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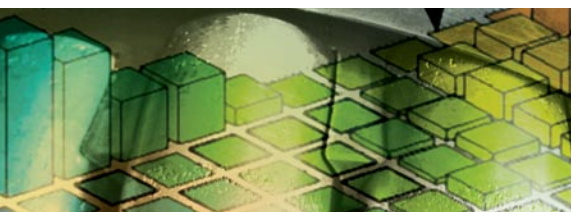

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EDLETTER

Not long ago I joined a teleconference featuring Denise Bode, CEO of the American Wind Energy Association (AWEA), along with representatives of Siemens, Winergy Drive Systems, and Leeco Steel, who discussed the negative effect the expiration of the Production Tax Credit (PTC) will have on the U.S. wind industry should it not be renewed. "American manufacturing jobs are coming back, with tens of thousands of new jobs from wind power," Bode stated in a press release announcing the event. "But these jobs could vanish if Congress allows the Production Tax Credit to expire, in effect enacting a targeted tax increase, and sending our jobs to foreign countries. Congress must act now to keep this American manufacturing success story going." A report by Navigant finds that extending the PTC will create and save 54,000 jobs, and its expiration will kill 37,000. As we go to press, Congress is considering what actions it will take in this matter, but the fact is that the PTC has been an overwhelming success and its renewal will allow the U.S. wind industry to continue building on the investments that have been made so far. Smart decisions by our lawmakers will also encourage companies from overseas that are considering locating here to do so. Please join us in supporting AWEA's efforts to assure the continued success of the U.S. wind industry by visiting www.awea.org.

We have a stellar lineup for you in this issue of the magazine, beginning with "Monitoring Rotating Machinery" by Ashley Crowther and Tugan Eritenel of Romax Technology. Sherif El-Henaoui of Moog explains why wind turbine builders should adapt to "Changing Wind Farm Requirements," and Bryant Zavitz and Kevin Kirkley of the Tindall Corporation have penned an excellent feature discussing "Optimal Tower and Foundation Design." Brendan FitzPatrick of Geopier describes the Rammed Aggregate Pier system in "A Foundation for Success," and Martin Fischer of AMSC reports on the continued evolution of monitoring systems in "Integrated Condition Monitoring."

Maintenance columnist Merritt Brown of Rev1 Renewables endorses establishing your own post warranty preventative maintenance program in this month's installment, and Mike Graska of the Professional Logistics Group discusses the nature of "variability" and its effect on your supply chain in his logistics column. Construction columnist Ron Krizan of the NAES Corp. shares tips on how to identify broken tiles by observing surrounding ground conditions, and John Skiller of SKF Renewable Energy describes new technologies for easing maintenance procedures. Wind Energy Services (WES)—a member of the Molded Fiber Glass Companies (MFG)—is this month's profile, and I'd like to thank Gary Kanaby for discussing the company's growth and capabilities with me, and Martin Schmidt-Bremer, Jr., COO of WindGuard North America, is our Q&A subject.

At a time when there's a job crisis in this country, we need to be doing everything we can as ambassadors of the wind energy industry to help people understand the potential and benefits. Whether that's contacting your congressional representatives, writing a letter to the local paper, or simply having a conversation about wind with a college student trying to identify a promising career track, let's be proactive in helping shape this country's renewable energy policy.

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MAXWELL TECHNOLOGIES RINGS NASDAQ CLOSING BELL

Maxwell Technologies, Inc., CEO David Schramm (above center) rang the market closing bell on Wednesday, October 26, 2011 at NASDAQ's MarketSite in New York City's Times Square. Maxwell was honored in the closing ceremony for its 28 years of participation on the stock exchange and its profile of innovation and leadership that exemplifies a NASDAQ company. Sales of Maxwell's ultracapacitor products have grown from $5 million in 2004 to a run rate on pace to reach $100 million by the end of 2011.

Maxwell is a leading developer and manufacturer of innovative, cost-effective energy storage and power delivery solutions. Maxwell's ultracapacitor products provide safe and reliable power solutions for applications in consumer and industrial electronics, transportation, and telecommunications. Its high-voltage grading and coupling capacitors help to ensure the safety and reliability of electric utility infrastructure and other applications involving transport, distribution, and measurement of high-voltage electrical energy. Its radiation-mitigated microelectronic products include power modules, memory modules, and single board computers that incorporate powerful commercial silicon for superior performance and high reliability in aerospace applications. For more information please visit www.maxwell.com.

CASTROL INDUSTRIAL SECURES AGREEMENT WITH SIEMENS

Castrol Industrial has signed a purchase agreement with Siemens Wind Power to use the company's flagship gear oil, Castrol Optigear Synthetic X 320. The award of the new contract has been the impetus for Castrol Industrial starting up the production of Castrol Optigear Synthetic X 320 at its U.S. manufacturing plant in Warminster, Pennsylvania, to help the company better serve Siemens operations in Hutchinson, Kansas, and supply locally-produced lubricants to other customers in the U.S. and surrounding markets.

"The deal is the latest in a long-standing working relationship with Siemens, a company that recognizes the importance of working with global partners to ensure consistency and quality in all markets served," according to Sven Thiesen, key account manager wind energy, Castrol Industrial. "We are pleased to be working with such a forwardthinking, innovative and growing business and are incredibly proud to be supporting Siemens' global expansion plans."

Today, Castrol Industrial provides 100 percent fulfillment of all Siemens' wind turbine gear box

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.

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lubrication needs with its Castrol Optigear Synthetic X 320 product, and supply of complementary products, including hydraulic fluids and greases to the company's wind energy business. Over the past five years Castrol Industrial has supplied Siemens Wind Power with gear box lubricants of consistent high quality and standardized packaging globally for first fill and ongoing maintenance applications. Siemens Wind Power is one of the world's leading suppliers of wind power solutions for onshore, offshore and coastal sites.

While Castrol Industrial ships Optigear Synthetic X 320 from Europe to serve the Chinese market, the company continues to evaluate the option of manufacturing at its Taichang plant in China to meet the growing demand in this region, which represents significant future potential. Learn more at www.castrol.com.

TRAVELERS FORMS DEDICATED CLEAN ENERGY & TECHNOLOGY PRACTICE

The Travelers Companies, Inc., which has been offering insurance products and risk management services for clean energy and technology businesses for more than two decades, announces the formation of its Clean Energy & Technology Practice. This new practice creates a streamlined source of clean energy and technology-focused insurance products, and risk and claim management resources.

"With Travelers' long experience working closely with clean energy and technology businesses, and as these businesses continue to grow and expand, the Clean Energy & Technology Practice makes it easier for independent agents and brokers to access the breadth and depth of Travelers' products and services," says Joe Tracy, president, Travelers Inland Marine. "The Clean Energy & Technology Practice offers rounded total account solutions. Through a single touch point, customers experience a streamlined process that provides access to a broad spectrum of insurance products and risk management services."

The practice brings together all of Travelers' existing clean energy and technology practice areas, providing customers, including wind and solar manufacturers, contractors, power producers, owners and developers, smart grid, fuel cell development, alternative, and other energy efficient solutions with industry-specific insurance protection. The Travelers Clean Energy & Technology Practice has extensive capabilities and interest in supporting U.S. entities and their international exposures that focus on technologies that are energy efficient or environmentally friendly.

Interest and demand for clean energy and technology is increasing dramatically in the United States and across the globe. As a result, these demands have fueled the growth of businesses in the renewable energy industry focusing on technologies that are energy efficient or environmentally friendly. "Clean energy and technology companies are expanding across the globe, each with a unique risk profile that our underwriters are trained to understand and address," says Kathy Swendsen, president, Travelers Global Technology. "By combining our expertise under one practice, in conjunction with our independent agent and broker network, we help our customers avoid the growing pains of inadequate coverage as their businesses evolve."

The Clean Energy & Technology Practice will be spearheaded by Travelers veterans Tracy and Swendsen and co-managed by Kirstin Simonson, underwriting director for Global Technology, and Lauren Cutro Berry, underwriting vice president for Inland Marine. For more information visit www.travelers.com/cleanenergy.

NEW VICE PRESIDENT/GM AT NAES POWER CONTRACTORS

NAES Corporation announces the addition of William "Will" Day as vice president and general manager of the NAES Power Contractors office in Hillsboro, Oregon. He is responsible for all activities for NAES Power Contractors emanating from the Hillsboro office.

Day has over 30 years' experience in the generation industry. Before joining NAES he served as vice president of development engineering and construction at Calera Corporation, a Silicon Valley startup technology venture. Prior to that he spent 20 years in various leadership roles at NRG Energy and Cajun Electric Power Cooperative. During his career Day has held director level roles in transmission, operations, construction, business development, and mergers/acquisitions. He has also represented companies on industry and partnership boards both domestically and internationally.

Headquartered in Issaquah, Washington, NAES is the world's leading provider of comprehensive services to industries that generate or consume power. For over 30 years, it has specialized in providing services centered on safe, reliable, and cost-effective performance including operations and maintenance; retrofit and maintenance services; on-site turbine inspection/overhaul services; staffing solutions; and customized services designed to improve plant and personnel effectiveness. NAES is owned by ITOCHU International, Inc., the U.S. affiliate of ITOCHU Corporation. With operations in over 80 countries covering a broad range of industries, ITOCHU is among the world's largest corporations. Go online to www.naes.com.

MORTENSON AND ENXCO PARTNERSHIP TO BUILD 19TH WIND PROJECT

Mortenson Construction, a leading North American renewable energy contractor, was recently selected by San Diego-based developer enXco—an EDF Energies Nouvelles Company—for the construction of the Pacific Wind Project. Located on the south slope of the Tehachapi Mountains in Kern County California, the 8,500-acre project will generate 140 megawatts of wind power, which is enough energy to power approximately 39,000 homes.

Mortenson is responsible for the design and

construction of access roads, foundations, erection, overhead and underground electrical collection system, and a 14,400 square-foot O&M facility that will support the Pacific Wind Project as well as other enXco projects slated for development in the area. Construction began in December, 2011, and is expected to be completed in August, 2012.

The Pacific Wind Project is the 19th wind power facility that Mortenson has constructed in partnership with enXco. Together the partnership has provided nearly 2GW of energy throughout the United States. In early October Mortenson completed construction of enXco's 205.5 megawatt Lakefield Wind Project in southern Minnesota. In Minnesota alone the enXco/Mortenson partnership has developed and constructed approximately 36 percent of the state's wind energy capacity.

"Our long-established relationship with enXco represents a cohesive partnership that reinforces our commitment to renewable energy though out the United States," says Tim Maag, a vice president and general manager of Mortenson's Renewable Energy Groups.

Since entering the renewable energy market in 1995 Mortenson Construction has become a leading builder of wind power facilities in North America, constructing more than 100 wind projects generating more than 11,000MW of renewable power across the United States and Canada. With 100 percent of Mortenson's business in the power sector coming from renewable energy, Engineering News-Record ranked Mortenson the 11th largest power contractor in the U.S. for 2010. Go online to www.mortenson.com/wind.

INNOVATIVE GEARBOX CONCEPT ANALYSIS FROM ROMAX

Romax Technology is pleased to announce the availability of release R14.0 of the precision bearing, gearbox, and driveline simulation and analysis software, RomaxDesigner, and wind turbine drivetrain specific variant, RomaxWind. The release includes many productivity and feature enhancements and introduces the innovative new Concept Modeller module option.

The Concept Modeller module revolutionizes the speed with which complex

gearbox models can be created, functionally analyzed and exported to CAD for packaging analysis. The point and click user interface incorporates drag and drop editing and sizing features, resulting in over 10x speed improvement and reduced data entry errors when creating fully compatible RomaxDesigner models.

Designers can create gearboxes using conventional "stick diagrams" that are as easy as using pen and paper. Possible gearbox layouts include complex ravigneaux and plus-planet planetary arrangements and the latest dual-clutch arrangements. The Concept Modeller module takes the stick-diagram input and generates 2D and 3D representations that can be easily analyzed visually by selecting cut planes through the design. The module allows high-speed analysis of the basic properties required to evaluate many design concepts and select those that merit more detailed study. The properties include:

- Powerflow path analysis for each transmission ratio, speed and torque;
- Gear sizing analysis to aid in the determination of packaging requirements;
- Calculation of tooth passing frequencies to provide early indications of likely NVH performance.

No data re-entry is required on concept designs that are taken forward into RomaxDesigner for precision analysis. "We are seeing higher levels of innovation in our customer's transmission designs and design processes as they rise to the challenges lower emission vehicle designs with rapidly evolving powertrains", said Younsu Park, director of simulation technology. "A recent gearbox project involved the analysis of 58 conceptual layouts, of which six were selected for detailed analysis. RomaxDesigner release R14.0, with our new Concept Modeller option is making significant productivity improvements in this type of workflow."

Based on extensive feedback from users, 20 productivity enhancements have been included in release R14.0. Commonly used functions have been assigned quick-click buttons, tabs during data entry have been re-ordered to match the most common workflows, and new visualizations have been added to more easily confirm correct data entry. Learn more at www.romaxtech.com.

WIND ENERGY SERVICES EXPANDS SERVICES AND WORKFORCE

One segment of the wind energy business that is not stagnating is onsite service and maintenance of wind generation equipment, according to Wind Energy Services Company (WES), a specialist in composite components such as blades, nacelles, and nose cones. The company announces that it has expanded service offerings to meet the evolving needs of wind farm operators, and as a result anticipate doubling their workforce in the coming year. The expanded services that the company is adding include dynamic rotor balancing, comprehensive rotor service maintenance programs, and replacement composite parts for older-model equipment.

One reason behind the increasing demand for turbine repair and maintenance is the maturing of the installed base of wind turbines, some of which is aging out of warranty. As fleets age, instances of breakdown become more frequent and overall productivity declines, especially impacting profitability when the equipment is no longer covered by manufacturer warranty.

WES has created a range of planned maintenance programs tailored to a variety of operator needs. These comprehensive programs include inspection, corrective repairs and restoration, and preventative measures like leading-edge protection. The programs are scheduled during low-wind seasons to minimize loss of production revenue. For instance, in the Midwestern U.S. the summer months offer optimum working and curing conditions, as well as efficiencies in mobilization to the site, translating to bottom-line cost savings.

North American operators have historically been slow to implement pro-active maintenance practices, electing instead to manage breakdowns as they occur. Recent studies by independent researchers have shown that over the lifecycle of a turbine, repair costs are substantially less with scheduled maintenance programs than on an emergency call basis. As the industry pursues ways to improve their efficiencies and profitability, preventative maintenance is gaining acceptance as a necessary best practice.

