WIND SYSTEMS

OCTOBER 2010

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PH Windsolutions, Inc.

Structural Adhesives for Turbines

A Measured Change

Measuring for Wind Energy

Near Term Power Prediction

Calculating Micropitting for Wind

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Logistics—**BDP Project Logistics**

Q&A: John Brown
Geodetic Systems, Inc.


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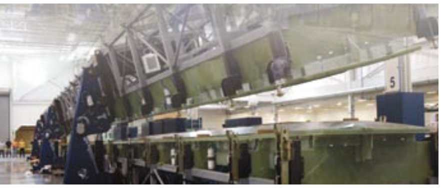
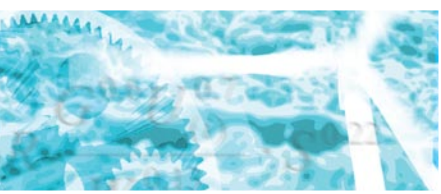
FEATURES





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RESOURCES

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EDLETTER

While preparing each issue of *Wind Systems* magazine I am constantly reminded of the opportunities that exist in this market for innovative, forward-thinking, entrepreneurial companies and individuals to make their mark. There's just so much room for new technologies, materials, processes, software, and turbine and associated equipment designs to emerge and revolutionize the industry that it's truly a pleasure to have a front-row seat to this parade of progress. While you'll find plenty of evidence in the following pages, I was especially mindful of this trend during my interview with Ian Comishin for our company profile of PH Windsolutions. Its Powerhinge mould handling systems automate an expensive and involved process that once took multiple cranes and skilled operators, allowing for greater efficiency and repeatability than ever before. You're sure to enjoy learning about this relatively young company, and blade manufacturers will definitely benefit from doing so.

As for our feature lineup, Gerrit deGlee of the Carl Zeiss IMT Corporation has written "Measuring for Wind Energy," pointing to the importance of developing an in-depth inspection strategy when manufacturing wind components. Ann Pattison of Lufft USA discusses how the wind industry is moving toward ultrasonic anemometers and other alternative data collection for site assessment in "A Measured Change." Representing the LORD Corporation, Anita LaFond has penned "Structural Adhesives for Wind Turbines," explaining how adhesives can work better than other fastening devices in certain applications. Dr. Stefan Beermann of KISSsoft AG describes new software that permits the reliable calculation of complex interrelations long before construction of a wind farm occurs in "Calculating Micropitting for Wind Energy," and Andrew Kusiak and Zijun Zhang—who are both with the Department of Mechanical and Industrial Engineering at the University of Iowa—explore data mining in "Near Term Power Prediction." K. Venkateshwar Rao and Manasa Gantayat of Lucintel present a competitive analysis indicating an ever-strengthening global market in "Growth Trends in Wind." Technology columnist Jose R. Zayas of Sandia National Laboratories explores the effect of siting selections on military radar installations, and Mark Plaskett, PE, of Hayward Baker describes vibo compaction for preparing loose soils in his construction column. Our maintenance columnist Merrit Brown of Rev1 Power Services concludes his two-part series on bolt-tensioning techniques, and Hüseyin Kizilagac of BDP Project Logistics provides insights into shipping concerns in remote—and sometimes dangerous—areas in his logistics column. John Brown, president of Geodetic Systems, explains the process and benefits of utilizing photogrammetry in determining tower flange flatness in this month's Q&A. Again, it's amazing to consider how much expertise you'll find packed into this issue's pages.

Speaking of which, remember that these pages belong to you, and I'm eager to hear how you'd like to fill them in upcoming issues, so don't hesitate to contact me whenever you have a story idea you'd like to discuss. Also be sure to stop by and see us November 1-3, 2010, at CanWEA booth #2120 in Montreal!

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VESTAS TO MOVE NORTH AMERICAN HEADQUARTERS

Vestas will move its North American sales and service headquarters into the historic Meier & Frank Depot Building in Portland's Pearl District. Gerding Edlen Development, Inc., will transform the sturdy structure, vacant since 2001, into one of Portland's newest and most distinctive buildings. Construction is expected to begin in October 2010. Vestas plans to occupy the space in early 2012. The building will be designed with the intent to achieve LEED (Leadership in Energy and Environmental Design) Platinum certification. There are only 15 buildings in Portland designated as LEED Platinum, the highest rating given by the U.S. Green Building Council. Gerding Edlen, headquartered in Portland, is one of the nation's largest developers of LEED-certified properties having developed more than 40 LEED projects since the inception of the U.S. Green Building Council.

Built in 1928, the Meier & Frank Depot Building will undergo a

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.

complete historic renovation. When redeveloped the building will be 172,000 square feet that will include a 22,000 square-foot addition on the fifth floor complete with an ecoroof terrace and gardens. Additionally, the building will have what is believed to be the largest roof-mounted solar energy array in Portland's central business district. The total project cost for the developer is estimated at $66 million.

"We are making a long-term commitment to Portland," says Martha Wyrsch, president of Vestas-American Wind Technology, Inc. "As a company devoted to wind power, it makes sense for us to be part of a community that so strongly supports clean energy."

"I am so pleased that Vestas is making a long-term commitment to grow their business here in Portland," says Mayor Sam Adams. "This announcement shows the success of working strategically to grow quality jobs by building on our competitive advantage as a leader in clean technology and sustainable industries. Moreover, our joint efforts mean that local architects, construction workers and engineers will get to work now converting a Portland landmark into one of the most energy-efficient buildings in the United States."

Vestas' Portland employees work in such fields as engineering, sales, project management, training, technology, accounting, human resources, legal services, and marketing, among others. Vestas, which employs about 2,400 people in the United States and Canada, also has 30 full-time employees in central and eastern Oregon who maintain and service wind turbines.

"This is a great day for Vestas, for the City of Portland, and for the state," Oregon Gov. Ted Kulongoski says. "This building represents the very best in public and private partnerships. Our collective investments in this project will pay off now and in the future in the form of more green jobs in Portland. It also will establish a stronger renewable energy foundation for Oregon as a whole."

Vestas, the world leader in producing high-tech wind power systems, has supplied more than 40,500 turbines globally since 1979. Vestas sold its first wind turbine in North America in 1981 and since has supplied more than 11,000 turbines to the United States and Canada. Learn more at www.vestas.com.

MORTENSON CONSTRUCTION BUILDS ITS FOURTH WIND FACILITY IN ILLINOIS

Mortenson Construction has started construction of White Oak Energy Center near Bloomington, Illinois, adding 150 megawatts to Illinois' approximate 2,000-megawatt wind generating capacity. Located in agricultural terrain in central Illinois along the McLean and Woodford County lines, the wind power facility, developed by Chicago-based developer Invenergy Wind LLC, will consist of 100-1.5 megawatt GE turbines. Mortenson is responsible for the design and construction of access roads, foundations, and the erection of the turbines. Invenergy is the sixth largest owner of wind generation assets in the United States, according to the American Wind Energy Association.

According to the Illinois Wind Energy Association, an average 100-megawatt wind farm in Illinois creates 150 temporary construction jobs and 10 permanent maintenance jobs. "We are excited to be building another wind energy project in Illinois and look forward to partnering with the local community to safely deliver this project to our customer, Invenergy," says Tim Maag, vice president and general manager of Mortenson's Renewable Energy Groups. "The White Oak project will be our fourth wind project we have built in Illinois, which represents approximately 40 percent of the state's total generating capacity."

Since entering the renewable energy market in 1995, Mortenson Construction has become a leading building of wind power facilities in North America and has erected 5,000 wind turbines 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 2009. In addition to wind power, Mortenson's Renewable Energy Groups also construct facilities that generate solar power, biofuels, and hydro-electric power.

The White Oak facility has been in the planning process for several years. With Illinois' robust wind resources, evolved transmission system, and progressive public policy, the project marks another significant step for a state leading the way in renewable energy. Learn more by visiting www.mortenson.com/wind.

FINAVERA RENEWABLES SIGNS AGREEMENT FOR BRITISH COLUMBIA PROJECTS

Finavera Renewables, Inc., has signed a participation agreement with the McLeod Lake Indian Band for the Tumbler Ridge, Wildmare, Meikle, and Bullmoose Wind Energy Projects. The agreement was completed at a signing ceremony at the McLeod Lake Indian Band Annual General Assembly. The agreement sets out the guidelines for engagement between Finavera and the McLeod Lake Indian Band and represents a commitment by the parties to enter into discussions to develop further agreements.

"We support Finavera Renewables and others in the wind energy business as they represent the future for electric power generation. When done in a responsible way wind energy, unlike hydro dams, gives us power without destroying the land around us," says Chief Derek Orr. "We are looking forward to being actively involved with Finavera Renewables."

"I would like to thank Chief Derek Orr and the McLeod Lake Indian Band for their hospitality during their community's Annual General Assembly," says Finavera Renewables CEO Jason Bak. "The signing of this participation agreement illustrates our commitment to building a long term, mutually beneficial relationship with the McLeod Lake Indian Band."

Under the terms of the agreement Finavera and the McLeod Lake Indian Band will address several key areas: training and employment opportunities, assessment of potential project impacts, and economic development opportunities. The agreement also sets out key principles that will guide future discussions between Finavera and the McLeod Lake Indian Band: respecting each other's distinct identities, interests, and priorities while exploring common interests and opportunities, engagement, and consultation that are meaningful and results oriented, and a commitment to honest and open sharing of information and ideas and to joint problem solving.

McLeod Lake Indian Band has a membership of some 475 people and is part of the Tse'khene tribal group. The band owns several companies that are actively engaged in road and site construction, logging, and pipeline construction. The administrative center of the band is at McLeod Lake with a sub-office in Chetwynd, BC. For more information on Finavera Renewables contact Myke Clark, SVP Business Development, at (604) 288-9051 or mclark@finavera.com. Go online to www.finavera.com.

3M AND ROPE PARTNER LAUNCH STUDY ON BLADE EDGE EROSION

3M is partnering with Rope Partner to conduct an in-field study on the effects of leading edge wind turbine blade damage. The purpose of the yearlong study is to quantify the reduction in overall wind turbine output due to leading edge erosion. This data-driven study will be the first published work to put verifiable numbers behind this widespread issue for wind turbine blades.

As wind turbine blades rotate, reaching speeds of 180 miles per hour at the blade tips, they are constantly exposed to the elements and harsh outdoor conditions. Any airborne object such as sand, rain, and hail can lead to damage on the leading edge of the blade. This erosion negatively affects aerodynamics by causing turbulence that may reduce the overall turbine output.

"3M has been addressing the needs of the wind industry for more than 10 years. Our deep expertise and history with polyurethane tape technology has proven effective in tough environments. Similar polyurethane tape technology from 3M is also used in the aerospace industry to protect the leading edge of helicopter blades and aircraft radomes against erosion," says Pam Kellenberger, global business manager for the 3M Wind Energy business. "Our best-in-class wind blade protection tapes can mitigate the output losses from leading edge erosion, and we are pleased to be on the forefront of quantifying and addressing such a widespread challenge for wind turbines."

"Over the last decade at sites all across the globe we've seen firsthand the damage caused by leading edge erosion when conducting our inspections for wind turbine maintenance and repairs," according to Chris Bley, director of business development at Rope Partner. "We've seen sites where significant erosion occurs in a little as two years after installation. Our customers are concerned about the effects this erosion will have on the performance of their turbines, and we are committed to finding answers for them through this important study."

A recognized leader in research and development, 3M produces thousands of innovative products for dozens of diverse markets. 3M's core strength is applying its more than 40 distinct technology platforms, often in combination, to a wide array of customer needs. Visit www.3m.com. Rope Partner is the premier provider of turbine maintenance, repair, and inspection services requiring specialized access approaches. Since 2001 in the U.S. and 1998 in Europe its rapid-response WindCorps™ technicians have partnered with clients to deliver cost effective, environmentally appropriate solutions, resulting in increased turbine availability and operational longevity. Go online to www.ropepartner.com.

PRESSURE TRANSMITTERS AND TEMPERATURE SENSORS FROM DANFOSS

Located on top of towers that can extend 80 to 110 meters into the air, wind turbines are subjected to powerful operating forces. And because wind turbines are difficult to access for maintenance and repair, reliable monitoring and control components such as pressure and temperature sensors are vital for trouble-free operation.

Because they're a critical link between control system fluids and components, choosing accurate, long-lasting pressure transmitters and temperature sensors is a must. Based on decades of experience with wind farms globally, Danfoss' range of pressure transmitters and temperature sensors are ideal for demanding wind turbine applications. Monitoring and controlling hydraulic pressure and temperature in wind turbine equipment and subsystems is a complex process; at startup pressure rises and it's released at shutdown, and for lubrication and rotation functions maintaining a minimum pressure level is crucial. To ensure smooth and safe operation the temperatures of the hydraulic unit, generator, drive shaft, gearbox, oil braking, and cooling systems have to be accurately monitored and controlled. That's where Danfoss comes in.

Pressure and temperature signals are used by controllers to adjust valves, pumps, and other equipment to maintain stable operation and, increasingly, to control safety functions. Designed to handle over-pressure and pressure spikes, liquid cavitations, dirt contamination, intense operating cycles, and extreme temperatures, Danfoss pressure transmitters and temperature sensors have been keeping wind turbines rotating, and safe, for decades.

Two industry favorites are the MBS 3000 pressure transmitter and the MBT 5310 temperature sensor. Fitted with a pulse snubber, the MBS 3000 can withstand water hammer, liquid

cavitation, and pressure peaks. Designed to handle the heavy vibrations in wind turbines, the MBT 5310 features a spring-loaded sensor to ensure close and reliable contact, and it can withstand temperatures up to 200°C. For more information please visit www.danfoss.us/ia.

LINCOLN ELECTRIC OPEN INTERMOUNTAIN TRAINING CENTER

Lincoln Electric has partnered with Davis Applied Technology College (DATC) to open its new Intermountain Training Center in Kaysville, Utah. The 5,000 square-foot, world-class welding demonstration and training facility will serve a dual role. For Lincoln the center provides a venue for the manufacturer to conduct customer seminars and training for new products, cost reduction, productivity/process improvements, automation, and engineering design, as well as for continuing education for existing customers and distributors. For DATC this public/private partnership supports and enhances the college's existing welding program and provides graduates with the welding skills for today's job market requirements. Officially known as the Lincoln Electric Intermountain Training Center at Davis Applied Technology College, the center was completely revamped and outfitted with the latest Lincoln Electric welding equipment and technology.

"Partnering with DATC improves our operational efficiency, as well as enabling us to more effectively provide Lincoln Electric's advanced welding technology knowledge

through distributor training and customer seminars in a facility unmatched in the Intermountain area," says Richard Peterson, district manager. "DATC is an industry-driven organization, which has several successful industry partnerships. Its close relationships with welding-related industries in the area will help improve opportunities for Lincoln."

DATC welding instructor Nick Price is excited about this new partnership after taking over the instructor responsibility at the beginning of the year. "I don't think we could have a stronger partner for the college," he says. "Lincoln Electric is going to do really big things for us. Besides keeping up with the latest equipment, they will always make sure we have the newest, state of the art equipment available to students, who will benefit greatly from this partnership.

Michael Bouwhuis, DATC campus president, anticipates this partnership will provide a strong level of quality and value to the historically strong welding program. "The marriage created by this partnership links state-of-the-art equipment to newly renovated facilities, forming one of the finest welding facilities in Utah," he says. "This will also enhance the quality of technicians in the manufacturing sector of the economy to new levels of performance."

The Lincoln Electric Company is the world leader in the design, development, and manufacture of arc welding products, robotic arc welding systems, weld fume control equipment, and plasma and oxyfuel cutting equipment. The company holds a leading global position in the brazing and soldering alloys market. For more information go to www.lincolnelectric.com. Davis Applied Technology Center (DATC) is one of eight campuses of Utah College Applied Technology and is located just north of Salt Lake City. DATC provides training in an open-entry, open-exit environment that annually prepares more than 7,400 high school and adult students with career and technical skills. Learn more at www.datc.edu.

TRELLEBORG SUPPORTS WORLD'S FIRST FLOATING WIND TURBINE

Statoil's innovative new offshore floating Hywind wind turbine, now successfully moored in the North Sea off the Norwegian coast, is demonstrating how Trelleborg Offshore's syntactic foam buoyancy technology is contributing to the future of offshore power generation. "It is subsea technology that has already been extensively proven," says Gary Howland, renewables sales manager for Trelleborg Offshore. "Trelleborg Distributed Buoyancy Modules (DBMs) developed for deepwater support of umbilicals and risers in the oil and gas industry are ideal for this application, helping reduce project risk by using proven technology.

"People see the tower and turbine but forget that the expertise in designing the subsea portion is also critical," he says, "as ultimately it keeps the whole turbine afloat. The dynamic floating structure weighs 5,300 tons and is 165 metres tall; with a total of 65 metres above sea surface. The 13km of power offtake and communications cabling attached to the structure further adds to its weight. It's like the proverbial iceberg; the mass floating below the surface ensures stability. Unless the weight is supported by properly designed buoyancy the whole structure would be much less able to resist the extremes of the offshore environment and the cable could suffer premature damage."

