WIND SYSTEMS MAGAZINE

WIND SYSTEMS

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  WINDPOWER 2013 in Review
- Combined Effects of Gravity, Bending Moment, Bearing Clearance, and Input Torque on Wind Turbine Planetary Gear Load Sharing
- Maximizing the Benefits—and Your ROI —in Wind Power

WIND DRIVETRAIN CONDITION MANAGEMENT

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Klüber Lubrication

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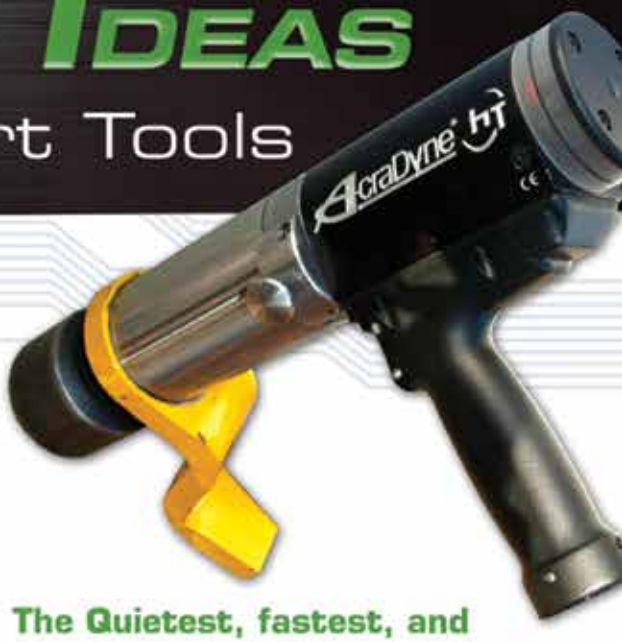

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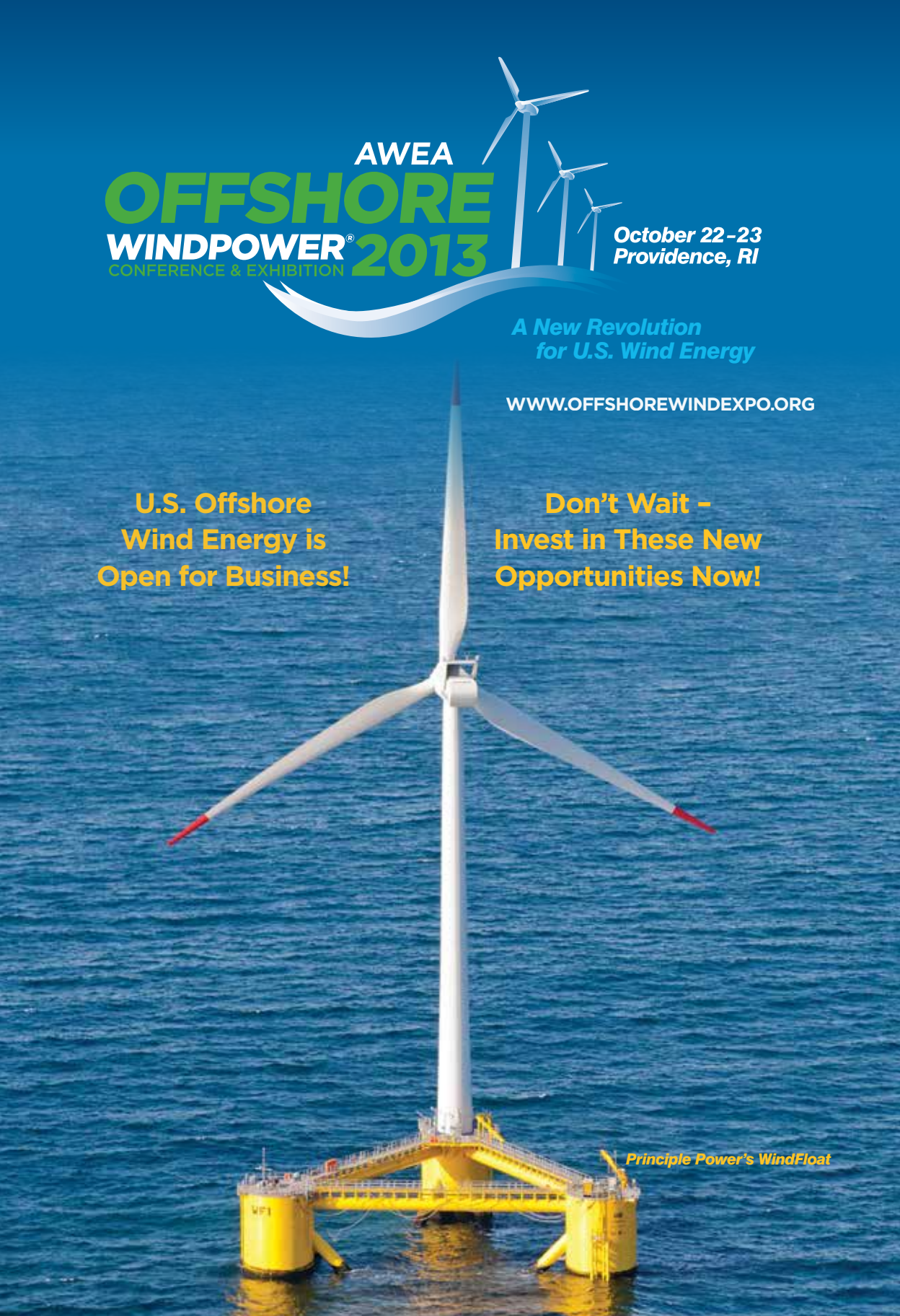
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EDLETTER

Dear Wind Energy Industry,

We need to talk.

We've known each other for a while now, and it's been the best time of my life. Those four days we spent together in Chicago were, in a word… magical.

I know you've got a lot going on right now, but I need just a minute or two of your time. It's important.

I guess I'm saying that we're at a point where it's time for us to define the relationship.

No! Wait! Please don't be afraid. Please don't walk away. I promise this is not a scary proposition. Please, just hear me out. I just want to make this work.

Let's face facts. The time has come for everyone involved to make adult decisions. Nobody is as young as they used to be. You've evidenced that. In the past year alone, I've seen you make amazing strides into maturity.

It wasn't that long ago that you were just an infant—totally reliant on the subsistence of others. But now it's time to put away the comforts of your youth. I'm both curious and excited to see the kind of industry you can be as you enter the next stages of your life.

See, I've heard about your past. Word gets around. I know there was a time there were you when pretty cocky. I've been told it was difficult to watch. Everybody's adolescence is difficult. You grow so fast that you feel awkward and unsure about yourself. Advice comes from so many different directions that it's difficult to make sound, informed decisions.

You puff yourself up when times are good, and the suitors clamor for your attention. But rarely do these suitors—these opportunists—stick around when things get tough. And I know that's the case. That's not just a random, anecdotal thought. I know because I've heard about the heartbreaks, too—in 2000, '02, '04, and in 2010.

It's tough when others give up on you. But you can't let your past dictate your future. We learn from all of our experiences… successes and failures. I know you know all of that. You proved it in 2012.

But make no mistake, there are plenty of people who are wholly, unquestionably committed to you—people who are in it for the long haul.

I'm not saying it's going to be easy or that we can survive on hope and good intentions. It's going to take hard work, planning, communication, and compromise.

You're right on the cusp of doing some amazing things in the years to come. I sensed it in Chicago. Sure, there's uncertainty. Sure, there are concerns about instability. But far beyond those is your renewed vision for our future.

Some people don't see it. They don't get it. I've heard them tell me how you're not right for me. You're too high maintenance… unreliable… risky. But I see who you want to be. I know there's a great future ahead of us.

That's pretty much all I wanted to say. And I know there's no convincing you if you've already made up your mind. It's a lot to take in—a lot to consider. It's a long road ahead, and the highway is still… under construction. But if we get started now, we can be the ones to draw the map.

So what do you say? Are you ready to commit?

Where is this relationship going?

Stephen Sisk, editor
Wind Systems magazine
editor@windsystemsmag.com
(800) 366-2185 ext. 209

WIND SYSTEMS

David C. Cooper
Publisher

Chad Morrison
Associate Publisher

EDITORIAL
Stephen Sisk
Editor

Tim Byrd
Associate Editor

SALES
Glenn Raglin
National Sales Manager

Mike Barker
Regional Sales Manager

Tom McNulty
Regional Sales Manager

CIRCULATION
Teresa Cooper
Manager

Kassie Hughey
Coordinator

Jamie Willett
Assistant

ART
Jeremy Allen
Creative Director

Michele Hall
Graphic Designer

Rebecca Allen
Graphic Designer

CONTRIBUTING WRITERS
Julian Bell
Steve Casey
Diane Davis
Michael Graska
Yi Guo
Parveen Gupta
Jonathan Keller
William LaCava
Jack Wallace

Media solutions

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David C. Cooper
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ZF SERVICES LAUNCHES 2.5MW TEST BENCH AT ILLINOIS WIND SERVICE CENTER

ZF Services, LLC announced the completed installation of the 2.5MW test bench at its Vernon Hills, Ill. Wind Service Center. The project, which began with construction in September 2012, is the result of a $1.6 million grant.

The recently completed test bench will be able to test over 200 gearboxes annually. ZF Services, LLC launched this new project with an open house on May 8th—coinciding with WINDPOWER 2013—while hosting their customers and local vendors at the Vernon Hills facility to showcase the test bench, redesigned facility and extensive portfolio of technical possibilities. The recently completed test bench and redesigned facility now allows the company to offer an even wider range of services, providing a tailor-made one-stop shopping approach for multi-brand gearbox and mechanical drive train repair.

ZF has been present in the region for over the past 35 years, and customers can continue to anticipate great customer service. The centrally located facility has a 20-man wind service team dedicated to servicing customer needs, including field technicians for on-site up-tower repairs. Through a close link to the ZF Wind Power research and development team in Lommel, Belgium, ZF Services, LLC has access to continuous ongoing developments to support customer requirements in repairs and gearbox enhancements. The regional wind service center at ZF Services, LLC will be stocking genuine spare parts and exchange gearboxes covering the full product range of ZF Wind Power.

With more than 7,000 ZF gearboxes installed in North American, ZF designed the wind service facility with the intent to service this large installed base of ZF gearboxes as well as other multi-brand products. The ZF Services, LLC Vernon Hills facility is now one of ZF's 8 wind service locations worldwide; with 6 having load testing capabilities. For further questions please contact your ZF representative.

"The ZF Services Vernon Hills service organization continues to grow as evidenced by our recent investments in the facility, equipment, and personnel over the past three years. Our North American wind industry customers will have the same great service experience that our other industry customers received in this region over the past 35 years," said Scott Gardiner, director of wind services for North America.

For more information, visit www.zf.com/na.

SIEMENS WINS 100MW TURBINE AND SERVICE ORDER FROM SOUTH AFRICA

Siemens Energy has been awarded an onshore wind power order for the Sere wind power plant on the west coast of South Africa. This is already the second wind power order for Siemens from South Africa. The Sere project is a flagship project for the customer ESKOM, which is one of the world's largest utilities. The scope of supply includes the delivery and installation of 46 wind turbines of the type SWT-2.3-108, with an output of 2.3MW, a rotor diameter

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

of 108 meters on 115 meter towers each. The deal also includes a five-year-service agreement. Installation of the wind turbines is scheduled to begin in the second half of this year, with the start of operations expected during first half of 2014.

"South Africa has outstanding conditions for the utilization of wind energy and has set up a remarkable renewable energy program with the Independent Power Producer Procurement Program. We are proud to contribute to the development of wind power in South Africa with our technology, and especially proud that ESKOM has chosen to rely on us for their first large project," said Felix Ferlemann, CEO of the Wind Power Division in Siemens Energy.

The first wind power order from South Africa was awarded to Siemens by Mainstream Renewable Power Limited, Globeleq, and local B-BBEE investors Thebe Investments, Enzani and Usizo for the Jeffrey's Bay onshore wind power plant with a total capacity of 138MW.

For more information, visit www.siemens.com.

NORDEX NEARED BREAK-EVEN IN Q1 ON SUBSTANTIAL SALES SURGE

The Nordex Group posted a 30.6 percent increase in sales to EUR 259.0 million in the first quarter of 2013 (previous year: EUR 198.3 million). This performance was underpinned by strong business in the core European region, which contributed 94 percent of sales. On the other hand, business in America contracted by a substantial 57.6 percent, accounting for only 5 percent of consolidated sales, while Asian business remained persistently weak.

The greater volume of business was also reflected in production and installation activity. Thus, Nordex produced 60 percent more turbines in the first quarter, completing more than twice the capacity of the same period of the previous year.

This performance together with reduced structural costs in the United States and China, which had previously operated below capacity, resulted in a substantial improvement in operating earnings. As a result, the loss at EBIT level came to EUR 0.6 million as of March 31 (previous year: loss of EUR 9.0 million) and was therefore fully in line with budget. The consolidated net loss was reduced by 40 percent to EUR 8.4 million (previous year: loss of EUR 14.0 million).

Due to increased purchasing and production activity, the working capital ratio widened to 11.8 percent (December 31 2012: 8.7 percent), with cash and cash equivalents declining by 29.3 percent to EUR 194.2 million (December 31 2012: EUR 224.3 million). Net cash outflow from operating activities amounted to EUR 60.0 million (Q1/2012: inflow of EUR 34.8 million).

Order intake continued to climb in the first three months of 2013. At EUR 327.9 million, new business rose by 5 percent, compared with the high level of the same period last year (Q1/2012: EUR 312.3 million). This performance was driven by sales successes in Northern Europe, particularly in the domestic German market, as well as successful marketing of the N117/2400 low-wind turbine. Thanks to the best first quarter since 2008, firmly financed orders grew to EUR 1,141 million (previous year: EUR 837 million), thus creating a solid basis for the company to achieve its full-year sales target.

The Management Board of Nordex SE confirms its forecast for 2013 and expects a further increase in sales to EUR 1.2 - 1.3 billion (2013: EUR 1,075 million). Given slightly weaker capacity utilisation in the first half of the year compared with the second half, management expects operating earnings to improve in the final quarters, resulting in a full-year EBIT margin of 2 – 3 percent.

For more information, visit www.nordex-online.com/en.

SIEMENS SIGNS 15-YEAR WIND SERVICE EXTENSIONS IN NORTH AMERICA

Siemens has signed 15-year contract extensions with RES Americas to continue providing service and maintenance at two wind projects in North America. Siemens will provide long-term service f.or the 26 SWT-2.3-93 wind turbines operating at RES Americas' Whirlwind Energy Center. Long-term service will also be provided by Siemens for the 72 SWT-2.3-93 units in operation at RES Americas' Hackberry Wind Farm. Both projects are located in Texas. This is Siemens' first wind service contract signed with a duration of 15 years in North America.

Siemens currently has an existing five-year agreement with RES Americas for both sites. Under the new agreements, Siemens will provide 15 additional years of service, maintenance, and warranty along with an availability guarantee. The extensions will help both projects perform at high levels of efficiency and availability

for years to come, and most notably, over the entire estimated 20-year lifecycle of the units. Siemens' advanced remote monitoring and diagnostics are included along with the company's Advanced Grid Performance (AGP) upgrade at both sites.

With a combined output of approximately 226MW, the Whirlwind and Hackberry wind projects, located in West Texas, produce enough electricity to power an estimated 68,000 Texas households annually.

For more information, visit www.siemens.com.

AWS TRUEPOWER ESTABLISHES PRESENCE IN ISTANBUL, TURKEY

Renewable energy consultant AWS Truepower LLC has announced it is further strengthening its position in the global renewable market by establishing a partner consultancy in Istanbul, Turkey. This office will provide the Turkish renewable energy market with access to AWS Truepower's 30 years of experience in technical consulting, advisory services, software and data for wind and solar technologies.

The new consultancy will be led by Ahmet Gurel and employs several staff with experience in renewable energy technology and has a well-established network of customers and partners.

"We look forward to working with Mr. Gurel and his team to expand our global footprint with their local presence," said Joan Aymamí, vice president of international business. "Having a local office in Turkey will help the company build and grow relationships, and address and respond to the unique needs of the market."

Demand for renewable energy is growing rapidly in Turkey as growth in energy demand outpaces economic expansion. Projections show that by the end of 2023 the country could have 18GW of new wind capacity. Turkey has the potential to install 40 GW of onshore windpower capacity, with 11GW megawatts of wind projects already licensed.

AWS Truepower will offer services such as renewable resource and energy assessments, infrastructure support services, independent engineering and due diligence studies, energy forecasting, grid integration studies, operational assessments and other services to support successful renewable energy projects. These services will help the Turkish market maximize system performance and better plan renewable energy delivery.

For more information, visit www.awstruepower.com.

DEUS RESCUE ACHIEVES ISO 9001 CERTIFICATION

DEUS Rescue has announced that it has become ISO 9001 certified for the manufacture, assembly and supply of fall protection equipment. The company has been registered to the ISO 9001:2008 standard signifying that

it has developed a quality management system (QMS) that focuses on continual improvement of customer satisfaction by delivering quality products.

DEUS Rescue's QMS processes include areas such as purchasing, shipping and receiving, production, employee training, records control and more.

In addition, the company has direct control over third-party testing and certification of its products to industry standards such as NFPA, ANSI, CSA, EN and others. More than a one-time achievement, a significant ongoing component of the DEUS Rescue QMS is to regularly monitor supply chain efficiency and customer satisfaction by measuring a number of key objectives such as on-time deliveries and, most important, product conformance. Consistent with that is the company's continuous commitment to maintaining and improving its quality standards.

