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TECHNOLOGY
UpWind Solutions

SEPTEMBER 2013

FEATURES

DEPARTMENTS

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EDLETTER

Everybody needs a good six-month vacation every now and then, right? By outward appearances, that's what it seems like the U.S. wind energy industry did for the first half of this year.

Clearly, that's not the case. The industry has been working diligently, and has done so within the abbreviated timeline set forth by factors that were out of its control.

Still, it's frustrating that the industry faced and excrutiatingly long delay after the now-traditional "wait-and-see" period following the PTC renewal. Healthy anticipation gave way to anxiety, which in turn gave way to uncertainty, doubt, and worry. That's not good for industry confidence or workforce morale.

On the plus side, industry activity is on the uptick. In its second quarter market report, AWEA reported that wind energy demand is still high, citing RFP/PPA activity and projects currently underway.

That's a glimmer of encouragement and hope. Unfortunately, those statements were immediately preceded by the fact that in the first half of this year, the U.S. wind energy industry installed 1.6 MW of capacity. That's not a typo in the abbreviation. One-point-six-megawatts. With an "M."

Allow me to put that in perspective. In 2012—our biggest year ever—the industry installed 2,988 MW of capacity in the same time period. This year, we've installed five one-hundreths of one percent of the 2012 number.

Prefer a real-life illustration? Imagine working in a completely different industry—tourism perhaps. Last year, the company you worked for was booming. Families swarmed your area and packed out the hotels, restaurants, and attractions—spending boatloads of cash. Your boss was essentially printing money, and rewarded you for a job well done by giving you a nearly $3,000 raise.

Cut to this year, and the tourism in your area has bottomed out. There is simply nothing happening. Your boss is barely able to keep the doors open. Instead of a $3,000 raise, he rewards you with a buck-sixty.

Please don't draw any industry parallels from that illustration. The point is that you don't begrudge your boss for not being able to match the raise from the prior year because there were factors at play that were out of his control. Still, you can't help but be disappointed. You've got two options: sit around, mope, sling blame; or vow to really get after it, determined to once again see success and reap the big reward.

AWEA is correct, however. The industry is regaining momentum. Developers are proposing and and starting projects. Component suppliers and manufacturers running wide-open to fulfill new orders. Utilities are snatching up as much wind as they can.

The waiting period was a chance to decompress, reboot, and refresh (much like a vacation) after all that happened in the industry in 2012. Now we're back to our tasks at hand.

We've had this time to organize and focus. Still, I wonder if we've grown so accustomed to the boom-and-bust cycle that we now depend on these lulls to recharge our batteries and strategize. Do we now depend on the boom-bust cycle itself as part of our routine? Do we plan for it? Is it a vacation to us? If so, is that wise?

Those are not rhetorical questions. I'd love to hear your opinions on the industry—on any and all topics. Please feel free to call or e-mail me at any time.

Speaking of reboots, *Wind Systems* will be making some revolutionary changes in the coming months as we step into what is expected to be a big year for the industry. I'll discuss those changes here in future issues as 2014 draws nearer. We've been working diligently on examining and defining our role in the wind energy industry. We're excited about what we've got planned, and look forward to serving our readers industry information needs in innovative new ways in the future.

Thanks for reading!

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PALDISKI ONSHORE WIND FARM OFFICIALLY OPENED IN ESTONIA

GE has announced the opening of the Paldiski Wind Farm on the Pakri peninsula in northwestern Estonia. With 18 GE 2.5-100 wind turbines, the Paldiski Wind Farm marks the commercial debut of the company's wind turbine technology in Estonia, one of Europe's most promising wind sectors. GE representatives were joined at the ceremony by officials from Eesti Energia AS and Nelja Energia AS , the owners of the wind farm, as well as President of Estonia Toomas Hendrik Ilves.

"I am glad that Paldiski wind farm has been completed. One more efficient power plant has been added to Eesti Energia's generating portfolio, as wind conditions on Pakri peninsula are excellent," said Sandor Liive, chairman of the Eesti Energia management board. Eesti Energia currently operates four wind farms: Paldiski, Aulepa, Narva and Virtsu, with a total capacity of 111 MW.

Thanks to strong winds coming off the Baltic Sea and the installation of the Paldiski Wind Farm, Estonia experienced a significant development for wind power last year. According to Martin Kruus, who is the chairman of the board of both Nelja Energia and the Estonian Wind Power Association, Estonia erected a record number of wind turbines last year with a total capacity of 86 MW that led to the overall capacity of 269 MW. "The amount of wind energy generated during 2012 grew by 23 percent," said Kruus.

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

"Wind continues to play a significant role in powering communities, and GE's wind turbines offer high efficiency and reliability for a broad range of wind conditions," said Cliff Harris, general manager, GE Renewable Energy Europe. "Our 2.5-100 wind turbine is a product of GE's evolution in the wind industry and is an excellent addition to the multi-megawatt wind sector. Advancements in serviceability and grid integration from earlier GE turbine models make it a great fit for Estonia's robust wind conditions."

To ensure successful operation and maintenance support, the wind farm is supported by a 10-year full service agreement from GE, which includes advanced anomaly detection, unplanned maintenance and an availability guarantee.

For more information, visit www.ge-energy.com.

EWEA OFFSHORE 2013 WILL ADDRESS FINANCE CONCERNS

Offshore wind in Europe has now reached a capacity of 6,040 MW, from 58 wind farms in the waters off ten countries. 1,045 of those MW were installed in the first six months of 2013 alone, when 277 new turbines came online. Across the Atlantic, offshore wind projects are still in their infancy, but a new horizon for wind energy is starting to open up. With construction on the much-debated Cape Wind project expected to begin later this year, and new offshore leases currently being awarded along the Atlantic coast, the opportunities for offshore wind in the U.S. have never been greater.

But is the technological know-how up to speed? Turbine size, foundation type and maintenance strategies are all crucial considerations for any project developer. Then there is the complexity of getting these projects online: convincing investors; negotiating permitting and logistics; training and recruiting staff; connecting to the grid. Here, the mature markets of Europe have much to offer in terms of best practice, shared experiences, and technical expertise.

When Europeans wanted to know about computers in the 1990s, they didn't stay in Europe; they went to Silicon Valley in California. Now the reverse is true for wind energy: while the U.S. wind industry already has several decades of onshore expertise, it's their European neighbors who have the experience in offshore. And the European offshore wind industry will be gathering this November at EWEA OFFSHORE 2013—the world's largest offshore wind energy conference and exhibition—to share its knowledge, display its products, and do business. The event, held every two years, is a showcase for companies and a learning opportunity for thousands of professionals. The 2011 edition attracted more than 480 exhibitors and over 8,200 participants, and exhibition space for this year's event in Frankfurt, Germany in November is almost sold out.

But things in the offshore wind sector have changed since 2011, and the focus and location of the 2013 event have been chosen to reflect this. Given the massive requirements for investment in developing offshore wind, and the current economic crisis, finance is a major concern for the offshore wind industry—in the first half of 2013, despite strong growth in offshore installations, just one European project reached financial close. The conference's Financing Track will center on a major issue for investors: Risk—overcoming transmission risk; de-risking projects; and how new financing instruments can lower the cost of capital.

While wind energy in the U.S. has been given another breath of life thanks to the extended PTC, much investor uncertainty in Europe stems from the current lack of a stable EU regulatory framework for renewable energy beyond 2020. At the forefront of the political debate is the question of binding EU climate and energy targets for 2030, and in this context, EWEA's OFFSHORE 2013 event will open with a high-level plenary session featuring European politicians debating their positions on 2030 targets, which has far-reaching implications for the entire wind industry.

Another important question for investors is the relatively high cost of offshore wind, and the maturity of an industry that has grown so quickly. Throughout the conference program, sessions have been designed to show how the sector is addressing the twin issues of reducing the cost of energy and moving towards full industrialization. The conference tracks 'Markets, Strategies and Planning,' 'Future Technologies,' and 'Industrializing the Supply Chain' hold a wealth of information from people working in the offshore wind energy sector.

The opportunities for exchanges between the participants from different countries and regions will be key for many attendees. In 2011 in Amsterdam, 62 countries were represented among the participants, making it a truly international event. With companies exhibiting and presenting from the U.S., Asia and all across Europe, the 2013 event will certainly follow suit.

At an event with such a diverse mix of participants and activities, occasions for making new contacts are everywhere—including specific networking events such as the lively opening reception and the glamorous conference dinner. Of the previous EWEA OFFSHORE event, Jean Huby, CEO, Areva Wind said "If we want to succeed in offshore wind we need to build strategic partnerships. We need to know the people, we need to network with them and here we have the whole industry present."

AWEA REPORT: WIND DEMAND HIGH DESPITE LATE PTC RENEWAL

After coming to a standstill in the first half of 2013 due to Congressional delay in extending the federal wind energy Production Tax Credit (PTC), activity in the U.S. wind industry is ramping back up as a strong wave of utilities sign up for more wind power, according to the American Wind Energy Association's U.S. Wind Industry Second Quarter 2013 Market Report.

Throughout 2012, the industry awaited a policy signal from Congress via a PTC extension, but that extension didn't come until New Year's Day of this year. As the industry had previously warned, with wind energy project timelines spanning 18-24 months, the delay had serious consequences, and its impacts have continued to ripple through the industry well into 2013.

Only 1.6 megawatts (MW) of wind power were commissioned during the first half of the year and none at all during the second quarter, yet activity is now robust in areas that indicate impending project construction—namely, requests for proposals (RFPs) and power purchase agreements (PPAs). More than 20 RFPs have been issued, and extremely competitive prices for wind energy are spurring utilities to ink contracts for even more megawatts than their initial RFPs requested. Approximately 1,300 MW are now under construction, while more than 3,600 MW in PPAs are secured. In total, utility plans for more wind announced in the first six-plus months of the year total nearly 5,000 MW.

"The market pattern playing out in U.S. wind energy right now tracks exactly with warnings sounded by the industry a year ago, and with studies that examined the consequences of not extending the PTC," said AWEA CEO Tom Kiernan. "No industry can contribute what it's capable of giving America without stable policy, and wind energy is Exhibit A of that reality. The industry is hard at work getting geared up to meet the strong demand for more wind energy, but if it's going to generate more jobs and clean energy for America in the future, it simply must have the same kind of policy certainty under which other industries operate."

GL GARRAD HASSAN CONTINUES TO HELP UNLOCK NEW CAPITAL FOR OFFSHORE WIND

With the support of technical due diligence advice from GL Garrad Hassan, Sumitomo Corporation and its subsidiary Sumitomo Corporation Europe have agreed to invest significant amount of equity in two Belgian offshore projects. The Belwind 1 operational wind farm and Northwind project together account for 127 wind turbines and 381 MW of generating capacity with total project cost of about €1,550 million. The investment by Sumitomo is further evidence that offshore wind is attracting new sources of equity capital. Sumitomo agreed to take 39 percent of Belwind 1 and 33 percent of Northwind.

Specialist engineering knowledge and skills from GL Garrad Hassan provided technical due diligence to Sumitomo Corp. The GL Garrad Hassan team examined the key areas of technical risk, including energy production, technology and design, asset status, contracts, grid and permitting.

The Sumitomo investment is the latest of a number of project finance deals involving alternative equity for European Offshore Wind Projects. This is seen as

a healthy trend as it reduces the reliance on the already stretched balance sheets of European Utilities.

Jo de Montgros, Head of Independent Engineering at GL Garrad Hassan, commented: "This deal is proof, if it were needed, that offshore wind is a proven asset class. We were delighted to be able to assist with the mobilisation of new capital in the offshore wind business by providing the required level of clarity and independence to our customer."

For more information, visit www.gl-group.com.

NORDEX'S FIRST N117/2400 WIND FARM INSTALLED IN FINLAND

Nordex has installed its first N117/2400 wind farm in Finland, simultaneously passing an important milestone in this country. Comprising nine N117/2400 multi-megawatt turbines, the 21.6 MW Honkajoki wind farm has now been connected to the grid for Finnish wealth management company Taaleritehdas. Mounted on steel tube towers with a height of 120 metres, the turbines will yield of up to 75 GWh per year. Honkajoki is the first project under a frame contract signed with Taaleritehdas in June 2012 providing for the delivery of up to 111 turbines.

Nordex completed the Honkajoki wind farm ahead of schedule thus allowing Taaleritehdas to generate energy earlier than anticipated and tap into the "early bird premium" for wind power generated before 2016. "This marks a real success for our new activities in Finland and creates an excellent basis for future projects with Taaleritehdas," said Lars Bondo Krogsgaard, a member of Nordex SE's Management Board.

Honkajoki is located in a flat woodland region in the southwest of Finland. Thanks to the Nordex N117 wind turbine and its remarkable suitability for Finnish wind conditions, the wind farm achieves a high capacity factor around 40 percent.