For Hywind, Trelleborg Offshore designed and supplied 45 off polymer-coated syntactic foam DBMs which supply buoyancy support for a 3 ton, 100 meter section of cable as it exits the turbine spar and descends to the sea bed at -220 meters. The buoyancy modules include an internal clamp for secure fastening and precise positioning on the cable. The cable is supported mid-water in what is known as a 'Lazy Wave' configuration, featuring gentle long radius curves that minimise stress on the cable while accommodating natural movement created by wind and waves.

"For optimum buoyancy under different sea conditions, the precise position of the buoyancy modules on the cable is pre-calculated," Howland explains. "The positions must be maintained, despite stresses during launch and in operation. The clamp is crucial; the design, material selection and manufacturing technique are critical in ensuring the finished clamp maintains the buoyancy module position, during cable contraction and expansion, over the 20 year lifetime of the project."

Using advanced polymer material technology, Trelleborg Offshore provides high integrity solutions for the harshest and most demanding offshore environments. As part of the Trelleborg Engineered Systems Business Area of Trelleborg Group, it specializes in the development and production of polymer and syntactic foam based seismic, marine, buoyancy, cable protection, and thermal insulation products, as well as rubber-based passive and active fire protection solutions for the offshore industry. Go online to www.trelleborg.com/offshore.

PORTABLE MECHANICS' SERVICE SETS FROM SNAP-ON INDUSTRIAL

You can't always bring the big job to the tool crib, so Snap-on Industrial is bringing the tool crib to the job. Portable mechanics' service sets put large and small hand tools—including screw drivers, wrenches, and pliers, along with multimeters and other specialty equipment—at easy reach for professionals looking for maximum protection of their tools and equipment combined with great accessibility. A hard-sided Pelican™ 0450 case houses a

choice of two comprehensive tool offerings. Everything starts with the mobile tool case that features rugged trolley wheels and handle for easy and secure mobility. Each configuration comes with seven custom foam-equipped removable drawers, and an integrated top tray includes custom foam tool storage as well. Two automatic pressure equalization values keep water molecules out and ensure easy opening, whether you're at 1,000 feet below the ocean's surface or at 50,000 feet in the air. Cases are also water, temperature, drop, and impact resistant. Each unit meets DOD (Air Force) operation guidelines and complements existing safety programs. Tool coding etched into each tool with corresponding number laser printed into the tool's individual storage space simplifies inventory control and maximizes overall accountability.

Snap-on Industrial is a division of Snap-on Incorporated, a leading global innovator, manufacturer, and marketer of tools, diagnostics, equipment, software, and service solutions for professional users. Products and services include hand and power tools, tool storage, diagnostics software, information and management systems, shop equipment and other solutions for vehicle dealerships and repair centers, as well as customers in industry, government, agriculture, aviation and natural resources. For more information call (877) 740-1900 or visit www1.snapon.com/industrial.

AMSC ACQUIRES STAKE IN BLADE DYNAMICS LTD.

American Superconductor Corporation has acquired a 25 percent ownership position in Blade Dynamics Ltd., a designer and manufacturer of advanced wind turbine blades based on proprietary materials and structural technologies. Founded in the United Kingdom in 2007, Blade Dynamics has developed wind turbine blade technologies designed to increase the efficiency and performance of very high power (multi-megawatt) wind turbines while also reducing costs. The Dow Chemical Company, through its Venture Capital group, also made a minority equity investment in Blade Dynamics.

"Blade Dynamics has developed unique and proprietary structural designs and manufacturing methods aimed at overcoming critical barriers that are facing today's wind industry," says Blade Dynamics founder and CEO Paul Rudling. "Utilizing advanced manufacturing processes, innovative structural designs, proven composite materials, and our advanced Bladeskyn surface coatings, our wind turbine blades provide compelling performance and efficiency advantages for wind turbine manufacturers. We see tremendous potential for this technology and are delighted to work with AMSC and Dow. Blade Dynamics will now be able to utilize AMSC's unique wind turbine design capabilities and business model as well as Dow's global reach and composite materials to capitalize on the tremendous opportunities we see in front of us."

Today's 2 megawatt (MW) wind turbines require rotors that are more than 70 meters (230 feet) in diameter, and 5 MW wind turbines require rotors that are at least 120 meters (360 feet) in diameter. Rotor diameter is the diameter of the swept area of a wind turbine's blades. Ideally, these wind turbines would be equipped with even larger-diameter rotors to maximize power output. Yet cost, weight, and transportation factors have historically limited the size of rotors, outweighing performance and efficiency benefits.

"The design and manufacturing processes for wind turbine blades have remained fundamentally unchanged for 20 years," says AMSC founder and CEO Greg Yurek. "Today, however, the market is migrating to higher wind turbine power ratings. Onshore wind turbines now exceed 2 MW in many locations, and offshore wind farm developers are increasingly seeking wind turbines with power ratings exceeding 5 MW. Blade Dynamics presents us—and the entire wind industry—with a game-changing wind turbine blade technology that enhances performance and reduces weight and cost for high power wind turbines. We view this as a compelling investment and expect many wind turbine manufacturers, including our own AMSC Windtec™ licensees, to quickly migrate to the Blade Dynamics solution to avail themselves of these competitive advantages. In fact, AMSC Windtec and Blade Dynamics engineers have already been working in close collaboration to optimize blades for AMSC Windtec turbine designs."

AMSC has acquired its 25 percent stake in Blade Dynamics for $8 million in cash and will have one seat on the Blade Dynamics Board of Directors. In addition to providing AMSC Windtec licensees with a differentiated blade offering, AMSC expects that its investment could expand the company's sales opportunities with other wind turbine manufacturers around the world. AMSC also expects that Blade Dynamics technology will provide a compelling blade platform for the company's 10 MW SeaTitan™ superconductor wind turbines. For more information go to www.amsc.com, www.bladedynamics.com, or www.dow.com.

DEERE REACHES AGREEMENT FOR SALE OF WIND ENERGY BUSINESS

Deere & Company has announced that it has signed a definitive agreement to sell John Deere Renewables, LLC, its wind energy business, to Exelon Generation Company, LLC, a wholly-owned subsidiary of Exelon Corporation. "As Deere sharpens its own strategic focus, we have concluded that the company's resources are best invested in growing our core equipment businesses around the world," says Samuel R. Allen, Deere & Company chairman and chief executive officer. "We have chosen to place the wind portfolio with Exelon in part due to its demonstrated leadership in the energy industry."

Deere said the $900 million sale, including earn-out provisions, will result in an after-tax charge of approximately $25 million in its fourth quarter results. The charge was not reflected in Deere's fourth quarter earnings forecast of approximately $375 million that was announced August 18th.

John Deere Renewables includes 36 completed projects in eight states with an operational capacity of 735 megawatts. The definitive agreement includes the completed projects plus numerous others in development. Subject to regulatory approvals, Deere anticipates the transaction to close within the 2010 calendar year. For more information contact Ken Golden, director of strategic public relations at Deere & Company, at (309) 765-5678. Go online to www.deere.com.

SIEMENS AND SAMSUNG ENTER INTO MAJOR SUPPLY AGREEMENT FOR CANADA

Siemens Energy and Samsung C&T Corporation have signed an agreement for the supply of wind turbines with a total capacity of up to 600 megawatts (MW). The wind turbines to be delivered under this supply agreement will be deployed at selected wind projects in southern Ontario and will provide clean power to approximately 240,000 Canadian homes. Furthermore, Siemens will establish a blade manufacturing site in Canada that is set to create up to 300 jobs in the province.

"With this supply agreement we are strengthening our position in the rapidly growing wind power market in Canada," says Jens-Peter Saul, CEO of the Siemens Wind Power Business Unit. "Furthermore, by investing in a new blade production facility in Canada, Siemens is pushing further ahead with the regionalization of its wind manufacturing network in important markets."

Siemens also recently invested in a U.S. nacelle production facility in Hutchinson, Kansas, which will start producing nacelles in December 2010. Siemens has been working with Samsung C&T and its development partner Pattern Energy on this first phase of development under Ontario's Feed-in Tariff (FIT) program where Samsung has committed to develop 2,000 MW of wind power over the next six years. The new wind turbine supply agreement is a significant step on the road to realizing this commitment.

The installed capacity of wind power in Canada is expected to increase from 3,400 MW today to more than 15,000 MW in 2020. Siemens already has a strong presence in Canada, so far the company has installed a total of 130 2.3-MW rated wind turbines at Kruger Energy's 101.2-MW Port Alma wind farm and TransAlta's 197.8-MW Wolfe Island wind farm in Ontario, and is supplying an additional 152 units of its 2.3-MW wind turbines to four recently announced projects, which will bring Siemens installed capacity to a total of 550 MW by the end of 2011.

Wind energy is part of Siemens' Environmental Portfolio. In fiscal 2009 revenue from the portfolio totaled about EUR23 billion, making Siemens the world's largest supplier of ecofriendly technologies. In the same period the company's products and solutions enabled customers to reduce their CO2 emissions by 210 million tons. This amount equals the combined annual CO2 emissions of New York, Tokyo, London, and Berlin. Further information is available at www.siemens.com/energy.

AFC-HOLCROFT SUPPLIES GEARBOX EQUIPMENT TO BREVINI WIND

AFC-Holcroft is pleased to announce the receipt of a new furnace order for a sealed quench furnace line that will be used to process specialized components utilized in the wind energy market. The furnace line is based on AFC-Holcroft's standard, modular UBQ (Universal Batch Quench) family of products, but was modified to optimize its efficiency for the mix of products required by this customer.

Brevini Wind, headquartered in Italy, is expanding their facility in Indiana, where the equipment will be installed. AFC-Holcroft is pleased to be part of the premium Brevini

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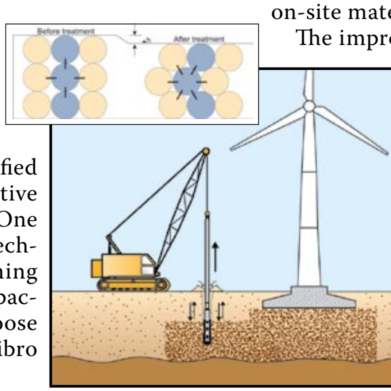
Mark Plaskett, PE
Hayward Baker, Inc.

When performed properly, vibro compaction is an efficient and economical alternative to traditional deep foundation systems for many wind turbine sites with loose granular soil conditions.

A DEEP FOUNDATION SYSTEM consisting of a mono-pole or drilled/driven piles is often recommended by the geotechnical engineer when the geotechnical exploration at a planned wind turbine tower location reveals that the subsurface conditions consist of loose, clean, granular soils (sands and silty sands). However, often the loose soils may be improved economically to enable the tower to be constructed on a shallow mat foundation. The improvement process permits the use of a higher soil bearing capacity and reduces both overall and differential settlement of the proposed foundation. Seismic liquefaction potential is also reduced as a result of the loose soils being densified beyond the threshold relative density for liquefaction. One ground improvement technique consists of performing a regular pattern of compaction probes within the loose soils, which is known as vibro compaction.



Vibro compaction is performed using a specially designed down-hole vibrator. The vibrator is typically between 10-15 feet long. Extension tubes are added to the vibrator to enable the vibrator to penetrate to the required depth at each particular site. Treatment depths in excess of 100 feet have been performed. The vibrator—also known as a vibro probe, or vibro flot—consists of a ±18 inch diameter closed end steel casing with an internal electric or hydraulic motor spinning an eccentric weight. The rotating eccentric weight causes the vibrator to oscillate horizontally, thereby imparting vibrations at the treatment depth. The vibratory energy allows the soil particles to move into a denser configuration by reducing the inter-granular forces between the soil particles. The improvement results in higher bearing capacity, lower settlement, and lower liquefaction potential. The vibrator can be suspended from a crane, excavator, or attached to a fixed-mast rig.

At each compaction point location the vibrator penetrates the ground by means of its weight or rig down-thrust, and it is assisted by the vibratory energy and (occasionally) water jets integral to the vibrator. After reaching the bottom of the treatment zone the soils are densified in situ for a specific time, and the vibrator is then raised several feet and the process repeated until reaching the ground surface. A crater will form at the compaction point location, indicating that deep densification is taking place. Clean granular backfill is added with a front-end loader to fill the crater. Oftentimes on-site material is utilized as backfill.

The improved soil characteristics depend on the soil type, the soil gradation, the spacing of the compaction points, and the time spent compacting the soils. The spacing for compaction points is generally between 6 and 14 feet, with centers arranged on a triangular or square pattern. The treatment is carried out to a depth sufficient to meet the design. Although the process is typically used to densify sands and silty sands it can also be used on mine spoils, provided they are granular in nature.

A quality control program is essential to assure the successful performance of a vibro compaction program. Field-scale testing should be performed at the beginning of the program to verify construction quality and design parameters. Consistent compaction point quality is ensured by monitoring the construction procedure and backfill quantity. The effectiveness of vibro compaction in granular soils can be readily verified using common test methods such as Standard Penetration Testing (SPT), Cone Penetrometer Testing (CPT), or Dilatometer Testing (DMT). The testing is performed between compaction points to verify that the design densification has been achieved.

Vibro compaction is available as a design-build service by specialty contractors. When properly designed and constructed, a vibro compaction program is an efficient and economical alternative to traditional deep foundation systems for many wind turbine sites with loose granular soil conditions.

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Merritt Brown
Rev1 Power Services, Inc.

In this conclusion of a two-part series, the author continues his discussion of proper bolt-tensioning techniques, providing tips on how to avoid the related failure and downtime.

IN THE SEPTEMBER INSTALLMENT of this column we began discussing various ways to avoid turbine failure resulting from bolt failure and/or improper bolting assembly techniques. We closed our conversation during an examination of the relationship between torque and tension, and the role lubricants play. The purpose of lubrication is to ensure that the applied torque stretches the bolt along its axis rather than twisting around its diameter. Just as failing to properly lubricate a bolt can increase torque readings, lubricating a bolt designed to be dry torqued could actually result in over tightening. Over torquing will cause failure by damaging the threads and deforming the bolt, sometimes with the failure not occurring until long afterward.

Whether using a manual torque wrench or a hydraulic unit, the importance of correct torque application cannot be overstressed. Uneven or additional loads that are applied to a bolting assembly may result in wear or premature failure. Sequential bolt-up procedures should be followed according to ISO standards using a cross-pattern or “star” pattern to apply torque in stages and ensure stress is applied uniformly across the bolted joint. The harder, high tensile bolting commonly found in wind turbine assemblies are also “notch sensitive,” having geometrical irregularities, notches, and holes that can build up stress concentrations and lead to fatigue and failure. Nuts and bolts may have severe stress risers formed by tool tears, and even ordinary tool marks can cause severe damage to the part if they fall in a region of high stress, such as a fillet under the head of a bolt. For this reason washers with a chamfer on one side are used on many turbine bolted connections to clear the radius under the head of the bolt, and to ensure consistent mating with the nut. Improperly installing this washer or using a normal, sharp-edged washer can cause a cut under the head of the bolt and create a stress riser at its most vulnerable point.

Although OEMs will each have their own specifications for break-in maintenance, this comprehensive service typically occurs at about the first 500 hours of turbine operation. The clamping forces that hold a bolted flange together change with temperature, and regardless of the time of year each turbine is assembled, almost all metals expand when heated. As one of the most critical inspections, a 100 percent re-torque of the turbine bolting is standard activity, from base to blade. Unlike the initial installation, however, there is no simple method to measure the tension of a bolt already in place other than to tighten it and identify at which point the bolt starts moving. When the bolt starts moving and the torque value drops sharply, this is considered the applied torque value and should be within tolerance of the initial setting. In addition to the 500 hour service, annual and semi-annual service checks will require at least a 10 percent re-check of tensioned bolts. Identified by witness marks on the heads of these bolts, a service technician will recheck a sequenced sample at each bolted joint to ensure the tensions have remain unchanged.

At a minimum, torque wrenches and other tensioning tools should be calibrated once each year through a certified lab, and most manufacturers state a 4 percent error as the maximum acceptable limit. Following heavy use or an unintentional drop, tensioning tools should also be recalibrated. A good practice is to also reset the wrench back to its lowest setting after each use, allowing relief of tension on the internal spring and helping to keep it from weakening. Cleanliness is also important, as a precision instrument with the slightest amount of dirt may throw off the calibration enough to break a bolt, strip a thread, or leave a bolt dangerously loose.

Joint strength is important to the longevity of a wind turbine, and if bolting is not torqued properly the joint is doomed to fail, and catastrophe can be lurking around the corner. The purpose of an OEM torque specification is to ensure that bolts are tensioned correctly. Expectedly, a calibrated torque wrench and diligent adherence to the turbine installation manual will help keep those turbines upright with optimum performance.

