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The Windy Flats wind power farm near Goldendale, Wash. Windy Flats consists of 114 SWT-2.3-93 wind turbines that together generate 262.2 MW. Photo courtesy Siemens Energy

aging the WIND

By Russell Ray, Managing Editor

With nearly 47,000 MW of wind power capacity in the U.S. and more than 8,000 MW expected to go online in 2012, wind power's rapid growth poses a tremendous challenge for utilities and grid managers charged with managing a growing source of intermittent electricity.

It's a high stakes chess game with Mother Nature as grid operators perform a sophisticated balancing act using advanced turbine technology, best practices, forecasting techniques, modeling and other tools to get the most out of North America's wind energy resources. The best solution for integrating large amounts of variable wind power is increased transmission capacity, but the siting, permitting and construction of new transmission can take many years to achieve.

Meanwhile, the industry has made great progress in managing the variable nature of wind energy. Higher capacity factors and penetration levels for wind energy mean the industry is getting better at predicting wind power output hours and days in advance with increasing accuracy and confidence. The increased output also stems from larger rotors and turbines and building wind farms in strategic areas to maximize output.

On the grid, there must be balance between load and generation. Achieving that balance while integrating larger amounts of variable wind power is one of the biggest challenges facing the power sector. But better forecasting methods, advanced computer software, the use of spinning and non-spinning reserves, and more grid interconnections have given the industry the tools it needs to accommodate large amounts of wind power.

During the early development of wind power in the U.S., integration was not a high priority for utilities and grid managers, said Charlie Smith, executive director of the Utility Wind Integration Group (UWIG). "In fact, if there were any system disturbances, the typical requirement was that the wind plant get off the system." Smith said. "Today, wind plants are an integral part of the system and are expected to ride through disturbances and provide power control and voltage control just like any other power plant."

In 2011, the U.S. installed nearly 7,000 MW of new wind power. That's a 31 percent increase over 2010, according to the American Wind Energy Association (AWEA). Last year, construction began on more than 8,000 MW of wind power capacity. What's more, U.S. wind generation rose 27 percent in 2011 to 120 terawatthours, up from 27 terawatthours in 2006 *(See table on this page)*, according to the Energy Information Administration, the statistical arm of the Department of Energy.

Although utilities can't directly control wind energy output, changes in output tend to be gradual and predictable. According to AWEA, wind power accounted for nearly 8 percent of the electricity placed on the grid in Texas in 2010. At one point in 2010, wind power accounted for 25 percent of the power on the Texas grid, AWEA said.

"Texas serves as a powerful example of how wind is being reliably and cost-effectively integrated," the association said.

U.S. NET GENERATION FROM WIND, 2006-2011

	Terawatthours
2006	26.58
2007	34.44
2008	55.36
2009	73.88
2010	94.65
2011	119.74

Telvent DTN, a leading provider of weather forecasting services, provides data to more than 100 wind power facilities in North America. Don Leick, senior energy project manager for Telvent, said the accuracy of wind power forecasting has greatly improved but requires sophisticated techniques and data crunching to devise an accurate forecast.

"It's a complex challenge to do an accurate wind power forecast for such a highly variable source," Leick said. "You're predicting wind at a height that's not at the surface level, which makes it more complicated. It's typically 80 meters."

Telvent provides utilities customized forecasts based on the characteristics of the wind farm and historical generation data.

"It's a trained forecast that ends up being highly customized to the characteristics of that particular wind plant and how wind direction affects that plant," Leick said. "That's the approach we take. It discovers the variables that matter."

Wind farms generally operate at 20 percent to 40 percent of their maximum capacity. Average capacity factors have improved, thanks to better estimates on wind speeds and direction.

"Relatively small increases in wind speed can mean fairly large increases in power because it's a cube relationship," Leick said.

A relatively new technique in wind power forecasting uses a series of likely probabilities to determine wind power output and the amount of stand-by reserves required.

"Not many utilities are doing it," Leick said. "They're learning how to do this – the technique of probabilistic forecasting."

The technique uses historical information on wind speeds and generation as well as variations, or errors, in the weather forecast. For example, probabilistic forecasting can tell grid operators that there is an 80 percent probability that there will be X amount of wind power at a certain time of day.

"I can base my reserves off of that," Leick said. "Probabilistic forecasting allows you to be more intelligent about your reserve planning. It's something people are beginning to see the value of."

Turbine and equipment manufacturers are responding to the power sector's need to improve wind power integration by engineering new quick-firing gas turbines and technologies that give utilities more control over the flow of electricity.

General Electric's aeroderivatives gas turbine is capable of ramping up to full production in just minutes, allowing power producers to offset lost generation when the wind stops blowing. "The turbine can go from cold iron to 50 MW in just 10 minutes and make up for the lost electricity," GE said.

The average size of a U.S. wind turbine in 2011 was 1.97 MW, up from 1.77 MW in 2010, according to AWEA.

"For a while, there was a strong trend of capacity factor improvements that were driven by two things," UWIG's Smith said. "One was locating wind

"Today, wind plants are an integral part of the system and are expected to ride through disturbances and provide power control and voltage control just like any other power plant."

– Charlie Smith, Utility Wind Integration Group

plants in better wind regimes. The other was larger rotors for extracting more energy."

But rising capacity factors have leveled off because transmission limits are preventing developers from building wind farms in the best places for harnessing the wind. Also, the development of larger rotor technology has slowed.

"Relatively small increases in wind speed can mean fairly large increases in power because it's a cube relationship."
- Don Leick, Telvent DTN

"When you talk about system practices and policies that are important for integrating large amounts of variable generation, I think transmission is No. 1," Smith said. "You've got to be able to move the wind from where it's generated to where it's used. You've got to aggregate wind output over very broad geographical regions."

The Federal Energy Regulatory Commission's Order 1000 may be the best tool for integrating large amounts of wind power. Issued last July, the new rule requires transmission plans to reflect state and federal standards for renewable power and establishes a method for allocating the cost of building new transmission broadly to the beneficiaries of transmission projects. The rule is expected to remove the barriers to the development of new transmission capacity, Smith said.

The new rule is "providing a strong framework for inter-regional cooperation and looking at regional solutions, including cost allocation," he said.

AWS Truepower is a consulting company that provides modeling and wind farm siting services to independent system operators and utilities. To help utilities and developers select the best sites for wind farms, the company creates hypothetical facilities and then simulates weather data to determine the potential wind power output.

"From that, we can extract the variables necessary to run through a power conversion based on whatever the technology might be," said Ken Pennock, forecasting business manager for AWS.

Because supply must equal demand, power schedulers have to be certain the power will be there.

Forecasting by itself doesn't provide the certainty required to bring balance to the grid. "It's a matter of having a system that is intelligent enough to blend together all of those probabilistic values to get to a final answer," Pennock said.

Utilities and grid managers need better data to improve the integration of wind power, Pennock said, adding that government could enhance the data used in U.S. weather models.

"Europe by far has developed a better system than the U.S.," he said. "Data gathering for weather models in the U.S. is very limited and it needs to be enhanced. Private companies can't deploy the number of sensors that would be necessary to enhance the input into weather models, but the government can."

Last year, wind power was the No. 2 source of new electric capacity in the U.S., representing 35 percent of new capacity, according to AWEA. What's more, turbine manufacturing continued to grow last year in the U.S., home to 23 turbine manufactures. The U.S. had only five turbine manufacturers in 2005.

"As the market expands, we're getting more companies involved," said Elizabeth Salerno, director of data and analysis for AWEA.

The biggest concern for the U.S. wind power market is the expiration of the Production Tax Credit at the end of this year.

Wind turbine manufacturers have not received any orders for new projects in 2013 due to the uncertainty surrounding the PTC, Salerno said. pe

REPORT: U.S. WIND INSTALLATIONS TO DROP IN 2013

The global wind industry will install more than 46 GW of new wind energy capacity in 2012, according to a five-year industry forecast published April 17 by the Global Wind Energy Council (GWEC) at the European Wind Energy Association (EWEA) 2012 Conference in Copenhagen. By the end of 2016, total global wind power capacity will be just under 500 GW, with an annual market in that year of about 60 GW.

Overall, GWEC projects average annual market growth rates of about 8 percent for the next five years, but with a strong 2012 and a substantial dip in 2013. Total installations for the 2012-2016 period are expected to reach 255 GW, with cumulative market growth averaging just under 16 percent.

"For the next five years, annual market growth will be driven primarily by India and Brazil, with significant contributions from new markets in Latin America, Africa and Asia," said Steve Sawyer, GWEC Secretary General. "While the market continues to diversify across all continents, it is at the same time plagued by continued slow economic growth and budget crises in the OECD (Organization for Economic Co-operation and Development), as well as the continuing credit crunch."

For the second year running, the majority of new installations were outside the OECD.

GWEC expects the North American market to have a strong 2012, as both Canada and Mexico will install well over 1,000 MW to complement what is expected to be a strong year in the U.S., which began the year with more than 8 GW under construction. It now seems unlikely that the reauthorization of the federal Production Tax Credit will happen in time to have a major impact on the 2013 market, so a substantial drop is expected in 2013 in the U.S. market, while Canada and Mexico remain strong. Overall, just over 50 GW is expected to be installed in North America from 2012-2016, bringing total installed capacity to just over 100 GW at the end of the period.

Maintaining Wind Turbine Performance

By Brian Wheeler, Associate Editor

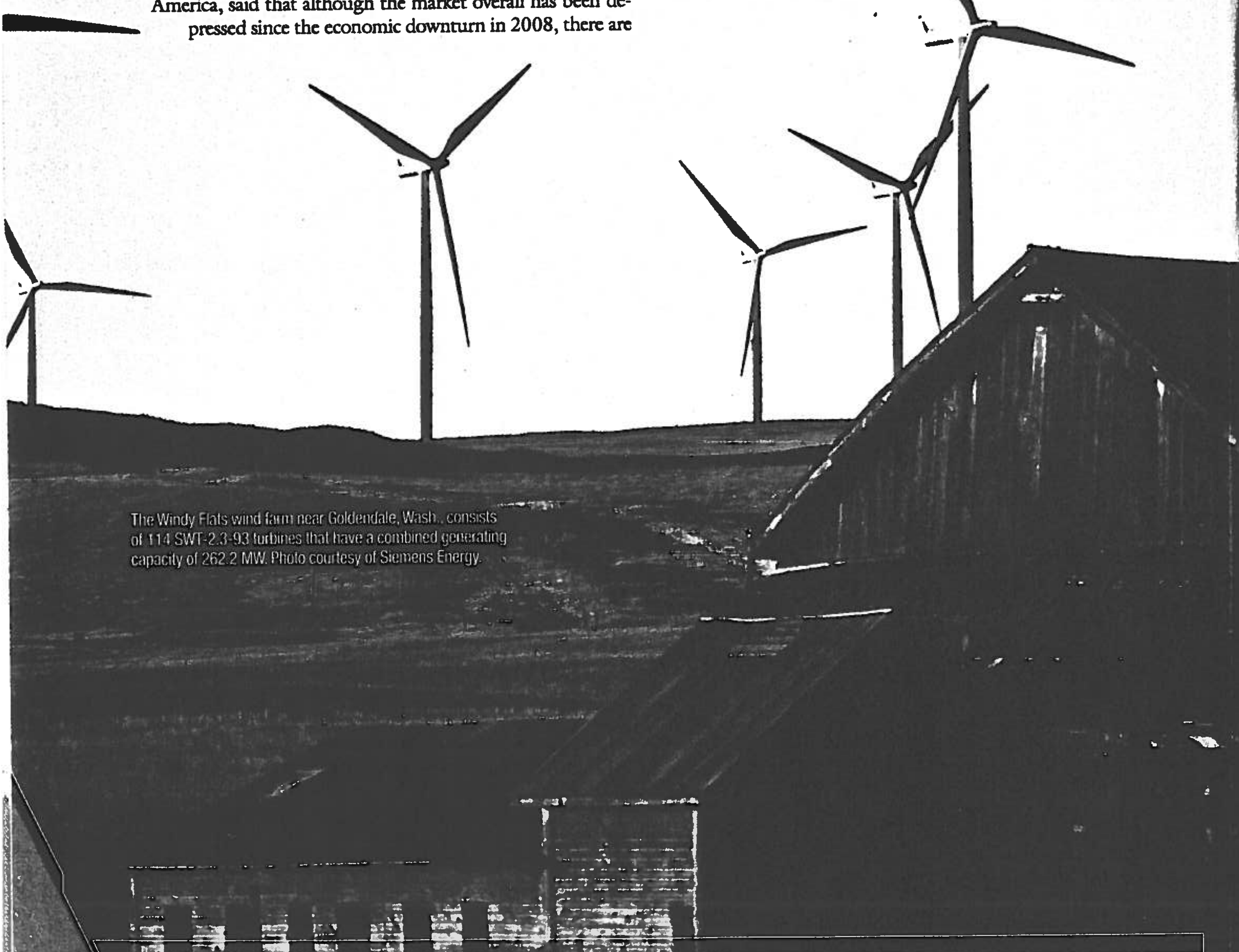
As the push for renewable energy sources continues to grow in the United States, wind energy is often looked at as a key source of power generation to meet renewable energy goals. At the end of 2010, the U.S. had 40,181 MW of installed wind capacity. In the first quarter of 2011 an additional 1,118 MW was installed, more than doubling the first quarter of 2010. According to the U.S. trade group the American Wind Energy Association (AWEA) and the National Renewable Energy Laboratory, there is still potential for 10,400,000 MW of wind energy capacity in the U.S.

Canada has an installed capacity of 4,611 MW that generates about 2 percent of the country's total electricity demand. The province of Ontario leads the nation with 1,656 MW of capacity and Acciona Windpower North America, for one, is looking to add more capacity. Joe Baker, CEO at Acciona Windpower North America, said that although the market overall has been depressed since the economic downturn in 2008, there are some opportunities in pockets through North America; specifically in eastern provinces of Canada, Ontario and the West and Midwest regions of the U.S. In May, Acciona announced that the Lameque Wind Power Project in New Brunswick entered commercial operation. The 3,100 acre wind farm consists of 30, 1.5 MW turbines that generate up to 45 MW for New Brunswick Power.

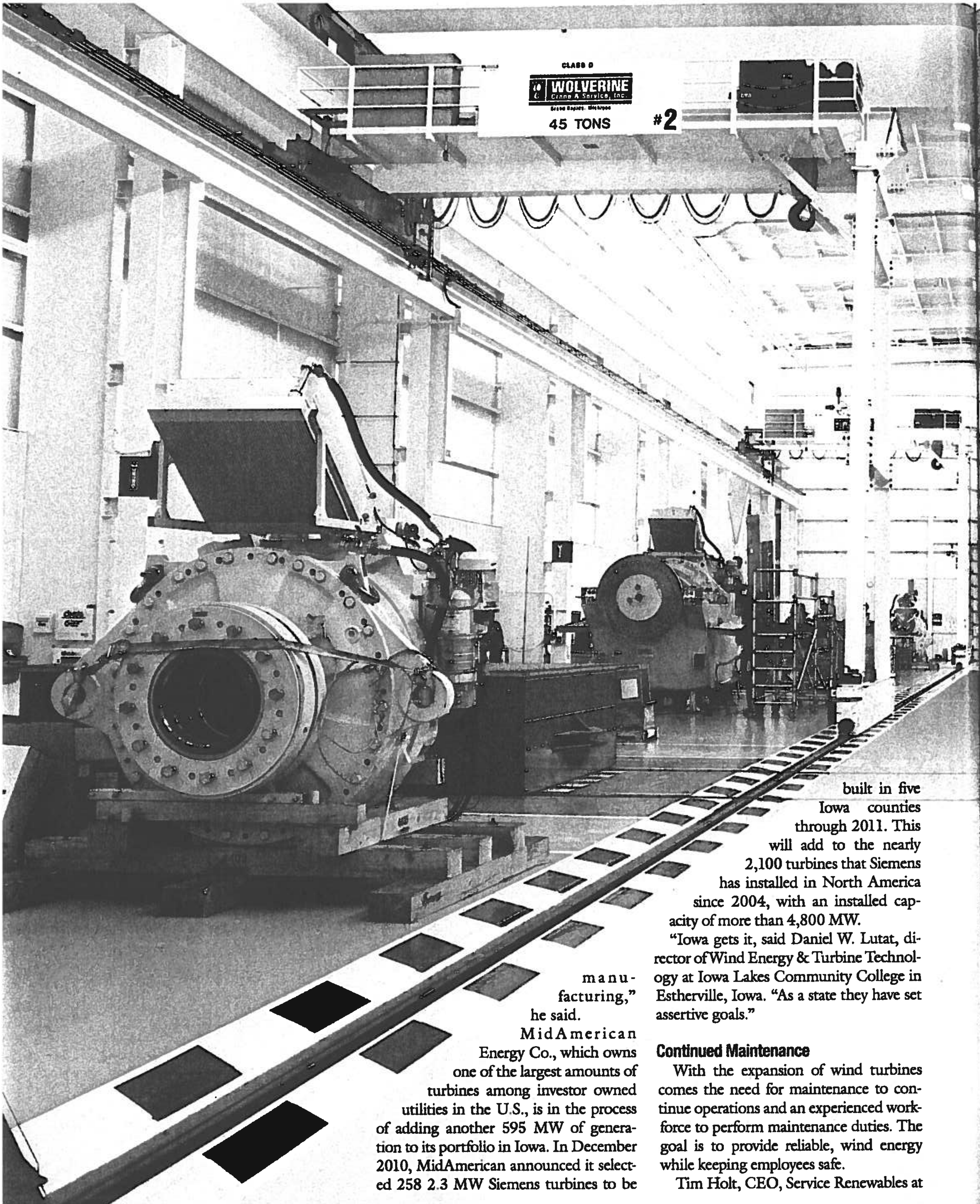
"We have seen the market in the last six to nine months picking up somewhat," said Baker.

Also in that pocket of opportunity is Iowa. Ranked number two in the U.S. in terms of installed capacity with 3,675 MW, the state is home to Acciona Windpower's turbine manufacturing facility. Iowa was also one of the first states in the U.S. to institute a renewable energy standard in 1983, said Brian Crowe, project manager, Iowa Department of Economic Development.

"We expect to continue to keep adding generation and



The Windy Flats wind farm near Goldendale, Wash., consists of 114 SWT-2.3-93 turbines that have a combined generating capacity of 262.2 MW. Photo courtesy of Siemens Energy.



manu-facturing," he said.

MidAmerican Energy Co., which owns one of the largest amounts of turbines among investor owned utilities in the U.S., is in the process of adding another 595 MW of generation to its portfolio in Iowa. In December 2010, MidAmerican announced it selected 258 2.3 MW Siemens turbines to be built in five Iowa counties through 2011. This will add to the nearly 2,100 turbines that Siemens has installed in North America since 2004, with an installed capacity of more than 4,800 MW.

"Iowa gets it, said Daniel W. Lutat, director of Wind Energy & Turbine Technology at Iowa Lakes Community College in Estherville, Iowa. "As a state they have set assertive goals."