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

BROADWIND REPORTS Q2 2013 RESULTS

Broadwind Energy, Inc. has reported sales of $51.4 million for the second quarter of 2013, a 9 percent decrease compared to $56.3 million in the second quarter of 2012.

The decline reflected weaker activity in the Gearing and Services segments, partly offset by stronger revenue in the Towers and Weldments segment due in part to a 42 percent increase in industrial weldments revenue compared to the prior-year second quarter.

The company reported a net loss from continuing operations of $0.2 million or $.01 per share in the second quarter of 2013, compared to a loss of $4.2 million or $0.30 per share during the second quarter of 2012. The improvement was due to stronger operating results in the Towers and Weldments segment as well as the gain on the sale of the company's idle tower facility during the current-year quarter. The company reported non-GAAP adjusted EBITDA (earnings before interest, taxes, depreciation, amortization, share-based payments, and restructuring costs) of $2.7 million during the second quarter of 2013, compared to $1.1 million during the second quarter of 2012.

Peter C. Duprey, president and chief executive officer, stated, "Our second-quarter results showed the strength of our Towers and Weldments segment in which we booked $52 million of new orders during the period, and announced another $70 million after quarter-end. We have sold out our 2013 capacity, and are now booking orders well into 2014. We expect 2014 production to reach or exceed our design capacity of 500 towers. During the second quarter, we demonstrated a dramatic improvement in productivity and tower through-put compared with last year when we were experiencing production issues associated with manufacturing multiple tower types at the same time. Process improvements that we initiated in 2012 and a generally better mix of towers resulted in strong EBITDA in the quarter.

"Finally we have strengthened our balance sheet by achieving some major milestones, including selling our idle Brandon, South Dakota tower facility for $12 million, paying down additional debt of $6 million and ending the quarter with $18 million of cash."

The company booked $59 million in new orders during the second quarter of 2013. Additionally, a $35 million tower order from 2010 was removed from backlog due to a change in the customer's U.S. wind requirements. As a result, net orders for the second quarter of 2013 were $25 million, a 17 percent decrease compared to the prior-year second quarter. Towers and Weldments orders, which vary considerably from quarter-to-quarter, totaled $18 million, net of the $35 million cancellation noted above. Second-quarter net Gearing orders totaled $5 million, a 70% decrease from the prior-year second quarter, reflecting continued weakness in orders from natural gas and other industrial customers as well as less demand for wind replacement gearing. Net orders for Services totaled $3 million compared to $5 million in the prior-year quarter, due to weaker demand for field services, as a number of customers have insourced work during a period of low turbine construction activity.

At June 30, 2013, backlog totaled $143 million, up from $137 million at June 30, 2012. Subsequent to quarter-end, the company announced new tower orders of $87 million, $17 million of which were included in backlog as of June 30, 2013.

Towers and Weldments segment sales totaled $37.5 million in the second quarter of 2013, compared to $37.0 million in the second quarter of 2012. Tower section volume in the second quarter of 2013 was down 12 percent compared to the prior year. The prior-year production consisted of a greater number of lighter, lower-value sections as compared to the current-year second quarter. Additionally, $4.4 million of completed tower sections remained in inventory at quarter-end because a customer first article qualification process was not completed as planned. Revenue for these sections will be included in the third-quarter results. Consistent with the Company's strategic focus on diversifying end markets, industrial weldments sales of $3.2 million increased 42 percent compared to the prior-year period, more than offsetting the tower shortfall noted above. Non-GAAP adjusted EBITDA for the second quarter was $5.3 million; nearly triple the prior-year second quarter adjusted EBITDA of $1.8 million. The dramatic improvement was the result of improved operating efficiencies and a less variable and more profitable mix of towers. During the second quarter of 2012, productivity suffered due to the production of multiple tower types in that quarter. Towers and Weldments segment operating income for the second quarter of 2013 was $4.1 million, up $3.5 million from the second quarter of 2012 due to the factors described above.

Gearing segment sales totaled $10.4 million in the second quarter of 2013, compared to $14.1 million in the second quarter of 2012. The 26 percent decrease was due primarily to lower demand from mining and natural gas customers as well as protracted manufacturing issues with a new line of gearboxes for an industrial customer. Gearing segment non-GAAP adjusted EBITDA for the second quarter of 2013 was a loss of $0.1 million, decreasing from $1.3 million in the prior-year second quarter due in part to lower volumes and lower margins, partly offset by reductions in fixed costs and lower compensation, bad debt and other professional expenses. Gearing segment operating loss for the second quarter of 2013 increased to $3.9 million, from $1.6 million in the prior-year second quarter. The increased operating loss was partly attributable to $0.7 million of higher restructuring charges and $0.5 million of accelerated amortization as well as the factors described above.

Revenue from the Services segment was $4.1 million in the second quarter of 2013, compared with $5.7 million in the second quarter of 2012. The 29 percent decrease was due in large part to depressed field service activity as a result of very low wind turbine installations across the United States, reflecting the curtailment of development work in late 2012 in response to the uncertainty regarding the production tax credit as mentioned above. This has resulted in wind farm operators insourcing non-routine maintenance projects during this same period. Non-GAAP adjusted EBITDA loss for the second quarter of 2013 was $0.6 million, compared with $.5 million in the prior-year second quarter. As a result of the 29 percent drop in sales, the company reduced headcount during the quarter and reduced SGA costs compared to the prior-year second quarter. Services segment operating loss of $1.3 million in the second quarter of 2013, increased $0.2 million, from a loss of $1.1 million in the second quarter of 2012, reflecting $.1 million of additional restructuring charges in the current-year second quarter as well as the factors described above.

For more information, visit www.bwen.com.

LARGEST FEDERALLY-OWNED WIND FARM BREAKS GROUND AT U.S. WEAPONS FACILITY

Building on President Obama's Climate Action Plan, which calls for steady, responsible steps to reduce carbon pollution, the Energy Department today broke ground on the nation's largest federally-owned wind project at the Pantex Plant in Amarillo, Texas. Once completed, this five-turbine 11.5 MW project will power more than 60 percent of the plant with clean, renewable wind energy and reduce carbon emissions by over 35,000 metric tons per year—equivalent to taking 7,200 cars off the road. The Pantex Plant is the primary site for the assembly, disassembly, and maintenance of the United States' nuclear weapons stockpile.

Under the Obama Administration, federal agencies have reduced greenhouse gas emissions by more than 15 percent—equivalent to permanently taking 1.5 million cars off the road. To build on this accomplishment, the Administration has established a new goal: the federal government will consume 20 percent of its electricity from renewable sources by 2020—more than double the current goal of 7.5 percent.

"As the largest energy user in the country, the federal government has a tremendous opportunity to lead by example in taking actions to improve energy efficiency and increase renewable energy usage to save taxpayers dollars and reduce greenhouse gas emissions," said Deputy Secretary of Energy Daniel Poneman. "Responsible development of America's wind energy resources is a critical part of our all-of-the-above energy strategy, and the Pantex wind project furthers our commitment to lead by example and to advance a cleaner, more sustainable energy future."

Located on 1,500 acres east of the Pantex Plant, the wind farm will generate approximately 47 million kilowatt-hours of electricity annually – more than 60 percent of the annual electricity used for Pantex, or enough electricity to power nearly 3,500 homes. The project is expected to complete construction and start generating electricity in summer 2014.

Siemens will construct the wind farm under a performance-based contract that uses long-term energy savings to pay for the project costs, avoiding upfront costs to taxpayers. In 2011, President Obama challenged federal agencies to enter into $2 billion worth of performance-based contracts within two years. Federal agencies have since committed to a pipeline of nearly $2.3 billion from over 300 reported projects, including the Pantex wind project.

Last week, the Energy Department released two new reports showcasing record growth across the U.S. wind market, increasing America's share of clean, renewable energy, and for the first time representing the number one source of new U.S. electricity generation capacity. The 2012 Wind Technologies Market Report found that Texas is the country's largest and fastest growing market. With 12,214 MW of total wind capacity installed at the end of last year, Texas has more than twice as much wind power capacity as the next highest state and more wind capacity than all but five countries worldwide.

The Energy Department and the National Nuclear Security Administration worked with interagency partners, including the Environmental Protection Agency and the Federal Aviation Administration, as well as Texas Tech University to launch this project.

STUDY PRICE OF U.S. WIND NEAR AN ALL-TIME LOW

Annual wind power additions in the United States achieved record levels in 2012, while wind energy pricing is near an all-time low, according to a new report released by the U.S. Department of Energy and prepared by Lawrence Berkeley National Laboratory (Berkeley Lab). Roughly 13.1 GW of new wind power capacity were connected to the U.S. grid in 2012, well above the previous high in 2009, and motivated by the scheduled expiration of federal tax incentives at the end of 2012. The prices offered by wind projects to utility purchasers averaged $40/MWh for projects negotiating contracts 2011 and 2012, spurring demand for wind energy. At the


THE TECHNOLOGY
INSIDE

same time, even with a short-term extension of federal tax incentives now in place, the wind power industry is facing uncertain times, in part due to low natural gas prices and continued policy uncertainty.

"Wind energy prices—particularly in the central U.S.—now rival the lows set back in 2003," notes Berkeley Lab Staff Scientist Ryan Wiser. "This is especially notable because technology advancements have allowed wind projects to be built in lower quality wind resource areas."

Key findings from the U.S. Department of Energy's "2012 Wind Technologies Market Report" include:

- Wind is a credible source of new generation in the U.S. Wind power comprised 43 percent of all new U.S. electric capacity additions in 2012 and represented $25 billion in new investment. Wind power currently contributes more than 12 percent of total electricity generation in nine states (with three of these states above 20 percent), and provides more than 4 percent of total U.S. electricity supply.
- Despite challenges, a growing percentage of the equipment used in U.S. wind power projects has been sourced domestically in recent years. Wind turbine and component manufacturers met the challenge of supplying a 13 GW market in 2012, albeit with growing pains. Seven of the ten wind turbine suppliers with the largest share of the U.S. market in 2012 had one or more operational manufacturing facility in the United States in 2012; in contrast, only eight years earlier, there was only one active utility-scale turbine manufacturer assembling turbines domestically. In part as a result, a growing percentage of the equipment used in wind projects has been sourced domestically. Focusing on selected trade categories, the percentage of wind turbine costs attributable to imported equipment declined from 75 percent in 2006-2007 to 28 percent in 2012. Conversely, if one assumes that no wind equipment imports occurred though other trade categories beyond those analyzed in the report, then domestic content increased from 25 percent in 2006-2007 to 72 percent in 2012. Exports of wind-powered generating sets from the United States have also increased, rising from $16 million in 2007 to $388 million in 2012.
- Turbine scaling is boosting wind project performance. Since 1998-99, the average nameplate capacity of wind turbines installed in the U.S. has increased by 170 percent (to 1.94 MW in 2012), the average turbine hub height has increased by 50 percent (to 84 meters), and the average rotor diameter has increased by 96 percent (to 94 meters). This substantial scaling has enabled wind project developers to economically build projects in lower wind-speed sites, and is driving capacity factors higher for projects located in fixed wind resource regimes. Wind power curtailment—disallowing the production of electricity from wind projects even when the wind resource would allow for such production, due to transmission or power system limitations—has recently declined in what have historically been the most problematic areas (e.g., West Texas) as a result of concrete steps taken to address the issue.
- Falling wind turbine prices are pushing installed project costs lower. Wind turbine prices have fallen 20 to 35 percent from their highs back in 2008, and these declines are pushing project-level costs down. Based on a large sample of wind projects, average project costs in 2012 were down almost $200/kW from the reported average cost in 2011, and down almost $300/kW from the reported average cost in both 2009 and 2010. Among projects built in 2012, the windy Interior region of the country was the lowest-cost region, with average project costs of ~$1,760/kW.
- Wind energy prices have been falling since 2009, and now rival previous lows. Lower wind turbine prices and installed project costs, along with improved capacity factors, are enabling aggressive wind power pricing. After topping out at nearly $70/MWh in 2009, the average levelized long-term price from wind power sales agreements signed in 2011/2012—many of which were for projects built in 2012—fell to around $40/MWh nationwide. This level approaches previous lows set back in the 2000-2005 period, which is notable given that wind projects have increasingly been sited in lower quality wind resource areas. Wind energy prices negotiated in 2011 and 2012 are generally lowest in the Interior region of the U.S., with prices averaging just above $30/MWh, and typically ranging from $20-40/MWh. Even with today's very attractive wind energy prices, however, wind power sometimes struggles to compete with what are currently very low natural gas and wholesale power prices in many parts of the country.
- Looking ahead, projections are for slow growth in 2013, followed by a much stronger year in 2014. Though federal tax incentives are now available for wind projects that initiate construction by the end of 2013, it will take time to recharge the project pipeline. "As a result, 2013 is expected to be a slow year for new capacity additions, lowering not only U.S. but global growth forecasts," says Mark Bolinger, Research Scientist at Berkeley Lab. "The year 2014, on the other hand, is expected to be a strong year as developers commission projects that began construction in 2013." Projections for 2015 and beyond are much less certain: despite the improved cost, performance, and price of wind energy, policy uncertainty – in concert with continued low natural gas prices and modest electricity demand growth – may put a damper on medium-term growth expectations.