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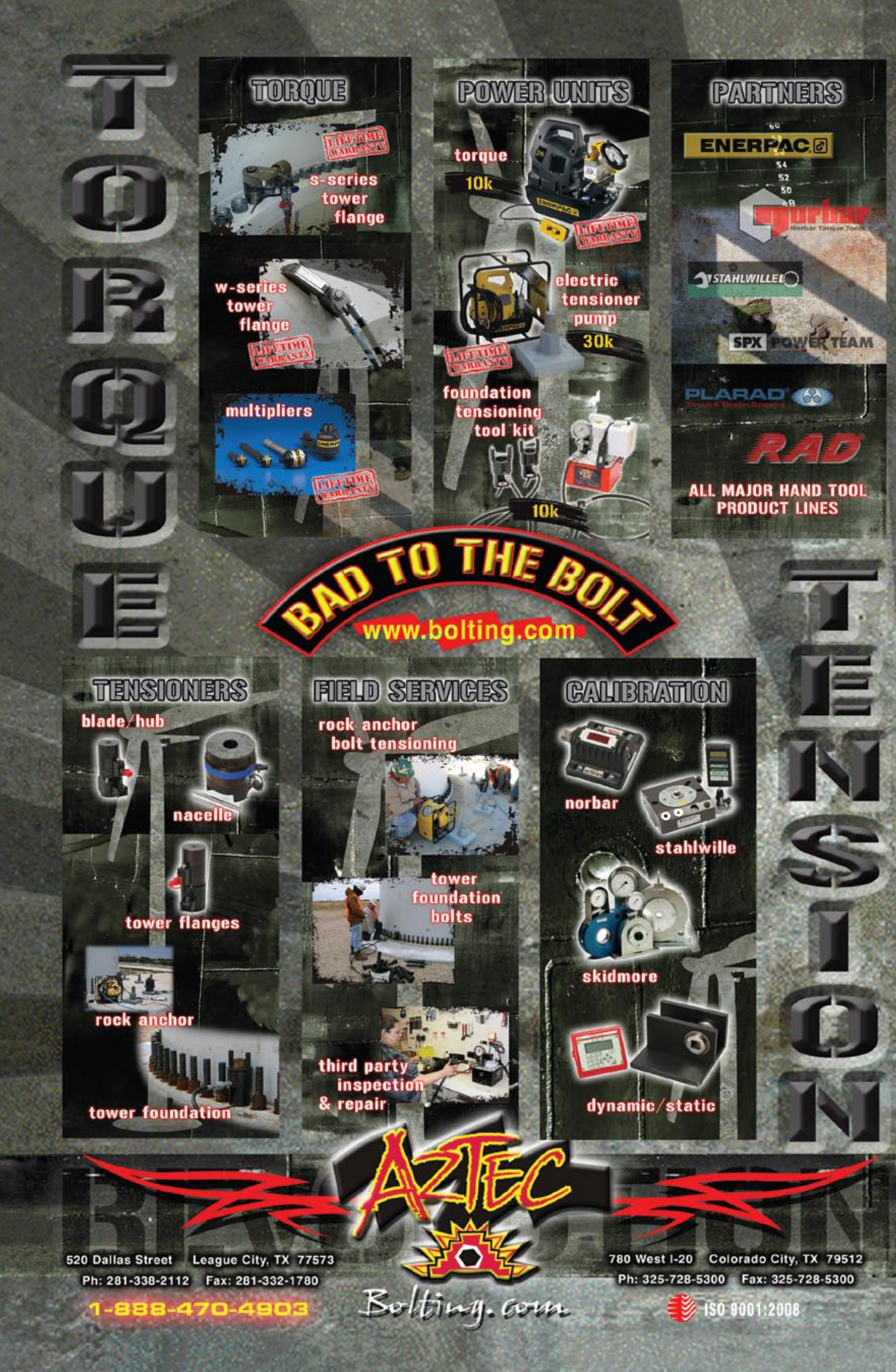
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Jose R. Zayas
Sandia National Laboratories

In addition to obvious siting factors such as location and productivity, national security concerns such as the effect turbines have on radar must also be taken into consideration.

THE SITING OF A WIND FARM PROJECT can be a lengthy, costly, and a complicated process once a developer takes into account the different requirements. Not only is it critical to identify a site on its resource viability, environmental impact assessments, transmission, and interconnection availability are just a couple of the required processes that must also be conducted or evaluated. Although the aviation impact assessment process has always been required, it is only recently that the industry as a whole has become aware of the complexity and magnitude of this process. A U.S. Department of Defense report was issued in 2006 documenting the impact of wind turbines on military missions, and awareness has increased since that time. Today many proposed projects are either on hold, deferred, or cancelled. Solely in 2009 there were nearly 9,000 megawatts that fell in either one of those categories; this is comparable to the number of installed MWs at 9,900+.

The problem the industry faces is that wind turbines can impact a radar's ability to perform its mission, independent of the type. It has been shown that wind projects can affect military radars, commercial aviation radars, weather radars, and border surveillance radar, just to name a few. Wind turbines are large obstructions with significant degrees of freedom. The combination of a large moving rotor, tracking of the wind (yawing), and the size of the machines create both a dynamic clutter and Doppler effect, which affects radars differently. The clutter of the machine is basically due to the return of the radar signal through reflectivity, and it is proportional to the radar cross-section (RCS) of the machine. Although the base of the tower is stationary, the nominal area of the turbine to the radar is dynamic since the machine is constantly tracking the wind. Wind turbines are made of highly reflective materials—steel, fiberglass, and carbon fiber composite—and can scatter and return a significant amount of the energy. The turbine tower is the most reflective component, but since it is constantly stationary the rotor is the largest problem to the radar. In most cases the signature can be quite large and can affect the radars/operator's ability to differentiate the wind farm from flying aircraft and weather storms. The Doppler effect is due to the moving rotor and can affect the moving target indicator of a radar.

Researchers at the national laboratories, in academia, and in industry have been investigating various ways to mitigate this challenge, with mitigation options divided between those for radar and others for the turbine. When assessing options for the radar one must keep in mind that, independent of mission, many of the radars across the country are over 30 years old, and the ability to modify them is significantly lower than that of a new unit. Additionally, radar replacement is feasible, but economics are the challenge since typical long-range radar can cost in the neighborhood of $20 million. As far as mitigation opportunities, options exist in software upgrades and hardware components that increase the sensitivity of the radar that can attempt to omit the static and dynamic obstruction of the turbines. An additional option is an in-fill or gap-fill radar, which consists of one or more lower cost radars (implementation depends on company) within the wind farm that provides resolution above the farm. The information from the in-fill radar can then be combined with existing units to provide a complete coverage map. There are various strategies and companies pursuing these options today, and preliminary results show promise.

Mitigation on the turbines is focused on reducing the RCS of the turbines themselves. RCS reduction, which is often referred to as "stealth," addresses the impact on both dynamic clutter and Doppler since it makes the turbines appear significantly smaller to the radar. There are multiple methodologies to reduce RCS that are being investigated, and the preliminary analyses and tests show promise. All options being researched are taking into account key wind metrics to continue to ensure wind energy viability. These include economics, impact to manufacturing process, and impact to O&M, just to name a few. These mitigation options will never completely mask the farms, but they can provide a valuable methodology that either independently or in combination with radar options can facilitate the siting of projects.

Although it would be ideal to have the ability to replace the existing radar network with newer assets that are able to mask wind turbines and preserve mission, it will be some time before that can happen. In the meantime, mitigation options on both the radar and the turbines must be explored and implemented. As the number of installations increase, the siting challenges will most likely increase as this new technology fights for its place in our future. It is important to keep all missions in perspective, as in this case where we must balance national security and our new energy security mission.

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Hüseyin Kizilagac
BDP Project Logistics

The potential for wind projects in developing companies is growing in leaps and bounds, which will create logistics challenges. Here's what you should know, and do.

WIND ENERGY POTENTIAL in a number of developing and emerging countries could be substantial. A recent U.N. wind study of countries from China to Nicaragua show approximately 13 percent of the land area has potential for development, compared to just 1 percent a number of years ago when wind potential was based on unreliable data. Among the nations surveyed Nicaragua, Mongolia, and Vietnam have the greatest potential, with about 40 percent of land area suitable for wind farms.

In Nicaragua, U.N. data estimates its potential at 40,000 megawatts, equivalent to 40 nuclear power plants. Vietnam's economy has grown rapidly and faces the need for a greater and more reliable power source. Opportunities for wind power in Saharan Africa and in the Middle East—such as Syria and Libya, as well as South Africa—are also great due to favorable investment climate, ideal natural conditions, and increasing energy demand.

Extreme temperatures produce extreme winds, giving many African countries some of the highest wind velocities in the world. Morocco and Egypt have taken steps to commercially harness wind power. Ethiopia has commissioned wind energy projects, and Tanzania and South Africa are planning projects. And in Kenya 365 large turbines will be installed near Lake Turkana, which will create the biggest wind farm on that continent.

However, with opportunities come challenges. Compared with wind energy projects in industrialized countries, projects in developing and emerging countries can incur higher costs for transportation, installation, and maintenance, as well as additional factors associated with the demanding climate conditions.

These countries have little or no infrastructure, and limited technology in place. While China may not be considered by most as a developing country, there are still significant transportation hurdles for wind farm developers in many parts of that country. The project in Kenya will require transporting turbines to a very remote location, and roads and bridges must be repaired before trucks can even be brought in. The challenges are even greater when components are coming from many locations and must arrive within a specific timeframe.

Transportation obstacles in developing countries can be overcome with the right project management, logistics resources, and freight-forwarding partners who can help ensure successful delivery of the cargo and prevent potential damages during shipping and handling. In other words, resources who can take planning and execution to an even higher level, providing solutions to issues such as authorization of road permits, special equipment importation, and temporary customs clearance. Many ports in developing countries do not have the necessary special equipment, and little to no experience in handling wind components, so look for a logistics provider that offers solutions that go beyond the norm.

Logistics providers must work with a knowledgeable, experienced marine surveyor at the entry port or discharge port, which is particularly important if the port has never handled wind components. Marine surveyors are responsible for making sure the cargo is properly handled—they inspect, survey, and document the physical movement at the port. The surveyor should have knowledge of how wind components should be lifted and handled. An inexperienced surveyor, or no surveyor, could prove costly.

The management of risk is also very important, especially for projects in developing countries. One of the logistics priorities should be the avoidance of damages and loss. But even with the best procedures damage can occur, and when that happens, delays will result. Insurance will help to mitigate the financial impact of damages, but it won't help the schedule impact. So a risk management program that relies upon having insurance and avoiding damage is very important.

In some developing countries, transporting components can—or must—include armed guards. For example, transporting from the port to the jobsite for the planned wind farm in Kenya is a long trip. Trucks may have to stop, and suitable locations must be selected to ensure cargo is secure. Personal safety issues cannot be ignored, either. Your logistics provider can help determine what security measures are appropriate. They should thoroughly review and make an assessment of the risks for each step in the project transportation timeline to help take the worry out of operating in developing countries.

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PH WINDSOLUTIONS, INC.

By Russ Willcutt

Photo credit: thanks to Janicki Industries, www.janicki.com, and the DeWind Co., www.dewindco.com.

With blade manufacturing facilities sprouting up throughout North America, this company is poised to provide increased efficiency through automated processes.

AS WIND TURBINES GROW larger, so do blades, requiring ultra-efficient manufacturing processes that ensure the highest possible structural integrity. And with blade-manufacturing facilities under construction throughout North America and around the world, PH Windsolutions, Inc., is in a position to streamline their process from the first day of production.

"With our fully automated Powerhinge mould-closing system, manufacturers no longer need to assign multiple cranes and highly skilled employees to position, close, and open the moulds," according to Ian Comishin, director of operations. "That means you can apply those important assets elsewhere, utilizing your resources more effectively and increasing productivity tremendously."

A previously existing company was founded in 2003 by Gabriel Mironov as Powerhinge Automation in Montreal, Canada. He relocated to China in 2007 where he founded Red Maple, which was eventually purchased by Gurit. After his departure PH Windsolutions was then launched as a separate, unrelated business entity in that same city by some of the former employees. Led by Marc Robitaille—who is president, and a longtime expert in developing cutting-edge industrial control and robotic systems—the company has ranged beyond its flagship Powerhinge device. Mould makers can now integrate the Powerheater heating system, hydraulic mould clamping, alignment systems, and other mould tool sets, providing blade makers with a higher level of manufacturing consistency.

Described as a company that solves problems—"we will take on any automation challenge that comes our way," Comishin says—PH Windsolutions is constantly gathering feedback and comments from its customers, improving and modifying its existing designs and seeking new ways of making blade manufacturing easier. This is enabled by the company's dedication to innovation, enhanced by the Canadian government's support of research and development activities.

"We're lucky to be in Montreal because there are some really great universities nearby, and that puts us in contact with all of these bright young engineers and technicians who are graduating and looking for work," Comishin explains, "and we're also contacted by program directors seeking internships for college students, so we get to know them even before they graduate. And Canada has a great program for supporting research, in that we receive salary support for hiring graduates who are involved in R&D."

In addition to these talented design and application engineers, the company's technicians are so knowledgeable that PH Windsolutions is one of the few mould tooling providers allowed access to blade-manufacturing facilities around the world, particularly in its territories of Europe and North and South America. "These companies are very protective of the manufacturing processes and techniques they've developed," Comishin explains, "but we've made clear we're committed to providing confidentiality, and that our only intent involves learning all we can about their particular application in order to optimize the design requirements. We want to make sure the equipment we provide suits our customer's needs perfectly."

The response to this approach has been remarkable, he says, since many blade manufacturers had simply resigned themselves to paying the extra costs associated with the manual nature of these processes in the past. Since the Powerhinge is completely automatic and extremely easy to use, the experienced crane operators and equipment once required to manipulate and position the moulds can now be assigned to other tasks. Once Comishin and his colleagues make potential clients aware that this automated technology exists, they immediately realize how the system will revolutionize their manufacturing process and how quickly it will pay for itself. "It's been our experience that these companies are grateful to have the opportunity to learn about this technology," he explains, "so the reception has been quite gratifying, and we now have more than 200 systems in service worldwide."

As this industry continues to grow and evolve, efficient manufacturing is just one factor that will help lower the cost of energy derived from the wind. Forward-thinking companies such as PH Windsolutions are invaluable resources in that endeavor. "Our primary focus is on developing blade manufacturing concepts that require less labor," Comishin says, "while at the same time delivering the highest level of quality and repeatability."

Call (514) 522-6329, e-mail sales@phwindsolutions.com, or go to www.phwindsolutions.com.

STRUCTURAL ADHESIVES FOR WIND TURBINES

For certain applications, adhesives can work better than other fastening devices and technologies. Read on to learn how LORD has helped a turbine manufacturer refine its design.

By Anita LaFond

Anita LaFond is with Constructive Communications, which represents the LORD Corporation. Go online to www.lord.com.

WHEN PEOPLE THINK OF "wind power" they often picture huge wind farms with towers dotting the horizon, but there are other means of harnessing the power of the wind as well. A new alternative energy concept captures not only wind, but also exhausted air from mechanical equipment to produce usable energy. Wind turbines manufactured by Green Cycle Wind provide valuable energy output from both natural wind and waste wind energy, helping customers reduce their energy bills. The wind turbines feature "dual-source" technology, an alternative energy concept developed by Vince Blake, founder of Green Cycle Wind.

"The wind turbines utilize two production sources to generate electricity, natural wind and wind energy from mechanical/HVAC-equipment-produced exhaust air," Blake explains. "This technology combines the green principles of both wind energy and recycling. By recycling a mechanical waste product, we greatly reduce the need to depend on intermittent natural wind resources."

DESIGN CHALLENGES

During the design stage for various turbine applications Green Cycle Wind found that the original construction material for the turbines, galvanized steel panels, were too heavy and not strong enough for certain installations. The company switched to lightweight composite aluminum panels, which were more durable and could more easily be adapted to different applications.

When Green Cycle Wind changed its construc-

Fig. 1: Green Cycle Wind's turbine utilizes both natural and waste wind sources to reduce energy bill costs for companies.

tion methods from galvanized steel to composite aluminum panels, the company also had to revise its turbine design and manufacturing procedures. The metal fasteners that held the original galvanized steel panels together were not only heavy but were prone to rusting and loosening, and they would not work well for the lightweight aluminum composite panels. In searching for a solution, Green Cycle Wind found that structural acrylic adhesives from LORD Corporation—a producer of general purpose and specialty adhesives and coatings—offered a solution that reduced weight while also providing benefits in reduced assembly time and corrosion protection.

LORD Corporation has extensive experience in supplying structural adhesives for product assembly and other bonding applications where high strength and ease of use is required. For Green Cycle Wind's wind turbine models, LORD's adhesives are used in the manufacture and assembly of the core blade components and turbine housings.

ADHESIVE ADVANTAGES

Structural acrylic adhesives are very high in shear strength, ranging from 1,000-4,000 psi, allowing them to be as strong as welding and most other conventional fastening methods. They maintain their strength over a wide temperature range as well: -40 to 170 degrees C. Unlike screws, bolts, or rivets that concentrate the stress at the point of attachment, adhesives spread the stress over the entire bond area. Adhesives act as a sealant by keeping out moisture and can compensate for dimensional irregularities by filling in gaps on poor fitting parts.

In assembly operations, adhesives are easier to use than mechanical fasteners or welding techniques. The adhesives are available in convenient cartridges with an applicator that permits instant application without measuring or hand mixing. Minimum surface preparation is required. There is no need to pre-drill holes and fill in over screw heads, and they eliminate rework caused by burning from welding operations. For Green Cycle Wind's wind turbines, the advantages of using LORD structural adhesives included:

- Improved assembly time;
- Elimination of stress concentrations caused by fasteners;
- Ability to mate complex joint designs, particularly at the blade area;
- Reduced noise and vibration;
- Environmental resistance.