"This is really about DEUS Rescue making a full-court commitment to readiness and quality for our customers," said Shain Rae, president of DEUS Rescue. "Receiving our ISO certification is not only a statement about our having achieved the highest level of quality manufacturing today, but also our commitment to continuously raising our standards in every aspect of our business. This boldly states to our customers that when they deal with DEUS Rescue, they receive the highest assurance that we will do whatever it takes to deliver a quality experience—across the board—now and in the future."

For more information, visit www.DEUSrescue.com or call 866-405-3461.

NCAR POWERS UP RENEWABLE ENERGY FORECASTS

The National Center for Atmospheric Research (NCAR), building on a pioneering wind energy forecasting system that saved millions of dollars for Xcel Energy customers in eight states, has entered into a new agreement with the utility for even more sophisticated weather forecasts.

In the next two years, NCAR scientists and engineers will develop custom forecasting systems to predict sudden changes in wind, shut down turbines ahead of potentially damaging icing events, and even predict the amount of energy generated by private solar panels. The systems will be used by Xcel Energy control centers in Denver; Minneapolis; and Amarillo, Texas.

The cutting-edge forecasts will help Xcel Energy, and potentially other utilities, to provide reliable power to their customers and reduce costs while moving to greater use of wind and solar.

"This is pushing the state-of-the-art still further, using the latest science to enable Xcel Energy to generate energy from the atmosphere more effectively," said NCAR program director Sue Ellen Haupt, who is overseeing the new project.

Xcel Energy officials say the more accurate forecasts are critical as they increase their use of renewable energy.

"The importance and value of accurate renewable energy generation forecasts increases with the size of our renewable energy generation portfolio," said Ben Fowke, chairman, president and CEO of Xcel Energy. "Xcel Energy has been the largest utility provider of wind energy for the last nine years and we are continuing to grow our renewable energy portfolio."

The new project represents the latest venture by NCAR into renewable energy. In addition to the lab's earlier work with Xcel Energy, NCAR is also spearheading a three-year, nationwide project to create unprecedented, 36-hour forecasts of incoming energy from the Sun for solar energy power plants.

"By creating more detailed and accurate forecasts of wind and sun, we can produce a major return on investment for utilities," said Thomas Bogdan, president of the University Corporation for Atmospheric Research, which manages NCAR on behalf of the National Science Foundation. "This type of cutting-edge research helps make renewable energy more cost competitive."

Xcel Energy has been utilizing increasing amounts of energy from renewable sources, especially wind. But this shift means relying on resources that are challenging to predict and manage.

Energy generated by a wind turbine, solar panel, or any other source must be promptly consumed because large amounts of electricity cannot be stored in a cost-effective manner.

If an electric utility powers down a coal or natural gas facility in anticipation of wind-driven energy, those plants may not be able to power up fast enough should the winds fail to blow. The only option in such a scenario is to buy energy on the spot market, which can be very costly.

In order to help utility managers anticipate wind energy more reliably, NCAR began designing a wind energy prediction system for Xcel Energy in 2009 that saved the utility's customers more than $6 million in 2010 alone. The specialized system relies on a suite of tools, including highly detailed observations of atmospheric conditions, an ensemble of powerful computer models, and artificial intelligence techniques to issue high-resolution forecasts.

For more information, visit ncar.ucar.edu or xcelenergy.com.

Julian Bell
Signal Energy Constructors

Successful project road design and construction requires keen attention to geographic and environmental variables.

WITH THE EXCEPTION of a handful of southeastern states, virtually every state in the country has a wind farm. Often overshadowed by the electrical and turbine-related construction items, proper road construction is critical to the success of every wind project. Contractors must build quality roads, crane pads, and crane paths to allow the delivery and movement of project material and equipment—turbine components in particular—or risk missing key project deadlines.

Soil conditions, construction methods, and road materials vary widely by region. Contractors therefore must have an in-depth understanding of exactly how to design and build roads in each region.

Wind project access roads must be designed to handle all major project loads (concrete trucks, turbine component delivery vehicles, and million-pound main erection cranes) during the intense and short-lived construction phase. After construction, traffic is predominantly for O&M purposes and has a relatively low impact on the roads. Project road design must strike a balance between the needs of these two periods..

The following are some of the critical items for wind project road design and construction:

DESIGN CRITERIA

Roads must be designed to the requirements of the wind turbine delivery vehicles and the main erection crane.

- Horizontal design—Turbine components are delivered using extremely long vehicles (often exceeding 170 feet), with specific requirements for turning radii, road width, turnouts (to allow for traffic to pass), and turnarounds (to allow the delivery vehicles to turn and travel in the opposite direction). In addition, the roads must be wide enough (typically 34 feet wide) to allow the main erection crane to travel, where necessary.
- Vertical design—The main erection crane and the heavy construction vehicles cannot travel up (or down) grades exceeding a certain slope (typically 10 percent), or travel over surfaces with excessive vertical curves. The wind turbine manufacturer and erection contractor will require specific vertical curve and slope limits for their equipment.
- Cross-section strength—Project roads must be designed economically for the specific loading and site/strength characteristics. The road cross-section typically consists of a subgrade and base material of varying depths that will permit the travel of all construction traffic with acceptable rutting and deformation limits.

SUBGRADE

Road strength begins with the subgrade. Generally consisting of scarified and compacted native soil, a strong subgrade is required to provide the strength necessary to withstand the heavy wind project loads. Contractors must carefully examine the geotechnical report to determine the proper moisture content for maximum subgrade compaction, and the proper compaction criteria to result in minimum deformation and rutting.

BASE MATERIAL

Once the subgrade is properly constructed, contractors will place and compact the base material atop the subgrade. The base material, typically an aggregate of some type, provides a smooth and uniform driving surface, reinforces the road strength and improves road drainage properties. Base materials vary from region to region (e.g. caliche in the Southwest, limestone, sand and gravel). The road design must match the depth of the base material with the strength of the subgrade to establish a road that meets the needs of the project loads. In areas with low-strength soils (resulting in a low-strength subgrade), or areas where a great deal of rain is expected, it is common for the road design to include reinforcement with synthetic materials (geogrids and geofabrics). These materials can bridge low strength subgrades and allow, in some instances, a decreased base thickness and a higher tolerance for precipitation.

DRAINAGE

Proper drainage is a key to road longevity. Standing water creates weak areas that will eventually result in road failures and roads may become impassable. Additionally, improperly channeled water allows erosion to occur and leads to the breakdown of road surfaces. Drainage structures carry water away from the roadbed and are designed based upon the topography of the road as well as the amount of surface water that is anticipated to flow onto the road.

Proper road design and construction is an absolute necessity for the success of a wind project. No project can support the cost of a true "all-weather" road-concrete or asphalt. However, the wind contractor's mission is to design project roads that will support the delivery of project material in anticipated weather conditions, and have contingency plans ready in the event that weather conditions make construction travel difficult.

Julian Bell is the director of preconstruction for Signal Energy Constructors, an EPC/BOP renewable energy contractor with more than 7,000 MW of utility scale project experience. For more information visit: www.signalenergy.com.

Jack Wallace
Frontier Pro Services

Testing generator winding insulation—by way of the "megging" process—is a wise addition to your maintenance schedule.

INSULATION TESTING OF YOUR generator windings is a data acquisition method that—if completed during regular maintenance cycles—can help you understand the health of your equipment.

A good part of a wind turbine technician's time is spent checking, lubricating, and inspecting mechanical components. The repetition of these actions helps them notice when something is not in line with the normal status of these services.

Electrical components within the turbine require the same type of attention. A potential silent failure may be waiting within your turbine that could be anticipated with the use of some simple data collection. That data is obtained by performing insulation testing of your generator and motor windings.

Electrical insulation on your inductors performs a very important task of keeping the current within the proper circuit. When electrical insulation fails, a short circuit may occur, leading to a violent explosion and destruction of components. Inspecting the insulation quality of your generator and other motors is now easier than ever, and the data collected may help you decide where to spend your money in a controlled and planned manner. This inspection process is easily achieved with the use of a mega ohm meter—commonly referred to as a "megger." This meter is able to measure high resistance values, and does so by using a high voltage to look for stressed and weakened areas of insulation on the windings of the conductors that comprise a generator or motor or other inductor.

The process of "megging" a generator or motor is the same. Remember, these test are performed with no power, other than that provided by the mega ohm tester.

To perform the test, first disconnect all electrical power and isolate the inductor. Make the system safe to work on with no power present per your company's safety policies for electrical systems. Next, disconnect the generator power conductors and isolate the generator stator windings and perform the test per your test meter. If the disconnection point is done in the terminal box of the generator, then a visual and smell test can be made of the generator connections also. This allows the technician to get familiar with the normal sights and smells within this component's electrical connection box (This action alone may save you a surprise event should something abnormal be found). This same test should be performed on wound rotors to get information on the health of the insulation of the inductors comprising the generator rotor. For this part (after ensuring you follow proper electrical safety), you could disconnect the supply cables before or after the slip ring on the rotor. If you have strange readings you may want to isolate the rotor from the slip rings.

The insulation testing tools today are much more sensitive than in the past. Meggers and the process of megging used to be a no-value event, as a good winding would send the indicator needle straight into the "infinity zone." Any reading less than this would raise an eyebrow as a slightly abnormal event. The mega ohm meters of today now have the capacity to read the actual resistance reading of the winding in terra ohms and may not end up in the infinity zone. This is beneficial because you can have a real starting value to record and track as the test is repeated on an annual schedule.

There are two parts to the simple megger testing. One part of the test is to place the megger into the testing process for one minute and the record that value. This value is called the Insulation Resistance value (also known as the IR). You are looking for a high value resistance reading. The second part of the test is the same, except that the test duration is 10 minutes. This part of the test is called the Polarization Index (also referred to as PI). The PI is formulated as the resistance after 10 minutes divided by the resistance after one minute.

This test helps to determine if there is moisture or other contaminants that may be a reason of concern.

In the past, most meggers were hand-cranked. Ten minutes of hand cranking proved to be difficult and discouraged many from performing the test.

You may be asking yourself: "Do I really need to perform these tests?" The answer really depends on your needs for useful data in your decision making process. Without this data, the quality of the insulation on your inductor windings is unknown. Having this data allows you recognize trends or abnormalities, and can aid in preventing a surprise event.

Jack Wallace is director of wind turbine technical services for Frontier Pro Services. He can be contacted at jwallace@frontierpro.com. For more information on Frontier Pro Services, visit www.frontierpro.com.

Diane Davis
Red Lion Controls

Industrial Ethernet is a key component as wind farm communication needs expand.

AS THE USE OF WIND FARMS continues to grow worldwide, technology is a key component to keeping wind farms up and running at top efficiency. An important part of the technologically-savvy wind farm is industrial-grade Ethernet, which has evolved to combine rugged networking with reliable performance, and advanced features. This article will examine what industrial Ethernet is, how it has evolved, and the benefits it provides wind farms.

WHAT IS INDUSTRIAL ETHERNET?

Industrial-grade Ethernet switches are specially designed and built to operate in rugged areas, and have been tested, and proven to work under harsh conditions that include high and low temperature fluctuations, dust, vibration, electromagnetic interference, and more. This differs from standard commercial-grade Ethernet switches that work in environments such as wiring closets and data centers where wide varying temperatures, shock, and vibration levels and electronic interference do not exist. Commercial-grade switches cannot function in wind farm environments, and will quickly fail if deployed there.

THE EVOLUTION OF INDUSTRIAL ETHERNET IN WIND FARMS

Wind farms have evolved from using basic unmanaged industrial Ethernet switches to higher speed managed switches that offer more advanced features and functionality. Over time, these industrial-grade switches have evolved beyond basic connectivity to provide faster speeds—moving from Ethernet speeds of 10 megabits per second (Mbps) to Fast Ethernet at 100 Mbps and now Gigabit Ethernet at 1 gigabit per second (Gbps), which equals 1000 Mbps. This is important because today's wind farms are adding video surveillance to monitor activity in and around turbines. In addition to faster speeds, the number of ports has increased, moving from four ports to eight, 16, and even 26 port switches.

Many industrial switches now include more advanced management, security, and configuration features to speed installation and make setup easier. These advanced features also provide the ability to track and control the traffic that flows through the network, which makes Ethernet-based communications more efficient and secure. And, most of these switches comply with various industry standards, which allow standards-based switches from different vendors to work together.

These advancements enable wind farm operators to spend less time installing, deploying, and maintaining the network, and more time focusing on the actual wind farm itself. In addition, today's industrial Ethernet switches are designed for scalability. When a wind farm grows, the network can easily expand with it. Finally, these switches have built-in redundancy so if a cable is cut or a switch fails, it does not take down the entire network, and operations keep running.

HOW INDUSTRIAL ETHERNET HELPS WIND FARMS

Located in remote areas ranging from dry, dusty deserts to corrosive oceans, wind farms face extreme conditions nearly every day. These include fluctuating temperatures, heavy dust, high humidity, and salty air. With rugged packaging, advanced features, and built-in redundancy and monitoring capabilities, industrial Ethernet switches allow wind farm operators to build networks that perform reliably in these extreme environments.

In addition, wind farms generate a significant amount of data with regard to how well they are working and the attention that each turbine needs. By transferring data over an Ethernet network, operators can remotely monitor and control wind turbine status and performance in real time. This enables predictive and preventative maintenance, which helps to minimize wind turbine failures or downtime. Operators can now spend less time on networking issues and more on running the actual wind farm to maximize overall system uptime and efficiency. The end result helps ensure that each turbine is producing as much energy as possible. This is important because the more energy that is produced, the more profitable the wind farm will be. And, of course, this also means that there will be more power available for consumers.

From industrial Ethernet switches, Wi-Fi and cellular M2M devices to HMIs and RTUs, Red Lion Controls offers a full line of industrial automation and networking products to connect, monitor and control wind farm environments regardless of size or location.

Diane Davis is the director of product management for Ethernet networking with Red Lion Controls, a technology-based company specializing in communication, monitoring, and control for industrial automation and networking. For more information, visit www.redlion.net/together.

Michael Graska
Vectora Transportation LLC

Defining supply chain management can be confusing. Its true meaning is best comprehended by understanding the foundation and the individual functions.

WHAT IS THIS THING called supply chain management? Sometimes the term seems so vast and multifaceted that it is hard to get your head around the concept. Let me give you my interpretation of what supply chain management is. I do not take full credit for this definition since I have had many influences throughout my 30 years in this industry. But I have boiled down supply chain management to mean:

> Understanding how demand and supply variables influence the movement of material, information, and money within your organization; and using the proper tools and techniques to efficiently and responsively move material, information and money between your customers, your suppliers and your organization.

That rather long sentence captures the what supply chain management is. It also gives a blueprint on what to manage within the supply. The three things all companies must manage within their supply chain are material, information and money. Material is what makes up your product or service. It encompasses the raw material for the product all the way through the finished goods. It is the way you add value to sales. Information is equally as important as material. If material is the "what" in the scenario, information is the how and why. Handing information accurately and timely is critical for an optimized supply chain. Money, of course, is the measure of the value of your work. It is equal in importance to material and information. You can envision supply chain management as a three-legged stool, where each leg is of equal importance.

So how does one manage this three-legged stool? I like to break down the supply chain process into five separate functions built on a foundation. The foundation always comes first in any project, so let's lay the groundwork.

One layer of foundation is the vision, mission, and values of the organization. Vision, mission, and values give the supply chain process the boundaries to work within. It creates, as I like to say, the forest in which to operate. A second layer is metrics. How are your company and your supply chain being measured? Metrics is the scorecard that lets you know not only how you are doing, but also how far away you are from achieving your goals. Finally, information technology is that binding agent of the foundation that ties it all together. IT assists you in doing your job, and connects all of the functions within the supply chain.

The five supply chain functions I mentioned are: customer service, inventory, supply, transportation and fulfillment.

I'm often asked why customer service is a function of supply chain management? Customer service sets the business rules that in many ways drive the demand and supply of the product. Rules in place can determine response times, inventory levels, configuration of the product, and many more supply chain variables.

Inventory needs to be planned and forecast. It is a major financial burden on a company but it is also necessary. I liken inventory to an insurance policy. You hope you never have to use it. But you have it if you need it. You need to have enough, but having too much is wasteful.

Supply is the function of making or buying what is needed for you product. The supply plan is derived from customer service, and inventory policy. It has to be both efficient and responsive to support the company's goals.

Transportation is the movement of material within the supply chain. This can be a rather large expense for some companies. It is also influenced by customer and inventory policy. Most companies have different transportation strategies based on product and customer type. In other words, they do not use a cookie cutter approach to transportation but rather customize the solution to the requirement.

The last function is fulfillment. Warehousing and store locations are determined within this function. Of course transportation and fulfillment work hand in hand to determine the lowest total cost, and most responsive way to deliver the product.

To summarize, supply chain management is using customer service, inventory, supply, transportation and fulfillment planning, and execution to move material, inventory and money to support your organizations goals. Sounds simple right? Well, it's sort of like my golf game. When it works, it's a thing of beauty. But it needs constant attention and practice. Even then, I'll still hit some bad shots. But as my father told me once... "It's not how well you hit your shot after a good shot., It's how well you hit it after a bad shot."

Much like supply chain management.

Michael E. Graska is senior manager of operations and engineering for Vectora Transportation LLC. For more information, go to www.vectoratransportation.com.

KLÜBER LUBRICATION

By Stephen Sisk

No two tribology applications are exactly the same. As such, Klüber Lubrication takes a precision needs-based approach in helping its clients determine the proper lubrication products.

Oil is oil, right? There's no difference.

Try to take that position with a representative of Klüber Lubrication. They will swiftly, yet tactfully, educate you on the fallacies in your reasoning—with eight decades of experience, a catalog of more than 2,000 specialty lubricants, and German precision.