Another new offering from WES is spare parts for older turbines. Through the Molded Fiber Glass Companies (MFG), WES's parent company and one of the largest manufacturers of composite components in the U.S., WES is now supplying custom orders of replacement blades, nacelles, spinners, hatches, and other FRP components that are no longer stocked by the OEM. MFG's process for creating tooling from a customer's existing part is quick and non-destructive to the part itself.

With the business expansion, WES anticipates a doubling of their workforce in the coming year, and is actively recruiting top talent for their Gainesville, Texas, headquarters as well as satellite service centers in California and South Dakota. "We want to attract and bolster the top blade repair force in the industry, especially with experienced technicians with management aptitude and ambition," says Gary Kanaby, director of sales for WES. "It's a job like none other—a blend of extreme sport, technical know-how, and business sense, and we're looking for the very best of the breed to join our premier team."

The company is currently seeking candidates to fill position openings for onsite team leaders, project manager, and composite repair technicians, and it anticipates bringing on 25 or more new teammates in the next six months. More information is available at www.windenergyservicesusa.com.

GE SOFTWARE POWERS RESEARCH ON EFFICIENT WIND ENERGY PRODUCTION

GE announces that it is working with Illinois Institute of Technology (IIT) to investigate ways to improve wind farm productivity and efficiency. The results of the study will directly contribute to future product and service designs. The project is part of a larger Department of Energy (DOE) investment of $9 million to an IIT-led consortium to enhance the leadership role of the U.S. in testing and producing the most advanced and efficient wind turbines in the world. The two-year project will focus on helping wind farms to reduce maintenance costs and improve availability through predictions of impending problems. The project's research will be conducted near Marseilles, Illinois, on a GE 1.5 MW series wind turbine operated and maintained by Invenergy, the nation's largest independent wind power generation company.

"With skyrocketing costs, wind farms need to know ahead of time what needs to be fixed—and what doesn't," says Stacey Kacek, GE Intelligent Platforms' general manager, Asset Intelligence. "If they have credible early warning of impending equipment problems, the farms can prioritize tower inspections, optimize crane usage, and leverage resources in remote locations. Being able to avoid surprises and take control of maintenance in a proactive way translates to significant cost savings for the industry."

IIT students will be conducting research using GE's Proficy SmartSignal software on the GE wind turbine to learn how to detect faults even earlier and more accurately than currently possible. The project includes adding more sensors than the industry standard to improve condition-monitoring precision, and enhancing the SmartSignal models to include measurements of vibration, lube oil, and blade pitch motors. The IIT team will monitor the turbine remotely from the IIT campus and analyze the energy output and overall equipment performance.

"Proficy SmartSignal software essentially acts as a supporting experienced operator and technician, leveraging past experience and working 24/7," says Dave Parta, project manager, GE Intelligent Platforms. "In the wind industry, the solution is used to monitor the sensors on remote turbines and provide exception-based notifications when a turbine is not acting as it should based on its history. This is particularly challenging, given constantly changing wind speed, direction, shear, and turbulence. The SmartSignal solution collects and

analyzes tens of thousands of data points daily on wind farms across the country and provides early warning of impending turbine and instrumentation failures."

"The goal of this project is to illustrate how advanced and automated predictive diagnostics can improve the availability, reliability, and cost performance of wind power generation," says Mohammad Shahidehpour, IIT Bodine professor and director of the Robert W. Galvin Center for Electricity Innovation, who is serving as the principal investigator for the consortium. "As a result of this research, we hope to improve the sensoring and modelling of wind farms. We'll also be developing wind energy courses to address the technical, operational, social, and environmental aspects of wind energy. This will ensure that we have not only the technology, but also the talent necessary to compete and further innovate in the global marketplace." For more information go to www.ge-ip.com/smartsignal.

CAPITAL SAFETY OWNERSHIP CHANGES

Capital Safety announces its acquisition by KKR, a leading global investment firm, from Arle Capital Partners, which had owned the company since 2007. KKR has signed an agreement to pay $1.12 billion for the company, with transfer occurring in January 2012, subject to mandatory regulatory approvals.

Under its previous owner Capital Safety doubled its revenues through a commitment to aggressive research and development, which led to the launch of innovative first-in-the-industry products such as ExoFit NEX™ and i-Safe™ RFID equipment management system, enhanced its global supply chain and expanded into emerging markets for fall protection equipment. It also successfully executed five strategic acquisitions in Australia, Columbia, France, and the U.K. to broaden its offerings for customers worldwide.

"Strong interest in our company is confirmation of our strategic direction and testament to the most experienced team of fall protection experts in the world," says Anders Pettersson, Capital Safety Group CEO, adding that KKR's intent is to continue to strategically invest in Capital Safety's position as the world leader in supplying fall protection solutions and expects continued expansion for the company, both in terms of products and markets served. "Without them we could not have countered the global economic stresses and served a record number of customers with a record number of products."

Capital Safety, the world's leading designer and manufacturer of height safety and fall protection equipment with 20 operating sites worldwide, is home of the DBI-SALA, UNILINE, and PROTECTA brands. All of Capital Safety's fall protection and rescue systems are backed by extensive training, knowledgeable technical assistance, and professional customer service. To learn more call (800) 328-6146, (651) 388-8282, or visit www.capitalsafety.com.

BARRICK INAUGURATES PUNTA COLORADA WIND FARM IN CHILE

At an inauguration ceremony held in northern Chile in November Barrick Gold Corporation marked the official opening of the Punta Colorado Wind Farm, the largest wind farm ever built by a mining company in the country. The event was attended by the President of the Republic of Chile, Sebastián Piñera, the ministers of Mining and Energy, Hernán de Solminihac and Rodrigo Álvarez, and authorities from Chile's Atacama and Coquimbo regions. This large-scale $50 million project, located in the town of La Higuera in the Coquimbo Region of Chile, consists of 10 wind turbines that generate 20 megawatts of power, enough to supply the energy needs of 10,000 families. The wind farm has the capacity to expand to 18 turbines and generate 36 megawatts, which would raise the total investment in the project to $70 million. The power generated by the wind farm feeds into Chile's Central Interconnected Systems power grid.

"The inauguration of this wind farm is a milestone for Barrick, reflecting our belief that renewable energy and energy conservation benefit both the environment and our company," says Igor Gonzales, President of Barrick South America. "We are also very pleased to contribute to the diversification of Chile's national energy grid and to support policies for the development of renewable energy. We will continue to explore innovative technologies to make our company more energy efficient and to reduce our carbon footprint."

The wind farm is one of a number of renewable energy projects and conservation initiatives that support Barrick's broader climate change strategy. In Nevada, the company has a one-megawatt solar farm. In Argentina Barrick invested $8.5 million in a wind turbine that now provides up to 20 percent of the electricity needs for its Veladero mine. At 4,110 meters above sea level in the Andes Mountains, the wind turbine is recognized by Guinness World Records as the world's highest-altitude wind generator.

In 2010, 15 percent of Barrick's purchased and self-generated electricity came from renewable sources. The company completed more than 25 projects to reduce its energy and greenhouse gas footprint last year. These programs reduced the company's GHG emissions by 206,200 tonnes over business as usual in 2010. Learn more at www.barrick.com.

Ron Krizan, P.E.
NAES Corporation

Identifying broken tiles usually calls for close observation of ground conditions such as sinkholes or swampy patches that don't dry out.

IN THIS INSTALLMENT WE'LL LOOK at ways to identify broken tiles and methods to repair them quickly and efficiently. From last month's column—available at www.windsystemsmag.com—it should be assumed that if you are working in tiled farm country, you should anticipate damaging tiles.

The first thing is to effectively spot and ascertain damaged tiles. While there are innumerable ways to damage a tile, there are luckily only a few ways to spot and notice damaged tiles from the surface. The first and easiest is to look for and identify small sinkholes in the field, typically ranging anywhere from 2 inches in diameter to over 4 feet, and that are as deep as the tile. These sinkholes are caused when a single section of clay tile becomes crushed while the tile is still flowing with enough water to create a suction action that essentially liquefies the earth above it and then sends it downstream in the undamaged pipe. While crop damage is usually minimal with this type of break, it presents the greatest risk to farm machinery, especially if it is discovered by accidentally driving into it.

The second and far more common type of damage is a crushed tile made of clay or plastic that either stops flowing altogether or is crushed to the point where the flow is diminished significantly. Once the tile is crushed water will slowly start backing up and will eventually appear on the surface, either as very obvious standing water or more subtly, as otherwise healthy crops start to show signs of excess moisture. These are the types of tile damage that are hard to determine in the field, since the damage may take years to manifest itself. It is not uncommon for a partially crushed tile to finally build up enough sediment that it stops working altogether three to five years after the initial damage. Also, the damage will not show itself in particularly dry years, or during years with well-spaced rain showers. The tiles were designed to quickly remove the excess ground water after major rains or flood events. So, without these rains a broken tile may show no signs of apparent damage.

Typically the landowners or farmer tenants will approach you with concerns about damaged tiles. Their extensive knowledge of their property helps them identify subtle year-to-year nuances that would otherwise go unnoticed by construction personnel. If they indicate that there is a broken tile in the area, it is usually best to assume that they are correct. Ideally, it is advisable to line up a local tiling contractor to come in and make the repairs as needed. However, if you plan on repairing the tiles yourself, prepare for a little trial and error to find the physically damaged spot. Many times the wettest location is not where the tile is actually broken, but where it has built up enough "head" to become apparent on the surface.

Unless it is obvious where the tile is damaged, start by digging a trench perpendicular to the suspected direction of the tile. Once you find the tile, it is easy to discover where you are in regards to the damaged section. If water is boiling up at you from the tile, you are upstream of the break; if it is dry, then you are downstream. Keep narrowing in on the damage until you find the crushed section. Also, keep in mind that if you suspect that it was crushed by tracked equipment instead of cut by a collector line, it is an excellent idea to look 20 feet up- and downstream for where the other wheel track crossed the tile.

Once you find the break, it is a relatively simple process to remove the damaged section and splice in a new piece. However, based on the level of water the tile was holding back, you may have to allow it to drain for several days or pump the water out of the hole to make an effective repair. Another suggestion is to have a small dry-erase board and camera with each tiling crew. Instruct your crews to note the tile type, size, location (GPS coordinates), date fixed, and the approximate heading of the tile. If you have the capabilities, plot these locations on a map and provide the photos to the landowners upon completion of the project. Also, keep a set for your records as you may be dealing with making repairs on those tiles for several years after construction.

Damaging tiles in farm country may be inevitable, but being proactive in identifying the issues and making proper repairs is definitely the best remedy—other than not disturbing them in the first place!

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Merritt Brown
Rev1 Power Services, Inc.

Establishing your own post warranty preventative maintenance program, coupled with predictive maintenance, will reap benefits for owner/operators.

ONE OF THE LEADING REASONS why wind energy development is such an attractive investment opportunity today is that if developed, operated, and maintained appropriately the project will have a relatively short payback period with a long future of profit generation. This presumes that the turbine is operated efficiently for its 20-year life, that major components have not repeatedly failed, and that prudent maintenance practices were followed. As the project transitions into post-warranty operation and turns the corner from payback to profits, costs associated with maintenance strategies enter more into the O&M limelight. It is at this point where there may be a less compelling desire to maintain the turbines in the same way as they were when new, particularly for tasks related to preventative maintenance. The question then becomes whether it is as profitable to perform the same level of maintenance on an aging project, and if not, what needs to change? Simply continuing to follow the same preventative maintenance before and after the warranty period may not make the best sense. Establishing your own post warranty preventative maintenance program coupled with predictive maintenance will reap the most benefits, and if you are a risk taker there may even be a little room for reactive maintenance as well.

Because a wind turbine cannot be maintained constantly, we initially need some practical determination of when it is appropriate to perform maintenance. The OEM typically determines the interval, and sticking to it is affected by what is found during these activities. The result of following this routine is that much of the maintenance performed during the early years is probably unnecessary, while in the later years too much time may pass between visits that could result in increased unplanned outages. Also not very helpful, additional shutdowns in a new turbine's life to perform preventative maintenance may even contribute to the wear of the turbine components, leading to a shortened life.

Missing from the modern wind turbine preventative maintenance program are the site-specific factors that affect the operation and wear of turbine components. Preventative schedules are provided as turbine-specific, and while they address the normal operation of components, they stop short of addressing unusual environmental conditions that can greatly impact their wear cycles. The effectiveness of a schedule is dependent upon the root cause analysis program on it was based, and the ground rules used for its cost efficiency. Seldom, however, does a preventative maintenance strategy evolve into predictive maintenance, a strategy that bases maintenance need on the actual condition of the turbine component rather than on some preset schedule. In fact, two methodologies dominate modern wind industry maintenance programs, preventative schedules provided by the OEM and reactive maintenance performed in lieu of any other type of maintenance activity.

It might surprise readers that, according to a study by the U.S. Department of Energy, more than 33 percent of maintenance activities fall under a preventative strategy, while a whopping 55 percent are reactive. The wind industry is full of examples where this run-to-failure policy replaces any other type of maintenance activity and where it is presumed that the maintenance and replacement costs for this type of service is actually less than the preventative maintenance costs. This is a policy that allows a turbine component to run until it breaks down, at which point repair or replacement will be performed. A reactive maintenance program is paradoxical in that, for new equipment there will likely be minimal incidents of failure. We experience that any equipment, no matter how little maintenance is actually performed, will likely operate for some time without failure. As some large project owners choose to waive an annual transformer oil analysis program, they in return accept a few transformer failures whose aggregate cost to replace could be more or less than the monitoring program itself. A project owner might decide that it's okay to run a transformer to failure as long as a failure itself doesn't result in an environmental hazard. It may be acceptable to not replace worn blade bearings as long as failure of the blade doesn't result in catastrophic damage to the turbine structure. A damaged gearbox can continue to operate to failure as long as other drivetrain components are spared from the event. Those are some pretty big considerations in a post-warranty world because, while waiting for the component to fail, the life of the turbine is being shortened. During the time we think we are saving maintenance and capital cost by performing only reactive maintenance, we may actually be spending more than we would have under an observable maintenance approach. Owners should realize there is a place for different maintenance practices in the wind industry. It begins with understanding the actual status of the overall project, at all times.

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John Skiller
SKF Renewable Energy

Proper maintenance procedures will prolong the lifespan of your wind turbines and related components, and new technologies are being developed to simplify the process.

IN THE WIND POWER INDUSTRY, the sheer diversity in the design and size of wind turbines represents a challenge for the growing number of service companies offering maintenance and repair. Individual turbine power has increased as well as the number of wind turbine installations. Wind turbines are normally designed for an operational life of 20 years, but reality has shown that the survivability of major subsystems such as gearboxes falls short. This has brought a higher demand for service operations on gearboxes. Wind farm operators and utilities face the same challenge of how to maintain availability and reduce downtime, and especially when gearbox repairs are required on short notice.

