# Four Strong Winds

**Wind. It is an omnipresent source of power.** It has been used to pump water, grind grain, hold gliders aloft, and move ships around the globe. But when fossil fuels emerged as part of the industrial revolution, wind lost its prominence as an important energy source.

Today, however, wind power is making a comeback, and electricity generated by wind is one of the fastest growing sources of renewable energy. The global energy economy includes a significant focus on developing renewable energy alternatives to crude oil, natural gas, and coal, as governments and industry struggle with issues such as emissions from coal-fired generators, cost and delivery of natural gas, and real and perceived risks of nuclear power.

"The growth in wind-generated electricity has a number of social benefits," notes Jason Edworthy of Vision Quest Windelectric, Canada's largest producer, based in Calgary. "The development of a rural wind farm provides land rental income for farmers and business tax revenues for the local communities, and the environmental footprint of a wind farm is small. As a result, we sell our wind energy as a branded product."

And the future of wind power? To a strong degree, growth can only continue if the electricity supply is reliable and economical, and that requires effective lubrication.

Four major challenges that lubricants have to face include trends towards larger equipment with higher levels of force on all bearings and gears; offshore locations with potential for seawater contamination and corrosion; increasingly

BY RAY BERGSTRA

Photo: REpower Systems (Jan Oelker)

**About This Series**

Consumers everywhere expect electricity to be plentiful, safe and reliable — and that won't happen without lubricants. In this three-part series, *Lubes'n'Greases* looks at the technologies, people and lubricants that create the buzz.

October: Hydro

**This month: Wind**

December: Nuclear

*Turbine manufacturers are focusing new efforts on wind power, and on the lubrication needed for reliability.*


*Photo: Vestas*

tough specifications from OEMs; and remote installations accessible only by helicopter, making maintenance highly difficult. These trends clearly provide new hurdles for tribologists and lubrication engineers working for gearbox and bearing manufacturers, additive suppliers and lubricant manufacturers.

**Scoping the Market**

Global generating capacity from wind turbines continues to increase in the 20 percent per year range, and the Global Wind Energy Council pegs global capacity at 50,000 megawatts (MW) in 2005. There has been significant growth in all global regions. As with many environmentally driven industrial initiatives, Europe leads the way right now, with approximately 36,000 MW of wind-energy generating capacity. Growth is particularly strong in Denmark, Spain and Germany. By contrast, there are approximately 7,000 MW of capacity in the United States.

The prospects for wind energy as a sustainable industry remain highly positive. The technology is much more refined since wind power re-entered the market 25 years ago, and mechanical reliability and efficiencies have improved. Unit capacity has greatly increased, and if oil and gas prices remain high, wind power is expected to be cost competitive sooner rather than later.

Primary challenges to the wind power industry are cost, reliability and infrastructure. With respect to infrastructure, the bottom line is that the power generated at the wind farm needs to be tapped into the main power grid. Frequently, this infrastructure is not in place, especially when the windiest locations are often remote from large urban and industrial centers. While governments and/or utility initiatives deal with this issue, lubricants will do their part in terms of costs, efficiency and reliability.

At the same time, equipment manufacturers are focusing on building larger turbines that generate more watts per unit. This "bigger is better" approach is certainly not new in industry, as the same applies to oil tankers, passenger aircraft and excavating equipment.

One key aspect of the larger and more efficient wind turbines is that the longer blades enable a more consistent and reliable power supply under lower and intermittent wind velocities. Larger, slower-rotating wind turbines can better maintain the torque required to drive the generator.

In the recent past, typical wind turbine installations relied on blades that were 20 to 30 meters long, to generate between 0.5 and 1 MW of power. Newer units installed since 2002 are generating over 2 MW using blades of 45 meters, and even larger units, capable of 5 MW output each, are planned over the next several years. The newest scaled-up plants have bearings larger than 2 meters in diameter and drivelines stretching 10 meters long. Their rotor blades span 80 meters, and their towers loom over 100 meters high.

**Ill Winds**

Each wind turbine is constructed with a number of key areas where lubrication is required, all crowded into the gondola or "nacelle" that perches at the top of the tower. A hydraulic oil is required to operate the blade pitch and rotor brakes, and greases are required for such areas as the generator, main and shaft bearings. But most importantly, gear oil is required for the gears and bearings in the gearbox, and this is where most of the lubricant development work has focused.

Why exactly are the gearboxes in wind turbines so difficult to lubricate? The simple answer is that high gear ratios (greater than 50:1) are used in order to convert the low speed and high torque rotor to the low-torque/high-speed requirements of the generator. Using longer blades means more torque can be generated even under low wind speeds, but it leads to ever higher gear ratios and to gearbox contact forces of up to 4 million Newton-meters. (One Newton weighs 102 grams, and it takes one Watt of power to raise one Newton through one meter a second. So a 4 MW turbine exerts the mechanical force, or torque, needed to lift 408,000 kg — say, 450 big cows — through 1 meter every second.)