Continued Maintenance

With the expansion of wind turbines comes the need for maintenance to continue operations and an experienced workforce to perform maintenance duties. The goal is to provide reliable, wind energy while keeping employees safe.

Tim Holt, CEO, Service Renewables at

Acciona Windpower manufacturing facility based in West Branch, Iowa. Photo courtesy of Acciona Windpower.

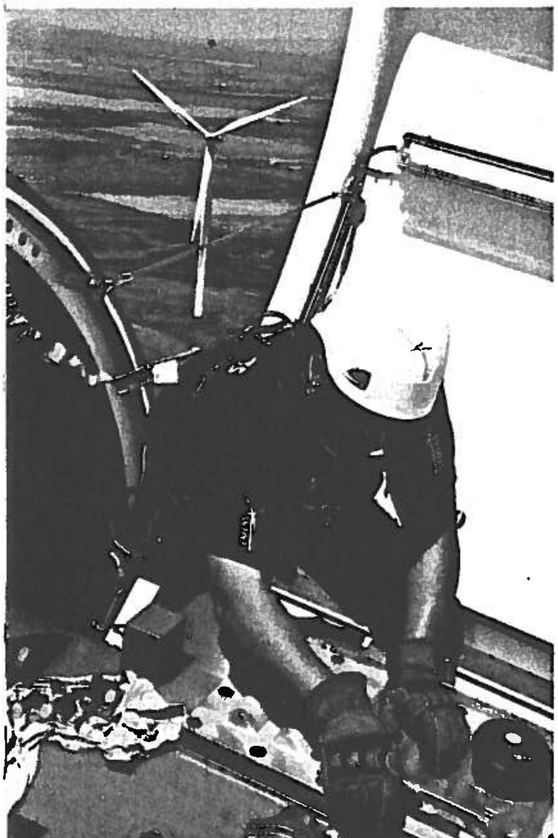
Siemens Energy, said the company instituted maintenance and monitoring strategies that focus on allowing technologies to run for decades.

"We are committed to making sure we provide more than just maintenance," he said. "We also provide monitoring that signals needed maintenance before potential issues arise, resulting in much shorter downtime."

As turbines operate, they experience wear and tear from natural factors such as weather, which can lead to maintenance challenges. Holt said Siemens monitors weather patterns not only for tornadoes, hurricanes and blizzards, but also for atmospheric changes that can cause icing or lightening strikes, which can affect wind turbine performance.

"We also continue to increase our ability to monitor weather changes affecting our turbines and our ability to evaluate and gather as much data as possible to properly schedule maintenance while keeping safety and quality in mind," he said.

By executing scheduled maintenance, technicians, operators and original equipment manufacturers can be prepared in advance and ensure that turbines are operating and delivering energy as laid out in performance contracts. Acciona Windpower North America, for example, focuses on the warranty time after the project enters commercial operations. During that two-year period the company performs maintenance every six months as part of the contract to make sure there are no issues with gearboxes, generators, blades and major and minor components. Also, technicians must make sure all components are lubricated and functioning properly.



A technician inspects a turbine at the Windy Flats wind farm. Photo courtesy of Siemens.

"As companies learn more about how turbines fare in the field, they typically modify requirements to ensure the optimum interval for servicing," said Lutat.

And customers are asking for longer-term maintenance services from original equipment manufacturers (OEMs). Part of the uncertainty in the U.S. and Canada is that there is little long-term data that will help predict how turbines will function after 30 or 40 years of operations. The North American wind industry is still relatively new when compared to other forms of generation, Baker said. In the time since large-scale wind energy entered the North American market, technology has changed multiple times in the form of gearboxes, blades and generators. This has also led to the dearth of long-term data and a lack of a consistent and predictable pattern. Baker said it can't be said for certain that a gearbox, for example, needs to be changed after, say, 11 years of operation. The appropriate maintenance interval could be 17 years or even six years.

"It is kind of all over the board," he said. "So (the customers) are looking for longer term operations and maintenance and as the OEM we are interested in participating in that."

Training Programs

Between 2004 and 2008, North America, and Iowa in particular, saw a rapid build out of wind energy capacity. In 2004, just as the boom was getting underway, the Wind Energy & Turbine Technology degree program began at Iowa Lakes Community College. In that first year, a single instructor and 15 students made up the Associates Degree program. Six years later, at the start of the 2010-2011 academic year, the program counted 176 students and six instructors. What's driving growth is demand for technicians that have exposure to the machines they are going to be working on, said Lutat.

"You can't just take someone from an automotive or machining technical side and all of a sudden make them a wind turbine technician," he said.

Iowa Lakes Community College has established an advisory committee comprised of industry professionals from operations and maintenance to turbine construction. This committee is consulted with regularly for feedback and advice on course offerings. The board lets the college know about changes within the industry that can lead to additions, modifications or deletions from the students' curriculum.

"We try hard to stick to training on fundamentals that transcend design, so our graduates leave us with a broad exposure to wind energy concepts," said Lutat.

The community college also actively engaged AWEA and helped develop the AWEA Seal of Approval for wind turbine service technicians. Iowa Lakes was one of three programs nationally to receive the Seal of Approval in January 2011.

"The field is ripe for improvement and we believe that our graduates will be among those that transform wind energy systems in America," said Lutat.

Direct Placement

Siemens Energy has focused its recruiting on two areas: the community colleges and the military with community colleges providing direct placement of graduates into the wind energy workforce.

"We can find graduates of Associates Degree programs who have already chosen renewable energy as a career," said Holt. "They have already made a significant investment in the wind power industry."

In January 2011, Siemens collaborated with multiple community colleges and launched a pilot intern program and selected five students as technician interns. Four of the five interns went on to full-time positions in Texas and Oklahoma.

Iowa Lakes Community College students prepare for a tower climb on the college's Vestas V-82, 1.65 MW turbine. Photo courtesy of Iowa Lakes Community College.

"Considerable strategic planning is required to meet the anticipated demand for highly-trained technicians and engineers," said Holt. "Retaining these highly qualified employees requires attention to their professional development needs and establishing a challenging, rewarding work experience."

Acciona Windpower North America has yet to see a shortage of qualified workers in the U.S. and attributes that to work being done by state governments, private industry and community colleges. Baker said that although it is unlikely to happen, if there were an explosion of projects in the North American wind power market, it could possibly pose challenges.

"We have the people in place," he said. "I don't see that there is going to be any shortage in the next three to five years." pe

Wind Farm Transformer Design Considerations

Unique requirements call for thoughtful analysis and reevaluation

By Donald E. Ayers and Michael Dickinson, Director New Business Development, Pacific Crest Transformers

Each turbine in a wind farm is equipped with a step-up transformer, which boosts (steps up) turbine generator output voltage from a few hundred volts to the collector system's medium voltage distribution levels. These wind turbine step-up transformers are failing at an alarming rate and developers and operators of utility scale wind farm projects are scrambling to identify the most likely causes for this widespread failure.

The root cause of the failure is not hard to find: conventional distribution transformers that typically are used simply cannot stand up to the severe duty requirements of a wind turbine step-up transformer. To guarantee the future reliability of this valuable renewable energy source, wind turbine step-up transformers must incorporate these unique requirements, which include variable loading, harmonics and non-sinusoidal loads, transformer sizing and voltage variation, low voltage (LV) fault ride through, as well as protection and fire behavior, step-up duty, switching surges and transient over-voltages, loss evaluation and gassing.

Wind Power's Biggest Challenge

Wind turbines are distributed in an array in which ambient winds blow across fan blades connected to turbines that generate electrical energy. However, while wind always blows it does not blow according to any regular schedule or wind speed, so turbine output energy varies continually.

Alternating current (AC) electrical energy cannot be easily stored; with no "shelf life," wind energy must be consumed by the end user as soon as it is generated. Generation plants of all kinds typically scale back production when demand is light and ramp up production to meet the higher demand when consumers turn on the switch. Unfortunately, wind power is not well suited to this type of supply side control.

When the wind blows, turbines can provide power. When the wind speed is low, only a fraction of the designed power capacity is generated. Below a certain speed (approximately seven miles per hour), the turbines cannot generate power at all. Ironically, in very high winds the turbines must also be stopped to prevent damage. Timing becomes a critical issue because invariably when customer's demand is greatest, wind-generated electricity may not be available. Thus, utilities must use the wind generated power whenever it is available and control the supply demand by other means.

Even though the turbines are designed for the maximum wind speed they can mechanically withstand, they often only operate at a fraction of that capacity. Full 100 percent capacity is possible only with ideal conditions, which typically occurs only with sustained wind speeds over 30 mph.

Throughout Europe, wind turbines typically produce less than 20 percent of their theoretical capacity. In the United States, designers plan for an average load factor of 30 percent. Wind power sites in California average 20 percent load factor, while the Energy Information Agency (EIA) reported that the average contribution to consumption throughout the U.S. in 2002 was 12.7 percent of the theoretical installed turbine capacity.

So how does this type of loading affect the performance of a wind turbine step-up transformer? The variability means that the turbine is operating at continually changing power levels, which subjects the transformer to frequent daily thermal cycling. Compared to distribution transformers that often see only one cycle a day based on loading, the wind farm step-up transformer can cycle from low load to high load several times a day, at the whim of the local winds.

This cycling causes repeated thermal stresses on the winding, clamping structure, seals and gaskets. Repeated thermal cycling allows nitrogen gas to be absorbed in the hot oil and then released as the oil cools, forming bubbles within the oil that can migrate into the insulation and create hot spots or partial discharges that can lead to insulation damage. Continuous thermal cycling can also cause accelerated aging of internal and external electrical connections.

These cumulative effects put the wind turbine step-up transformer at a higher risk of insulation and dielectric stress and failure than either the typical "off the shelf" distribution transformer or the power generator step-up transformer experiences.

Harmonics and Non-sinusoidal Loads

Transformer design is based upon the principle of creating a fluctuating magnetic field from a uniform sinusoidal input alternating voltage source to induce current flow in, and voltage potential across, an electrically separate conductor in that fluctuating field.

A purely uniform sinusoidal waveform is possible only theoretically. In real world applications of transmission and distribution power systems, voltage and current waves get distorted from the ideal. In fact, total harmonic distortion (THD) of 1 to 2 percent is common at the point of generation. Additional non-linear loads such as switching actions, rotating machinery, variable frequency drives and electronic devices of all types add further distortion to the ideal wave shape. These cumulative distortions repeat every cycle, adding peaks that ride on the voltage and current waveforms and occur at other than the fundamental frequency of 60 Hertz.

The danger from harmonics is that they increase the eddy and stray losses within the transformer. Eddy and circulating currents in a winding conductor cause additional heating, which must be addressed with additional cooling to avoid insulation degradation and premature transformer failure.

Wind turbine generators, like conventional generation sources, will produce generator-caused distortions which, in turn, result in harmonic wave forms. In addition to these harmonics caused by the generators, the turbine step-up transformers are managed with solid state controls that contribute their own form of damaging harmonics.

only realistic choice available.

The problem with large, sprawling turbine arrays is the need for connecting the individual turbine step-up transformers to the "collector" bus results in long cable runs. This in turn results in increased voltage drops, cable-related resistive and capacitive losses and increased potential for cable ground faults.

The extensive use of cable in wind farms, coupled with their "daisy chain" connection pattern, leads to two primary system problems.

The first problem is the potential for cable faults. A radial wind farm configuration typically connects 10 to 12 transformers in a daisy chain fashion. The padmount transformers are configured with a loop-feed bushing arrangement. Thus, the transformer at the end of the radial line is connected to the next transformer, and so forth, until the first transformer in line is connected to the collector bus. Since a cable fault can happen anywhere along this radial line, the transformer must be able to handle fault currents from a fault at any location. Here's where the usefulness of the fault ride through requirement is shown, since otherwise clearing a fault would require disconnecting a complete radial line, approximately 20 to 30 MVA of generation.

The second problem is a single or double line-to-ground fault causes voltage stress on the transformer. A single phase cable fault on the delta-connected high voltage (HV) winding causes one phase to ground, thus putting phase-to-phase voltage between the other two phases and ground. The resulting voltages overstress the insulation system of the transformer. Finding and clearing the cable fault is exacerbated by the longer cable runs and the wind farm layout.

To help alleviate this type of dielectric stress, grounding transformers should be used at critical locations within the wind farm. The grounding transformer provides a zero sequence impedance to support the voltage on a faulted leg during a single-line-to-ground fault.

Increased exposure to lightning strikes is another issue. Since wind farms are in remote areas, typically at higher elevations or exposed plains, wind patterns are unobstructed by surrounding terrain and man-made or natural obstacles. This increases the transformer exposure to storm events and lightning strikes. Surge arresters should, therefore, figure prominently in the wind turbine step-up transformer protective equipment list.

Perhaps an even greater concern is transient over-voltages cause by switching. As wind speed increases, the turbines are brought on line; when the wind strength begins to wane, the loading drops and ultimately the turbine is switched off line. This can happen multiple times within a 24-hour period as surface wind is affected by diurnal heating cycles or incoming weather patterns. This can also happen when a feeder breaker opens and disconnects the turbine step-up radial line from the collector circuit.

Breaker operations introduce a transient recovery voltage (TRV) wave into the wind turbine step-up transformer voltage circuit. This phenomenon is exacerbated by the use of vacuum breakers, which have extremely rapid switching times. The TRV surges associated with breaker switching operations on either the HV or LV side of the transformer can combine with cable capacitance to produce standing waves and ringing that are many times the original voltage levels.

These extreme voltages can lead to transformer dielectric failures. When the frequency content of the high voltage, fast rise-time, TRV surges coincide with the internal resonant frequencies of the winding, the circuit can resonate and elevate the electric stress in the windings beyond the dielectric withstand strength of the windings.

One of the most common specification errors on padmount transformers has to do with BIL ratings and insulation coordination. On 34.5 kV rated windings, the highest rated dead front bushing is rated at 150 kV BIL, so most specify 150 kV BIL as the insulation level of the associated winding. Instead, a good practice would be to specify a full 200 kV BIL for the winding, while leaving the bushing at 150 kV BIL. It is much easier to replace a failed bushing than a failed transformer.

Loss Evaluation

Because of the speculative nature of wind farm developments, the initial site developer or contractor is most often interested in a transformer with a low purchase price. The owner/operator who inherits the wind farm from the developer/contractor after it is put in service is more interested in the total cost of ownership, which includes the purchase cost plus the costs for losses, maintenance, repair/replacement and associated down time for failure events.

To balance these diverse interests, most projects invoke some form of cost evaluation including the purchase price, a weighted cost factor for losses over the life of the transformer and the theoretical cost of energy during that time. In the case of a conventional application, such as a steam generating plant, the loading factor is generally higher than 95 percent, whereas due to variations in wind speed, a wind turbine transformer loading factor ranges from 25 to 40 percent. In 2009, the load capacity factor for U.S. wind farms as a whole was 30 percent.

Cost evaluation models developed by the National Electrical Manufacturers Association (NEMA) and the Department of Energy (DOE) have failed to take this into account. NEMA standard "TP1-2002 Guide for Determining Energy Efficiency for Distribution Transformers" and the DOE 10 CFR Part 431 efficiency rule, applicable to distribution transformers built and shipped in the U.S. Jan. 1, 2010 or later, are modeled for transformers with a 50 percent load factor. To muddy the waters further, the DOE standard does not apply to wind farm step-up transformers since step-up distribution transformers are excluded. Thus, unless the specification has an evaluation formula, the manufacturer is not obligated to provide any specific efficiency for this specific wind farm application.

Since the operational loading profile for wind turbine step-up transformers is so different from conventional distribution or power transformers, wind farm developers should be cautious about applying typically used price evaluation formulae when calculating the total cost of ownership for wind turbine step-up transformers.

Combustible Gases

Insulation systems in liquid-filled transformers are composed of paper and an insulating fluid, generally mineral oils, natural ester fluids, or synthetic silicone oils. These fluids exhibit high dielectric strength, heat transfer properties and chemical stability.

Both the paper insulation and the dielectric fluid will generate some combustible gases during operation. Gases generated from oil decomposition include hydrogen, methane, ethane, ethylene and acetylene, while those used to monitor paper decomposition include carbon dioxide and carbon monoxide. Abnormal conditions, including faults or extreme loading conditions, generate higher amounts of combustible gases.

Cyclical loading causes the gas to be absorbed into the fluid and then released from the fluid as the fluid heats and cools. Depending upon the rapidity of the temperature changes, the creation of bubbles may short circuit insulation clearances. These conditions would not lead to a complete insulation failure, but more likely a low level partial discharge that would probably result in elevated levels of hydrogen gas in the oil.

Harmonic content within the transformer can cause additional losses and heating within the transformer. If not properly addressed, this heating can lead to both paper and oil decomposition products. Since the heating is generated from the winding conductor outward, the appearance of carbon monoxide would indicate thermal decomposition of the paper.

Fault ride-through events produce fault level currents that will generate heating of the conductor. Without proper coordination of fault current levels and duration, excessive thermal conditions will decompose the paper, producing higher than normal levels of carbon monoxide.

Insulation coordination, if not done properly, can lead to rapid insulation deterioration and eventual failure. Transient voltages from lightning or switching, if not damped out by the protection system, can lead to insulation damage. A transient overvoltage within the transformer, depending upon its level and intensity, can produce any of the primary combustible gases. Often this damage goes undetected even though it can lead to short-term electrical failures. As noted, this potential damage can be prevented by insulating the winding at its full level, regardless of the available bushing.