KIT CONCEPT

Kits from SKF have the potential to make gearbox bearing replacement a more straightforward task for the most common gearboxes in use. Initially SKF has developed kits based on the most popular wind turbine gearbox types. The goal is to cover the majority of the common types on the market. The new bearing kits combine SKF's strong industry knowledge with manufacturing capabilities and distribution expertise. SKF can determine the components needed for refurbishment and deliver a complete kit specific to different gearbox types.

For the service provider and the wind turbine operators, the kits offer a number of practical and potentially time- and cost-saving benefits. Since SKF holds the kits in stock, they can offer swift delivery from a dedicated source, which can help reduce downtime and lost productivity. Holding of a stock by the workshop is eliminated because the kits provide the requirements of each individual repair job so inventory and warehousing costs for the service company are significantly reduced. Having the bearings available as kits will make it easier for the wind farm owner or the service provider, avoiding the time spent searching and simplifying the sourcing of multiple parts. All this is supported by the worldwide availability of SKF distributors and a well-developed logistics network.

SOLUTIONS REQUIRED

Wind power is booming. In 2009 the world's wind power capacity grew by almost a third, bringing total installations up to 157.9GW. Although that's only 2 percent of the world's total electrical energy generation capability, growth continues at a high level. This brings challenges not only from the perspectives of design, manufacture, and installation, but also from the perspective of the operational and maintenance requirements of an ever-larger asset base. All that machinery needs maintenance, particularly key components such as the gearbox. Repairs and refurbishment become ever more pressing issues as turbine systems become older through the years.

According to the publication Wind Energy—the Facts, produced under an EU-funded program, operation and maintenance costs for a new turbine may easily make up 20 to 25 percent of the total average cost per kWh produced over the lifetime of the turbine. While gearboxes have around a 10 percent annual chance of failure, the consequence of that failure can be disproportionately costly. The loss of productivity when the gearbox is in a workshop while waiting for spare parts can add up to thousands of dollars a month through reduced generation capacity. Bearing availability can be a problem, starting with getting to know which types of bearings are actually in the gearbox. SKF wind gearbox kits are designed to offer faster, easier maintenance when bearing replacement is required."

SKF believes the kits will be especially helpful to the emerging third-party service industry supporting wind farm operations, concerning turbines in their post-warranty phase. Whether these service companies are associated with the original equipment makers or based in-house with the power-producing company itself or operating as independent companies, all share the goal of keeping the turbines up and running.

> "Having the bearings available as kits will make it easier for the wind farm owner or the repair workshop."

EXPANDING SERVICES

SKF has focused on applying reliability-centered maintenance technology to wind turbines for many years and has extensive knowledge and experience in providing remote condition monitoring service, asset management service and spare parts management services. By providing wind farm operators and utilities with fast, single-source access to the right parts for the right application, SKF wind gearbox bearing kits simplify the process of identifying and ordering components. Available for rapid delivery for a range of gearboxes, the kits help wind farms reduce short-notice repair times and can also serve as a proactive maintenance upgrade to boost gearbox performance.

John Skiller is global business engineer at SKF Renewable Energy. Go online to www.skf.com.

Michael Graska
Professional Logistics Group, Inc.

Variability is the "ghost in the machine" when it comes to supply chain efficiency. Learning what the variations are will increase your chances of incurring unnecessary delays.

I WAS ATTENDING A SUPPLY CHAIN networking event recently when the discussion turned to problems within supply chains. Several of the senior executives at the table were complaining about spending millions on software and other technologies and still not seeing the results they'd expected. A friend at the table who knew my background asked what I thought. Of course I explained that I was not sure of all the issues concerning each of the companies at the table, and so I hesitated to give a succinct answer. I listed numbers issues that could affect supply chain efficiency, but my friend pinned me down and asked "what is the one thing that causes the most supply chain problems?" I paused and thought for a moment before responding. "Well, if I can only state one issue and only one, then I would say it's variability." Those at the table asked me to explain further, so I continued. "Variability will cause all sorts of supply chain inefficiencies. Variability can happen at any point within a supply chain, and these events can amplify throughout the supply chain, causing even more problems."

Variability within a supply chain is the major factor preventing optimization of a supply chain. This holds true whether you are shipping small commodity items such as screws, or large project items such as wind turbine blades. To improve the efficiency of a supply chain you have to eliminate as much variability throughout the chain as possible. Sounds simple, but it can be exceptionally difficult based on the complexity of the supply chain, and the events that can have variability are numerous. What are some of things that can have variance with a supply chain? I categorize them as internal events and external events.

Internal events are things that can be controlled by the stakeholders in the supply chain. Some examples are items such as information, material, and execution. Examples of information variability are wrong information on commercial invoices, bills of lading, schedules, requests, and other types of communications between entities handling the cargo. We have all experienced a delay of a shipment due to incorrect information on a piece of paper. The higher the variability of information, the more likely it is that delays will occur. Time is taken to resolve miscommunications resulting in delays in the supply chain.

Material discrepancies can be as simple as not having enough pallets for all the cargo, or as complex as not having the correct crane to accommodate the load. Once again, these are variances to the requirements. Especially in project cargo transportations, stow, load, and lifting plans are created based the dimensions and weight of cargo. Deviating from the plan (a variance) could cause a delay in shipment.

People are responsible for the execution within the supply chain. If there are variances in the activity of people performing their jobs, it will result in variability within the supply chain. If a crew is late to a job or not trained properly, this will result in a variance, which in the end will lead to disruptions within the supply chain. Another example is your supplier compliance, and how well they deliver.

> **"Variability within a supply chain is the major factor preventing optimization, and this holds true whether you are shipping small items or wind turbine blades."**

External events may or may not be within someone's control. Weather is not controllable, but our response to it is. Are you prepared for inclement weather, and have you taken the proper precautions? Understanding the volume of traffic within your supply chain will allow you to plan better and eliminate as much variability as possible. Other examples of external events are labor rules and regulations and differences between state DOT regulations, including escorts and permits.

How can you take variability out of the supply chain? Start by focusing on the internal events that may cause the greatest variance. You can't fix what you don't measure, so take the time to measure what is happening. I would also apply quality control techniques such as statistical process control, root cause analysis, and Pareto identification. Once the internal events are under control you can turn your attention to external events. While they all may not be controllable, at least contingencies can be planned and implemented. Doing so will save both time and money.

Can all variability be eliminated? I don't believe so, but some rather famous companies have certainly come close.

Michael Graska is project leader with Professional Logistics Group. For more information go online to www.prologisticsgroup.com.

WIND ENERGY SERVICES CO.

By Russ Willcutt

With a parent company known as a pioneer in manufacturing blades and other wind components, the maintenance services provided by WES are unsurpassed.

FOR THE PAST 24 YEARS Molded Fiber Glass Companies (MFG) has been manufacturing blades, nacelles, and spinners for the North American wind industry, specializing in composite structures for more than six decades in all. With so many years of accumulated knowledge, it was a natural decision for the company to launch Wind Energy Services (WES) in 2007 to offer a full range of blade repair, inspection, and maintenance services to wind farm owner/operators.

"MFG has 13 factories, and five of them manufacture components for wind energy," according to Gary Kanaby, director of sales for WES. "We've been inspecting and maintaining the blades we manufacture for years, so WES was a natural offshoot of that experience, offering these specialized skills onsite for any make of blade as a resource to owner/operators."

In describing the company's capabilities, Kanaby says WES takes a "cradle to grave" approach, beginning with inspections as components reach the construction site. Various repairs are performed onsite as work progresses or when damage occurs, we provide ongoing preventative measures during and after the warranty phase and even end of life disposal. "We want to be involved in the entire lifecycle of the blades," he says, "all the way from monitoring their safe delivery, to ensuring their productivity during active service, to taking them down when the turbines are retired."

A unique benefit for customers derived from the relationship between MFG and WES is their ability to service blades and other composite components that can't be repaired onsite in three of MFG's manufacturing facilities—Aberdeen, South Dakota; Gainesville, Texas; and Adelanto, California. These factories are fully equipped with overhead cranes, materials, and the skilled labor needed to restore the parts to "like-new" condition.

Preventative maintenance can help avoid a repair scenario, however. "We have been trained by Mankiewicz on how to use their blade coatings properly," Kanaby says, "and also by 3M on how to apply the tape they've developed to protect the leading edge of the blade. The reason that's so important is because when that edge begins to wear, the blade becomes less productive, which affects the whole turbine by throwing everything off balance. Evidence has proven that when we're able to conduct this type of preventative maintenance early on, there is considerably less downtime due to emergency repairs. European operators have long understood the value of this type of approach, and it's finally starting to catch on in North America as well."

Another service WES offers is dynamic blade balancing, which involves both aerodynamic and mass balancing. During tower erection these tests ensure that the blades are balanced and working at maximum efficiency. Down the road the tests check for continued integrity, as water and even oil can collect in the blades and upset the balance, leading to a host of problems within the nacelle.

WES has recently begun offering replacement spare parts for older model turbines. Operators in need of a blade, nacelle, or nose cone due to a devastating weather event or normal wear frequently discover that the OEM no longer carries what they need, or may no longer be in business. To answer this need WES can supply newly manufactured spares through MFG made from tooling generated from the customer's part. This process is fast and does not injure the original part.

Under the heading of expert services, WES can address lightning damage, tip repairs and replacement, shipping- and construction-related damage, splitting and erosion of the trailing and leading edge, structural repairs, gelcoat and paint, blade balancing, and bolt tensioning and replacement. Inspection services include high-power photography, physical inspections from a platform or crane, lightning system continuity checks, and issuing third-party inspection reports. Other services include tower inspection and cleaning, as well as repairs to the nacelle and spinner. Scheduled maintenance packages are also available, as are end of warranty inspection services.

WES can deploy teams rapidly from three strategically located depots to locations throughout the continental United States. The company currently has projects underway in Maine, California, Texas, Colorado, Minnesota, Iowa, and elsewhere. MFG and WES support the industry through active involvement in standards development through the American Wind Energy Association (AWEA).

According to Kanaby, what sets WES apart is its long experience manufacturing blades and other components through MFG, as well as its engineering capabilities. "We are known for being able to handle the most difficult repair jobs," he says. "We may not be the largest service company, but we provide the best services, and that's why we're growing."

Call (877) 349-2523 (FIX-BLADE), or go to www.windenergyservicesusa.com. Also visit www.moldedfiberglass.com.

A FOUNDATION FOR SUCCESS

Rammed Aggregate Pier systems by Geopier are now commonly used for foundation support solutions on tower sites around the world, helping to allay geotechnical risks.

By Brendan FitzPatrick, P.E.

Brendan FitzPatrick, P.E., is director-North America at Geopier Foundations Company, Inc. Call (704) 799-3185, e-mail bfitzpatrick@geopier.com, or go online to www.geopier.com.

SUCCESS OR FAILURE IN CONSTRUCTION is largely determined by how well risks are managed. Foundation system selection represents one of the largest risks to any project because of the inherent uncertainty that exists when working in the ground. This risk is never more critical than on wind farm projects where the project "site" covers many square miles and geotechnical conditions may vary drastically from one turbine location to another. For the maximum chance of success on any project, owners, designers and constructors must manage risks carefully by selecting foundation systems that are cost-effective, reliable and also adaptable to variations in geotechnical conditions.

FOUNDATION OPTIONS

Foundation system selection needs to consider performance as well as construction cost and schedule. Even the most efficient foundation systems must also have sufficient flexibility to adapt to changes in conditions that may be encountered in the field during construction.

The most efficient foundation scenario involves support of a turbine on competent soil at the design foundation bearing elevation. In this instance, a large concrete, inverted "T" foundation is used for turbine support. This approach represents one with the least expense and lowest foundation construc-

Fig. 1: Turbine site prior to RAP installation.

tion risk. Unfortunately, wind projects are sited in soil conditions that often exhibit insufficient support capacity to meet performance requirements and additional foundation support measures are needed.

One option in wide use involves over-excavation and replacement of poor soils. This approach requires large volumes of soil be excavated and removed at the tower location and the area is backfilled with thin, controlled lifts of high-quality engineered aggregate (similar to roadway construction material) prior to foundation construction. The tower foundations are then designed and constructed as the same inverted "T" foundations as those supported on natural competent soils. While this approach meets performance requirements if constructed properly, the risk of schedule delays and cost overruns remains high because of the potential for encountering high groundwater (requiring dewatering operations), inclement weather or deeper excavation requirements than anticipated to remove unsuitable soils.

Other options, in cases where the poor soils extend too deep for excavation, fall into the "deep" foundation category. Deep foundations are used to bypass thick zones of soft or compressible soils to transfer foundation loads to more competent bearing materials. These include driven piles, drilled piers (caissons), augercast-in-place piles, grout piles, and other forms of rigid inclusions. While these systems provide acceptable performance, tower foundation costs are typically much higher. These designs require thorough analysis to account for the behavior of the pile group under the complex turbine loads. Additionally, costs for deep foundations are often prohibitive because piles need to extend to depths sufficient to develop shaft resistance or bear on hard material (i.e. rock or hard glacial soil). Construction schedule risks exist from uncertainty of installation depths to reach bearing strata, low daily production rates, and difficulty with material delivery to the often-remote sites.

INTERMEDIATE SUPPORT

For more than a decade, many wind farm project teams have reduced performance and construction risk and saved time and money by considering support solutions beyond the traditional construction approaches. Rammed Aggregate Pier® (RAP) systems designed by Geopier Foundation Company have provided support for structures for over two decades. These Intermediate Foundation® systems have been used extensively on wind projects in the United States, Canada, Mexico and in Europe.

Fig. 2: An illustration of the process.

The concept involves densifying or reinforcing poor soils through the installation of stiff aggregate piers that uses high frequency vertical ramming energy during construction. Installation of RAP elements is accomplished by either replacement (Geopier® system) or displacement (Impact® or Rampact® systems) construction techniques to depths of up to 45 feet. The replacement system involves drilling a 24-36 inch diameter cavity depending on design requirements; placing thin lifts of aggregate within the cavity and vertically ramming the aggregate using a high-energy patented beveled tamper. The displacement system involves driving a specially designed mandrel and tamper foot into the ground using a strong static crowd force augmented by dynamic vertical impact energy. After driving to design depth, the hollow mandrel serves as a conduit for aggregate placement. Aggregate is placed inside the mandrel and delivered to the tamper head. The mandrel is then raised approximately three feet and then driven back down two feet, forming a one-foot thick compacted lift. Compaction is achieved through static down force and dynamic vertical ramming from the hammer.