Before the conversation is over, chances are you'll respond to specific questions about your lubrication needs with shrugs and quizzical expressions. Go ahead and wave the white flag. Defer to the experts.

For more than eight decades, Klüber Lubrication has provided innovative, application-specific lubricants to a wide range of industries—from automotive to pharmaceuticals to renewable energy. The company's customer-focused, needs-based development process (inadequately illustrated above) has elevated Klüber to the pinnacle of the specialty lubricants industry.

That philosophy can be attributed and traced back to the founding principle of its founding father Theodor Klüber, who in 1929, set out to formulate and produce specialty lubricants of exceptional quality.

Along the way, the company's efforts to solicit and understand the exact needs of specific industrial applications, combined with rigorous, comprehensive testing and analysis were and still are instrumental in the formulation of Klüber's lubrication products.

Headquartered in Munich, Germany, with its North American location in Londonderry, N.H., Klüber employs nearly 2,000 people. Of that number, nearly half are in direct contact with customers—taking and fulfilling product orders or fostering the needs identification and co-development processes.

Klüber has established itself as a significant name in the wind energy industry worldwide, primarily in recent years with the push toward renewable energy.

"We've really been active in North America for the last six years", said Jesse Dilk, Market Manager for Klüber Lubrication North America L.P. "When the global industry started growing, we formed a business unit of team members who focus on local wind markets throughout the world."

Klüber lends its extensive experience in creating specialty lubricants to developing lubricants to meet both current and future wind energy lubrication applications.

Among its portfolio are lubrication solutions for main gearboxes, yaw gears, main bearings, generator bearings, slip rings, pitch mechanisms, and slewing rings.

Specific product offerings for wind energy include:

- Klüberplex BEM 41-141 for bearing applications
- Klüberplex AG 11-462 for open gear applications
- Klübersynth AG 14-61 for gear/pinion interfaces and plain bearings at low temperatures
- Klübersynth GEM 4-320 N for gear drives

The research and development process is a cornerstone for Klüber. Although a brief description can't do the company's R&D process justice, it involves pairing a lubricant with a specific industrial application. Existing products are first considered and tested in the specific application either on test rigs or in the field. If an existing product does not meet the exact needs, Klüber's 150 scientists and engineers will enter the development stage. The testing and development process continues until a lubricant arises that meets the exact requirements of the application.

We run lubricants on our test rigs and screen them to find the ones that show the best performance for the real application," Dilk said. "That's how we either choose or continue to develop a lubricant. If a product performs very well on all of our tests, we offer it as a solution to the OEMs."

With the advent of new technologies and the push toward maximum efficiency in the wind energy industry, Klüber is investigating the varying demands that will arise for turbine component lubrication.

As rotors and turbines in general, increase in size, lubricants that may have been satisfactory in older, smaller designs are less likely to provide optimal lubrication.

"What was a good lubricant for old turbines may not be the best solution for new models," Dilk said. Another example is the move toward active blade pitching—blades turning into and out of the wind on a relatively constant basis.

In short, the harder a component works, the harder the lubricant works. It's necessary to choose the proper lubricant that can withstand the increased workload. The company's KlüberMonitor Grease Condition Analysis provides regular insight on the current condition of the grease that is in service. As a result, the failure rate of expensive components or systems can be reduced.

Klüber Lubrication is part of the Chemical Specialties division of the Freudenberg Group, and operates in more than 30 countries spanning the globe. In addition to wind energy, the company serves a large range of other industries and customers, such as: automotive, food and beverage, cement, marine, mining, textiles and wood.

For more information about Klüber Lubrication, visit www.klubersolutions.com.

For technical articles by Klüber staff regarding wind energy, visit www.windsystemsmag.com and enter the search keyword "Kluber"

For more information about Klüber Lubrication, visit www.klubersolutions.com. For technical articles by Klüber staff regarding wind energy, visit www.windsystemsmag.com and enter the search keyword "Kluber."

TO BOOM OR NOT TO BUST?

WINDPOWER 2013: Incoming leadership stresses unity and long-term policy to combat looming challenges facing wind energy.

From Staff and Press Reports

COMING OFF A YEAR WHEN WIND ENERGY experienced the highest amount of growth in its history, industry players wasted little time celebrating as they convened in Chicago on May 5-8 for the American Wind Energy Association's annual WINDPOWER Conference and Exhibition.

In 2012, driven largely by the looming December 31 expiration of the Production Tax Credit, wind energy developers installed more than 13GW of new wind energy capacity—exceeding 60GW of total installed wind energy capacity and making wind the leader among all power generation sources in newly installed capacity.

But the driving force behind that rapid growth is now providing uncertainty and instability, as Congress granted only a short-term extension of the PTC as part of the last-minute "fiscal cliff" negotiations early this year.

Overcoming that uncertainty and instability was a central theme throughout the conference, as evidenced by the event's "Solutions for Success" slogan.

American wind power must develop a vision for predictable policies that create a stable business environment and allow the industry to grow to its full potential, industry leaders said during the first day of the conference on May 6.

"That's good news, but it's just another chapter in a story we keep writing every day," incoming AWEA board chairman and EDP Renewables North America CEO Gabriel Alonso said regarding record installations in 2012 and future growth.

Alonso went on to say that the industry could still be "vibrant and sustainable" if it deployed significantly less than that—to the tune of about 8GW annually. However, a boom-bust cycle brought on by uncertain policies "does not make for a sustainable industry," he said.

The incoming chairman's comments came during and immediately following the conference's opening session, at which incoming AWEA CEO Tom Kiernan, Iowa Gov. Terry Branstad, Chicago Mayor Rahm Emanuel also spoke.

In spite of the challenges wind energy currently faces, Alonso applauded the industry's recent accomplishments. Aside from the continuous growth, "The technology evolution has been phenomenal over the last few years," Alonso said, with capacity factors surging right along with the size of blades and towers.

In outlining the association's vision for achieving stability and sustainability within the industry, Alonso described a five-pillar strategy:

First, AWEA must be strengthened so it can better advocate, provide essential data for members' success, develop standards, powerfully convey wind power's compelling message, and do more for the industry.

Second, the industry must strengthen its brand against competitors and unify its message in order for America to truly understand how wind power is good for America.

Third, the industry must develop a long-term plan and strategy that includes clear near-term and mid-term action steps.

Fourth, members of the industry must become united by tapping the power of AWEA, its regional partners, and other vehicles to speak for wind power with one voice.

Finally, "We need YOU," Alonso said. The number of people speaking to their government representatives, whether in Washington, D.C., or in their communities, must grow manifold, he said. If 100 people today are participating in trips to the nation's capital to visit with their representatives, that number must become 1,000. "You are powerful," said Alonso. "You have a message that matters."

Tom Kiernan, who would officially take on his role as AWEA CEO later in May, was officially introduced to his new industry during the opening session. Kiernan,who was previously president of the National Parks Conservation Association since 1998, and a senior official at the Environmental Protection Agency under President George H.W. Bush, said his passion for wind energy is personal.

"Wind power is clean, affordable, and homegrown," Kiernan said. "The country needs us to succeed. The natural world needs us to succeed. And frankly, my children and your children need us to succeed."

Kiernan also echoed Alonso's call for a new vision. "We need to craft a long-term plan for both the industry and for AWEA," he said.

Nevertheless, near-term issues will need to be addressed, and Kiernan made that clear. Following the opening session, he made sure that members of the media understood the immediate matter at hand. "To be clear, it is AWEA's top priority to extend the PTC and ITC."

Meanwhile, at the afternoon's Power Session, high-level representatives of AWEA, the National Wildlife Federation, the American Wind Wildlife Institute, and the National Audubon Society joined Jose Zayas, director of the Wind and Water Power Technologies Office at the U.S. Department of Energy (DOE), to launch discussion of a new vision for the wind energy's future.

According to Zayas, DOE's new effort will succeed the "20 Percent by 2030" technical report produced by DOE in 2008, and will take into account changes in wind technology, energy markets, and competing forms of energy in the intervening years. "My job," Zayas said, "is to make sure wind energy is at the table and has a key part to play in the energy mix of the future."

The process for developing the new strategy, he said, will be a collaborative one much like that employed in developing the 20 Percent report, in which environmental groups, utilities, energy experts and others will be brought together to look at the potential for wind energy in 2020, 2030, and 2050. He said DoE's goal is to reduce carbon emissions by 80 percent by 2050.

The general session on day two of the conference featured two separate panels of wind industry leaders and prominent wind energy users, who discussed how U.S. wind energy is strongly positioned to build on its growth and status as a mainstream energy source, particularly by capitalizing on its many benefits.

During the panel discussions, industry leaders spoke of how they share the good news that the clean, affordable energy source is a win-win choice for America. The second panel of corporate purchasers of wind power – including some of the best-known brand names in American business – told how wind energy is saving their businesses money, giving them protection against energy price spikes, and making their communities cleaner.

"The business case for wind is very compelling," said Paul Gaynor, CEO of First Wind. He satated that wind power is now saving consumers large sums in Massachusetts and Connecticut—to the tune of $1 billion and $800 million, respectively.

Oklahoma has embraced wind energy because of the "realization that they have this great wind resource, and the price is very attractive," said Kevin Walsh, managing director for renewable energy at GE Energy Financial Services.

As the president and CEO of a company in wind energy's extensive supply chain, Shermco Industries' Ron Widup offered his own perspective on building political clout for wind power: "We have a three-pronged approach," he said. "Jobs, jobs, jobs."

Panelists spoke of the importance of wind, with its long-term power contracts, as fixed-cost insurance against volatile fossil fuel prices. Wind energy, Walsh said, is "a form of hedge because the fuel is free."

"It's about long-term stability," echoed Tim Rosenzweig, CEO of Goldwind USA. "It's a great way to lock in rates."

Panelists were bullish on continued improvements in the industry, driving down costs in all facets from technology to finance and improving turbine performance via more output. Turbines are already lasting longer than their 15-20 year expected lifespan, and that durability "will continue to get better and better," said Widup. That impacts everything from a project owner's bottom line to the cost of capital for new projects, panelists noted.

The result is that the industry is advancing much more rapidly than anyone might have predicted. Susan Reilly, CEO of RES Americas, highlighted the initiative announced yesterday to expand on the DOE's 2007 report showing the feasibility of 20 percent wind energy by 2030. "I think that's incredibly exciting for all of us because we've achieved more than what we predicted when the study was first done," she said.

After industry leaders shared their product's benefits, corporate purchasers shared their firsthand experience with the product from the user perspective, and provided hard numbers to back up the benefits.

Lee Balin, Sustainability Manager for the Bloomberg's Global Sustainability Group, reported that his company has saved $48 million since 2008, thanks to its renewable energy purchases and efficiency programs.

"We believe [in renewable energy] as a hedge against rising fuel prices in the future," said fellow panelist Greg Butler, Global Supply Chain Stewardship Director in the Office of Global Sustainability at medical technology company BD.

For Walmart, energy is its second greatest controllable expense, said Greg Pool, senior manager for Renewable Energy and Emissions. Saving on renewable energy,

therefore, helps the company's bottom line as well as helping the company in its goal to be a good global citizen, and fostering clean air in communities where it operates—which in itself has economic benefits for the company, he noted. Walmart has set the bold goal of running on 100 percent renewable energy worldwide.

"Walmart is open for business to do wind deals," Pool announced. He said the industry should look beyond utilities to diversify its customer base.

Direct purchases are also in the playbook of fellow panelist Google, which must power its electron-hungry data centers as cost-effectively as possible. The tech giant has entered into PPAs for wind and even invested in projects. It purposely seeks to locate its data centers in close proximity to renewable energy and renewable resources, said Gary Demasi, director of operations for data center location strategy and energy. The company has over 260MW of wind secured through long-term contracts and utility agreements. Available wind power and utilities willing to provide it, he said, "is becoming an increasingly important part of our consideration of where we go and where we grow."

The conference also hosted more than 40 individualized sessions, including specialized technical training courses, presentation sessions, and panel discussions on a wide range of wind energy-related topics. A poster presentation and display drew submissions from more than 200 wind energy personnel.

In total, nearly 600 exhibitors and close to 10,000 attendees filled the WINDPOWER 2013's classrooms and exhibition floor, a sign that despite current challenges, the wind energy industry and its personnel are committed upholding the industry's new pledge toward sustainability, stability, and growth.

Next year's event will mark AWEA's 40th anniversary, and for the first time ever, the site for WINDPOWER 2014 will be in Las Vegas, next May 5-8. Booth reservations are now open and were selling briskly in Chicago. For details, see www.windpowerexpo.org/2014.

NEWS FROM WINDPOWER 2013

AIRGENESIS LLC'S TWIN-ROTOR TURBINE DESIGN SECURES NEW POWER CURVE VALIDATION

Airgenesis LLC, designers of a unique twin-rotor utility-scale wind turbine, has announced that its turbine design has received additional power curve validation and its fourth U.S. patent. Power curve data was created and validated by DARcorp. of Lawrence, Kansas.

Findings show that the double-blade configuration offset at 30 degrees allows the wake of the front rotor miss the aft rotor, producing a 92 percent yield. Increasing rotor speed achieved higher electrical production, at the same time reducing the torque on the drive train.

DAY 1

DAY 2

DAY 3

WIND SYSTEMS THANKS WINDPOWER GUESTS, CONGRATULATES WINNERS

Wind Systems would like to thank all WINDPOWER 2013 attendees who helped make our conference a success by visiting our show booth in Chicago. Our staff was working diligently to answer your questions and share our vision of becoming your primary source for the latest, most insightful wind energy industry information available.

Each day of the exhibition at 11:30 a.m., *Wind Systems* offered conference attendees a chance to win a DBI-SALA ExoFit NEX harness from Capital Safety (see Product Showcase item on page 51) and a Snap-on toolbox.

Harness winners (top to bottom, above-left): Ben King of Laramie County Community College; Aubrey Friedman of A. Friedman & Asociates Inc.; Mark Jones of TenderLand Renewables.

Toolbox winners (top to bottom, above-right): Mark Winward of GE Energy; Travis Johnson, a student at Oklahoma State University-Oklahoma City; and Jenny Jeffrey of Complete Wind Corp.

Congratulations, winners! Thank you for coming by and participating in our drawing. If you came by our booth during the conference, but weren't one of our lucky winners, please visit us next year at WINDPOWER 2014 in Las Vegas!

The Airgenesis double-blade configuration (described at length in the April 2012 issue of Wind Systems; http://windsystemsmag.com/article/detail/357/) is capable of producing an unprecedented 11 net MW per tower at 16.5m/s with a 48.8 meter blade length, eliminating any need for government subsidy.

In addition, the structure can begin to produce electrical energy at wind velocities of 3m/s. Designed for maximum efficiency and ease of maintenance, the Airgenesis design results in a lighter and significantly less complicated nacelle.

Once installed, routine maintenance on Airgenesis' towers can be performed at ground level including swapping out generators and clutch systems. The drive system features five 50-foot drive shafts maintaining vibration free operation due to its low rpms, expansion couplers, and thrust bearings. All 12 of the turbine's generators are located at ground level.

The design allows for the relocation of a large portion of the nacelle weight to the base of the tower. A sophisticated mechanical clutch system and integrated ratcheting generator mechanism have nearly tripled the energy production of a single tower.

"This is going to be a game changer for the wind industry," said inventor Danny J. "Skip" Smith of Wheatland, Wyo., who has invested nine years in perfecting Airgenesis' technology. "It may very well make other wind energy turbines obsolete in comparison."

Airgenesis LLC currently has more than 250 patents and patents pending encompassing 144 countries, and final engineering and CAD files are nearing completion. Airgenesis LLC carries no debt and Smith maintains 87 percent ownership.

With engineering development reaching successful conclusion, Airgenesis LLC is currently seeking experienced industry investors/manufacturers to purchase part or all intellectual property including patents, patents pending, engineering drawings, and CAD files for unlimited U.S. and worldwide potentials.

For more information, visit www.airgenesiswind.com.

UPWIND SOLUTIONS AWARDED O&M CONTRACT FOR BP WIND FARMS IN TEXAS AND KANSAS

UpWind Solutions, Inc., a third party provider of asset management operations and maintenance services for the wind energy, announced they have signed O&M agreements for the Trinity Hills, Sherbino 2, and Silver Star 1 wind farms in Texas and the Flat Ridge 1 wind farm in Kansas, representing a combined 485MW of production. The four wind farms are owned by wholly-owned subsidiaries of BP Wind Energy. The contract is for UpWind technicians to perform O&M services on a total of 194 Clipper C-93 and C-96 turbines.

"The geographic location of our regional hub in Sweetwater, Texas and five years of experience working with Clipper technology is what established UpWind Solutions as the strongest independent service provider candidate to take on the operations and maintenance of the four BP Wind Energy sites" UpWind Solutions' CEO Peter Wells said.

The four wind farms provide the equivalent electricity needed to supply over 145,000 average American homes annually.

As part of the company's overall approach, UpWind Solutions' technicians not only complete rigorous and comprehensive technical training with a focus on maintaining the highest safety standards in the industry, they are also encouraged to find solutions that optimize wind turbine availability and performance for wind project owners, ensuring the highest return on investment.

For more information, visit www.upwindsolutions.com.

ROMAX LAUNCHES INSIGHT HEALTH MANAGEMENT PLATFORM PREDICTIVE MAINTENANCE SUITE

Recently launched at WINDPOWER 2013, Romax Technology seeks to provide the wind energy industry with a complete health monitoring

service suite with the InSight Health Management Platform predictive maintenance suite. Following on the heels of its April 2012 software launch, the company now offers comprehensive health monitoring services for a full lifecycle management approach.