The full report, a presentation slide deck that summarizes the report, and an Excel workbook that contains much of the data presented in the report, can all be downloaded from: http://emp.lbl.gov/reports/re.

Complete preparation, including accounting for all factors prior to the pour, goes a long way in preventing costly foundation failures.

A RECENT REPORT BY GCUBE, a prominent renewable energy industry insurance provider, listed the top five categories of wind project insurance claims in 2012: blades, gearboxes, generators, transformers and foundations. Of these, average foundation claims were far higher than other claim types. An average claim for blade damage or failure was $240,000; average gearbox claims came in at $380,000. Foundation claims averaged $1,300,000 and rose to $2,500,000 in exceptional circumstances. Accordingly, contractors should closely examine their foundation construction procedures to guard against foundation failures.

Avoiding foundation defects depends on complete preparation for each pour. Here are some good ways to be prepared:

BACKUPS FOR EVERYTHING

Foundation concrete must be placed in continuous pours. Most designs for spreading footing foundations allow cold joints only between the pedestal and base. Accordingly, the contractor must have backup equipment available in the event of a failure of critical equipment. This includes pump trucks, generators, finishing equipment, heaters, and any other equipment necessary to insure the integrity of the foundation. If critical equipment fails, the contractor is running against the clock to get the pour back on track before the concrete is unsuitable to pour. A typical life of a load is 90 minutes. Haul distances take up a portion of this time, so backup equipment must be on-site and available.

READY-MIX/BATCH PLANT AVAILABILITY

Whether the contractor is using a ready-mix plant or a batch plant, the facility must be able to keep up with the pour rate needed for the project. Otherwise, pours may be interrupted. A pour rate of 120 cubic yards-per-hour is not unusual, and many ready-mix plants may be unable to meet this schedule. If possible, a backup ready-mix plant should be available, and each facility should have generators available to power the plant in the event of a loss of grid power.

BACKUP MATERIAL

The ready mix facility (or batch plant) must have adequate material on hand to support all pours. The aggregate used for foundations is more than likely not going to be the aggregate typically stocked by the ready mix plant. Any substitutions may greatly affect concrete strength and suitability, and contractors should require (and verify) an adequate stored quantity of aggregate.

WEATHER

Weather is a concern for every pour. The contractor must be confident that the pour can be completed once it starts. Any interruption because of weather can result in serious impacts the integrity of the foundation pour. Accurate daily weather prediction is essential.

Hot Weather Temperature Control—Temperature control as concrete is poured is critical for proper curing. If the concrete is too hot, it can dry out and cure too fast, resulting in a higher possibility for defects. Some ways to control excessive concrete temperatures include:

- Irrigate aggregate piles with cold water pipes and pull aggregate from the interior of the piles.
- Spray rebar with cold water immediately prior to the pour to help reduce the interior foundation temperature.
- Upon pour completion, immediately place cure and seal and cover the foundation with plastic.
- Place ice in the concrete mix at the plant. While expensive, this helps lower concrete temperatures prior to the pour.
- Use chilled water in the concrete mix.

Cold Weather Temperature Control—In cold weather, the object is to prevent cold temperatures from hindering the concrete from developing the proper strength. Contractors need to be concerned when average daily temperatures are below 40° F and the air temperature is not greater than 50° F for more than half a day. The foundation must be kept warm enough to prevent the water in the concrete from freezing, which can result in preventing hydration and dramatically affecting concrete strength and long-term structural integrity. Contractors can take a number of measures to avoid deficiencies caused by low temperatures, including:

- Insure material (aggregate, sand, cement) is not frozen. Do not wash aggregate in cold weather.
- Run material through heaters prior to mixing.
- Keep materials in large piles and take from the interior.
- Pre-heat all rebar.
- Blow hot air on the covered pour and the completed, covered foundation.
- Use hot water in the concrete mix at the plant.
- Use insulated blankets (measurable R-value) over the competed foundation.

TESTING

An often overlooked measure is to cure test cylinders in the same environment as foundation pour to insure test result accuracy.

Julian Bell is the director of preconstruction for Signal Energy Constructors, an EPC/BOP utility-scale renewable energy contractor. For more information visit: www.signalenergy.com.

Jack Wallace
Frontier Pro Services

Schedule contracted maintenance tasks like blade repairs and end-of-warranty inspections well in advance of your completion deadline in order to avoid frustration.

AS MORE AND MORE WIND POWER PLANTS come off of warranty, scheduling for specialty sub-contractors becomes an issue.

Your approach scheduling services in the wind industry has a large effect on the success of your maintenance efforts. In the wind industry maintenance sector, "when, how, and who" really affects the bottom line of your profitability. In our industry, schedules for service are often adjusted daily due to weather changes. For example, if a turbine is scheduled for lubrication service, but winds are strong, instead of stopping the turbine to perform the service, you can allow the turbine to run and come back on another day when the wind is not blowing. At some wind farms, they may just stop the turbine and do the service, and eat the energy production loss. This is not the best option for production, as that wind will never come back. As an owner of a wind farm, you know there are a variety of things that affects the schedule of the wind farm maintenance. Other factors that affect the schedule include: the availability of resources (budget, personnel, parts, equipment, and tools); utility rates; power outages (both scheduled and unscheduled); and varying weather conditions (e.g. lightning, no wind, extreme wind).

Some services that your wind plant requires are not handled by your O&M staff and are contracted out to specialist subcontractors. These services may include: blade inspection and repair; end-of-warranty inspections; and condition monitoring services. Scheduling these services may require long lead times.

There is limited manpower for specific skilled workers in wind, and you, the wind farm owner, are competing with other wind farm owners, operators and managers for these skilled companies and individuals. Let me say that again. You are competing with all the other wind farms in the U.S. for specialty services. For example, in many regions in the U.S., blade maintenance service is performed in the summer months due to the weather patterns. During other seasons, the northern part of the U.S. is too cold or wet to schedule continuous composite repairs. It is well known that scheduling a blade repair in the winter months will cost you considerably more in labor and delays due to weather. This is because of the affects of temperature and moisture on the materials used for service (not to mention the higher wind speeds). This is partly why most blade repair is scheduled during the warmer months. If you are planning to have blade repair performed in August, you can bet that many of the other wind farm owners in the Northern Hemisphere are planning the same thing. You are competing for services with everyone else in the nation for the attention of these service providers. Believe me, as the turbines age, there are more and more needs for repair.

Those wind farm operators who give a decision-maker a budget and allow him time to investigate, choose, and hire a subcontractor will get the first choice of contractors. These operators have successfully scheduled services and reduced their stress level. Those that don't do this are only causing delays and stress to their own internal operation.

Another area that requires advance scheduling is end-of-warranty inspections. Getting that experienced technician out to your wind farm to perform the inspection and provide a report takes some time—but that is just the beginning. The data from the end-of-warranty inspection report needs to be reviewed by an individual or team within the company. Big decisions need to be made as to what may be reported as a warranty claim, and how to follow up on the inspection to get the best results. This takes time, and if the turbine has many warrantable problems, spending quality time on this could result in saving hundreds of thousands of dollars in the cost of repairs. Any undiscovered problems in the turbine become the responsibility of the owner once the warranty period expires. An experienced inspector can get the manufacturer to fix these problems under warranty before it expires.

Scheduling these services a year or more in advance is not unreasonable. If you wait until even six months in advance, you may find that you are too late to get the work performed as you wish.

Why can't you get the service as you had hoped? You did not have the budget in place to schedule the service early enough. You called on contractors that provide the service and found that they were already scheduled elsewhere. Time is ticking and now you are under pressure.

If you don't schedule these specialty services early enough, you will find that the work does not get done, costs extra, or the damages creep up on you later. The damage creep will increase your risk, cost and reduce your ability to be proactive because you will find yourself chasing fires and you will not be able to plan as you wish. Not getting an end-of-warranty inspection done on time is just unthinkable to me, as that could cost you thousands if not millions of dollars in the future that could have been avoided.

If you're the buyer, you need to be ready to schedule your work. To do this you need to supply your decision-maker with a budget, know what you want, and know when you want it. Otherwise, you're just wasting time and delaying or preventing the service from being performed.

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

Jean-Paul Cane
UpWind Solutions

A case study surrounding the impact of Vortex Generators on wind turbine performance.

WIND FARM OWNERS ARE CONSTANTLY SEEKING new technology to help optimize and increase Annual Energy Production (AEP) and while Vortex Generators (VGs) have existed for some time, the latest technology and installation procedures have made VGs a popular topic in wind energy. UpWind Solutions, in partnership with SMART BLADE®, studied the design and installation of VGs to determine exactly how they affected the AEP and the potential ROI for the wind farm owner.

VG CASE STUDY

The case study spanned three months and compared turbines with the UpWind Solutions – SMART BLADE® VG solution to control turbines without them for the purposes of the VG performance evaluation. After analyzing the data, the following conclusions were drawn:

- The mean AEP increase experienced within the three-month time period is in the range of +2.1% to +2.5%. Considering the good condition of the blades and simple topography of the site this is considered a very good performance result.
- The turbine performance without VGs is characterized by significant power scatter. This is most likely the result of considerable aerodynamic stall of a big part or even the entire blade during storms with gusty wind conditions.
- The overall effectiveness of VGs on this site is positive and is able to increase the revenue of the operator/owner with a high ROI.

The AEP of the turbines was calculated based on the actual wind distribution of the site and the measured power curves of the test (A & B) and control turbines (C & D). In all cases the test turbine had a slightly lower performance than the control turbine. However the installation of VGs fully reversed this trend and further increased the energy yield of the test turbines. The increase in AEP for the three months of measurement data were +2.14% for test group A and +2.45% for test group B.

Considering the fact that the test turbines were quite new and their blades are in good condition without indication of any erosion or surface roughness, the AEP increase is quite significant. Addeitional revenue of the turbines (approximately $7,000 per turbine per year) due to the VG installation can consequently pay-back for the VG installation investment in a very short time.

INSTALLATION PROCESS

Every wind turbine manufacturer uses a different geometry for their blades. Thus, for optimal performance improvements, the VG design and installation procedure must be customized for each blade type. This technique is used for every installation of VGs on different turbine platforms. Naturally, identical turbines do not require individual flow analysis procedures, thus keeping the development and installation cost and time to a minimum.

To identify the optimal VG position, it is necessary to investigate in depth the aerodynamic performance of the rotor blades. For this reason, SMART BLADE has developed a proprietary flow analysis methodology that involves flow visualization and advanced image processing and flow analysis. A team of SMART BLADE engineers are responsible for the analysis of the aerodynamics of every new wind turbine type. Custom-made equipment is installed on site and the aerodynamic performance of the test turbines is carefully analyzed.

VALUES OF A CUSTOM INSTALLATION PROCESS

Customized: Custom VG designs maximize energy yield for every turbine technology in which the VG solutions are installed. The design work is performed at the SMART BLADE research facilities in collaboration with the Institute of Fluid Dynamics and Technical Acoustics of TU Berlin. The VG design is accomplished by means of wind tunnel measurements on actual wind turbine airfoils and extensive flow simulations (CFD).

VG Location: A custom V-shape installation line optimizes the stall delay vs. drag penalty. The wind tunnel tests and flow analysis of SMART BLADE® resulted in customized installation locations for each type of blade.

Repeatable: Once the VG pattern is developed, precise installation processes are formulated to assure accurate and repeatable VG placement during installation. Templates ensure aerodynamic balance and reduce total turbine down-time.

Proprietary Adhesive: To install the VGs, rope access technicians apply a durable, proprietary rapid curing adhesive tape. The self-adhesive, cost effective tape reduces room for error and assures form bonding of the VG on the blade even in extreme climates. Utilizing the new adhesive also increases the speed of installation.

Speed: Utilizing custom templates, processes, self-adhesive backing, and skilled rope access technicians, UpWind Solutions was able to achieve an average of less than one day of downtime per turbine resulting from the new installation techniques that improves speed of implementation.

Safety: Safe, certified rope access technicians manage high quality installations at high speed with minimum down-time for the turbines.

Jean-Paul Cane is the Rope Access product line manager with UpWind Solutions. He can be reached at 541-646-3088, or at jeanpaul.cane@upwindsolutions.com. Download the complete case study at academy.upwindsolutions.com/vg-case-study.