During construction of each RAP system the high frequency energy delivered by the hydraulic hammer, combined with the beveled shape of the

Fig. 3: Turbine excavation reinforced and prepared for foundation construction.

tamper, not only densifies the aggregate vertically to create a stiff aggregate pier but also forces aggregate laterally, resulting in lateral stress increase in surrounding soil. The lateral stress increase reduces the compressibility of the surrounding soil and promotes positive coupling of the RAP element and the soil to create an improved composite, reinforced soil zone.

The system reinforces poor soils, which improves the bearing pressure of the reinforced zone beneath turbine foundations, controls total and differential settlement (angular distortion) of the foundations and improves the rotational and dynamic stiffness values to achieve the desired turbine performance. The soil reinforcement designs are developed on a project-specific basis depending on site and tower loading conditions to support shallow inverted-T foundations, like those bearing on engineered fill or competent native soils. The use of the intermediate solution eliminates the need for massive over-excavation or deep foundations and also allows for adaptability in construction based on soil conditions encountered at the site.

CHALLENGING SITES DEMAND FLEXIBILITY

Recently, engineers with HDR Engineering, Inc. (HDR) were faced with the challenge of designing a large wind farm in Franklin County, Iowa. The project involved the design and construction of 121 wind towers traversing 33,000 acres, or about 51 square miles. The project featured Vestas V82 model turbines, with 80-meter hub heights, capable of generating 1.65MW of power.

Working with the project geotechnical engineers (Terracon), the design team determined that the foundation risks for many sites could be managed cost-effectively by supporting towers on octagonal inverted-T foundations bearing on competent soils or perhaps limited areas of shallow over-excavation. Multiple, different-sized tower designs were prepared to accommodate the different soil conditions and variation in maximum allowable soil bearing

Fig. 4: Foundation excavation proceeds.

Fig. 5: RAP supported turbine.

pressures from site to site.

Typically, when over-excavation depths exceed three or four feet below the foundation, alternative approaches become more cost-effective. Many sites across the 51 square miles encountered these conditions where the shallow foundation option bearing on native soil was inappropriate. HDR and Terracon, working with Geopier engineers, found a solution by using an intermediate RAP approach to provide acceptable performance and keep foundation costs under control while utilizing the existing shallow foundation designs prepared by HDR. The soil conditions requiring reinforcement ranged from soft to stiff clay with occasional silt and sand layers to thick deposits of loose clayey sand, silt and sand. With variable soil conditions and groundwater levels as shallow as three feet at some sites, multiple RAP construction approaches (replacement and displacement) were required. The versatility of the Geopier technologies ultimately resulted in a solution for 37 tower sites.

Once selected, prime contractor RMT, Inc. utilized the RAP system constructed by licensed installer Foundation Service Corporation, Inc. (FSC), of Hudson, Iowa. During detailed design FSC and Geopier identified each site as either a replacement (Geopier approach) or a displacement (Impact) approach. Different RAP design approaches were then developed based on the different soil conditions for each site. The soil reinforcement designs incorporated a grid of RAP elements ranging between 56 and 100 piers per turbine site with piers extending 9-17 feet below the footing to reinforce the poor soils.

Construction of the RAP systems at each site was typically completed within two to four days depending on the installation method and soil conditions encountered. In some instances, unexpected variations in soil conditions resulted in the need to adjust installation methods. Fortunately, the RAP systems afford the flexibility to modify the construction approach (displacement Impact or replacement Geopier) with rapid changes to the RAP design made in a day or two and no subsequent structural design changes to the foundations. These adjustments allowed the project to continue moving forward to meet schedule goals despite unexpected variations in conditions.

Quality control testing on the project included the performance of full-scale modulus load testing to evaluate the response of the pier under applied stresses. Measurements confirmed the pier stiffness met or exceeded the design requirements when loaded to pier stress levels more than four times the maximum foundation stress.

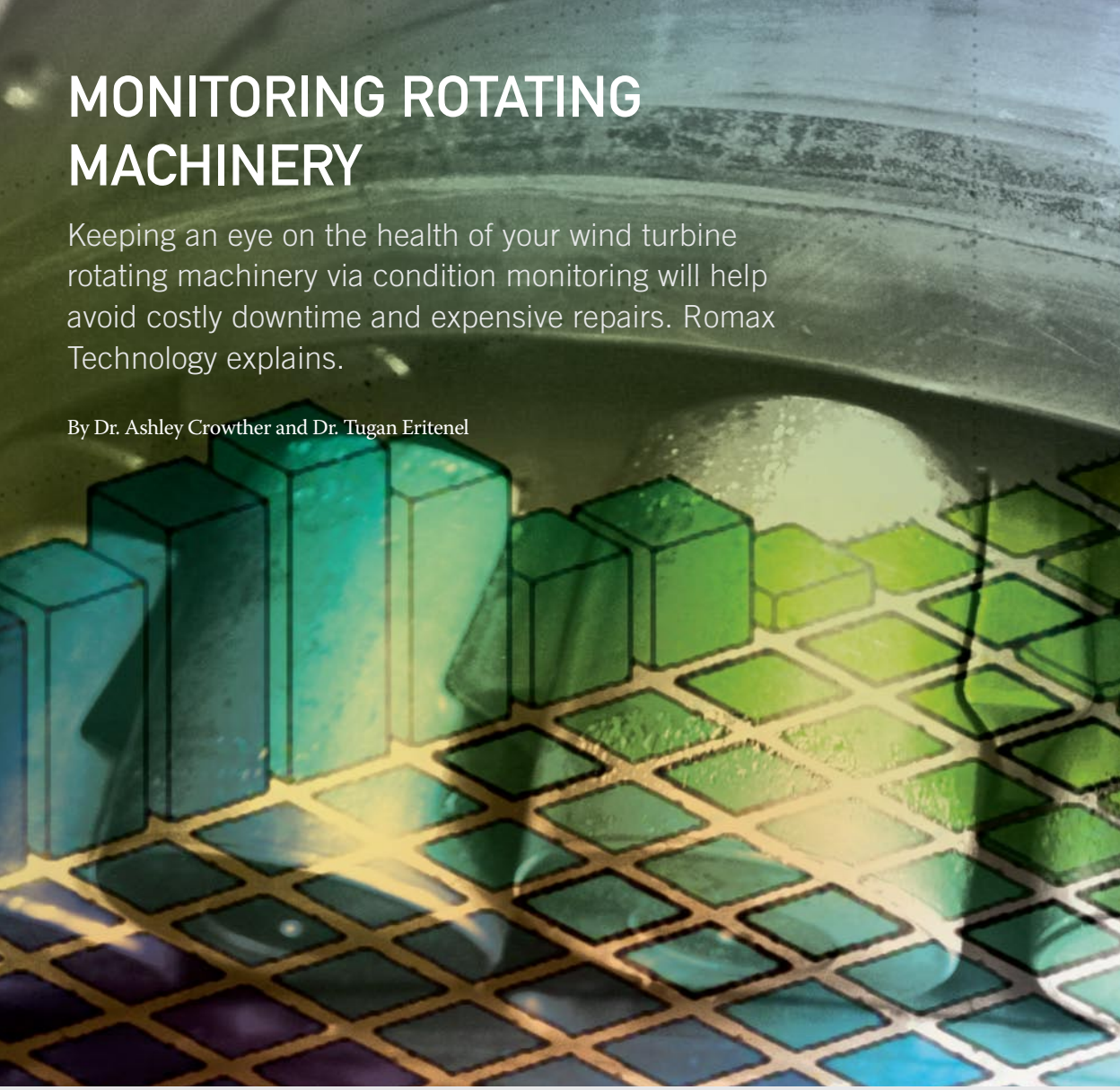
SUMMARY

Rammed Aggregate Pier systems are now commonly used for foundation support solutions on turbine sites across the Americas and Europe as a means to manage geotechnical risks and provide superior construction and performance. This intermediate foundation approach reinforces a variety of poor soil conditions, allows the use of cost-effective inverted-T foundations and provides flexibility during construction to make construction/design changes based on conditions encountered at specific sites to help maintain schedules. With over 1,000MW of towers supported, Rammed Aggregate Pier systems are fast becoming a preferred foundation support solution to manage geotechnical construction risks and deliver successful time and cost-saving solutions.

MONITORING ROTATING MACHINERY

Keeping an eye on the health of your wind turbine rotating machinery via condition monitoring will help avoid costly downtime and expensive repairs. Romax Technology explains.

By Dr. Ashley Crowther and Dr. Tugan Eritenel



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THE ROTATING MACHINERY IN A WIND turbine has demanding requirements. Consider that designing a wind turbine gearbox is equivalent to designing an automotive gearbox to last for two million miles, with 15 times as many cycles. The machine must be light and thereby flexible, and it is subject to transient loads and overload, idling conditions, and temperature extremes. Service of this long duty cycle machinery must be performed 80-odd meters from the ground.

Fortunately, various offline and online monitoring technologies help to keep an eye on the health of your machinery—vibration, temperature, and lubricant condition, for example. The technology is generally well established yet the application of monitoring is still challenging, and no all-encompassing gadget or approach is going to warn you of every machinery failure. Tuning monitoring equipment, or your approach to problems reoccurring in your wind farm and machinery, is generally a good step to take.

COMMON PROBLEMS

A few examples of common problems the industry is facing today include:

Type 1: Inclusions in gear material, from poor quality control on the raw material manufacturing. The inclusion acts as a stress concentration and can result

in tooth fatigue failures, often readily identifiable from visual inspection due to characteristic beach marks radiating out from the crack origin.

Type 2: Gear surface tempering (grinding burn), where the surface temperature of the case hardened gear has not been controlled properly during grinding. This can even lead to re-austenization and re-hardening of the material. Temper grinding burn will reduce the surface hardness and residual stress condition, which will reduce wear resistance. Re-hardening burn will produce a hard, brittle surface layer, and cracks may begin in the tooth surface and result in low life for pitting and fracture.

Type 3: Axial cracking in through hardened bearings, where the bearings are prone to cracking as they have inherent poor toughness and residual tensile stresses due to the heat treatment process (compared to case carburized bearings). They may suffer from hydrogen embrittlement, have superimposed hoop stresses from inner ring raceway fits, and they are often subject to harsh overload conditions in the wind turbine. The cracks may lead to the raceway slipping on the shaft, and potentially a catastrophic failure in the gearbox. Any cracks will also form a nucleation point for surface rolling contact fatigue, where the raceway surfaces will break up due to fatigue spalling.

Type 4: Poor load sharing conditions in double row spherical roller mainshaft bearings, where the downwind raceway of the bearing supports all the thrust loading from the blades, while the upwind raceway becomes unloaded. The operating condition is poor (i.e. the axial to radial load ratio on the downwind race is too high), and the bearing tends to suffer from adhesive wear and micropitting toward the roller ends due to roller skewing under the extreme load conditions. The generated debris then contaminates the grease, causing surface indentations on rollers and raceways, and eventually leading to a runaway surface fatigue failure.

These four examples are machinery problems that, if they happen two or so times in your fleet of 100 turbines, you can reasonably expect them to happen again. A Weibull analysis using the failure records will provide estimates of future failures with a statistical basis and indicate whether the failures are due to infant mortality, aging, or from some random external influence. Getting a grip on how to detect the problem consistently and plan your maintenance and repair in advance, as well as avoiding secondary damage or catastrophic failure, will bring a good payback.

DETECTING DEFECTS

Temperature trending is easy to do. Every modern turbine SCADA system records 10-minute temperature data for the gearbox oil and several bearings, mainshaft bearings, generator bearings, and various other locations such as pitch motor temperatures and generator winding temperatures. Temperature can provide a good indication of a problem (see fig. 1), which provides the distribution of temperature each week. The bearing showed a clear trend of overheating; the replacement was scheduled two months out when mean temperatures approached 75°C and the damage was approaching a critical stage (fig. 2).

Yet not all damage is obvious, or the trend slow. For example, if inclusions are present in the gear material the fatigue crack origin is likely to be subsurface, and cracking may propagate along the tooth axially some distance before reaching the surface, at which point a large tooth segment may be quickly liberated. This

is a catastrophic failure that requires immediate shut down. Detecting such damage should not be difficult. The RMS (root mean square value of the vibration level) will increase rapidly, and the envelope spectra (a demodulated vibration signal) will show an obvious issue. Figure 3 provides an easy "spot the difference" example.

An axial crack forming in a wind turbine bearing raceway is actually similar to the type of controlled experiment performed in research laboratories, where a raceway or roller has a line defect machined for production of a clear repetitive impulse. The crack will cause a sharp impulse when it passes through the bearing contact zone, exciting the structural system in a similar fashion to a modal test. The impulse will excite natural frequencies of the structure that are detected at the various vibration sensor locations, depending on the transfer function between impulse location and sensor. The natural frequencies become a carrier frequency, and when the envelope analysis technique is applied the signal is demodulated to provide the frequency of the defect. Figure 4 shows the frequency spectra for a bearing that has developed such a crack and the marked change in the frequency spectra.

Defects on inner raceway, outer raceway and rollers occur at different frequencies. For stationary outer raceway, an inner raceway defect is manifested by roller pass frequencies (RPFI) modulated with shaft frequencies (ω_s) as the crack rotates through the contact zone. The outer raceway defect frequency (RPFO) has no modulation for a fixed outer raceway. The roller defect frequency (2RSF) is twice the roller spin frequency as the defect hits the inner and outer raceway once per roller revolution and is modulated by the cage frequency (ω_c). These defect frequencies commonly include higher harmonics. Table 1 provides a summary for a fixed outer raceway.

AVOIDING FAILURE

Many installed condition monitoring systems (CMS) are configured with certain envelope analysis parameters, yet they don't necessarily band pass the appropriate carrier frequency to detect the crack. Figure 5

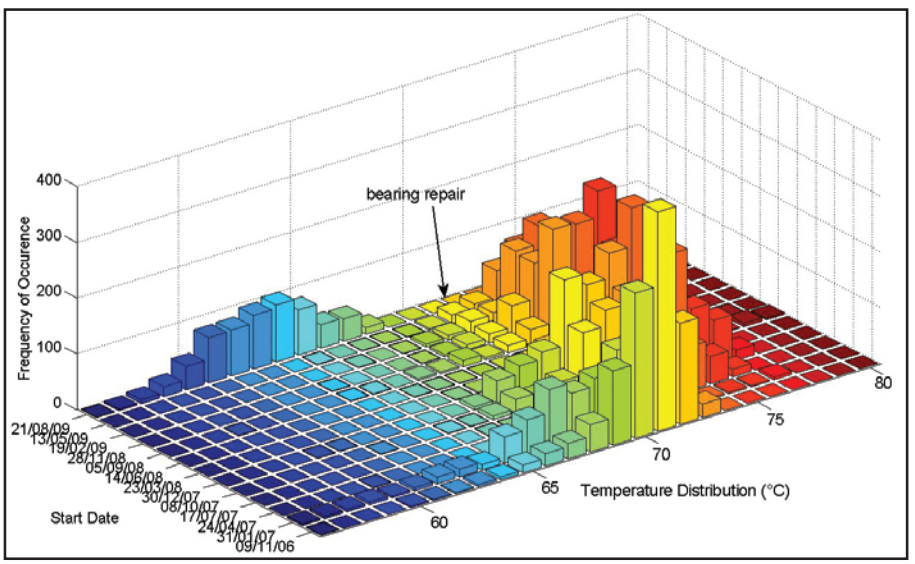

Fig. 1: Gearbox bearing temperature across wind farm.