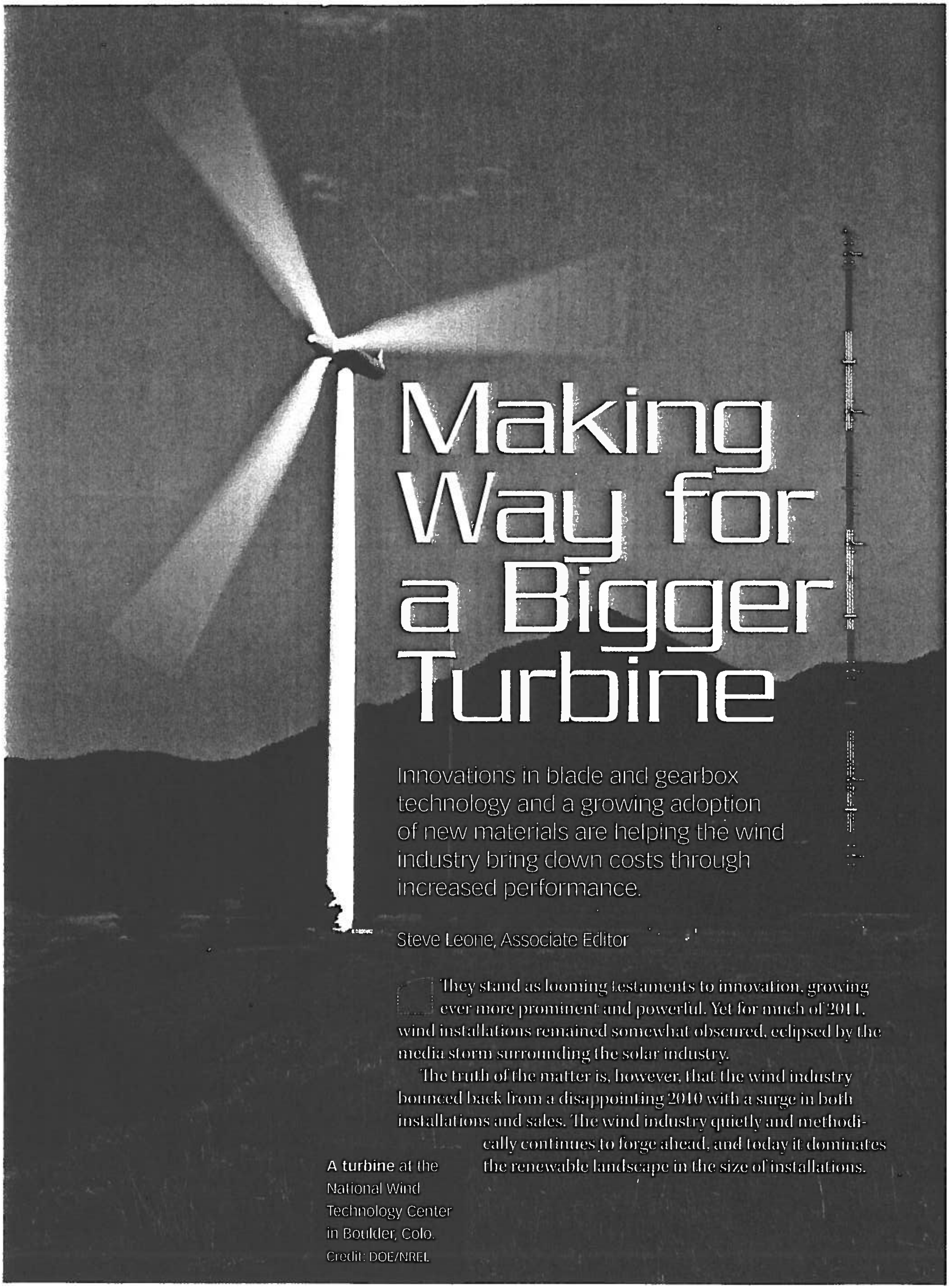
Periodic monitoring of the combustible gases within a transformer will give confidence that the units are operating properly. The correct application and protection of transformers for wind turbine step-up applications will take all these potential sources of gas generation into consideration.

Analysis and Reevaluation

The role of the wind turbine step-up transformer in this process is critical and its design needs to be carefully and thoughtfully analyzed and reevaluated. Wind farm step-up transformers are a unique application and demand their own special requirements. The IEC is currently in the process of finalizing its transformer standards for wind farm applications, and the IEEE Transformers Committee has formed a wind farm transformer standard task force. This activity is long overdue.

Under the economic pressure exerted by today's competitive market, developers are basing equipment purchasing decisions largely on the lowest initial cost rather than long-term total cost of ownership, network stability, less down time and lost revenue from high maintenance issues. The relatively large numbers of recent failures strongly suggests that these transformer designs need to be made substantially more robust. The practice of using conventional "off the shelf" distribution transformers as a low-cost solution is folly. pe

Authors: Mike Dickinson began his career in the transformer industry in 1972 at Pacific Crest Transformers. Currently Mike is in charge of Business Development at PCT.



Making Way for a Bigger Turbine

Innovations in blade and gearbox technology and a growing adoption of new materials are helping the wind industry bring down costs through increased performance.

Steve Leone, Associate Editor

They stand as looming testaments to innovation, growing ever more prominent and powerful. Yet for much of 2011, wind installations remained somewhat obscured, eclipsed by the media storm surrounding the solar industry.

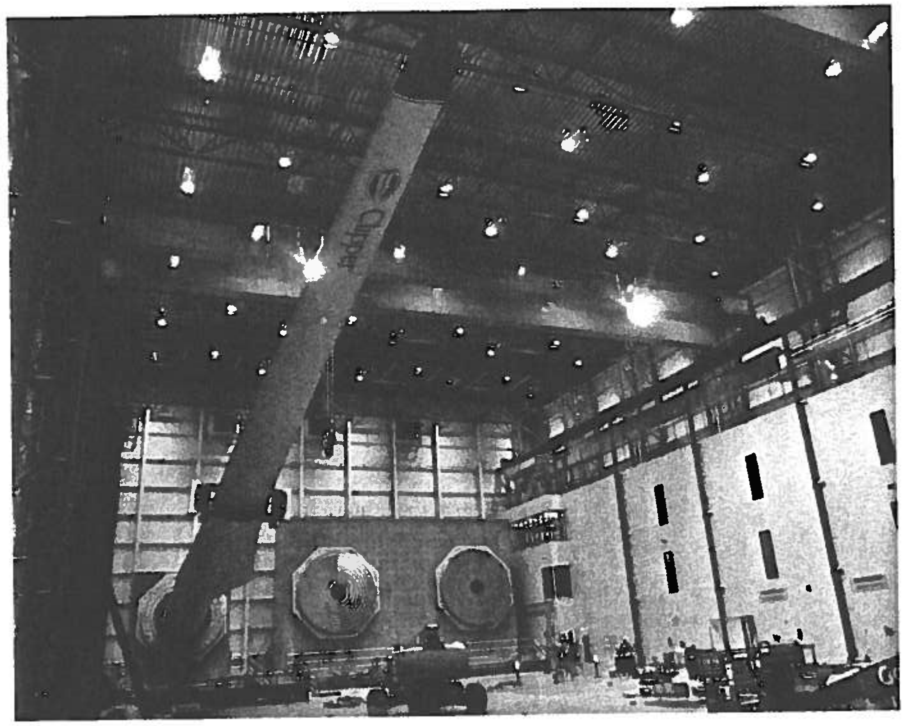
The truth of the matter is, however, that the wind industry bounced back from a disappointing 2010 with a surge in both installations and sales. The wind industry quietly and methodically continues to forge ahead, and today it dominates the renewable landscape in the size of installations.

A turbine at the National Wind Technology Center in Boulder, Colo. Credit: DOE/NREL

Through October (the most recent numbers available by press time), the wind industry placidly posted three strong quarters behind a steady drop in prices and the realization that Congress may not extend the Production Tax Credit (PTC) past its December 2012 expiration date. According to a project list compiled by the American Wind Energy Association (AWEA), through the first three quarters of 2011 the wind industry installed 29 wind farms larger in total capacity than the biggest solar project installed during that same period.

With the wind industry eager to continue its momentum with or without the PTC, two things are clear: turbines must get bigger and engineers must work to drive down costs. It's a proven formula that's paying dividends beyond the traditional stronghold of the Midwest, as the technology becomes a bigger part of the landscape in places like New York, Massachusetts and Maine.

But how to get there, and from where will the cost gains come? Dan Shreve, a partner with Make Consulting, says his company is looking at that question and has come out with a new report on wind turbine trends. The report breaks down the materials used for components like hubs and blades, and determines how a component's cost impacts its performance. Sometimes, more costly materials can open the door to cost-savings with other components. Engineers have found this to be the case with rotors, where new materials and novel approaches are pushing costs down and performance up. The result, though, is a turbine capable of better returns.



Clipper Windpower's wind turbine blade is installed for commissioning testing at the Wind Technology Test Center in Boston, Mass.
Credit: DOE/NREL

How Big Can They Get?

Fort Felker, Director of the National Renewable Energy Laboratory (NREL) Wind Technology Center, remembers a time when many questioned whether the industry had hit the ceiling with the height and capacity ratings for wind turbines. Today, those same folks might be shocked to learn that companies like GE are actively working to build turbines that reach into the 10- or even 15-MW range. Few are skeptical anymore that eventually we'll get to those scales.

"The landscape is littered with people who predicted turbines couldn't get any bigger," said Felker. "They said that at 50 kW. They said that at 100 kW. They said that at half a MW and they said that at 1 MW. It's just silly to predict a limitation because again and again, the industry has found ways to innovate to get past technology barriers that are perceived at any given size."

Technological barriers aside, it is market conditions that serve as the real driving force behind the growth of turbine capacity. To become more powerful, turbines must get bigger. But there's a growing friction between developers coming to town with wind behemoths and local residents questioning how the turbines will impact the landscape. Nowhere is this conversation as vocal as it is in places like bucolic New England, which prizes its rolling hills and its scenic views.

Today, it's not unusual to see the installation of a 3-MW turbine, though most remain smaller than that. We're seeing 5- to 7-MW turbines in the offshore markets of Europe. The giants we're likely to see in the future will mostly be offshore, where there are usually fewer logistical constraints and not-in-my-backyard objections. Eventually, mega-turbines will be installed in deep water far offshore on floating platforms. Their assembly will be done on land and they'll be shipped relatively intact to their final destination where they'll "drop anchor," so to speak. This convergence of large turbines and, eventually, of floating platforms and new transmission, could also make assembly far easier.

Wind turbine manufacturer Gamesa, though, is bucking the notion that large turbines will be pushed offshore. It has recently introduced a 4.5-MW onshore turbine that is taking an innovative approach to common transportation and assembly hurdles that larger turbines face. As rotors get bigger, they can handle much longer blades. But the longer the blades get, the more difficult it becomes to transport them on roads, rails and bridges, and around power lines and curves. Gamesa gets around this by shipping the blades in two pieces and assembling them on site.

For Felker, this is further evidence that companies will find creative ways to get around perceived limitations and build bigger and bigger turbines. It does, though, bring up a new set of challenges, according to Shreve. "Construction costs money and it adds complexity. Wind farms are generally not the most hospitable environments and having to take on larger levels of on-site assembly presents a great deal of new challenges to project developers."

Bigger Rotors, Better Materials

There's a race on right now as manufacturers push to dramatically increase wind turbine's power and economics and to do that, many are focusing on increasing the size of the rotor while being mindful of load and costs.

One way to build a more powerful turbine is through the use of innovative materials. Many turbine makers are analyzing the cost benefits of switching from fiberglass to alternative materials like carbon fiber, which is prized for its ability to reduce weight and increase performance. Because it's been prohibitively expensive, most manufacturers that use carbon fiber do so exclusively in the blade spar and the spar caps, an area considered the primary structural element for the blade. "It's about clever utilization of the material. Effectively, they're doing this to get the best bang for the buck," said Shreve. "They're trying to achieve the rigidity, the stiffness required to enable the system's operation. This is critical for larger rotor diameter."

Though carbon fiber will remain expensive in the near future, Felker sees a couple of paths that could significantly bring down its cost. One is an innovation being made in the airline industry. Boeing has introduced its 787 jet, which uses carbon fiber reinforced materials for about 50 percent of its airframe. The quantities produced to service that aircraft will create a more vibrant market for carbon fiber, and this should ultimately push down its cost. Felker also pointed to research being done at the Oak Ridge National Laboratory in Tennessee. There, researchers have launched a consortium with 14 companies to push the development and commercial application of low-cost carbon fiber.

The interest in manufacturing wind turbines with alternative materials doesn't end there. Traditionally, manufacturers use balsa wood in their blades to separate layers of fiberglass, resulting in light yet stiff structures. Many manufacturers are now starting to look to advanced materials like WebCore, which has been engineered specifically for wind blades. "People are asking, 'What's the real engineering need and let's create a material from scratch that satisfies that need,'" said Felker. "This will continue to be a trend over the next five years or so."

Eventually, mega-turbines will be installed in deep water far offshore on floating platforms.

Tremendous strides are also being made in blade geometry and systems and control analysis. In both cases, new approaches are being used to better manage loads on wind turbines under various conditions. A curve or a bend in the blade may not vastly increase performance, but it can reduce stress and even noise. And a sensor that measures incoming gusts could allow it to react to sudden conditions. These innovations may not reduce initial costs, but they add value and longevity to an installation.

"Over the 20-year life, are you going to reduce blade fatigue, such that you'd be able to minimize maintenance on blades, in the gearbox and in different areas within the drivetrain? It's tougher to monetize and to truly put your arms around," said Shreve.

Direct Drive Versus Geared Drives

Years ago, direct drive technology was a novel concept with serious cost limitations. Today, we're starting to see direct drive turbines that are cost-competitive with geared systems.

While a vast majority of deployed wind turbines use geared technology, direct drive has been able to make inroads because of its potential to improve reliability. Since geared turbines come with many more parts, the thinking goes that direct drive technology with fewer moving parts will require fewer onsite repairs.

Siemens and GE are among those beefing up their direct drive products, joining a market that already includes Enercon and Goldwind. Much of these turbines are destined for the offshore market, where there is less resistance to large turbines and a greater need for turbines that need less maintenance. According to Felker, the industry is still figuring out which environments respond best to geared technology, and which environments would be better served by direct drive turbines. Ultimately, though, there will be room for both.

And the growing competition between the technologies may be instrumental in achieving new highs in capacity and new lows in cost.

"What that's going to do is push the gear technology to get better, and that's going to push the direct drive technology to get better," said Felker. "A little competition in fact is going to do a lot."

Chief among the concerns with gearless turbines is the price volatility associated with rare earth minerals, which are central to everything from computers and military weapons to the magnets that power direct drive technology. China currently controls as much as 97 percent of these metals, and recently there has been a sharp spike in prices and a deep drop in availability.

Many corporations, desperate to maintain price stability and eager to wrestle the market control away from China, are investing heavily in new mining operations. While rare earths are not all that rare around the globe, finding locations with a high enough volume to support a profitable mining operation has proved difficult. Mining giants Molycorp and Lynas are among those opening or expanding operations in places like the U.S., Australia and Malaysia. Ultimately, many expect these efforts will help stabilize prices and supply.

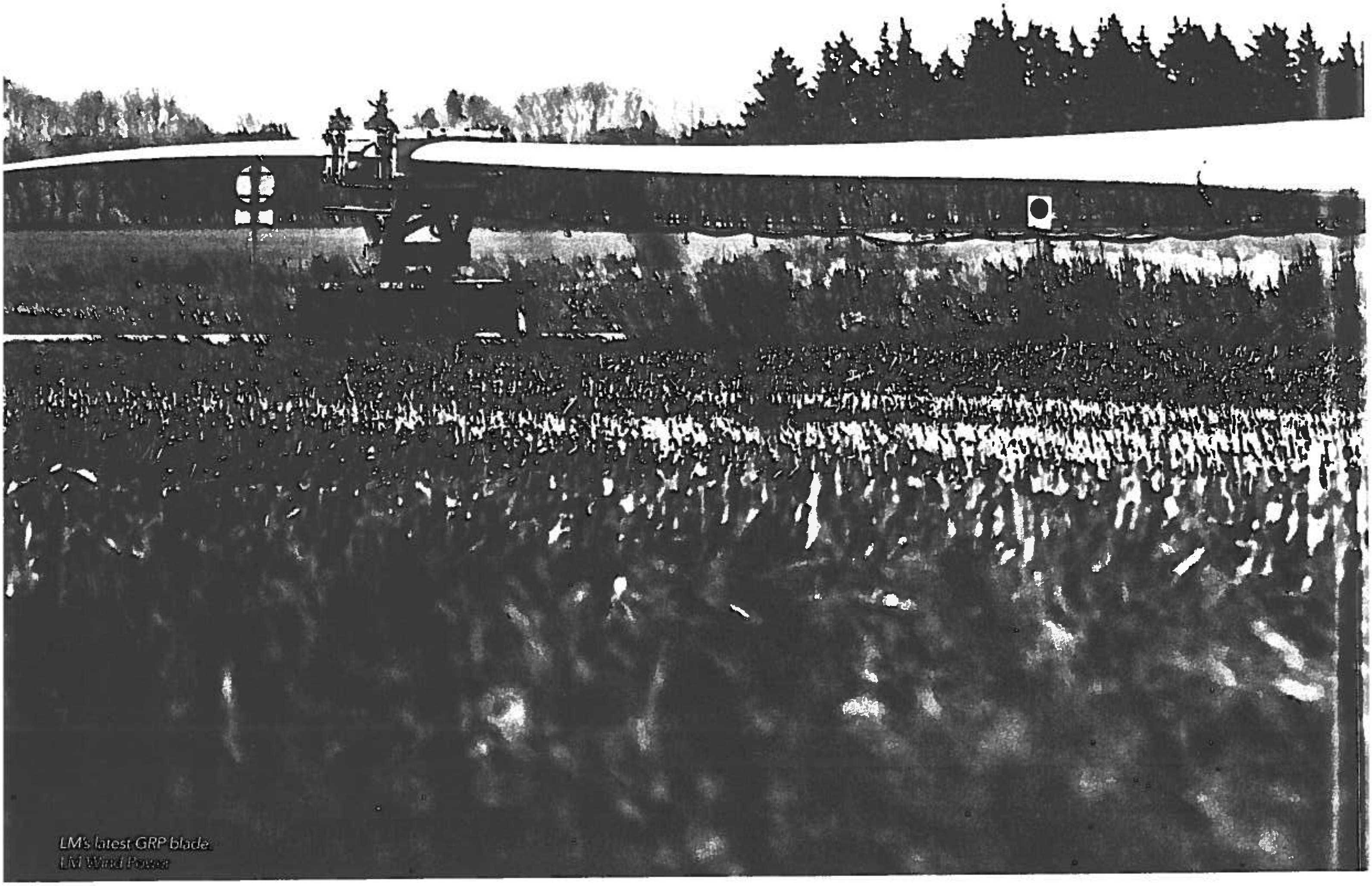
And that stability could further help the industry continue its momentum in both pricing and technology in 2012 and beyond. ■

By James Lawson

ON THE CUTTING EDGE

NEXT GENERATION MATERIALS IN TURBINE BLADE CONSTRUCTION

As machines get ever larger and rotor diameters grow to match, wind turbine blade materials are evolving, with new designs, materials and manufacturing processes. Strength and lightness are the goals of materials scientists working in wind.



LM's latest GRP blade.
LM Wind Power

It's a hard job being a rotor blade these days. They must be longer and stiffer to extract as much power from the wind as possible, but lighter per unit length, maintenance-free and damage-resistant. Meeting these goals at the lowest possible cost means researching and employing the very latest materials in blade construction.

Stopping longer, slimmer turbine blades hitting towers when deflected by wind loads is probably today's biggest challenge. It requires stiffer composites which must be lighter too: blade mass scales as the cube of the turbine radius and, as blades get longer and heavier, buckling in compression (the blade's tendency to collapse under its own weight as it stands vertically) becomes the major fatigue failure mode instead of flexural fatigue.

Three or more times as strong and stiff as glass, carbon fibre is the alternative to the commonly used glass reinforced plastic (GRP). It helps designers build longer blades with a thinner spar section, while retaining the necessary stiffness. A thinner spar also avoids the problems associated with resin wetting in thick lay-up sections of GRP.

According to a study by SGL Rotec, a carbon-based design for a 53 metre-long blade should be about 20% lighter than the GRP equivalent and will have looser design constraints in areas like flutter. Lighter blades reduce root loadings as well as those on the rest of the structure, in turn reducing weight and cost. SGL's study envisaged a benefit of €100,000 over the lifetime of a 3 MW turbine.

