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12

IN FOCUS

SHAPING THE FUTURE OF THE WORKFORCE

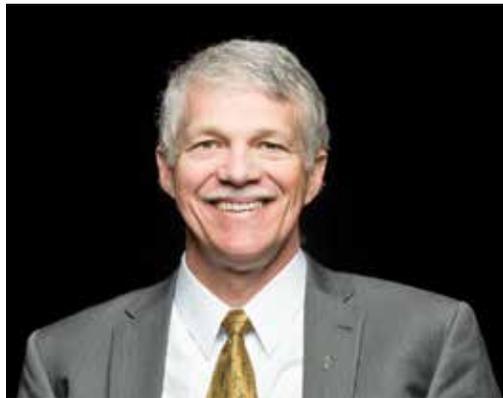
The need to ensure wind-energy O&M technicians are properly trained, as well as be motivated to continue that education, becomes a priority.

COMPETENCY-BASED TRAINING

As the need for more technicians continues to grow, the Wind Turbine Technician Academy at Kalamazoo Valley Community College is making sure those techs are properly qualified. 18

PROFILE

Broadwind Energy is a precision manufacturer of structures, equipment, and components for the wind industry, clean tech, and other specialized applications. 24



CONVERSATION

AWEA president Tom Kiernan says AWEA works hard to attract new and diverse groups to WINDPOWER each year. 28



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DIRECTION

8

Wind-energy industry R&D spending to top \$36.9 billion by 2028 ▼ *DNV GL issues landmark study of R&D pathways for supersized turbine blades* ▼ *Ardian acquires wind farm from OX2 to create Nordic sustainable energy platform*



CROSSWINDS

44

LOOKING FOR LIGHTNING

Vaisala launches ground-breaking technology that can detect lightning events and their severity, allowing for quick detection of potential damage inflicted on wind farms.

TAILWINDS

THE BUSINESS OF WIND



▼ MAINTENANCE

Gearbox Express partners with Invenergy Services **30**

▼ INNOVATION

Deutsche WindGuard Consulting accredited for calibrating nacelle Lidar **34**



▼ CONSTRUCTION

Lee Maynard named new Terex Cranes global sales director **37**

▼ MANUFACTURING

Siemens Gamesa to supply 21 MW for China wind farm **40**



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Celebrating 10 years reporting on wind

Wind Systems is celebrating 10 years of giving you the best and most recent news and information about the wind industry. It's been a long and fun road, and I'm happy to say we're still going strong.

And it's not just our birthday. In a few short weeks, hundreds of companies will come together in Houston for WINDPOWER 2019 to discuss the wind industry. Industry experts and insiders will conduct business and share their insights on the future of wind and what it means for the U.S.

Wind Systems will be there, too. I'll be making my rounds to say hey to new friends and old to get your take on the wind industry and your place in it.

As we've done at past WINDPOWER events, *Wind Systems* also will be giving away a Snap-On toolbox every day during the show at 11 a.m. These toolboxes are amazing, so please make a point to come by our booth (#3154) and register for a chance to win.

My colleagues and I are excited about heading to Houston in May, and to keep that level of excitement cranked up to 11, we are using our April issue as a primer for WINDPOWER, as well as shining a spotlight on a very important aspect of the wind industry: training and workforce.

In our April Conversation, we feature a Q&A with AWEA president Tom Kiernan. He shares his thoughts on this year's WINDPOWER and what attendees should expect from presenters as well as AWEA's approach to having Houston as a backdrop for the show.

One of those exhibitors at this year's show will be Vaisala. In this month's Crosswinds, I had the privilege of talking with Brooke Pearson, lightning global solutions manager for Vaisala. In the article, Pearson discusses Vaisala's ability to detect the frequency, location, and severity of lightning strikes quickly and accurately in order to expedite turbine maintenance. It's a fascinating technology that the company is excited to share with the industry.

The wind technician is still one of the fastest growing occupations in the U.S., so it's important to make sure those entering the workforce have received the best training they can get.

This month's inFocus section features several industry experts who share their knowledge on what the industry needs in relation to a much-needed workforce and how those needs are being met.

With April giving you a taste of what to expect at WINDPOWER 2019, stay tuned, because our May issue will feature even more. And please make a point to stop by our booth and say hey. Who knows? You might win a toolbox. (Don't worry; we'll ship it to you. We know it won't fit in the overhead.)

As always, thanks for reading!



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AWEA recognizes leaders in safety

From AWEA

The American Wind Energy Association (AWEA) recently recognized five accomplished individuals and companies as part of its Safety and Health Excellence Recognition and Excellence in Operations programs. Each year, these programs recognize industry leaders who go above and beyond to prioritize operational efficiency and workforce safety.

Chris Meehan, vice president of Wind Operations at Invenery, a leading U.S.-based wind farm developer and operator, earned the Excellence in Operations Award. The award distinguishes an individual or company for excellence in efficiency and effective operations of its wind projects and for constructive collaboration with others in the industry to improve the quality of O&M services.

“Chris Meehan was nominated and selected by his industry peers for always prioritizing safety and exemplifying operations best practices,” said Tom Vinson, vice president of Policy and Regulatory Affairs at AWEA. “He helped create a culture of engagement among managers and technicians at Invenery projects to ensure safety always comes first.”

AWEA also recognized four companies for their dedication to advancing safety and health in the wind industry through the Safety and Health Excellence Recognition Program. This program has two levels of recognition highlighting the companies’ commitment to environmental, health and safety (EHS) best practices, and for laudable safety achievements.

AWEA’s Safety and Health Gold Achievement was presented to Apex Clean Energy, Third Planet Windpower, and Wanzek Construction for demonstrating safety as a core value and for their participation in AWEA’s efforts to advance EHS in the industry.

Acciona Energy was awarded AWEA’s Safety and Health Silver Recognition for successfully integrating health and safety as key values in their company and making measurable achievements in their safety performance.



The American Wind Energy Association (AWEA) is the premier national trade association that represents the interests of America’s wind energy industry. For more information, go to www.awea.org



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DIRECTION

THE FUTURE OF WIND



New technologies on blade segmentation and turbine erection will unlock previously untapped pockets of the global market. Courtesy: Ad-liftra, [creativecommons.org/licenses/by-sa/3.0\)](https://creativecommons.org/licenses/by-sa/3.0/)

Wind-energy industry R&D spending to top \$36.9 billion by 2028

As the wind-turbine market enters a new era driven by subsidy and tax credit free cost parity, a new generation of wind-energy technology is poised to hit the market by 2020. Markets that are shifting toward a competitive tendering process continue to drive the need for higher AEP as well as lower CapEx, OpEx, and LCOE.

Additionally, new technologies on blade segmentation and turbine erection will unlock previously untapped pockets of the global market, in both space constrained sectors or areas of complex terrain where conventional technology is not cost effective.

Collectively, the industry will spend approximately \$28.2 billion in private R&D by 2028, matched with approximately \$8.7 billion in public R&D funding over the same time-frame. The private investment represents an industry average of approximately 5.3 percent of expected revenue and is a significant increase off the average industry low of approximately 2.7 percent back in 2013.

Regionally, Western Europe, Japan, and China will dominate the R&D and technology development landscape with North America lagging behind due to an unfavorable political environment in the U.S. and lack of meaningful government support for climate-change technology.

India is potentially emerging as a hotbed of technology development as low costs and government initiatives on renewables and manufacturing competency development continue to drive optimism. GCC states also are poised to see an increase in spending on renewable energy technologies in general over the next 10 years.

Australia, New Zealand, Singapore, the Philippines, Malaysia, and Indonesia are likely to see some modest spending on R&D as increased wind penetration increases awareness of technology function and development opportunities.

Eastern Europe, Latin America, and

Africa will see minimal R&D spend in the next 10 years, but they have an opportunity to grow as wind-turbine capacity additions increase in those regions and economies recover.

The overall trend in onshore wind-technology development appears to be focused on system integration. This is driven by expected growth in distributed generation technologies as well as the increasing cost competitiveness of solar technology. Wind-turbine OEMs are shifting focus to go beyond just turbine production and incorporate energy storage and solar into turnkey systems with fully integrated controls.

Digitalization also is driving a significant portion of technology development as data analytics companies, turbine OEMs, sub-component suppliers, asset owners, and even ISPs all look to incorporate asset performance optimization, asset health management, and even energy trading/balancing capabilities into their product and service offerings.

Nevertheless, in this era of advanced-technology development for performance enhancement and LCOE reduction, it is also imperative to consider the bankability of new technologies as a guide on the likelihood and timing of commercial adoption. There is a plethora of new ideas stuck in the conceptual and preliminary design phase that appear to be attractive but lack a path and the corresponding investment to become commercially available.

Many major asset owners, as well as turbine OEMs and sub-component suppliers, have rekindled their external technology scouting activities, and these efforts are poised to drive M&A to fill specific gaps. The era of “not invented here” seems to be dwindling as technology partnerships and license agreements are likely to see an increase in the coming years.

There is a significant amount of technology at a mid-range technology

readiness (maturity) level and will require the bulk of the total investment. A total of 46.2 percent of all innovations have undergone some type of bench-testing, prototype development, or field testing, while 23.3 percent are commercially available or in a pre-series development stage, and 30.6 percent are still in a design stage.

Companies must continue to focus on R&D spending to ensure their products remain competitive, and governments need to continue to support the companies who make such investments. A strong correlation has long existed in markets that spend the most on R&D and those with the most wind-capacity additions. Ultimately, R&D is a precursor to subsequent technology deployment, and therefore the cost reductions associated with achieving economies of scale in that market.

MORE INFO www.intelstor.com

DNV GL issues study of R&D pathways for supersized blades

DNV GL recently released an in-depth study, commissioned by the U.S. Department of Energy’s Lawrence Berkeley National Laboratory, which examines the challenges associated with manufacturing and deploying next-generation, increasingly larger land-based wind turbines. In the past decade, the U.S. wind energy industry has achieved significant improvements in energy production and cost efficiency, driven in part by increased turbine, blade, and tower size. However, the industry is quickly approaching a logistical cost and capability ceiling as turbine components become too large for existing infrastructure and transportation to accommodate.

Currently the largest blades deployed in the U.S. are 67 meters, but blades up to 88.4 meters — or almost

as long as a football field — have been deployed in Europe; blades up to 115 meters are on the horizon. As turbine component sizes increase, logistical constraints can either reduce the number of developable sites or elevate costs, which can make some potential sites economically uncompetitive. Finding new solutions to logistical challenges associated with ever-larger components can enable the wind industry to achieve optimal wind levelized cost of energy (LCOE) options for every region of the United States.

HIGH-VALUE R&D OPPORTUNITIES

DNV GL explored three innovation pathways to help identify high-value R&D opportunities:

► **Innovative transportation:** To address physical constraints and challenges, new methods can facilitate the transportation of blades from factories to wind projects via road, rail, or air.

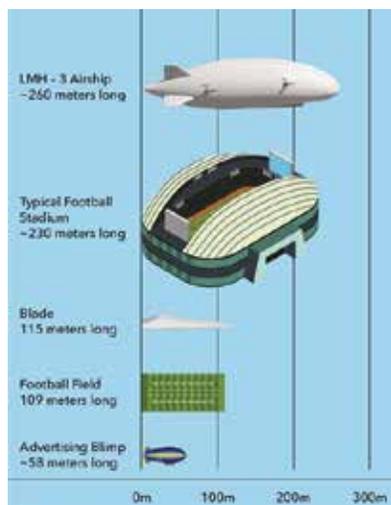
► **Segmented blades:** Segmented or modular blades may enable the use of more cost-effective transportation, but must also account for the impacts on blade design, manufacturing, and on-site assembly.