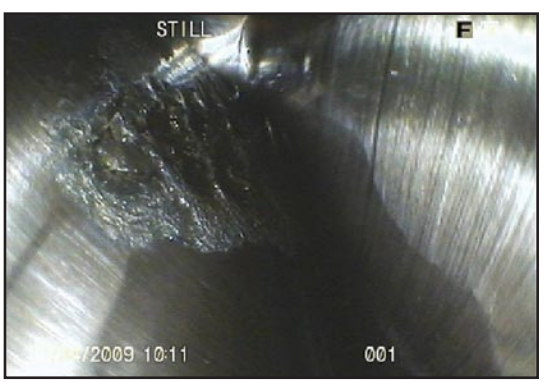

Fig. 2: Bearing suffering from macropitting leading to increases in temperature and vibration.

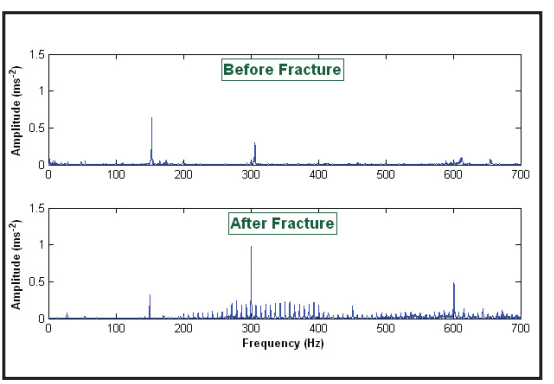

Fig. 3: Gearbox envelope spectra before/after gear tooth fracture.

illustrates this, with the RMS of a standard envelope (and RMS) from installed CMS compared to an envelope technique customized by Romax to find cracks occurring at this particular wind farm. In this case temperature data also showed no evidence of the crack formation and growth.

Main bearings failing from micropitting and surface fatigue are another challenge. Here the rotational speeds are very slow, and the bearing fault frequencies are falling in the range of 1-5Hz. The machine has speed and load variations within the same frequency range which brings some challenges. When the shaft

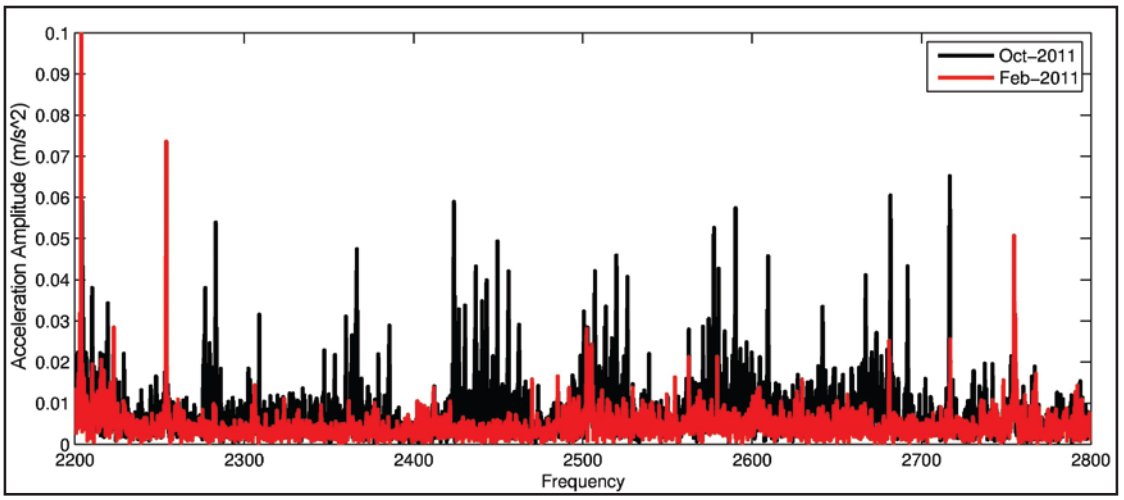

Fig. 4: Acceleration frequency spectrum for wind turbine in February and October. The increased response is from bearing axial crack. The vibration signal is from a gearbox accelerometer.

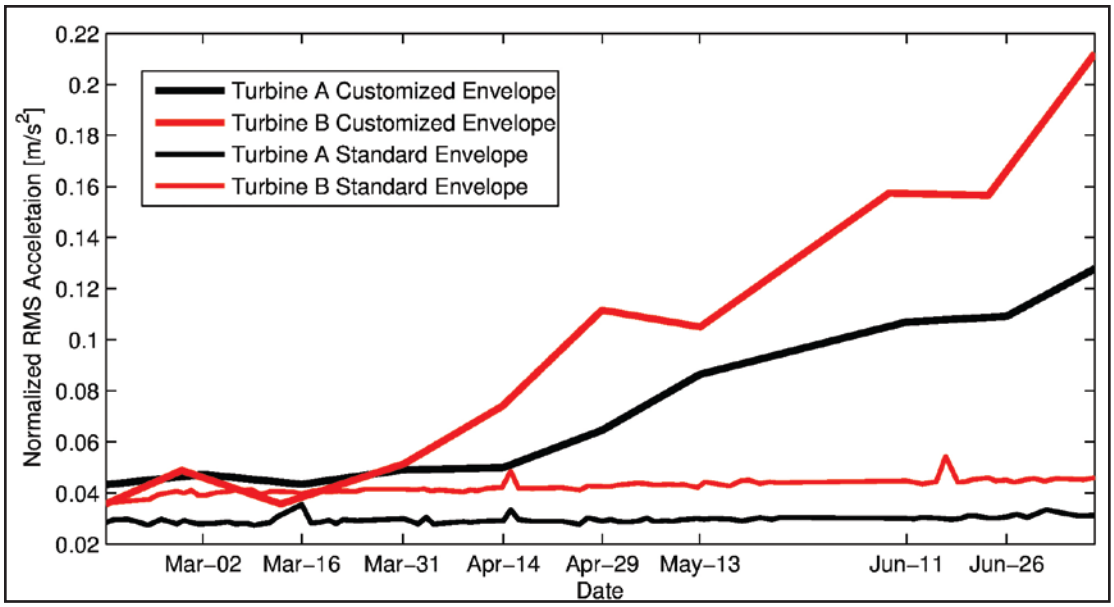

Fig. 5: Envelope analysis of the acceleration signal for wind turbine in February, August, and October. Dashed lines indicate bearing inner race crack frequencies with harmonics.

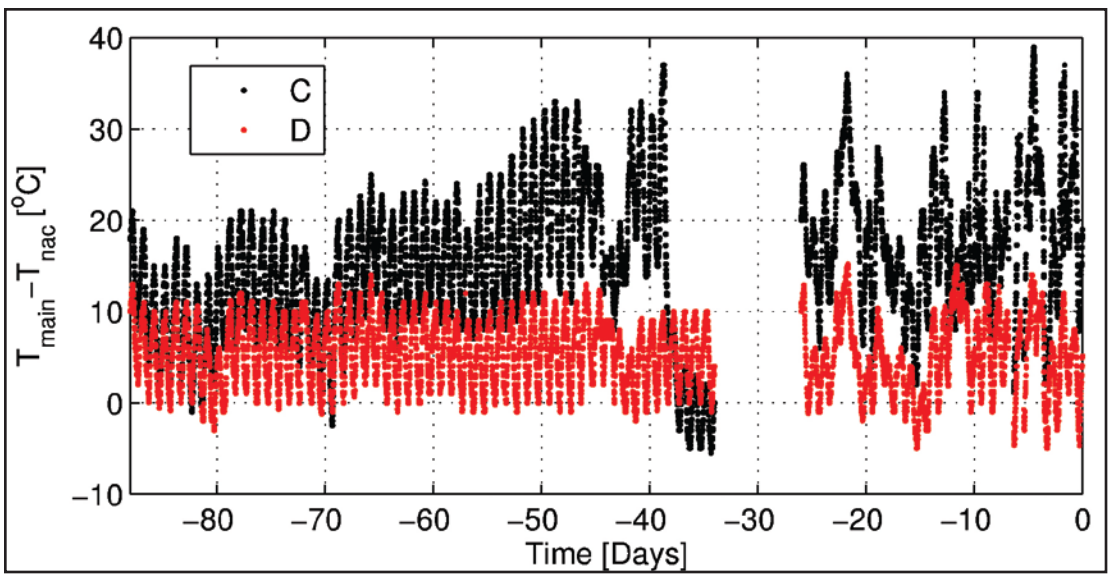

Fig. 6: Temperature trend for turbines A and B.

speed varies the machine frequencies vary with time, which smears the spectrum. In order to compensate for the speed fluctuations, the shaft speed is used to re-sample the vibration signal.

Nonetheless, a combination of techniques allows the detection of the bearing failure, which for this common failure mode can be six to nine months in development from initial damage to a critical state. Figures 6-8 provide temperature and vibration examples for a group of the turbines (note that the days on the graphs correspond). Here several bearings at the site are failing, yet temperature trends are only clear in one machine, where the damage is severe. A combination of several vibration techniques including customized envelopes and trending fault frequencies as well as certain envelope bands does yield good results. Once a certain level of damage is reached, the bearing defect trends can decrease (fig. 7). This is a sign that the damage has progressed from isolated areas to a large proportion of the raceways and rollers, as was the case when the bearing was inspected at day 0. The customized envelope is providing a much earlier and clearer indication of damage, and the temperature trend only provides a late

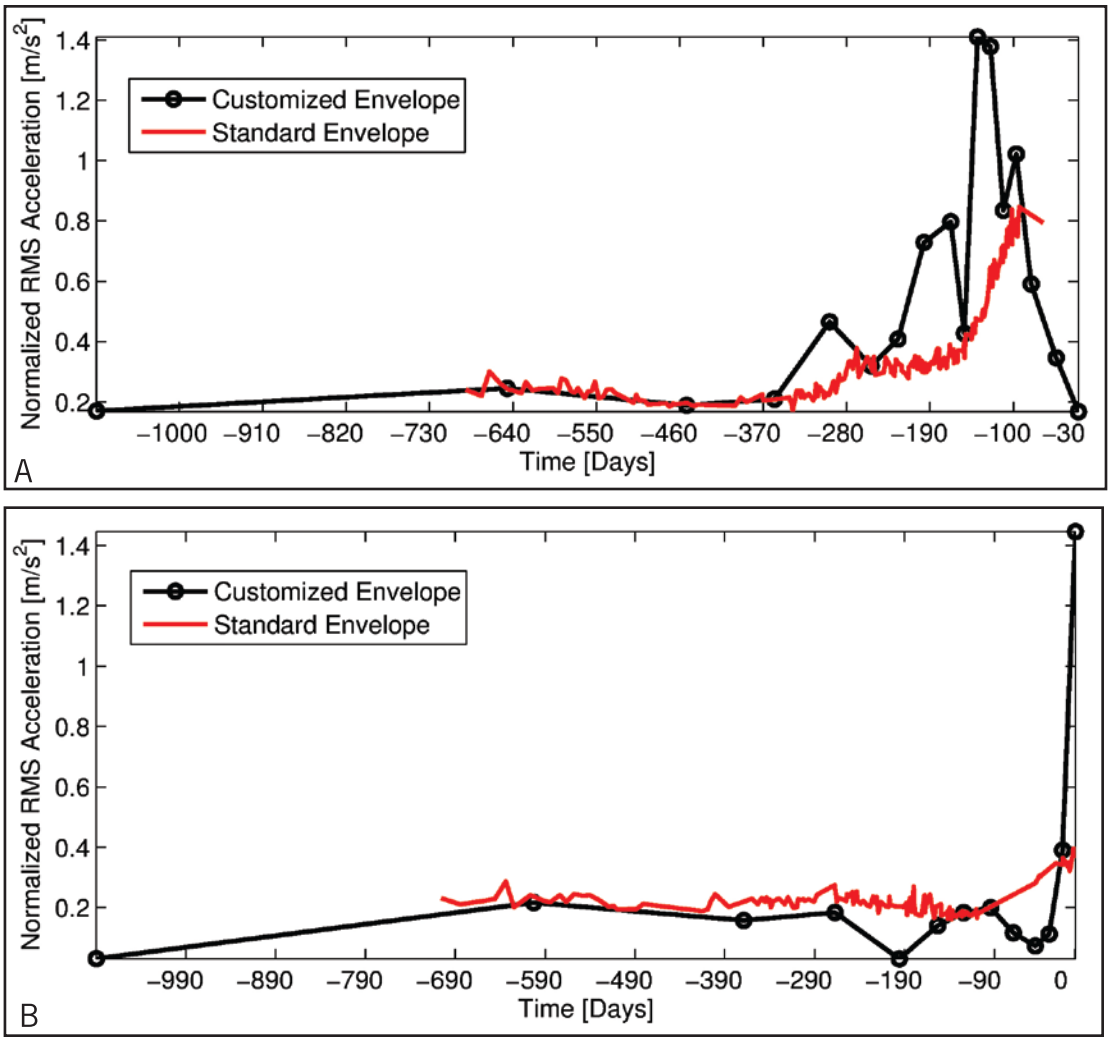

Fig. 7: Vibration trend of (a) turbine A and (b) turbine B. RMS values are normalized for easy comparison.

indication. See fig. 8 for an image of the condition of the main bearing for Turbine A at -128 days, and fig. 9 during teardown inspection by Romax engineers.

Understanding the root causes of failures and not having surprise problems that stop or reduce production at your wind farm reduces O&M costs. When failures occur, perform root cause analysis with experienced inspection engineers, gear and bearing designers/analysts, and metallurgists. Use the turbine data that is available, whether SCADA/vibration or both, and develop approaches that work well for the failures that occurring commonly. Conduct an annual vibration data acquisition and as-

Fig. 8: Turbine A main bearing condition at -128 days.