The industry discussion over replacing glass with carbon fibre has been simmering for years. Vestas and NEG Micon, which merged in 2004, were the first to use carbon and today Vestas and Gamesa (which also share a common heritage) along with SGL Rotec and DeWind are among the minority of manufacturers which publically admit to using carbon. Other manufacturers, such as REpower an LM, have flirted with carbon but subsequently discontinued its use.

The 'cost of stiffness' is the main factor here: carbon's cost (maybe 20 times higher than E-glass), consistency and security of supply have hampered its widespread adoption. How well a manufacturer's own resin system and manufacturing process suits carbon is another factor.

GRP's development life is far from over though. LM Wind Power's new 73.5 metre blade for Alstom's Haliade 150–6 MW wind turbine uses pure glass-fibre technology, while Sandia National Labs came up with a 100 metre glass-fibre design last year.

Developing stronger fibres and adding more glass are two ways to increase GRP performance, though composites with glass content much more than 55% by volume are more susceptible to fatigue. This is a current area of research at Fraunhofer IWES while improved E-glass fibres have recently appeared that offer significant performance increases at various price points.

With an urgent requirement for very large turbine blades and prices continuing to drop (despite rising demand from other sectors like automotive), it looks like carbon fibre is poised for a breakthrough. Lux Research predicts wind energy will take over from aerospace as the leading user of advanced composites and will account for nearly 60% of the market by 2020, up from today's 35%.

As the use of carbon rises, how best to mix carbon and glass to form hybrid composites that optimise cost and performance is becoming important. Carbon is about four times as stiff as glass fibre and deforms less under tension, but it performs worse in compression.

WHAT ELSE IS ON OFFER?

Beyond glass and carbon, little is heard of other fibre types. Basalt seems a likely contender, with higher strength and stiffness than E-glass. It got some attention in wind some six years ago when Ahlstrom worked with Kamenny Vek to produce some biaxial basalt fabrics for testing in wind turbine blade laminates. Professor Paul Hogg, vice principal for Research and Enterprise, Royal Holloway, University of London, says the variation in performance from supposedly similar fibres could be a factor in basalt's lack of popularity.

'There are a lot of other high-modulus fibres available like boron, which has amazing strength and stiffness,' says Dr Arno van Wingerde, head of the Rotor Blade Competence Centre at Fraunhofer IWES. 'But then they told me what it costs – about €5000 per kilo. That's OK for an F-16 maybe, but not a turbine blade.'

The way in which carbon or glass fibres are woven together – their 'fibre architecture' – has a big effect on the strength, stiffness and fatigue performance of the finished composite. For example, conventionally woven mat – where the warp runs over and under the weft – results in built-in defects in the finished composite while not all fibres will take up the load directly along their axis, so putting more of the load through the weaker matrix polymer.

Non-crimp and unidirectional fabrics, whose filaments can be directly aligned with the greatest loads, appeared long ago to tackle these problems. But laying up multiple fabric sections into shapes like spar caps or roots is a complex and time-consuming process that can introduce further weaknesses: wrinkles, dry zones, and poor fibre alignment. Poorly laid 'wrinkled carbon' caused a 7 metre section of a prototype Vestas V112 rotor to snap off during trials at the company's testing centre in Lem, Denmark in 2010.

'Composites are two dimensional, so you have to fold a fabric to make a T-section,' says Hogg. 'Inevitably there will be an area with no fibres, just resin, and that's very susceptible to splitting. Delamination within the structure is the long-term durability challenge.'

By making it easier to form joints and eliminating built-in defects, 3D fabrics improve fatigue performance, increase strength and aid manufacturing. Using single-fibre-thick layers of 2D fabrics, 3D fabrics are built up using a variety of stitching, weaving, braiding

'[BORON] COSTS ABOUT €5000 PER KILO. THAT'S OK FOR AN F-16 MAYBE, BUT NOT A TURBINE BLADE.'

and tufting methods that introduce a third, through-the-layers 'Z-fibre' reinforcement. This vertical stitch or tuft helps prevent delamination, while varying its depth means the fabric can easily take on the shape of the desired joint and make sure fibres take up the load rather than the matrix. Suppliers such as 3Tex and Techniweave offer complete pre-woven structures such as blade roots and spars.

Better fibre architecture should also help to increase the volume fraction of fibres in a composite without fatally decreasing fatigue performance – an obstacle when building very large GRP blades. 'The fibres interfere with each other and we are working to overcome that,' says van Wingerde. 'You need to keep the fibres completely straight, parallel and separated from each other. It's a big job and there are lots of hurdles.' IWES is intending to test a glass blade of more than 80 metres this summer.

Most manufacturers make their blade halves separately and bond them together during assembly, so the adhesives used are critical to the performance. 3M's W1101, a two-part epoxy paste specifically developed for this application, offers reduced process times and better durability and crack resistance. According to 3M, it cures two to four hours faster and has 200% higher peel strength and 75% higher fracture energy compared to the 'industry-standard epoxy adhesive'.

Blade core materials are also evolving from end-grain balsa, SAN and PVC foams towards thermoplastics like PET. Easily recycled, PET can easily be cut and formed into complex shapes or melted and bonded to other parts. But, PET requires a slightly higher density to match the mechanical strength and stiffness of SAN and PVC, and a substantially higher density to match balsa. 'The industry wants to use PET because it's cheaper and you can remelt it to recycle, but the characteristics are not there yet,' says Professor Povl Brøndsted of the Department of Wind Energy, Risø DTU.

Blade materials continue to evolve hand in hand with manufacturing: better performance is no use if it adds too much complexity and cost to production. With the industry moving away from traditional manual processes, new materials must be compatible with automated techniques like robotic lay-up or top-coat spraying. Recycling is becoming more important, too, something that current blade materials struggle with.

The bottom line is always cost per kW/h. Any extra power produced must be set against turbine manufacturing, installation and maintenance costs – and any material that doesn't help reduce a turbine's lifetime cost of energy must be ruthlessly discarded.

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By David Appleyard

COUNTING THE COST OF CAPITAL

While facing short-term challenges such as a difficult financing context, the wind sector's fundamental economics should ensure its bright outlook over the longer term, argues Christian Kjaer of the European Wind Energy Association (EWEA).

With a background in journalism, economics and policy development, EWEA's CEO has welded the organisation into an effective lobbying group backed by rigorous research. For the wind sector, he now expects the next five years could be challenging, although he remains upbeat over its prospects in the long run.

WT: What do you think has made this industry pretty robust in the face of challenging economic circumstances?

CK: We're increasingly competitive. We're at a point now where we can actually offer a product at the same cost per kilowatt-hour for a new power plant as a new coal or gas-fired plant. With the current costs of gas in the US as an exception, wind power can compete and deliver electricity at the same cost. And it's a choice that hedges against future fuel and carbon prices.

Long term, that's the most attractive nature of wind energy. We're not competitive if oil prices go back to US$20 a barrel. But if they go to $150 or stay at $125, we are. We cost less than half the price of a new nuclear power plant.

WT: What are the challenges in the short term?

CK: Access to and cost of capital and infrastructure grids. The next five years may challenge us. What did the banks do in the financial crisis of 2008? They shortened the maturity of loans and they increased risk premiums. So basically it means that the wind industry or any other industry that needs capital to make investments has not benefited from the very low interest rates in the economy.

The good news is that new avenues are opening up in terms of financing. We need long-term financing and, of course, lower risk premiums. What the industry is increasingly trying to do is to match the long-term assets that we are building with companies that have long-term liabilities such as insurance companies or pension companies.

That's a much better match but it requires two things. It requires us as a sector to do much more in terms of educating those institutions about the technologies and risks. The other element is that the decision on whether they invest or not crucially depends on the political risk of an investment. We are paying way too much for

WT: What about international influences on manufacturing?

CK: The European company's competitor – and I assume the Chinese's, the Americans' and the Koreans' as well – it's gas and coal for electricity production. Pressure from other competitors is good because it keeps us lean and if we're lean we can take on the competitor much earlier and better. A manufacturer might be able to build cheaper in China but once shipped to Europe it's going to be significantly more expensive than the one built in Germany. The alternative is coming to Europe and building wind turbines. That's not a scary scenario: it creates jobs. Two thirds of the wind turbine is sub-supplied and happens outside of the manufacturer. If companies come to Europe, they're going to use a large amount of European components.

What we crucially need in the wind industry is for that trade to be open and I'm very concerned about the protection that always comes when you have an economic crisis, and countries turn protectionist. We would like fairer market access to many markets.

WT: How can wind address integration?

CK: Infrastructure needs to be much better integrated because that's a precondition for competition to work. We want to compete. We have a very cost competitive technology but we can't prove it unless competition works and it doesn't. We need market reform. The main message is you can really use wind energy to create jobs and economic activities. What wind can do is create jobs. We need to address the affordability and shortage of capital. We need to figure out how can we mobilise capital to make the necessary investments to create the jobs to take the European economies back on track.

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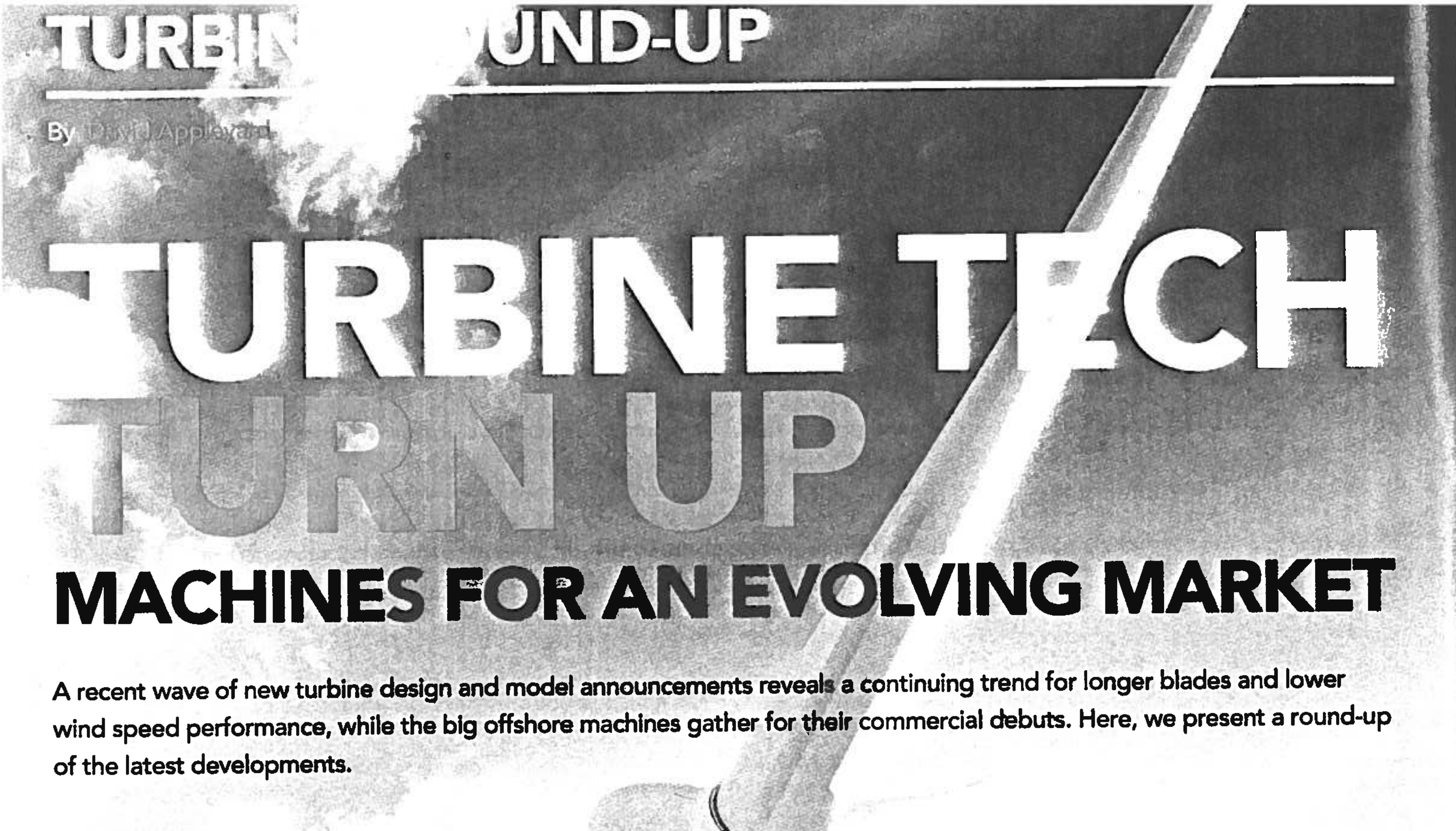
By David Appleyard



TURBINE TECH TURN UP

MACHINES FOR AN EVOLVING MARKET

A recent wave of new turbine design and model announcements reveals a continuing trend for longer blades and lower wind speed performance, while the big offshore machines gather for their commercial debuts. Here, we present a round-up of the latest developments.

Presenting figures that show the global wind industry will install more than 46 GW of new wind energy capacity in 2012, the Global Wind Energy Council (GWEC) forecasts that by the end of 2016, total global wind power capacity will be just under 500 GW, with an annual market in that year of about 60 GW*.

The turbines that will deliver the bulk of those forecasts are emerging now as companies gear up towards series production of the latest generation of machines by 2013 and 2014. As with the previous few years, the bulk of these developments appear to fall squarely into two camps. On the one hand are design upgrades and rotor diameter increases; on the other are the large offshore machines, several of which are now moving from pre-commercial trials onto the market.

New turbines on the market

While the areas of development may fall into two clear camps, some manufacturers are less easy to categorise so distinctly. Take Spanish player Gamesa, for example. This group appears to be pushing hard on new turbine developments, announcing a swathe of projects both on and offshore.

For the offshore sector, in May 2012 the company announced it will install its first new 5 MW prototype at Arinaga Quay in Gran Canaria Island, saying its decision was driven by technical and wind resource considerations, offshore market trends and investment return criteria.

The location will optimise returns on investment and has reduced transportation cost, due its proximity to Gamesa's factories in Spain, where the turbine will be manufactured, the company says. Indeed the announcement spells the end for activities at Cape Charles, Virginia, USA, the location of the Offshore Wind Technology Centre, opened jointly with Newport News Shipbuilding, which will now wind down at the end of the year as the design of the G11X-5.0 MW offshore platform is completed.

'The offshore wind power market is developing at a firm pace. However, demand is being tempered by economic and financial factors and the difficulties being encountered by developers in accessing credit. The authorities are firmly committed to the develop[illegible] offshore wind power in major markets such as the UK, G[illegible]ce and China. Based upon the current situation, th[illegible]ppears to be set to develop later than others. R[illegible]ountry specific market conditions warrant even more [illegible]op-making process than ever, from both the technology a[illegible]l standpoints,' said Jorge Calvet, chairman and CEO of Ga[illegible] explaining the decision.

Installation of the new machine is expected to begin in the second quarter of 2013, with a view to achieving certification in the following months, to permit the installations of the pre-series turbines towards the end of 2013 or early 2014.

The offshore prototype – the G128-5.0 MW (50 Hz) – has a 128 metre rotor diameter. It is based on the existing G10X-4.5 MW machine. The initial prototype of the G128-4.5 MW, featuring a semi-integrated main shaft in a two-stage gearbox with mid-speed range output and a permanent magnet synchronous generator using a full converter, connected to the grid in April 2009. Now installing the first pre-series of the machine, Gamesa says the blades have new aerodynamic features and a structure which substantially reduces the machine's weight.

Running parallel to the development of its offshore technology, Gamesa is making progress on the installation of its offshore manufacturing base, having recently announced it had entered in Memorandum of Understanding (MoU) talks with the Forth Ports at Leith, Scotland, regarding the establishment of two plants (blades and nacelles) for its UK offshore operations.

Meanwhile, Alstom has also declared its vision to move ahead with its offshore ambitions, recently installing the first prototype of its new 6 MW machine, featuring its 150 metre rotor diameter. This direct drive machine uses a permanent magnet generator from Converteam, which has equipped Alstom's two 6 MW offshore wind turbine prototypes. In March, the so-called Haliade 150 machine was commissioned at Carnet in the Loire-Atlantique, in France, ahead

'LOWERING THE COST OF ENERGY IN RELATION TO OFFSHORE WIND ENERGY OUTPUT IS ESSENTIAL FOR THE INDUSTRY.'

of year-long tests on land before a second turbine is placed in the sea off the Belgian coast in autumn 2012. Pre-series production is planned for 2013 with production in series due to start in 2014.

Meanwhile, Alstom and LM Wind Power have developed the 73.5 metre-long blades designed specifically for Alstom's offshore machine. The use of specifically developed material compounds will enable LM to maximise strength and durability while producing an exceptionally light blade, they say. The blades are currently the longest in the world and will be manufactured in partnership with LM Wind Power in Cherbourg.

The Carnet site was chosen for its geological characteristics that are very similar to the submarine environment in which the wind turbines will eventually be installed. The 25 metre sub-structure (known as the jacket) was installed on pillars driven more than 30 metres into the ground on which the 75 metre high tower was then mounted. The wind turbine and its support structure have a total combined weight of 1500 tonnes.

Sticking offshore, Germany's REpower Systems SE has now seen its 6 M turbines, rated at 6.15 MW, installed offshore after the first units were erected in March 2012 at the Thornton Bank wind project, 28 km off the coast of Belgium.

With 48 machines set to be developed at the site, REpower and Belgian offshore project development company C-Power NV will execute the installation of the first 30 turbines for phase 2 of the wind farm, planned for 2012, as well as a further 18 designated for installation during a third extension stage by mid-2013.

With a diameter of 126 metres, three prototypes of the REpower 6M were installed at the Ellhöft wind farm, near the German-Danish border, in 2009. In 2008, REpower installed six of its 5M turbines for the first construction phase of Thornton Bank in water 12–27 metres deep. A further two turbines will be installed in the Westereems wind farm near Eemshaven in the Dutch province of Gronigen, a few kilometres from the German border. Completion is planned for mid-2012. RWE Innogy will use this machine at its Nordsee Ost offshore wind farm, some 30 km North of Helgoland. A total of 48 of the 6M turbines will be delivered over the course of 2012.

In a related development, on the last day of 2011, REpower acquired from SGL Rotec GmbH & Co. KG the remaining 49% stake in PowerBlades GmbH which it did not own. PowerBlades was founded in 2007 as a joint venture for the production of rotor blades for wind turbines. 'The acquisition of the shares enables us to continue growth at our site in Bremerhaven as well as in the offshore sector,' said Gregor Gnädig, REpower's chief operating officer. The move followed the autumn 2011 completion of a hall expansion at Bremerhaven that will support 300 MW of additional production capacity from 2012.

Elsewhere in the offshore sector, Areva's Multibrid 5 MW M5000 platform is also set for series production in 2013–14. Late 2011 the company unveiled the latest product extension of its M5000 product platform with a new 135 metre rotor diameter version of the hybrid drive machine. With the 66 metre long blades the M5000's swept area will increase by 35% to 14,326 m². Serial manufacture of the M5000-135 is expected in the second half of 2014. Areva Wind general manager Jean Huby explained: 'Lowering the cost of energy in relation to offshore wind energy output is essential for the industry.'