InSight leverages Romax's work over the last two decades in drivetrain design, analysis, monitoring and operations and maintenance technical services for onshore and offshore wind farms.

At present, there are many data sources and analytical capabilities, available to monitor different aspects of the drivetrain such as the gearbox and bearings for conditions such as vibration, oil analysis, wind direction and temperature. Romax's world-leading software and services allow a combination of multi-source data to be unified on a single intuitive software platform. When combined with engineering consultancy and turbine maintenance services to ensure optimum turbine reliability and health, Romax provides maximum flexibility and helps mitigates risk.

This launch signifies the continuous development of InSight in response to an increasing industry need to monitor more than just the drivetrain. This means that failures will be detected up to six months in advance, allowing for preventative correction, rather than a costly, complete deterioration of the components.

Based on over two decades of operating in the industry, Romax has recognized a trend in the phases of wind farm health management maturity and has loosely segmented these phases into three groups - "fire-fighting", "managed" and "predictive." The InSight solution enables wind farm owners and operators to evolve from 'fire-fighting' through to managed and ultimately to an optimum state of predictive maintenance. The benefits of this are that operating costs are significantly reduced, maintenance and investment planning improved and revenue and energy generation is increased.

"This latest version of the InSight software combined with our engineering service team will change the way you view your turbine's health" Romax CEO Dr. Peter Poon said. "We are expanding the value and breadth of knowledge we can provide to our customers through an advanced and integrated system approach that works openly with your existing systems. With our expert engineering knowledge and visibility of turbine health, we can recognize warning signs early enough to reduce downtime, and costs to optimize reliability."

For more information, visit www.romaxtech.com.

GL RENEWABLES CERTIFICATION PUBLISHES NEW CMS CERTIFICATION GUIDELINE

GL Renewables Certification has published its new "Guideline for the Certification of Condition Monitoring Systems for Wind Turbines." This guideline was compiled in cooperation with its Wind and Marine Energy Committee. The new guideline, presented at WINDPOWER 2013, covers the most important requirements for the development, installation and operation of condition monitoring systems.

Obtaining economical wind turbine operations is vital in light of initial wind farm development costs. Operators and manufacturers aim to achieve wind turbine availability of more than 97 percent. In order to reduce unplanned downtime, increase availability and to reduce maintenance costs, continuous condition monitoring of wind turbines is indispensable.

The updated guideline reflects the latest developments of condition monitoring systems for wind turbines and future requirements.

"Currently almost all condition monitoring systems are operating independently from the control system and almost exclusively the drive train is monitored," GL RC CMS expert Dr. Karl Steingroever said. "Future condition monitoring systems will be partly or fully integrated into the control system and include the monitoring of the entire wind turbine. In tsxhis context the definition of interfaces between the systems is playing a major role."

GL RC's guidelines and technical notes are discussed in its Wind and Marine Energy Committee before publication. The Wind and Marine Energy Committee represents the relevant groups in the field of wind energy. The members of the committee are drawn from public authorities, wind turbine and component manufacturers, engineering consultants, institutes, universities, technical associations and insurance companies.

For more information, visit www.gl-group.com/en/certification/renewables/.

WOMEN OF WIND ENERGY ANNUAL LUNCHEON RECOGNIZES HONOREES

The winners of the Women of Wind Energy (WoWE) Awards were announced May 8 at the annual luncheon held at WINDPOWER 2013. The awards spotlight both prominent industry professionals as well as up-and-coming next generation of leaders.

WoWE continued its tradition of bestowing the "Women of Wind Energy Champion" award on a recipient who has repeatedly gone above and beyond to encourage and support the career development of women in the wind energy sector. All three winners provide examples of achievement, creativity and courage.

"Highlighting and recognizing the stories of incredible women and men like this year's WoWE Annual Award winners is critical not only to recognizing and appreciating their successes but also to help other women in the sector see role models and new career pathways," said Kristen Graf, WoWE Executive Director.

2013 WoWE Award Recipients:

- Champion Award—Ian Baring-Gould, Senior Mechanical Engineer at the National Renewable Energy Laboratory, received WoWE's Champion Award. This newest award seeks to honor an individual who has significantly contributed to the advancement of women in the field of renewable energy through mentoring and professional development that goes beyond expectations as well as advocating for work place practices that

support women in a manner that fosters a path forward. Since the inception of WoWE, Ian has been an active participant in the organization and its membership. Through his involvement with the Wind for Schools program, he has consistently encouraged the involvement of young women. Ian has a deep understanding of the importance of engaging kids at a younger age, particularly girls. Ian is at the forefront of educating the next generation of wind consumers and professionals. As a result of his passion, creativity and commitment, countless women have been inspired and involved in this exciting industry.

- Woman of the Year—Lucille Olszewski was honored with the Woman of the Year Award. Each year WoWE seeks out a woman who stands out for her leadership, inspiration, and significant contributions to the expansion and improvement of renewable energy completed at the highest level. Lucille first started in the wind industry in the mid-1980s as a young meteorologist with one of the largest wind manufacturers and developers in the world. During her 30 years in the industry Lucille has developed a keen eye on all fronts having assessed over 9,000MW of planned capacity and sited over 14,000 wind turbines. She has pioneered radio telemetry systems for meteorological data collection and was the first to use cell phone technology for data collection. Lucille is highly respected among her peers and known for her integrity.
- Rising Star—Dr. Julie Lundquist, Assistant Professor at the University of Colorado at Boulder with a joint appointment at the National Renewable Energy Laboratory, was honored with the Rising Star Award. This award is given to a woman who is relatively new to wind energy and is already making significant professional contributions by demonstrating unusual talent, dedication and innovation in her renewable energy work. During her time at Lawrence Livermore National Lab (LLNL), Julie's research moved ahead the frontier of wind energy forecasting. She has studied the effects of atmospheric stability and turbulence on wind energy forecasting and wind turbine performance. This research has revealed relationships in the atmospheric boundary layer that affect wind resource assessment and wind energy forecasting. Her work extends beyond traditional academia into how the industry can revolutionize wind resource assessment.

For more information, please visit www.womenofwindenergy.org.

WIND DRIVETRAIN CONDITION MANAGEMENT

The advantages of vibrational analysis in combination with oil contamination analysis.

By Steve Casey and Tom Marek

Steve Casey is general manager and Tom Marek is business development manager for Moventas. For more information, visit www.moventas.com.

COST EFFECTIVE CONDITION management is one of the key ways to optimize the overall drivetrain performance and successfully achieve the estimated energy production in wind turbine generators. Wind turbine gears are exposed to extreme changes, both in terms of load and environmental circumstances. A drivetrain failure can mean prolonged down-time and very expensive major component repairs or replacement work. Therefore, it is essential to develop condition monitoring systems and analyzing methods that are truly comprehensive and relevant to the operating system.

Few condition monitoring systems have been developed specifically for wind turbine drivetrains. It is critical that these systems incorporate precise measuring instruments and highly automated analyzing tools. One single service engineer must be able to accurately provide information about each possible upcoming failure based on the available instruments and analyzing tools while closely monitoring hundreds of wind turbines. The most challenging components to monitor are the slow rotating machine parts in the drivetrain.

Traditional condition monitoring systems focus mainly on measuring vibrations from rotating components. For proactive results it is no longer sufficient to simply perform vibration analysis. This needs to be done in combination with oil condition and particle contamination analysis.

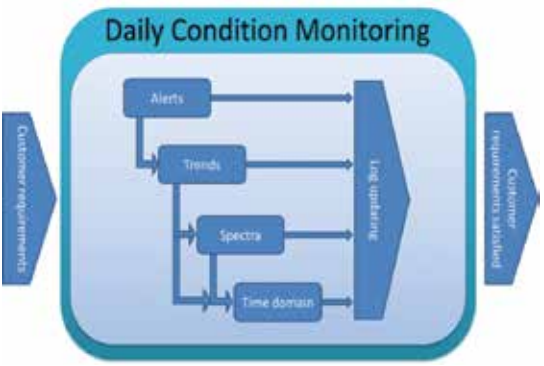

Figure 1: Moventas' daily condition monitoring process.

Figure 2: Construction of a medium speed gear.

PROACTIVE VERSUS REACTIVE MAINTENANCE STRATEGIES IN MIXED GENERATION GRIDS

Electrical power generation is a critical resource and is managed and regulated by many federal organizations like NERC, FERC, and independent grid-system operators to ensure supply and demand management, optimal power quality, and uninterrupted supply. With many new sources of power generation being added to grids coming from wind and other renewable plants, effective management of generation forecasting by asset owners is critical. Nuclear asset operators are required to maintain detailed plans for asset monitoring, predictive maintenance, and long term maintenance plans. First quartile performing thermal asset owners also have well developed strategies to analyze data and plan maintenance activities into future planned maintenance outages. Thermal asset operators do have an advantage over renewable asset operators: location of generating assets. There is a large disparity in physical layout and original equipment instrumentation between traditional thermal power generation assets and renewable assets. Thermal assets are housed most commonly in a cluster of buildings and structures located more conveniently in a well-defined area and sub-systems are normally enclosed from the elements. In many cases, wind plants can stretch over thousands of acres/hectares and have hundreds of individual generating assets in one location. Given this more challenging plant layout and associated terrain based and seasonal access challenges, it is critical for owners of wind power generating assets to secure instrumentation to monitor "critical to failure" operational performance data and create proactive or predictive maintenance strategies to control costs of operation, optimize capacity factor, and generation revenue and provide accurate day-ahead generation bids to their grid operators. Wind generating asset operators

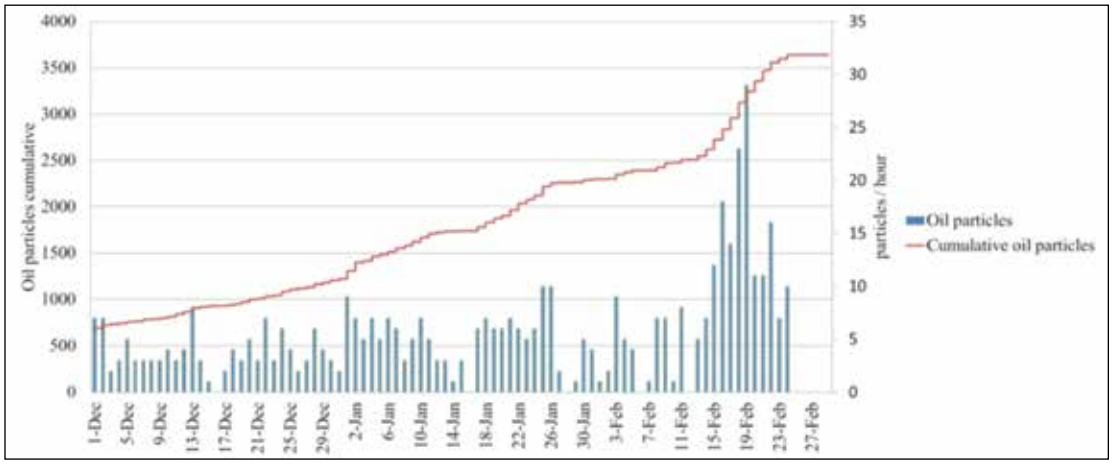

Figure 3: Failure can be seen from the rise in oil metal particle contamination.

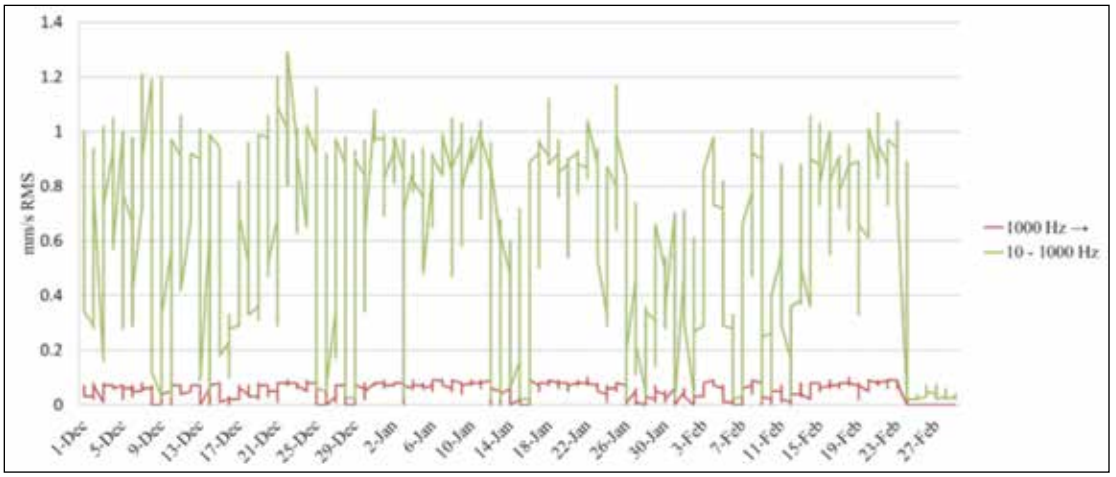

Figure 4: Overall, vibration velocity has remained steady despite of failure.

seeking first quartile cost per megawatt and revenue optimization must incorporate not only hardware and software to collect data and stream it to a central location, but they must also have the necessary resources to trend and analyze this data. More importantly, the data must be converted from strictly technical form to more digestible presentation quality to facilitate dialogue and quick action when required.

THE CHALLENGE

More often than not, the level of accuracy and cost effectiveness comes in to play when condition management of wind turbine gears is considered. The continuous surveillance of a wind turbine gear fleet must be automated and optimized because one analyst must be able to monitor hundreds of systems and, at the same time, every failure has to be found. A wind turbine drivetrain can face several different failure modes, which require extensive and reliable instrumentation.

The combination of oil metal contamination and vibration analysis has been previously studied on machines with high rotation speeds. However, there are many challenges in monitoring machines with low rotational frequencies and especially those with intermediate speed gears. Low rotation frequency demands a relatively lengthy measuring time, which can be very challenging due to limited memory of the measuring device. It is difficult to achieve a proper time domain signal from a wind turbine where the rotation frequency varies during the measurement. Varying load and rotation frequency is problematic when calculating the Fourier transform as regular impacts do not show up clearly in the spectrum. With low rotation speeds the energy of impacts is low and therefore difficult to differentiate from the background noise of the vibration spectrum.

Oil contamination can provide valuable information about the existence of a failure but it does not say anything about the root cause. This is why we need a combination of oil contamination and vibration analysis. With low rotation frequencies, vibration levels do not rise above alarm limits but do provide valuable information

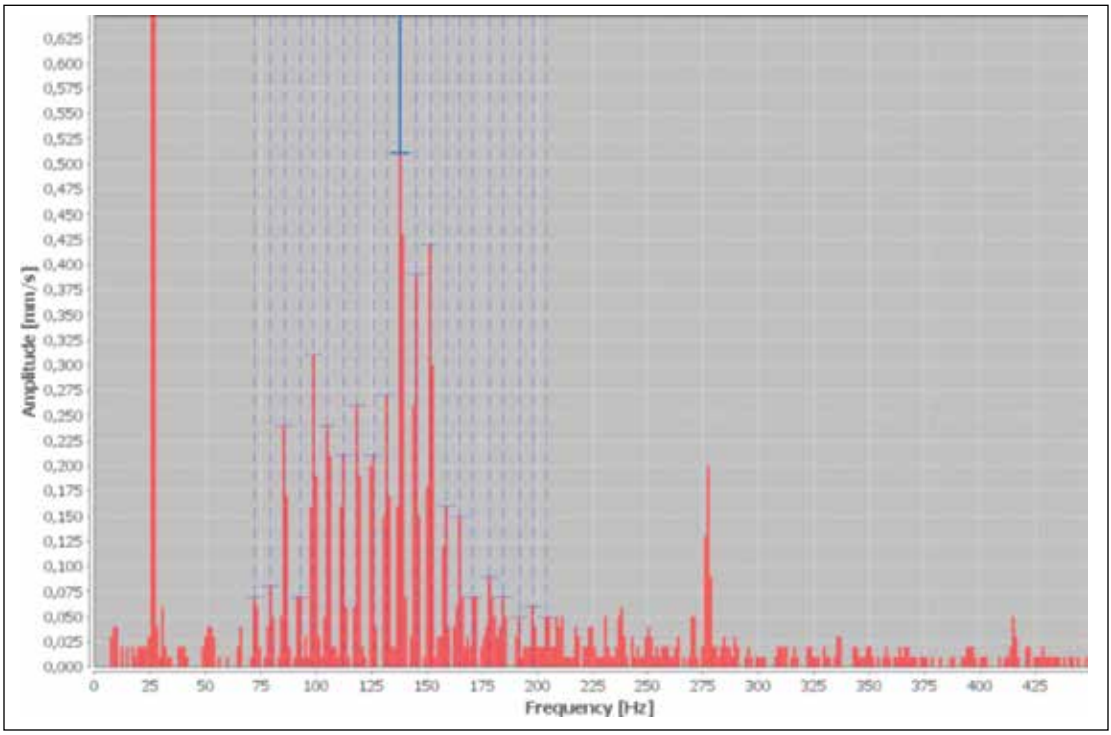

Figure 5: Velocity spectrum with side bands corresponding to rotation frequency.

about the root cause of a failure when that failure is initially detected with oil contamination surveillance.