PERFECT SOLUTION

LORD was able to offer a complete solution for Green Cycle, not just the adhesive product. "Our solutions package included everything from adhesive selection to joint design, assembly process, and fixturing to process control and dispensing," according to Carlos Cruz, product assembly adhesives and coatings, market manager, Americas region. "Our

Fig. 2: LORD collaborated with Green Cycle Wind to assemble components of their dual source wind turbine.

Fig. 3: LORD Corporation's new Maxlok adhesive is utilized in the construction of the dual source Green Cycle Wind turbine to improve joint design, reduce weight and reduce assembly design.

next-generation Maxlok acrylic adhesives were the perfect choice to meet Green Cycle Wind's challenging requirements including bonding dissimilar materials, improving durability and fatigue life, reducing weight reduction, and enhancing product aesthetics. We even provided R&D technicians to Green Cycle Wind, whose suggestions on how to manufacture the wind turbines saved them time and money over their previous methods."

LORD's technical service group helped its client implement the solutions package. "Reducing assembly costs and improving fatigue life were definitely the key drivers in the successful collaboration with Green Cycle Wind's turbine design," says Bob Zweng, global product integrator at LORD. "With our strong adhesive implementation know-how we were able to offer immediate input, sharing best practices with novel application processes and proven joint fabrication techniques."

BEYOND ADHESIVES

According to Blake, the partnership could not have been better. “They go beyond the typical customer service procedures that most companies pride themselves on,” he says. “It’s not just about ‘buy our adhesives.’ They truly collaborated with us every step of the way, showing us how to use the adhesives and offering ideas on how to market our products.”

Fast turnaround and expert technical-service material evaluations enabled Green Cycle Wind to quickly validate their finished product with confidence. “We have a long history of working with customers in a partnership mentality,” says Cruz. “LORD’s goal is to help customers improve their products by using the proper adhesive for the application. Their unique design and approach to the marketplace has great potential for exponential growth. This business relationship further demonstrates how we continue to expand and establish our presence in the wind energy market through innovative solutions.”

TURBINE DEVELOPMENT

One of Green Cycle Wind’s wind turbine installations will be for a large, multinational company in the Chicago area. In this application the turbines will harness waste exhaust from four cooling towers that are below the ground. The turbines will be mounted at ground level, and all the energy harvested will be returned to the electrical system to power everything from the cooling towers to the building’s lighting system.

“The wind turbines operate in the same manner, whether they are taking exhaust from roof-mounted or below-ground equipment,” Blake says. “Our turbines are very adaptable to the surrounding environment, and they can be mounted behind a building, next to a building, or on top of a building.”

Currently, Green Cycle Wind is planning to build a full-scale manufacturing facility to produce wind turbines using structural adhesives. LORD Corporation is

Fig. 4: Green Cycle Wind’s turbine made with LORD Maxlok adhesives allows companies to implement green solutions.

Fig. 5: LORD Corporation's sales and technical support allowed Green Cycle Wind to reduce costs and improve performance and durability for their wind turbine

assisting the company with a complete adhesives solutions program that includes joint design support, application recommendations, adhesive dispensing, parts processing, automation, parts fixturing, and final assembly. At its plant in Schaumburg, Illinois, the company has built an active-demonstration turbine wind unit that explains the waste-energy recovery process and shows measurement of the new energy generated. The demo cell points out the various components included in the wind turbine assembly, including LORD structural adhesives.

Green Cycle Wind's wind turbines are generating a lot of interest for other applications as well. Commercial building structure engineers are considering using the wind turbines as a means to utilize green technology, recover wasted energy, and reduce future energy dependences. The wind turbines are easily adaptable to urban environments with no structural upgrades needed for roof installations.

"The 'waste' wind produced by mechanical/HAVC equipment that is used in our equipment is a consistent, predictable source compared to natural wind, which is intermittent," Blake says. "Our electric wind generators produce a steady, reliable source of electric energy that provides consistent savings on energy bills. Even in wind-poor areas the turbines will produce significant amounts of renewable energy."

BONDING PARTNERS

To bring the benefits of wind turbine energy to an even larger audience, Green Cycle Wind is working globally with partner agreements in South America, Europe, and Asia. LORD Corporation is working with Ellsworth Adhesives, a preferred distributor partner, to meet the requirements of its client's global initiatives. Relying on LORD's structural acrylic adhesives and support program, Green Cycle Wind is well on its way to becoming a leader in the alternative energy market, having learned that adhesives are the ideal bonding solution for its wind-turbine applications.

GROWTH TRENDS IN WIND

A competitive analysis of conventional and renewable energy sources by Lucintel indicates strong global growth for wind in the coming years.

By K. Venkateshwar Rao and Manasa Gantayat

K. Venkateshwar Rao and Manasa Gantayat are with Lucintel. Learn more at www.lucintel.com.

DESPITE GOVERNMENTAL EFFORTS to tap various energy sources there exists a gap between demand and supply, and industries across the globe are bracing themselves to face the challenges posed by the gravity of energy crisis. Even the recent economic slowdown and increasing use of different energy sources have failed to mitigate the growing hunger for power, and demand for electricity is increasingly on the rise in India, China, and other developing countries due to the rapid pace of industrialization and increasing usage of industrial goods.

A recent research paper from Lucintel titled "Competitive Analysis of Conventional and Renewable Energy Sources: Opportunities and Cost Analysis" shows that, although most of the countries are dependent on conventional energy such as coal, natural gas, and nuclear, etc., due to growing environmental consciousness and government incentives entrepreneurs and investors are increasingly being attracted toward nuclear and renewable sources. Renewable energy's share will increase due to financial and governmental norms such as the Kyoto protocol, production tax credits, investment tax credits, and Feed in Tariff (FIT), etc.

In the last five years there was strong growth in renewable energy as compared to conventional energy. Renewable energy is likely to witness strong growth in the future, too. In the future solar/thermal might witness strong growth because utility companies are keen to generate electricity from the solar/thermal sources. There was miniscule growth in the nuclear energy, as it takes eight

to nine years to construct a new nuclear plant.

We found that in the overall energy market, acceptance and installation of other forms of electricity generation—particularly alternative "clean" generating technologies—could have a somewhat negative impact on conventional energy industry profitability. On the other hand, recent volatility in fossil fuel costs, coupled with the environmental problems associated with burning such fuels, could be a positive factor driving increased acceptance of alternative technologies, especially environmentally friendly technologies such as wind and solar. Power costs from solar generation have decreased via better technology, efficiency, and capacity scale. With the recent (mid 2008) uptick in fuel prices, energy costs became more competitive.

Wind energy was the fastest growing energy sector, with an average growth rate of 27 percent from 2004 to 2009. Europe has seen a consistent growth because of favorable government tax credit policies. Following these trends the U.S. government offered a production tax credit (PTC) in 2001 and 2003, and this resulted in a growth rate of 63 and 36 percent respectively in those years. However, in 2004, with the expiry of the PTC, wind turbine installations in the U.S. saw a virtual stop, and only 502 MW of new capacity was added that year. Interest in wind bounced back, however, and global cumulative installed capacity of wind energy reached 158 GW in 2009. The United States played a vital role in the growth of wind energy. The U.S. contributes nearly 22 percent i.e. 35 GW of global capacity installed. Wind energy contributed 3 percent of total energy market in terms of capacity installed in 2009. Among renewable energy sources wind energy contributed 64 percent of the total, excluding hydro energy.

Europe has championed growth in wind energy, and of the total 76152 MW installed in 2009 Europe installed 51 percent. The North American and Asian regions accounted for 25 and 22 percent of these new installations, respectively. The top five countries driving the growth of wind energy market in the last 10 years are Germany, Spain, the U.S., India, and China. Globally, new wind energy capacity installations have surged from under 47,620 MW in 2004 to more than 157,899 MW at the end of 2009, a cumulative growth of 27 percent.

The future of the wind energy market seems to be bright due to several economic and environmental reasons. The compound annual growth rate is expected to be 19 percent per year in cumulative capacity during 2010 to 2015. Currently, the overall wind energy industry is deemed to be profitable, and it is expected to remain profitable in the future based on an analysis of industry fundamentals and the competitive environment.

Contributing to industry profitability is the fact that revenue is concentrated in a relatively small number of major suppliers, many of whom have established positions in various countries and/or with specific wind farm developers and operators. On the negative side, the award of wind turbine orders typically occurs via a bid process where suppliers are quoting multimillion dollar installations to be delivered at a future date; the implicit financial risks of uncertain raw material prices, coupled with the pricing pressures of the bid process, tend to diminish profitability potential to some degree.

We found that the levelized cost of energy (LCOE) of wind energy declined during 1995 to 2003 due to a decrease in the price of the wind turbines, thereafter increased due to a rise in the price of wind turbines and again declined in 2009 due to a decrease in the price of the wind turbines. The price of wind turbines increased due to increase in the price of the raw materials such as steel, glass fiber, and copper.

The renewable energy segment grew robustly in

2009. Wind energy was the largest addition to renewable energy capacity, with 38 GW additions in 2009. The major renewable energy sources are wind energy, solar photovoltaic, solar thermal, geothermal, and marine, tidal, etc. China was the key driver, with new wind capacity installations of 13 GW in 2009.

The cumulative capacity installed of wind energy in 2009 was 157 GW, with additional capacity installed being 37 GW. The growth rate of wind energy was 27 percent CAGR in the last five years (2004-09) driven by growing environmental awareness, legislative support and incentives, and a move toward greater energy security. In the energy sector, wind energy is the most rapidly growing energy sector in the world. The driving forces for the growth of wind energy market are listed as follows.

Reduced environmental impacts: Many countries have decided to reduce carbon emissions to help alleviate global warming. By 2020 the EU-27 countries have decided to reduce emissions by at least 20 percent, compared with 1990 levels. As wind is renewable energy there are no carbon emissions, therefore increasing the number of countries opting for renewable energy such as United States and Europe, which are expected to generate 20 percent renewable energy by 2020. As many countries have signed the Kyoto protocol to reduce the carbon emission growth rate of carbon producing energies such as coal and natural gas, energy is expected to slow down in future. One of the major driving forces behind the high growth of wind energy installations is the Kyoto protocol, which aims to cut emissions of greenhouse gases by 5.2 percent in relation to 1990 levels before 2008-2012. This is a very ambitious target, given that global energy consumption simultaneously continues to rise. The fact that wind power is a clean energy source that has become increasingly competitive compared to other sources of energy in recent years gives grounds to believe that the utilization of wind power throughout the world will make an important contribution to achieving the targets laid down in the Kyoto protocol. Wind energy provides greatly reduced environmental impacts per unit of energy produced, compared with conventional power plants. Environmental costs are becoming an increasingly important factor in utility resource planning decisions. Wind energy is a key solution in the fight against climate change, and it is well on track to saving 10 billion tons of CO_2 by 2020.

Electricity demand: There is growing electricity demand in the developing countries like India and China. As there is strong growth in the industrial sector and substantial increase in the usage of consumer durables, there is more demand for electricity in various countries. Global electricity demand has been growing with a CAGR of 3 percent in last five years to reach 18,000 TWh in 2009.

Incentives: The production tax credit (PTC) in the Unites States is $20/MWh. There is investment tax credit, too, for renewable energy. In the new U.S. budget $80 million has been earmarked for wind energy. The Indian government will offer Rs. 380 crore ($81 million) in incentives to wind energy projects. In Germany, Feed in Tariff (FIT) wind onshore (20 years in total)- Euro 83.6/MWh for at least five years, Euro 52.8/MWh for further next 15 years. Wind offshore (20 years in total) –Euro 91 /MWh for at least 12 years and Eoro 61.9 / MWh for further eight years. In Spain FIT, fixed feed in tariff euro 68.9/MWh and premium tariff euro 38.3 /MWh. In India FIT, 3.76-5.64 INR/KWh. In China FIT 0.51CNY /KWh to 0.61/KWh depending on the wind output.

Greater fuel diversity and less dependence on fossil fuels: Greater fuel diversity and less dependence on fossil fuels—which are often subject to rapid price fluctuations and supply problems, are significant issues around the world today—with many countries rushing to install gas-fired electric generating capacity because of its low capital cost. As world gas demand increases the prospect of supply interruptions and fluctuations is expected to grow, making further reliance on it unwise and increasing the value of diversity.

Cost: The cost of generating electricity from wind energy is low as compare to other renewable energy sources such as solar PV and solar thermal.

For the conventional energy such as coal, natural gas, and nuclear, the major drivers are the cost of generating electricity. The cost of generating electricity from the conventional energy is lower as compared to renewable energy. The abundance of raw materials and the non-reliance on nature are the major drivers behind conventional energy. On the other hand, recent volatility in fossil fuel costs, coupled with the environmental problems associated with burning such fuels, could be a positive factor driving increased acceptance of alternative technologies, especially environmentally friendly technologies such as wind and solar.

The research would not be complete without analyzing the LCOE of different energy sources. The LCOE is the cost of generating energy for a particular system. It is an economic assessment of the cost of the energy-generating system including all the costs over its lifetime: initial investment, operations and maintenance, cost of fuel, etc. Some of the significant outcomes of our analysis on levelized cost are: the levelized cost of energy of solar PV is maximum, which is \$295/MWh followed by solar thermal (\$197/MWh); the levelized cost of energy of wind is \$ 106/MWh. The cost decreased in 2009 as compared to 2008 due to decrease in the wind turbine cost; and the levelized cost of energy of coal is \$80/MWh.

We found that the LCOE of solar PV is maximum among all the energy sources due to high capital cost. The LCOE of natural gas is low among all the energy sources due to minimum capital cost requirement. The LCOE of natural gas is less, followed by coal. As per the study the levelised cost of energy will increase in future for coal, natural gas, nuclear, and wind. There will be decreases in the LCOE of solar PV and solar thermal.

We found that the cost of generating electricity from solar photovoltaic and solar thermal will significantly decrease in the near future. The cost of generating electricity from solar photovoltaic will decrease substantially due to a decrease in the price of the solar module. More and more solar module and polysilicon players will enter the solar photovoltaic market.

As per our estimates, the energy market is expected to grow at a CAGR of 3.2 percent in terms of capacity installations during 2010 to 2015. There will be strong growth in global renewable energy, with 19 percent CAGR in next five years up to 2015. Solar thermal is expected to top the growth rate, with 62 percent CAGR in the next five years (2010-2015). The CAGR of solar photovoltaic is expected to be 32 percent, and wind 19 percent in the next five years (2010-2015).

A MEASURED CHANGE

The wind industry is moving toward ultrasonic anemometers and other alternative data collection methods for site assessment and turbine control.

By Ann Pattison

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ACCURATE, PRECISE, and reliable measurements of wind speed and direction are critical in today's increasingly competitive North American wind industry. Demand for reliable wind data is high, and manufacturers are responding with more equipment choices than ever before. As the size of wind turbines increase to 100m and beyond, finding the right mix of remote sensing technology to accurately measure the wind is becoming more of a challenge. New high tech sensor technologies using ultrasonic signals, radars, or lasers used exclusively in meteorological scientific research applications in the past are now being widely used in the wind industry as long life and reliability begin to overtake low cost as the primary consideration.

Ultrasonic, radar, and mechanical sensors measure the wind in very different ways. The "cups" for speed and "vane" for vector change measurement physically move with changes in the wind and give readings of wind speed and direction. Ultrasonic sensors, or "sonics," operate with no moving parts. On a typical ultrasonic anemometer a pulse of sound is transmitted by a transducer on the "north" facing side of the sensor. The time it takes to travel to the "south" transducer is accurately measured by a microprocessor within the sensor. The wind speed is calculated as a function of the time it takes the ultrasonic to travel to the opposite transducer. With no moving parts the measurement is immediate and precise. Sodar and lidar uses radar and lader respectively to

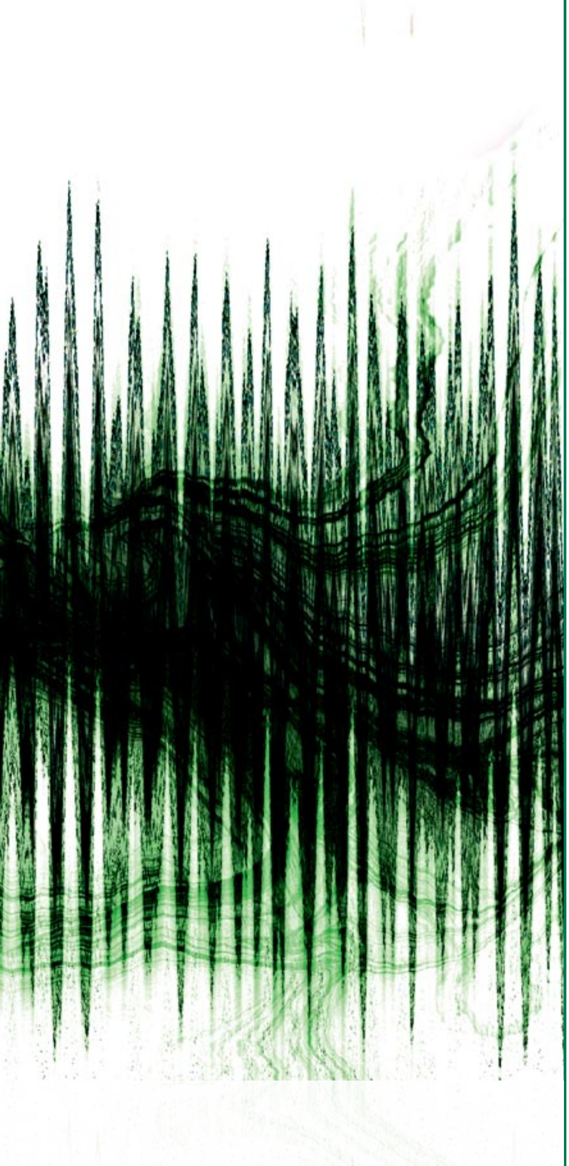

Fig. 1: V200A ultrasonic anemometer with 20W heater.

measure wind speed at various heights. These also have no moving parts and can be moved around a prospective site, as they typically are in mobile a ground-based units.