► **On-site manufacturing:** Deploying a temporary blade manufacturing factory at the project site to fabricate blades from raw materials to finished product largely eliminates transportation challenges associated with longer blades.

“DNV GL identified a number of R&D activities that could make contributions to the viable development of supersized blades. These recommendations are feeding into the U.S. Department of Energy-funded ‘Big Adaptive Rotor’ project to assess and prioritize technology needed to develop a cost-competitive land-based 5-MW turbine with 100-meter-long blades,” said Ryan Wisler, senior scientist, Lawrence Berkeley National Laboratory.

ACCELERATION OF R&D

The acceleration of R&D to make supersized blades feasible requires collaboration between researchers in the United States, turbine manufacturers, blade manufacturers, and transpor-



tation logistics companies. Blades are the most critical component in determining the technical and economic performance of wind turbines. The logistics associated with supersized blades adds additional levels of complexity into the development process, which the industry and researchers must work collaboratively to address.

“To realize continued progress in making wind energy cost-competitive across all regions in the U.S., the wind industry must accelerate R&D in innovative approaches to blade design, manufacture, and transportation,” said Richard S. Barnes, executive vice president, Energy North America at DNV GL. “The good news is that there appears to be fertile ground for R&D and accessible solutions on the near horizon.”

High-value R&D areas include:

► Further advances in high-stiffness/low-cost materials like industrial carbon fiber and thermoplastics materials.

► Advanced controls and sensor technologies that could be applied to monitor or enable blade bending in transport or monitor or control segmented blade loads such that low-weight blades can be achieved.

► Reducing the blade chord dimension would enable operation at higher tip speeds and improves blade transport potential, but issues related to aeroacoustics and leading-edge erosion need further improvement. Advanced aeroelastic modeling of

dynamic stability and deflections can enable the development of more slender blades that can allow controlled deflection during transport.

► The pathways identified by this study represent opportunities that, if realized, could significantly enable wide-scale deployment of supersized turbines across all regions of the United States.

MORE INFO www.dnvgl.com/energy

Ardian acquires wind farm from OX2

Ardian, a world-leading private investment house, recently announced a 300 million euro investment to build a wind farm in Åndberg/Härjedalen, Sweden. Ardian acquired the development rights of the project from OX2, a leading Nordic renewable energy developer. Ardian has also engaged OX2 to lead the construction and technical management of the facility. The wind farm will be operational in 2021 and is expected to produce in excess of 800 GWh per year.

The 53-turbine wind farm will be one of the largest in Sweden, which is a world leader in the innovation and development of sustainable energy. Sweden has passed legislation to go “carbon neutral” by 2045, with Denmark, Norway, and Finland all having made similar commitments.

Ardian’s portfolio in the Nordics, which already includes two wind-farm investments in Norway and Sweden, will now exceed 400 MW of gross capacity, corresponding to the yearly energy consumption of more than 600,000 electric vehicles. Separately, OX2 is currently building a record of more than 1 GW of wind power in the Nordics, of which approximately 90 percent is in Sweden.

“In OX2, we have found an excellent partner,” said Amir Sharifi, managing director at Ardian Infrastructure. “We look forward to together building a state-of-the-art wind farm using the latest available technology. Our goal



OX2's Raskiffet wind farm. Ardian has also engaged OX2 to lead the construction and technical management of a wind farm in Åndberg/Härjedalen, Sweden. (Courtesy: OX2/ Joachim Liljercrantz)

is to achieve solid returns without subsidy and a positive impact on all stakeholders.”

“We are very pleased to have established a good business relationship with Ardian after a realization process that was characterized by a high degree of professionalism and spirit of cooperation,” said Paul Stormoen, managing director at OX2 Wind. “We are now looking forward to beginning construction together with our sub-contractors. The wind farm is a significant local investment and a further important contribution to the ongoing global transition to a renewable energy sector.”

MORE INFO www.ardian.com

President proposes \$193.4 million for BOEM in 2020

President Donald Trump recently proposed a \$193.4 million fiscal year 2020 budget for BOEM to safely and responsibly manage offshore energy and mineral resources.

The president’s budget request reflects careful analysis and focuses on the execution of BOEM’s mission,

including offshore oil and gas exploration and leasing, offshore renewable energy, marine minerals management, and science-based analyses.

It continues to support efforts vital to advancing the president’s Executive Order 13795, Implementing an America-First Offshore Energy Strategy, which requires BOEM to develop and implement a new National Outer Continental Shelf Oil and Gas Leasing Program (National OCS Program) in conformity with the provisions of the OCS Lands Act.

“This Administration calls for boosting domestic energy production to stimulate the nation’s economy and strengthen America’s energy security, while providing for environmental stewardship,” said BOEM’s Acting Director Walter Cruickshank. “The FY 2020 budget request allows BOEM to continue its efforts to advance these goals as part of our statutory mission.”

With this request, BOEM proposes to focus resources in the following areas:

► **2019-2024 National Outer Continental Shelf Oil and Gas Leasing Program (National OCS Program):** Pursuant to Executive Order 13795 – Implementing an America-First Offshore Energy Strategy – and Secretarial Order 3350

– America-First Offshore Energy Strategy – BOEM initiated efforts to develop a new National OCS Program in FY 2017. These efforts continued through FY 2018 and FY 2019. For FY 2020, BOEM requires additional funds to support personnel and contracts necessary to implement the new National OCS Program. Note: The FY 2020 Budget assumes continued lease sales in areas available under the current OCS 5-Year Program, but does not presume a particular secretarial decision on the 2019-2024 Program.

► **Renewable Energy:** In recognition of the role renewable energy can play in achieving this Administration’s America-First Offshore Energy Strategy, BOEM will continue to advance renewable energy through an aggressive leasing program, while ensuring that its environmental review and permitting process for renewable energy projects is coordinated, predictable, and transparent.

► **Marine Minerals:** BOEM facilitates access to and manages OCS marine minerals, which include sand and gravel resources that are used for coastal resilience projects (e.g., hurricane recovery and response, beach nourishment and coastal restoration activities, and protection and restoration of important ecological habitats). BOEM also seeks funding to initiate an OCS Critical Mineral Inventory to assess the nation’s offshore supply of critical minerals, potentially reducing the nation’s vulnerability to economic disruption, as well as negative national security impacts caused by a lapse in imports.

► **Environmental Analyses:** The need for energy must go hand-in-hand with responsible environmental stewardship. In accordance with Secretarial Order 3355, BOEM is conducting its environmental analyses in a transparent, coordinated, and streamlined fashion to ensure that decisions are informed by the best available science. BOEM will also continue to use environmental science as the foundation for sound policy decisions. ✎

MORE INFO www.doi.gov

IN FOCUS

TRAINING & WORKFORCE

SHAPING THE FUTURE OF THE WORKFORCE





Altitec technician Ewa Pilch in Mexico. (Courtesy: Altitec)

The need to ensure wind-energy O&M technicians are properly trained, as well as motivated to continue that education, becomes a priority.

By TOM DYFFORT

With the recent end of the Scottish government's Transition Training Fund, the future of energy workers' jobs is facing a challenge. How can we help mold the future of wind operations and maintenance with the best quality training and skill development?

KEY CHALLENGES

We have seen an increase in applications for rotor-blade repair and maintenance roles where, despite holding a training certificate for blade repair, applicants lack some of the basic skills we would expect from someone ready to work on a blade.

There is a wide range of rotor-blade repair and maintenance technician courses in the market teaching the skills necessary to transition into the wind sector. But as a service provider, as well as a training provider, Altitec has had to send a number of technicians qualified in blade repair and maintenance "back to school" in recent months.

The issue isn't just about one or two people not having absorbed the skills needed to work on a turbine rotor blade to a high enough level or not having enough practice to have mastered these skills. The deficiency covers a fundamental lack of knowledge about the job they are preparing to do. If this trend continues, it will inevitably cost the industry money, as service providers need to provide remedial training to certified technicians before they are fully able to work on site.

Transferring skills to new technicians can't be left to textbook information soaking. Hands-on knowledge transfer from experienced technicians and blade engineers with years of up-tower experience will lead to a greater level of competence among new technicians.

A LACK OF FUNDING

The closing of the Scottish government's Training Transition Fund in March 2019 shows the need for continued support for skilled workers eager to develop careers in the renewable energy industry. While this funding for training is scheduled to end, the demand from skilled workers to transition to sustainable careers in the renewables sector will not.

Since 2016, the Transition Training Fund has helped Scot-



Altitec technician Marcin Walukiewicz in Northern Ireland. (Courtesy: Altitec)

tish residents in the oil and gas sector to retrain in other sectors. The fund will close at the end of March, or when the £12 million (\$15.76 million) of funding runs out – whichever comes first. Re-training for a career in a sustainable sector like the wind-energy industry is not a small investment for the average worker. The cost of a training course and subsistence during the course can be more than a month's salary. However, the prospective pay-off – new skills to apply to a career in a sustainable sector – is appealing.

FUNDING A GROWING WIND WORKFORCE

One of the three main ways training is funded is through

direct-cash payments from the trainee to the training provider. However, this is not always the best way to get people into the industry. While we love the stories of how our most dedicated technicians got into the industry by eating beans and sleeping in their vans to pay for their rotor-blade training course, this won't realistically attract the number of technicians needed to ensure the smooth running of wind farms around the world as the industry grows.

Where trainees are not able to provide full funding immediately, there are loan systems from trainers or loan companies. But these, of course, have their associated challenges. Trainers, even if they can reach a repayment agree-

ment with trainees, often don't have the balance sheets to offer this. While given rotor-blade repair and maintenance technicians may initially work seasonally, despite the remunerations available, it can prove a challenge for trainees to manage the loan in the short term.

A funding scheme run by the government is another route, but of course there are regulations and influences involved. For example, in return for funding, the government may request inputting into the syllabus or ensuring the trainer meets a quota of some sort. This invites the question of how we can ensure that training syllabi are structured to provide the highest quality, model and manufacturer-agnostic, knowledge transfer. The high-level of knowledge transfer is not all down to the course structure, the individual trainers play an important role themselves.

Investing in the right course to deliver the right skills is essential.

The industry needs training to be delivered direct from the blade edge, taking lessons learned from up-tower on to the training course. With technology use developing rapidly in the sector, trainees need to be exposed to the latest techniques and technologies and learn about their latest uses.

A course syllabus written and delivered by blade technicians and engineers who have experience of working in the field, as well as providing training to graduates, is the most effective method of knowledge transfer for such a complex skill set. Even the highest-skilled technicians — those who are delivering the courses — never stop learning.

In contrast, a static syllabus, packaged up and delivered to future rotor-blade technicians without reference to more recent developments risks weakening the knowledge transfer. When choosing a training provider, technicians must consider what recent experience the trainers have in conducting these repair and maintenance tasks, and how much time have they been putting into nurturing their own skills in the last few months?

We risk losing our future workforce if the training courses they pay for don't secure them a rotor-blade repair technician job when complete. It is important that training providers don't let our industry down by failing to deliver on the promises of their syllabus.

WHERE DOES TECHNOLOGY FIT IN?

With concerns over the future viability of jobs in the energy industry more widely, it is clear technology will have a large part to play in future wind-turbine repair and maintenance jobs. Advanced technologies such as AI and machine learn-

▼ The use of artificial intelligence is rising across the energy sector. And it is clear that in wind energy, AI and machine-learning technology have a strong future; in fact, they are being deployed in inspection roles in the sector even now. ▼



Altitec technicians Cerri-Ann Morgan and Ben King on a U.K. offshore wind farm. (Courtesy: Altitec)

ing are more likely to supplement the wind-energy job of the future rather than replace it.