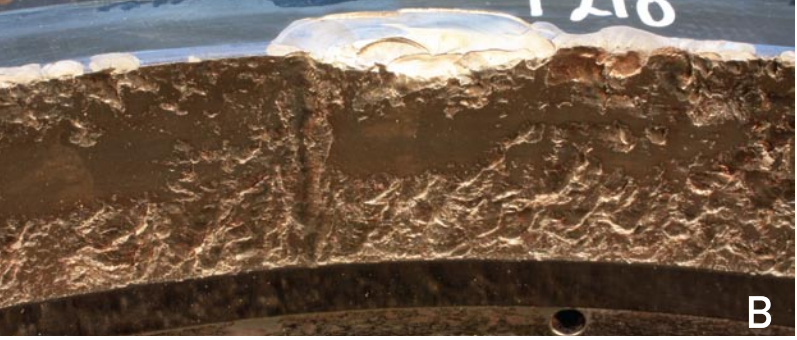

Fig. 9: Turbine A main bearing condition at RCA teardown inspection (a) showing outer race compression (b).

sessment campaign if CMS is not installed and is too costly. Apply reliability statistical methods to predict component lifetimes, and if poor consider re-engineering or other mediation to extend service life.

CONCLUSION

Romax Technology is a global engineering consultancy providing services to the wind industry. We have designed certified gearboxes for nine different turbine manufacturers and provide services to wind farm owner/operators including machinery inspection, SCADA assessment, vibration analysis, root cause analysis, and problem solving. Romax has U.S. offices in Boulder, Colorado, and Troy, Michigan.

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CHANGING WIND FARM REQUIREMENTS

Wind turbine builders will need to address the changing requirements of wind farm operators in a cost-effective manner to remain competitive. Moog explains.

By Dr. Sherif El-Henaoui

Dr. Sherif El-Henaoui is the European marketing manager for Moog, Inc. Visit online at www.moog.com.

THE WINDS OF CHANGE MAY SOON affect wind turbine design. Moog recently conducted a worldwide survey of wind farm operators and wind turbine builders to better understand their needs vis-à-vis blade pitch control. We found that, excluding macroeconomic forces, there are three trends likely to affect the design of wind turbines in the medium term. First, the world will see new wind farms in hard-to-reach areas with harsh weather conditions. Second, wind power will account for a larger part of total electricity supply. And third, there will be an increased focus on improving turbine efficiency, especially in mature markets.

Addressing these issues while maintaining rapid growth will be challenging. Wind turbine builders will need to nurture mutually beneficial relationships with key subsystem suppliers in order to improve performance, while increasing production volume and expanding their geographical scope.

OFFSHORE AND ELSEWHERE

As wind energy grows in importance, new wind farms will increasingly be located in harsh environments that are difficult to reach. Offshore installations present particularly difficult issues. Offshore wind capacity is growing fast, with 13,500MW of new capacity expected to be installed globally between 2010 and 2014 [1]. The

current generation of offshore wind turbines face strong wind conditions and waves one meter high or more.

As the number of offshore wind farms grows, operators and owners are likely to locate these farms in deeper waters and further from shore. In the United Kingdom, for example, the average maximum depth of water in which wind turbines are located is projected to increase from 15.6 meters for projects commissioned between 2005 and 2009 to 27.1 meters for those commissioned between 2010 and 2014. Similarly, the distance from shore is projected to increase from 9.1 kilometers to 19.8 kilometers [2].

A similar trend will apply to onshore wind farms, with new wind farms increasingly being located in remote locations with harsh climates. China, for example, has declared its intention to create seven wind power bases with a capacity of at least 10GW each by 2020. Two of these are in Eastern and Western Inner Mongolia. Inner Mongolia is bitterly cold, with long winters during which temperatures can drop as low as -23°C. Blizzards are common in winter and there are frequent sand storms during the short summer.

TOTAL ELECTRICITY SUPPLY

In its reference scenario, which assumes that there are no major changes in energy policy, the International Energy Agency (IEA) expects wind power as a percentage of total electricity generated globally to increase from 0.9 percent—the share in 2007—to 3.7 percent in 2020, and 4.5 percent in 2030. Under its 450 scenario, which assumes that countries take coordinated action to control greenhouse gas emissions, the share of wind increases to 5.1 percent in 2020 and 9.3 percent in 2030 [3].

The share of wind in Europe will be significantly higher than the world average. The IEA projects the share rising to 14.6 percent in 2030 in its reference scenario and to 20.1 percent in its 450 scenario for the European Union. The shares in Denmark and Spain are likely to be even higher than this (fig. 1).

INCREASING SCALE

The scale of wind farms is also increasing, with 50+ MW wind farms becoming more common. This is especially true for China, the U.S., and offshore installations. In addition, clustering of wind farms within a region will become more common (e.g., China). The growing scale of wind farms increases their impact at a local level, since they account for a larger share of total electricity production within a region. Wind turbines are also expected to become larger in size. The average wind turbine size increased to 1,599 kW in 2009. It is likely to increase further as operators install larger turbines in new locations and they replace existing wind turbines in Europe with new models.

Repowering of older, smaller wind turbines in mature European markets like Denmark, Spain, and Germany to increase output from high quality sites will accentuate this trend. Survey respondents generally agreed that repowering would gain importance in Europe. “Some wind parks are almost 10 years old, so we will see a lot of them being repowered in the next 10 years,” according to a European wind turbine builder. “This is currently occurring on a small scale in Denmark and Germany.”

“In Europe, land is restricted and many plants are aged,” a U.S. turbine manufacturer adds. “Therefore, they will have to be replaced.”

As wind’s share of total power generation rises, operators will require accurate wind power predictions to schedule the operation of other generation resources. This becomes important when wind energy’s share of

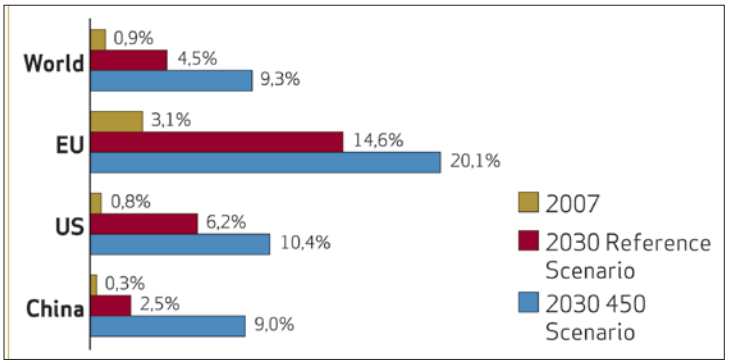


Fig. 1: Wind energy percentage share of total power generation (Source: International Energy Agency).

installed capacity reaches 5 percent, and critical at 10 percent.

FOCUS ON EFFICIENCY

The top 15 wind farm operators accounted for 35 percent of total wind power capacity in 2008, versus 23 percent in 2003 [4]. Utilities will continue to increase their share of wind power capacity since they are cash rich and do not face the financial constraints that developers do.

The growing role of utilities in wind power is leading to a greater focus on efficiency. They are demanding reliable solutions and will focus more on energy efficiency, uptime and O&M cost management. Respondents to our research questions generally agreed that operators were increasing scale in wind power and would demand higher levels of operational efficiency. A representative of a European consulting firm laims that large energy suppliers will become the main operators of wind farms, which means that requirements in terms of quality and efficiency will become more demanding. A European wind turbine builder adds that "The more plants they operate, the more they are forced to address efficiency."

These trends are likely to change the factors that wind farm operators manage and measure and, therefore, the attributes they look for in the wind turbines they purchase. There was general agreement among survey respondents that reliability was becoming more important in influencing the purchase decisions of operators. Operators want more output and there is a trend toward larger wind turbine systems. However, when breakdown or failure occurs, the larger the system the bigger the loss. In other words, reliability and uptime are extremely important. Or, according to a U.S. manufacturer, "Technical availability is more important, even if the price of the turbine is higher. Our contracts guarantee technical availability and actual performance. If these are not fulfilled, we provide rectification or compensation or both."

Reliability is seen by survey respondents as especially important for offshore installations, since these can be difficult and expensive to access in the event of a failure. Condition monitoring systems—which usually monitor the gearbox, bearings, and generator—are likely to become more widely adopted in the future for a number of reasons.

First, the growing size of wind turbines exposes operators to greater loss of revenue in the event of failure, as well as the cost of repair. Operators are therefore more willing to invest in monitoring systems so they can detect potential problems early, carry out preventive maintenance, and minimize downtime. "The other important factor is the size of the turbine," according to the operator of a wind farm in the U.S. "If I have a $2 million machine

and the gearbox costs $500,000, then I definitely want to use condition monitoring."

Second, operators feel that condition monitoring is more essential for offshore installations than for onshore because of poor accessibility and the high cost of maintenance. The growth of offshore wind farms will therefore lead to growth in condition monitoring. The main objective is to keep mean time between failures (MTBF) as low as possible, especially for offshore installations, since maintenance for offshore involves more cost and more risk. Condition monitoring is therefore essential, especially for offshore parks with limited access.

Third, operators see a greater need for conditioning monitoring for wind turbines located in harsh environments. The proportion of wind turbines in such locations is likely to grow over time. As a European wind farm operator explains, "If the turbine is located in a very windy environment, the probability of it breaking down is high, so we would install a condition monitoring system on a windy site."

Fourth, insurance companies are increasingly requiring condition monitoring systems for offshore turbines and may offer favorable terms for onshore turbines with these. And finally, large utilities are more willing to invest in condition monitoring systems, since they have used these for other forms of power generation and understand the value they provide.

FOCUS ON PITCH CONTROL

Accurate forecasts and the ability to conform to the grid code will grow in importance as the share of wind power in electricity generation increases. Some of these requirements can be met by varying the output from the wind farm, which can be done relatively easily if the wind farm uses pitch-controlled wind turbines. The increasing interest in improving turbine efficiency in mature markets is also likely to stimulate interest in pitch systems, since these can help improve turbine operation through reduced friction, better wind utilization, or both.

The growing size of wind turbines will also increase the importance of pitch systems because of their role in managing loads, which reduces wear on components, minimizes downtime and increases lifetime. Individual pitch control, which dynamically adjusts the pitch of each blade in real time to optimize rotor loading, is also likely to be more widely adopted in the future. Survey respondents expressed strong interest in this new technology. A Japanese wind farm operator says that "More precise response to wind conditions would enhance life-time and revenue of the wind turbine, and is therefore desirable."

CONCLUSIONS

Wind turbine builders will need to cost-effectively address the changing requirements of wind farm operators to remain competitive. The key issues wind turbine builders need to address include:

- Finding a cost-effective response to the need for greater reliability. Pitch control will be a key system that requires more attention;
- Catering to the likely increase in need for condition monitoring;
- Assisting wind farm operators to satisfy increasingly stringent grid code requirements.

Addressing these challenges and satisfying customer expectations is challenging. Wind turbine builders are unlikely to do it alone. Developing mutually beneficial relationships with subsystem suppliers who understand these requirements is a key to success.

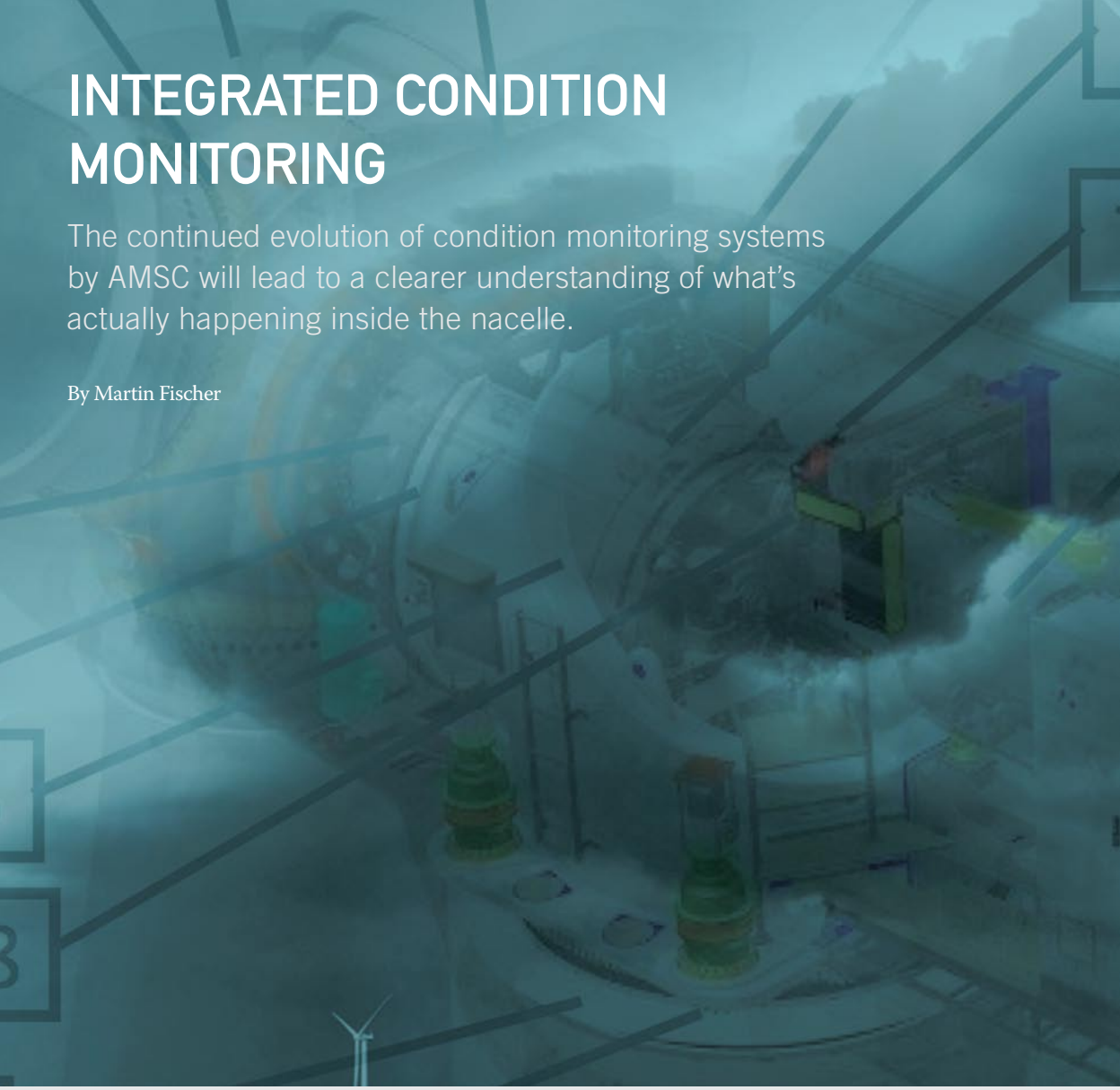
REFERENCES:

1) World Market Update 2009. BTM Consult, March 2010
2) UK Offshore Wind-Charting the Right Course. BWEA
3) World Energy Outlook 2009. International Energy Agency
4) World Market Update 2009. BTM Consult, March 2010

INTEGRATED CONDITION MONITORING

The continued evolution of condition monitoring systems by AMSC will lead to a clearer understanding of what's actually happening inside the nacelle.