Meanwhile, GE has announced that its 4.1-113 offshore turbine it has nicknamed 'Big Glenn' – GE's first direct-drive offshore wind turbine – passed its initial 200 hour trial run. 'The variation in wind speed gives the team confidence that the turbine performs reliably under all wind conditions,' says Vincent Schellings, offshore product manager for GE Energy, adding: 'Now we will begin validating the design and obtain initial results before summer. Our initial focus will be on the power curve and loads validation.'

Widely acknowledged as the current offshore wind market leader with its 3.6 MW, 120 metre rotor machine, Siemens has continued development of its new 6 MW direct drive turbine.

In a clear move towards offshore commercialisation of its latest offering, Danish utility group DONG Energy has received full consent to test two of the turbines at their Gunfleet Sands 3 demonstration project site off the coast of South East England. The two turbines are due to be installed by November with construction starting as *REW* goes to press. Featuring direct drive technology, the two turbines will have a rotor diameter of 120 metre with a swept area of 11,500 m².

'NO OTHER FORM OF RENEWABLE ENERGY OFFERS A CHEAPER PRICE PER KILOWATT HOUR'

Siemens is currently testing and validating the performance of the turbine and a pre-series of up to 50 SWT-6.0 wind turbines will be installed at on- and offshore sites in Denmark, Germany, the Netherlands and the UK during 2012 and 2013, it says. The SWT-6.0 will be available with rotor diameters of 120 metres and 154 metres and a tophead mass of 350 tonnes. The SWT-6.0-154 will be using the new 75 metre long B75 Quantum Blade, while the SWT-6.0-120 is to be equipped with the B58 rotor blade used on the SWT-3.6-120.

The SWT-6.0-120 is the third direct drive wind turbine type developed by Siemens. 'In tendency large wind turbines have always been heavier per megawatt than small ones. The SWT-6.0-120 breaks this rule, having a weight per megawatt similar to that of many turbines in the 2 to 3 MW range,' says Henrik Stiesdal, chief technology officer of the Siemens Wind Power Business Unit.

Meanwhile, in December last year, Siemens signed a strategic alliance with Shanghai Electric that will see two new 49:51 joint ventures created for the Chinese wind power market. In each of the ventures, Siemens will have a stake of 49% and its Chinese partner Shanghai Electric 51%. One of the joint ventures will be engaged in R&D and production of wind turbine equipment for the Chinese market and for Siemens' global supply network. The second will be responsible for sales, marketing, project management and execution as well as service in China.

Also in China, Sinovel has recently received GL Renewables Certification Design Assessment compliance for its SL 3000/90 50 Hz offshore wind turbine. The turbine uses variable speed control and double-fed inductive generator. The SL3000 series is suitable for onshore, offshore and intertidal installation, and is designed to be adaptable to a variety of wind energy resource conditions, as well as being available in a cold climate version and 60 Hz versions.

New onshore designs

Late April saw Enercon unveil its latest turbine, the E-92/2.3 MW. This new machine, which has a 92 metre rotor diameter and is rated at 2.3 MW, is another designed for inland sites with far less wind.

The new device has the same major components as the E-82, such as generator, main carrier, grid feed system, and WEC control system. Specified for wind class IIA zones, its newly developed rotor blades are 5 metres longer, yet lighter, then those of its stable mate, the company says, adding that the new machine can deliver 10%–15% more yield than the E-82.

The GRP blades are manufactured using the same half shell and vacuum infusion technique, but have a different profile and a redesigned internal structure. 'The aerodynamic profile has been modified in such a way that it minimises stress on the machine and increases energy yields at the same time,' states Alexander Hoffmann, engineering manager of the Enercon rotor blade division. Managing Director Hans-Dieter Kettwig cited the attractive price-performance ratio of generating power, by adding: 'No other form of renewable energy offers a cheaper price per kilowatt hour'.

Gamesa's latest offshore development came just weeks after the company had launched a new turbine, the G114-2.0 MW, designed for better returns at low-wind speed sites. With the first machines expected to be delivered in late 2013 the Class IIIA machine features a 114 metre diameter rotor with a swept area of 10,207 m². The machine is offered at a range of tower height options from 93 metres to 140 metres or higher, depending on the target location.

Claiming the lowest power density on the market for its segment, the new machine is based on the G9X-2.0 MW platform, which is offered with a selection of five different rotors from 80–114 metres. Gamesa says it will begin manufacturing initial prototypes of the G114-2.0 MW in the third quarter of 2013, with the first turbines supply to begin at the end of the same year.

The company has also announced the European-wide launch of its major turbine components (gearbox, generator and blade) reconditioning services business. It aims to extend the useful life of wind turbines and lower operation and maintenance (O&M) costs by upgrading and replacing internal turbine parts with the most up-to-date technologies. By enabling owners to optimise and lengthen the lifespan of their machines they improve turbine yield and the productivity of their wind farm projects, Gamesa says. The company considers its O&M business as a cornerstone of future profitable growth thanks to its potential for producing recurring revenues.

In the onshore segment, REpower presented a 50 Hz version of its new MM100 wind turbine last autumn. With rated capacity of 2 MW, 100 metre rotor diameter and a 100 metre tower, the turbine was specially developed for low-wind speed locations. A prototype of the MM100 50 Hz is to be constructed in mid-2012 and the serial launch is planned for 2013. The MM series first began production in 2002.

'We are currently experiencing great demand for large-rotor turbines,' explained Andreas Nauen, CEO of REpower at the launch. With a claimed 104.8 dB(A), the MM100 is also the quietest turbine of its class, REpower says.

In mid-March Siemens launched its new gearless wind turbine for low to moderate wind speeds, the SWT-2.3-113, with a prototype of the new machine installed in the Netherlands. Featuring direct drive and a compact permanent magnet generator, with a capacity of 2.3 MW and a rotor diameter of 113 metres the new machine is designed to maximise power production at sites with low to moderate wind speeds. It is fitted with the Siemens B55 Quantum Blades. To date, Siemens has installed and commissioned a total of five gearless SWT-3.0-101 wind turbines in Denmark and Norway.

This year Dutch wind turbine manufacturer Lagerwey Systems completed installation two of its new L93-2.6 MW turbines at Test Site Lelystad in the Netherlands. The project was funded by standard wind farm financing from Rabo Bank in the Netherlands. The turn-key project also includes a long-term full service agreement for the installed turbines with Lagerwey Systems.

Lagerwey Wind expects the A certificate for L93-2.6MW to be obtained during 2012. With the launch of L93-2.6MW, the company is now dedicating resources to design and develop a new 3.5 MW wind onshore turbine in 2012–13. The company also has a conceptual design for the 6 MW offshore turbine and is considering developing the turbine with selected strategic partners for mass production.

Also set to undergo testing at Lelystad is Leitwind's new generation of direct drive wind turbines, the LTW101 and LTW104 for both medium and low wind speed regions. The new turbines operate with a synchronous generator using permanent magnets.

The LTW101 is a 3 MW wind turbine for medium wind sites and the LTW104 is a 2-2.5 MW machine for medium and low wind sites. Furthermore there is a choice of two different hub heights, 95 metres and 143 metres. The first prototype of the LTW101 IIA will be installed this year while the new prototypes of the LTW104 are due to start trial operations at the end of 2012.

GE has also revealed a new onshore machine for the European market with the debut of its 1.6-100 turbines for Fina Enerji's Tayakadin wind project in Istanbul, Turkey. 'GE's 1.6-100 technology builds on the broad experience of our 1.5 and 2.5 MW series, with more than 17,500 of those units installed today,' said Stephan Ritter, general manager of GE's Renewable Energy business in Europe. Featuring a 100 metre rotor diameter and 80 metre hub height, the 1.6-100 provides the highest capacity factor of any wind turbine for class III sites, GE claims. GE also announced a new maintenance tool – PulsePOINT Advanced Monitoring and Diagnostic Services – which it says helps reduce costs and achieve optimal energy production by increasing reliability. The system collects wind farm and fleet data from hundreds of turbine sensors and key SCADA control parameters.

Meanwhile, Nordex – which recently announced plans to withdraw from offshore and sell the assets – has showcased new towers for the N117/2400 onshore turbine, which it is now offering on 91 metre and 120 metre tubular steel towers as well as in Europe on a 141 metre hybrid tower, again for low wind areas in difficult or complex terrain.

With new designs and upgrades evidently coming thick and fast, the broad trends that are seeing firms move towards larger offshore machines and extend the low wind performance of their portfolios look set to continue. As always, the next few years will see tomorrow's projects populated with today's prototypes.

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*See the News Analysis section in this edition of *Renewable Energy World* magazine for more on GWEC's latest figures.

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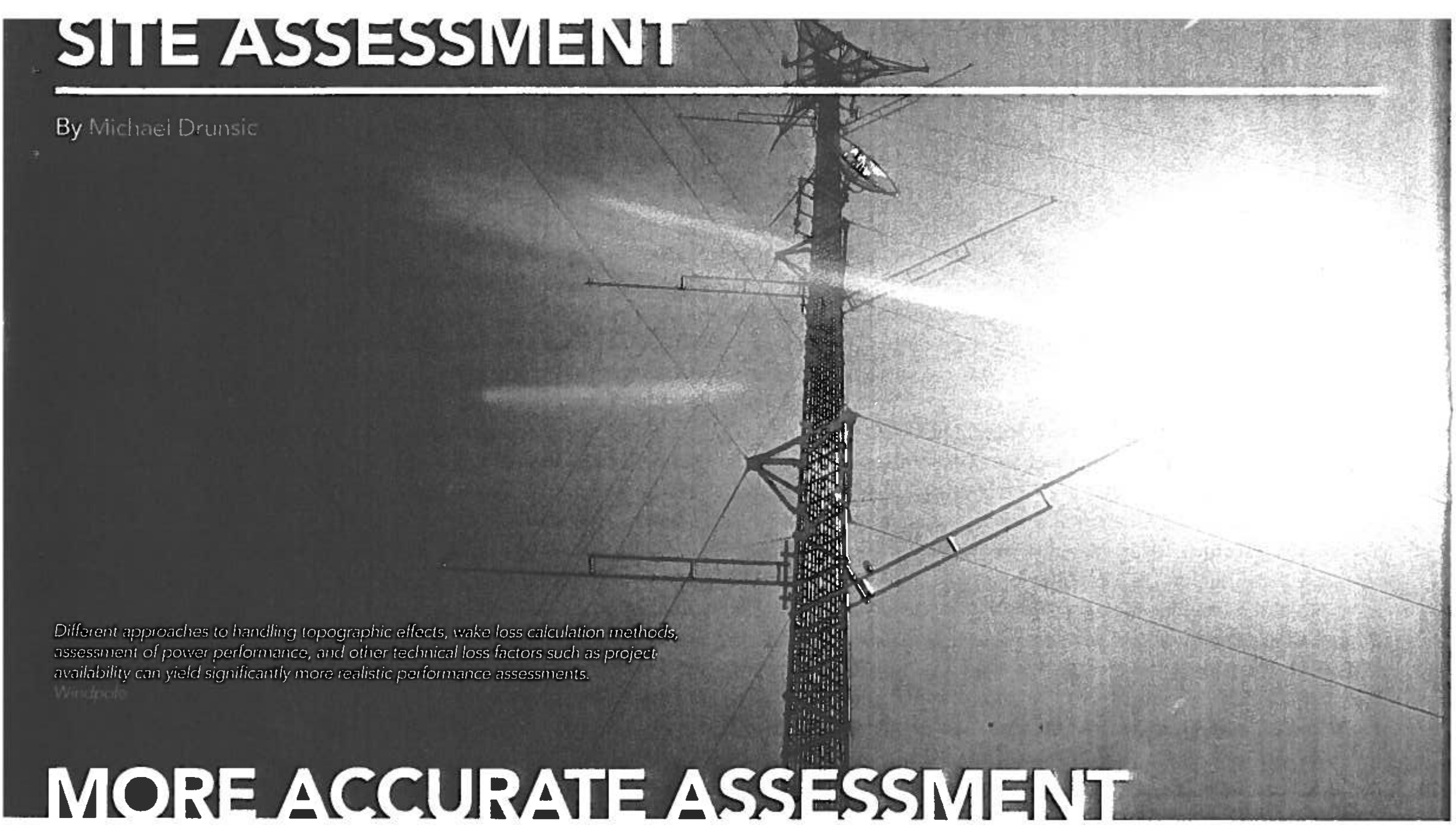
By Michael Drunsic



Different approaches to handling topographic effects, wake loss calculation methods, assessment of power performance, and other technical loss factors such as project availability can yield significantly more realistic performance assessments.
Windpole

MORE ACCURATE ASSESSMENT

PINNING DOWN PERFORMANCE

Accurate pre-construction assessments are critical to securing project financing and ensuring investor confidence. However, North America's wind power industry has developed a reputation for producing energy below levels predicted by pre-construction wind resource and energy assessments. What are the reasons for over-prediction, and how can such assessments be improved?

Wind power projects involve diverse risks for investors. Along with credit, technology and interconnection risks, production risk is a key component in project evaluation. Accurate wind resource and energy assessments are therefore critical when evaluating project feasibility and obtaining financing. However, North American wind projects have been performing significantly below expectations on average, revealing a systemic bias in pre-construction energy assessments.

Concerns emerged in the early 2000s from lenders and other industry participants. Third-party energy assessments were developing a reputation for over-predicting annual energy generation, and banks and investors relying on the estimates were losing confidence. Many investors adapted by applying a 'haircut' to the estimates, limiting the ability of developers to leverage debt.

In response to the emerging underperformance trend, DNV KEMA began assembling a database to assess the magnitude of the bias and identify the key drivers. Its most recent update and assessment of project performance was completed in April.

This database contains production data from 89 North American wind power facilities, and 476 years of operation (369 independent project years) for projects that began operations in 2000 or later. The database also includes pre-construction production estimates for each project, and captures a diverse sampling of regions, project sizes and turbine technologies. This information was used to develop a distribution of operating performance relative to pre-construction estimates.

Analysis of the recently updated database shows that on average significant bias remains in pre-construction energy assessments. But the bias is substantially smaller for assessments with comprehensive, realistic and site-specific loss estimates, and do not rely on generic wind flow and wake modelling tools not tuned to site conditions. While the average industry underperformance bias is about 5%–8%, depending on the method and time period, when examined by the organisation performing the assessment, the data show average underperformance biases between about 1% and 10%, depending on the organisation that completed the analysis.

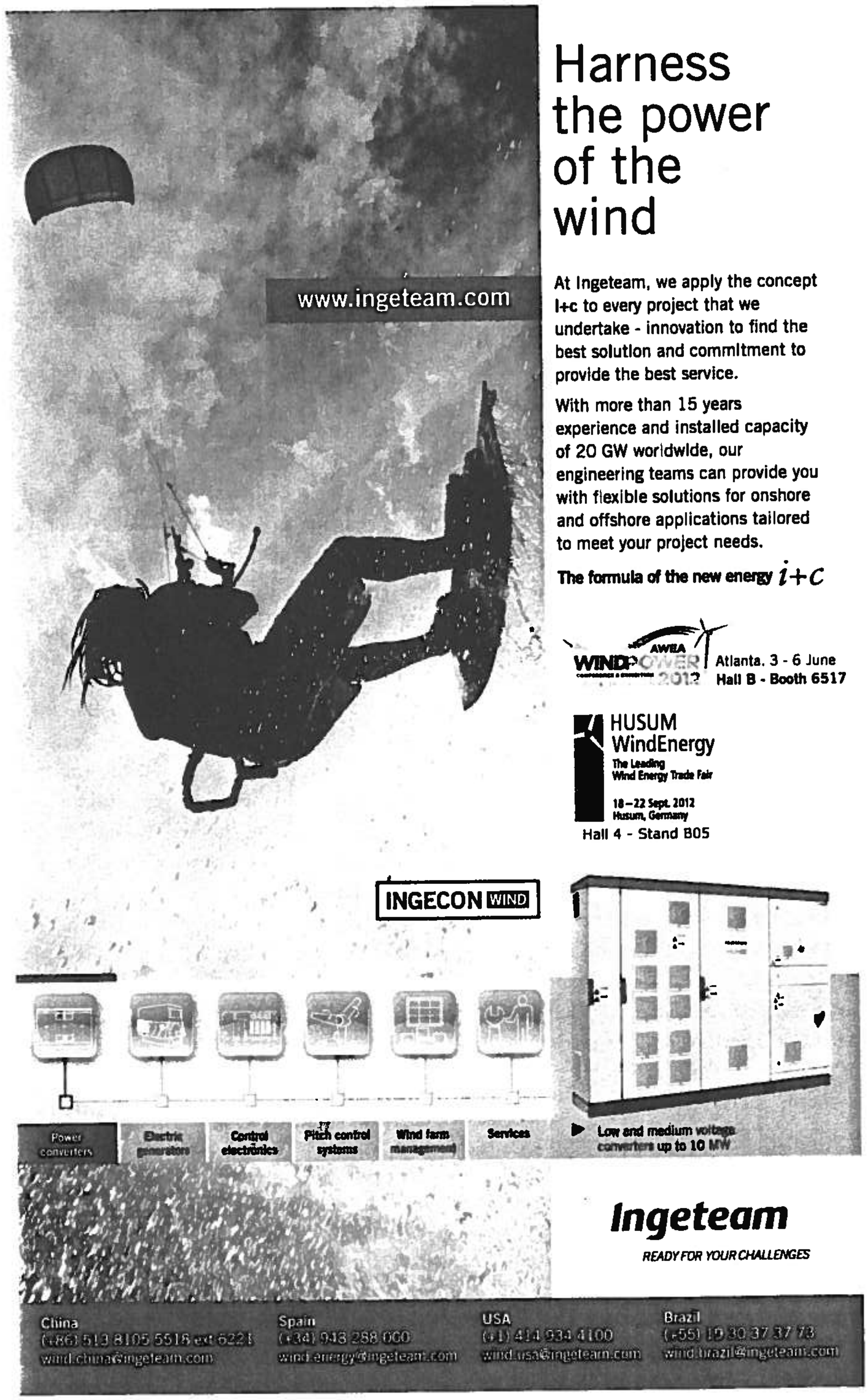
Pre-construction estimates may be improving. Our database in 2006 showed an average project performance at about 87% of estimates (i.e. a 13% over-prediction). As more projects and more years of operations were included, average over-prediction decreased to 11% (in 2008), 9% (in 2009 through 2011), and 8% for the current analysis. This trend may reflect the larger data set each year. But we expect the trend to improve as consultants' methods come more in line with operating experience. That said, there is still considerable room for improvement.