Grants are beginning to be offered for the development of robotics and AI systems for rotor-blade repair and maintenance, which is indicative of the market push to develop and adopt new and innovative technologies to support wind-turbine operations and maintenance. This, of course, invites the question of how such technology will contribute to rotor blade repair and maintenance operations, whether it will replace technicians, or how inspection and repair crews might integrate robotics and similar technologies into their site work.

Rotor blade service providers use a wide range of technologies in their operations, including powered ascenders to speed access, drones for improving inspection procedures, and digital technologies for recording inspections, analyzing repairs, and supporting maintenance practices

including installing aerodynamic add-ons to improve blade performance.

The use of artificial intelligence is rising across the energy sector. And it is clear that in wind energy, AI and machine-learning technology have a strong future; in fact, they are being deployed in inspection roles in the sector even now. However, the use of autonomous robots to repair rotor blades remains some way off for the time being.

Where technologies such as robotics and AI are making progress is in the inspection of turbine blades. While drone flights are currently piloted, it is expected that automated flights for inspections will become reality a lot sooner. All this technology requires expertise and support to operate, so while the technician role won't disappear, it will evolve to encompass the technologies that are making the job more effective and more efficient.

This, in turn, means that the training of the workforce must adapt to ensure technicians have the skills to operate these technologies. Human engineering and technical expertise will always be essential to support technology and provide consultancy in the complexities of identifying, diagnosing, and completing repairs.

WHAT COMES NEXT?

The new world of skilled clean-energy jobs is part of a wider transition for skilled manual workers. While this is no

9-to-5 job, it demands high skills, pays well, and offers great careers to those who pursue it.

Our industry shouldn't leave it to chance to find these people. That's why we set up the Altitec Academy, and it is why technicians who have been short-changed on their training should feel aggrieved. As an industry, it is up to us to make sure we are not only attracting and training people in sufficient numbers, but that we are equipping them for a future in the wind-energy industry by ensuring they receive quality training that will equip them for an evolving industry.

While it is important that the government provides clarity on how it will continue to support skilled workers looking to transition into renewable energy and sustainable jobs, the industry should also not simply wait around for government funding and support. Educating the future workforce on what to look for in a training course, incorporating on-site experience into teachings and adapting to new ways of working are all effective ways of ensuring we are empowering and enabling the wind-energy workforce of the future. It is no secret that wind energy can provide opportunities for highly-skilled technicians – we now need to enable the transition. ✨

ABOUT THE AUTHOR

Tom Dyffort is the managing director for Altitec.



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COMPETENCY-BASED TRAINING

Learning the skills necessary to be successful as a wind-turbine technician requires hours of hands-on practice. (Courtesy: KVCC)

As the need for more technicians continues to grow, the Wind Turbine Technician Academy at Kalamazoo Valley Community College is making sure those techs are properly qualified.

By THOMAS SUTTON and DELIA BAKER

Creating an educated workforce skilled to meet the demands of a changing economy is the focus at Kalamazoo Valley Community College's Groves Campus. Originally opened in 2001 as one of 18 M-TEC facilities across the state, the Groves Center was financed by a \$5 million grant from the Michigan Economic Development Corporation. It offers a variety of training programs for those looking to embark on a new career path, including fast-track training academies that are designed with input from local employers.

One of its most notable programs is the Wind Turbine Technician Academy (WTTA), which was launched in 2009 and has quickly earned a reputation as one of the premier training sources for wind-industry professionals.

The Wind Turbine Technician Academy provides an opportunity for individuals to learn, develop, and master skills that are highly sought after in the wind-energy industry.

The WTTA is a competency-based, 24-week training program designed to teach individuals the skills necessary to work as wind-turbine technicians. Upon successful completion of the program, students typically enjoy a high placement rate within the wind-energy industry.

The program meets Monday through Friday from 8 a.m. to 4:30 p.m. During scheduled service trips, students can expect to work 10 to 12 hours a day to complete the scheduled tasks. The college has educational affiliations with two Michigan-based utility companies that give the WTTA sole responsibility for several utility-scale turbines in the state. Students can expect to spend at least two weeks working in the field on these turbines.

COMBINING KNOWLEDGE AND APPLICATION

The field service trips are a unique way for WTTA's trainees to combine the theoretical knowledge and laboratory application on turbines that are producing electricity to the grid. Graduates receive real-world experience well before they are hired by an employer in the wind industry.

Kalamazoo Valley's WTTA differs from similar programs in the U.S. in that it is competency-based rather than credit-based. Each competency has been validated by the industry as a necessary skill for wind-turbine technicians. Students must demonstrate with 100 percent proficiency they can complete the tasks. These competencies are proven by hands-on demonstrations completed in the presence of one of the instructors or representatives from the industry who may be visiting.

As students are completing the competency demonstration, they will need to describe what they are doing as well as answer questions from the person evaluating them. This provides opportunity for students to learn the



Graduates of the WTTA typically take positions as wind-turbine technicians either on a wind farm or as a traveling technician. (Courtesy: KVCC)

theory and reasoning for the tasks they are performing. Instructors work closely with each student to develop and strengthen troubleshooting skills. There is not always one solution to each problem encountered in the industry, so instructors try to guide students to discover the most preferred solutions.

Learning the skills necessary to be successful as a wind-turbine technician requires hours of hands-on practice. So, as a general rule, the college aims to keep the class

▼ **New wind-energy projects are being constructed throughout the U.S., and they will require technicians to maintain and service wind turbines. The demand for highly trained wind-turbine technicians will continue to rise as more projects are constructed.** ▼

time to a minimum, spending about 85 percent of their time in the laboratory or in the field.

TRAINING SERIES

Additionally, students enrolled in the academy must complete ENSA GWO BST training series, which includes working at heights, first aid, fire prevention, and manual handling. All work-at-heights training is completed on the college's 100-foot climbing tower or on the indoor climbing structure.

In order for this type of training to be successful, class sizes must remain small. The college only accepts a maximum of 12 students each session, allowing it to maintain an ideal student-to-instructor ratio. Acceptance into the academy is based on a detailed application process.

Individuals are required to apply for the academy with an application similar to a job application. They need to provide contact references, pass a mathematics test, as well as conduct an interview. This application process allows the WTTA team to identify individuals with the most potential for success.

Graduates of the WTTA typically take positions as wind-turbine technicians either on a wind farm or as a traveling technician for virtually every major OEM and service and maintenance provider in the U.S. wind industry. New wind-energy projects are being constructed throughout the U.S., and they will require technicians to maintain and service wind turbines. The demand for highly trained wind-turbine technicians will continue to rise as more projects are constructed.

CAREER OPPORTUNITIES

The WTTA team is constantly being notified of career opportunities in the wind industry. The school maintains a private network in order to inform previous graduates of available opportunities.

In order to meet goals put in place by the U.S. Department of Energy, the wind-energy industry will need to continue growing.

Currently trending in the U.S. wind industry is more corporate ownership of wind assets. This allows a corpo-



The WTTA is a competency-based, 24-week training program designed to teach individuals the skills necessary to work as wind-turbine technicians. (Courtesy: KVCC)

ration to identify their actual energy costs for many years — sometimes up to 20 years. With the increased demand from private industry, wind energy will continue to grow. The growth in wind energy is coupled with a steady increase in employment for people to support the increased wind capacity.

At the same time, technology is ever changing, and turbines are becoming more efficient and sophisticated every year. This requires a workforce with diverse skill sets in order to maintain and repair legacy machines as well as the newer and more advanced machines. WTTA's close working relationships and validation from the industry, coupled with its competency-based program, allows the college to continuously improve to make certain its grad-



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All work-at-heights training is completed on the KVCC's 100-foot climbing tower or on the indoor climbing structure. (Courtesy: KVCC)

uates receive the knowledge and skills needed to satisfy all of the requirements of the industry.

CERTIFICATIONS

Kalamazoo Valley's WTTA has earned both the American Wind Energy Association (AWEA) seal of approval and certification by the Bildungszentrum für Erneuerbare Energien (BZEE) Renewable Energy Education Center. Upon successful completion of a series of written and practical tests, as well as a completion of the field service, students receive certification as a service technician for wind-turbine engineering through the BZEE.

Companies in the wind industry have become familiar with Kalamazoo Valley's WTTA program. Employers benefit from hiring its graduates because they are not only hiring an employee who is fully certified and competent, but they also have gained experience on real components and actual field experience all within the 24-week training period.

Kalamazoo Valley runs two academies per year; one typically starts during the first week of January, and the other normally starts the first week in July. To learn more about the WTTA, contact Delia Baker at dbaker2@kvcc.edu or (269) 353-1554.

Established in 1966, Kalamazoo Valley Community College is a comprehensive, fully accredited, public, two-year college with about 10,000 students. Kalamazoo Valley offers certificate programs in more than 20 areas of study and associate degrees in 25 others. In addition to associate degree and certificate programs in business, health care, human and public service, technical occupations, and industry, the college also provides a quality experience for students preparing to transfer to four-year institutions following graduation. ✨

ABOUT THE AUTHORS

Thomas Sutton is the director of Wind Energy and Technical Training Services. In 2008, he became a key developer of the Wind Turbine Technician Academy at Kalamazoo Valley Community College including the Quality Management system. Sutton is an active member of the International Technical Committee and travels to Europe where he helps develop global work-safety-at-heights training programs. He is also active in the American Wind Energy Association and is serving on the Safety Steering Committee, ANSI Standard Committee for Safety in the Wind Industry, ANSI Standard Committee for Wind Technician Training Standards as well as many working groups promoting worker safety and education. Sutton also delivers safety-at-heights training to the wind academy and general industry as a College Instructional Partner with ENSA North America.

Delia Baker is program coordinator for Technical Training Services. Baker obtained a Bachelor of Business Management from Western Michigan University in 2012. She joined the team at Kalamazoo Valley in September 2017 after several years working in sales for a relocation company.



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PROFILE

BROADWIND ENERGY

‘WE CAN WELD
ANYTHING’

In 2016, Broadwind was able to put more than 100 tower sections on barges and ship them across the Great Lakes. (Photos courtesy: Broadwind)

BROADWIND ENERGY

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Broadwind Energy is a precision manufacturer of structures, equipment, and components for the wind industry, clean tech, and other specialized applications.

By **KENNETH CARTER** ▸ Wind Systems editor

When a company makes a name for itself by handling massive steel objects, it seems only logical that those objects would involve the creation of wind turbines.

That skill has been the cornerstone of Broadwind since its inception — welding.

“We were a welding company,” said Matthew Boor, director of business development with Broadwind. “We welded a lot of things. But our bread and butter is building the giant towers for the wind OEMs you’ve heard of. That’s what we’re best known for, and at the core of that is obviously handling massive steel objects and welding them. We can cut metal, roll it, weld it, paint it, and then assemble as needed.”

3,000 TOWERS AND COUNTING

Broadwind is one of the first producers of 100-meter turbines in the U.S., and is one of the largest producers of utility scale tubular wind-energy towers in North America. The company has built more than three dozen designs for leading turbine OEMs and designed proprietary internals for others. The bottom line is Broadwind has built more than 3,000 wind towers since 2008, according to Boor.

Broadwind specializes in the production of wind-turbine towers as well as fabrications for other industries. It has production facilities in Manitowoc, Wisconsin, and Abilene, Texas. The company fabricates heavy, next generation wind towers that are larger, more technically advanced, and designed for multi-megawatt turbines.

And Broadwind has been very busy when it comes to those towers, according to Boor.

“As far as I know, we’ve built more different models of towers for more customers than anyone else,” he said. “Other companies have probably built more towers than us, but not for as many different customers and not as many different types.”