LUDECA, INC.

By Stephen Sisk

Combining easy-to-use components, site services, and a support culture, LUDECA, Inc. offers the wind energy industry unique solutions to shaft alignment and condition monitoring.

AS A WIND FARM OWNER OR OPERATOR, how far would you go to ensure that your assets perform as efficiently as possible, for as long as possible?

Individual answers may vary, but the importance of the premise—operating efficiently and being able to plan for ordinarily unforeseen circumstances—can hardly be denied.

You don't have to be an engineer to understand or appreciate that premise. Having the knowledge and ability to make it a reality, however, is a different story. Some things are best left to the experts. Don't try this at home. Trust the professionals.

For more than a decade, wind farm owners for a large part have been trusting their efficiency and preventative maintenance needs to Florida-based LUDECA, Inc.—the exclusive distributor for Prüftechnik products in the United States, the Caribbean, and Venezuela.

That trust and the resulting long-term relationships, directly parallel the company's mission of combining experience, knowledge, and support "to be the premier provider of reliability solutions and technologies to industry."

"LUDECA, Inc. was founded in 1979 and engages in the sales and service of laser shaft alignment systems, condition monitoring, and vibration analysis equipment, oil particle counting systems, and reliability-centered maintenance services," said Alex Nino, wind application engineer with LUDECA.

Building on 24 years of industrial equipment sales and service, LUDECA first entered the wind energy marketplace in 2003. Three years later, in response to the expanding wind industry landscape, the company created the LUDECAwind division.

Through LUDECAwind, the company supplies wind energy maintenance personnel with tools to perform valuable O&M predictive and preventative maintenance tasks, resulting in increased efficiency, reduced downtime, and sizeable long-term cost savings.

"LUDECAwind offers laser shaft alignment systems for alignment of the high speed shafts in wind turbines (gearbox to generator), as well as geometrical alignment / flatness measurement of tower segments and flange hubs, and condition monitoring through vibration analysis," Nino said. "In addition, we offer both portable instruments to perform out-of-warranty inspections and online vibration monitoring as well as an online particle distribution counter."

Shaft alignment, Nino said, is essential not just for wind turbines, but in all rotating equipment applications.

"It guarantees that the machinery will run smoothly and efficiently," Nino said. "It also extends the life of the machinery by eliminating potential premature wear. By performing proper shaft alignment, the users and owners of the machinery will benefit from the savings of having true scheduled maintenance and lower energy consumption."

"LUDECAwind's shaft alignment systems are specifically designed with wind industry applications in mind," Nino said, and are among the easiest to use alignment solutions in the industry.

"Our laser alignment systems are unique in that they only require a single beam laser, and minimal angle of rotation. We have brackets that fit all wind turbine manufacturers and provide the required accessories to guarantee excellent alignment for all the wind turbines and training for the technicians who are performing the work," Nino said.

Specific LUDECAwind product offerings and their applications include:

- OPTALIGN® SMART wind— a generator-to-gearbox shaft alignment system.
- LEVALIGN® EXPERT— a flatness and leveling measurement system for tower segments and rotor hub flanges.
- VIBROWEB® XP wind— a compact online vibration monitoring system.
- VIBEXPERT® wind— a portable data collector forvibration analysis; pre-loaded with turbine OEM data.
- WEARSCANNER®— a particle counter that monitors the distribution of wear particles in lubricants.

In addition to these products, LUDECAwind also the following services to wind farm operators:

- On-site condition assessment including drivetrain vibration monitoring.
- Dynamic alignment target monitoring and optimization.
- Dynamic foundation monitoring
- Flatness measurement of (hubs, flanges,and towe segments)
- Event monitoring and torque measurement
- Telemonitoring from its GL Certified condition monitoring center.

Beyond the company's product and services offerings, the comprehensive support and training functions that sets LUDECAwind apart from competitors in the industry.

"We provide service and in-depth training in several areas such as alignment, vibration analysis, reliability-centered maintenance, and balancing," Nino said. "Our mentoring, consultation, and after-sales services allow us to offer our customers the support they need when they need it."

For more information about LUDECA, visit www.ludeca.com, call 305-591-8935, or e-mail info@ludeca.com.

COVERING YOUR ASSETS

Long-term reliability and personnel safety in electrical power systems depends on quality components, mindfulness of standards, verification, and documentation.

By Mike Moore

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THE PLANNING AND PERFORMANCE of any reliability based maintenance program has always created challenges regarding methodology and frequency of test, contractor qualifications and selection, as well as regulatory and standards interpretation and implementation. Debate also revolves around the effectiveness of on-line predictive maintenance strategies and preventative programs that impact uptime.

With this said, one of the hardest line items to justify in the budget "prove up" is electrical system maintenance and its impact on the reliability to the wind plant. Many components of these electrical systems, including the turbines, were not designed for the ease of maintenance programs. This can be complicated when third-party engineering review and acceptance testing is not included in the development process. Many electrical projects, whether for normal equipment service or even for safety related maintenance, can come with unplanned costs that exceed budgets and create havoc with project cash flow. Additionally, simple test methodology and contractor selection errors as well as poorly implemented maintenance strategies create costly and possibly catastrophic outages. So what do you do? You have to build a "Cover

Your Assets" strategy that protects the electrical equipment and systems, the electrical workers as well as the other stakeholders.

This article is the first of an occasional three-part series that will offer the wind plant owner, designer, developer, and operator some fresh insight—through the eyes of a field-savvy, NETA accredited third party electrical maintenance organization and an EASA-qualified machine repair facility—on how a safety- and reliability-driven electrical protection plan can be developed, documented, and implemented. Each article will be centered wind industry specific challenges:

Part 1—Wind farm electrical specification and installation practices that impact long term reliability and personnel safety.

Part 2—Wind farm electrical practices that impact the turbine and its related components. Not to include the collector system or substation.

Part 3—Wind farm electrical practices that impact the balance of plant to include collector system, substation and the interconnect substation.

FACING REALITY

If the safe, reliable operation of a newly-installed electrical power system and related components is to be achieved, several key components are required:

1. The power system and components must be designed and engineered correctly by a qualified firm that considers maintenance practices, personnel safety and long term reliable operation during the specification and planning process.
2. Only proven quality, design tested and defect free electrical equipment should be specified and procured.
3. The installation must meet all applicable codes and standards and be performed by qualified contractors and vendors.
4. Verification of all of the above should be performed through an independent, third-party inspection process, especially in the absence of AHJ personnel.
5. All information should be documented and archived for future engineering, repair, replacement, upgrade or expansion needs.

Although it sounds pretty simple, these steps often don't happen on an electrical construction project, especially one that is at a remote location.

STANDARDS AND RECOMMENDED PRACTICES

Consensus technical standards and recommended practices are usually developed to establish uniform engineering criteria and practices that help with compatibility, reliability, and safety. The utilization of these standards helps ensure proper design and construction. Some of the applicable standards and regulations that should be considered are listed below, but there are many others.

OSHA—Occupational Safety and Health Administration (OSHA) was established to "assure safe and healthful working conditions for working men and women by setting and enforcing standards and by providing training, outreach, education and assistance". The agency is also charged with enforcing these regulations.

NFPA—The National Fire Protection Association (NFPA) creates and maintains standards and codes for use and adoption by local governments that cover a wide range of topics from model building codes to the firefighting equipment.

Especially crucial for wind plant maintenance consideration is the NFPA 70B, which explains the importance of electrical equipment maintenance, as well as the 70E, which addresses arc flash and the electrically safe working environment.

Current NFPA Standards:

- NFPA 70 — National Electrical Code
- NFPA 70B — Recommended Practice for Electrical Equipment Maintenance
- NFPA 70E — Standard for Electrical Safety in the Workplace
- NFPA 72 — National Fire Alarm and Signaling Code
- NFPA 101 — Life Safety Code
- NFPA 704 — Standard System for the Identification of the Hazards of Materials for Emergency Response
- NFPA 921 — Guide for Fire and Explosion Investigations
- NFPA 1001 — Standard for Fire Fighter Professional Qualifications
- NFPA 1123 — Code for Fireworks Display
- NFPA 1670 — Standard on Operations and Training for Technical Search and Rescue Incidents
- NFPA 1901 — Standard for Automotive Fire Apparatus

NEC—The National Electrical Code (NEC), while having no legally binding regulation as written, can be and often is adopted by states, municipalities and cities in an effort to standardize their enforcement of safe electrical practices within their respective jurisdiction.

AHJ—The authority having jurisdiction (AHJ) is the governmental agency or sub-agency which regulates the construction process where the site is located. They often have their own standards that should be considered during the system design process.

NESC—The National Electrical Safety Code (NESC) or ANSI Standard C2 is a United States standard of the safe installation, operation, and maintenance of electric power and communication utility systems including power substations, power and communication overhead lines, and power and communication underground lines. It is published by the Institute of Electrical and Electronics Engineers (IEEE).

PLANNING FOR MAINTENANCE

Maintenance planning of the electrical equipment and systems should begin at the inception of the project. Consideration should be given to crucial elements such as logistics, access, and equipment configuration, as well as ease of electrical and mechanical isolation. Often the question is asked, "Why test 'new' electrical equipment?" Since the protection of both personnel and the electrical systems is so critical at startup of the plant, verification of proper operation is required. Third-party electrical acceptance is the best manner of confirming the safe performance of the electrical system and its specific components. The test data also provides baseline information that is important to a good maintenance regime. Two general categories of tests are useful. The first—acceptance testing—verifies that all is well at startup. Maintenance testing is used periodically to assure continued reliability, regardless of the operation methodology chosen for the wind plant. The International Electrical Testing Association (NETA) defines these categories as ATS and MTS.

NETA ATS—Acceptance tests are not manufacturer's factory tests. They comprise those tests necessary to determine that the electrical equipment has been selected in accordance with the engineer's requirements, installed in accordance with applicable codes and installation standards, and perform in accordance with their design and setting parameters. The ANSI/NETA Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems assists designers, specifiers, architects, and users of electrical equipment and systems in requesting the required tests on newly installed power systems and apparatus—before energizing—to ensure that the installation and equipment comply with specifications and intended use as well as with regulatory and safety requirements.

NETA MTS—Maintenance tests help determine if electrical equipment is suitable for safe and continued service. When dealing with service-aged equipment, many criteria are used in determining what equipment is to be tested, as well as the intervals and extent of the testing. Ambient conditions, availability of down time, and maintenance budgets are but a few of the considerations that go into the planning of a maintenance schedule. The owner must make many decisions each time maintenance is considered. It is the intent of the ANSI/NETA Standard for Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems to list a majority of the field tests available for assessing the suitability for continued service and reliability of the power distribution system.

Some suggested sources for maintenance strategies are the IEEE STD 902-1998 (Yellow Book): IEEE Guide for Maintenance, Operation and Safety of Industrial and Commercial Power Systems; NFPA 70B: Recommended Practice for Electrical Equipment Maintenance; or NETA MTS-2011: Standard for Maintenance Testing Specifications for Electrical Power Equipment and Systems. The NETA testing standard also offers guidelines for the frequency of maintenance tests within "Annex B" of the document.

ENGINEERING, MAINTENANCE & SAFETY

In recent years, the wind industry has expanded at a rapid pace. These are exciting—and often chaotic— times for the electrical construction contractor and the new generation of wind farm electrical workers. Many of these workers have never been exposed to the hazards that the wind turbine and collector system present, and most of them still have very little knowledge of the toxicity of electricity. In the last several years the wind industry has found the value of proper engineering on the front end of a project, including acceptance testing and commissioning prior to initial energizing. Additionally, many studies have shown that routine maintenance, including testing of electrical distribution equipment, has increased reliability and minimized downtime for commercial and industrial facilities; these same philosophies hold true for wind farms.

The same can be said about protecting electrical workers who operate or service energized electrical equipment, as we now can calculate that the incident energy produced by an arcing fault is proportional to its operating time. This aspect of incident energy means that proper maintenance and testing of the over-current protective devices (OCPD) is not only an operational issue, but is also a safety issue.

The very nature of maintaining an operational wind farm in a remote, outdoor and often windy environment also presents unique hazards typically not found in the commercial or industrial workplace.

REGARDING CONTRACTORS

The introduction of third-party contractors to the work site is one of the biggest exposures to liability and risk for either the plant owner or the contractor. How do you ensure the use of a contractor that has the desired safety culture as well as technical depth and talent? Before any work takes place, you should qualify the company to make sure their safety goals align with yours. You should then qualify the electrical workers to ensure that they can safely perform their services for your customer and livelihood, as well as safely interact with your electrical workers.