By Martin Fischer



Martin Fischer is general manager of advanced technology at AMSC. Call (978) 842-3000 or go online to www.amsc.com.

CONDITION-BASED MONITORING has been proven to provide significant cost savings in many industrial applications employing rotating equipment, including wind energy. It leads to high availability, low O&M costs, and a lower overall cost of energy. Condition monitoring systems take the surprise elements out of the actual operation by providing a view on what is actually happening inside, especially when it comes to large wind energy converters (WEC) or offshore turbines. By being able to accurately determine parts that are soon going to fail, maintenance can be planned much more effectively.

ELIMINATING GUESSWORK

Wind turbine reliability today still causes major financial headaches for turbine owners and operators. O&M costs for a single large onshore turbine have been estimated to be approximately $7/kW/year, whereas these costs are estimated to surge to about $40/kW/year for offshore turbines. In total these costs can represent about 10 percent of the total cost of energy for onshore turbines, and up to 35 percent for offshore turbines.

Failures can affect all of a wind turbine's subsystems, with varying consequences and costs arising from downtime and repairs. In the case of most failures, damage accumulates slowly during operation. Contin-

uous monitoring allows turbine operators to intervene at an early stage and minimize any further damage or lost availability.

AUTOMATED MEASUREMENTS

Condition monitoring has been used for various rotating machines for years with great success. Only during the past decade, however, has there been a movement to automate this work in order to get regular, accurate vibration measurements that help operators understand whether their wind turbine components are in good condition or whether they are soon going to fail. This has helped operators schedule service in advance,

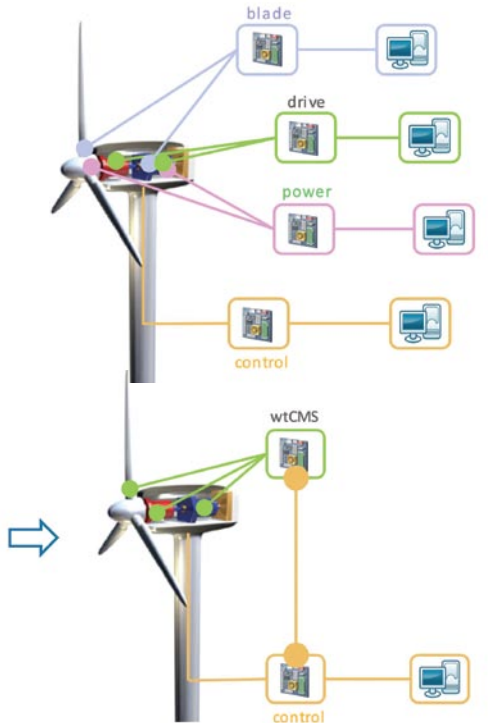


Fig. 1: AMSC's integrated approach (at bottom).

eliminating total failures, keeping downtime to a minimum, and saving unnecessary costs.

Condition monitoring systems today are not able to say that a given component will fail for sure, nor can they prevent a failure. However, once a certain level of vibration is reached then it's easy to predict when a component will fail. Operators can recognize vibration patterns, for example, when teeth are broken on a gearbox. Although they cannot eliminate the failure of the gearbox, they can proactively reduce the damage that the broken teeth cause to the gearbox and possibly other equipment. They can reduce the operational speed or take other measures to keep the turbine up and producing a lower amount of energy.

EARLY WARNING

Most online condition monitoring systems with fault detection algorithms allow early warning of electrical and mechanical defects to eliminate the risk of complete component failure. Effects on auxiliary equipment can be prevented as well. This allows necessary maintenance activities to be scheduled well in advance, avoiding difficulties with bad weather or the lack of in-stock parts.

Condition monitoring can even show indications of extreme external weather conditions, such as icing or wave-induced tower oscillation in the case of offshore wind turbines. This saves in overall maintenance costs, reduces downtime, and significantly lengthens intervals between maintenance, as well as the overall lifetime of the WEC itself.

PREVENTING DOWNTIME

The aim of any condition monitoring system is to understand as comprehensively as possible the status of a wind turbine at any given moment. It is not possible to predict the future, but it is possible to prevent many failures in advance with the support of condition monitoring systems.

When operating a wind turbine, three main maintenance strategies are most typical. These include corrective maintenance, scheduled maintenance, and condition-based maintenance. With corrective maintenance no action is taken until something breaks, which can be highly risky. Scheduled maintenance takes a more preventive approach by changing parts that could potentially be worn out. This strategy helps eliminate risks but is very costly, as parts that could still have considerable operational lifetime may be changed too frequently.

Condition-based monitoring using a condition monitoring system is the strategy that finds the optimum point between corrective and scheduled maintenance strategies. By having information from an advanced data mining algorithm that indicates just how bad a given component really is, operators can make a much more informed decision of whether that component can run until the next scheduled maintenance or not.

INTEGRATED MONITORING

Condition monitoring generally works using a series of vibration sensors on the main bearings, gearboxes, generators, and other key components, sending vibration signals to a monitoring station which can be located miles away. The drivetrain monitors measure surface accelerations as an indication if any part is wearing too quickly.

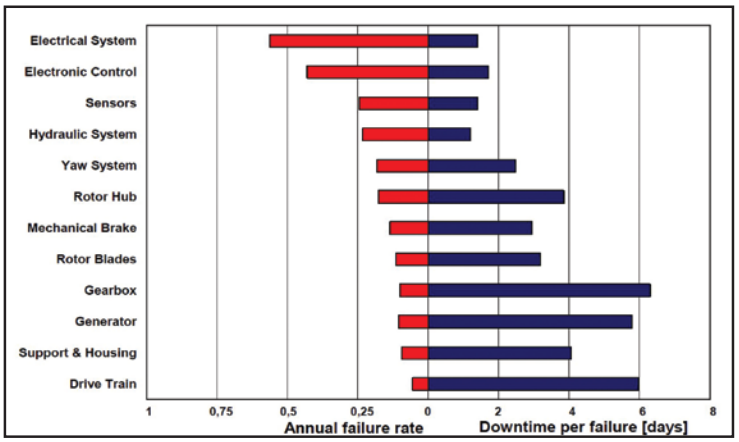


Fig. 2: Wind turbine reliability.

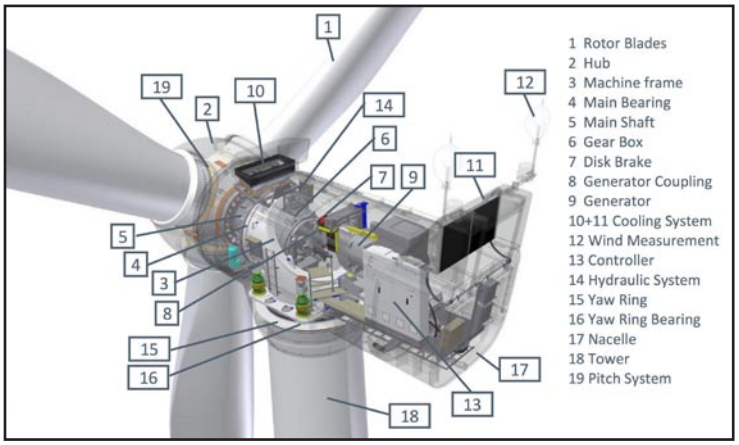


Fig. 3: Sources of vibration on a WEC.

Vibration sensors are the most common tools used to measure the wear and tear on components. For example, these sensors can be used to measure the effect of bearing or gear wear on the drivetrain. AMSC's wtCMS™ condition monitoring system is unique in that the condition monitoring capabilities are fully integrated within the wind turbine control system. This gives essential information about turbine operation modes directly to the main controller. No additional sensors are required, which results in a reduced total number of components and increased reliability in comparison to similar, non-integrated monitoring systems (fig. 1).

The wtCMS system provides wind park operators with virtually real-time information regarding the condition of selected sub-systems and components. It also features an automatic measurement system with online analysis and alarm generation. Communication all happens to the AMSC wtSCADA™ supervisory control and data acquisition system, which results in accurate vibration trend visualization for onsite and remote users.

The vibration signals alone don't tell much, but trained operators can pick up on problems by observing trends over several days, weeks, or months, and they can then use the expertise gathered over the years by AMSC to make intelligent decisions about any necessary repair work required.

AMPLE AUTOMATION

Besides being highly integrated, the wtCMS system also offers the highest degree of automation. This set of tools can monitor a large set of data automatically, which is another specific advantage for wind park operators because they can count on AMSC's years of experience and knowledge database to bring them automatically analyzed data cheaper and more quickly.

AMSC's wtCMS consists of a core CMS processor module that receives and processes measurement signals. A condition monitoring module

enables input for up to nine analog signals from accelerometers, plus three additional channels. It also allows input of additional signals and variables from the main controller.

The wtCMS cabinet contains the heating element, cooling ventilator, and thermostats for environmental control, power supply, and electronics protection. Instrumentation includes general-purpose accelerometers, low frequency accelerometers, and accelerometer connection cables. The entire system operates reliably in an exceptionally wide temperature range from -45°C to +60°C.

VIBRATION SOURCES

Sources of vibration are numerous on a WEC. Failures can affect all of the sub-systems, but the downtime and repair costs of the failure rates differ dramatically. For example, the electrical system typically experiences a high rate of failures annually, but is relatively quick to repair. In comparison, the drivetrain does not fail often, but when it does downtime can be considerably long if the replacement components must be manufactured from scratch and shipped then to the wind park site (fig. 2). Other sources of vibration can be the tower oscillations, yaw movement, oil pumps, generator defects, the power converter, or the mechanical feedback coupling from line voltage variations (fig. 3).

Examples of just a few of the signal patterns captured automatically in the integrated wtCMS system indicate shaft unbalance, misalignment, mechanical looseness, damaged gear teeth, or wear in any bearing parts. In total, wtCMS is able to detect more than 30 different signal patterns, and the list is constantly growing.

DATA MANAGEMENT

The AMSC wtCMS system offers ease of use for every wind turbine operator. Data can be accessed quickly to make well-informed decisions. All results from the wtCMS are communicated directly to the wtSCADA system (fig. 4). The fully integrated systems allow results visualization and comparison with overall WEC performance. A high degree of advanced automated analysis and intelligent software algorithms minimize the amount of effort needed to reach the right conclusion.

In addition, the advanced data-mining algorithms from AMSC enable accurate analysis and long-term trends. The single user interface for wtSCADA and wtCMS provide easy and automatic evaluation of results from the analysis and visualization. The benefits of an integrated condition monitoring system are clear: an early indication of system damage allows optimal performance, cost efficiency, and the highest reliability from each turbine. The wtCMS can even be configured to monitor specific frequencies of interest for each type of WEC.

CMS OUTLOOK

Development plans at AMSC are ambitious when it comes to creating the next generation of condition monitoring systems to further enhance the reliability and uptime of wind turbines. AMSC was one of the first companies to offer automated solutions for wind turbines. To date we have delivered more than 650 condition monitoring systems since launching them to the market as part of our portfolio in 2005. Our development plans are to continue to expand our range of monitoring tools for all critical parts of a WEC that are subject to deterioration. This would include the electrical components and blades, for example.

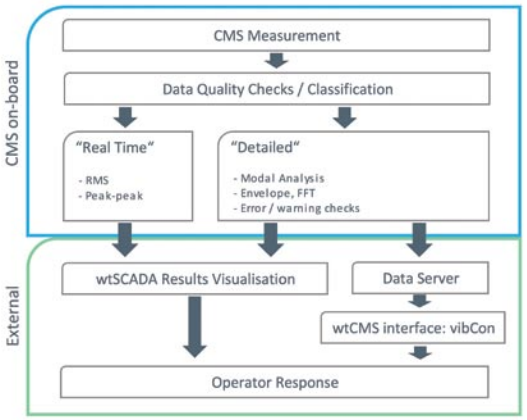


Fig. 4: Fully integrated wtCMS data management for ease of use.

In the future, any kind of sensor could be used as part of the CMS strategy, and not just vibration-based sensor systems. Plans even call for developing a condition monitoring system that is self-contained. This means it could be run by trained personnel, but would not require specialists for the result interpretation. This next generation would use all of the competencies within AMSC to provide a system in an algorithm form that works automatically on all available data.

For example, the converter currently features its own diagnostics system that sends information to the turbine control regarding immediate failures. AMSC plans to use the converter's diagnostic system to help detect failure as part of the CMS in the future. This would enable the converter to not only diagnose itself, but also all surrounding electrical systems as well. AMSC has the data needed to put this into an algorithm and turn the converter from a reactive component into a proactive one for greater reliability.

SUMMARY

Again, the goal in the future is to continue to minimize the efforts needed from operators through the use of intelligent software algorithms and automated analysis. AMSC's customers benefit from these continuous software improvements, and we're now developing additional measurement systems for advanced monitoring that will be integrated into our existing platform. We want to do all we can to make sure wind turbines are reliable, and that they have the lowest possible risk of failure, minimized maintenance costs, and high availability.

OPTIMAL TOWER AND FOUNDATION DESIGN

A new measure of wind tower scalability for greater hub heights and larger turbines, courtesy of the Tindall Corporation.

By Bryant Zavitz, P.E. and Kevin Kirkley, P.E.

Bryant Zavitz, P.E., and Kevin Kirkley, P.E., are with the Tindall Corporation. Visit online at www.tindallcorp.com and www.atlasctb.com.

THE GROWTH OF WIND POWER and its sustainability depends on good return on investment. The goal everywhere is minimizing cost/kWh. Several strategies are emerging to attain this goal:

- Improve turbine efficiency;
- Access better wind conditions (high mean wind speed);
- Improve turbine output;
- Reduce cost of acquisition and construction;
- Reduce cost of maintenance.

Three of these strategies are answered directly by the implementation of greater hub height. All of them are influenced by optimal tower design. Overall, the economics show a shorter payback is obtainable by employing a larger tower.

THE CHALLENGES

Significant structural challenges are connected with implementing higher wind towers. Higher towers require more massive and costly foundations. Flexibility of the high tower must be addressed. It is more difficult to achieve the natural frequency required for proper turbine operation. These factors add significantly to the up-front engineering burden during the design stage.