HARDWARE

In the following case, the condition of the various gears within the gearbox is monitored using the Moventas condition management system (CMaS). This is a remote monitoring system specifically designed for wind turbine gears. CMaS is developed to monitor a large number of wind turbine gears very effectively by using sophisticated analyzing methods, algorithms, and intelligent sensors. These sensors are used to recognize possible damage to gears and other mechanical components in advance, before they start to affect and interfere with the turbine operations. When the sensor has processed and analyzed the data, it is then transferred to the CMaS main unit. Data transfer is conducted over a field bus. This means that in a normal operation mode, only key parameters are transferred. Spectrum and time domain data is also transferred regularly, but daily analyses are based on monitoring key parameters. When something outside the norm occurs, more-detailed data and raw signals are transferred. It is very important to successfully transfer key figures without losing any information. When daily monitoring is based on the analysis of key figures, monitoring is extremely cost effective.

In this particular case, the monitoring system has three Moventas intelligent vibration sensors (IVS-20), which all measure the spectrums, time domains, and key values in all three directions. Also included is a GasTOPS MetalSCAN full flow oil particle counter and other sensors for measuring temperatures and oil quality. Because wind turbine nacelles are a dynamic environment and have limited access for maintenance and troubleshooting, the connections between sensors and signal processing units must be durable and reliable to ensure maximum equipment up availability. Every nacelle and drive train has a specifically engineered configuration of sensor locations, cable routings, and processing units. Heavy duty, signal grade cabling is used to connect all devices. Connections at the processing units for oil and vibration data are heavy duty mil-spec components. Uninterrupted transmission of data is achieved through the use of mobile broadband technology. Mobile broadband SIM cards are employed to transmit data to surveillance centers. The use of mobile broadband also avoids any potential conflicts with access to turbine controller fiber communication access, and prevents the possibility of compliance issues with regulations pertaining to power generation cyber security. The flexibility of the CMaS unit does allow users the option to between broadband connectivity and their own turbine level fiber connection to fit their surveillance and data collection needs.

ANALYSIS METHODS

Daily monitoring routines (Figure 1) consist of checking each instance where the alarm has exceeding the alarm limit in every gear that is

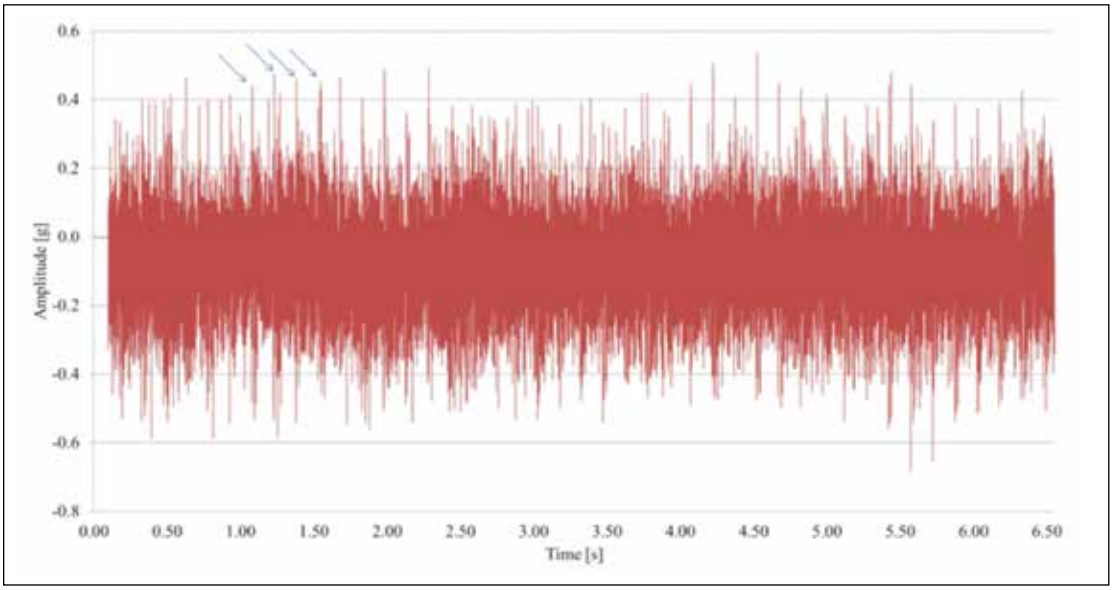

Figure 6: Measured time domain signal clearly shows hits corresponding the rotation frequency of the medium stage.

Figure 7: Visual inspection of gear show a fractured tooth.

monitored. If abnormal behavior is found, a closer inspection is performed to check for patterns and trends of those measurements. Spectrum and time domain analysis are used for finding the root cause of a possible failure.

INTERMEDIATE SPEED GEAR

This example will concentrate on remote monitoring of a medium speed gearbox (Figure 2), having one planetary gear and one helical stage gear. The ratio of this gearbox is 1:28 and the nominal rotation speed of the output shaft is 464 RPM.

CASE STUDY: Broken Tooth in Intermediate Speed Gear

At the beginning of December 2011, an unexpected rise in oil particles was detected with alarm limit monitoring (Figure 3). At the same time, there was no change in overall vibration levels or bearing temperatures (Figure 4).

Closer analysis of vibration spectrums indicated that there was a possible failure in the intermediate speed gear. This can be seen in the velocity spectrum (Figure 5), where there are side bands on both sides of the rotation frequency of the medium stage.

This provided the first clue that there was a failure in the intermediate stage, which was verified by analyzing the time domain signal where there were clear hits on the spectrum (Figure 6).

As soon as the root cause of this failure was identified, the client was immediately informed and a Moventas' Field Service Engineer was dispatched to make a visual inspection of the gear. During the visual inspection, a fractured tooth was found on the intermediate speed gear. The tooth was not yet broken, but it was cracked (Figure 7).

CONCLUSIONS

In this case, a failure would not have been found if vibration analysis was the only option in the condition monitoring system because the vibration levels remained steady despite the failure. Nevertheless, the root cause of the failure would be impossible to find without vibration measurements and spectrum and time domain analysis.

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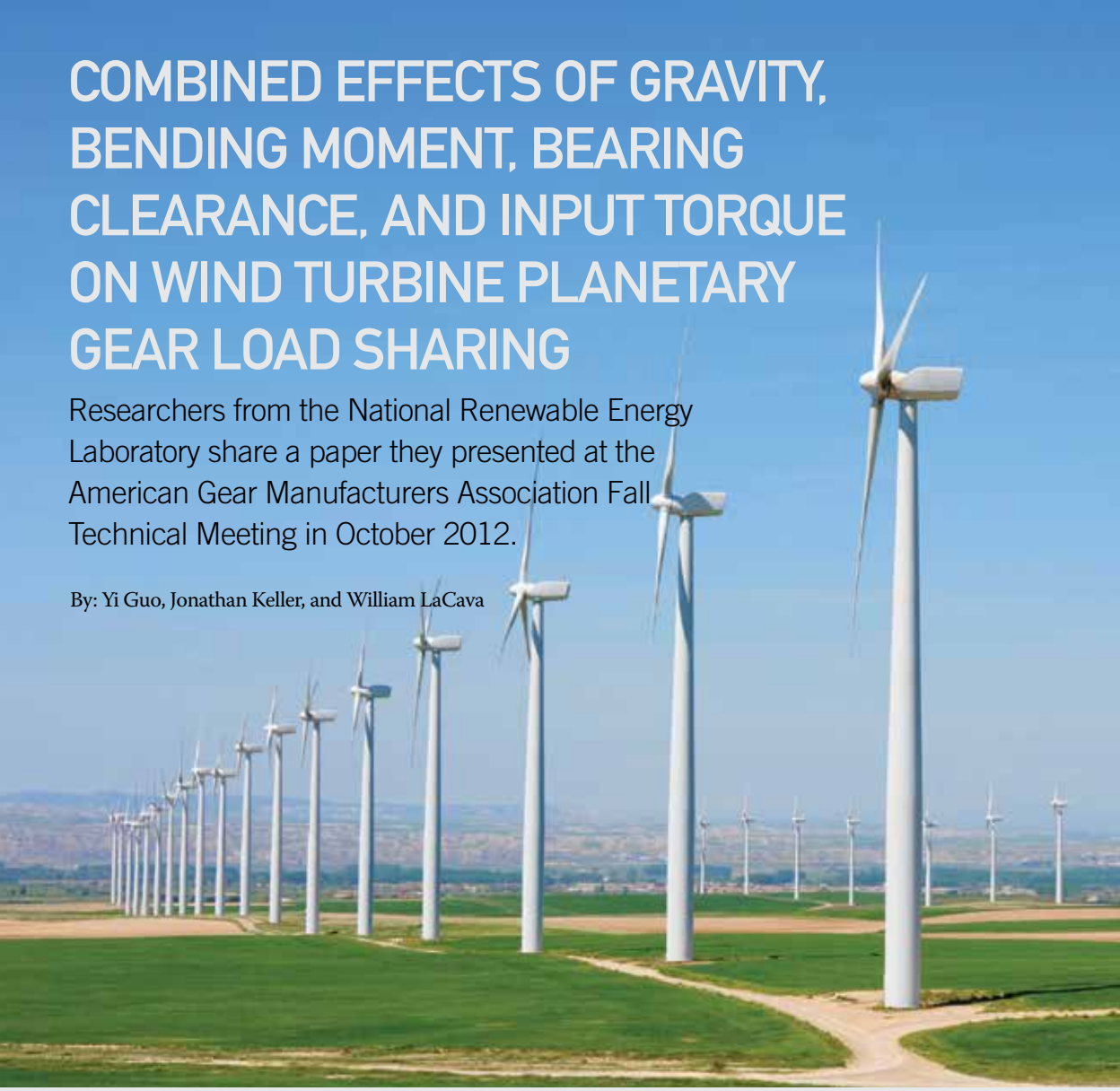
COMBINED EFFECTS OF GRAVITY, BENDING MOMENT, BEARING CLEARANCE, AND INPUT TORQUE ON WIND TURBINE PLANETARY GEAR LOAD SHARING

Researchers from the National Renewable Energy Laboratory share a paper they presented at the American Gear Manufacturers Association Fall Technical Meeting in October 2012.

By: Yi Guo, Jonathan Keller, and William LaCava



Jonathan Keller is a senior engineer and Yi Guo is a postdoctoral researcher with the National Wind Technology Center, a research facility of the National Renewable Energy Laboratory. William LaCava is a Ph.D. student at the UMass Amherst. For more information, visit www.nrel.gov/nwtc.

ABSTRACT

This computational work investigates planetary gear load sharing of three-mount suspension wind turbine gearboxes. A three-dimensional multibody dynamic model is established, addressing gravity, bending moments, fluctuating mesh stiffness, nonlinear tooth contact, and bearing clearance. A flexible main shaft, planetary carrier, housing, and gear shafts are modeled using reduced degrees-of-freedom through modal condensation. This drivetrain model is validated against the experimental data of the Gearbox Reliability Collaborative for gearbox internal loads.

Planet load sharing is a combined effect of gravity, bending moment, bearing clearance, and input torque. Influences of each of these parameters and their combined effects on the resulting planet load sharing are investigated. Bending moments and gravity induce fundamental excitations in the rotating carrier frame, which can increase gearbox internal loads and disturb load sharing. Clearance in carrier bearings reduces the bearing stiffness, and thus the bending moment from the rotor can be transmitted into gear meshes. With bearing clearance, the bending moment can cause tooth micropitting and can induce planet bearing fatigue,

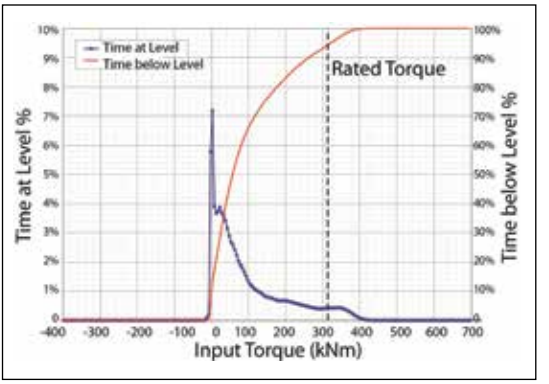


Figure 1: Torque distribution throughout measurement campaign on NEG Micon NM48/750 turbine [2,18].

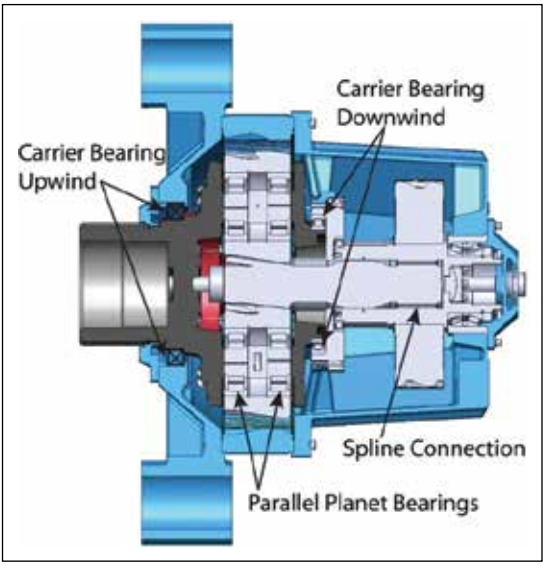


Figure 2: Cut-view of the GRC gearbox configuration.

leading to reduced gearbox life. At low input torque, planet bearings are susceptible to skidding. At rated torque and beyond, planet bearings are at risk of fatigue.

INTRODUCTION

Wind turbines have traditionally experienced premature gearbox failures [1]. The cost of gearbox rebuilds, as well as the down time associated with these failures, has elevated the cost of wind energy. The National Renewable Energy Laboratory Gearbox Reliability Collaborative (GRC) was established by the U.S. Department of Energy in 2006; its key goal is to understand the root causes of premature gearbox failures and improve their reliability using a combined approach of dynamometer testing, field testing, and modeling [2]. A major modeling activity of the GRC is to evaluate assumptions and uncertainties in current design practices that could affect gearbox reliability. As a part of the GRC program, this paper investigates planetary gear load-sharing in three-mount suspension wind turbine drivetrains that affects the load path and gearbox component life.

Compared to parallel axis gears, planetary gear systems provide high power density by splitting the input torque into multiple, parallel sun-planet and ring-planet load paths. Planetary gear systems are commonly used in wind turbine drivetrains and they use nearly or exactly equally-spaced planet gears, theoretically leading to equally shared

Figure 3: 750 kW wind turbine drivetrain of NREL GRC.

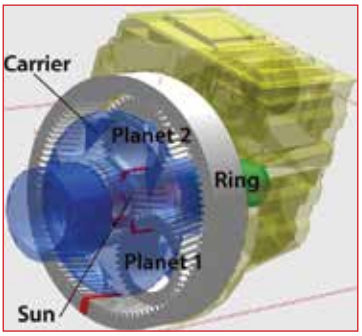


Figure 4: (a) Side view and (b) axial view of the multi-body model of the examined gearbox with flexible carrier and housing.

loads at each planet. However, in reality planet gear loads are not always equally shared among planets [3,4,5,6,7,8,9,10,11]. With unequally shared loads, planet bearing forces increase, leading to reduced bearing life and potential premature failure. Planetary gear load sharing is an important design parameter for drivetrain reliability. The degree of unequal load sharing has implications for tolerance schemes and gearbox loads.

Early studies by Hidaka and Terauchi [3] investigated disturbed load sharing by manufacturing and assembly errors on a Stoekicht planetary gear. This unequal load sharing was not significant when the mesh frequency was lower than 1000 Hz. Hayashi et al. [5] developed a method to measure the planet gear shearing stress and studied the influences of gear tooth profile error and eccentricity on load sharing. Ligata el al. [6] investigated the effect of pin position error on planet load sharing and a method for computing the planet load sharing from root strain-time histories was proposed. Singh [12] found that the tangential pin position error has a greater effect on the load sharing compared to the radial error. It was also shown that the sensitivity to pin position error increases as the number of pinions in the planetary gear set increases [6,12]. Singh [13,14] developed a formulation to estimate load sharing considering the unequal planet spacing for three to seven planetary gears. The analytically predicted load sharing factor was compared against a finite element analysis using the program developed by Vijayakar [15].

Various techniques have been investigated to improve load sharing. Studies show using a flexible ring gear improved load sharing when a number of manufacturing and assembly errors were present [4,16]. Kahraman et al. investigated the effects of ring gear flexibility on planetary gear loads using a finite element model and experiments and found contradictory results [10,17]. They found that adding flexibility to the ring gear was not as effective as a floating sun in improving load sharing. Kahraman [9] developed a two-dimensional lumped-parameter model to calculate tooth and bearing loads of planetary gears. The study also investigated the effect of a floating sun on load sharing and found it did not improve disturbed load sharing due to pin position errors. Similar results were shown in the study by Singh [12].

This aforementioned research on load sharing is limited to unequally spaced planets due to manufacturing errors and eccentricity. Input torque is considered as the only applied load to these planetary gears in prior studies. Nearly all horizontal-axis wind turbine gearboxes carry various combinations of input torque and non-torque loads. The non-torque loads include bending moments caused by the rotor weight and tower shadow, wind induced moments, moments caused by the controller, thrust, etc. Three-mount suspension drivetrains studied by NREL GRC show significant bending moment on the main shaft, which is mainly caused by the rotor weight and aerodynamic forces [2]. This bending moment has the same order of magnitude as input torque [2,18]. Other wind turbine designs adopt a two main bearing configuration to reduce the transmission of these non-torque loads into gearboxes. These turbines still have a small amount of bending moment present on the main shaft.

The measured load spectrum of the GRC turbine considering various wind and weather conditions is shown in Figure 1. Over 90% of the time, the GRC wind turbine operates below rated torque. Within the entire load spectrum, the turbine operates below 10% of rated torque over 50% of testing period. Gearbox reliability at low input torque has received little attention in the past because prior research has mainly focused on the low bearing and tooth loads with low input torque. Influences of bending moment are not considered for the low load conditions.