Sodar and lidar use radar and laser respectively to measure wind speed at various heights. Sodar (sonic detection and ranging) systems are used to remotely measure the vertical turbulence structure and the wind profile of the lower layer of the atmosphere. Sodar systems are like radar (radio detection and ranging) systems, except that sound waves rather than radio waves are used for detection. Most sodar systems operate by issuing an acoustic pulse and then listening for the return signal for a short period of time. Generally, both the intensity and the Doppler (frequency) shift of the return signal are analyzed to determine the wind speed, wind direction, and turbulent character of the atmosphere [1]. Lidar is similar, but it uses laser light to detect changes in wind speed and direction.

When averaged over periods of time, sensor measurement accuracies are comparable. Any quality sensor (and qualities do vary) measure at the level reported in sensor's published specifications. Data may be reliable and accurate when averaged over time, but mechanical sensors will not always reflect turbulence (rapid changes in wind speed and direction) and gusts due to the simple physical limitations of moving parts. A mechanical sensor is affected by the start-up torque of the moving cup and vane. Observed differences occur in measured wind speed because of the time it takes a mechanical sensor to physically start up or register a change in wind direction. An ultrasonic sensor is not affected by physics of inertia. It will measure a change in wind direction or a high gust immediately and in real time. Sodar and lidar are difficult to compare directly.

NWS TAKING THE LEAD

The inability of mechanical sensors to measure sudden changes prompted the National Weather Service to initiate a widespread change to all its Automated Surface Observation Systems (ASOS) from mechanical to ultrasonic sensors. ASOS systems serve as the United States' primary surface weather observation networks. There is a network of 883 ASOS weather systems installed throughout the United States. The majority of these are used for aviation services managed by the FAA. Data is public and available for use by anyone for reference purposes. The NWS initiated the weather sensor upgrade program in 2000 following a new requirement by the Federal Aviation Administration (FAA) stating that all sensors needed to be capable of measuring variable gusts at three second intervals. Mechanical sensors are not designed with this capability. Most can only measure rapid wind speed changes to five-second gusts.

Reliability was another stated reason the NWS decided to make the switch to ultrasonics. Al Wissman, the acting operations division director of the NWS says "there were mechanical deficiencies in the old sensors. Freezing was always a problem, and when the sensors froze they became inoperable or inaccurate. This is a huge problem when directing aviation" [2]. Not only are ultrasonic sensors often heated, but the ultrasonic pulse itself creates heat when operating. This prevents ice formation on the sensor transducer heads, even with a non-heated sensor. The upgrade of the systems from mechanical to ultrasonic wind sensing equipment was completed in 2005.

Ultrasonic sensors are ice resistant on tall towers and less susceptible to damage caused by falling ice. In a recent test conducted with Lufft brand ultrasonic wind sensors, these highly heated ultrasonics were proven to continue operation in extreme freezing rain and high wind conditions over extended periods of time as per MIL standard- 810F, the U.S. military standard for ice resistance. Future ultrasonic anemometers with intelligent interfaces will deliver added values such as an electronic compass and barometric pressure sensor. Virtual temperature comes as a standard measurement with the Lufft ultrasonic sensors. Lufft sensors were also proven corrosion and vibration resistant in similar MIL standard tests.

Wind developers will often use ASOS, along with other NWS data as reference when determining the feasibility of a project site. New site measurements from met towers are correlated with existing wind data from a geographical area and used to validate data. NWS data is used as a general reference since many wind developers currently use mechanical sensors to capture onsite wind data, there is an increasing problem of inconsistency when referencing the ASOS ultrasonic wind data for a region. When submitting a wind project for financial review, consistency of data is the primary point of consideration.

WIND ANALYSIS FOR SITE ASSESSMENT

Until the last few years, ultrasonic sensors and remote sensing (sodar and lidar) have been a secondary measurement for wind profilers. This is partially due to the perceived high cost and low concern for long lifecycles in the profiling and assessment market. Widespread use of mechanical sensors in the industry's past has not only been a matter of price, but of historical precedent for industry accepted measurement standards. Mechanical sensors are the only ones certified as Class A. Class A or Class 1 is the term for a sensor meeting the MEASNET and/or IEC standards. The IEC and MEASNET qualify Class A devices for contractual applications, the verification with standards, and resolving disputes between the utility and end customers. Class A has become a common name for sensors in the wind assessment business since the standard was released. Only a handful of sensors are manufactured and calibrated to meet this specific regulatory standard for wind measurement, all of them mechanical.

Though mechanical sensors have a qualified international standard for performance, they do not always perform to that standard or do not meet all the qualifications. Issues of icing, start up speed, vibration and poor tolerance to high wind gusts are just a few of the maintenance pitfalls mechanical sensor users have grown accustomed to. One study put out by the Center for Renewable Energy Sources (CRES) reported that mechanical sensors need to be recalibrated after 12 months of use in the field [3]. This is due to the fact that they have difficulty withstanding impact of sustained wind over time and are susceptible to other environmental hazards.

Steve Kropper, CEO of Windpole Ventures, says that "If we look at a life cycle costs over five years, a cup anemometer with a calibration certificate may cost just $350, but as soon as it fails the anemometer looks expensive. It costs roughly $1,000 every time we have to climb a tower. Now each sensor costs $1,700. And that makes ultrasonics look like a smart buy. Further, regardless of cost sensor failure undermines the Windpole mission for dependable, real-time hub height wind resource data. So frequent cup sensor failure is not an option" [4]. Kropper contracted with GL Garrad Hassan on a 12-month study comparing ultrasonic anemometers with industry standard cup anemometers.

WIND ANALYSIS FOR TURBINE CONTROL

The majority of large turbine manufacturers have gone to ultrasonic anemometers as a lower maintenance means of controlling a turbine's pitch and yaw system. A turbine control anemometer acts as the eyes and ears of any wind turbine. Turbine control and project SCADA systems rely on this relatively small component to direct the turbine into the prevailing wind for optimal efficiency. When it is placed high atop a wind turbine, an anemometer with moving parts that freeze over or break off stop all data transmission to the turbine controls. A "met fault," as it can be called in the SCADA world, brings a turbine down immediately. It is critical that a wind turbine cease operation if communication with the anemometer is interrupted. If a turbine continues to operate when it is not pointed directly into the wind, the shear across the turbine blades can cause damaging mechanical strain on the machine.

Any power that is produced during the time after a turbine shuts down for a met failure is not recorded by the SCADA control system. Less sensor reliability means decreased wind farm reliability and significant lost profits for owners and utilities. "Turbine anemometer failure events are not only bad for the owner, they are a nightmare for the utility," according to one large Colorado Utility representative. "With more wind than ever feeding into the grid, this is true now more than ever." It is clear that the wind industry's eyes are turning to sensor reliability as linked to project reliability.

So which sensor is best for you? Turbine manufacturers and wind profiling/forecasting specialists still use mechanical sensors on a regular basis. These industry professionals claim that the data is more accurate and reliable as cup sensors. A mechanical wind sensor can be the right choice when considering [5]:

- A low-cost alternative;
- A situation where moving parts are preferred;
- A replacement to match an old mechanical system where a high tech upgrade is not desired;
- Data does not need to be logged or archived;
- A shorter life cycle for the sensor is not an issue;
- A system that requires extremely low power (<4VA).

Ultrasonics are a newer technology. Change is always a challenge, especially in an industry used to doing things fast and in a certain way. One leading developer who is familiar with both methods of meteorological measurement says that "Consistency and price are the main reasons the industry has been reluctant to switch over to ultrasonics… consistency that is changing now that the National Weather Service replaced their mechanical sensors with ultrasonics over five years ago" [6]. Although more expensive, ultrasonics are the best choice when considering:

- Measurement of 3D wind speed and direction is needed;
- Extreme accuracy is required;
- Maintenance free is a priority (such as on the top of a turbine);
- A long life cycle with little risk of replacement is desired;
- Extreme cold and environments where ice is prevalent.

Remote sensing such as sodar and lidar are finding more acceptance with wind prospectors who want to quickly assess a site with a compact moblie unit. There is still some uncertainty with data reliability and the industry has been slow to accept sodar or lidar as the sole source of measurement when financing a new wind power project. Sodar and lidar are advantageous when considering:

- Quick deployment for a cursury study of a larger wind site;
- Measurement at extremely high hieghts is desired without the construction of a tall tower;
- A portable system, sodar can gather wind data on an operating wind farm to predict maintence needs;
- A low cost compliment to installed met tower data or purchased tower data.

Mechanical, ultrasonic, and radar- and laser based technologies all hold their own place in an ever-adapting wind industry. While mechanical sensors are a time-tested and internationally regulated technology, the precision and maintenance-free aspects of sensors with no moving parts are bringing them into the spotlight as time goes on. The National Weather Service upgrade from mechanical to ultrasonics started a trend. However, the IEC specifically cites mechanical sensors for use in wind assessment. Time, research, and experience will show how the industry will accept growing use of ultrasonics, sodar, and lidar technology. For now it appears this new technology has found a firm and growing place for wind assessment and turbine control applications.

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MEASURING FOR WIND ENERGY

When manufacturing components for wind turbines, take the time to review your inspection strategy in some detail. Here, Carl Zeiss provides some pointers.

By Gerrit deGlee

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ACCURATE MEASUREMENT IS IMPERATIVE to maintaining success in manufacturing wind turbine components. Poor-quality components result in extra costs and inconvenience for everyone involved. It's important to always maintain the compliance of dimensional drawing requirements for individual pieces that make up a turbine. For example, when a gearbox is not manufactured properly it will potentially lead to premature failure of component gears, bearings, and perhaps even the housing itself.

MEETING DESIGN CRITERIA

If there is a problem due to inaccurate measuring, it can easily cost $200,000 just to bring a crane out to a tower location before any work is done. A gearbox rebuild can cost upwards of $100,000, and generator rebuilds can cost around $25,000. It is not uncommon to have a three month lead time to get a crane capable of servicing these larger wind turbines, resulting in the loss of revenue for a full fiscal quarter. Any unplanned maintenance in these areas can affect the reputation of the wind farm, the company whose logo is on the nacelle, and potentially the entire wind industry.

So how do you make sure that gears, bearing races, housings, and other machined subcomponents meet design criteria? The easy answer is to measure them, but this is easier said than done for a couple of reasons. Let's

start by looking at how the tolerances commonly specified on these parts are often quite challenging. Many of the piece parts are very large, and many companies simply do not have gages of sufficient size or accuracy to make the necessary measurements. It's very common to underestimate the repeatability requirements of the gage that is being considered for inspection. Typically, when you have a manufacturing tolerance, you would like your gaging variation to be less than 10 percent of the manufacturing tolerance. This means that the gaging system must have an average repeatability of less than 4 percent of the part tolerance.

One example would be that if the part drawing shows a dimension with a 0.001 inch tolerance, the gaging system must exhibit an average repeatability within 0.000033 inches (0.025 mm would require an average repeatability of 0.0008 mm). This criteria is even more crucial when producing parts for the wind turbine industry, because the volumes are not typically large enough to do machine tool offsets based on statistical sample sets. When measuring one part, the data must be correct and trusted (fig. 1).

There must be both accuracy and repeatability in your gaging systems to ensure correct actionable data. If you measure a part a second time and get a different result, then your gaging strategy should be in question. Specifics that can influence the results of the measuring machine include the machine size, the weight capacity, the thermal environment, and vibration sources.

UNIQUE MEASUREMENTS

Sometimes, bigger really is better. Carl Zeiss manufactures many unique models of coordinate measuring machines (CMMs) that address different measurement problems. Among these are systems specifically designed to measure large wind turbine parts. Carl Zeiss has built and delivered high precision gantry measuring systems with measurement volumes up to 5 meters wide, 11 meters long, and 3.5 meters high. As the measurement systems become larger it is necessary to account for environment factors that may be negligible in smaller sized systems.

To ensure the best accuracy Carl Zeiss has chosen to use steel structural components on these larger high-accuracy machines, similar to most machine tools. The structure was designed using the latest finite element design tools available. Other materials, especially for larger machines, will have the tendency to increase variability. For example, when used in these large-scale machines granite is subject to swelling with humidity changes. This can affect the bearing relationships, requiring greater bearing offsets that result in measurement variation. Another adverse characteristic of the large-scale granite construction is that granite has very low thermal conductivity. When there is a change in the thermal gradient in a facility it will result in a bowing of the granite member. Over the long reaches of the CMM, this translates into significant potential measurement error. Carl Zeiss has carefully considered these environmental impacts in the design of these coordinate measuring machines.

How do you know the system accuracy is sufficient? There are some pretty good standards that specifically address this topic. ISO 10360 covers CMM measurement accuracy quite well. The difficulty is that some manufacturers may

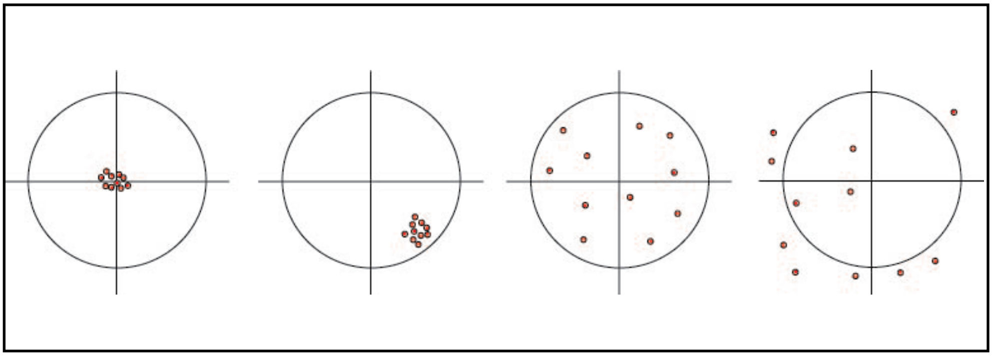

Fig. 1: There must be both accuracy and repeatability in your gaging systems to ensure correct actionable data.

be more aggressive with their accuracy statements than others, making it difficult to use this as a clear differentiation value. Note that the accuracy specification only applies within the environmental specifications of the supplier. These specifications are usually footnoted, indicating that the tests are done with very short styli. Another point to consider is that the uncertainty of an indexing probe device is not considered in this statement.

The chart shown in fig. 2 is an example of repeated measurements of a traceable artifact on a large Zeiss MMZ G gantry machine. The red lines indicate the limits, and the small plus (+) marks indicate multiple measurements of the reference standard.

TESTING THE TECHNOLOGY

There is a better way to ensure that you're getting the right machine. As previously mentioned, in order for a gage to produce meaningful results they must be repeatable. By asking the prospective suppliers to perform a Gage Repeatability and Reproducibility (GR&R) study you will begin to see the differences in the proposed systems. This test ties all of the pieces together. It requires the use of probe configurations necessary to measure your parts. The test will show whether the system can reproduce the measurement results from one inspection to the next. Otherwise the data from the gage is meaningless.

To learn more about GR&R studies, the Automotive Industry Action Group (AIAG) Web site—www.aiag.org—and Measurement Systems Analysis (MSA) manual are good sources. Some manufacturers will discourage GR&R tests. This should definitely be considered a red flag. Why would they discourage the opportunity to show the capability of their machine to measure specific parts? One argument is that the test ideally requires the use of 10 different parts. For a variety of reasons this can be difficult to accomplish with large, low-volume parts. Smaller subsets of parts are also acceptable. As a minimum alternative, send a single part and have the prospective vendor inspect some critical dimensions. Then remove the part from the gage, reload the workpiece, and then rerun the inspection cycle. This should be done approximately 10 times to review the range of measurement results. Mathematically, the average range of measurement results should be less than 4-5 percent of the part tolerance to ensure you are not using over 10 percent of the production tolerance; with an 8-10 percent range you can expect a 20 percent GR&R.

Yet another key advantage of the Zeiss CMM is the choice of sensor technology only available from Carl Zeiss. For larger components it is often necessary to acquire accurate data from features located a long distance from the sensor. The Zeiss VAST scanning sensor is able to take single points or scan surfaces using long probes. Through the use of patented force generators within the probe sensor it is possible to do this with the highest accuracy and repeatability. The sensors are critical to achieving the repeatable measurement results. The sensor contribution to measurement uncertainty and variability is limited in the ISO 10360 tests.