DATA COLLECTION

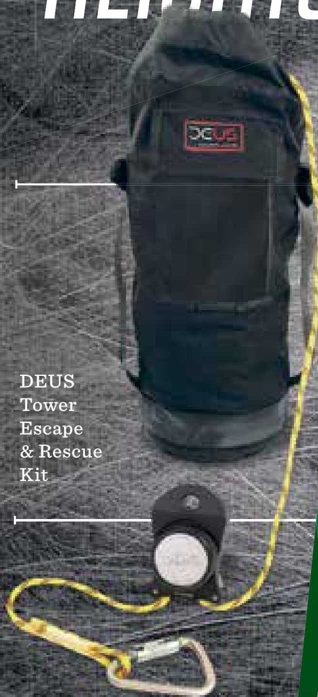
Specifying the collection and delivery format of the initial technical data is a must. Quality equipment performance data is extremely vital to trend and track the electrical equipment and system performance for the long term planning for any eventual modification of testing methodologies or frequencies of maintenance to equipment throughout the electrical equipment's extended years of service.

CONCLUSION

To assure the owner that his electrical assets are safe and reliable, the contracting officer should always confirm the qualifications of the testing company prior to awarding any contract. Certification requirements are placed in bid documents to protect the consumer. Nationally-recognized certification agencies and technicians with these certifications have a proven level of competency. The consumer is assured that the technician has a well-rounded knowledge of electrical testing.

All good testing and maintenance stratagems are designed to ensure the profitability of the operation. Periodic electrical testing, vibration testing, and alignment of the drive train are time consuming operations and are sometimes difficult to perform on a regular basis. However, the cost of unplanned outages including cranes, staffing and emergency generator repairs can also dramatically affect the bottom line. Good planning, proper testing, and clear decisions regarding the condition of the equipment will always pay off with reduced overall maintenance costs.

TAKING DESCENT TO NEW HEIGHTS



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CRITICAL COMPONENT—CABLES

Choosing the right cable for specific turbine applications is essential for wind farm success.

By Uwe Schenk

Uwe Schenk is the global segment manager–wind with Helukabel. He can be reached at wind@helukabel.com, or by phone at 847-930-5118. For more information, visit www.helukabel.com.

FROM THE ROTOR TIP TO THE TOWER BASE, cables are located throughout the wind turbine keeping these renewable energy power generators operating at peak efficiency. From power cables, torsion cables, fiber optic conductors, and cables for monitoring and communications to medium-voltage and fiber-optic cables for connecting into the local power grid, cables are a critical component in the success of a wind farm.

The cable framework in a wind turbine generator system (WTGS) depends on various factors, which are predetermined by the tower structure and the customer. There are various types of towers and these can be classified into five categories: steel-tube towers, concrete-tube towers, wood towers, pylon towers and hybrid towers. The hybrid towers are made of steel-reinforced concrete and steel elements and can currently be constructed up to 460 ft (140 m) in height. Depending on the construction of the tower the design of the cable framework can then be suggested to support the turbine's power generation capacity. A wind turbine produces between 1.0 and 7.6 MW, and that power needs to be brought down from the nacelle.

COPPER OR ALUMINUM? HOW ABOUT BOTH.

The turbine's power cables can be made of copper or aluminum. Each conductor material has its own group

are used as compared with flexible copper cables. These savings are inclusive of the fact that more aluminum is needed to match the power levels of copper cable (i.e. a larger gauge size is needed for the aluminum cable).

Cable selection should be a collaboration between the cable manufacturer and the turbine developer. These discussions should take place with the engineers during the planning phase. The ideal power cable network should come from the four different types of existing designs. Those are Class 2 copper, Class 5 copper, Class 2 aluminum, and Class 5 aluminum. In Class 2, both copper and aluminum are rigid and inflexible. The Class 5 strand structure is the flexible version.

COPPER FOR THE LOOP

Every manufacturer of electric cables and wires has their own philosophy on selecting the correct insulation and conductor material. There are suppliers that recommend aluminum for the torsion application in the WTGS cable loop. However, many cable manufacturers test their cables for up to 10,000 cycles only. Experience tells us that testing for 15,000 to 18,000 cycles gives a more accurate, long-term test result.

Results from tests run in our turbine test tower and from past experience shows that the aluminum application doesn't work effectively in the loop. With WTGS service lives of approximately 20 years, demands of up to 15,000 torsion cycles will be placed on the wires in this application. This part of the power cable network, from the generator through the freely suspended loop and through the tower interior wall represents genuine stress for the wires. That is why cable specialists use exclusively Class 5 copper cabling, which has a much better ability to cope with load. The ongoing movement of the torsion cables requires a non-stick surface that allows the cables to glide easily. Therefore, special, highly abrasion-proof materials are used as the insulation material for the conductor insulation and jacketing.

In addition, through our extensive tests we have discovered that torsion cables with a braided shield, so called C-shield, is not optimal for loop cables. We have seen damages on these types of cables after 1,000 torsion cycles. These tests further showed that a D-shield is best for high endurance under consistent twisting and un-twisting conditions.

The loop cable is one of the trickiest points in the power cable network of a wind turbine and can be the Achilles heel, if the correct cable is not selected.

of supporters. Those that prefer copper cable feel this material has been tested over time and has proven to be safe and reliable. Aluminum is preferred by others because it focuses on the commercial aspect of the project, i.e. aluminum is cheaper than copper.

Aluminum makes you relatively independent of the price trend, whereas copper is much more volatile. When the copper price changes the project's management team might have to re-think their entire material calculations to stay on budget. With aluminum, they do not have to recalculate to such a large extent. In a nutshell, one can speak of cost savings of up to 40 percent for the electrical power cabling when flexible aluminum power cables

ALUMINUM FOR THE TOWER

The conventional construction method of the wind turbine is the steel tower with three to four segments. This is where the opportunity exists for the tower constructor to pre-install the power cables. During on-site assembly, the individual cables can then be connected to each other through compressed joints using approved crimping technology. During the cable connection process, up to 80 compressed joints evolve that have to be well-executed

Figure 1: A view of the tower and loop cables of a wind turbine.

Figure 2: All aluminum and copper/aluminum cable lugs for aluminum power cables with crimp tool.

and well-insulated to guarantee long-lasting, permanent function. Connecting the wires in an entire plant in such a fashion takes two to three days and is very costly. This critical part of the power cable network has to function correctly throughout the entire lifetime of the WTGS.

If you consider that a crane deployment when assembling wind tower carries the cost of about $66,000 per day, the installation time needs to be kept as short as possible. For plant constructors who want to reduce this expenditure to the minimum, some manufacturers provide a cabling solution where the cables after the loop can be installed in the tower ready to plug-and-play in as little as five to six hours. A Class 5 aluminum design can be flexibly pulled into the tower structure and routed in conduits through the foundation to connect to external transformers.

CONNECTORS FOR ALUMINUM CABLES

The electro-technical aspects, however, are of the utmost importance, since a cable is only as good as the connectors that secure it at each end. Cable and connection technology should be matched and tested as one system. The conductor fill factor in the cable lug or compression connector is an important aspect. Additionally, the slight vibrations in a WTGS should also not be neglected. Previously, only a mechanical pull-out test on the cables and connection was sufficient. For a manufacturer to provide a firm statement around product reliability, the mechanical tests need to be supplemented by an electrical test. The cable manufacturer's philosophy is to not interrupt the power cable network if at all possible. So an uninterrupted installation into the tower up to the inverter

Figure 3: A view at the HELUKABEL wind cable test tower. Up to 20 cables can be tested at once under conditions found in wind turbines located throughout the world.

in the tower base is preferred. In practical application, that means a prefabricated aluminum line with aluminum/copper compression joints to the loop and an aluminum/copper pressure cable lug to the inverter. In keeping with the spirit of plug-and-play, the wire can be installed through the tower and up to the inverter in one piece.

SPECIAL CRIMPING TECHNOLOGY ENSURES CONDUCTIVITY

Standard crimp or screw technology is not recommended with a finely-stranded aluminum cable designs due to the surface of the conductor, which oxidizes more. With conventional crimping technology, the electrical values in large cross-sections would be relatively high and insufficient. That causes excessive heating of the cable lug under load. Due to the higher temperature on the wire, the temperature of the insulation material also rises. This higher stress accelerates the aging process of the line, since contacting aluminum demands the greatest attention.

To work around this problem, cable manufacturers have developed special connection technology for finely-stranded aluminum cables. The crimp contour makes the aluminum flow, mechanically rupturing the surface of the wire and making it conductive. This means the contour penetrates deep into the stranded bundle, facilitating ideal contact between all strands even in the bundled conductors. Another connection option is a screw technology with shear bolts. Performance reliability is extremely important. To ensure that components are in compliance, it's important for customers to make sure the connecting equipment meet certain regulations such as IEC – DIN EN 61238-1 Class A.

OIL AND HIGH TEMPERATURES

The gearbox up in the nacelle requires aggressive oils and grease that can damage the cables if exposed for long periods of time. In this part of the wind turbine it is therefore important to choose cables with high oil resistance. In addition, the temperatures inside the gearbox can reach 70°C (158°F). In other words, cables that can endure higher

Figure 4: Wind cable performance can be reduced in part by exposure to extreme temperatures, oils and other lubricants, and mechanical stress. It's important to select cables that can withstand these and other challenges within the turbine for long-lasting cable performance.

temperatures (in Helukabel's case up to 145°C (293°F) are suitable for applications in the nacelle.

INTERNATIONAL REGULATIONS AND APPROVALS

Every county has its own regulations and that is something wind turbine manufacturers should consider when choosing a cable supplier. Cables with multiple international approvals (e.g. UL, CSA, FT4, CE, VDE, TC, and WTTC) can be used in wind towers no matter where in the world they are constructed.

HALOGEN-FREE FOR THE AMERICAN AND CANADIAN REGIONS

The customer can be rest assured that both conductor materials are being protected by jacket materials that do not use halogen. The use of halogen-free cables has been a staple in the European market as the regulating body would like to prevent harmful toxins from being release in the event of a fire. However, the trend for using halogen-free cables within turbines is ever increasing in the U.S. and Canada. While UL/CSA places high importance on not allowing any fire to arise in the first place, if one does breakout regulators would also like to prevent halogen's harmful components, such as fluorine, chlorine and iodine, from being released. Additionally, halogen further contaminates the turbine when it combines with moisture, creating hydrocyanic acid.

STRENGTHENING THE LINKS

Transforming wind power through new manufacturing value chain efficiencies.

By Ramesh Saligamé

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LAST YEAR WAS A BANNER YEAR for wind power by virtually every measure. Globally, 2012 saw the addition of 40 GWof wind energy capacity. The United States alone accounted for nearly one-third of that, with 13.1 GW—a new record. The surge has been largely attributed to uncertainty over extension of the production tax credit and the rush to complete projects by year-end. By the time Congress finally extended the credit in January, new installations had already begun to slow and last year's boom is not likely to be repeated. While installations in 2013 are expected to remain flat, the outlook is more optimistic for 2014, as projects initiated in the coming year reach the production stage.

Slower market demand is bound to put downward pressure on prices. Given the market's significant tailwind, wind power original equipment manufacturers will be looking to shrink their total costs across the entire manufacturing value chain, not only to remain competitive, but to accelerate adoption of wind-powered energy generation. Indeed, if wind power is to compete with fossil fuels and grow beyond its current six percent share of the nation's generating capacity, driving down the cost of bringing wind turbines to

market—which is passed on to energy producers and ultimately to consumers—is an industry imperative.

While the total cost of a wind turbine typically represents fifty-five to seventy percent of the total cost of an installed system, the overall cost basis is trending downward and will likely continue to do so over the foreseeable future. A key contributor to lower costs is innovation in the assembly process. Under pressure from project developers and system owners, wind turbine OEMs are achieving lower costs by shifting assembly closer to the demand site in order to minimize the soaring costs of transportation—which by some estimates can add 10 to 15 percent to the cost of a wind farm project. Bringing that number under control requires sophisticated logistics, a tightly knit supply chain and relationships with component manufacturing partners that have the geographical reach to deliver products and provide services where they are needed.

In addition, key technology advancements are playing a major role in reducing the costs of turbine engines. Refinements in design and the use of lighter materials are helping to reduce both manufacturing and operating costs of blades and towers. The trend toward longer blades and taller towers stands to improve overall turbine efficiency and performance, meaning that more energy can be extracted from the wind with fewer turbines needed.

The industry is understandably focused on the costs of more expensive elements of the wind turbine value chain—specifically turbine blades and towers. A less obvious but increasingly compelling opportunity to take cost out of the value chain lies in the design and assembly of the system electronics. Transformer, generator, cabling, and other control systems represent between eight and twelve percent of the total cost of the system—not a huge portion at first glance, but considering the average cost of a commercial scale turbine ranging from three to four million dollars, any incremental savings could add up quickly, especially when scaled over a large installation. That said, value chain cost considerations also apply to smaller turbines for farms ranging from five hundred thousand to one million dollars apiece. Designed properly, a system's electronics can not only lower the cost basis of a wind turbine system, but also enable developers and turbine original equipment manufacturers to deliver a more efficient product to their customers.