BROADWIND’S OTHER COMPANIES

A few other companies fall under the Broadwind Energy umbrella, and they also take on wind-industry functions, as well as duties for other industries, according to Boor.

“We own Brad Foote Gearing in Cicero, Illinois. They can cut gears and rebuild gearboxes,” Boor said. “That business is also part of Broadwind Energy, but it was a much older business before they became part of the family, so to speak. A chunk of their business is for wind companies.”

Brad Foote Gearing builds and repairs precision gears and gearboxes for wind, oil and gas, mining, and other industries. Brad Foote has produced more than 4,500 MW of wind gearing and is focused on the manufacture of custom engineered systems and gearboxes. It has been in the gear business since 1924.

Another Broadwind company is Red Wolf Company, LLC



Broadwind is one of the largest producers of utility scale tubular wind-energy towers in North America.

based out of Sanford, North Carolina, according to Boor.

“Red Wolf is a really interesting company with distinctive capabilities,” he said. “Their core competencies are procurement, pre-assembling, and kitting items as diverse as tooling, testing equipment, consumables, and raw materials with a degree of accuracy that borders on prescience. We then prepare these for shipping, building custom crates and outfitting containers that can be job hopped, if desired.”

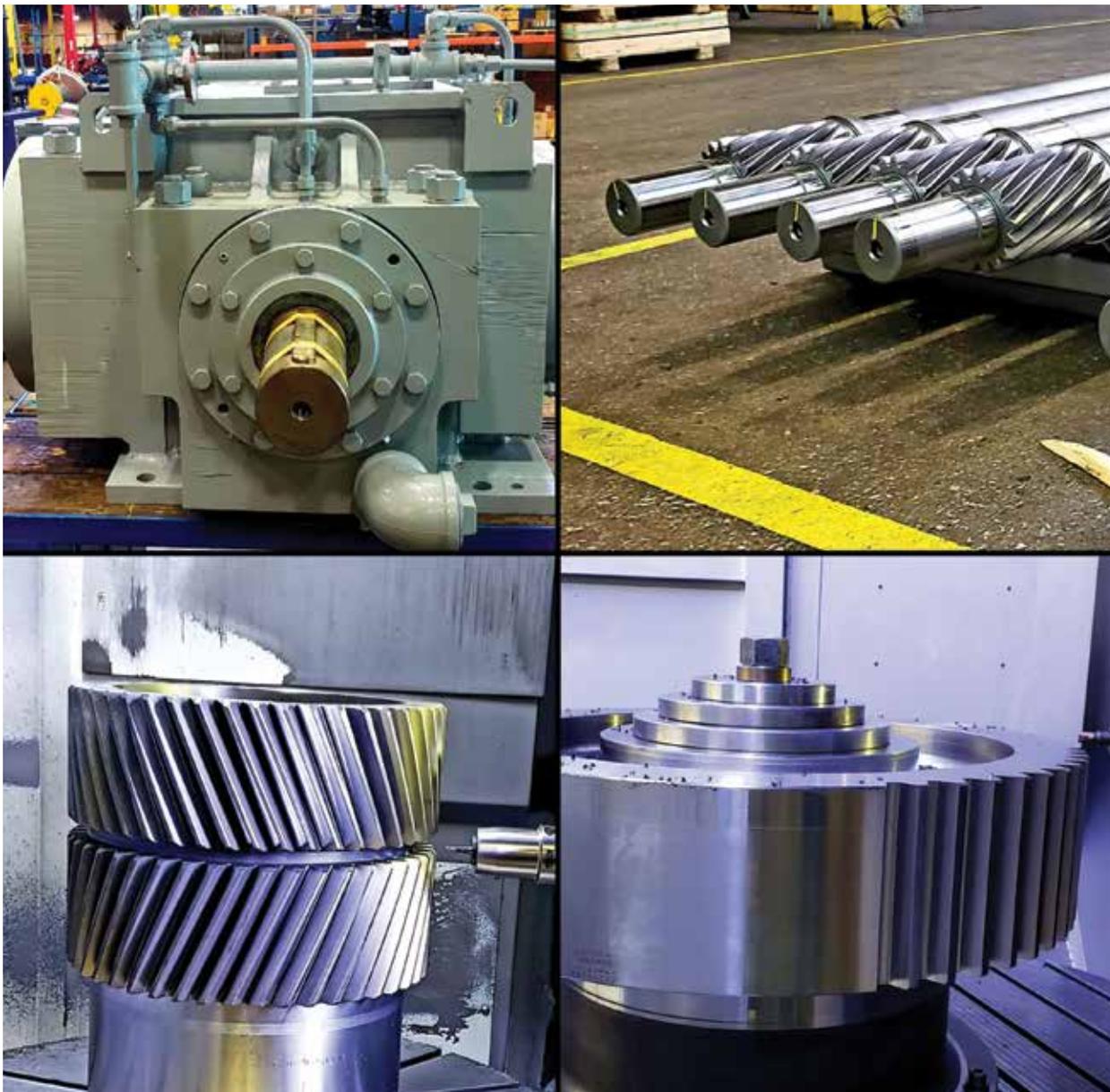
Red Wolf custom packages and ships for different industries and is best known for its work preparing tooling and critical spares kits for gas-turbine outages, according to Boor.

“If you’re going to work on a gas turbine in, say, Algeria, Red Wolf finds everything that you’ll need to do that job, packages it in a way that makes sense, and then gets it ready to ship overseas in such a way that it can actually stay on site for months — even years — without degradation,” he said. “Then, when they uncrate, everything’s there ready to use. It’s accounted for. This business has a place in wind as well as solar construction, really any pre-construction services.”

MORE THAN JUST TOWER CONSTRUCTION

In addition to manufacturing towers, Broadwind also makes lifting beams that pick up the towers, according to Boor.

“What it comes down to is that we can weld anything,” he said. “It can hardly be too large. We can pick up extremely



Broadwind owns Brad Foote Gearing, which builds and repairs precision gears and gearboxes for wind, oil and gas, mining, and other industries.

heavy things, and that lends itself to a lot of really interesting opportunities. Our paint booths are huge. They're 25 feet wide by 25 feet tall by 135 feet long."

Broadwind has four of these paint booths — two in Manitowoc and two in Abilene, according to Boor. The Manitowoc plant has the capacity to produce 350 wind towers per year, while the Abilene facility can fabricate almost 200 annually.

Making towers for a diverse number of major players in the wind industry has allowed Broadwind's knowledge base to increase exponentially over the years, he said.

"We have a ton of experience, and that's helped us learn how everyone builds towers," Boor said.

CUSTOMER SERVICE

That experience has created a strong relationship with Broadwind's customers and how the company helps them accomplish their goals.

"Sometimes it's as simple as an RFQ," Boor said. "It'll start with that, or sometimes we have existing relationships with turbine OEMs. There's a quoting process that we follow, and again, having such a deep bench of experience helps us determine if a process or design is derivative of something else. For example, this design looks like so-and-so's design from eight years ago, and we know exactly how to do this."

Once all of that is in place, Broadwind has developed an in-house APQP process that ensures customer specifications aren't overlooked, according to Boor.

"We developed this a few years ago, and the simplest way to put it is it's a massive checklist that makes sure we're not missing specifications or measurements or tests that have to be done along the way," he said. "We're making sure that we meet all the customer's specifications. That sort of thing just comes from being in this business for 10-plus years. You can't cheat experience."

MAJOR ACCOMPLISHMENTS

That experience has also brought about many accomplishments both inside and outside the wind industry, according to Boor.

"Last year, we partnered with Goldwind and actually built what was, at that point, the tallest wind turbine in North America," he said. "On the heavy fabrications side of the business, we built the tallest flagpole in North or South America, and that stands at an insurance company in Sheboygan, Wisconsin. It's over 400 feet tall."

Broadwind's Wisconsin facility is on a peninsula that leads directly into Lake Michigan, which gives the company deep-water access to the Great Lakes and beyond. That advantage has allowed the company to further its expertise with wind, according to Boor.

"In 2016, we did a project with Gamesa — at that point they were just Gamesa — to actually put more than 100 tower sections on barges and ship them across the Great Lakes," he said. "That was a proud moment, and it took a lot of coordination to make that happen."

Boor added that he would expect Broadwind's Wisconsin facility to be in a perfect position to be involved with the expected rush of offshore wind projects gaining momentum in the Atlantic and even the Great Lakes.

LOOKING TO THE FUTURE

All-in-all, Boor expects a bright future for Broadwind.

"We are excited about the future, specifically determining what the future looks like in a post-PTC world in a couple years," he said.

That will be a challenge, according to Boor, but he said he thinks it will ultimately be a positive one.

"We live in an energy-hungry world," he said. "Energy consumption has slowed down, but it still continues to grow. Certainly, as tower sizes increase and turbine output increases, there's more need for larger machines and companies that have larger capabilities to make these things. I like how we're positioned for that." ✈

MORE INFO ▶ Contact Matthew Boor at Matthew.Boor@bwen.com or (920) 482-3543.

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Tom Kiernan

President ▸ AWEA



“AWEA works hard to attract new and diverse groups to the conference each year, with the goal of sparking new conversations, new connections, and innovative ideas.”

▸ What went into planning this year’s WINDPOWER?

Attendees from all over the globe take time out of their schedules to attend WINDPOWER, and we don’t take that lightly. It is important to ensure those days are filled with top-tier speakers, world-class education, cutting-edge technology, and premium networking, and we work hard to make the event as efficient as possible for both attendees and exhibitors.

The planning process begins with our WINDPOWER marketing task force, which is made up of executives from industry-leading companies. They help us identify ways to be forward thinking and innovative across each touchpoint on the show floor. This year, the task force developed the show theme of Wind Plus — how wind connects so effectively with other energy technologies in serving an increasingly diverse customer and community base. On the show floor, in the education theaters, and throughout the event space, we will be highlighting wind’s collaboration with other renewable technologies and traditional energy.

The education team is continuing to work with our program chairs, Miguel Prado, EDPR North America CEO, and Silvia Ortin Rios, E.ON North America COO, on developing a robust and timely agenda that will capitalize on the conference being located in the energy capital of the world. The development of the program involves an extensive stakeholder collaboration process with industry, government, and academics working to develop sessions that will help grow the industry with timely insights and research.

▸ What should attendees expect in the way of presenters?

Regardless of your expertise in the renewable energy industry, it’s essential to know what’s on the horizon for the U.S. wind-energy market and, more broadly, the utility-scale renewable market, how to influence it, and how to ensure success across the industry. That’s why the education program at WINDPOWER 2019 is vital to any serious professional in renewable energy.

Presenters this year will range from experts in siting, transmission, energy storage, and finance and investment to those who focus on operations and maintenance, offshore, supply chain, and electrification.

▸ Will there be any presentations devoted to offshore wind?

The potential offshore wind pipeline in the U.S. swelled to over 25,000 MW in 2018 as states committed to developing large amounts of offshore wind as part of their electricity mix. It is clear that companies see enormous business potential in developing offshore wind projects.

This year’s WINDPOWER will kick off with a pre-con seminar that will provide helpful insights for companies looking to enter this market by estimating the supply-chain deliverables, both in terms of quantities and cost; shedding light on the procurement process; and laying out timelines.

In addition to the pre-con, we will also have WINDPOWER sessions focused on innovating offshore wind technology by leveraging other offshore energy advances and balancing co-existence of offshore wind with other users of the ocean. There will also be discussions around financing offshore projects.

▸ With Texas being a leader in U.S. wind energy production and the show’s venue being in Houston, are there any special tie-ins?