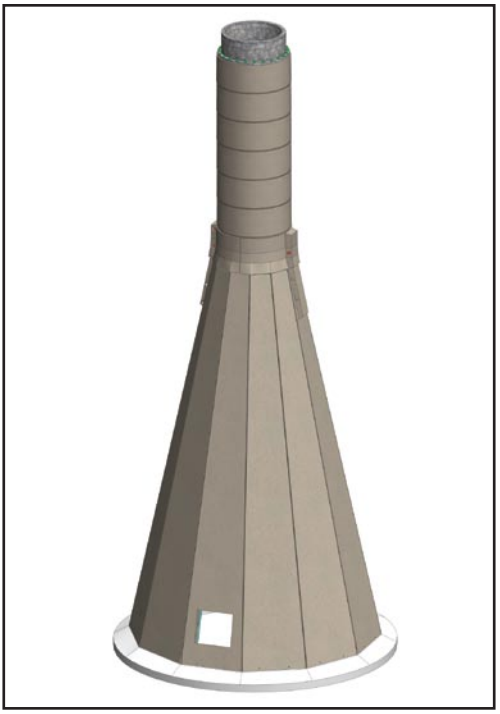


Fig. 1: Depicted here is a 40-meter Atlas CTB and ring foundation.

Transportation of larger tower pieces poses a special problem. Most highways have a 4.5-m width limitation, and vehicles handling long sections find it difficult to negotiate the curving roads that commonly serve remote wind farm locations. Construction time for higher towers can be longer, lengthening return on investment by delaying the commencement of revenue bookings.

DESIGN STRATEGIES

Designers are turning to a variety of new technologies to minimize costs connected with detail design, tower components and foundations. One alternative is employing precast concrete. Hybrid precast concrete/steel towers are proving attractive for several reasons. They offer easy transport of manageably sized component pieces, rapid erection, high strength and stiffness, the prospect of reduced maintenance and an attractive lifetime cost. Some designers are using cast-in-place hybrid towers with concrete 60 m high and 8 m diam. at the base. Others are employing prefabricated concrete rings bolted together on-site and post tensioned using external tendons. Some precasters have a continuous taper tower design, where the diameter at ground level approximates that of steel.

With these conventional diameter designs, the challenges of tower frequency and load concentration at the foundation remain. Foundations are necessarily thick, massive, and expensive to construct.

THE ATLAS CTB

One design has emerged that addresses the challenges with foundation loading, complexity and cost challenges. This is the Tindall Atlas CTB™ Tower Base (fig. 1), a patent pending design featuring a flared precast concrete base section. The Atlas CTB comprises the lower 40m of hybrid tower system that serves as an elevated platform to support conventional steel monotowers 80m to 100m in height to achieve hub heights to 140 meters and designed for wind turbines from 1.5MW to 3MW and up.

The Atlas CTB truncated cone base assembly is composed of 12 or more stave units. The multiple precast concrete staves are erected, assembled and post-

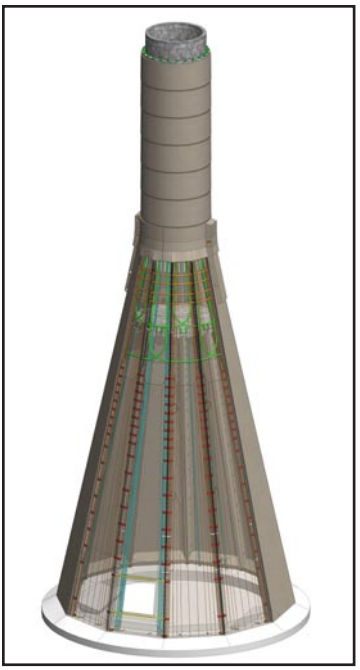
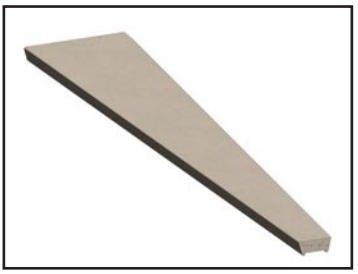


Fig. 2: Cutaway of a 40-meter Atlas CTB.



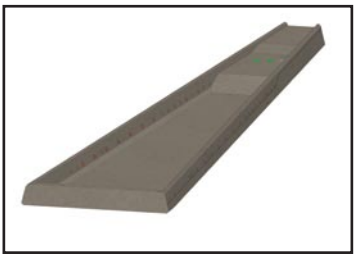


Fig. 3: The same stave component is used in all Atlas CTB Tower Base sizes.

tensioned on site. The staves are captured by an outer precast ring system at the tower transition region. This concrete transition ring controls the stave tops and provides an uninterrupted transition from the truncated cone base to circular precast concrete tubular sections that form the upper part of the Atlas CTB and provide the support for the steel tower.

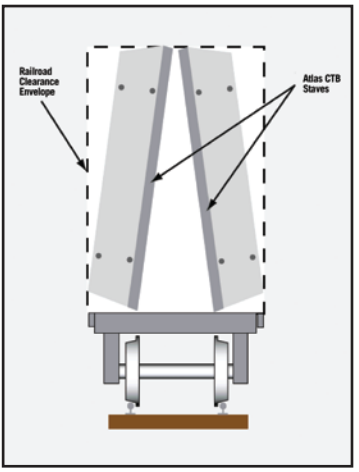


Fig. 4: A pair of Atlas CTB staves are easily transportable by rail within a 3-m W x 4.5-m H conventional rail transportation footprint.

The vertical staves that form the truncated cone base are identical for each assembly (fig. 2); they are of a size that makes them easily transportable in pairs by rail (figs. 3, 4). Most importantly, the modular, multiple stave design affords design simplicity and scalability to accommodate towers of various height and turbine size. With increasing numbers of staves, the base diameter increases to accommodate the loads imposed by greater heights and larger turbines.

FOUNDATION COMPARISON

The larger footprint and lower foundation pressure characteristic of the wide Atlas CTB Tower Base does away with the massive, costly foundations required by narrow diameter base sections. The 0.75-m to 1-m-thick ring foundation (fig. 5) accommodates loading using 50-60 percent less concrete than other tall tower options.

With no high-mass concrete pours, this contractor friendly ring foundation poses no thermal cracking concerns during curing. The wide load distribution makes the simple ring foundation less sensitive to settlement throughout its service life and provides for improved dynamic performance that is less sensitive to the prevailing soil conditions.

STRENGTH DEVELOPMENT

Post-Tensioning. The composite transition region is vertically and circumferentially post-tensioned together, resulting in a bi-axially compressed condition. No tension is present under applied loads. Multiple pairs of tendons are passed down through the transition assembly, the stave beneath, the neighboring stave, then back up to its anchorage point (fig. 6). These looped tendons provide precompression (increased shear capacity) of the grouted stave-to-stave joints. Moreover, additional circumferential tendons are employed at multiple shear key locations situated lower in the conical tower base. Altogether, the combination of tendons gives the Atlas CTB Tower Base outstanding resistance to all anticipated bending, shear and torsional forces.

Strength Benefits. The post-tensioned stave/ring system produces a high tower frequency. The result is a tower with superior dynamic properties, thanks to the post-tensioning process and the natural dampening qualities of precast concrete.

ECONOMIC ADVANTAGES

The Atlas CTB Tower Base design concept promises significant economic advantages relative to installed cost, schedule compression, extended life cycle and reduced maintenance.

Site Work. The onsite construction process is significantly shorter with the Atlas CTB Tower Base design. The structure is composed of factory or site-manufactured pre-cast components. This repetitive, precast manufacturing process reduces field construction work and the concrete tower construction becomes principally erection instead of field construction. No welding and requisite testing are necessary. Apart from the foundation, no concrete forms have to be built. The large amounts of waste

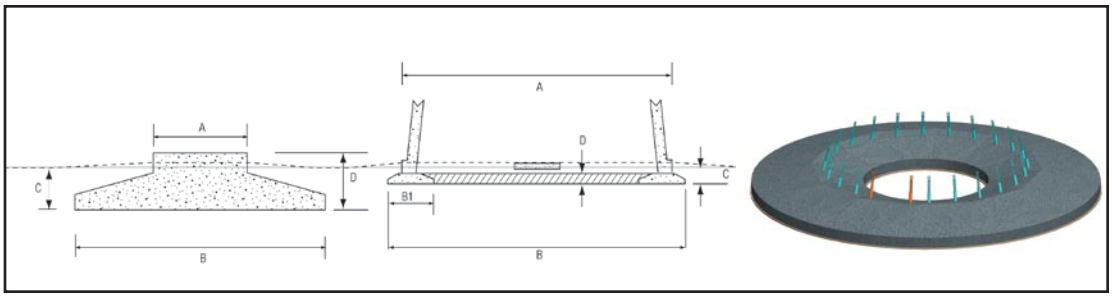


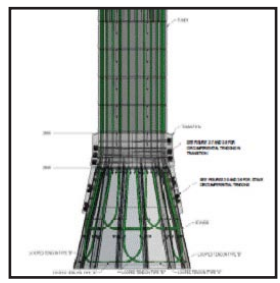
Fig. 5: The Atlas CTB Tower Base uses a simple, load-distributing ring foundation (right), much less complex than the conventional deep wind tower foundation.

typical with construction sites are not generated. Pieces can be placed using standard cranes.

Maintenance Factors. Low maintenance over an anticipated 50-year service life enhances the economic attractiveness of the Atlas CTB Tower Base. There is no periodic tightening required since the primary connections are post-tensioned throughout the structure and at the foundation. The structure needs no painting over its lifetime. Given the rigidity and superior dynamic properties of the Atlas CTB, the service life of the turbine and related components should be extended.

The Atlas CTB Tower Base is designed as an answer to the specific challenges encountered in the need for higher unit power output in the wind farm, with enhanced return on investment and expanding the wind resource footprint by increasing hub heights and creating viable wind development in low wind speed regions. Furthermore, with its selectable number of staves for increased base diameters, the design is scalable to accommodate the loads presented by higher hub heights and the next generation of high-output turbines.

Fig. 6: Biaxial post-tensioning with multiple pairs of tendons prevents concrete tension, while securing the rings and stave tops into a rigid structure.



ADINDEX

Martin Schmidt-Bremer, Jr.
chief operating officer/WindGuard North America, Inc.

TELL US ABOUT THE COMPANY'S BACKGROUND AND HOW IT CAME TO BE FOUNDED.

WindGuard North America is a company within the WindGuard Group, which is headquartered in Germany. The main company, Deutsche WindGuard GmbH, was founded by Dr. Knud Rehfeldt in 2000. He had established the DEWI office in Spain prior to launching the company. DEWI is a state-funded entity that conducts research and provides various services to the international wind industry. He was on his own in the early days, focusing on due diligence and site assessment, and then former colleagues from DEWI began joining him as the company grew, lending their expertise to help build Deutsche WindGuard's range of services and capabilities. So this is a company made up of a team of professionals that are literally second to none.

WHEN DID YOU ESTABLISH NORTH AMERICAN OPERATIONS?

The decision was made in 2007 to start offering our services in the U.S. The office here in Springfield, Virginia, was opened in 2010 so that we could share our services with OEMs, wind farm owner/operators, and others throughout North America. I mentioned that we are a company within the WindGuard Group, and we have sister companies devoted to technical inspections, offshore, consulting, and site assessment services, among others. We represent all of those companies and related services here at WindGuard North America. I am a trained technical inspector for wind turbines myself, so when a client requires technical inspections I pull together and lead a team from Germany, determining the size of the group by the scale of the project. We are accredited by the DAkkS—the Deutsche Akkreditierungsstelle GmbH, which is the national accreditation body for the Federal Republic of Germany—as an inspection body for wind turbines according to DIN EN ISO/IEC 17020, so we are held to very high standards in terms of our technical knowledge and skills. We can also help settle disputes between owners and OEMs providing inspection services, where we conduct our own inspection as an independent third party and present the results for the purposes of comparison. Other services we provide in the area of technical inspections and management include rotor blade inspections, video endoscopy and oil analysis, technical management, and performance optimization. We have also developed the WONDERv2 wind farm management system, which provides a platform for collecting and analyzing wind turbine operational data and can be used with any turbine with remote monitoring capabilities. WONDER is currently transitioned to be net-based. We also conduct power curve measurements to make sure turbines are performing as expected, and vibration analysis to ensure system integrity and help to avoid expensive breakdowns. Our site assessment activities involve everything from wind measurement—we'll sell customers the equipment or do the work ourselves, and we generally suggest gathering at least 12 months of uninterrupted data to get a clear idea of a site's potential—in addition to site assessments, anemometer calibration, and LIDAR/SODAR remote wind sensing. Offshore services include consulting and safety training. Another scenario might involve a bank or a developer requiring due diligence, where we would assemble a group from WindGuard Consulting to handle that project. So we provide a full range of services, as you can see, and we possess expertise in nearly every aspect of the wind energy industry.

DESCRIBE YOUR WIND TUNNEL CENTER IN GERMANY. IT SOUNDS VERY IMPRESSIVE.

It really is. We have two proprietary wind tunnels that are primarily used for calibrating anemometers, with two more in the works. They are also used by OEMs in the development of their flow and wind direction sensors. Then we have a climatic and icing wind tunnel that is used for testing anemometers and measurement devices that will be used in extreme environments, which is often the case with wind farms. One of the things we are testing for there is the effect ice has on the accuracy of measurements, and we also test the heating devices used to mitigate icing. Finally we have the large acoustically optimized wind tunnel, designed to test the aerodynamics of turbines, full-sized blade segments, and models of whole wind farms. This huge tunnel is often used for the aerodynamic and acoustic testing of new turbine designs and other equipment used in the wind industry. So we see ourselves as both an asset and a resource for OEMs and owner/operators around the world, and we have a growing list of satisfied clients to point to here in the United States as well. Whatever the challenge, we're definitely equipped to help identify a solution.

For more information contact Schmidt-Bremer at (571) 331-7927 or m.schmidt-bremer@windguard.com.
Go online to www.windguard.com.

news

New products from Sandvik Coromant

CoroMill® 316

Economical milling as easy as 1, 2, 3

New inserts for the exchangeable head milling system

CoroMill® 176

Reduce cutting time by 50% with our new full profile hob

Customize and utilize

with Coromant Capto® clamping units

Quietly boosting your productivity

with Silent Tools® adapters

Coromant Capto® C10

Make light work of heavy machining

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SANDVIK Coromant

Your success in focus

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

SOLUTIONS FOR WIND TOWERS

SITE IMPROVEMENT FOR NEW FOUNDATIONS AND FOUNDATION REHABILITATION

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

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

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