Suppliers of wind turbine system electronics compete in a fragmented market. Although a healthy percentage of electronic components are outsourced today, the changing regulatory environment, mismatches in supply and demand, and the wavering financial stability of several suppliers has prompted a growing number of original equipment manufacturers to start insourcing as a counter-measure to these market dynamics. Many are finding, however, that building versus buying is an expensive proposition that ties up valuable cash and requires a skill set outside their core competency. And, to make things worse, a lack of diversification makes them less able to adapt to changes in business conditions.

Wind turbine system developers and original equipment manufacturers can achieve better utilization of capital resources through methodical project planning. The key is to partner with manufacturers across the wind power ecosystem that do more than build components to spec, but who have the engineering expertise and market knowledge to find ways to reduce costs without compromising performance. To compete in an environment of downward cost pressure, suppliers to OEMs must be able to add value not only through design, but also through improved sourcing, supply chain management, manufacturability, testing, and certification. They must also be able to leverage significant economies of scale in procurement and manufacturing.

Original equipment manufacturers stand to benefit if they look at design and manufacturing as an integrated process. Manufacturing partners who are steeped in wind turbine technology and understand the end product should be able to design components that can be manufactured more efficiently and cost effectively. In the electronics realm, for example, that may mean figuring out how to build a wind pitch system with fewer components, shrink the electronics footprint and reduce weight without sacrificing functionality. A supplier should also be able to provide full design-for-manufacturability, which streamlines the production process, and to perform all testing required for certification before delivering the product to the original equipment manufacturer. This requires having standing relationships with certification bodies and being fully conversant in current certification requirements.

Improving the efficiency of components and of the manufacturing process are important steps in reducing costs. Equally important is eliminating slack in the supply chain. Suppliers need to be able to demonstrate efficient logistics management at every step from the sourcing of components to the delivery of finished products when and where they are needed. Effective logistics operations today are supported by sophisticated modeling tools and techniques that enable companies to optimize everything from availability of materials to sourcing locations, transit times and distances.

As assembly is moving closer to the demand site, project developers and turbine original equipment manufacturers will be increasingly reliant on manufacturers that have a meaningful presence in the regions where projects are located. This need is likely to be met by companies that have developed a global network comprised of a highly diversified and skilled workforce experienced in assembly processes that can be matched with specific product requirements. Given that the need for wind power tend to be modulated by government incentives, the workforce at the local level needs to be flexible so that it can expand or contract based on fluctuating demand. This requires organizations with access to and knowledge of existing governmental guidelines that preside over the businesses.

As indicated in the accompanying table, supply chain management can influence the costs of turbine components rather significantly. Today's splintered value chain adds overhead through the duplication of purchasing and planning services.

CASE STUDY:

In a recent request for proposal, a North American wind turbine manufacturer sought out a more efficient solution for manufacturing its wind pitch systems. These systems can weigh as much as 1,000 pounds with the batteries, cabling, control box and the enclosures. Furthermore, this manufacturer's systems needed to ship to assembly locations in Europe and the U.S. This required due diligence of the assembly team skill sets, infrastructure for positioning cranes to lift the systems while being assembled inside the factory, and a localized supply chain to help in lowering logistic costs and lead times. At the same time, it was critical to ensure that these specialized skills could yield economies of scale to keep operating costs in check. While a localized supply chain was important, so too were control over duties on inbound and outbound shipments. Finally, even though wind pitch systems can run into the tens of thousands of dollars, the most important consideration was achieving the overall lowest landed costs including air freight, which can run up to eight hundred dollars for a 1,000 pound system.

The original equipment manufacturer needed a manufacturing partner that clearly understood these requirements. Product quality and reliability were crucial, meaning the manufacturing site had to be qualified and certified. The duty structure for outbound shipments could not become cost-prohibitive, which eliminated certain locations. The partner modeled these requirements across different geographies and ultimately recommended a location that met the cost basis and quality requirements of the original equipment manufacturer.

A brief directional comparison of three locations that were considered is shown in the accompanying table, with weightings assigned to each of the key considerations...

	Location 1	Location 2	Location 3
Geography	3	1	2
Materials	3	2	1
Logistics	3	2	1

** Table Legend: 1 = First choice 2 = Second choice 3 = Third choice

TOTAL COST OF WIND POWER

ITEM	RANGE	TREND	SIZE	LOCATION	TECHNOLOGY	GEOGRAPHY	MATERIALS	LOGISTICS
TOWER	26% - 32%	←→	◔	◔	◔	◑	◕	●
ROTOR BLADES	22% - 32%	←→	◑	●	●	◔	◔	●
ROTOR HUB	2% - 4%	↓	◕	◔	◔	◑	◔	◑
MAIN SHAFT & FRAME	3% - 6%	↓	◑	◑	◑	◑	◔	◑
GEAR BOX	11% - 15%	↓	◔	◑	●	◔	◑	●
GENERATOR	3% - 5%	↓	◔	◔	●	◑	●	●
YAW & PITCH SYSTEMS	4% - 6%	↑	◔	◔	◔	◕	●	●
POWER CONVERTER & TRANSFORMER	7% - 9%	↓	◔	◔	◕	◕	◕	◑
OTHER	12% - 18%	←→	No single element drives overall decision					

Key

- Item to Consider
- Electronics Content
- ● Significant
- ○ No impact to cost

KEY TERMS

SIZE:	*Output of the turbine; number of wind turbines*
LOCATIONS:	*On-shore vs. off shore and assembly facility as close to demand as possible*
GEOGRAPHY:	*Localized supply chain, labor, factory where components are are produced*
MATERIALS:	*• Steel, Plastics --> Blade, Hub, Shaft* *• Magnetics, Fiber glass, Aluminium --> Nacelle, Wind vane* *• Ferrites, Ceramics, Teflon --> Transformer, Generator, Bearing, Yaw* *• Concrete, Brass, Steel --> Tower, Base*
TECHNOLOGY:	*Complexity that drives component design*
LOGISTICS:	*The impact of not manufacturing close to the assembly site*

When compounded by a general supply-and-demand imbalance, these inefficiencies produce excess inventory in the pipeline. Supply chain considerations should model the entire value chain with variables that include lead times, minimum order quantities and assembly times. The same logic can be applied on a trickle-down basis to individual suppliers across the value chain.

Materials management in the electronics realm of the wind power value chain is critical given the emphasis that customers place on the reliability requirements of the manufactured product. Original equipment manufacturers need to pay special attention to vendor qualification and component selection. The purchasing leverage of the supply chain partner should also be considered, as it can lower the costs of component procurement. In today's wind power business, it is essential for an effective supply chain partner to have the tools to model and manage the value chain around the globe and deliver the lowest landed costs.

In the effort to reduce costs across the value chain and spur wider adoption of wind energy, developers and wind turbine original equipment manufacturers must be able to count on their industry partners for creative solutions. An important precondition to any successful manufacturing partnership is the financial viability of the supplier. Developers and original equipment manufacturers need the flexibility to stretch their capital, and downstream partners in the value chain must be able to shoulder some of the financial burden and withstand extended payment terms. Moreover, they must have the wherewithal to invest in their own infrastructures, including assembly and test equipment, new design tools, and, of course, sufficient project staff resources. Financial stability also means demonstrating the ability to raise capital through debt financing if required.

Wind power has moved far beyond the fringes of imagination. It is proven, viable and increasingly popular with energy producers, municipalities, corporate customers and consumers. However, if it is to make the transformation from an "alternative" to a mainstream energy source—and deliver all the attendant benefits to the environment and to society—it must be not only technically viable, but economically as well. The challenge is not simply to seek out ever-lower bids, but for turbine original equipment manufacturers and their partners across the ecosystem to work closely together to drive innovation that will produce greater efficiencies and drive down costs.

EVOLUTION IN SAFETY

Promoting global wind turbine safety through the collaborative development of codes and standards.

By Kenneth Boyce

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ACROSS THE GLOBE, wind power generation resources continue to grow. As an example, the United States ranks second in global wind power, with more than 13 GW of new wind power installed in 2012 to pass the 60 GW milestone for installed wind power capacity.[1] The U.S. wind base experienced 28 percent growth in 2012 and wind power was the source of more than 40 percent of all new U.S. power capacity in 2012.[2] The U.S. Department of Energy has indicated that wind could supply 20 percent of the U.S. electricity by 2030—requiring some 300GW of new wind generating capacity.[3]

With this type of rapid development and deployment of new wind resources, standards become critical for supporting consistent market expectations, performance benchmarks, and fundamental design features—most importantly including safety. While many of the incidents were minor, safety incidents involving wind turbines over a five-year period in the United Kingdom were recently reported as occurring at approximately the rate of one per day.[4] As more wind turbines are installed, new technologies are introduced to meet market and performance objectives, and the existing turbine population ages, looking to new and evolving safety standards in the

design and development phase provides many benefits in supporting a safe wind infrastructure.

INTERNATIONAL ELECTROTECHNICAL COMMISSION STANDARDS

The International Electrotechnical Commission (IEC) has published the IEC 61400 series of standards to help establish these types of standardized expectations. IEC 61400-1, *Wind Turbines - Design Requirements,* outlines minimum design requirements for wind turbines. The standard "specifies essential design requirements to ensure the engineering integrity of wind turbines. Its purpose is to provide an appropriate level of protection against damage from all hazards during the planned lifetime."[5] The standard is a holistic document that covers many aspects of the design, installation, and use of sophisticated electromechanical equipment, and IEC 61400-1 is supplemented by numerous parts to focus on specific design or performance aspects, or types of wind turbine equipment and installations; for example, IEC 61400-2, *Wind turbines – Design requirements for small wind turbines.* However, it is notable that of over 90 pages of requirements in IEC 61400-1, approximately five focus on electrical safety of the equipment, controls and protection. In those few pages, IEC 61400-1 does identify the need to evaluate most critical aspects of a wind turbine: electrical aspects, control system functions, protection system functions and critical components. However, as the IEC 61400 documents are written today, they do not provide detailed guidance on how to adequately evaluate these critical aspects. Work was recently initiated to review enhancements to the specific requirements for electrical safety.

SAFETY STANDARDS AND CODES FOR THE U.S. MARKET

In order to help support a safe deployment of wind turbine system infrastructure during this projected period of rapid and significant growth, UL has led the collaborative development of national standards addressing the safety of wind turbine systems, with a focus on the electrical safety, performance of the controls and protection systems, as well as prevention of fire within the equipment. These efforts recognize that there are some fundamental differences between the installation requirements of the IEC 60364 series and the prevailing U.S. codes such as ANSI/NFPA 70, *the National Electrical Code* (NEC), and differences in other important safety requirements. As a result, two wind turbine safety standards have been developed by UL: UL 6141, *Standard for Safety for Large Wind Turbine Systems,* and UL 6142, *Standard for Safety for Small Wind Turbine Systems.* Each of these standards have been developed through a standards technical panel comprised of equipment producers, users, technology experts, scientists, regulatory authorities, and other technical experts with an interest in these specific products. The standards have been developed using a consensus-based approach, and at this time both standards have achieved the required support within the panels to establish consensus. The American National Standard for safety of small wind turbines was jointly published last year by UL and the American Wind Energy Association (AWEA) as ANSI/UL 6142/AWEA 6142. UL 6141 has reached consensus, and UL is working with the standards panel to finalize the publication as an American National Standard in the near future.

Because these requirements will constitute the American National Standards for safety, assuring compliance with the requirements for exporters, buyers, owner/operators, and other involved parties is an important measure for demonstrating due diligence in addressing workplace and consumer safety, supporting easy equipment installation and acceptance, and establishing confidence among customers. Based on the critical role of these standards for the U.S. market, the following overview provides significant aspects of the requirements for design and testing.

These standards focus on the safety of the wind turbine systems. However, they do not cover mechanical or structural integrity of the wind turbine system or subassemblies, or verification that the manufacturer-defined controls and protection limits maintain the system within its safe mechanical and structural limits. The wind turbine power, control and protection systems are evaluated only to the extent that they function within the manufacturer's specified limits and response times. These control and protection functions are evaluated with respect to risk of electric shock and fire. It is intended that the electrical subassemblies that address power transfer control and protection functions evaluated per this document are to be coordinated with the mechanical and structural limitations specified in established performance and safety standards, such as the IEC 61400 series documents. They focus on land-based turbines, and do not specifically cover turbines for offshore installation.