Texas is known to be a big producer and consumer of energy, but many Texans find it surprising that the state leads all states in wind-energy production by a large margin. With 16 percent of generation coming from wind, there’s great potential for the state to become an even bigger player in clean energy. A recent study conducted by Rice University finds that Texas could easily generate most of its energy through wind and solar due to the state’s unique geography. One of our panels will include energy leaders in Texas who will discuss what needs to happen for the state to reach its



Last year's WINDPOWER in Chicago, Illinois, was a big success. (Courtesy: Wind Systems)

clean-energy potential and reap the economic and environmental benefits of a cleaner grid.

We'll have many of our Texas companies well represented this year with Shell, BP Energy, EDPR, E.ON, and Pattern all having important roles in the program. In addition, this year's event will have "on the road" learning opportunities throughout Houston that attendees can choose to add on. These local learning sessions include a boat tour of the Port of Houston, blade services safety and repair demonstrations at the WindCom facility or a tour of the EDF trade floor.

► **If I were a first-time exhibitor, what should I expect to gain by attending the show?**

AWEA works hard to attract new and diverse groups to the conference each year, with the goal of sparking new conversations, new connections, and innovative ideas. My hope is that exhibitors are able to meet and connect with prospective customers, while strengthening bonds with existing customers, learn about new developments in the industry, and strengthen their brands — all in a few busy days. Our goal is to make that process as efficient as possible over the course of three days.

Five education stations, plus the ePoster gallery, will be located on the exhibition floor for convenient learning opportunities for attendees and exhibitors. This keeps attendees from being pulled off the floor and away from booths throughout the day. Tuesday wraps up with a happy hour on the show floor to allow for attendees to continue exploring the hall and networking with additional exhibitors.

We are also implementing a "workforce development Thursday" that will keep attendees engaged until the very end. This new initiative will spotlight job opportunities in wind, as well as the growing operations and maintenance segment of the wind industry. Field staff and wind technicians are invited to register for the Thursday program for free or attend the full event at a significantly discounted

rate. Participating exhibitors will highlight current job openings and staff their booth with individuals ready to discuss opportunities within their company.

In addition, the last day of the show will have educational sessions that focus on relevant technical and operations and maintenance topics, as well as safety demos on the show floor.

► **Could you give a quick preview of what attendees will learn from your opening address?**

Wind energy is the largest renewable energy source in the country and will become, along with solar and storage, the dominant long-run players on the clean grid of the future. While that future is exciting, getting from here to there is worth significant consideration and discussion.

In my remarks, I look forward to discussing how those of us in the wind and utility-scale renewables industry need to evolve our thinking, our behavior, and our companies to profitably move from our businesses of today to business models of the future. I will also share, importantly, how this growth and rapid evolution will create even more clean energy jobs in America, more opportunities for veterans, and greater prosperity across the rural and urban landscapes of America.

► **What are you personally looking forward to at this year's show?**

The vision behind this year's theme, Wind Plus, is to bring together not only those working in wind but across energy sectors, local communities, individual land owners, and corporate energy buyers. This year's program focuses on wind energy's ability to thrive through innovation and collaboration while building alliances to propel the industry forward. I am really looking forward to taking this next step forward to powering the future, together! ✈

MORE INFO ► www.windpowerexpo.org



Gearbox Express is North America's largest independent remanufacturer of gearbox assemblies and main shafts for the wind-turbine industry. (Courtesy: Gearbox Express)

MAINTENANCE

Gearbox Express partners with Invenergy Services

Gearbox Express (GBX), North America's largest independent remanufacturer of gearbox assemblies and main shafts for the wind-turbine industry, recently announced a partnership with Invenergy Services, an award-winning sustainable energy solutions provider.

Through the partnership, GBX has secured Invenergy Services to perform major component and field service work, resulting in the combined and expanded geographic footprint of service coverage. GBX and Invenergy

Services will now be able to provide a superior product at a lower cost to more asset owners.

"Invenergy's award-winning services platform and desire to perform repairs and replacements in house aligns incentives where we can both focus on our core competencies," said Gearbox Express CEO Bruce Neumiller. "We believe that Invenergy Services' capabilities, combined with our equipment and industry expertise, make for a winning combination."

"Invenergy Services is excited to expand our services capabilities with this agreement, which not only deepens our relationship with Gearbox Express, but also enhances our ability to meet our customers' wind-turbine drivetrain needs," said Brad Purtell, director of Invenergy Services Busi-

ness Development. "Ultimately, this agreement means delivering cost reductions for our customers due to the scale of the fleet that both Invenergy and Gearbox Express serve."

MORE INFO InvenergyServices.com

MAINTENANCE

Iberwind partners with ONYX InSight to upgrade V90 fleet

Iberwind and ONYX InSight recently announced hardware and software upgrades to Iberwind's Vestas V90 3-MW fleet to power predictive maintenance practices and boost profitability of the

fleet. Turbine upgrades will include the installation of ONYX InSight's ecoCMS hardware, which monitors the condition of a turbine's drive train and its cloud-based fleetMONITOR™ software, which maps turbine health and provides early failure detection across all assets.

Iberwind has installed 323 wind turbines under management in Portugal, with capacity of 730 MW, which equates to about 15 percent of wind energy in the country. As Iberwind aims to reduce the costs of operating and maintaining these turbines, it has looked to leading predictive maintenance technologies to bring efficiencies to the process. Supported by a program of training and technology transfer from ONYX InSight, Iberwind will build its in-house capacity to monitor the condition of its wind turbines, achieving a balanced management of their health through early failure detection.

As owners and operators look to better manage the operational costs of producing energy and to pass sav-

ings onto customers and investors, improved oversight and understanding of operations and maintenance will be essential. The technologies that underpin predictive maintenance, including hardware, software, and machine learning algorithms will be essential for achieving this.

"Iberwind consistently outperforms for availability and is a forward-thinking adopter of technology for managing assets and driving down the cost of operations and maintenance," said Ashley Crowther, Global Vice-President, ONYX InSight. "Adopting the right technologies that will enable them to operate in an increasingly digital world will allow Iberwind to better manage operational budgets and improve turbine performance."

"We are constantly searching for ways to optimize the control of wind farms, and now we are taking predictive maintenance to the next step," said Rui Maia, COO of Iberwind. "ONYX's hardware and software solutions allow us to continually refine our approach to monitoring assets and

responding with a maintenance and repair plan. By embracing digital technology, we are able to take advantage of ONYX's high levels of service and flexibility to our needs."

ONYX InSight will be installing ecoCMS, an innovative condition monitoring system that uses Micro-Electro Mechanical Systems (MEMS) technology to increase coverage of sensors on a turbine's drivetrain. Triaxial accelerometer sensors monitor vibration as well as turbine rotor balance and all provide a temperature signal. ONYX's fleetMONITOR™ will allow Iberwind to study turbine performance across its fleet and provide it with the capacity to eventually monitor all turbines in its multi-brand fleet. In choosing a predictive maintenance supplier, Iberwind conducted a rigorous selection process that evaluated technical and service levels to identify best in class for options in the market.

"Iberia is an extremely competitive market, and it is essential for our partners that they are provided with flexible solutions for monitoring their fleets," said Jose Morais, ONYX InSight's Iberia manager. "As we increase our presence in Portugal and Spain, we are pleased to be partnering with a forward-thinking owner such as Iberwind."

MORE INFO www.onyxinsight.com

► MAINTENANCE

The iSpin technology products available in Japan now

Hokutaku Ltd. and Romo Wind AG recently announced their exclusive partnership for the distribution of iSpin technology-based products and services in Japan. Hokutaku Ltd. will provide Romo Wind's product and service portfolio to the Japanese market and will support the full life cycle from the distribution, installation,



Iberwind has installed 323 wind turbines under management in Portugal, with capacity of 730 MW, which equates to about 15 percent of wind energy in the country. (Courtesy: Iberwind)

commissioning, and maintenance to measurements and analysis of iSpin measurement data.

With its advanced and accurate wind-measurement capabilities including turbulence intensity, yaw misalignment, and inflow angle measurements, in addition to wind speed and direction, the iSpin equipment is an enabler for load calculations and assessments as well as the optimization of the turbines in terms of yaw misalignment correction.

“With iSpin technology, Hokutaku Ltd. customers will be enabled to detect and correct yaw misalignment, therefore increase the revenues and reduce loads of the wind turbines,” said Brian Sørensen, CEO Romo Wind. “In addition, the iSpin technology will allow for the first time to measure the performance of all the wind turbines in a wind farm as well as other important wind-site conditions.”

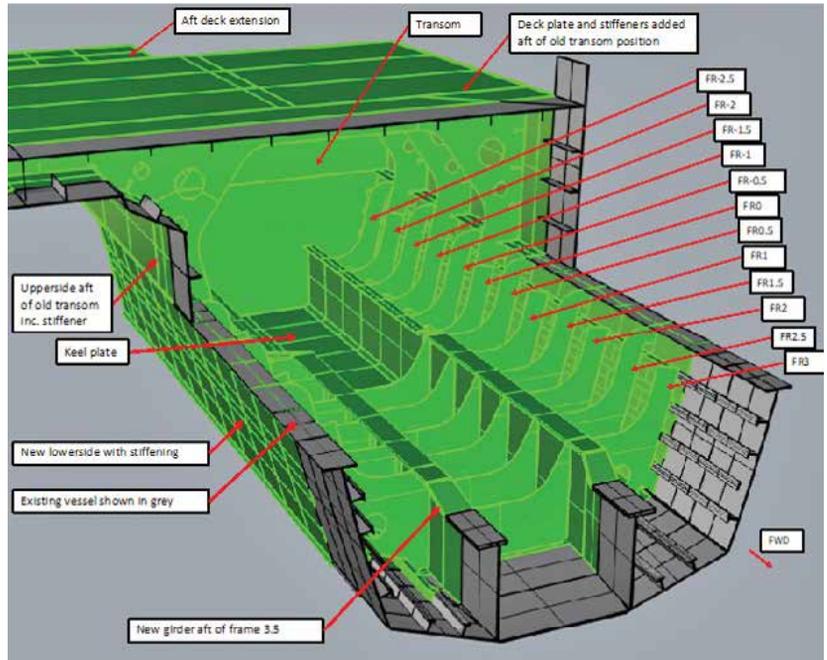
“The ability to measure accurate wind speed, yaw misalignment, turbulence intensity, and inflow angle is key for the optimization of wind turbines in such a complex terrain as we have it here in Japan,” said Satoru Yoshida, vice president of Hokutaku Ltd. “We are glad that we are now able to offer the advanced iSpin wind-measurement products and services to our customers exclusively. This will improve wind-turbine performance and contribute greatly to the wind-power industry in Japan.”

MORE INFO www.romowind.com

MAINTENANCE

Evolving offshore wind scope requires refits of aging CTVs

With a significant proportion of the European offshore wind support vessel fleet entering the latter phases of its operational lifetime or no longer able to meet changing industry demands, there is a growing emphasis on the vessel market to refit or repurpose CTVs.



Chartwell Marine has substantial expertise in vessel repurposing, including re-flagging, re-coding, and complete vessel conversion – such as from crew transfer vessel (CTV) to ferry, or leisure fishing boat to workboat. (Courtesy: Chartwell Marine)

In doing so, vessel owners and shipyards can seize a commercial opportunity to maximize the value of these assets and support the overall sustainability of the offshore wind sector.

That, at least, is according to Chartwell Marine, a pioneer in next-generation vessel design that has supported a number of offshore wind vessel refit projects in recent months. Chartwell Marine has substantial expertise in vessel repurposing, including re-flagging, re-coding, and complete vessel conversion – such as from crew transfer vessel (CTV) to ferry, or leisure fishing boat to workboat.