Alternatively, there are instances where an indexing probe system is beneficial. For this case Carl Zeiss offers the best combination; an indexing and scanning sensor. The VAST XXT sensor mounted to the indexing RDS head can take single points, scan the part, and index the sensor in 2.5-degree increments for ultimate access to geometry. An example where the RDS might be beneficial would be the inspection of a turbine hub. Specific inspection needs will dictate the sensor appropriate for the job.

SOFTWARE SOLUTIONS

Software allows you to get the most from your

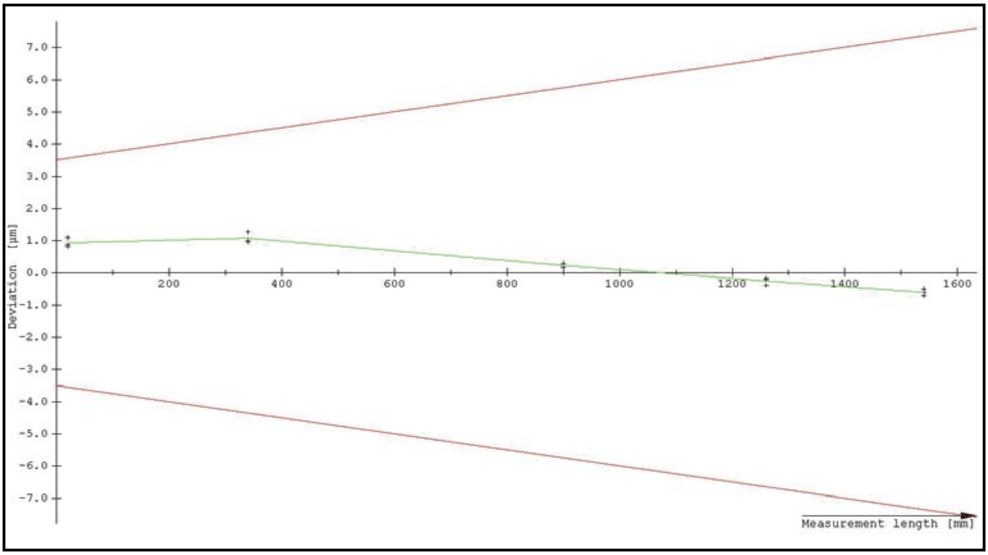

Fig. 2: Repeated measurements of a traceable artifact on a large ZEISS MMZ G gantry machine.

coordinate measuring machine. The Zeiss CALYPSO®-based software has a user-friendly platform that provides the user with many metrology tools. This CAD-based software has tools to measure everything from gearboxes to bearing races, ring gears to pinions, and the ability to do profile measurements of turbine blades.

There are many features within the software to help the user focus on quality control rather than software manipulation. For example, when doing a GDT evaluation the user


MMZ B

Fig. 3: Nose cone being measured on a ZEISS MMZ G gantry machine.

enters the data as it appears in the GDT control frame, referencing the pertinent datums as necessary. The software will create the necessary coordinate reference frames for the analysis. There are even tools to increase inspection throughput, graphical output options, and much more.

When a fly lands on a railroad track, does it bend? While this may be an extreme example, the theoretical answer is yes. With this thought in mind, a proper foundation must be considered when installing a gantry machine. Even a concrete foundation will bend when weight is applied to it. Since a gantry machine is usually built on a foundation, consideration must be given to the weight of parts being loaded, fixtures, and even the loading mechanism. All these components have the potential to cause the machine bed (the foundation) to bend. When you purchase a machine from Carl Zeiss we will provide recommended foundation drawings for your specific set of circumstances.

Another thing to take into consideration is that vibration in a plant can affect measuring machines. When the foundation is designed to accommodate the needed weight, Carl Zeiss will include the recommended vibration isolation system. Typically, there are three possibilites: 1) a passive system with a foam type of lining around the rebar reinforced concrete block; 2) a spring isolated system, and; 3) a pneumatic damping system. The soil conditions at your installation site, coupled with the prevalent vibrations, will dictate the system that is necessary. Any measuring machine that is installed without consideration of the prevalent vibrations will produce questionable results.

CONCLUSION

The large turbine wind energy business is a high-dollar business. In recent years, much of the warranty repair has been covered by the OEM suppliers of turbines. In the near future many of these earlier installations—within the past five years—will have expired warranties, and the burden of paying for the unscheduled repairs will fall on the wind farm owner. Whether the cost is covered under warranty or later by the wind farm, in all cases the costs come back to the consumer.

When manufacturing components for these wind turbines, take the time to review your inspection strategy in some detail. The points discussed in this article apply to other gaging systems, just as they do for coordinate measuring machines.

NEAR TERM POWER PREDICTION

While the variability of wind has become a challenge in the operation and management of wind turbines, data mining is an emerging science that offers a solution.

By Andrew Kusiak and Zijun Zhang

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WIND ENERGY IS BECOMING A SIGNIFICANT player in the electricity supply market. However, the variability of power generation due to uncertain wind supply has become a challenge in the operations and management of wind turbines. Data mining is an emerging science offering great potential to handle this challenge. The data utilized to establish data-driven models has been collected from the SCADA (Supervisory Control and Data Acquisition) systems at a sampling frequency of 0.1 Hz.

MODELING POWER GENERATION

In this article two types of data-driven wind power models are presented. The first model for power prediction is developed based on the power curve equation [1], frequently referred to in research and practice. In the power curve equation all parameters, with the exception of the power coefficient, are measurable. Thus, to estimate the power generated from a wind turbine the power coefficient needs to be computed first. Data-mining algorithms are applied to train the model for the power coefficient.

Besides estimating the turbine-generated power used on the power curve equation, data-mining algorithms can be directly applied to predict the power based on parameters such as wind speed, generator torque, and blade pitch angle. The advantage of this approach for predicting the power generation process is that the error amplified by some terms of the power curve equation can be mitigated.

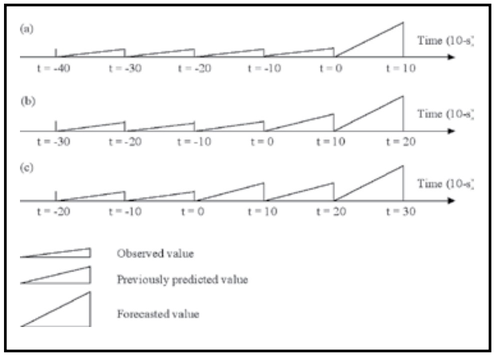


Fig. 1: Prediction with data-driven time series models.

MULTI-PERIOD POWER PREDICTION

These data-driven models are not only able to estimate the power generated at the current time, they are also able to predict the power generated in the future, such as 10 seconds to 1 minute ahead. In order to predict the generated power in the future, the future values of parameters of data-driven models need to be predicted first. The second model discussed in the next section is utilized to demonstrate short-term power predictions. Three parameters—wind speed, generator torque, and blade pitch angle—are considered in the model. The approaches to predict the future values of these parameters are discussed below.

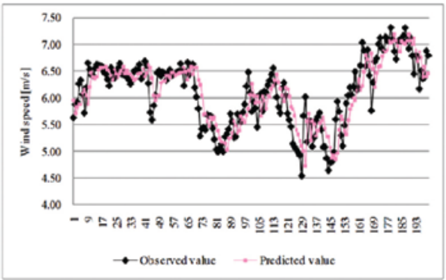
Time-Series Wind Speed Prediction Model

In this section the data-driven approach is used to establish time-series models to predict wind speed by considering its past states. The logic behind constructing the time-series models to predict wind speed is illustrated in fig. 1.

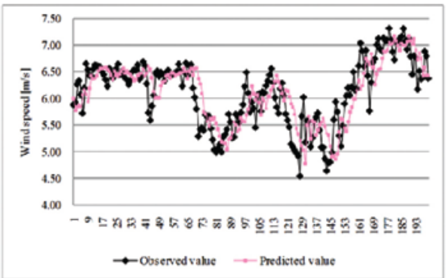
Figure 1(a) demonstrates the one period (state) ahead prediction based on the past states. The four past states, i.e., the mean measured values over the intervals [t = –40, t = –30), [t = –30, t = –20), [t = –20, t = –10) and [t = –10, t = 0), are the inputs of the data-driven model to predict the mean value over the interval [t = 0, t = 10). The model itself is learned by a data-mining algorithm from the industrial data. Figure 1(b) shows the prediction of future values at two periods (states) ahead. The previously predicted mean value in the interval [t = 0, t = 10) and the past observed values, [t = –30, t = –20), [t = –20, t = –10) and [t = –10, t = 0), are now treated as the inputs of the model to predict the future state. The prediction function for this state is learned by a data-mining algorithm. Figure 1(c) illustrates the

Model	MAE	Std. of MAE	MAPE	Std. of MAPE
Neural networks	0.3835	0.3776	0.0592	0.0678
Support vector machine	0.4405	0.3712	0.1017	0.1566
k-nearest neighbor	0.5368	0.5079	0.0843	0.1263
Boosting tree	0.5277	0.4571	0.1252	0.2326
Random forest	0.8207	0.7578	0.1219	0.1326

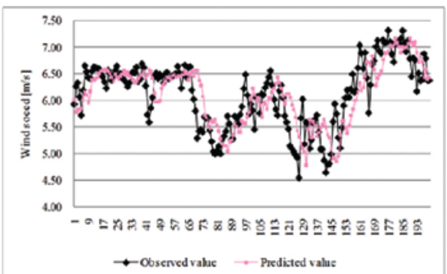
Table 1: Testing results of five algorithms in wind speed prediction.



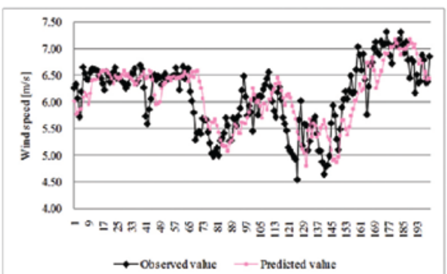
(a) The First 200 observed and neural network predicated value at *t*+20-s time period.



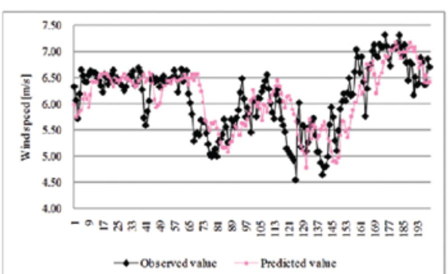
(b) The First 200 observed and neural network predicated value at *t*+30-s time period.



(c) The First 200 observed and neural network predicated value at *t*+40-s time period.



(d) The First 200 observed and neural network predicated value at *t*+50-s time period.



(e) The First 200 observed and neural network predicated value at *t*+60-s time period.

Fig. 2: The first 200 data points of wind prediction 20-50 seconds ahead.

three-state predictions ahead. The mean value of the future value in the time interval [t = 20, t = 30) is predicted using new inputs, the two past observed values in the intervals, [t = –20, t = –10) and [t = –10, t = 0), and the two previously predicted values over the intervals, [t = 0, t = 10) and [t = 10, t = 20). The formulation of a data-driven model to predict wind speed at one time interval (state) ahead is expressed as equation 1:

$$\hat{\upsilon}_t = f_A(\upsilon_{t-T}, \upsilon_{t-2T}, \upsilon_{t-3T}, \ldots, \upsilon_{t-nT}) \quad (1)$$

In this equation the parameters—i.e., the number of past states of wind speeds—need to be selected. The importance analysis of the Boosting tree algorithm, which provides the capability to evaluate the contribution of past states to predict future value, is utilized here. Based on the importance analysis, the past states at time t – T, t – 2T, t – 3T, t – 4T, t – 5T and t – 6T, are then selected to estimate the wind speed at time t. The same five data-mining algorithms discussed in this section are used to develop the time-series model for wind speed prediction. Table 1 presents the test results of models extracted by five different algorithms, and Neural Networks is the most effective algorithm of the five to develop the time-series model.

Based on the model developed by a Neural Network, prediction of wind speed at t + 20T, t + 30T, t + 40T, t + 50T and t + 60T can be produced by iteratively implementing the logic presented in fig. 3. Figure 2 illustrates the first 200 data points of predicting wind speed 20-50 seconds ahead.

Prediction of Controllable Parameters

Prediction of future settings of controllable parameters is a complicated issue. However, in a short-term prediction such as one minute ahead an assumption that the future blade pitch angle and generator torque remain the same as the current value can be used to simplify the prediction process of the two controllable parameters, the generator torque, and the blade pitch angle.

The primary reason behind this assumption is that the blade pitch angle, which the blades currently deploy in wind turbines, is essentially fixed below the rated wind speed, and therefore the probability that it will change in 60 seconds is small. The same logic can also be applied to the torque ramp rate. This assumption can be verified by the Markovian analysis of wind speed.

The stochastic nature of the wind prompts modeling its behavior with Markov chains. The probability of the wind speed changing between states is modeled in fig. 3. To develop the irreducible Markov chain in fig. 3 the wind speed is partitioned into 10 intervals (states): [0m/s, 3.5m/s), [3.5m/s, 5m/s), [5m/s, 6m/s), [6m/s, 7m/s), [7m/s, 8m/s), [8m/s, 9m/s), [9m/s, 10m/s), [10m/s, 11m/s), [11m/s, 12m/s), and [12m/s, ∞).

Table 2 shows the transition matrix that presents the probability of the wind speed change (increase or decrease) with the time change to the next minute. The rows and the columns in Table 2 represent the wind speed intervals (states). As presented, the wind speed is likely to stay at its original state (interval) or its neighbor state in 60 seconds. For example, if the wind speed at the current time is [6m/s, 7m/s), the probability that it will still remain in [6m/s, 7m/s) over the next 60 seconds is 0.7075, and the probability that it will move to the neighbor states, here [5m/s, 6m/s) or [7m/s, 8m/s), in the next 60 seconds is 0.2352 (0.1058 + 0.1294).

Table 3 presents the summary of the probability of wind speed remaining at its original or neighbor state at future time intervals t +10-s, t + 20-s, t + 30-s, t + 40-s, t + 50-s, and t + 60-s.

Multi-Period Prediction of Wind Power

The modules of wind speed, generator torque, and blade pitch angle prediction discussed in the preceding two sections are then integrated to predict the power produced at different future intervals. Figure 3 shows the first 200 data points of power prediction 10-60 seconds ahead.

CONCLUSION

In this article SCADA data was used to predict the power produced by a wind turbine at different intervals. Two different models were introduced. The first model learned the power coefficient function from the

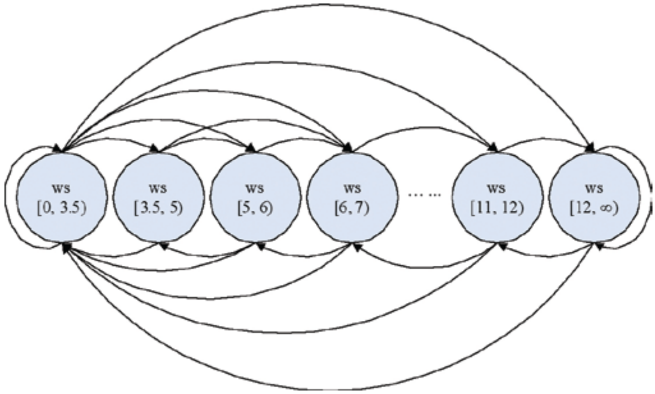
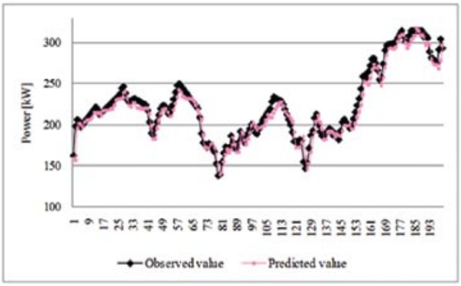
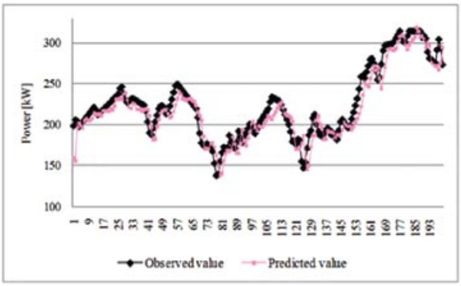


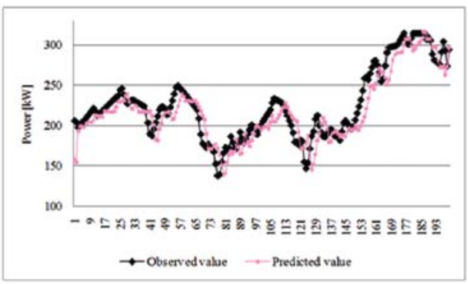
Fig. 3: Markov chain of the wind speed.



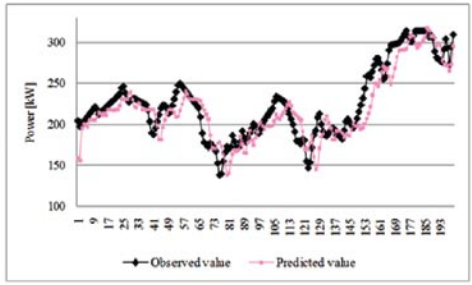
(a) The First 200 points of *t*+10-s predictions by model-two.



