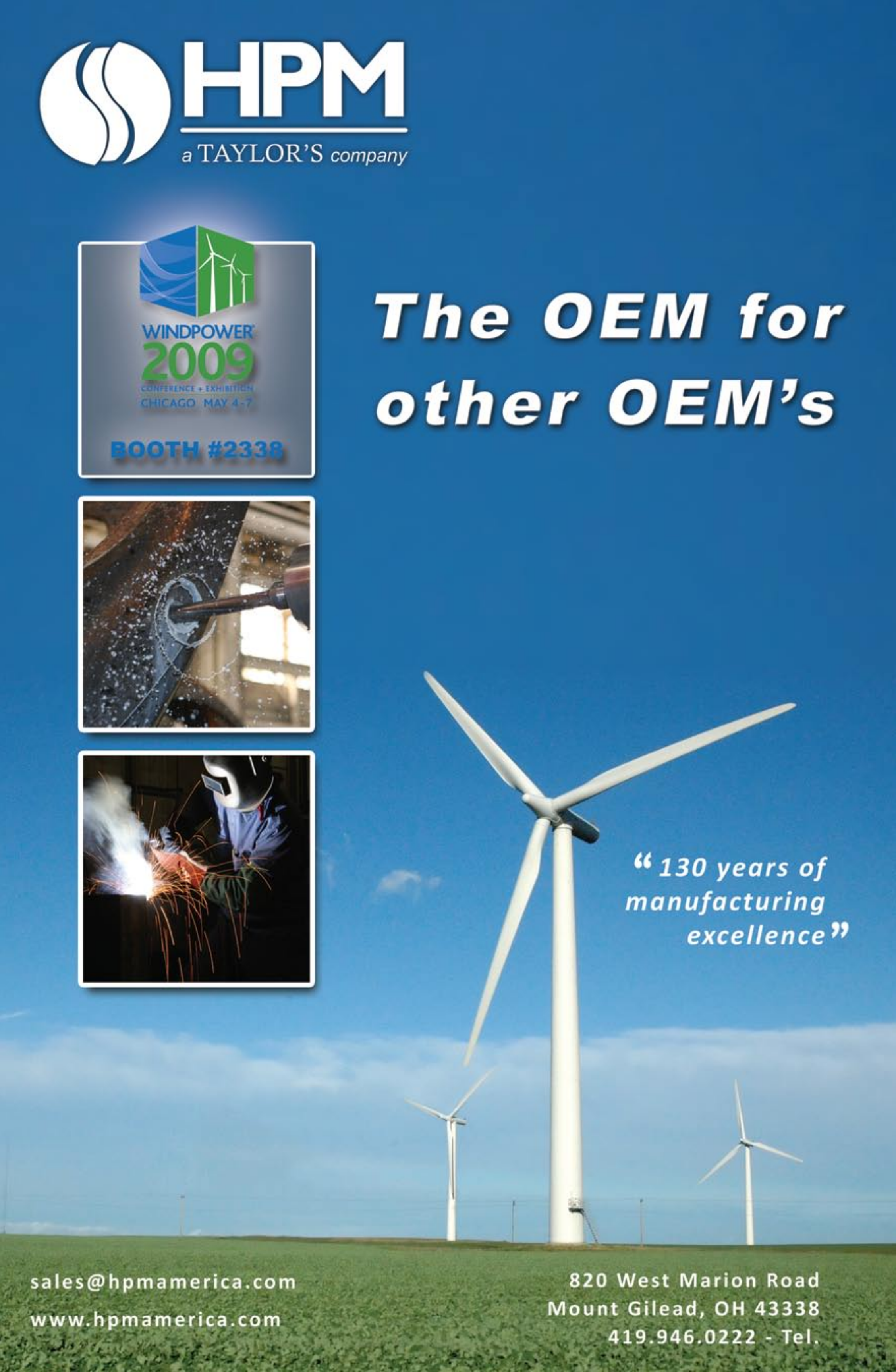
Absolutely. While they may have been dealing with literally hundreds of individual suppliers before, we become their single source and point of contact should they choose to work with us, and our quality experts manage all of the necessary documentation for each part, such as drawings and certificates, on file. We also provide trade working capital relief, because they're not paying for the parts until they are used on the line. And we know when every single part is moved, because it must be scanned on the floor or in our warehouse, and we track shipments so that we always know where they are in transit, whether that be on land, at sea, or in the air.

## IS EACH CONTRACT SINGULAR, IN TERMS OF YOUR LEVEL OF INVOLVEMENT?

Yes. Each contract is tailored to meet the customer's individual needs, and we work with them to establish terms and conditions that result in a fair and equitable contract for both parties. Should we enter into an agreement, however, we do require a three-year commitment, which allows us to negotiate long-term agreements with our suppliers in order to obtain the best possible prices and on-time deliveries. I would say that among the many ways we provide value to our customers is by managing their global supply chain, having strong quality and sourcing infrastructure supported by digitized tools, and offering tailored inventory management solutions. By working with Gexpro Services our customers can count on us to effectively manage their wind turbine component needs, which allows them to refocus their energy and resources on meeting their manufacturing goals and objectives We're here to offer our market and supply chain expertise and resources to ensure 100-percent product fulfillment, and to help them reach their market penetration.

Visit online at www.gexproservices.com


Standing Tall
Manitowoc
In Wind Energy Construction, We're One of the Big Boys
Wanzek's dedicated wind teams have installed more than 2000 MW of wind generation capacity, and every year we're doing more than the year before. Growth like that only happens if you do quality work on schedule. That's what we do, job after job.
Get responsive constructors on your project. Contact Wanzek today.
BOP constructors roads foundations erection-heavy lift electrical
WANZEK
Heavy/Industrial Constructors
a MasTec company
wanzek.com 701.282.6171


HPM
a TAYLOR'S company
WINDPOWER
2009
CONFERENCE + EXHIBITION
CHICAGO MAY 4-7
BOOTH #2338
The OEM for other OEM's
"130 years of manufacturing excellence"
sales@hpmamerica.com
www.hpmamerica.com
820 West Marion Road
Mount Gilead, OH 43338
419.946.0222 - Tel.