While offshore wind is a young sector, with the majority of large-scale European projects no more than 10 years old – and expected to continue operating for 25 years in total – vessel lifetimes do not match those of offshore wind turbines. Furthermore, rapidly evolving construction and operational standards mean that many of the CTVs originally commissioned to service these projects may no longer meet the requirements of offshore wind developers and operators.

This is not to say, however, that these vessels are no longer fit for purpose. Indeed, for vessel owners, there are two main options on the table: One is to repurpose these catamarans for operation in other sectors, or for different functions within offshore wind. Offshore wind CTVs have been redeployed effectively for purposes including survey, dive support and security.

The other option is to conduct refits that extend the operational lifetime of the vessels in offshore wind. This often involves upgrades to propulsion systems, increasing the number of people who can be carried onboard, and lengthening of the hull to enhance deck space and potentially seakeeping. Chartwell Marine has provided design consultancy services to shipyards and vessel owners on a number of these refit projects.

Recent contracts have included supporting shipyard Diverse Marine in full refits of CTVs *Maestro* and *Don Quixote*, both of which were acquired by Turner Icení in early 2019. *Maestro*, an 18-meter catamaran, has been

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refitted with Volvo IPS propulsion system, while *Don Quixote* has been refitted with 1,400 horsepower MAN engines and Hamilton 651 waterjets, and lengthened from 20 to 23 meters. Both are set to re-enter service later this year.

“For a sector like offshore wind, which is founded on principles of sustainability, vessel support is one area where substantial efficiencies can be realized,” said Andy Page, managing director at Chartwell Marine. “With robust design support, vessels that are starting to reach the end of their utility for offshore wind operators can either be upgraded in a cost-effective manner to re-enter service or set to work in other maritime sectors.”

“This creates plenty of opportunity for U.K. shipyards to carve out a niche in vessel refits – particularly during the winter months when demand drops off a little,” he said. “Furthermore, given an overall shortfall of new builds currently in build, and demand for offshore wind crew transfer vessels ramping up considerably, these vessel refits may well help to plug a gap until the next generation of offshore wind CTVs starts to enter operation.”

MORE INFO www.chartwellmarine.com

MAINTENANCE

MSA launches new full-body harness lines

MSA recently announced the launch of the new V-SERIES full body harness line for fall protection: V-FLEX™, V-FIT™, and V-FORM™. Each is designed for comfort and differing needs.

With the V-SERIES, users can focus on their work instead of their harness. The exclusive racing-style buckle eliminates the need for chest straps, creating a closer, more comfortable harness. An athletic cut contours the harness to the body for increased upper torso mobility. A pull-down adjustment allows the wearer to easily and quickly



The V-FIT harness line. (Courtesy: MSA)

make adjustments in order to get the right fit.

The V-SERIES harness line is suitable for use in multiple work-at-height

applications in industries such as construction, general industry, and oil and gas.

MORE INFO MSAsafety.com/vseriesfallprotection

INNOVATION

Deutsche WindGuard accredited for calibrating Lidar

Deutsche WindGuard Consulting GmbH is now accredited according to DIN EN ISO/IEC 17025 for the calibration of nacelle-mounted Lidars. The calibration laboratory can now calibrate all kinds of wind remote sensing devices and completes its range of services in this department.

Nacelle Lidars have gained in importance in the last years — especially with regard to the verification of warranted power curves.

“Measurements with nacelle Lidars have the great advantage over classical



Nacelle Lidars have gained in importance in the last years — especially with regard to the verification of warranted power curves. (Courtesy: Deutsche WindGuard Consulting GmbH)

power curve tests that there's no need for the installation of a met mast," said Dr. Klaus Franke, head of Deutsche WindGuard Consulting's calibration laboratory for remote sensing devices. "Especially in offshore measurements, nacelle Lidars are a cost-efficient alternative."

While nacelle-mounted Lidars are not yet included in IEC standards, they are widely used for power-curve verification measurements.

"We are part of an IEC task group that develops an IEC standard for the use of nacelle Lidars in the frame of wind measurements, which will be published sometime next year," Franke said.

For each measurement, traceable sensors are absolutely essential. The calibrations are conducted on the existing WindGuard test field.

MORE INFO www.windguard.com

INNOVATION

Vestas expands 4 MW platform for sites with extreme weather

As part of its efforts to offer innovative solutions to meet customer needs, Vestas is introducing the V136-4.2 MW Extreme Climate wind turbine. This new variant of the powerful and proven 4 MW platform offers maximum energy production in low to medium wind speeds, while being designed to handle extreme weather conditions that have previously been challenging to exploit.

The V136-4.2 MW Extreme Climate is being introduced at the 2019 Japan Wind Expo to highlight the turbine's specific suitability for many project sites exposed to severe climate in Japan and Asia. The new variant is also applicable for other markets with similar conditions around the world, such as Southern China, Caribbean, and the U.K., for both onshore and offshore sites.

Building directly on the popular

V136-4.2 MW turbine, the Extreme Climate variant features design optimizations that include a reinforced blade and a strengthened hub. The new variant is capable of withstanding extreme wind speeds of 53 m/s (exceeding IEC class I extreme wind speed), and extreme wind gusts of up to 74-78 m/s. The variant is also designed to withstand above-average frequency events and intensity of light-

ning strikes associated with typhoons, such as those seen in Japan.

The V136-4.2 MW Extreme Climate is also highly suitable for areas with low-grid capacity, thanks to Vestas' state-of-the-art full-scale converter that offers advanced active and reactive power capabilities.

"With the introduction of V136-4.2 MW Extreme Climate, Vestas is connecting our proven technology with

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The V136-4.2 MW Extreme Climate is being introduced at the 2019 Japan Wind Expo to highlight the turbine's specific suitability for many project sites exposed to severe climate in Japan and Asia. (Courtesy: Vestas)

customized solutions to help customers unlock low to medium wind sites with high turbulence,” said Thomas Korzeniewski, Vestas’ vice president of Product Strategy. “The larger rotor delivers improved energy production with the strength and versatility necessary to handle extreme wind gusts and high turbulence.”

“Vestas’ global experience and wide range of industry-leading offerings mean we can offer customized sustainable energy solutions to meet the needs of specific markets like Japan,” said Clive Turton, president of Vestas Asia Pacific. “We are building on the reliability of Vestas’ 4MW platform to broaden its applicability for diverse and challenging wind and weather conditions.”

Ready to meet extreme climate conditions and market requirements, the V136-4.2 MW Extreme Climate leverages Vestas’ wide range of turbine options and solutions, including site-specific tower solutions such as large diameter steel towers, transportation solutions for challenging sites, full type certificate for global applicability, as well as project specific solutions such as Vestas Cold Climate Solutions

and High Wind Operation (HWO).

Since its introduction in 2010, the Vestas 4 MW platform has built a powerful legacy where ongoing innovations have resulted in up to a 56 percent increase in energy production. Vestas’ comprehensive testing program combined with more than 7,000 turbines or 23 GW installed in 44 countries worldwide means the platform has proven its worth under highly diverse conditions.

Serial production is expected by mid-2021 and delivery later that year.

MORE INFO www.vestas.com

INNOVATION

AMETEK Spectro Scientific expands its software platform

AMETEK Spectro Scientific, one of the world’s largest suppliers of oil, fuel, and processed-water analysis instrumentation and software, expanded its cloud-based TruVu 360™ Enterprise Fluid Intelligence Platform with two

standalone versions — TruVu 360 Basic and TruVu 360 Pro — both of which can be installed on a customer’s local PC or corporate server.

The software integrates Spectro Scientific’s oil analysis hardware with data acquisition, reporting, and information management software, including an expert system that provides automatic diagnostics, an intelligence dashboard and recommendations for action.

TruVu 360 Basic is engineered for use with one Spectro Scientific MiniLab on-site oil analysis system for a single user. The software is installed on a non-networked local PC and is ideal for any small reliability team implementing an on-site oil analysis program. TruVu 360 Pro, also intended for use with one MiniLab system, can be installed on a company network server. It features multiple user licenses, which include site user, operator, and reader privileges. The software also provides email notifications about the oil-analysis report.

Together with the original TruVu 360 Cloud version, customers can now choose between TruVu 360 configurations that match their companies’ individual IT policies, allowing ease of operation, simplified and fast work flow, an adaptive rules engine, and high-quality oil analysis reports.

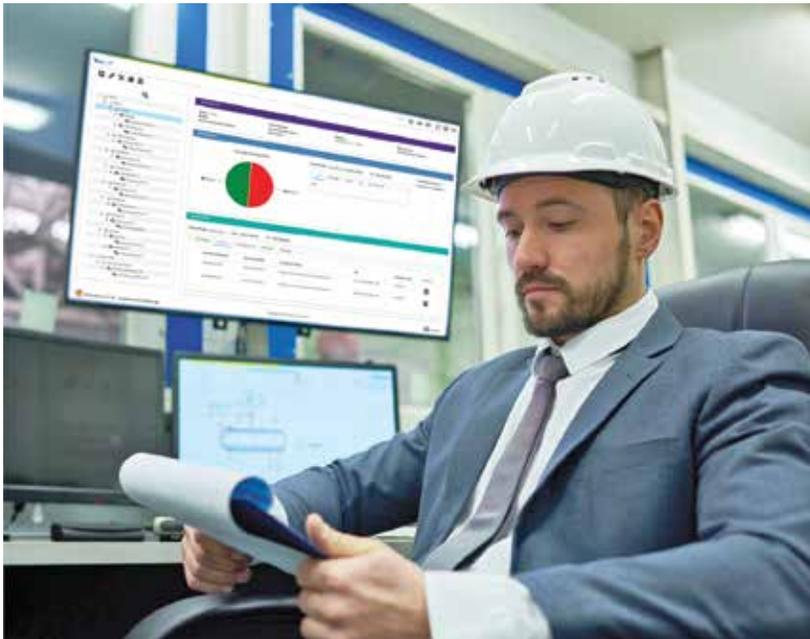
The TruVu 360 platform works with the Spectro Scientific MiniLab Series oil analysis hardware — an economical on-site oil analysis system with lab-quality results that doesn’t require a special lab facility. The sample volume is small, the operator training is minimal, and the system doesn’t require hazardous chemicals or reagents.

When performing measurements on-site, Spectro Scientific’s analyzers slash the wait time for analysis results from days or weeks to minutes, compared to lab-based fluid analysis. The analyzers enable users to make immediate maintenance decisions that reduce unexpected downtime and costs, eliminating potential catastrophic machine failures. The data produced also facilitates efficient scheduling of proactive maintenance and fluid re-

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AMETEK Spectro Scientific's software integrates Spectro Scientific's oil analysis hardware with data acquisition, reporting, and information management software. (AMETEK Spectro Scientific)

new actions, improving utilization of resources and machine time.

"The expanded TruVu 360 platform now supports all of our customers in different industries in compliance with their IT policies," said Spectro Scientific senior vice president Yuegang Zhao. "These options help them simplify and streamline the on-site oil analysis process, providing high-quality information and actionable intelligence that facilitates effective decision making."

MORE INFO www.spectrosci.com

CONSTRUCTION

Lee Maynard named new Terex Cranes global sales director

Lee Maynard recently became the new tower cranes global sales director at Terex Cranes. Maynard was previously the Terex Cranes director of sales for Europe and Russia in the Mobile Cranes business. In addition, he was



Lee Maynard

also the general manager for the UK&I and will continue in this role until a successor is found.