Where assessment can go wrong

The site-specific wind resource and energy assessment process typically starts with the project developer installing meteorological towers and sometimes deploying remote sensing equipment (sodar or lidar) at a site to obtain the data necessary to support an assessment. A comprehensive pre-construction wind resource and energy assessment typically includes:

- Evaluating wind speed and wind direction data from on-site instrumentation. This requires filtering for erroneous data caused by icing, tower shadow, flow obstructions, sensor failures, and other problems;
- Extrapolating met tower measurements from lower heights up to the wind turbine hub height after assessing how wind speeds change with distance above ground (shear), through the use of tower measurements, non-linear model approximations, and, when available and appropriate, remote sensing data;
- Developing long-term annual hub-height wind speed and direction frequency distributions for each met tower location. In some cases, this may require using longer-term data sources that are off site (if they are available and appropriate) and/or using relationships between on-site measurements to fill in gaps or extend the data record;
- Estimating wind speeds at the proposed turbine locations using wind flow models and other tools;
- Estimating 'gross' energy production for the project using the power curve for the proposed turbine and the estimated wind speeds at the proposed turbine locations;
- Estimating energy losses based on analysis of the project equipment downtime, array losses, turbine performance, electrical losses, environmental losses, and other sources of downtime or degraded performance;
- Evaluating individual uncertainties for all of the steps listed above. This requires some understanding or estimation of how uncertainties related to wind speeds impact energy generation non-linearly as well as an overall assessment of the total uncertainty at both annual and longer term (10 or 20 year) timescales.

It should be noted that any organisation's ability to conduct sound wind resource and energy assessments is generally limited by the data collected, and often those data are insufficient to preclude introducing a bias if standard industry numerical models are relied on. As a result, experience must be relied on to a great degree. In general, the better the measured data represents the conditions the project turbines are expected to experience, the lower the uncertainty and potential for bias in the resulting energy production estimate.



Causes of underperformance

Year-to-year variations in wind resource (bad and good wind years) account for some of the observed performance bias. Also, no attempt was made to correct for build out of additional phases or curtailment losses not considered in the original estimate. These factors may contribute to the observed bias, but several other root causes for over-predictions that are likely more significant contributors include:

- Inappropriate handling of topographic effects (often aggravated by inappropriate siting of measurement systems);
- Higher than modelled array losses;
- Lower equipment availability than assumed;
- Turbine power performance effects (often associated with atmospheric conditions unlike those used to calculate the turbine power curve).

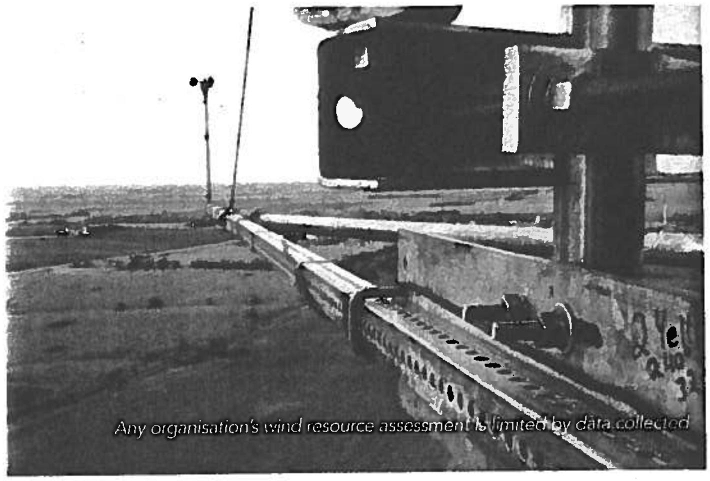
Ongoing research suggests these four points are indeed major contributors to overprediction. Some projects, however, are significantly impacted by other factors including curtailment and higher than expected losses due to environmental conditions, such as icing.

Research has shown that wind flow models commonly used in the industry often do a poor job of modelling wind flow across a site, with a tendency to underestimate variability in wind speeds, even in relatively simple terrain. Additionally, meteorological towers are often sited at the best exposed locations rather than the most representative locations. Providing such inherently biased model inputs invariably leads to overestimated wind speed predictions due to the model's tendency to underestimate wind speed variability.

Typically used wake models produce results reasonably close to actual performance on average, but can produce large over- and under-estimation under certain conditions. Research has indicated that measured wakes are much larger than models predict under stable conditions and, at some sites, these conditions occur frequently enough for overall wake losses to be significantly larger than typically modelled losses. Under stable conditions, there is not enough energy in the atmosphere to replenish wakes. This factor combined with low turbulence results in wakes that persist longer than current wake models predict.

Project availability has significantly contributed to project underperformance for several reasons. First, many consultants have assumed the manufacturer's guaranteed turbine availability in pre-construction energy assessments. But guaranteed availability typically is limited to a certain set of conditions and is generally based on time, not energy. Second, turbine availability has often been modelled as constant over the life of a project. DNV KEMA research, in contrast, suggests project availability declines over time as major components wear out. Third, balance of plant availability has often been overlooked or underestimated. Although balance of plant components such as substations and transformers often operate at high availability, an outage of one of these components can result in a large volume of lost energy.

Recent research in North America has shown a notable reduction in turbine power output at a given wind speed in certain atmospheric conditions, particularly in stable conditions, which are typically characterised by a steep wind shear gradient. Wind veer (or change in wind direction with height) may also occur under these conditions and adversely affects turbine performance. Under stable atmospheric conditions, the estimated hub-height wind speed is no longer a good proxy for the collective wind speed across the rotor plane. In these


Any organisation's wind resource assessment is limited by data collected

conditions, less useful energy is available in the wind than is indicated by the hub-height wind speed because of a decrease in wind shear across the rotor disc, combined with an increase in wind veer between the top and the bottom of the rotor. The common industry approach to estimating hub-height wind speeds has relied on extrapolation of measured wind speeds based on a measured shear profile derived from measurements lower than the hub height. This approach, particularly under stable conditions, can dramatically overestimate wind speeds at the hub height and across the upper half of the rotor.

Addressing underperformance bias

While the industry is making progress in understanding wind project performance, and recent developments have reduced overall industry bias, the process of getting to the 'right answer' in an energy assessment is not as well understood as we would like. Energy assessments must still consider many 'technically unsettled' or subjective issues. With current modelling tools, the ability of third-party consultants to further reduce uncertainty will be limited without more robust resource assessment campaigns by project developers. Fortunately, advances in resource assessment technology should facilitate such campaigns. In particular, the more widespread adoption of remote sensing devices will, if used properly (e.g. full-year or multi-year measurements at appropriate locations), help to get closer to the 'right answer' and reduce uncertainty in energy estimates. Even with more robust resource assessment campaigns and improved modelling, minimising the bias in energy assessment requires methods and assumptions that reflect variations from idealised, or average, atmospheric conditions and project operating scenarios that are frequently assumed but infrequently observed.

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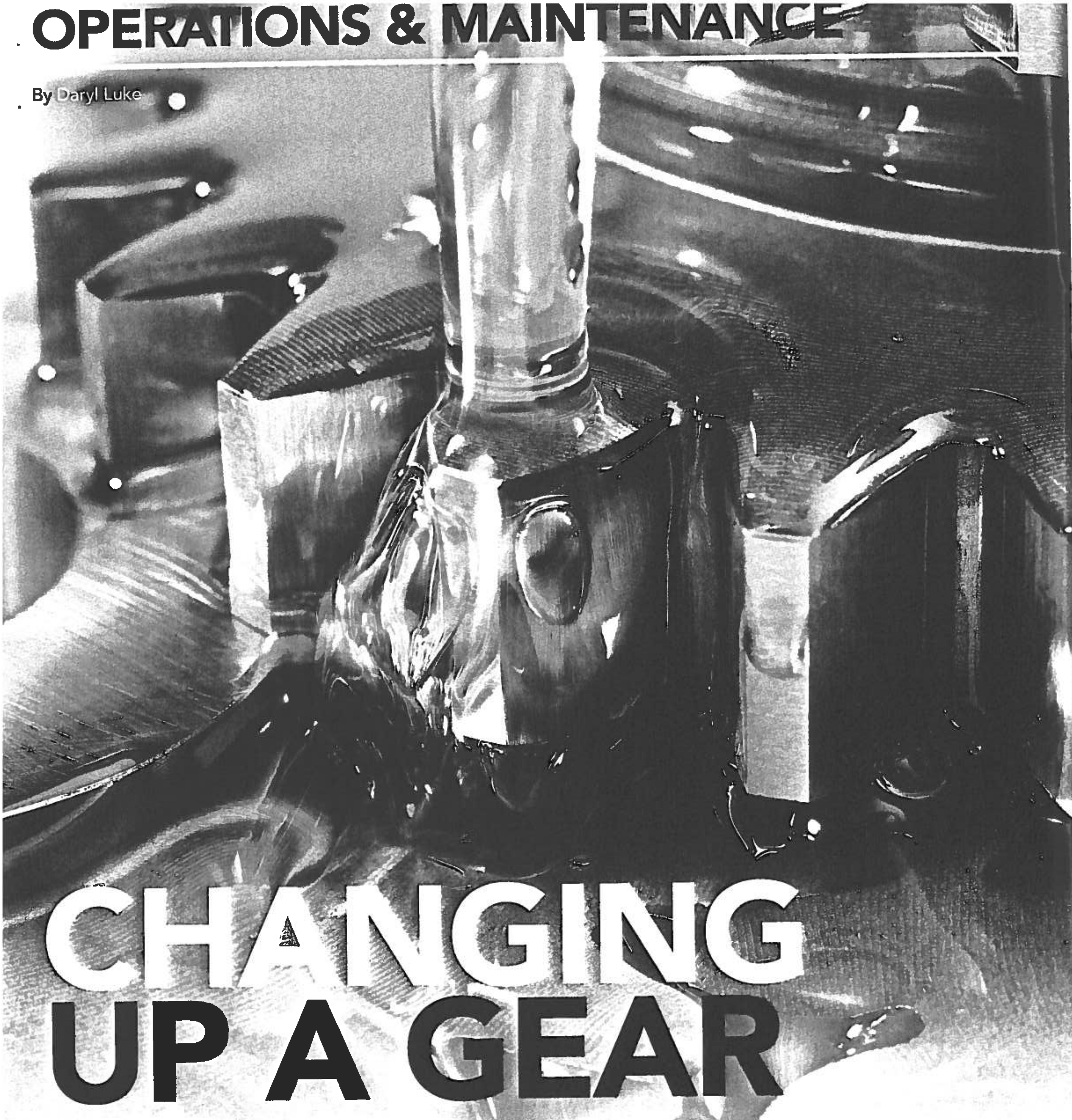
By Daryl Luke



CHANGING UP A GEAR

GEARBOX LUBRICATION AND ITS IMPACT ON OPERATIONAL LIFESPAN

A smoothly operating gearbox is crucial to delivering a fully functioning, long-lasting turbine, itself vital if the wind industry is to achieve its forecasted growth. With more pressure than ever on wind turbines to last longer and work more productively we reveal why gearboxes fail, how to prolong their lifespan, and why lubrication is so important to performance.

The lifespan of an average wind turbine is around 23 years, but turbines are under pressure to last longer, and work more productively.

Technological advances in wind turbine designs and the increasing search for locations with higher wind speeds – including offshore options – mean that turbine manufacturers must constantly keep pace, and the correct maintenance of turbine gearboxes is central to achieving this.

Finding the right supplier

Different drivetrain components have different requirements, and the right choice of lubricant is crucial to the smooth running of gearboxes and therefore the overall performance of turbines. Indeed, investing in the right lubrication could help to save a typical operator managing 50 wind turbines up to US$250,000 year-on-year.

To identify the right lubricant, users need to initially understand why gearboxes fail. The reputation of gearbox turbines has been somewhat challenged over recent years because of reportedly high failure rates. The target lifespan of 20 years has apparently not been reached before repair or overhaul has been required. That said, this isn't always the case – a major turbine manufacturer has reported that the mean age of their turbines is 23 years, with excellent gearbox reliability within that. In any event, at the moment gearbox turbines provide the majority of systems being commissioned and built today.

Gearbox failure (and how to avoid it)

There are three main reasons why many gearboxes fail – namely micropitting, bearing failure and foaming. All are serious, long-term problems but each can be relieved with lubrication which will extend lifespan and save the cost of replacing or repairing equipment. In order to avoid these problems, it's important to first understand why they occur.

Micropitting

Micropitting is surface fatigue, which can result in micro-cracking and the formation of minute micropits which can sometimes give a metal surface a frosted or grey appearance. In some instances micropitting can cause whole gear teeth to break off.

Although micropitting accurately describes the appearance and mechanism of the problem, it is sometimes also referred to as fatigue scoring, flecking, frosting, glazing, grey staining, microspalling, peeling and superficial spalling.

This phenomenon occurs under mixed-film elastohydrodynamic lubrication (EHL), where oil film thickness is of the same order as surface roughness average, and where load is borne by surface asperities and lubricant. In addition to contact stress due to normal loading, sliding between gear teeth causes tractional forces that subject asperities to shear stresses.

Micropitting is complex, unpredictable and difficult to control – despite extensive research on the problem. That said, there are ways to help prevent it happening in the first place. Engineers should maximise lambda (which essentially involves using a thicker film to coat the gear teeth and prevent them from touching), optimise gear geometry, optimise metallurgy, optimise lubricant properties and protect surfaces during running in.

Bearing failure

Bearings are among the most important components but are also often very fine and can damage easily. In particular the bearings which support the shaft that holds gear teeth in place have very fine tolerances, and can be damaged by even small particles.

The potential reasons for bearing damage are numerous. For example, working beyond the original design specification – speed, load and temperature could all change due to the changing requirements of a site. Also, careless handling and seals that are too tight can cause insufficient bearing clearance while inadequate or unsuitable lubrication can also cause failure.

Damage can be split into two categories – in the first instance primary damage occurs, signs of primary damage include wear, indentations, smearing, surface distress, corrosion and electric current damage .

Primary damage can then lead to more serious, secondary damage including flaking and cracks which can ultimately cause equipment failure. Even at the primary damage stage, bearings may have to be scrapped because they are causing excessive internal clearance, vibration and noise. Most failed bearings show signs of both primary and secondary damage. Another issue that can shorten bearing life is the impact of wear particles from the gear box – such as those emitted from micropitting.

A final potentially damaging problem is foaming, where the high speeds and loads that are consistent with wind turbines can cause severe churning, pushing air into the oil, meaning the lubricant doesn't pump or circulate, reducing its effectiveness. Additionally, foam can cause a potential safety hazard if it spills on to the floor.

Future gazing

So lubrication is essential to eliminating many of the problems of gearbox maintenance, and therefore turbine maintenance generally and while using an inferior lubricant can achieve short-term savings but can cause risky long-term effects. It has been estimated that the potential annual savings of switching to gear oil could be up to $5000 per wind turbine operated. This is when taking into account associated reductions in the typical number of oil changes, and the time and cost of changing parts, including labour costs. If you include potential lost revenue due to turbine downtime and the cost of fully replacing a gear box, the savings could be considerably higher.

The right lubrication can help to enhance performance, lifetime and productivity, as well as reduce downtime – all of this can help to deliver commercial benefits and competitive advantage. With increasing pressure on turbine machinery to work harder and last longer, lubrication is more important than ever.

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By Alistair Mackinnon

TURBINE TESTING

SETTING STANDARDS FOR SMALLER DEVICES

A global surge in small and medium-sized wind turbines is setting challenges for testing and will require new standards and certification in the UK and elsewhere.

As small and medium-sized wind turbines steadily become more popular worldwide, so does the need for confidence in their ability to perform as designed, both safely and reliably. This has resulted in a complex and challenging testing and certification regime. So what are these testing challenges and how can they be best tackled?

The testing criteria for small and medium-sized wind turbines are largely driven by international standards. For example, the UK's Microgeneration Certification Scheme (MCS) – which covers wind turbines with a rated power of less than 50 kW and a rotor swept area less than 200 m^2 – places heavy reliance on the British Wind Energy Association (BWEA) Small Wind Turbine Performance and Safety Standard, which in turn references a number of international standards in the IEC 61400 series.

Not-dissimilar criteria exist in the US and Canada, but rely on the AWEA 9.1 Standard instead. The Small Wind Certification Council (SWCC) is the body currently leading activity on this in North America.

Both the BWEA and AWEA standards are underpinned by and rely on IEC 61400-2: 2006, which provides the design criteria for small wind turbines. The 'dash 2' standard gives guidance on the design of a small wind turbine using either a simplified load approach or a more detailed and complex aero-elastic modelling approach, or a combination of the two.

The standard is applicable to the design of both horizontal axis wind turbines (HAWT) and vertical axis wind turbines (VAWT). In addition, there is a requirement to test the durability and safety and function of the turbine.

Standards to come

The next edition of the standard (Edition 3: 201x) is due to be published shortly. To deliver this next edition, an IEC maintenance team has been working very intensively for two years and has reviewed many of the criteria in the light of lessons learned and current best practice.

The resulting new version of the standard will give greater guidance, among other things, on the use of the simplified load approach and dealing with extreme wind conditions.

The performance of the turbine is assessed against the criteria in IEC 61400-12-1: 2006, the power performance standard, and IEC 61400-11: 2003, the acoustic performance standard. An evaluation of both of these aspects is crucial in determining a turbine's suitability for a particular wind regime, purpose and location.

Defining medium wind requirements

A UK Medium Wind Standard is currently at the draft stage and is scheduled to be published before the end of this year. Moving forward, it is hoped the international community will address the perceived issues with medium-sized turbines to make a UK standard unnecessary. While medium-sized turbines are unlikely to be the mainstay of wind farms of the future, they are likely to play a significant part in distributed and community wind projects, which means an appropriate standard supported by government incentives is likely to benefit all stakeholders in the longer term.

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Wind updates

Japan plans floating design

A consortium made up of Marubeni, the University of Tokyo, Mitsubishi, Mitsubishi Heavy Industries, IHI Marine United, Mitsui Engineering & Shipbuilding, Nippon Steel, Hitachi, Furukawa Electric, Shimizu and Mizuho Information & Research are participating in an experimental offshore floating wind farm project sponsored by the Ministry of Economy, Trade and Industry.

The project consists of three floating wind turbines and one floating sub-station off the coast of Fukushima. The first stage will begin in 2012 and consists of one 2 MW floating wind turbine, the world's first 66 kV floating sub-station and undersea cable. In the second stage of the project, two 7 MW wind turbines are expected to be added over 2013 and 2015.

It is understood that one of the most important themes of this experimental project is the coexistence of the fishery industry with the offshore wind farm industry.

New twin-blade design

Dutch company 2-B Energy has signed a deal with Scottish Enterprise to develop a two-bladed offshore wind turbine at Fife Energy Park in Methil, on Scotland's east coast. The company claims the design could reduce the cost of offshore turbines by as much as 45%.

Offshore test and demonstration facilities will be developed in Scotland, possibly by the end of 2014.

Designed to significantly reduce the number of components required throughout the lifetime of the turbine, the company claims lower operations and maintenance costs. The nacelle is mounted on a full lattice structure that rises from the seabed.

An artist's impression of the two-blade turbine 2-B Energy

Offshore transfer trials

Osbit Power (OP), Siemens Wind Power and Statoil have completed offshore trials of OP's offshore wind turbine access system at the Hywind Demo floating offshore wind turbine off the coast of Norway.

The system, MaXccess, was installed on the wind farm service vessel Bayard 3, operated by Fred Olsen Windcarrier. The trials saw transfer of personnel taking place in conditions ranging from 1.2–1.9 metres significant wave height.