With the increasing size of wind turbines, gravity induced excitation in the rotating carrier frame becomes an important vibration source. Gravity led to tooth wedging, a potential source for premature planet bearing failure, in a wind turbine planetary gear investigated by Guo and Parker [19]. Clearance is introduced in rolling element bearings to account for thermal expansion, interference fit, and surface roughness during operation. Clearances in wind

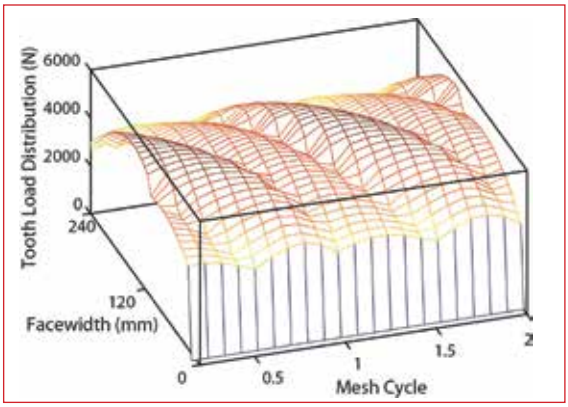


Figure 5: Tooth load distribution with profile and lead modification at .the sun-planet 1 mesh.

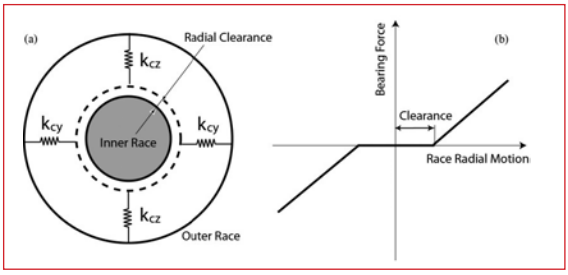


Figure 6: Nonlinear bearing model.

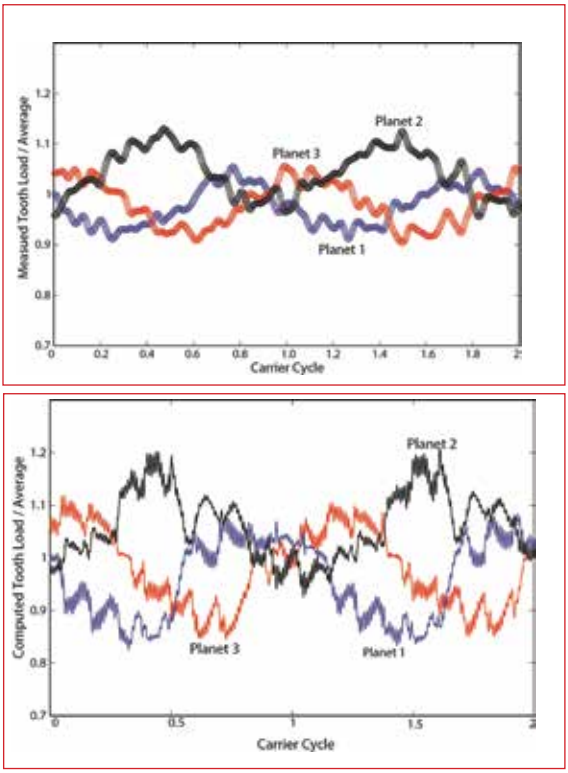


Figure 7: (a, top) Measured during the dynamometer testing; (b, bottom) calculated planetary load sharing at rated torque.

turbine bearings are large and can cause gear tooth misalignment, leading to uneven tooth and bearing load distribution and increased bearing vibration [19, 20, 21].

This study investigates the combined effects of gravity, bending moment, bearing clearance, and input torque on planetary load sharing of three-mount suspension wind turbine gearboxes. Gearbox internal loads at low input torque--a wind turbine operating condition that is rarely considered--are also studied under effects of bending moment.

GRC WIND TURBINE DRIVETRAIN DESCRIPTION

This study investigates the 750 kW turbine drivetrain used by the NREL GRC. This drivetrain has a spherical roller main bearing that supports the main shaft and rotor weight, and two trunnion mounts that support the gearbox. The gearbox includes a helical planetary stage with three equally-spaced planets and two parallel stages, with stage ratios of 5.71, 3.57, and 4.00, respectively. The rated input speed is 22.2 rpm. A cut-away view of the gearbox is shown in Figure 2. There are two parallel carrier bearings supporting the carrier. Each planet gear is supported by two identical cylindrical bearings. The sun shaft is connected to the intermediate shaft through a spline connection with 300 μm backlash to partially float the sun. The ring is bolted to the gearbox housing. This drivetrain configuration represents the majority of the existing three-mount suspension wind turbine drivetrains. Key parameters of the planetary section are listed in Table 1 and Table 2 (Appendix). Additional details of this gearbox are described in the literature [22].

EXPERIMENTAL SETUP AND INSTRUMENTATION

The GRC project instrumented two identical 750 kW wind turbine gearboxes for dynamometer (Figure 3) and field testing. Internal measurements include gear tooth loads, main shaft torque and bending, internal component deflections and misalignments, and planet bearing loads. The full description of instrumentation is detailed in [2].

Main shaft torque and bending were measured using three sets of strain gauges in full bridge arrangements. These measurements are taken near the center of the main shaft between the main bearing and gearbox [2]. The shaft torque and bending measurement serves as a reference for the input load being applied to the gearbox from the rotor side, and can also be used as the time series input for dynamic simulations. The bending moments caused by the blades and hub weight and aerodynamic forces were measured in the field tests, and are 29.2% to 64.6% of rated input torque [2].

For each planet bearing, three axial slots were machined into the inner diameter of the inner ring

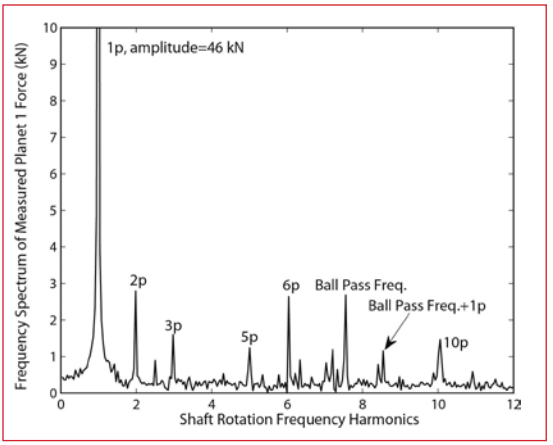


Figure 8: FFT spectrum of the measured planet 1 bearing force in the tangential direction.

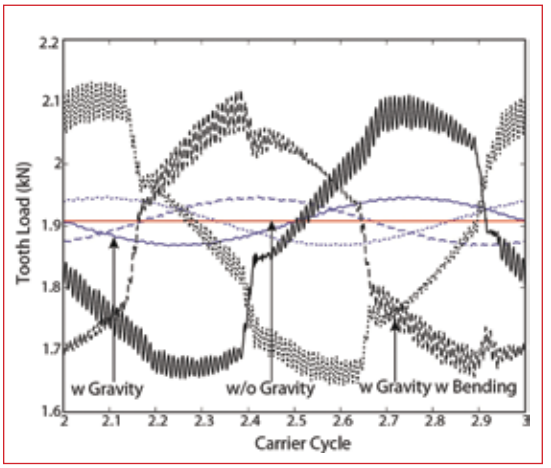


Figure 9: Dynamic tooth loads at the 1st sun-planet (–), 2nd sun-planet (––), and 3rd sun-planet (···) meshes without gravity and bending moment (red), with gravity (blue), and with gravity and bending moment (black). Carrier bearing clearance is 275 μm. Planet bearing clearance is 0.

and instrumented with strain and temperature gauges [2]. Two of the slots were located at different locations in the bearing load zone for each planet, and the third slot for every bearing was oriented 90° from the sun-planet axis, referred to here as top dead center (TDC). Two gauge sets in each TDC slot and two bearings on each planet provided an axial distribution of four radial loads along each planet pin. These gauges were calibrated to loads applied to the fully assembled planet pins and bearing pairs in a bench top test setup [23].

DYNAMIC DRIVETRAIN MODELING

The three-dimensional dynamic model of the wind turbine drivetrain is established in SIMPACK [24]. This model includes the main shaft, low speed planetary gear, planetary carrier, and housing as shown in Figure 4(a) and Figure 4(b). The parallel stages are not included in this study.

Gears are modeled as rigid bodies with six degrees-of-freedom x, y, z, θ_x, θ_y *and* θ_z. The gear contact analysis considers the time varying tooth meshing when the gears rotate by modeling the fluctuating mesh stiffness according to the AGMA 6006 standard [25]. The gears are modeled using a slicing approach to determine the load distribution across the gear tooth facewidth, which accounts for tooth profile and lead modification, tooth contact loss, and fluctuating mesh stiffness. The tooth load distribution of the sun gear teeth with tooth modifications is shown in Figure 5. This model also considers shuttling contact and sliding friction forces [26].

Bearings are modeled using diagonal stiffness matrices. Radial bearing clearance is included in the model as shown in Figure 6. Radial forces develop only when the relative displacement between the connected bodies exceeds a specified clearance. For instance, the radial forces of the carrier bearings are

$$(1)\ f_c^j = \mu_{cj} k_{cj} (\| j_c - j_h \| - \Delta_c), j = y, z$$

where $k_{cj}, j = y, z$ are the bearing stiffnesses. j_c, j_h are the displacements of the carrier and housing. The variable $\mu_{cj}, j = y, z$ tracks if the bearings are in contact according to

$$(2)\ \mu_{cj} = \begin{cases} 1 & \text{if} \quad (j_c - j_h) > \Delta_c \\ -1 & \text{if} \quad (j_c - j_h) < -\Delta_c \\ 0 & \text{if} \quad \| j_c - j_h \| < \Delta_c \end{cases}$$

The model includes the flexibilities of the main shaft, planet carrier, shafts, and gearbox housing, which are important structural components in the drivetrain that could affect gear dynamics. The gearbox front and rear housings and planet carrier are included as reduced finite element flexible bodies. Finite element models are created in Abaqus and reduced using the Craig-Bampton method [27]. Master degrees-of-freedom, referred to here as "nodes", are selected at each interface point. For the planet carrier, nodes at the main shaft connection, upwind and downwind carrier bearing connections, the planet-pin upwind and downwind bores, and planet pins are retained for the drivetrain model. Housing nodes were retained at each bearing location, the ring gear interface center, and the yoke mount centers. All the eigenfrequencies below 1,000 Hz of the housing and carrier are included for the super element creation in Abaqus. This cut-off frequency (1,000 Hz) is selected to include higher than 25th harmonic of the planetary stage mesh frequency at rated speed. After creating the super elements and performing modal analyses on the reduced matrices, the flexible bodies are imported into the multibody drivetrain model. The ring is modeled as a rigid body due to software limitations. Shafts are modeled using beam elements.

The sun spline connection is modeled using its diagonal stiffness matrix obtained through a finite element analysis

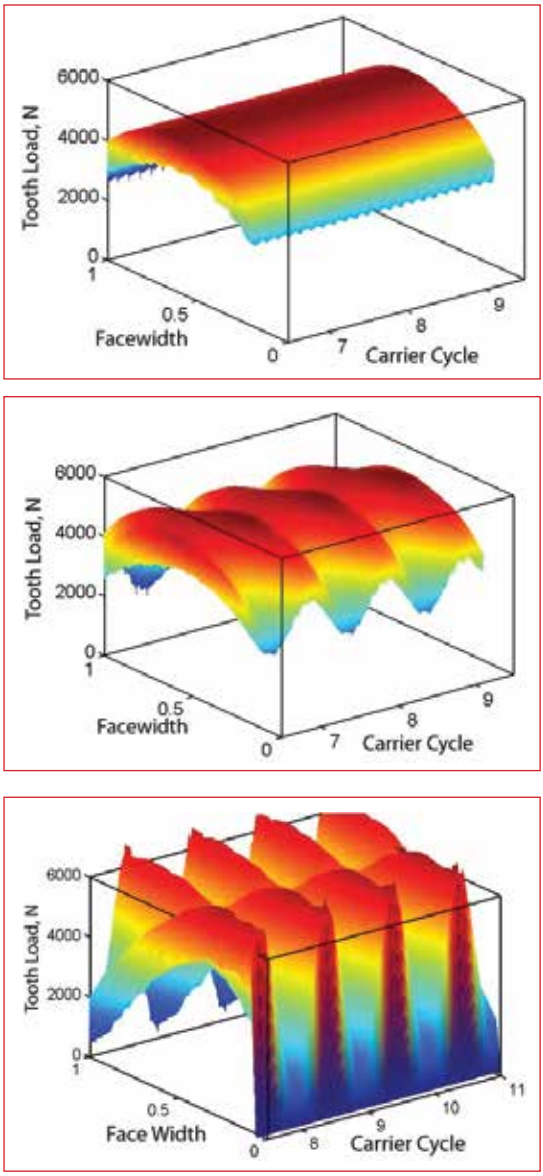


Figure 10: Tooth load distribution on the sun-planet mesh (a) without gravity and bending moment; (b) with carrier bearing clearance with gravity; (c) with clearance, gravity, and bending moment (10% of measured moment) at rated torque. Carrier bearing clearance is 275 μm. Planet bearing clearance is 0.

in RomaxWIND [28] (Table 4 in the Appendix). Spline facewidth, crowning, applied load, and surface lubrication affect these stiffnesses. Trunnion mounts are modeled using diagonal stiffness matrices extracted from the measured load-displacement curve [2].

MODEL VALIDATION BY EXPERIMENTS

A steady state dynamic analysis is carried out on the established model using the Newmark method at the rated speed. A step size of 1 ms is selected to include the first 10 harmonics of planetary gear mesh frequency. All components are allowed to vibrate. An average of 5%

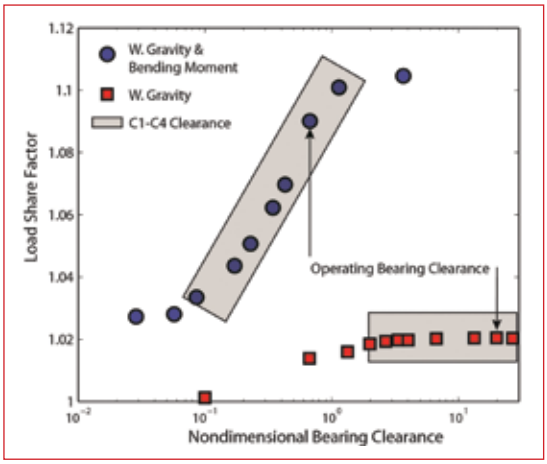


Figure 11: Load sharing factor sensitivity to carrier bearing clearance computed using the established model with gravity effect only (■) and with gravity and bending moment (●). Carrier bearing clearance is 275 μm. Planet bearing clearance is 0.

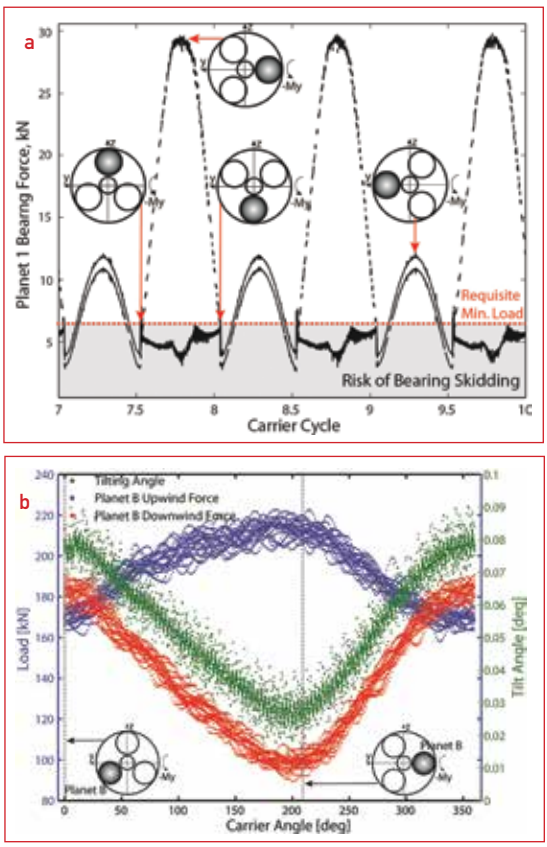


Figure 12: (a) Calculated upwind (––) and downwind (–) planet bearing loads at 5% of rated torque; (b) measured planet tilting angle and bearing loads at rated torque. Carrier bearing clearance is 275 μm. Planet bearing clearance is 0.

modal damping is used. Applied torque to the main shaft ranges from 35 *kNm* to 350 *kNm*. The measured bending moment is applied to the carrier.

The load sharing factor often refers to the ratio between the maximum and the average bearing force among planets [29] .

$$(3)\quad k_\gamma(t) = \max\left\{f_p^i(t)\right\}_i \Big/ mean\left\{mean\left[f_p^i(t)\right]_i\right\}_t, i = 1,\ldots,N$$

where $f_p^i(t)$ is the planet i bearing force that includes the upwind and downwind rows and N is the number of planets.