Maynard will be based in the Schaffhausen Terex Global office in Switzerland and, in his new role, will develop long-term strategies and identify growth opportunities in the global tower crane market with the



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The Fred. Olsen Windcarrier vessels have installed more than 400 wind turbines offshore and gained extensive experience installing the latest generation offshore wind turbines on some of the world's largest wind farms. (Courtesy: Fred. Olsen Windcarrier)

objective of increasing the company's worldwide market share and profitability. In addition, Maynard will take over management duties for the global Terex Tower Cranes Sales Team in EMEAR, North America, East Asia, and Australia and New Zealand.

Maynard will be able to draw on his extensive professional experience and crane industry knowledge. A qualified engineer, he has been with Terex Corporation since 2001 as a result of the acquisition of German crane and excavator manufacturer Atlas, and since then, he has been in a number of positions of increasing responsibility. Initially, after switching from engineering, he was a regional sales manager for Terex Construction, and in 2010 became the U.K. & IRL general manager for Mobile Cranes. In 2012, he assumed responsibility for the European sales and service organizations for mobile cranes as part of the man-

agement team. Most recently, he was responsible for all sales activities in Europe, Russia, and in CIS member states.

MORE INFO www.Terex.com

► CONSTRUCTION

Fred. Olsen Windcarrier wins first contract in Taiwan

Fred. Olsen Windcarrier recently was awarded a contract with Siemens Gamesa Renewable Energy (SGRE) for the transport and installation of wind turbines on the Yunlin Offshore Windfarm in Taiwanese waters for its 8 MW wind turbines.

Fred. Olsen Windcarrier will mobilize one of its special purpose-built jack-up installation vessels in Europe

during the spring of 2020, which will head to Asia to start working in this emerging market.

"This is a very exciting project as it is the first large transport and installation project in Asia for us," said Martin Degen, Commercial Manager, Fred. Olsen Windcarrier. "We are glad to have been picked by SGRE as a reliable partner for this new market. The contract will continue to strengthen our relationship with SGRE. We are looking forward to bringing our European experience and capabilities to the project, working with the local supply chain in Taiwan."

"Taiwan is a strong developing market for SGRE, as such it is essential that we operate with partners who we are sure to bring the right team and the right assets for the job," said Russell Brice, Head of Marine Operations, SGRE Offshore. "We are confident that Fred. Olsen Windcarrier

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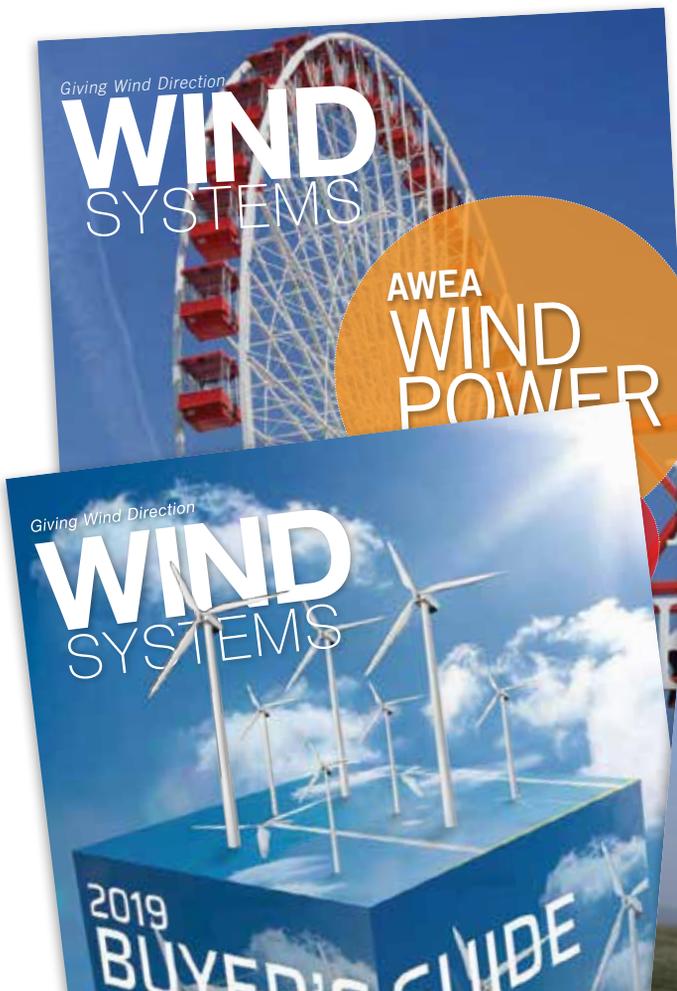
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will prove themselves with us again. We are looking forward to be working together again, this time for Yunlin.”

For the Yunlin Offshore Windfarm, Fred. Olsen Windcarrier aims at engaging various local stakeholders in their scope of work. This may include ship agencies, installation port authorities, steel fabricators, engineering consultancies, and R&D and education centers.

The Yunlin Offshore Windfarm (640 MW) is about six kilometers off the southwest coast of Taiwan and will feature 80 SG 8.0-167 DD machines. Installation will be split into two phases that will be carried out in 2020 and 2021, respectively. When finished, the Yunlin wind farm will supply power to more than 450,000 homes and reduce CO₂ emissions with more than 916,000 metric tons per year.

Fred. Olsen Windcarrier provides innovative and tailored services for the transport, installation, and maintenance of offshore wind farms.

The Fred. Olsen Windcarrier vessels have installed more than 400 wind turbines offshore and gained extensive experience installing the latest generation offshore wind turbines on some of the world's largest wind farms. The company provides complete project management services and carries a vast engineering expertise in-house and is capable of providing complete turnkey installation solutions for offshore wind turbines with in-house personnel.

MORE INFO www.windcarrier.com

▶ MANUFACTURING

Siemens Gamesa to supply 21 MW for China wind farm

Siemens Gamesa Renewable Energy (SGRE) reached a contract* to supply

six SG 3.4-132 wind turbines with a flexible power rating of 3.65 MW to a wind-farm project in Inner Mongolia, China. The project is developed by the State Power Investment Corporate (SPIC) of China, and it is the first order SGRE received from SPIC.

The order also marks the first landing of Siemens Gamesa 3.X platform model in China, and commissioning is expected in August 2019. Siemens Gamesa also will be responsible for the operation and maintenance of the turbines for five years, and six to 20 years warranty for major components.

The project in Hologola, Tongliao city, is designed as a continuation of a circular economy demonstration project with generated electricity to be self-used by an electrolytic aluminum plant of SPIC. The demonstration project maximizes the use of local resources, including wind, coal, water, and heating, etc.

The latest wind project is also expected to gather wind-farm per-



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Siemens Gamesa secured its first landing of Siemens Gamesa 3.X platform in China. (Courtesy: Siemens Gamesa)

formance data for a planned 6-GW wind-power base of SPIC that has been approved to establish in Inner Mongolia.

“We’re delighted to reach this milestone cooperation with SPIC, one of

China’s top five power producers,” said Richard Paul Luijendijk, CEO of SGRE Onshore APAC. “Based on our global scale and size, business diversification, and technological leadership, SGRE is better positioned than before to sup-

port our customers to harness the power of wind in the world’s largest wind energy market here and beyond.”

SGRE’s history and presence in China dates back to 30 years ago, where the company has installed close to 5.2 GW.

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The Vestas V110-2.0 MW turbine. (Courtesy: Vestas)

*This order forms part of the order intake disclosed by the company in the Q1 FY2019 results.

MORE INFO www.siemensgamesa.com

MANUFACTURING

Vestas receives 224 MW order in the United States

Vestas has received a 224-MW order in the U.S. for V110-2.0 MW turbines.

The order includes supply and commissioning of the turbines as well as a 10-year Active Output Management 5000 (AOM 5000) service agreement.

Deliveries are expected to begin in the third quarter of 2019 while commissioning is planned for fourth quarter of 2019.

The project and customer are undisclosed at the customer's request.

MORE INFO www.vestas.com

MANUFACTURING

Inox Wind licenses AMSC's 3-MW class wind-turbine design

AMSC, a global energy solutions provider serving wind and power grid industry leaders, recently announced that it entered into an exclusive license agreement for a 3-MW class wind turbine design in India with Inox Wind Limited.

Under the terms of the license agreement, AMSC and Inox have agreed that AMSC will be the exclusive supplier of electric control systems (ECS) for Inox's 3-MW class wind turbine. The terms and conditions of the ECS will be set forth in a separate ECS supply agreement between the parties.

"Inox was among the first manufacturers to produce 2-MW turbines locally, in volume, and quickly established a leadership position in the market based on performance and cost," said Devansh Jain, director of Inox Wind Limited. "Leveraging our

vertical approach, which combines best-in-class manufacturing with project development, the production of larger, more efficient 3-MW class turbines will give us the means to augment our market leadership. We remain committed to helping India bridge its power gap with high-performance wind turbines."

"This license agreement opens up the next chapter in our collaboration with Inox," said Daniel P. McGahn, chairman, president, and CEO of AMSC. "Our 3-MW turbine design extends Inox's product line of 2-MW turbines to include 3-MW class turbines and enables the possibility of market expansion. We believe this will place Inox in a strategically competitive position."

AMSC's 3-MW class wind turbine design is required to be certified as having a 3-MW power rating (according to GL2010 onshore guidelines). AMSC's 3-MW class wind turbine may operate up to 3.3 MW under certain grid conditions and certain ambient temperature conditions. ↘

MORE INFO www.inoxwind.com

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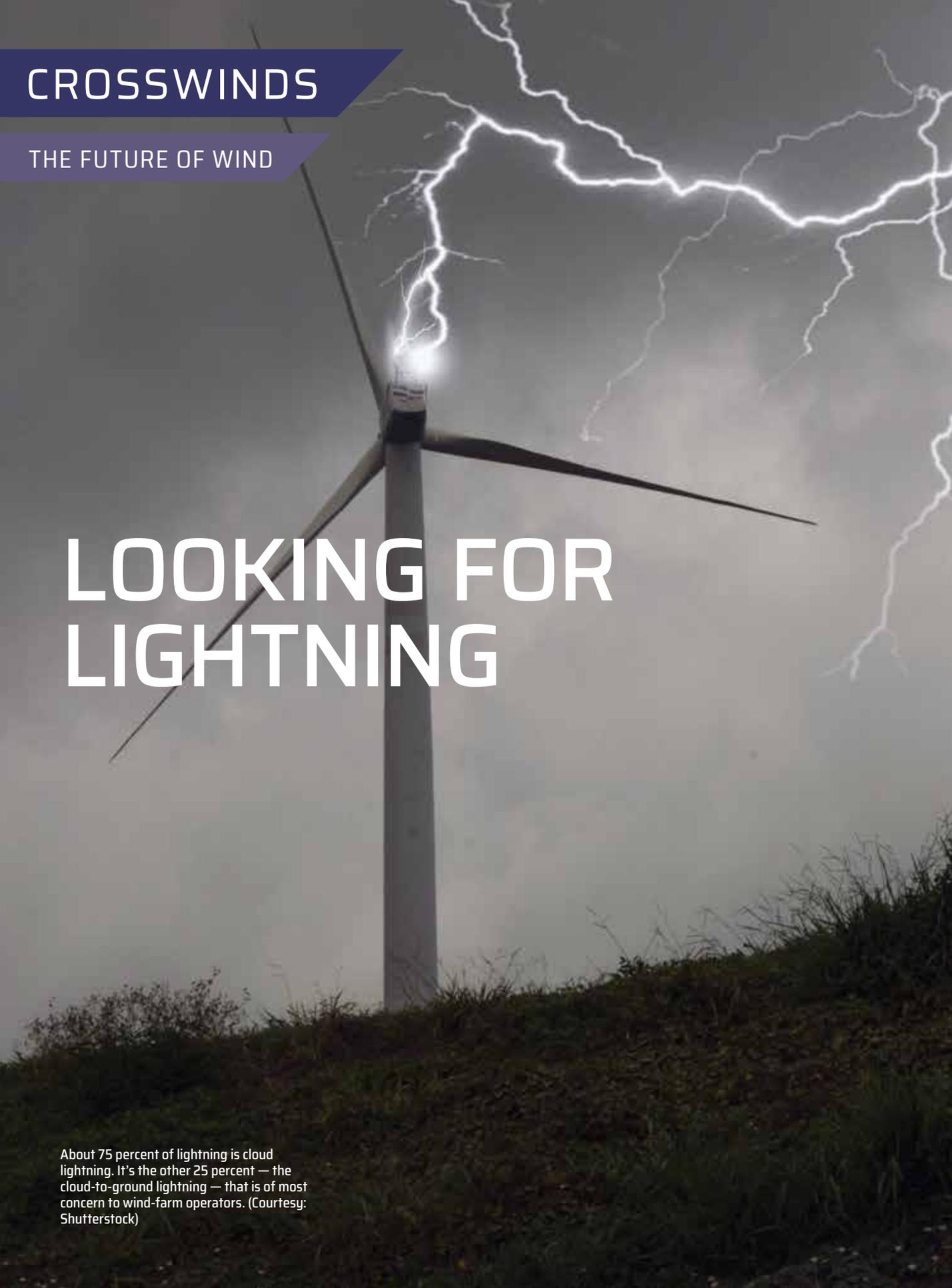
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THE FUTURE OF WIND