MaXccess clamps to the turbine buffer tube for personnel transfers.

UK-US boost floating tech

The US and the UK have announced plans to develop floating offshore turbines.

Although the final design has yet to be decided, the most likely design is vertical spar buoys, each moored by several catenary cables weighted at the ends.

An alternative under consideration is a tension-leg system, commonly used on offshore oil platforms.

Research by MIT and the National Renewable Energy Laboratory suggests that 5 MW turbines should be feasible at depths of up to 200 metres.

ECN-NREL in R&D alliance

The US Department of Energy's National Renewable Energy Laboratory (NREL) and ECN have signed a Cooperative Research And Development Agreement (CRADA) to collaborate on wind energy research.

NREL and ECN will collaborate on areas such as Advanced Controls of Integrated Turbine Systems (off- and onshore), Turbine and Wind Farm Wake and Array Effects. The collaboration is expected to enhance the efficiency of their R&D efforts by joint development and comparison of models and experimental data.

Fort Felker, Director of the National Wind Technology Center at NREL said: 'By sharing knowledge and working together, we will increase the scope and pace of our contributions to this important technology.'

Superconductor tech

Technology company Deutsche Nanoschicht GmbH has revealed a novel manufacturing process for the production of superconducting materials.

Working with BASF Future Business GmbH as a cooperation partner, Deutsche Nanoschicht claims the high temperature superconductors can be manufactured much more efficiently and with less environmental impact using a coating process based on chemical solution deposition. The ceramic layers produced in this way have superconducting properties because they feature flawless crystal orientation.

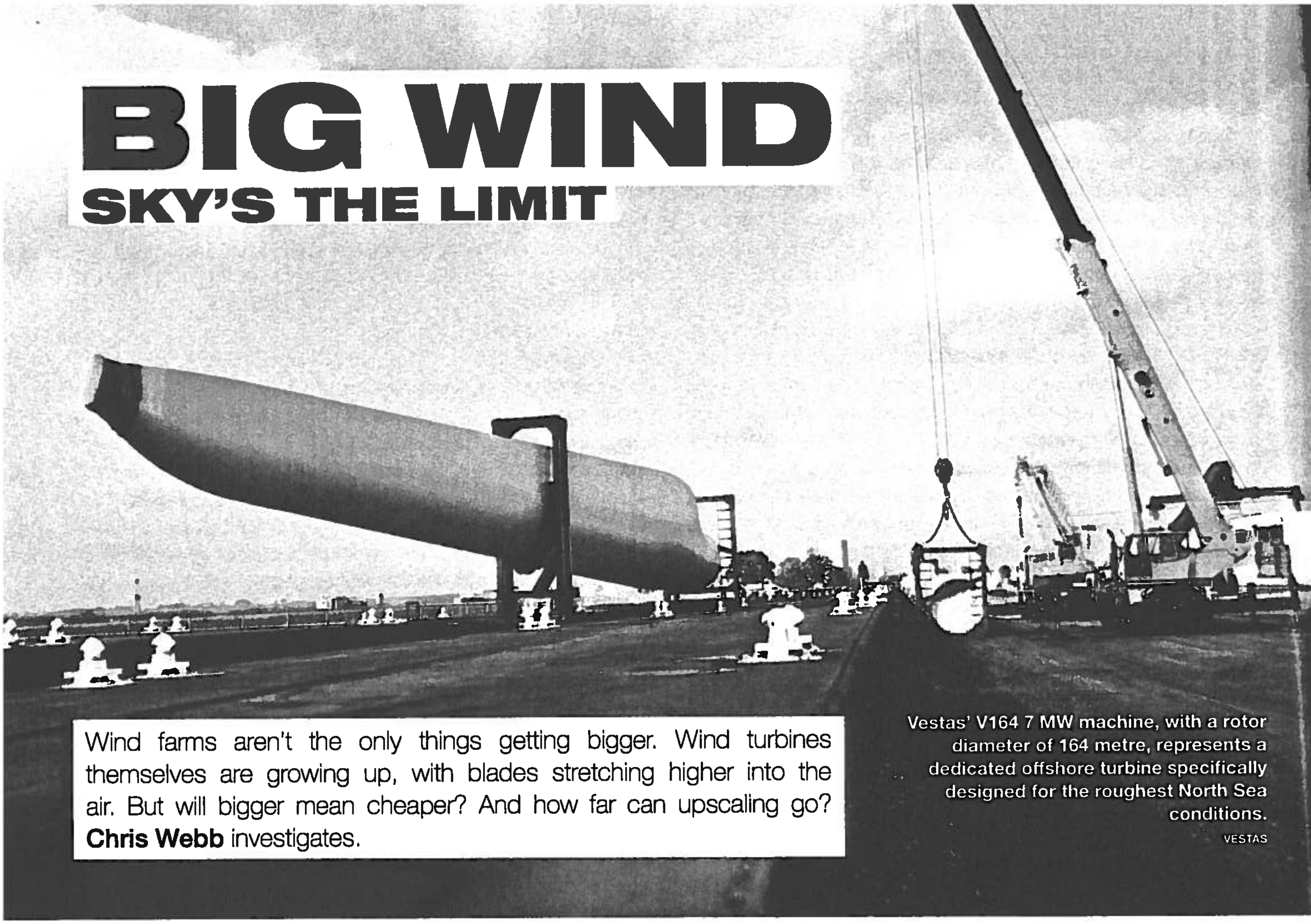
Dr. Michael Bäcker, Managing Director of Deutsche Nanoschicht explains: 'Wherever large volumes of electricity are generated, transported or used, the technologies we have developed facilitate innovative power engineering systems that operate efficiently with little impact on resources.'

Advertisers Index

BIG WIND

SKY'S THE LIMIT

Wind farms aren't the only things getting bigger. Wind turbines themselves are growing up, with blades stretching higher into the air. But will bigger mean cheaper? And how far can upscaling go? **Chris Webb** investigates.



Vestas' V164 7 MW machine, with a rotor diameter of 164 metre, represents a dedicated offshore turbine specifically designed for the roughest North Sea conditions.
VESTAS

Using sophisticated modelling techniques and comparing the results with existing turbine technology, a 2011 report set out to see if 20 MW offshore turbines could become a reality. The report, entitled *Upwind: Design Limits and Solutions for Very Large Wind Turbines*, compared theoretical 20 MW designs with present technology. 'Yes, we have the technology but the economics will decide. Costs models will tell us the way forward,' says Bernard Bulder of the Energy Research Centre of the Netherlands (ECN).

The goal of a larger turbine – to increase efficiency by capturing more wind energy using longer blades – was achievable, the report said. The US$33 million UpWind project determined to what extent such turbines are feasible, and whether they make financial sense.

A look into the near future was offered early last year, when Danish company Vestas debuted its 7 MW offshore giant. In October 2011 DONG Energy announced it would test the turbine, with plans to install six at a demonstration site in 2013. Also in 2011, GE Global Research, the technology development arm of General Electric, announced it was to partner with the Oak Ridge National Laboratory to develop a generator to support large-scale wind turbines in the 10–15 MW range. Work has begun on the first phase of the two-year, $3 million project funded by the US Department of Energy.

But the EU-backed Upwind research project is a step forward in assessing the challenges ahead. Made up of 48 partners, half from the private sector and half from the research and academic sector, UpWind is the largest public/private partnership designed for the wind energy sector.

UpWind demonstrates that a 20 MW design is feasible. No significant problems were found when upscaling wind turbines to that size, provided some key innovations are developed and integrated. These innovations come with extra cost, and the cost:benefit ratio depends on a complex set of parameters. The project resulted, for instance, in the specification of mass:strength ratios for future very large blades securing the same load levels as the present generation of wind turbines. Thus, in principle at least, future large rotors and other turbine components could be realised without cost increases, assuming the new materials are within certain set cost limits.

For its assessment of the differences between the parameters of the upscaled wind turbine, UpWind adopted a reference 5 MW wind turbine. This reference was based on the IEA reference turbine developed by the National Renewable Energy Laboratory (NREL). As a first step, this reference design was extrapolated (or upscaled) to 10 MW. The 20 MW goal emerged progressively during the project, while in the meantime the industry worked on larger machines. The largest concepts which are now on the drawing board measure close to 150 metres in rotor diameter and have an installed power capacity of 10 MW. While a 10 MW concept progressively took shape, UpWind set its mind to a larger wind turbine, a turbine of about 250 metres in rotor diameter and a rated power of 20 MW.

PUSHING THE BOUNDARIES

New concepts, components and materials are an essential part of the equation when it comes to upping the wind game. Research by Risø Denmark's National Laboratory for Sustainable Energy at the Technical University of Denmark shows that new technological possibilities arise as a consequence of the development of new materials with improved properties. For a long time the wind turbine sector has focused on the reduction of weight and an increase in the strength of blades. However, components such as the gear train and generator will also benefit from the use of new materials and advanced simulations.

In 2011 Vestas took its first steps towards these mega-turbines, revealing details of its next-generation dedicated offshore turbine: the V164 7 MW. Designed to ensure the lowest possible cost of energy, with a rotor diameter of 164 metres, it represents a dedicated offshore turbine, able to cope in rough North Sea conditions.

Lowering the cost of energy in relation to offshore wind is essential. Some of the major stepping stones in achieving this are size and subsequent increased energy capture, which means a need for much bigger turbines, specifically designed for the challenging offshore environment.

Vestas CEO Ditlev Engel says of the new turbine: 'Seeing the positive indications from governments worldwide, and especially from the UK, to increase the utilisation of wind energy is indeed very promising. We look forward to this new turbine doing its part in making these political targets a reality.'

According to Anders Søe-Jensen, president of Vestas Offshore, the offshore wind market is set to really take off over the coming years. 'We expect the major part of offshore wind development to happen in the northern part of Europe, where the conditions at sea are particularly rough. Based on our broad true offshore experience, we have specifically designed the V164 7 MW to provide the highest energy capture and the highest reliability in this rough environment.'

One of the innovative parts is the medium speed drive-train. 'Offshore wind customers do not want new and untested solutions,' says Finn Strøm Madsen, president of Vestas technology R&D. 'They want reliability and business case certainty.' Construction of the first prototypes is expected in Q4 of this year.

BIGGER MEANS BETTER DESIGN

But, as the Upwind report points out, growing turbines to 20 MW will require even greater innovation in a number of areas. The 20 MW concept provides values and behaviour used as model entries for optimisation – it's a virtual turbine, which could be designed with the existing tools, without including the UpWind innovations. This extrapolated virtual 20 MW design was found to be almost impossible to manufacture, and uneconomic. The extrapolated 20 MW would weigh 880 tonnes on top of a tower, making it impossible to store at a standard dockside, or install offshore with the current vessels and cranes. The support structures able to carry such mass placed at 153 metres height aren't possible to mass manufacture. The blade length would exceed 120 metres, making it the world's largest manufactured composite element, which cannot be produced as a single piece with today's technologies. The blade length would also require new types of fibres to resist the loads. However, the UpWind project developed innovations to enable this basic design to be significantly improved, and become a potentially economically sound design.

Key weaknesses of the extrapolated virtual 20 MW design are the weight on top of the tower, the corresponding loads on the entire structure and the aerodynamic rotor blade control. The future large-scale wind turbine system drawn up by the UpWind project, however, is smart, reliable, accessible, efficient and lightweight.

New technological possibilities arise as a consequence of the development of new materials with improved properties

After reducing fatigue loads and applying materials with a lower mass:strength ratio, a third essential step is needed. The application of distributed aerodynamic blade control, requiring advanced blade concepts with integrated control features and aerodynamic devices, is also a significant departure from current technology. Fatigue loads could be reduced 20%–40%. Various devices can achieve this, such as trailing edge flaps, (continuous) camber control, synthetic jets, micro tabs, or flexible, controllable blade-root coupling.

Further reducing the load requires advanced rotor control strategies for 'smart' turbines. The UpWind project demonstrated that individual pitching of the blades could lower fatigue loads by 20%–30%. Dual pitch (pitching the blade in two sections) as the first step towards a more continuous distributed blade control could lead to load reductions of 15%.

A STREAMLINED SYSTEM

Advanced control strategies are important for large offshore arrays, where UpWind demonstrated that 20% of power output can be lost due to wake effects between turbines. Optimised wind-farm layouts were proposed, and innovative control strategies developed, for instance lowering the power output of the first row (thus making these wind turbines more transparent for air flow), facing the undisturbed wind, allowing for higher overall wind farm efficiency.

'The more your system is optimised, the more your wind measurement must be reliable and accurate,' says Peter Eecen, work package leader at the Energy Research Centre of the Netherlands (ECN). 'Wind-measurement techniques for wind energy are progressing quickly. The UpWind project acted as a node to narrow down wind measurement uncertainties. It helped translate innovation into IEC standards, with support of the whole measurement community,' says Eecen.

After five years of research, the engineers at Risø concluded that the mega turbines would come with a 20% higher price tag than their smaller 5 MW siblings if these larger turbines were built in the same fashion. From the tip of the turbine blade to its base, and further to the grid, the project examined several areas needing further exploration to make mega wind turbines cost competitive.

Researchers hope that the increased power, combined with higher efficiency, will achieve greater economies of scale, reducing the cost of wind generation.

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Impact of Curtailment on Wind Economics

Why curtailment matters.

By Jonathan CHESZES Navigant

The increase in utility scale wind development across North America has and continues to change the energy supply mix in many jurisdictions. Driven primarily by state-level renewable portfolio standard (RPS) requirements and clean air regulation, state and provincial supply mixes once dominated by coal, hydro, nuclear and natural gas are now becoming more diverse. Intermittent generation sources — once a small component of total capacity — are becoming substantial. And, as a result, system operators have had to periodically curtail these intermittent generators in order to maintain system balance and reliability.

A 2010 study conducted for the National Renewable Energy Laboratory (NREL) revealed that 2009 wind generation curtailment varied significantly by jurisdiction — ranging from as low as 1 percent in the Midwest Transmission System Operator's (MISO) control area to as high as 16 percent and 10 percent in Texas and Alberta, Canada, respectively. These higher levels of curtailment can have a significant impact on a wind generator's economics. Table 1 provides an overview of the impacts of different levels of curtailment on both revenue and the Debt Service Coverage Ratio (DSCR), a key metric used by lenders to determine a project's ability to meet debt obligations.

At 1 percent curtailment, revenues and DSCR remain at a level that would be comfortable to most lenders. However, at 5 percent curtailment and higher, revenues and DSCR deteriorate, putting projects at risk of not meeting their debt obligations or reducing the amount of debt the project's cash flows can support.

Will Curtailment Continue to be an Issue?

Curtailment can occur for any number of reasons including local congestion, global oversupply, and operational issues. Each type of curtailment occurs with differing frequency depending on the regional and local system's generation and electrical characteristics.

Impact of Curtailment on DSCR for Wind Table 1

% of Generation Curtailed	0%	1%	5%	10%
Reduction in Revenue	0%	1%	5%	10%
DSCR	1.45	1.43	1.36	1.28
Reduction in DSCR		1%	6%	12%

Note: Calculations were done assuming a 35% Capacity Factor, total revenue of $85/MWh, a Debt/Equity ratio of 75/25, a cost of debt of 6% and an O&M of $40 kW-year.

Local Congestion

Local congestion occurs when there is more generation, wind or otherwise, than there is available transmission or distribution capacity to move the power to load centers. Nowhere has this been better demonstrated than in West Texas where there are excellent wind resources and limited transmission capacity. In 2009 there were about 8,000 MW of installed capacity but only 4,500 MW of available transmission, according to the same 2010 NREL study. As a result, monthly wind curtailment averaged between 24 to 28 percent in the February to April 2009 timeframe. Due to the shorter development times associated with building wind farms as compared to transmission lines, local congestion can have an ongoing impact on wind project economics. Although transmission development should eventually catch up with intermittent generation development (wind or other) and relieve the majority of curtailment, system planners typically design transmission upgrades to incorporate an allowable amount of congestion. For example, the Ontario Power Authority used a 5 percent planned congestion level when it assessed transmission expansions in a study it conducted under Ontario's Feed-in Tariff program.

Global Oversupply

During the economic downturn of 2008/2009, a number of jurisdictions across North America had more generating capacity than needed. During this time of low energy demand, several jurisdictions experienced periods of global oversupply — when the amount of generation on the system exceeded local demand — which, in some cases, created negative price environments. Concern over negative prices appears to be part of the reason Bonneville Power Administration (BPA) curtailed wind generators during periods of high hydro generation and low energy demand in 2011. Jurisdictions with an inflexible baseload resource (such as nuclear and large hydro in Ontario, or large hydro in BPA) are inherently more susceptible to periods of global oversupply. The incremental impacts of intermittent generation on systems with these characteristics can cause undesirable outcomes such as curtailment, negative price environments or temporary shutdown and restart of nuclear units.

While global oversupply conditions are anticipated to subside as energy demand recovers in the coming years, these conditions can have a significant impact on new and existing generators if they are not contractually protected against this type of curtailment.

Operational Curtailment

Operational curtailment includes curtailment related to ensuring sufficient supply is available to meet variations in demand and intermittent generation. As electricity demand increases and decreases throughout the day, so must generation. A system operator's ability to ramp up and down generation in order to meet changing demand is critical to ensuring that supply and demand are always in balance. The highest rate of increase in demand often occurs in the morning. Although some areas rely on storage hydro to increase output during these times, typically coal and/or natural gas generation provide this ramping capability. In anticipation of this period of ramping, coal and natural gas generators may need to be started early to ensure sufficient ramping capability to meet the changing load. In order to accommodate this generation, other intermittent generation, such as wind, may have to be curtailed.

As coal plants are retired in favor of natural gas combined cycle generation in order to meet new Environmental Protection Agency (EPA) regulations, operational forms of curtailment are likely to increase due to the reduced flexibility of natural gas combined cycle generation relative to that of coal. While the change-out from coal to gas has significant environmental benefits, from an operability perspective, coal-fired generation provides a distinct advantage in that it can operate at a lower minimum load ratio to its rated capacity. A typical coal plant can turn down to about 20 percent of its rated capacity, as compared to 40 percent for natural gas combined cycle units. For a 500-MW generator, the result is 100 MW of additional generation. Therefore, if natural gas combined cycle plants are being used instead of coal plants to ramp up supply to meet morning peak demand, there will be more supply on the system resulting in possible curtailment of wind in order to maintain system balance.

A typical coal plant can turn down to about 20 percent of its rated capacity, as compared to 40 percent for natural gas combined cycle units.

Ongoing development of intermittent resources (due to existing RPS rules, as well the substitution of coal-fired power for natural gas) means increasing the likelihood of curtailment. Assessing the project-specific risks associated with a new or existing project requires understanding its exposure to all types of curtailment. Unless contract provisions protect generators from all types of curtailment, developers, investors and lenders need to understand the project-specific interconnection, market rules, local generation and transmission system characteristics in order to forecast exposure to curtailment over a project's life.