Both standards contain fundamental requirements related to wind turbine safety. These include important safety features such as: electrical safety of the internal subassemblies; protection of internal assemblies from mechanical abuse; disconnecting means; emergency stop and manual shutdown protocols; protection from self-excitation; lightning protection; safety markings and instructions; and grid connectivity (based on a number of options that address the particular needs and conditions of the grid utility).

UL 6142/AWEA 6142 covers small wind turbines for which a user or service person cannot or is not intended to enter the turbine to operate it or perform maintenance, with rated output of 1500 V ac maximum. The standard addresses compatibility of equipment with the installation safety requirements of the NEC. This includes compliance with Article 694, Article 705 for Interconnected Electric Power Production Sources, as well as critical safety features such as conductor and equipment protection and grounding.

UL 6141 covers large wind turbines for which a user or service person may, or is intended to, enter the turbine to operate it or perform maintenance. UL 6141 addresses compatibility of equipment with the installation safety requirements of ANSI/IEEE C2, the National Electrical Safety Code (NESC) and the NEC as applicable. For the NEC, this includes compliance with critical safety features such as working space, conductor and equipment protection, grounding and Article 705 for Interconnected Electric Power Production Sources. For large wind turbines, there are some additional requirements unique to these larger products. These address topics including protection from flame spread within the turbine, and requirements for medium voltage equipment as applicable.

The NEC addresses safe installation of systems and equipment that are not under the exclusive control of a utility, as addressed by specific requirements in Section 90.2. The new 2014 Edition of the NEC has just been published by the National Fire Protection Association, and it contains important new requirements for safety of wind turbine installations in Article 694, "Wind Electric Systems". The new edition of the NEC applies to all wind systems regardless of rating, eliminating the previous scope limitation to turbines having a rating up to 100 kW. Another new addition requires that wind systems be listed and labeled for the application. A new revision also expands on the previous limitation for a maximum of 600V rating for wind systems for dwellings, to allow systems up to 1000 V for other applications.

HARMONIZATION INITIATIVES

The publication of these standards is a milestone in supporting the safe deployment of wind turbine generating systems in the U.S. market. However, as a global organization, UL focuses on supporting global realization of our public safety Mission and supporting our global customer base in distribution of their products. With these objectives in mind, there are several initiatives that are either underway or may be pursued in the future.

First, UL has integrated key concepts from, or references to, IEC standards into these national standards where relevant. This was performed with the intention of bridging the gap between the IEC standards and the prevailing requirements in applicable U.S. standards and installation codes. For example, safety related controls system requirements are coordinated with IEC 61400 requirements, and additional requirements for the performance of the integrated equipment were added based on prevailing local issues. This approach allows the use of relevant approaches from the IEC standards while ensuring that significant local issues are addressed in a holistic and comprehensive manner.

Additionally, UL is very active in IEC Technical Committees to support the development of the best worldwide requirements for safety and performance. UL is participating in a leadership role in a collaborative effort in IEC TC 88 in the further development and enhancement of the IEC 61400 requirements for electrical safety. This initiative will draw on the efforts of the standards panels that have generated the requirements of UL 6141 and UL 6142, with appropriate modifications made to reflect the global nature of the IEC 61400-1 requirements. In the past, such efforts have been very successful in the renewable energy sector, with benefits being seen in standards work on products such as solar power and inverters. Such efforts allow the best efficiency and outcome of the IEC standards development process, allowing balanced consideration while leveraging existing, relevant content in the development process.

In the future, harmonization of the U.S. national standards with the IEC 61400 requirements is also an option. UL looks to international harmonization as an important consideration in supporting global product development and distribution, where the relevant industries and UL are supportive of the need for the effort. As the wind industry continues to refine product offerings and market strategies, additional consideration will be given to the benefits of harmonization.

SUMMARY

As the global wind infrastructure sustains rapid growth, compliance with relevant standards provide validation of design principles and establish due diligence in addressing critical attributes such as safety. The IEC 61400 series of standards provides important information for addressing safety and performance of wind turbine systems. Efforts to address unique issues within the U.S. market has led to development of two safety standards, UL 6141 for large wind turbines and UL 6142/AWEA 6142 for small wind turbines. These standards, which are being published as American National Standards, contain key product safety requirements for the electrical system, electrical safety and controls system, grid connection, and related safety issues. Evolving Code requirements are promoting safety of wind installations, in part through reliance on the evaluation of turbines to the applicable product safety standards. In the future, collaborative efforts will lead to continued exchange of best practices and opportunities for broader harmonization. Development of these standards, and their use by the manufacturing community in design and development of wind turbine products, supports maximal safety and performance of the burgeoning wind infrastructure.

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WINDS OF CHANGE

Simplified field termination of optical fiber cables.

By Natalia Juhasz and Anthea Croghan

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NORMALLY, WHEN ASKING PEOPLE at trade shows if they know of fiber optic cables, I see hesitance accompanied by some shoulder shrugging, and eyes wandering, frantically trying to find the answers from my booth's advertising banners. When people think of fiber optics, they often associate it with the telecommunication industry, the Internet, or telephone cables. What most people don't know is that optical fiber's wide range of applications extends to industrial networking, including controls systems for solar and wind power. Industrialized fiber optics provide an effective means to transmit data in the harsh environments. How can the wind industry benefit from using fiber optics technology? Well, if we look back at history we can see how far fiber optics can take us.

Windmills, first developed in China and Persia, have been in use since 2000 B.C. Used extensively in the Middle East for food production by the 11th century, they influenced merchants and crusaders to carry the idea back to Europe, primarily to the Netherlands.

The Dutch adapted a new method of the windmill and used it to drain lakes and marshes in the Rhine River Delta. In the late 19th century, this technology was brought to the New World by settlers who

then pumped water to farms and ranches and later generated electricity for homes and industry. In Europe and later in America, industrialization led a steady decline in the use of windmills. However, it also sparked the development of larger windmills in order to generate electricity. These windmills became known as wind turbines, which appeared in Denmark as early as 1890.

Early in the twentieth century, advanced scientific research and discovery led to an onslaught of development, production, and manufacturing, creating an enormous demand for electricity. Seemingly in the blink of an eye, coal mining and crude oil production grew quickly to supply the natural resources necessary for electricity generation. With an insatiable demand for industrial and consumer electricity, the nuclear age rose as an added source for the energy needs of the world. In June of 1954, the first nuclear power plant began operation at Obninsk, Soviet Union. With this event, the world of energy changed forever: generation of billions of megawatts brought power and light to the farthest reaches of economically advanced continents, and incredible cities' infrastructures emerged around these powerful electrical stations. Centralized power generation, once a rarity, has become ubiquitous, often taken for granted as we switch on lights, charge smartphones, and enjoy the comfort of environmentally conditioned buildings.

This energy boom, unfortunately, also introduces hazards for the population. All too often, we witness scaled tragedies in far-away places as evidenced by refinery explosions, oil spills, and rare but far-reaching nuclear accidents. Names like Chernobyl, Fukushima, and Macondo are etched into our collective memories as useful reminders that all forms of energy generation have inherent risk.

Seeking clean and environmentally friendly ways to produce electricity, many turn their attention to modernized wind power and other renewable energy sources. "Wind energy became the number one source of new U.S. electricity-generating capacity for the first time in 2012, providing 42% of all new generating capacity." In 2011, German chancellor Angela Merkel proposed a plan to replace all of German nuclear power plants by 2022 and triple the renewables share by 2050. While these goals are ambitious, the larger picture presents a new era of innovation in alternative approaches to the energy generation.

Why fiber optic technology in the wind power industry? The simple answer is that the combination of safety, efficiency, cost effectiveness, and reliable performance in harsh conditions makes fiber very attractive for use in these applications. Fiber optic cable gear is commonly used in Supervisory Control and Data Acquisition (SCADA) systems within and between wind towers. All dielectric fiber optic cables offer the added advantage of reducing ground potential to help protect critically important controls equipment in the event of lightning strikes. Complex wind farms are commonly operated through fiber optic cables and switches to connect various servers to the turbines for monitoring and control of wind power plants. Daily, millions of meters of these cables provide seamless wind farm communications and data integration from the wind towers through centralized control networks.

Known for its ability to transmit vast amounts of data over great distances, optical fiber products

also offer these distinct advantages in the harsh environments of wind turbines and wind farms:

- Immunity to Radiofrequency Interference (RFI)
- Electromagnetic Interference (EMI) electrical isolation between the turbine and its controls
- Stable performance of wide operating temperature range
- Repeaterless links of several kilometers
- Simplified field connectorization with advanced cable and connector solutions

A rapid advancement of Industrial Ethernet to the wind power networks communications led to the rapid changes in the enterprise automation world and the introduction of a different breed of communications cables. Fast (100 Mb/sec) and Gigabit Ethernet (1000Mb/sec) data rates created demand for higher bandwidth, real- time communications. Previously widespread plastic optical fiber (POF) and copper cables could not provide these capabilities over the long distances required. Harsh and unpredictable wind farms weather conditions required an extra layer of protection for data communication transmission.

Graded-Index Polymer Clad Fiber (GI PCF) cables with Low Smoke Zero Halogen (LSZH) outer jackets were specifically designed for applications that require high mechanical reliability at the fiber level. Polymer Clad Fiber not only offers a robust

mechanical protection to a fiber core but also adds the important field termination capabilities to the product offering a reliable cable connectorization solution.

Naturally, power generation, transmission, and distribution create strong electrical noise. Because using optical fiber inside wind turbines offers immunity to radiofrequency interference (RFI) in addition to electromagnetic Interference (EMI), data transmission is not affected by electrical noise.

If optical fiber cable is the best choice, what prevents some manufacturers from using more of it in wind power applications? Is field termination too difficult? Are technicians too hesitant to work with the fiber?

These questions present serious obstacles in choosing optical fiber; the reality is that some cable technicians are hesitant to work with glass fiber. Some of the common misconceptions about optical fiber include that it is, "Too complicated, too fragile, too tiny to terminate, messy epoxies are used, tedious polishing processes are needed," and my personal favorite, "you need special training and certification to work with it."

Historically, a common fear of the handling and long-term reliability of using glass optical fiber in such environments has hampered its adoption in wind power applications. Through decades of development, companies like OFS have developed and proven the robustness and simplicity of using optical fibers in applications from subsea, to aerospace, medicine, factory automation, and oil and gas markets. Recently, significant inroads have been made to both improve fiber handling and simplify field connectorization. Today, companies like OFS, with GiHCS® optical fiber cables, and Panduit offer a Graded Index Polymer Clad Fiber (GI PCF) fiber solution along with LSZH (Low Smoke Zero Halogen) cables and LC field-installable connectors interoperable with commonly used SFP modular transceivers on their switch lines for Fast and Gigabit Ethernet Uplinks and switch ports.

Such optical fiber cable solutions help ensure stable performance in:

- widely fluctuating temperatures from -20 to +105˚C (-4 to + 221˚F)
- high vibration
- exposure to common industrial oils and chemicals
- exposure to severe electrical noise
- situations where time for connector training is minimal
- installations where technicians are not expert in fiber optics

Maintenance and onsite cable repair in harsh, exposed conditions present other big issues for some installers. In offshore applications where wind is stronger, towers are taller with larger wind turbines and longer blades than their onshore counterparts. Recognizing these problems, fiber optic engineers have now designed and developed a simple crimp and cleave termination system that allows for connectorization of ruggedized fiber optic cable with no need for epoxies or polishing and simplified termination training. Climbing the tower to repair or replace a data link is simplified with lightweight fiber optic cables and compact fiber optic tool kits that require no power during connector attachment. Following the instruction manual is extremely important; not only does it save technicians effort to "crimp it right" the first time, with no consumables, the system also increases the number of terminations they can perform with one single kit.

The simple steps for the field termination of optical fiber breakout cables involve: first, stripping the waterblocked outer jacket material; then, crimping the connector either directly onto the fiber optic coating (LC, SC, ST and SMA type) or ETFE-based buffer material (V-pin and F07-type connectors), depending on the connector, for strong, solid connector retention. Strong connector to cable retention is crucial for connectorization in a turbine where strong mechanical vibration is a concern. The third step is to create an optical finish on the fiber, using the special precision cleave tool with a diamond blade. This crucial, but simple step creates a near perfect optical surface for low connector insertion loss. The cleaving step eliminates the tedious need to polish the fiber end-face. No messy adhesives or polishing equipment needed, your connectorized cable is ready to transmit at Fast and Gigabit Ethernet data rates.

At trade shows, we perform hundreds of connector termination demonstrations. To prove the simplicity of this termination system, we ask our uninitiated customers to try the stystem for themselves through our "Crimpe, Cleave and Leave" competition. Contestants are timed while they terminate fibers and often achieve times under 40 seconds per connector.