This load sharing factor defined in Eq. (3) is a function of time. This study uses the maximum value of $k_\gamma(t)$ over time, defined as

$$(4)\quad k_\gamma^* = \max\left[k_\gamma(t)\right]_t$$

The computational results are compared to the measured planetary load sharing in Figure 7(a) and Figure 7 (b). Results show the load sharing factor exceeds 1.1 with disrupted load sharing. The calculated load sharing among planets agrees with the measured data in general. The fluctuating amplitude of load sharing factor is slightly different between the computed results and measurements. The measured shaft moment is applied to the carrier in the drivetrain model. Due to the main shaft weight, the shaft moment measured at the carrier during the experiment is about 15% lower than that at the measurement location. Different excitation sources during the measurement and simulation also contribute to this difference. Figure 8 shows the frequency spectrum of the measured planet bearing force. Measurement data is filtered with low sampling frequency that did not capture mesh frequency 36.7 Hz and its higher harmonics. The drivetrain model does not include the bearing excitation due to its stiffness variation with roller kinematic rotation that was observed during the experiments as shown in Figure 8.

The maximum load of planet 2 over a carrier revolution is higher than the other planets due to the asymmetry of planet spacing during operation, which is seen in both measured and calculated results (Figure 7). This planet asymmetry is caused by planet bearing clearance and tangential pin position error.

Tooth loads at the sun-planet and ring-planet meshes create significant tangential bearing forces under operating torques, which have the same order of magnitude as tooth loads. Planet bearings are in contact when gears are loaded under most operating conditions except at vibration resonances with tooth contact loss [21]. Planet bearing clearance, however, disturbs the planet symmetry by introducing tangential position error, leading to asymmetric shared loads among planets over time as shown in Figure 7 (a) and Figure 7 (b). With identical planet bearing clearance,

Figure 13: A cylindrical planet bearing with sliding marks in the circumferential direction [32].

planet bearing forces have identical shapes with only phase differences. The measurements in Figure 7 (a) are achieved by introducing planet bearing clearances in the drivetrain model (Figure 4). Bearing clearances in planets 1, 2, and 3 are 179 μm; 80 μm; and 179 μm, respectively that are chosen based on the measured clearances by the GRC project [30]. Figure 7 (b) can be regenerated by disturbing the mounting angles of planets by $\alpha_i = \delta_p^i / d_c$, where d_c is the center distance and δ_p^i is planet bearing clearance. Having a planet bearing clearance different from other planet bearings has the same effects on load sharing as tangential pin position error.

RESULTS AND DISCUSSION

Excitations Caused by Gravity and Bending Moment

With a rotating planetary carrier, the gravity force on a planetary gear is periodic in the rotating carrier frame. The gravity force vector is

$$(5)\quad \mathbf{f}_g(t) = \left[G_n \sin(\gamma), -G_n \sin(\Omega_c t)\cos(\gamma), -G_n \cos(\Omega_c t)\cos(\gamma)\right]$$

where $G_n, n = c, r, s, p$ denote the gravity forces of the carrier, ring, sun, and planet, respectively. Ω_c is the carrier rotation frequency and γ is the bedplate tilt angle.

The bending moment vector in the rotating carrier frame is

$$(6)\quad \mathbf{M}(t) = \left[0, -M_y \sin(\Omega_c t), -M_y \cos(\Omega_c t)\right]$$

The effects of gravity and bending moment on tooth loads are shown in Figure 9. Without considering gravity, tooth loads at different sun-planet meshes are nearly identical and time-invariant. Gravity causes the fluctuation of tooth loads by disturbing the system symmetry. The tooth load at the $l^{th}, l = 2, \ldots N$ sun-planet mesh has a phase difference of $2\pi(l-1)/N$ compared to that at the first sun-planet mesh. When the bending moment is considered, the tooth load fluctuation becomes significant and the maximum tooth load increases 11% compared to its nominal value. The high frequency content ($99\times\Omega_c$ and $198\times\Omega_c$) of the tooth load with bending moment in Figure 9 is caused by fluctuating mesh stiffness that is the dominant internal excitation.

Figure 10 shows the effects of gravity and bending moment on tooth load distribution. Without gravity and bending moment, tooth contact has a time-invariant, parabolic shape as shown in Figure 10(a). When gravity is included, the gear teeth carry the carrier weight, leading to a disturbed tooth load distribution. This tooth contact pattern changes periodically about carrier frequency. With bending moment, the load distribution is poor and the gear teeth have edge loading by carrying the bending moment and carrier weight. Excitations caused by gravity and bending moment in the rotating carrier frame are unavoidable for wind turbine gearboxes mounted in the horizontal axis. Bending moment plays an essential role in gearbox internal loads compared to gravity and the excitation from gear meshing.

Effect of Carrier Bearing Clearance on Load Transfer Path

In three-mount suspension drivetrains, carrier bearings are designed with a high load capacity to reduce the gearbox load sensitivity to non-torque loads such that gears only carry torque loads. Carrier bearing forces are one order of magnitude smaller than planet bearing forces because they are nearly balanced by almost self-equilibrating tooth loads at the sun-planet and ring-planet meshes. When the bearing clearance is larger than the carrier motion, the carrier bearings are not in contact during operation. Consequently, the gear teeth carry the non-torque loads and the carrier weight instead of the carrier bearings, resulting in cyclic tooth loads similar to Figure 9, Figure 10(b), and Figure 10(c). Clearance in carrier bearings plays an important role in this load path.

The variation of the load sharing factor (defined in Eq. (3)) with carrier bearing clearance is shown in Figure 11. The bearing clearance is nondimensionalized by dividing the motion amplitude of the carrier with infinite bearing clearance. When the bearing clearance is larger than the carrier motion, the load sharing factor converges to a constant, which indicates a limiting system with infinite bearing clearance. The load sharing factor increases 2% when carrier bearing clearance increases from 0 to 1 with gravity. With bending moment and gravity, the load sharing factor increases from 1.02 to 1.13 when bearing clearance increases. Without bearing clearance, the load sharing is nearly ideal. Reducing or eliminating this bearing clearance reduces

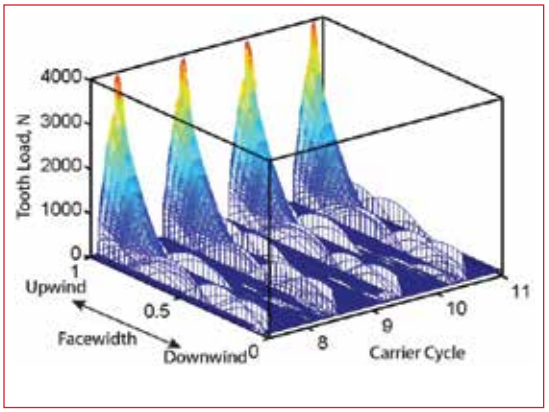


Figure 14: Tooth load distribution at the ring-planet 1 mesh when input torque is 5% of the rated. Carrier bearing clearance is 275 μm. Planet bearing clearance is 0.

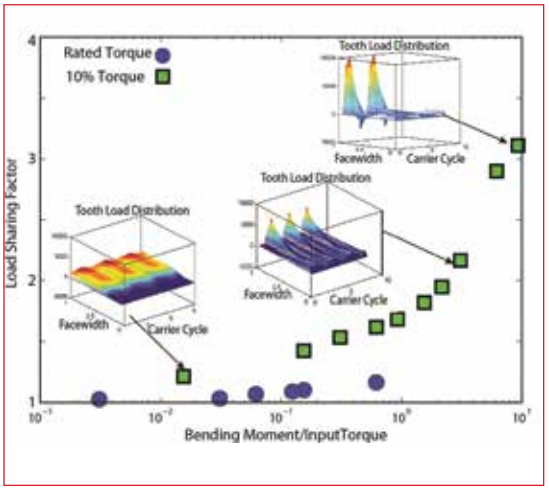


Figure 15: Load sharing factor sensitivity considering input torque, bending moment, gravity, and bearing clearance. Carrier bearing clearance is 275 μm. Planet bearing clearance is 0.

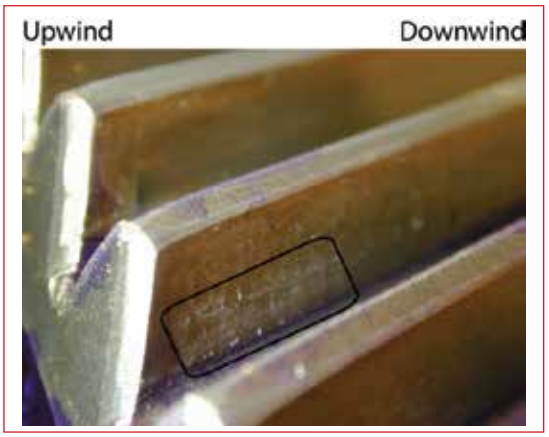


Figure 16: Ring gear teeth with edge loading.

gearbox load sensitivity to non-torque loads and improves load sharing.

The recommended bearing clearance within C1-C4 range according to AGMA 6006 standard [31] is larger than the carrier motion for the pure torque case. With the recommended bearing clearance, carrier bearings are lightly loaded or can be entirely out of contact during operation, leading to a reduced load carrying capacity. Calculating the nondimensional bearing clearance helps design the appropriate radial clearance for increasing the load capacity during operation.

Effects of Input Torque on Gearbox Internal Loading

The highest torque measured during a braking event in the field testing of the GRC gearbox is 189% of input torque [18]. Considering bending moment, results suggest that planet bearing loads at high input torque exceed the fatigue limit, which could lead to premature bearing failure.

When input torque is low, bending moment plays a dominant role in gearbox internal loads. Planet bearing loads of upwind and downwind rows at 5% torque are shown in Figure 12. The upwind planet bearing is heavily loaded compared to the downwind bearing over 50% time within a carrier cycle. The upwind bearing load reaches a maximum of 9.7 times the average load of the downwind planet bearing when the planet gear aligns with $-y$ direction (Figure 12 (a)). At this instant, the upwind planet bearing carries the majority of the bending moments while the downwind planet bearing carries much less. When this planet is moving away from the $-y$ axis and the next adjacent planet is moving towards $-y$, the load sharing of the prior planet at the upwind and downwind rows is nearly equal. This unequal load sharing between upwind and downwind rows of planet bearings was observed during the testing. Figure 12(b) shows the measured planet bearing loads and tilting angle (initially located at 210 degree counter-clockwise from $-y$) at rated torque. The upwind bearing load reaches the maximum when this planet aligns with $-y$, which agrees with the model prediction on the locations with highest upwind bearing loads as shown in Figure 12(a). This agreement qualitatively validates the model for capturing the load sharing between the upwind and downwind row bearings.

As shown in Figure 12(a), planet bearing loads are lower than the required minimum load for preventing rolling element sliding. Planet bearings are susceptible to skidding that

compromises the rolling integrity of the bearing, leading to a reduced bearing life. Typical planet bearing damage caused by skidding motion is shown in Figure 13. There is no skidding damage observed in the GRC gearbox because the gearbox was removed from service (due to other failure modes) long before skidding damage could develop.

Under the same loading condition of Figure 12(a), the tooth load distribution of the first ring-planet mesh is shown in Figure 14 When the upwind planet bearing carries majority of bending moments (carrier cycle from 7.5 to 8 in Figure 12 (a)), the gear tooth has edge contact towards upwind side and partial contact loss towards downwind side as shown in Figure 14. Unequal planet loads between upwind and downwind rows cause tooth edge loading.

Combined Effects on Load Sharing

Planetary gear load sharing relies on gravity, bending moment, bearing clearance, and input torque. Among them, bending moment and input torque are decisive parameters. A nondimensional quantity $M=M_y/T_{in}$ introduced here to consider the combined loading condition, where M_y is bending moment and T_{in} is input torque. Figure 15 shows the planetary gear load sharing with various values of M. Gravity and bearing clearances are included in the results. Load sharing is computed at 10% and rated torques. The load sharing-bending curve at 10% torque is higher than that with rated torque because the influence of gravity on load sharing factor is relatively higher at low input torque. Bending moment increases load sharing factor nearly linearly. A large bending moment induces nonlinear tooth contact, particularly at low input torque. At 10% torque, gear tooth load contact changes from slightly disturbed load distribution when the nondimensional bending moment is less than 0.02, to edge loading when it is larger than 0.02 and less than 2, and eventually reversing contact when it is larger than 2. With edge loading and reversing contact, gear teeth lose contact and reengage repeatedly over time. The time-varying tooth contact causes dynamic forces on planet bearings that could result in acceleration and deceleration of roller elements in entering and leaving the contact zone, thereby reducing bearing life.

Gear tooth edge loading has been observed during the GRC experiments as shown in Figure 16. Micropitting induced by the edge contact was evident at the upwind side of on the ring gear teeth, which agrees with the model predictions in Figure 14 and Figure 15. As found in both simulation and experiment, it is clear that the shaft bending moment has been transmitted from the rotor to the gears, which suggests the design assumption that non-torque loads are uncoupled from gearboxes is not valid.

CONCLUSIONS

A multibody dynamic drivetrain model was established to investigate planetary gear loads in wind turbine drivetrains. This model includes gravity, bending moments, tooth modification, fluctuating mesh stiffness, tooth contact loss, and bearing clearance. Unequal load sharing among planets and between upwind and downwind rows of each pair of planet bearings predicted by the established model agrees with the GRC dynamometer measurements. Planetary gear load sharing in three-mount suspension drivetrains depends on gravity, bending moment, bearing clearance, and input torque:

- Bending moments and gravity are fundamental external excitations for wind turbine planetary gears mounted in the horizontal-axis, leading to cyclical loading on gear teeth and planet bearings. They have stronger influences on planetary gear loads than fluctuating mesh stiffness. Bending moments cause unequal load sharing between upwind and downwind planet bearings, which can cause abnormal tooth contact consisting of tooth edge loading, partial contact loss, and reversing contact, resulting in tooth micropitting.
- Clearance in carrier bearings affects the gearbox load sensitivity to non-torque loads. With carrier bearing clearance, bending moment can transmit into gear meshes and planet bearings, leading to a reduced gearbox life. Planet bearing clearance has a similar effect on load sharing as tangential pin position error. It disturbs the symmetry of planets, leading to asymmetric bearing loads.
- At low input torque, the effects of bending moment on gearbox internal loads are dominant. Upwind planet bearing loads can be an order of magnitude higher than the downwind bearing loads. Planet bearings, in particular the downwind row, are at risk for skidding.

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APPENDIX

	Sun	Planet	Ring
Number of Teeth	21	39	99
Pitch Diameter (*mm*)	215.6	400.4	1016.4
Root Diameter (*mm*)	186.0	372.9	-
Base Diameter (*mm*)	198.8	369.3	937.4
Whole Depth Constant	2.4	2.4	2.4
Tooth Thickness (*mm*)	16.84	18.80	8.55
Module (*mm*)	10.0	10.0	10.0
Helix Angle (^{0})	7.4947 (right)	7.4947 (left)	7.4947 (left)
Backlash (*mm*)	0.25/0.29	0.25/0.29	0.30/0.36
Pressure Angle	20.0^0		
Center Distance (*mm*)	308.0		

Table 1: Geometric Parameters of the Planetary Gear.

	Sun	Carrier	Planet	Ring	Housing
Mass (kg)	181.6	756.9	104.0	480.0	1213.0
$I_{xx}\ (kg \cdot m^2)$	1.26	59.1	3.20	144.2	340.0
$I_{yy}\ (kg \cdot m^2)$	24.0	60.3	2.04	75.4	554.4
$I_{zz}\ (kg \cdot m^2)$	24.0	60.3	2.04	74.4	424.8

Table 2: System Parameters of the Planetary Gear.

	Carrier (Up)	Carrier (Down)	Planet	Trunnion
$k_x\ (N/m)$	10^{12}	10^{12}	10^{12}	
$k_y\ (N/m)$	1.8×10^9	1.4×10^9	3.4×10^9	0.1×10^9
$k_z\ (N/m)$	1.8×10^9	1.4×10^9	3.4×10^9	0.1×10^9
$k^{\theta}_{q_x}\ (Nm/rad)$	0	0	0	0
$k^{\theta}_{q_y}\ (Nm/rad)$	55×10^3	27×10^3	0.53×10^6	0.54×10^6
$k^{\theta}_{q_z}\ (Nm/rad)$	55×10^3	27×10^3	0.53×10^6	0.54×10^6

Table 3: Bearing Information.

Radial, *N/m*	Axial, *N/m*	Tilting, *Nm/rad*	Rotational, *Nm/rad*
20×10^9	0	3.5×10^6	10×10^9

Table 4: Sun Spline Stiffness.

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MAXIMIZING THE BENEFITS—AND YOUR ROI—IN WIND POWER

Understanding maintenance challenges and proper planning are valuable attributes.

By Parveen Gupta

Parveen Gupta is director of renewable energy for Bosch Rexroth Corp. For more information, visit www.boschrexroth-us.com.

MODERN WIND TURBINES CAN PROVIDE large amounts of electricity, cleanly and reliably. Nearly eight percent of electricity in the state of Texas comes from wind energy, and Germany, Spain, Portugal, Denmark, and Ireland now obtain more than 10 percent of their electricity from wind energy, according to the American Wind Energy Association (AWEA)[1]. The cost of producing wind energy is as competitive as any other new power source.

Because the Global Wind Energy Council (GWEC) predicts that off-shore wind farms can be installed and operational in less than two years[2], wind energy is also proving to be a quicker return on investment compared with other "green" energy sources. As a result, estimates from the GWEC indicate that investment in wind energy will reach $196.7 billion by 2020.[3]

Wind power's unique features—including large turbines and remote locations where wind farms are built—both contribute to its success and pose challenges for maintenance and repair. However, with the right planning and an experienced partner, these obstacles can be overcome to quickly maximize the benefits and ROI.

UNIQUE MAINTENANCE CHALLENGES CAN LEAD TO POTENTIAL PROBLEMS

Wind turbines are large and immense equipment—five times larger than they were 10 years ago.[4]

Wind power's unique features—including large turbines and remote locations where wind farms are built—both contribute to its success and also pose challenges for maintenance and repair.