LOOKING FOR LIGHTNING

About 75 percent of lightning is cloud lightning. It's the other 25 percent — the cloud-to-ground lightning — that is of most concern to wind-farm operators. (Courtesy: Shutterstock)

Vaisala launches ground-breaking technology that can detect lightning events and their severity, allowing for quick detection of potential damage inflicted on wind farms.

By **KENNETH CARTER** ▸ Wind Systems editor

Lightning and tall objects don't really play well together. And since wind turbines are, by their very nature, extremely tall, that means nature often uses these massive energy producers for target practice.

Those lightning hits can cause turbine damage ranging from the inconvenient to the catastrophic.

Being able to identify where lightning has hit in proximity to a wind farm — and doing it quickly — is vital to making sure repairs can begin as soon as possible.

LIGHTNING EXPERIENCE

New technology from Vaisala has been essential to helping detect those lightning events and their severity.

"We've been detecting lightning for 30 years," said Brooke Pearson, lightning global solutions manager with Vaisala. "Vaisala lightning technology is used all around the world. Across the USA, we have a lightning network called the National Lightning Detection Network, or the NLDN, that's owned and operated by Vaisala. Essentially, what we have are a number of sensors uniformly dotted around the USA, and what they're doing is detecting the electromagnetic waves emitted by all lightning events."

Although Pearson's role with Vaisala is to understand the needs of the marketplace, in this case, wind farms, that understanding also encompasses the needs of the National Weather Service, the military, and others.

Lightning is a fact of life and nature, and as wind turbines continue to get larger, it's important to know how often lightning forces its way into the equation.

While thunderstorms can vary in size and intensity, NOAA reports there are about 100,000 thunderstorms in the U.S. annually, and Vaisala's National Lightning Detection Network records about 70 million cloud-to-ground lightning strokes in the U.S. every year.

About 75 percent of lightning is cloud lightning. It's the other 25 percent — the cloud-to-ground lightning — that is of most concern to wind-farm operators.

BLADE DAMAGE

Some of the more common damage that lightning inflicts on turbines involves the blades, according to Pearson.

"That can be a drastic lightning strike, and I'm sure you've seen some of the images where you see a blade has virtually been blown off by a lightning strike, and it might have some dramatic fire associated with it," he said. "That's a huge problem obviously, but I think the more problematic situations are those involving more minor damage caused by lightning, which can go undetected and perhaps lead to a deterioration of a blade as time goes on."

This can affect power production, as well as the massive cost to replace a damaged blade, according to Pearson.

Once the costs of cranes and shipping and everything else associated with it are factored in, the total cost can reach \$200,000 or more.

CONTINUING CURRENT LIGHTNING

While Vaisala's lightning technology has been detecting lightning for three decades, what the recent advancement brings to the table is the ability to distinguish and detect "continuing current" lightning, Pearson said, which has the capacity to inflict the most damage on a wind farm's assets.

But what makes continuing current lightning so much more of a problem?

"It's a good question that everyone's been looking at," Pearson said. "The reality is that a lightning strike normally only lasts several 10s of microseconds, which is an absolutely small fraction of time. Whereas, these continuing current events can last up to a thousand times that period. They can last for a few 10s of milliseconds."

That time differential may not be detectable by human senses, but it can make quite a difference in the amount of damage that can be done, according to Pearson.

"The analogy that I've used is: Imagine a red-hot poker," he said. "If someone touched it to your skin very briefly, it would hurt, but you'd live. If someone held it to your skin for a much longer period of time — and it wouldn't have to be very much longer — you're talking about severe damage. That's one of the ways that I try and explain the difference between a normal lightning strike and one that has continuing current."

Lightning strikes with continuing current make up about 5 percent to 10 percent of lightning strikes, according to Pearson.

"It's only a small fraction, but it is the fraction that's likely to cause the most damage, because there is a huge transfer of electric charge and, consequently, a huge generation of heat," he said.

DETECTING EVENTS

The basic concept of Vaisala's technology is simple, although the methodology is quite complex, according to Pearson. The lightning network locates lightning events using a combination of direction finding, similar to triangulation, and a technique called time-of-arrival.

"Imagine you drop a pebble into a still pond of water," he said. "You'll know that the waves will ripple out from that pebble. Think of that pebble as lightning and those waves being electromagnetic waves instead. What we're doing is, at various points in that pond, we're detecting those waves. Because each lightning event has a unique electromagnetic signature, we can pinpoint within 100 meters or so of where that lightning actually occurred by comparing the precise



Some of the more common damage that lightning inflicts on turbines involves the blades. (Courtesy: Wojciech Wrzesien/Shutterstock.com)

time the wave hits each sensor.”

The lightning network is able to advise people on the amplitude of the lightning current as well, according to Pearson.

“It identifies the peak current in kiloamps,” he said. “A lightning strike can range from a few kiloamps up to the real big ones up to 300 kiloamps. You wouldn’t want to be in the way of that, by the way.”

Most cloud-to-ground lightning that might affect wind-farm assets is going to be in the range of 15 to 20 kA, according to Pearson. The lightning events with the higher magnitudes are the ones that are often flagged by asset managers because those are assumed to be the ones that cause the most damage. Ironically, continuing current tends to be associated with the lower magnitude lightning events.

SATELLITE ASSISTANCE

“Actually, these events with continuing current can cause huge amounts of damage,” he said. “The way we identify those is by combining our ground-based detection technique with data from the relatively recently launched satellite. There’s a lightning sensor, which is carried on GOES (Geostationary Operational Environmental Satellite) that was launched by NASA and NOAA. It’s looking down on a large area including the USA. It is looking at the optical signal emitted by lightning, so different to our ground-based lightning detection.”

Using that information, the satellite is able to determine the duration of the lightning event, and the Vaisala technology determines if it is a cloud-to-ground lightning strike as well as detecting precisely where it struck the ground, according to Pearson.

“Put the two bits together, and we can determine which strikes have continuing current,” he said.

Although lightning can cause power surges that can be harmful to a turbine, most lightning damage occurs from dramatic heating of the composite blade materials, according to Pearson.

“I think the primary issue on a wind farm is really about the blade damage, with some justification,” he said. “If the wind farms are responsible for transformers and other electrical equipment around, I think they would be concerned about lightning’s impact on those assets. It is really critically important that they apply high-quality surge and lightning protection. Voltage spikes can cause big problems.”

LARGE-SCALE DETECTION

Some wind turbines are equipped with lightning detection sensors; however, Vaisala’s technology can go beyond a pre-determined location, according to Pearson.

“The huge advantage of the way we are detecting lightning is that we can do it on a very large scale and with great accuracy,” he said. “Our detection capability, the National Lightning Detection Network, actually covers the whole of

AD INDEX

Abaris Training Resources.....	7
AIMCO.....	16
American Chemical Technologies.....	1
American Gear Manufacturers Assn (AGMA).....	23
AWEA (American Wind Energy Assn).....	33
Castrol Industries.....	3
Elevator Industry Work Preservation Fund.....	37
Gray Analytics.....	27
Kalamazoo Valley Community College.....	40
Mersen France Amiens S.A.S.....	35
Norbar Torque Tools Inc.....	5
NTC Wind Energy.....	7
Ozzie's Pipeline Padder.....	47
Petzl America.....	IBC
Snap-On Tools.....	17
Stahlwille Tools LLC.....	47
TEAM-1 Academy.....	21
Thermal Cam USA.....	27
The Timken Company.....	BC
TORKWORX LP.....	IFC
Transportation Partners & Logistics.....	40
United Gear Works.....	41
Wind Systems.....	39

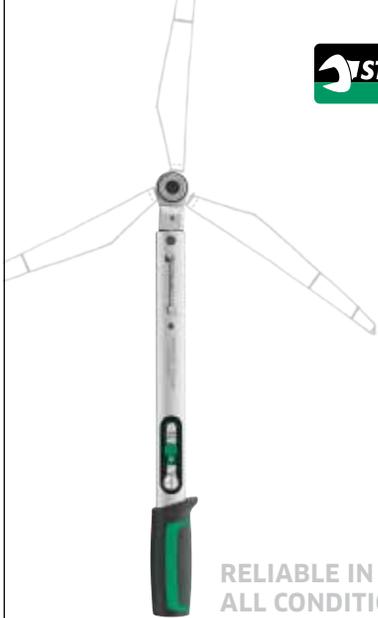
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 **WIND FARMS**



Although lightning can cause power surges that can be harmful to a turbine, most lightning damage occurs from dramatic heating of the composite blade materials. (Courtesy: Shutterstock)

the USA. We, by the way, also have a global network that detects lightning all across the globe. It's similar, but slightly different, technology, which means that we can do the same exercise in South America, for example. The issue is satellite coverage with respect to this continuing current capability. You need the satellite component for continuing current. We can detect lightning everywhere, but for the continuing current, we need to have the satellite's lightning data to add that extra bit of information."

As the technology gets rolled out, Pearson said wind-farm operators and others in the industry are interested in implementing it.

"We've talked to a number of organizations in the wind industry," he said. "Our intention is to release this to the industry in a few months' time. We're looking to make it available for this coming lightning season. There are many wind-farm operators who use our lightning data already, and we'll be able to talk to these organizations about it and how they can use this new information in the tools they already have."

LIGHTNING SEASON

With lightning season in the U.S. starting to ramp up in March and April, Vaisala's technology will be useful to wind

farms that dot the landscapes of Texas, Oklahoma, and Kansas, to name a few.

"Many of these wind farms might have several hundred wind turbines," Pearson said. "When you get a thunderstorm come through, you might have thousands of lightning strikes potentially impacting these hundreds of wind turbines, and they really need to determine fairly rapidly which ones are likely to have been damaged. They need to be able to manage their maintenance crews. It's a massive job to maintain and inspect these units, and they need to do it quickly and focus on those most likely to have been damaged to avoid further damage in the future, and loss of revenue from power interruptions."

And as the technology is introduced, Pearson said he thinks it will improve the efficiency of how the turbines are inspected and maintained.

"I think the more we can understand the impacts of lightning on wind turbines and wind farms, then that efficiency increase is going to make a difference to the way decisions are made," he said. "A lot of it is about having the information, but it's also understanding the information." ✎

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