With only four or five steps depending on connector type, field technicians can perform thousands of terminations using tools they are familiar with. Finally, a stress-free fiber optic zone, the holy grail of data communications, if you will.

Curiosity and genuine interest about fiber optics kept people in our booth longer and in just a few minutes, many change their perceptions toward optical fiber use in just a few minutes, following these new and simple steps. No more shoulders shrugging or eyes wandering, previous hesitation and doubtfulness are swept away. Our hope is that all of our contestants remember the benefits of fiber in the wind applications industry, the simplicity of learning and using the cable termination process, and the fun they had with our "Crimp, Cleave, and Leave" contest.

In the early stages of our lives, we learn new things by exploring, studying, and trying them; each new skill with its own learning curve. Similarly, adoption of renewable energy has its own learning curve and will take time, but the benefits for humankind are real. Windmills—basically unchanged in design for many centuries—have evolved into wind turbines, which now harness and transform the power of wind. This is made possible through technological advancements like simplified fiber optics, which contribute to a wind turbine's safety, control, and efficiency. We felt those winds of change, the change of people's perceptions, and the change of their vision as they learned new things and new technologies.

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3. Wind Energy Foundation, "Interesting Wind Energy Facts"

Lightweight Dust Muzzle™ Works to Remove Fiberglass Dust During Maintenance

San Diego based-Dust Collection Products manufactures a complete line of dust collectors for the hand held tools used in the wind generator manufacturing trades.

The most popular dust collector is the Dust Muzzle. It is an efficient, lightweight and affordable ($24.95) dust shroud that adapts to all electric and pneumatic right angle grinders. It is made from durable high-density polypropylene. When used with a 2hp industrial vacuum, is capable of removing up to 99% of fiberglass and other toxic dusts at the point of origin.

The smallest Dust Muzzles are made for pneumatic right angle die grinders. They are available for 2” and 3” discs and are most commonly used with the 3M Roll Lock system.

The Dust Muzzle is also available for 4 1/2 - 8” right angle grinders. It can be used with rubber backed sanding discs, silica carbide wheels and soft pad sanders as well as many other abrasives. It will also fit onto all pneumatic RO/DA sanders and can be adapted for cutting with carbide and diamond blades with diameters of 4”–7”.

The Dust Muzzle can be used as a point of origin dust collector for hole saws and core bits with diameters between ¼” and 3”.

In addition to Dust Muzzles, Dust Collection Products makes point of origin dust collectors for Skil™ saws and needle guns.

All of the Dust Collection Products tools are made to be used with 2hp vacuum systems that have a minimum of 100 CFM, over 80” of static water lift and .5 micron or smaller disposable filter bags. Call for free, knowledgeable and experienced technical support to help design a complete custom system with HEPA vacuums.

For more information, call 619-223-2154, e-mail sales@dustmuzzle.com, or visit www.dustmuzzle.com.

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

New STAUFF Mini Water Vac Cleans Oil Continuously

The STAUFF Mini Water Vac purifies hydraulic system oil, eliminating water, gas, and particulate matter. The purified oil satisfies the most stringent quality requirements.

The STAUFF Mini Water Vac dehydrates and cleans most types of oils such as lubricating, hydraulic, transformer, and switch oils while it neither removes nor alters oil additives.

The water removal process is based on pure vacuum evaporation inside a vacuum chamber at a maximum temperature of +65 °C / +149 °F.

Solid particle removal is achieved through a field-proven STAUFF Systems Micro Filter.

The oil temperature can be set using the integrated heater thermostat. The dehydration and filtering process is fully automatic and is controlled via the PLC.

Contaminated oil greatly increases maintenance costs and contributes to catastrophic machine breakdowns. The STAUFF Mini Water Vac offers protection against malfunctions, breakdowns and total system failures.

The STAUFF Mini Water Vac also protects the environment by reducing oil consumption and oil disposal.

For more information, call 201-444-7800 or e-mail filtration@stauffusa.com.

PSI Repair Services Introduces Cost-Effective Replacement for Obsolete Inverters

PSI Repair Services, Inc., a subsidiary of Phillips Service Industries, introduced a new, cost-effective replacement today for obsolete Xantrex™ Matrix Inverters found in GE 1.5 MW S Series wind turbines. PSI's replacement inverter is a form, fit, and function solution with advanced fault detection and higher efficiency parts than the OEM design. The drop-in replacement inverter allows wind farms to supplement their inventory with more reliable, longer-lasting technology while keeping their turbines online. PSI also offers repair services for Xantrex Matrix Inverters from GE 1.5MW S Series wind turbines.

PSI also repairs faulty Xantrex Matrix Inverters from GE 1.5MW S Series turbines with newer, more efficient parts, leading to improved performance and longer product life.

Xantrex Matrix Inverters repaired and replaced by PSI have been rigorously field tested with successful results. Plus, PSI provides custom crating for all inverters to secure them from damage during shipping. Our inverter crates are also perfect for long term storage and return shipments of damaged cores.

Benefits of selecting PSI to repair or replace your broken Xantrex Matrix inverter:

- Reduced repair/replacement cost
- Reduced turnaround time
- More reliable than OEM matrix inverter
- Runs cooler than OEM matrix inverter
- Improved, high-speed fault detection circuitry
- Designed for longer life—estimated to be twice the life of the original design
- Designed to work with newer generation IGBTs
- Upgraded matrix inverters have passed rigorous field testing
- Upgraded matrix inverters are corrosion protected
- PSI provides custom crating for our upgraded matrix

As a leading independent service provider in the wind energy industry, PSI Repair Services offers component repair and upgrade services for GE, Vestas, Siemens and Clipper wind turbines. PSI covers the critical electronic, hydraulic and precision mechanical components that drive the turbines' pitch and yaw systems and down tower electronics. PSI uses the latest diagnostic tools to detect failures down to the microchip level. Solutions can range from minor repairs to full replacement of printed circuit boards, with enhanced designs to improve performance and reliability. In other cases, PSI can replace inefficient OEM components with newer, more reliable technology or make modification improvements to the original design. PSI also provides comprehensive remanufacturing services for unsalvageable, obsolete components.

For more information, visit www.psi-repair.com/repair-services/wind-turbine-parts-repair.

Wind Turbine Bolting Tool Solutions from RAD Torque Systems

RAD® Torque Systems offers a fast, reliable and safe solution for the installation and removal of heavy-duty fasteners. All RAD torque guns have one thing in common; they use a patented planetary gear reduction technology which delivers one of the highest power-to-weight ratios of any controlled bolting system and never transmits working torque forces to the operator's hands.

The E-RAD electronic torque system has quickly become a favourite in the wind energy industry because of its ability to meet each wind tower manufacturer's specific standards for torqueing bolts. E-RAD's precision is truly remarkable with +/- 3% accuracy, +/- 2% repeatability and digitally traceable torque sequences.

E-RAD® electronic torque wrenches are lighter, faster, stronger, and quieter than conventional means of bolting:

- Lighter—Combining the latest advancements in ergonomic design with an unsurpassed power-to-weight ratio, the E-RAD Series torque system is a lightweight alternative that eliminates the need to move heavy hydraulic pumps.
- Faster—Compared to hydraulic wrenches, E-RAD dramatically decreases tightening times through the delivery of smooth and continuous torque.
- Quieter—Operating at only 75db, E-RAD may be the world's quietest torque gun and is ideal for sensitive environments.
- Stronger—E-RAD is specifically designed for heavy industrial usage where speed, accuracy and mobility are of key importance. The double cooling system allows for heavy duty continuous usage.

An advanced touch controller case provides the interface for all E-RAD® tools. The touch screen allows for fast and convenient error-free adjustments to both torque and angle. LED indicator lights indicate the status of torque procedure for maximum accuracy. Digital data collection allows for full traceability of each torque sequence performed to generate simple computer reports or view data logs directly on the tool.

The E-RAD series is available in seven models with torque power ranging from 100 to 6,000 Foot Pounds. An exciting new model, capable of over 8,000 Foot Pounds, is scheduled for release soon.

RAD Torque Systems product lines include pneumatic, electronic, digital, electric and battery powered torque tools. They are the 100% Canadian manufacturer responsible for DB-RAD, the world's first digital, cordless lithium-ion torque wrench and Smart Socket, a revolutionary transducer socket for torque verification and calibration.

For more information, visit www.radtorque.com.


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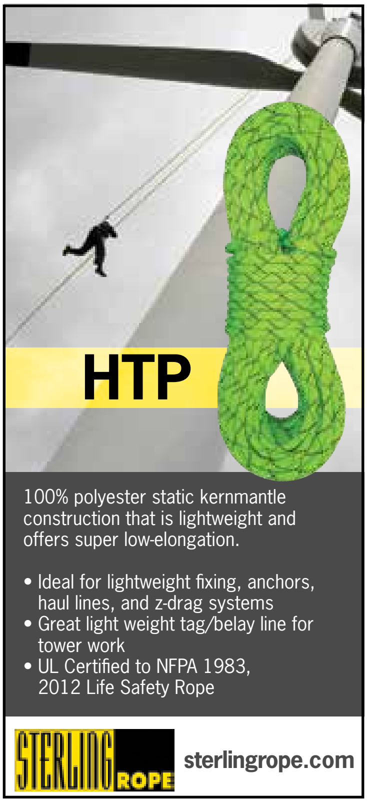
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ADINDEX

Chuck Cook
Director of Product Engineering, Maxwell Technologies

TELL US A LITTLE BIT ABOUT THE HISTORY OF MAXWELL TECHNOLOGIES AND HOW IT ENTERED THE WIND ENERGY INDUSTRY.

Maxwell Technologies got its start in 1965 as an engineering and research company called Maxwell Laboratories, which conducted advanced physics, pulsed power and space effects analysis for government agencies. This was the beginning of Maxwell's ultracapacitor products. Since then, many applications have emerged that use ultracapacitors' unique properties of long life and high-cycle capability.

WHAT PRODUCTS DOES THE COMPANY OFFER TO THE WIND ENERGY INDUSTRY?

We have four Maxwell modules that we developed specifically for the wind industry. These are two 16 volt (V) modules [a 58 farad (F) and a 500F version]; a 75V 94F module; and a 160V 6F module. In addition, we manufacture 350F D-cell ultracapacitors that a number of integrators use to manufacture other unique modules for wind customers.

WHAT ARE THE APPLICATIONS FOR THESE PRODUCTS?

They are used as the back-up power source in pitch control systems for wind turbines. There are a number of different systems that use either AC or DC motors for the movement of the blade pitch. The systems vary in operating current, voltage, blade size and motor type, which results in the need for different modules.

WHAT ARE THE ADVANTAGES OF ULTRACAPACITOR SYSTEMS OVER BATTERY-BASED SYSTEMS?

There are a number of advantages, including long life; wider operating temperature range; great low-temperature performance; lighter weight; eco-friendly green technology; and predictable aging. The result is a lower total cost of ownership compared to batteries.

HOW ARE WIND FARM OPERATORS ABLE TO SAVE MONEY BUY USING ULTRACAPACITORS?

The cost savings stem from the long life of ultracapacitors and the predictability of aging. Batteries need to be replaced three or four times during the lifespan of one ultracapacitor. This maintenance cost is relatively high considering the remote locations of wind farms, the weight of the batteries and the height of the towers. Because of the location of the pitch system in the rotor, it is a two-man job to replace the batteries. The cost is even more if it is offshore. The higher predictability of ultracapacitor-aging results in added savings by reducing unplanned downtime.

HOW LONG DO ULTRACAPACITORS LAST?

It depends on the operating conditions, of course, but ultracapacitors can last more than 15 years under the right conditions. Some ultracapacitor manufacturers are striving for 20 years. Operating temperature and voltage are the key variables.

HOW DO ULTRACAPACITORS WORK? TELL US A LITTLE ABOUT THE TECHNOLOGY INVOLVED.

An ultracapacitor is an electric double-layer capacitor. It uses an activated carbon film electrode, where the positive and negative electrodes are identical. The two electrodes are separated by a paper separator and filled with an organic solvent salt solution. It works on ion transfer between the electrodes at an atomic level. Because they are charge accumulators and not electrochemical reactions, ultracapacitors have a wider operating temperature range than batteries and can complete millions of cycles.

ARE ULTRACAPACITORS AVAILABLE AS AN UPGRADE TO EXISTING SYSTEMS, OR JUST FOR NEW INSTALLATIONS?

Yes, some turbine manufacturers have developed upgrade systems. It is more complex as an upgrade, however. If they design in ultracapacitors from the beginning, manufacturers can simplify charging systems, eliminate heating and cooling requirements for batteries, and streamline mounting and vibration systems.

For the complete Q&A with Chuck Cook, visit windsystemsmag.com.

For more information about Maxwell Technologies' wind energy ultracapacitors, visit www.maxwell.com.