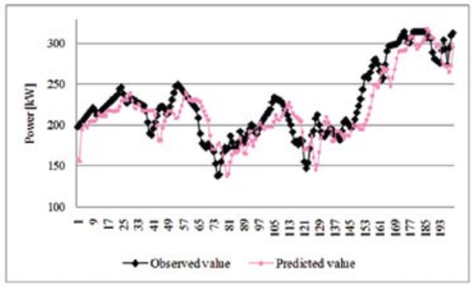
(b) The First 200 points of *t*+20-s predictions by model-two.



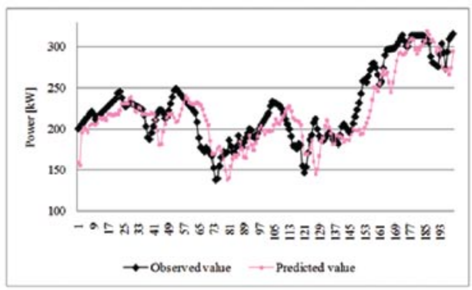
(c) The First 200 points of *t*+30-s predictions by model-two.



(d) The First 200 points of *t*+40-s predictions by model-two.



(e) The First 200 points of *t*+50-s predictions by model-two.



(f) The First 200 points of *t*+60-s predictions by model-two.

Fig. 4: Multi-period prediction of generated power from wind turbine.

WS Interval	[0, 3.5)	[3. 5,5)	[5, 6)	[6, 7)	[7, 8)	[8, 9)	[9, 10)	[10, 11)	[11, 12)	[12, ∞)
[0, 3.5)	0.8922	0.1015	0.0052	0.0007	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000
[3.5, 5)	0.1618	0.6397	0.1550	0.0345	0.0075	0.0014	0.0001	0.0000	0.0000	0.0000
[5, 6)	0.0049	0.1213	0.6718	0.1574	0.0343	0.0084	0.0013	0.0005	0.0000	0.0000
[6, 7)	0.0002	0.0147	0.1058	0.7075	0.1294	0.0327	0.0071	0.0021	0.0003	0.0002
[7, 8)	0.0000	0.0026	0.0313	0.1949	0.4660	0.2276	0.0581	0.0146	0.0037	0.0013
[8, 9)	0.0000	0.0001	0.0047	0.0446	0.2288	0.4392	0.2027	0.0568	0.0176	0.0053
[9, 10)	0.0001	0.0000	0.0007	0.0101	0.0822	0.2766	0.3581	0.1775	0.0709	0.0238
[10, 11)	0.0001	0.0000	0.0000	0.0027	0.0214	0.1066	0.2606	0.3227	0.1986	0.0874
[11, 12)	0.0000	0.0000	0.0001	0.0005	0.0038	0.0347	0.1239	0.2637	0.3217	0.2516
[12, ∞)	0.0000	0.0000	0.0000	0.0000	0.0007	0.0040	0.0201	0.0622	0.1448	0.7682

Table 2: Transition matrix of wind speed changes in 60 seconds.

State\Time	t + 10-s	t + 20-s	t + 30-s	t + 40-s	t + 50-s	t + 60-s
[0, 3.5)	0.9998	0.9986	0.9974	0.9960	0.9947	0.9938
[3.5, 5)	0.9947	0.9831	0.9739	0.9676	0.9613	0.9565
[5, 6)	0.9911	0.9744	0.9662	0.9596	0.9532	0.9506
[6, 7)	0.9884	0.9683	0.9586	0.9529	0.9466	0.9428
[7, 8)	0.9722	0.9299	0.9129	0.9033	0.8951	0.8885
[8, 9)	0.9646	0.9176	0.8971	0.8863	0.8762	0.8707
[9, 10)	0.9458	0.8786	0.8488	0.8331	0.8240	0.8122
[10, 11)	0.9313	0.8536	0.8214	0.8044	0.7874	0.7819
[11, 12)	0.9571	0.9007	0.8725	0.8532	0.8444	0.8370
[12, ∞)	0.9797	0.9501	0.9354	0.9260	0.9186	0.9130

Table 3: Probability of wind speed remaining at the original or neighbor state.

turbine data. The second model predicted the turbine power based on the value of the generator torque, blade pitch angle, and wind speed. The performance of the two models was impressive, with the second model demonstrating a certain accuracy advantage. The performance of the models has been discussed in detail [2].

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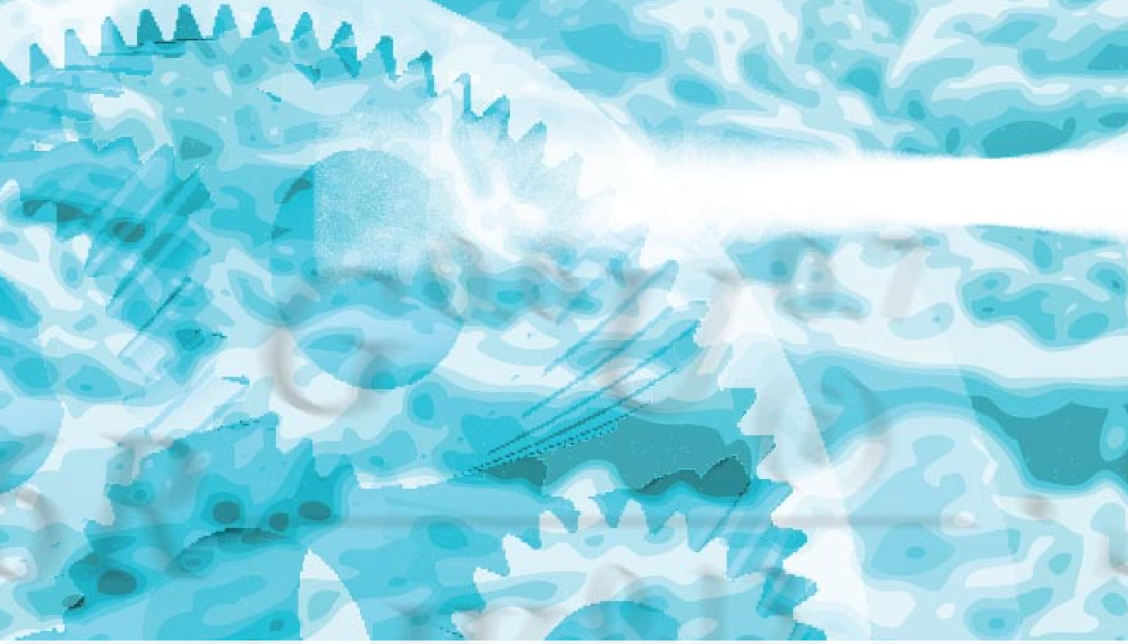
CALCULATING MICROPITTING FOR WIND ENERGY

Software by KISSsoft permits the reliable calculation of complex interrelations long before construction of a wind farm occurs, helping avoid component failure.

By Dr. Stefan Beermann



Dr. Stefan Beermann is CEO of KISSsoft AG. Learn more by visiting www.kisssoft.com.

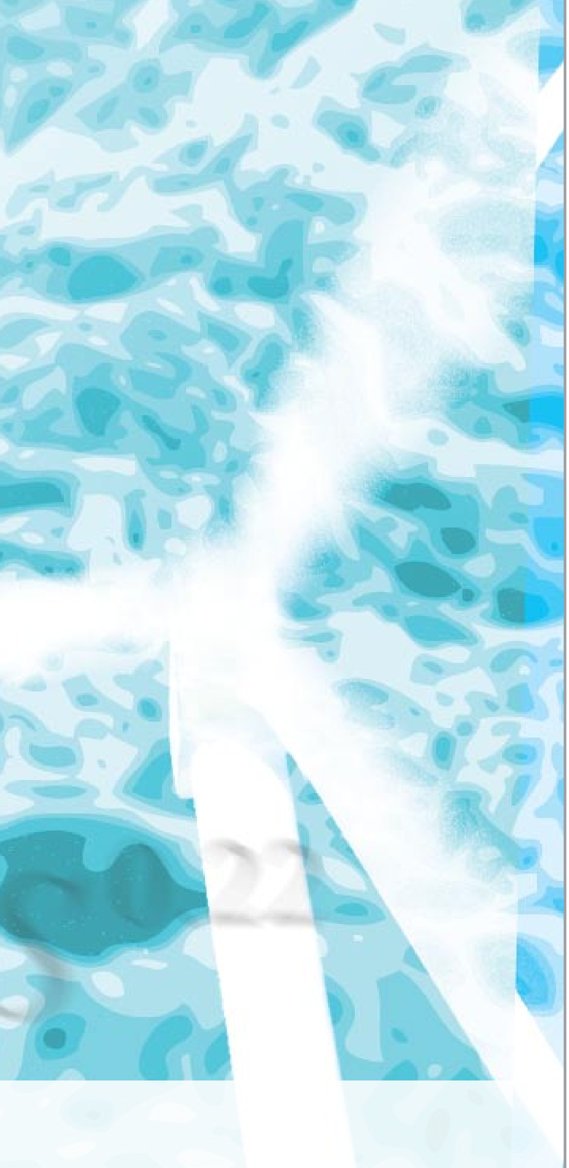
MODERN WIND ENERGY FARMS must achieve a long operational service life while keeping maintenance costs to a minimum. In order to achieve this, more manufacturers are investing in forward-looking product development. It is therefore of the utmost importance that the design engineer integrates the calculation of the individual mechanical components and the reciprocal effect with the environment in the development process as early as possible. This is where reliable calculation tools, together with professional knowledge, can make a critical contribution.

The new KISSsoft release 04/2010 includes methods for the design of machine components with important improvements relevant to the wind farms, such as tooth contact analysis and calculation of roller bearing service life—taking the internal geometry into consideration—and finally, the safety factor against micropitting.

MICROPITTING IN WIND ENERGY

During the eighties, as the first large wind farms were appearing in the United States, the first shortcomings showed up as classic gearing or roller bearing damages such as pitting, tooth root fracture, scuffing, or bearing failure. Due to the high rotor speeds, micropitting was not considered to be as significant at the time.

At the beginning of the 21st Century the power capacity of the equipment was drastically increased, and the rotor speeds were re-



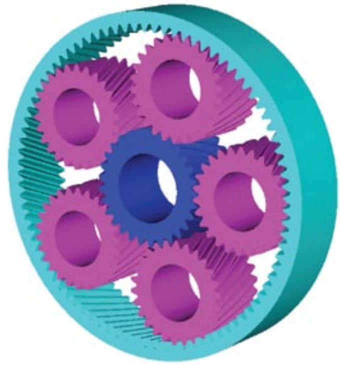


Fig. 1: Planetary gears displayed with 3D-Parasolid-Kern.

duced. The classic tooth damage was more or less weeded out by collected experience and the above-mentioned policies. The bearing damages, however, were not. During the following years the equipment capacity went on increasing while rotor speeds were continuously reduced.

Presently, bearings still constitute one of the main reasons for operational failure in the wind energy sector, while micropitting damage became the center of attention for gear and equipment manufacturers. Or, to be more precise, it concerned the operators. With continuously rising equipment capacities, as well as reduced rotor speed in the wind energy sector, the micropitting phenomenon attained increasing importance. Hence micropitting must basically be considered for gearing design and modification, and for the choice of lubricant.

THE MICROPITTING PHENOMENON

When the lubrication film thickness becomes so thin that the flanks make metal contact—meaning that the surface roughness exceeds the lubrication film thickness—boundary friction prevails, leading to surface damage. Subsequently, gray spots will show up, lending the teeth flanks a matte appearance. This is the so-called micropitting.

The specific lubrication gap thickness λ_{GF} – the ratio between the lubrication gap thickness and the surface roughness is relevant for the evaluation of whether a tooth is endangered by micropitting, which is characterized by a surface damage in the form of fissures that grow from the surface towards the interior. It thereby causes small pittings of approximately 10-20 µm depth, 25-100 µm length, and a width of 10-20 µm. The phenomenon mainly appears on case-hardened gears, but it can also occur with nitrided, induction-hardened, or through-hardened gears.

The material removed from the flanks will inevitably cause an increase in tooth profile errors that will lead to a reduction in the overall quality of the teeth. After a certain time either a stagnation of this material removal occurs or the process continuously persists. Consequential problems—which may or may not occur—are increased dynamic loads that again can lead to an increased noise level and higher tooth load, resulting in pitting. If not promptly removed by effective lubricant filtration, the eroded material transported by the oil can cause bearing damage as foreign particles. Such filtering procedures are already standard in the wind energy sector.

APPLICABLE CALCULATION METHODS

AGMA 925, from 2003, defines a method to analyze the risk of micropitting, among other methods that cover scuffing and wear. The main

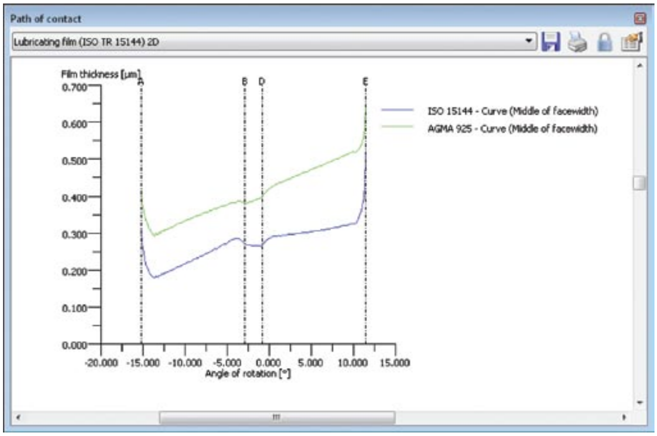


Fig. 2: Calculation of lubrication film according to ISO and AGMA.

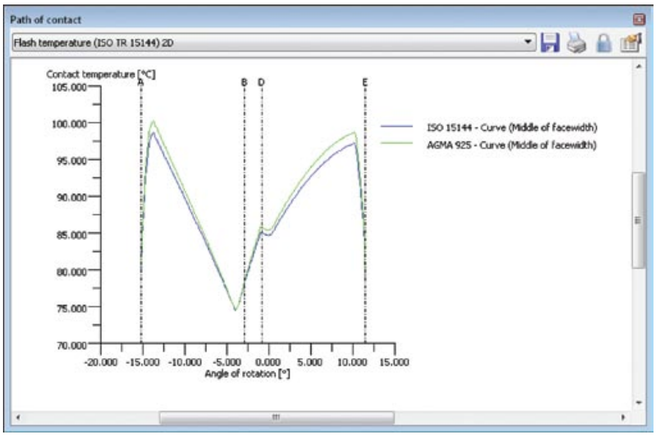


Fig. 3: Calculation of flash temperature according to ISO and AGMA.

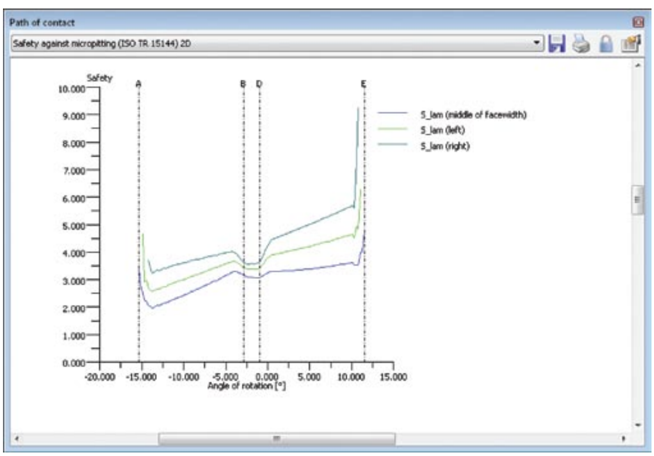


Fig. 4: Calculation of the safety against micropitting according to ISO/CD TR 15144.

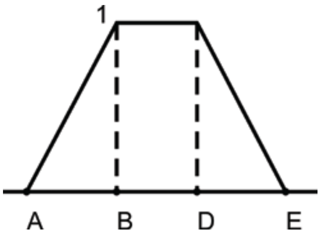


Fig. 5: Definition of load sharing factor X(i) for smooth meshing according to AGMA 925.

outline of the method is to determine the temperature of the gear body, adjust the viscosity of the lubricant to this temperature, and then calculate the oil film thickness. The central formula for the film thickness is:

$$h_{C(i)} = 3.06\rho_{n(i)}10^3 \frac{G^{0.56}U_{(i)}^{0.69}}{W_{(i)}^{0.1}}$$

In this formula the index (i) denotes a specific point on the path of contact, so the method investigates each contact point individually. The factor G is a material parameter, taking the reduced Youngs modulus into account and the pressure viscosity of the lubricant. $U_{(i)}$ is a local speed factor. It is influenced by the dynamic viscosity at gear tooth temperature, the reduced modulus of elasticity, the local entraining velocity, and the local radii of the flank curvatures. Finally $W_{(i)}$ is the load factor. The main influence parameter here are the load sharing factor $X_{\Gamma(i)}$ - multiplied with the unit load w_n – and the local curvature.