The largest wind turbines have blades that are 415 feet long and weigh 25.5 tons.[5] These massive turbines have the capability to produce 15 times as much electricity as ones that were built a decade ago.[4] Even though turbines in offshore wind farms require service only once or twice per year[6], their sheer size and remote locations pose unique challenges for routine maintenance. However, if the equipment is not checked or monitored regularly, reliability issues may arise that can result in excessive downtime and lost revenue.

Storms and other natural events can lead to gusting wind, which can cause unanticipated component damage in wind turbines such as cracks and damage between layers of composite materials on the surface of the blades. Without regular maintenance, the cracks can widen and deepen, causing the blades to become imbalanced, placing more stress on the gearbox and other components. Large gears in traditional gearboxes can become misaligned due to the uneven loads that are generated by damaged blades.

Although most blades are coated with lightning-proof epoxy, they are susceptible to lightning strikes when moisture seeps into developing cracks. When struck by lightning, the water that has accumulated in the blades instantly turns to steam. Depending on its intensity, a lightning strike could cause cracks to deepen, or spark a fire from the oil or lubricants in the gearbox, possibly destroying the entire turbine.

In addition, turbines located on offshore wind farms are particularly at risk for cracks and other damage that occurs from driving ice in the ocean, as well as from sea spray and precipitation that can freeze on the blades or on other components. Ice can cause minor cracks to expand, and create excess loads for the blades, leading to damaging vibrations.

The remote locations of wind farms can present challenges when it comes time to inspect the nacelles for repair or maintenance. Inclement weather and the turbines' location can make access difficult, often limiting service to just one or two times a year. Additionally, workers might need to repair multiple turbines that are spread out in the same wind farm, which may result in higher labor costs and a shorter time spent at each nacelle.

In addition, advanced logistics are required to coordinate the maintenance of the turbines and the repair of faulty components, including the shipment and installation of new parts. Because the components are so massive, their

transfer to a remote location usually involves coordinating among various logistics providers, including trucking companies, barge and vessel owners, among others.

OPTIMIZED COMPONENTS AND SERVICE PLANS PROVIDE IDEAL SOLUTION

These potential problems can be avoided with optimized components and software solutions, along with a proactive service and preventive maintenance program that boosts reliability and minimizes downtime and financial risk.

Because of the varied sizes and harsh conditions, wind turbines need efficient components that have been optimized to ensure maximum performance. Proven solutions include a specialized gearbox design and a robust remote condition-monitoring system that helps lengthen the life of the wind turbine and eliminate downtime. For example, the appropriate gearing design can harness gusts of wind and minimize its potentially uneven impact on rotors and other internal components. Alternatives to planetary gears include direct drives, magnetic bearings, torque-splitting systems, continuously-variable transmissions, and hybrid gearboxes.

Direct drives eliminate the need for a gearbox by increasing the number of magnetic pole pairs in a generator from the four or six conventional generators to 100 or more. In addition, a smaller number of moving parts boosts efficiency and reliability. However, turbines with direct drives cost up to three times as much as those with traditional gearboxes. The components themselves are costly and the systems are expensive to manufacture.

An active magnetic bearing system includes a magnetic shaft, controller and multiple electromagnetic coils attached to a stator shaft location. Magnetic bearings reduce the amount of wear, are more efficient than traditional gears and do not require lubrication. However, when exposed to higher loads, they need to be replaced more frequently. In addition, they require a great amount of power to generate the current needed to create enough of a magnetic force to handle those higher loads.

Torque-splitting systems utilize a gearbox design featuring external double helical gears that spread the torque among various generators that operate simultaneously. Like magnetic bearings, torque-splitting systems are unable to handle high loads, but one generator can be replaced without having to remove the entire gearbox. In addition, a turbine with one faulty generator can still operate at reduced capacity until it can be fixed.

Output shafts in gearboxes with continuously-variable transmissions, or CVTs, have the ability to maintain a constant speed of rotation, despite the fluctuations of wind gusts and changes to the rotor speed. Although CVTs are more efficient than traditional gearboxes, it's unknown whether this technology can be scaled for larger, off-shore wind farms.[7]

Besides the gears themselves, other components in the nacelle can be optimized to maximize the benefits of wind power. Designing the turbine with modular components, including multiple generators and gear units,

can simplify access for staff that need to replace faulty equipment. Other components, like asynchronous motors in electromechanical pitch adjustment systems, eliminate the need for regular maintenance.

Hybrid gearboxes, like the Rexroth REDULUS GPV main gearbox, weigh 15 percent less than traditional gearboxes, making installation and replacement easier and faster. Serviceability is also enhanced by the lighter weight as rigging equipment can be installed in the nacelle so repairs could be made without heavy cranes and lifts.

Control systems in wind turbines can be designed to maximize efficiency, as well. A control system that includes redundant monitoring and data exchange between and among the master control communication layer and axis drives allows the wind turbine to continue to operate and produce electricity in the event of a fault. Other areas of redundancy in wind turbines include backup systems for cooling, controls, and fluids.

Besides efficient components, a variety of monitoring systems can reduce downtime by detecting problems before they occur. A lubrication and oil condition monitoring system can detect the effects of wear and friction in cooling systems. A robust remote online monitoring system continually inspects the status of the rotor blades and alerts off-site operators to any conditions that deviate from the normal operation of the turbine. It can detect minor cracks and ice that can affect the performance of rotor blades. In addition, a remote online condition-monitoring

system can extend the life of the equipment by detecting problems at an early stage, so components can easily be repaired instead of replaced.

In addition to monitoring systems, a failure analysis program can help simplify maintenance and repair by determining why a fault occurred. The program should include a list of potential failures and the corresponding steps needed to repair or replace components. The plan also serves as a guideline for inventory and other equipment that will be required in case of an emergency.

Simply monitoring for problems is not enough. It is imperative to partner with a service and support organization that has technical knowledge and engineering expertise regarding wind turbine repair and maintenance. Some companies offer localized service centers that can handle preventive care, including the ability to perform measurements and tests. The service partner also should be able to provide a number of repair services—including overhauling, remanufacturing and regrinding of gear teeth—as well as OEM-quality spare equipment and upgrade kits for outdated parts.

After years of successful worldwide development and support, wind energy has proven to be a worthwhile investment. To maximize ROI and reduce high costs that result from unplanned downtime, ensure that the turbines are designed with control systems and optimized components specifically for the unique nature of a wind power application. A comprehensive preventive maintenance program and conditioning monitoring system helps lengthen the life of those components. Finally, partnering with an organization that specializes in the service and maintenance of off-shore wind farms can help overcome any potential obstacles that may occur.

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HYTORC's Patented Stretch-to-Load System Sets New Standard for Safety, Speed, and Accuracy

Over the last 50 years, HYTORC has become the most trusted name for industrial bolting. Leading the industry with groundbreaking innovations, HYTORC has set new standards in the field. HYTORC's stretch-to-load bolting system is in use by major manufacturers in the windpower industry in areas all over the world. This patented technology gives users the highest level of safety, speed, and accuracy available today. It is the only bolting system in the world that can achieve consistent bolt load accuracy within 5 percent, without time-consuming bolt measurement.

The HYTORC Avanti, shown here, can be used for standard torque or upgraded for Stretch-to-Load with additional drivers. This system eliminates the need for reaction arms and backup wrenches, which makes the job faster, by eliminating arm placement and the need for extra personnel, and safer, by eliminating dangerous pinch points. Furthermore, the HYTORC Nut, a Stretch-to-Load fastener, completely eliminates bolt damage, preventing the need for replacement bolts during maintenance.

Aside from the increased safety and speed, the major advantage of the Stretch-to-Load system is the tremendous accuracy that is attainable on a consistent basis. On pressurized vessels, the system has been so successful that it is backed by a zero leakage guarantee—something that many maintenance workers and contractors previously thought to be impossible. On jobs subject to vibration and movement, the system outperforms all others in accuracy and endurance. The system uses a counter-nut effect to prevent unintentional loosening, even on equipment with extreme vibrations such as railroad tracks and gyratory rock crushers.

A free on-site survey is available by request to help determine your needs. Stretch-to-Load fasteners are available in a number of different materials to cover all application needs. Please contact info@hytorc.com or call 1-800-FOR-HYTORC for a quick answer to your questions.

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

Capital Safety's ExoFit NEX Wind Energy Harnesses Represent the Next Generation in Fall Protection

Drawing on the success of prior generations of the ExoFit Harness lines, DBI-SALA/Capital Safety offers what they claim to be the most advanced harnesses available in the industry—the ExoFit NEX.

Marketed as "The Ultimate Full-Body Comfort Harness," the "NEX" implies that this is the next generation in harnesses. The ExoFit NEX expands on the features and benefits that the at-height workforce has come to rely on in the ExoFit and ExoFit XP products by incorporating ongoing research, new materials, and innovative features into the design and manufacturing processes.

At the heart of the ExoFit NEX are the company's three-pronged commitment to comfort, function, and durability.

Among the features and benefits are:

- 420 lb. Capacity—Large capacity adds to tool carrying options and jobsite flexibility.
- Revolver Vertical Torso Adjusters—Simple and fast adjustments that eliminate loose ends and lock into place, preventing slippage.
- Hybrid Comfort Padding—Lightweight, moisture wicking and breathable padding won't move or slip, always keeping the wearer comfortable.
- Tech-Lite™ Aluminum D-Rings—Extremely lightweight alloy commonly used in military and aerospace offers a higher level of security and comfort.
- Integrated Trauma Straps—Provide an adjustable, continuous loop for post fall, minimizing suspension trauma.

Duo-Lok™ Quick Connect Buckles—Lightweight one-handed use with memory-fit web-lock ensures fast, non-slipping connections.

- Protective Shoulder Caps—Provide protection and comfort when carrying heavy materials.
- Molded Lanyard Keepers—Easy holstered snap hooks break away to avoid trip hazard.
- Reflective Material—For greater visibility in dark and dangerous environments, reflective material is integrated on legs, chest, shoulders, and back.
- Built-In Carrying Pocket—Conveniently holds and protects a cell phone, camera, or other items.
- Removable Tool Loops—Allows various tool carrying options.
- Repel Technology Webbing—Water repellent to reduce attraction of mold and dirt—also has up to 5 times more abrasion resistance.
- Stand-Up Dorsal D-Ring—Patented spring-loaded design automatically stands-up, ensuring fast, easy, and safe connections to your fall arrest system.
- Superior X-Design—A single piece of material in the shape of an X wraps around the wearer for the ultimate in comfort, security, and no-tangle donning.
- Radio Holster—Conveniently holds and protects a radio, cell phone, or other item like a Lad-Saf™ sleeve.
- Ultra-Soft Edging—Moves with you. Doesn't rub or chafe.

ExoFit NEX Wind Energy harnesses, lanyards, and accessories meet OSHA/ANSI/CSA/CE requirements for global compliance.

For more information, visit www.capitalsafety.com.

Gearbox Express Introduces "Revolution" Upgrades

Gearbox Express, is introducing its Revolution gearbox upgrade. Revolution is a set of upgrades and a new thought process for wind energy gearboxes from 1.5MW up to 2.3MW. Developed by the team at GBX, Revolution addresses the most common premature failure modes of gearboxes.

"The Gearbox Express team has seen many gearbox failures, and a majority of them have the same premature failure characteristics," said Bruce Neumiller, CEO of Gearbox Express. "We saw a huge opportunity to address these common reasons by integrating upgrades that will provide significantly longer gearbox life. Revolution is a technical product unlike anything else in the industry and it creates a paradigm shift in the wind industry with a direct, commercial impact on our customers' business."

Revolution features:

- 5-year, no-risk warranty
- Case-carburized ring gear
- Timken® case carburized and coated cylindrical roller bearings in the HSS, IMS, and planet positions
- Water-Lok maintains low water concentration
- GBXtreme Filter to six micron while maintaining high flow at 1,000 beta
- Non-desiccant, GBX Water Blocker Breather System
- Factory filled with Amsoil EP55®, ISO 320 oil

Revolution gearboxes are built in Gearbox Express's 43,000 square-foot, climate-controlled facility in Mukwonago, Wisc., which also offers a highly-flexible, technologically-advanced 3.1MW test stand. In addition to Revolution, Gearbox Express technicians also remanufacture gearboxes to the latest revision level.

"When we started operations in 2012, we had a vision on how to help wind farm owners protect and manage their assets," said Neumiller. "Our growth has exceeded expectations and Revolution is another vital component to our business model that is based on keeping investments running."

Three wind industry veterans founded GBX, and succeeded in attracting millions of dollars of investment capital along with a $3.4 million low interest, revolving loan from the Wisconsin State Energy Program. Additional investments are forthcoming as GBX pursues its next growth phase.

"We are a company built by gearbox guys," said Neumiller. "We saw an absolute hole in the wind industry for an advanced company providing dedicated gearing, bearing and gearbox expertise. We have the best people, equipment, and parts. I'm looking forward to what we announce in the future."

For more information, visit gearboxexpress.com.

3M introduces Wind Blade Protection Coating W4600

Awareness is growing in the wind industry about the severe impact that erosion on the leading edge of wind blades can have on turbine output. Erosion can lead to a significant loss in annual energy production, costing owners and operators thousands of dollars. Blade repair and protection can help provide significant annual energy production improvements, reduce costly downtime, and protect the integrity of the blade.

3M™ Renewable Energy Division introduced an innovative solution for wind turbine blade protection at WINDPOWER 2013 on May 6. 3M Wind Blade Protection Coating W4600 is a two-component polyurethane coating that provides excellent erosion protection properties to help prevent and repair leading edge erosion on wind blades.

3M has a proven history of providing highly durable solutions in the industry with its 3M Wind Blade Protection Tape. This product has provided significant reductions in leading edge erosion, and has also helped extend maintenance and service intervals. Designed to offer game-changing performance and protection, 3M Wind Blade Protection Coating W4600 further expands 3M's portfolio of erosion protection solutions. The coating is designed for application in OEM facilities and can be easily applied via brush or casting.

"3M has performed extensive testing on this product, and customers will see that it provides superior performance for a critical industry need," said Christian Claus, business development manager, 3M Renewable Energy Division. "We are proud to expand our product offering to the wind industry."

For more information, visit www.3M.com.

ADINDEX

Bobbi McConnell
Executive Administrator, AIMCO Corp.

I UNDERSTAND AIMCO PLACES A HIGH VALUE ON A "BEST PRACTICES" APPROACH TO MANUFACTURING ITS LINE OF INDUSTRIAL TOOLS. CAN YOU TELL US A LITTLE ABOUT THAT?

Best Practices in manufacturing begin with the fundamental design of the product. Product design must result in a user experience that encompasses all aspects of the end-user's expectations on the applications it interacts with. Effective user experience goes well beyond simply giving customers what they say they want or checking off a feature list. AIMCO combines group design, engineering, marketing, and user interfaces into one cohesive package affording the end user the ultimate tool and user experience.

WHAT HAPPENS AFTER THE DESIGN STAGE?

Designs, once completed and handed off to manufacturing, should be produced, from front end to back end, with attention to detail in each step of the process. Materials used in production of the process should be thoroughly inspected for adherence to design specifications as well as quality. Effective processes flow correct materials to the production floor while facilitating quarantine of any nonconforming materials. Inspected components can then flow to the production area with the knowledge that they are suitable and, most importantly, safe for use on the final product. Documentation and data control principles, with controlled revisions, are a critical part of this being successful.

IS THERE ANYTHING THAT MAKES AIMCO'S MANUFACTURING PROCESSES UNIQUE?

One way AIMCO achieves a competitive edge is by utilizing their trademark PERQ (Productivity, Ergonomics, Reliability, and Quality) process. PERQ is the industry standard formula that matches the needs of the manufacturer with the assembly tools they use in their processes. Through this process we are able to identify the most effective assembly tooling systems, as well as the manufacturer´s needs, with the end result being increased revenue and decreased costs.

CAN YOU GIVE US AN EXAMPLE OF A NOTICEABLE NEW TREND IN MANUFACTURING?

Data collection and traceability have become a large focus for today's manufacturers. The ability to track vital statistics, torque, angle curves, and rundown plots assure that the assembly process is being performed accurately and to the proper specifications. Because data collection ensures the assembly line is running at its optimum pace and decreases the risk of human error, it has proven to be a critical element economically for those manufacturers where every second and turn of a nut, bolt, or screw is money to the bottom line.

HOW DOES A COMPANY INCREASE AND MAINTAIN OPTIMAL EFFICIENCY LEVELS?

Today's manufacturers utilize several systems, all with the goal of minimizing waste and maintaining optimal efficiencies. Waste can come in many forms, including too much material on hand, excessive handling of materials, and redundant steps in the production process. Organization of the workstations themselves is also an area of potential waste and the Japanese refer to this as Muda. Their belief is that a disorganized workplace is one that fosters mistakes in processes, delays on finding necessary items, and is a great source of improvement in process efficiencies. Wise companies strive for as clean and organized a process as possible so as to enable repetitive efficient movement of material and personal actions in the drive to produce the product.

WHAT CAN BE DONE TO MAINTAIN DESIRED PRODUCT QUALITY LEVELS IN MANUFACTURING?

Products today have varying levels of complexity, each dictating a level of verification to ensure that quality standards are maintained. Some products require rigorous testing at each step of the process while others are suitable for sample tests at predetermined intervals. In today's litigious societies and competitive markets, it is foolhardy to not have any form of product testing and data collection in place. These systems will ensure that not only is the product correct and ready for the user, but acts as insurance against defect claims should they arise.

For the complete Q&A with Bobbi McConnell, visit windsystemsmag.com.

For more information, visit www.aimco-global.com.

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