Curtailment will continue to have an impact on renewable project returns. Even curtailment of 5 percent of potential output, which has occurred in several jurisdictions in North America in the last few years, can reduce the DSCR such that incremental equity payments are required from investors. Projects operating in deregulated markets with insufficient transmission, significant amounts of wind, and/or inflexible baseload resources are likely to have the highest levels of exposure. However, even in regulated markets, site and zonal-specific details will play a significant role in estimating curtailment's total impact.

Jonathan Cheszes is a Managing Consultant with Navigant Consulting's Energy Practice, where he specializes in renewable energy economics and risk assessment, including quantifying curtailment risk across North America.

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Is Education the Fuel We Need for a Renewable Future?

Meg CICHON Associate Editor

We all dream of a renewable-dominant future and are working hard to get there. We also know there is a long road ahead of us, but according to a recent three-year ESRL study, solar and wind power could provide 70 percent of the continental U.S. electricity needs by 2030.

The study took 16 billion pieces of weather data, filtered out unlikely sites for power production, and developed a principle for an effective smart grid that would provide renewable transmission to balance production and demand.

The future is bright for renewables, but some may argue that there is a crucial missing link that could be a detriment for industry development: education. To address these concerns, several innovators have created programs to secure our energy future by educating our future workforce – from tykes to undergrads.

In North Carolina, a group of green energy advocates banned together to develop a weather kiosk that is: "Cool enough to notice. Close enough to check out." Outfitted with solar panels, a wind turbine and a weather station, Sprout (*see image, right*) calculates and combines data for wind speed/direction, solar elevation/irradiance, voltage, watts/m2 available and other statistics. Users can retrieve this data on Sprout's interactive touch screen or online. If a location already has a solar or wind project, Sprout can calculate what it produces on any given day. Sprout offers integrated lesson plans for all levels that allow students to use renewables in math, science and more.

While Sprout educates students about what renewables can produce, KidWind explains how systems are built. Established in 2002, KidWind offers a full wind energy curriculum, and even includes lessons about solar energy, generators, and energy efficiency. But in addition to this renewable-packed program, KidWind offers hands-on "challenges" throughout the U.S.

Students spend three months building a wind turbines, which are then entered into local competitions that are promoted on the KidWind website. Turbines are judged on power performance, construction and the student's knowledge of wind energy topics. The competition not only teaches students how to build a turbine, but it also teaches them about where wind comes from, energy transfer, the difference between power and energy, and much more.

Sprout and KidWind are just two of the many renewable education offerings out there, but they both tout compliance with the STEM (Savings Through Energy Management) program. This nationally recognized workshop is generally conducted in five lessons, one per week, and educates students about energy costs and career skills.

The program can have any focus, for example, the Wyoming NASA Space Grant Consortium in conjunction with several affiliates hosted wind-focused summer programs about energy and climate science. Grant director Dr. Paul Johnson explained in a statement, "This experience was, and continues to be, an investment in the state's next-generation scientifically literate workforce that adds value to as well as a sense of understanding about where rural communities fit into the nation's landscape."

Experts believe that educational initiatives like the STEM program are the key to a successful renewable future, but we need to step up our initiatives. Pace Global Energy Services CEO, Tim Sutherland was asked in an interview with Forbes why manufacturing CEOs claim that there aren't enough students with STEM skills to fill the U.S. need for technologically savvy workers. To which Sutherland responded:

Our educational system is failing to stimulate interest and to excite our children to learn more about the sciences, engineering and quantitative skills. If we continue down this path, our ability to compete in global energy markets and other markets will be materially compromised. Regardless of the energy modality, whether traditional fuels or renewable, America must do more to be competitive. I have no problem with 70% of Americans going to college, as long as the technical needs of our energy sector are being filled.

GE's 2.5-103 wind turbine started with an 88 m rotor. Courtesy: GE

Wind Technology Updates

By Sharryn Dotson, online editor

Wind turbine technology is undergoing a makeover as more project developers look to make large-scale wind projects. The bigger the development, the bigger the turbines need to be.

The National Wind Technology Center, a part of the National Renewable Energy Laboratory, said it is making breakthroughs in research, while companies such as General Electric say improvements to wind technology are just a normal course of business.

The potential end of the Production Tax Credit may not directly affect wind research in 2012, but an unstable market could spell trouble for research and development.

"We've seen the industry come down that cost curve and there's no reason to believe that would stop unless we don't have a certain and stable market," Elizabeth Salerno, chief economist with the American Wind Energy Association, said during the group's press call on 2011 results. "As long as we have a certain and stable market, research efforts will continue."

Onshore wind updates

Salerno said wind research has helped the industry within a short timeframe.

"We've seen a lot of improvements happen in capital cost and improvements with wind turbines over the last two years – better performance, more megawatts, very high capacity factors," she said.

Fort Felker, director with NWTC, said turbines are now being manufactured to actively support the power grid and keep it stable.

"Turbines operate in a way to meet the needs of the grid, give support for voltage and reliability," Felker said. "Modern wind turbines with power conversion technology have the ability to alter the ways for the grid to be more stable."

Another change is that the rotors are getting bigger, from 100 meters (m) to 110 m in general, and manufacturers are increasing the capacity of the turbines.

"An increase in diameter means more power capture at lower wind speeds," Felker said. "There are machines coming on that are 3 MW."

Alstom in September 2011 introduced the ECO 122, a 2.7 MW wind turbine for low wind sites. It features a 122-metre rotor diameter and a swept area of 11,700 m^2 . According to a release from Alstom, the turbine has a net wind farm capacity factor of up to 42 percent at a wind speed of 7.5 m/s.

Alstom said the ECO 122 turbine lowers balance of plant costs by 10 to 15 percent. The first turbine is expected to be installed by mid-2012.

Advanced control schemes help turbines operate more effectively. "Each turbine in the field is its own autonomous agent and maximizes power production," Felker said. "More control algorithms have larger rotors without higher structure loads."

Manufacturers are also incorporating controls into the actual turbine, Felker said. The next step in technology updates is the recognition of wind turbines being installed in huge arrays.

"Having these operating in an array and not independently, but as a coordinated faction, each turbine takes advantage of the state its neighbor is in," Felker said. "It has the potential for improving performance."

Another change that has occurred over the past 10 years is maturation in the wind industry, leading to a change in how NWTC assisted companies.

"Our role before was to assist new entrants into the industry and now we're focused on technology advancements to allow others to operate at a lower cost," Felker said.

Company's wind updates

GE entered the wind business a decade ago after acquiring the fleet from Enron. The company launched its newest turbine, the 1.6-100, in May during AWEA's 2011 Windpower Conference & Exhibition. The turbine, like Alstom's ECO 122, is targeted for areas with lower wind speeds, but it features a 100 m rotor.

The larger rotor also meant GE had to make changes in other parts of the turbine.

"In order to make rotor growth, we have to make advances in controls to handle the bigger loads and advanced materials so that you don't get disproportionate in mass," said Richard Reno, global projects leader with GE.

Reno said the company already has more than 2 GW in orders globally, totaling about $2.7 billion in commitments.

Reliability is also a big factor in technology development. "Our sites are running at more than 98 percent reliability," Reno said. "We put a lot of investment into the controls and other electronic equipment."

Ten years ago, the turbines were running around 85 percent reliability, Reno said.

"At that point in time, the mid-80s was good," Reno said. "But if you were driving a car that was only 80 percent reliable, chances are at one point during the week, it wouldn't run at all."

As for the future of wind upgrades, Reno said GE works by a strategy of evolution.

"The 1.5 turbine had a 77 meter rotor and today it's grown to 100 meters," Reno said. "The 2.5 started with an 88 meter rotor in 2004 and now has a 103 meter rotor."

Future plans are not hampered by the possible expiration of the PTC in 2012. "We've been focused a long time on global expansion and we're launching our products in Brazil, India, China and Australia," Reno said. "Fifty percent of our business is coming from outside of the U.S. so you can say we are prepared.

"We are still a big piece of the North American market and this is going to be a great year in that regard," Reno said.

Offshore wind updates

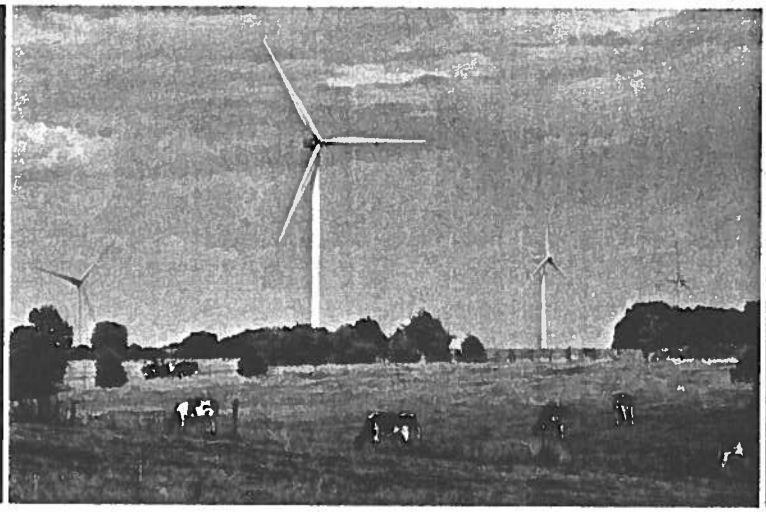
One update to offshore wind technology is to place the turbines thousands of miles closer to big cities without the visual barriers, NWTC's Felker said. Changing their siting would also help the turbines to be more accessible when it is time to perform maintenance or if a turbine is not operating properly.

"The industry has learned that there is a real benefit to having reliable turbines for offshore wind," Felker said. "A small problem that would be easily repaired in an onshore turbine is very difficult to do offshore."

Offshore wind turbines have to deal with a corrosive environment, hurricanes and accessibility issues compared to onshore, so the technology for offshore turbines is obviously different.

There is research aimed at technology improvements that would bring the costs of offshore wind down to be competitive with fossil fuels, Felker said.

"Cost parity is about ten years away," Felker said. "But it has tremendous opportunity."



GE's 2.5-100 wind turbine at the Wieringermeer Wind Farm in the Netherlands. Courtesy: GE

Future technologies

Felker said NWTC is looking into the future with alternative methods of generating power from wind. Some of those future technologies include floating turbines, which are assembled at port, towed out to sea and the foundations are installed in the water."

There are a few prototypes sited around the world, he said.

The Discovery Channel featured an innovative wind technology called windstalks. New York-based design firm Atelier DNA created the concept using carbon fiber "stalks," each 180-feet tall with concrete bases that are between 33- and 66-feet wide. The stalks are reinforced with resin and are about a foot wide at the base tapering to 2 inches at the top. The blowing winds cause the stalks to sway in the wind, creating energy.

Since wind does not blow all the time, two chambers below the site work as a battery to store energy. The idea is based on hydroelectric pumped storage systems, where water in the upper chamber flows through turbines to the lower chamber, releasing stored energy until the wind blows again.

A not so far off technology is airborne wind technology, like airborne wind turbines (AWT) or balloons tethered to the ground.

Makani Power is currently flying a 20 kW AWT called Wing 7. The AWTs use a rigid wing that flies between 300 and 600 meters. Turbines on the leading edge of the wing face into the wind as it flies and generates electricity, which is then transmitted to the ground through a tether.

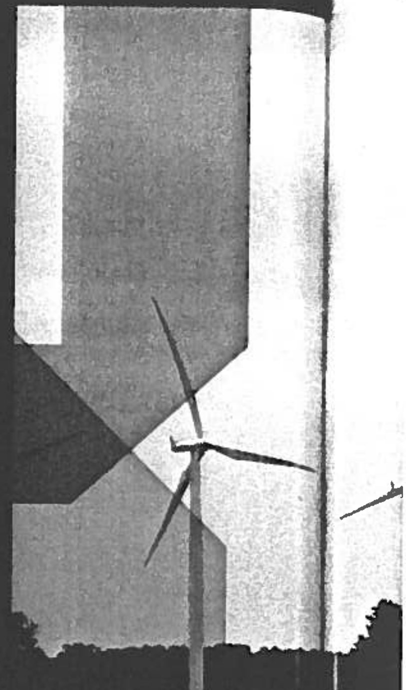
"Wing 7 is mechanically and aerodynamically comparable to the utility scale 600 kW wing we will be working on next," said Martine Neider, business development with Makani Power. "Our final goal is a 5 MW system."

Currently, Makani is working on proving their power curve by demonstrating that they generate the same amount of power in the field as they do in simulation, Neider said. They did this by showing all of the flight modes needed for fully autonomous operation, including takeoff, hovering, crosswind power generation and transition into and out of crosswind.

Neider said the Makani AWT could access five times the area as traditional wind turbines.

"The Midwestern plain states have particularly good wind resources but every state has areas that the AWT can utilize," Neider said. "In addition, the AWT can be used to access the exceptional wind resources off the Pacific coast because it can be mounted on a floating platform in deep water." pe

Ontario's Wind Power Sector at a Crossroads



The wind turbines of Wolfe Island, Ontario.
Credit Rehemtulla for QUOI Media Group.

Despite having Canada's largest population and being home to an energy-intensive manufacturing sector, Ontario was slow to adopt wind power. As recently as 2006, only 10 turbines were spinning in the province. Today, Ontario is home to more than 1,750 MW of wind power and plans are in place for this figure to increase to 7,500 MW by 2018.

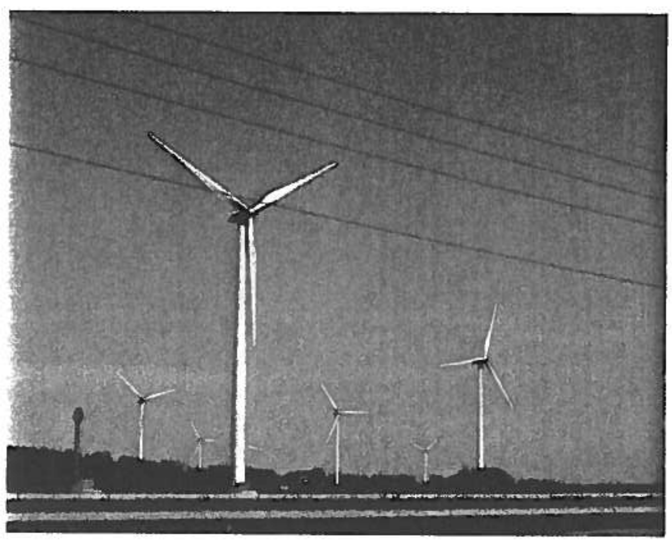
Marc Coward,
Principal, Renewable
Shift Consulting

The Policy Environment

As has been the case in other jurisdictions, the growth of Ontario's wind power sector has been nurtured by government policy. In particular, Premier Dalton McGuinty's Liberal government has been recognized as a North American leader in the development of renewable power since it enacted the Green Energy Act (GEA) in November 2009. The centerpiece of this legislation is a German-style Feed-in Tariff (FIT) for renewable power projects.

Energy policy was debated extensively in the months leading up to the October 2011 provincial election as the opposition Progressive Conservative party promised to repeal the GEA, which they cited as the reason for rising electricity rates. Rural areas, which have been most impacted by the rapid growth of wind power, voted overwhelmingly for the Progressive Conservatives. However, the incumbent Liberal party was re-elected, albeit as a minority government.

This is the context in which provincial officials find themselves as they conduct a mandatory review of the FIT program, which has been responsible for attracting billions of dollars of investment to Ontario — primarily from wind power developers and suppliers. However, an estimated 6,000 MW of wind and solar projects have been awarded power purchase agreements (PPAs) but are still in need of financing. This article examines three issues that are currently being reviewed and have the potential to significantly influence the future of Ontario's wind power sector.



A small portion of a very large wind farm flanking the King's Highway 10 north of Shelbourne, Ontario. Credit Robert Taylor via Flickr.

Curtailment

Wind power suffers from the disadvantage of being a variable resource. As such, there are times when too little wind is blowing and the province must be powered by other sources. Conversely, there are times when too much wind is blowing and the Independent Electricity System Operator (IESO), which runs the province's electricity market, curtails the amount of wind it acquires in favor of relying on power generated by baseload sources, notably the province's nuclear power stations that cannot easily have their output adjusted downward to accommodate high levels of wind power generation. In a recent submission to the IESO, a consortium of four developers that have invested heavily in the Ontario wind sector argue that the uncertainty caused by curtailment is preventing projects from obtaining financing.

Local Control Over Development

One of the most controversial aspects of the GEA was the removal of local authority over permitting for renewable energy projects in favor of a single provincial-level approval process. Wind power developers have been overwhelmingly successful at accommodating local concerns and are often seen as a welcome addition to the community, but there have been some high-profile battles and certain communities have been effective in shifting the debate from the merits of wind power to one of depriving communities of their democratic voice.

The Canadian Wind Energy Association (CanWEA) opposes a return to the patchwork quilt of permitting processes that existed prior to the unified provincial process. CanWEA President Robert Hornung acknowledges that "opportunities exist to strengthen the [municipal consultation] process," and his organization has made several suggestions to the Ontario government that would ensure proactive and meaningful consultation. Hornung adds that the industry "wants to work productively with all levels of government to ensure the jobs and investments continue flowing into rural communities across Ontario."

Melancthon Wind Farm Near Shelburne, Ontario. Credit John Vetterli via Flickr.

Transmission Access

As with any power project, it is one thing to build it but quite another to get it connected to the grid. Ontario, like many jurisdictions across North America, failed to invest properly in both transmission and generation infrastructure toward the end of the 20th century. From 2003, when the Ontario government decided to phase out coal-fired generation by 2014, new generation capacity has come online at a faster pace than new transmission capacity. Wind projects have been forced to compete with all new sources of generation, such as natural gas and biomass, for access to an increasingly constrained transmission system.

Some argue that wind power, being a variable resource, is ill-suited to the current transmission infrastructure and will never reach its full potential until electricity storage projects come online to smooth out the variable nature of this resource. However, Hornung notes that numerous wind integration studies have concluded that significantly more wind can be added to Ontario's transmission system before large-scale storage projects are necessary. The industry's main concern with respect to transmission is ensuring that the province will commit to make more capacity available for wind power beyond its current plan of 7,500 MW by 2018.

What's Next?

None of the issues discussed in this article are unique to Ontario, but how they are addressed over the coming weeks and months will have a major influence over the health of the province's wind power sector. As noted by my colleague Adrienne Baker in a recent posting on www.RenewableEnergyWorld.com, the Ontario Ministry of Energy is likely to be publishing its findings and recommendations for the changes to the FIT program in March and rolling them out in May.

Separately from the FIT review, the IESO is conducting a wide-ranging review of issues arising from the integration of significantly more renewable power generation capacity. The provincial transmission grid operator is currently consulting stakeholders on the subject of curtailment and hopes to draft new rules to address the issue in 2012 with a view to implementing them in approximately 18 months.

Marc Coward is the Principal of Renewable Shift Consulting, a Toronto-based firm that provides customized market intelligence and advisory services to clients seeking to acquire or find investors for renewable energy projects in Canada. His experience allows him to understand the Canadian renewable energy sector from a variety of perspectives. He holds an MBA with a concentration in finance from the University of Toronto and an M.Phil from the University of Oxford.