Some investigations were undertaken in Germany to calculate the risk of micropitting. The first method was proposed by the FVA in the early nineties. This method already invented the idea of a critical film thickness λ. However, it only took the situation at the operating pitch point into account. In a second paper, this one from 1999, the FVA introduced the formula

$$h_{\min(i)} = 1.6R\frac{G^{0.6}U_{(i)}^{0.7}}{W_{(i)}^{0.13}} \cdot S^{0.22}$$

with basically the same factors that the AGMA uses, according to Dowson. Obviously, the main difference to the AGMA 925 is the local sliding factor S, which takes the flash temperature into account.

ISO TECHNICAL REPORT

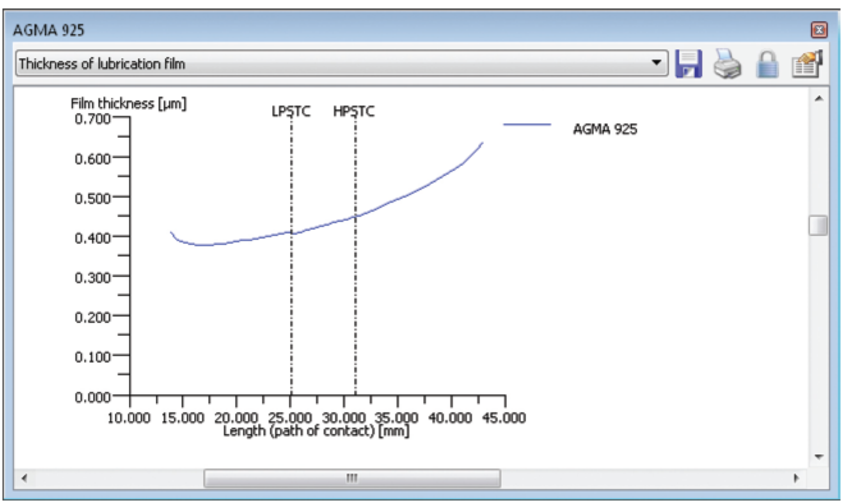
ISO is currently working on a technical report, ISO/CD TR 15144, for the calculation of the specific lubrication film thickness $\lambda_{GF,Y}$. It was originally planned to extend the standard ISO 6336 by a part 7, covering this topic. During open discussions, however, this was changed to the creation of a technical report.

In the current state ISO/CD TR 15144 follows the philosophy of the FVA using the same basic formula, thus including the gliding factor S. This leads to significant differences in the calculated film thickness according to AGMA and the ISO TR. In KISSsoft both methods—AGMA 925, and the later one proposed by FVA—are implemented so that comparison is easy.

As demonstrated in fig. 2, especially in the section of the recess sliding, the film thickness according to ISO is having a different tendency than the one according to AGMA. Where the film thickness according to ISO stays quite constant, the AGMA method calculates an increasing film thickness. Figure 3 shows the flash temperature determined with the two methods. Here the differences are negligible.

In the draft of the calculation of the lubrication film thickness and the risk analysis regarding micropitting, the data for the determination of the permissible specific lubricating film thick-

Fig. 6A: Calculated film thickness using the load sharing factor for several different values of the tip relief.



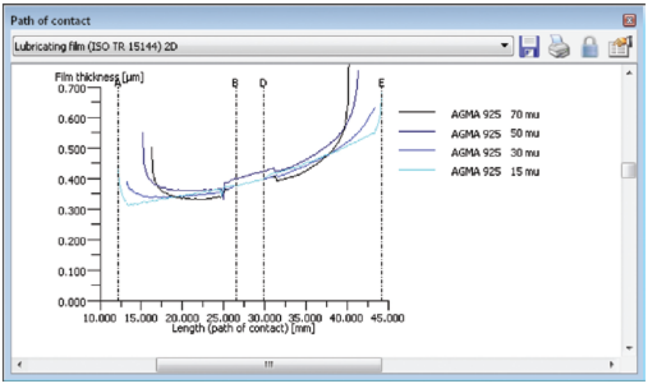


Fig. 6B: Simulation of the contact for several different values of the tip relief.

ness λ_{GFP} was missing. Values for λ_{GFP} had to be derived from the literature, whereby in this connection the data were often contradictory.

In the meantime, in the latest draft ISO/CD TR 15144 the determination of the permissible specific lubricating film thickness λ_{GFP} is included. With the implementation of this extension, the safety factor against micropitting can now be calculated. For the evaluation of the risk of micropitting, as already explained, it is critical how large the smallest specific lubrication film thickness λ_{GFmin} must be at minimum. Therefore it holds that $\lambda_{GFmin} \geq \lambda_{GFP}$ must be fulfilled in order to avoid micropitting, or respectively $S_\lambda = \lambda_{GFP}/\lambda_{GFmin}$ defines the safety factor against micropitting.

The minimum lubrication film thickness in the meshing of a gear pair serves for determining the risk of micropitting damage. Theoretically, if the film thickness is large enough, no micropitting will occur. Only if the ratio of permissible specific film thickness and minimum specific film thickness drops below 1 is the risk of micropitting a given. It is then dependent on the choice of the lubricant—and especially the additives, and other boundary conditions such as hardening procedure and surface structure—whether or not micropitting occurs. In practical applications, of course, the additional problem of determining the appropriate data for the calculation comes up, so that a minimum safety larger than 1 might be appropriate. Practical experience should always complement the calculation procedure.

LEVEL OF DETAIL

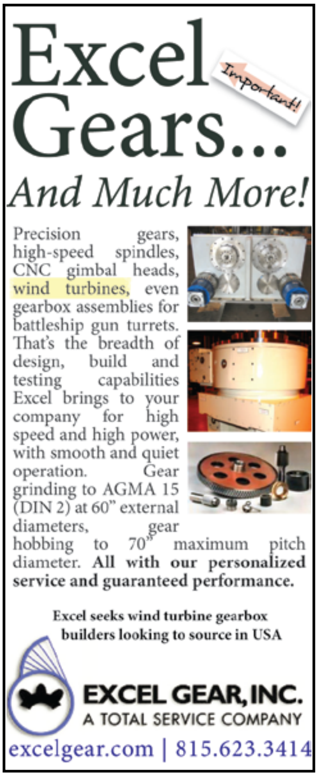
For the implementation of the methods mentioned there are two different approaches. The first one implements the method including the calculation of the normal force, Hertzian pressure, and temperature according to the specifications in the standard. The second approach uses a simulation model for the contact of the gears to determine the respective values. This corresponds to the method A of the ISO. Of course, the effort for the second approach is much higher. On the other hand, with modern computers the calculation time of this more-sophisticated approach is no problem.

To compare the results of the two approaches an example of a spur gear pair with a tip relief as profile modification is used. The calculation is according to AGMA, which defines a load sharing factor $X_{\Gamma(i)}$ to take the tip relief into account (fig. 5).

The standard specifies that the tip relief shall be "adequate." This leaves some room for interpretation. The left diagram in fig. 6 shows the resulting lubrication film thickness using the load sharing factor. In the right part of the figure the calculation was carried out with simulating the meshing of the gears, and thus determining the real normal force for a couple of different values for the tip reliefs (ranging from 15µm to 70µm). The resulting film thickness fits well to the first calculation if the tip relief has a value of 30µm. For the other values the curves are deviating, and most importantly for 15mm and 70mm the minimum of the lubrication film thickness is smaller than the minimum determined with the load sharing factor. Of course, 15µm are a too small a value and 70µm is a too large a value. Still, this comparison shows that the additional effort for the simulation pays back immediately, if only for determining the "adequate" value for the tip relief.

SUMMARY AND OUTLOOK

KISSsoft permits the reliable calculation of complex interrelations and provides founded decision bases long before the construction of a wind energy installation actually occurs. A balanced and optimally sized design thereby leads not only to savings of cost and weight, but also to reliable forecasts on future behavior, stability, and service life of the installation. Operation and maintenance are easily and accurately calculated, and due to calculation software such as KISSsoft the probability of damage can be drastically reduced in advance. With the planned ISO/CD TR 15144 calculation method, the safety factor against micropitting may be dealt with in a quick and realistic way.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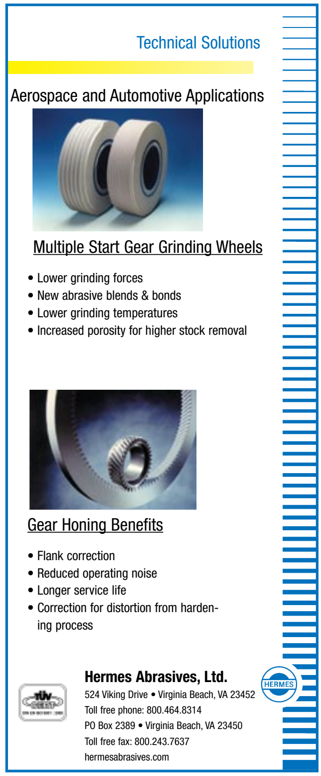
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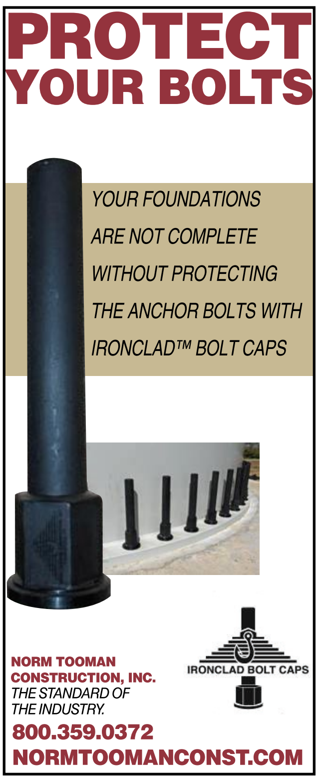
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supplier base as they expand their business units around the world. AFC-Holcroft's European branch office spearheaded this project, although equipment for the project will be built in North America. "We believe the time is right to invest in additional capacity, in North America specifically," says Jacopo Tozzi, president and CEO of Brevini Wind. "The UBQ furnace fit our needs for today and allows the flexibility of future expansion as the wind energy sector continues to grow."

"We are thrilled to add Brevini to the list of global manufacturing suppliers who have chosen AFC-Holcroft and our UBQ furnaces for their operations," says Marc Ruetsch, director of european operations at AFC-Holcroft. "Our UBQ furnaces have gained global acceptance by several multinational companies, due not only to their adaptability to changes in capacity, part loads and temperature requirement but also to their modularity, which allows easier reconfiguration options within existing floorspace for future capacity."

AFC-Holcroft is one of the world's largest manufacturers of heat treating furnaces. The company has a global reach, with organizations in the United States, Argentina, Australia, Brazil, China, India, Korea, Mexico, Poland, Russia, Spain, and Turkey, including manufacturing means in many of these countries. For more information contact Ruetsch at europe@afcholcroft.com. Go online to www.afc-holcroft.com.

NATURAL POWER TO ESTABLISH NORTH AMERICAN HUB

Leading renewable energy consultancy Natural Power is to merge their U.S. and Canadian operations to provide seamless service offerings to clients active across North America's national boundaries. Natural Power's new North American hub will be a center of excellence for consultancy services and product support across the company's range of offerings. CurrentPresident of U.S. Operations Jim Adams will take the helm as president of North American operations. Erin Harlos, currently the director at Natural Power's Vancouver office, will support as vice president. Between them, Adams and Harlos have over 14 years of experience spanning the wind and marine renewable sector.

"There is huge potential for the North American renewables industry, particularly in onshore and offshore wind," Adams says. "Natural Power has been active in North America for over five years and provides industry leading product innovations such as complex flow modeling to ensure new projects perform to expectations, due diligence to support project investment, and ZephIR lidar to efficiently validating models and provide bankable wind energy assessments. Additionally, drawing upon our extensive experience in providing full life-cycle services to Europe's offshore wind, wave, and tidal industries, we have the unique ability to bring very applied and seasoned products and services to North America's blossoming offshore renewables industry, leveraging many of the lessons learned in this rapidly growing market sector. With a dedicated North American hub we will better service both our consultancy customers but also our product customers who require local engineering, construction and operational support which we will now build at pace."

This fall Natural Power will be presenting and exhibiting at the AWEA Wind Resource & Project Energy Assessment Workshop in Oklahoma and AWEA's Offshore Wind Conference in Atlantic City), New Jersey, as well as at CanWEA's annual conference in Montreal. The team will also be hosting several educational Complex Terrain Workshops in the U.S. and Canada. Details on upcoming workshops can be requested by e-mailing training@naturalpower.com or visiting www.naturalpower.com.

SMART GRID CYBER SECURITY GUIDELINES FROM NIST

The National Institute of Standards and Technology (NIST) has finalized its initial set of Smart Grid cyber security guidelines. Guidelines for Smart Grid Cyber Security (NISTIR7628) include high-level security requirements, a framework for assessing risks, an evaluation of privacy issues in personal residences, and other information for organizations to use as they craft strategies to protect the modernizing power grid from attacks, malicious code, cascading errors, and other threats.

The product of two formal public reviews and the focus of numerous workshops and teleconferences over the past 17 months, the three-volume set of guidelines is intended to facilitate organization-specific smart grid cyber security strategies focused on prevention, detection, response, and recovery. "As we modernize the nation's electric infrastructure to make it smarter, more efficient, and more capable, we need to we need to make it more secure from end to end," according to U.S. Commerce Secretary Gary Locke. "These new cyber security guidelines will help government and industry meet this important responsibility."

"The development of common smart grid standards is a national priority, and these cyber security guidelines are an important step toward that goal," says U.S Energy Secretary Steven Chu. "If we are to truly modernize our electrical grid, we must have electricity producers, distributors and consumers all speaking the same language and all working together to make our grid more secure. Cyber security is an integral part of the grid."

The new report was prepared by the Cyber Security Working Group (CSWG) of the Smart Grid Interoperability Panel, a public-private partnership launched by NIST with American Recovery and Reinvestment Act funding from the Department of Energy. To access Guidelines for Smart Grid Cyber Security (NISTIR 7628) go to www.csrc.nist.gov/publications/PubsNISTIRs.html#NIST-IR-7628. Also visit www.nist.gov.

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John Brown
President/Geodetic Systems, Inc.

TELL US ABOUT THE COMPANY'S HISTORY AND GROWTH.

In 1953, fresh out of Yale and the University of Minnesota with undergraduate and graduate degree in mathematics, respectively, my father went to work for Helmut Schmid, a colleague of Werner Von Braun, the famous rocket scientist. He was working on the rocket range tracking missiles and bombs, which involved dropping a dummy from a plane with a strobe light attached and photographing its trajectory with several very large "ballistic" glass-plate cameras. After a few years he started a company focusing on industrial measurements, and when it went public he realized he didn't enjoy the associated responsibilities. He was a researcher at heart, so he bought out the division that was devoted to industrial photogrammetry and launched Geodetic Systems, or GSI, in 1977. A year later I graduated from Yale with a degree in engineering and applied science and joined the company, but it was kind of a sleepy enterprise at the time and I ended up going to work for a local engineering firm and just doing some part-time projects for dad on the side. Then personal computers were introduced in the early eighties, and I immediately saw their potential. I went to dad, who was still using glass-plate cameras and a mainframe to do his calculations, and I described how we could write new code for the PC and create a turnkey system to sell along with the photogrammetric film cameras he was developing. With the advent of digital photography and video cameras, and the continuing evolution of computer technology, we've kept refining our process over the years.

SO GSI WAS AN ESTABLISHED COMPANY LONG BEFORE ENTERING THE WIND INDUSTRY.

Absolutely. One of the company's first big jobs was to check the surface contour of a dish antenna at the National Radio Astronomy Observatory in Green Bank, West Virginia, which was the largest steerable radio telescope in the world at the time. Since then we've branched out into aerospace, automotive, shipbuilding, engineering, and nuclear, among other markets and industries. With the growth of the wind industry we realized that our technology would be perfect for the tower manufacturing facilities that are being built throughout North America. Checking the flatness of flanges with our digital camera based V-STARS measurement systems is a simple operation, and extremely fast, transforming a process that took an hour or more using other devices into one that takes a few minutes, or can even report measurements in real time using multiple cameras.

CAN YOU GIVE US AN IDEA OF HOW THIS PROCESS IS PERFORMED?

What really sets photogrammetry apart from other technologies, such as laser trackers or laser radar, is that we don't need a stable platform to do our measurements, so this system is ideal for the manufacturing environment. You begin by attaching small retro-reflective markers to the surface you want to measure and then taking pictures from several different vantage points, allowing for the triangulation required to determine flatness. That information is uploaded into a laptop, and the results are available within a minute or so. Because of the markers and the camera's built-in flash, the operator doesn't have to worry about holding the camera steady, and there's no need to focus or set the exposure. It's really an easy operation, and it works especially well in tower manufacturing facilities where flanges are being welded to wind tower sections because they tend to be on rollers, which makes attaching the reflective markers a breeze. The system is extremely portable, consisting primarily of a small, modified, industrialized digital camera and a notebook computer. It can even be used wirelessly so pictures can be transferred to the notebook for immediate processing. It can work indoors or outdoors, day or night, in the factory or in the field, and at practically any temperature. We also have a customer who's using the system to conduct static load testing of blades, so we're just at the beginning stages of identifying all the applications we'll be able to address for our customers in this market. This is really an exciting time for us, and for the wind industry as well.

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