This high gear ratio situation stands in contrast to traditional forms of power

*Continued on page 22*




Getting your basestocks from ExxonMobil means you can be sure you’ll have the supplies you need. That’s because we have a global network of refineries that manufacture CORE™ basestocks that are interchangeable as a result of our Base Oil Interchange Program (BOI). What’s more, our rigorous quality assurance systems ensure that our basestocks consistently meet our high standards. All of which enables you to drive costs from your supply chain. Clearly, when it comes to basestocks, we’ve got all the bases covered. To learn more, call 1-888-228-4437, option 1.

ExxonMobil
*Lubricants & Specialties*
moving AHEAD

*Continued from page 20*
generation that involve burning of fossil fuels. In large power plants, heat is used to generate high-pressure steam that drives the generators at the required speeds. Of course, in the case of portable generators, diesel or natural gas turbine engines can be used. In either instance, high rotational speeds can be generated directly without the need for severe gear ratios.

However, a diesel generator set typically can require 100 gallons of fuel per hour in order to generate 2 MW of power, the same level of output as a typical new wind turbine. At today's fuel pricing, that puts annual fuel costs at over $2.5 million, and this is what makes wind blowing for free look good.

Wind power units installed during the early 1990s often used gearboxes and industrial gear oils that were found later to be inadequate for the demands of their turbines. The problems were manifold: Gear-teeth surface finishing, insufficient data on dynamic forces, additive-hardware mismatches and oil cleanliness issues all contributed to poor gearbox life. In addition, "micropitting" became a well-known headache for anyone involved in wind turbines.

Micropitting is the term that describes a particular form of gear-tooth distress, mostly seen in surface-hardened gears that experience thin lubricant films due to high load and low speed operation. Typically, asperities (roughness) on the hardened metal surfaces cause metal fatigue in the softer subsurface. This leads to surface pitting, initially in the 10-micrometer range, but such pits can deepen, spread into each other and further gear-tooth failure.

Field tests also have contributed important lubricant performance data, including the 2001-2003 Klim wind farm field tests coordinated by Danish companies Vestas (the wind turbine manufacturer) and Elsam (the power company). Published results from these field tests found that synthetic fluids could provide advanced performance. Polyalkylene glycol (PAG) based oils performed particularly well, and were identified as the first choice for use in subsequent North Sea installations.

**New Standards**

Following the Klim tests, industrial gear and transmission manufacturers and bearing manufacturers have dedicated significant efforts to developing more reliable components for wind turbines. With the gearbox being the most critical issue for lubrication, FAG Bearings published a new bearing specification in 2003, which included a comprehensive range of performance requirements. These include wear protection under three lubricating regimes (boundary, elastohydrodynamic and mixed friction) as well as a wear test with water contamination. Bearing maker SKF also developed a specification, released in 2004, that included stiff requirements for chemical and thermal stability, corrosion protection and filterability.

## Who's Who in Wind Power

**Turbine Manufacturers:**
Bonus (Siemens)
Enercon
Gamesa
GE Wind
Vestas/NEC Micon

**Gearbox Manufacturers:**
Bosch Rexroth
Eickhoff
Hansen Transmissions
Jahnel-Kestermann
Moventas (formerly Metso Drives)
Winergy (Siemens)

Subsequently, a number of original equipment manufacturers — including Hansen Transmissions, Jahnel-Kestermann, Eickhoff, Winergy (formerly Flender, now a subsidiary of Siemens), Bosch Rexroth Getribetechnik, and Moventas (formerly Metso Drives) — sharpened their efforts specifically for wind turbine equipment. Many have issued higher performance requirements for lubricants, too.

As Wilfried Bartz, head of the Tribology Department at Germany's Technische Akademie Esslingen, points out, most of these new performance standards demand high load-carrying capacities, excellent wear and corrosion protection, wide temperature capabilities and — especially — very high viscosity indexes (V.I.) to ensure film strength.

OEMs want gear oils for their large new wind power plants to have a V.I. surpassing 150, for example, "and so that's the end of mineral oils in this application," he told a plenary session of the World Tribology Congress, which met in September in Washington, D.C. "These requirements can be covered only by synthetic gear oils, based on polyalphaolefins or polyglycols."

Likewise, the open-gear greases used in wind plants must be able to operate at temperatures ranging from -55 degrees C to +140 C, with occasional forays up to 160 C or more. The hydraulic oils, he added, require a V.I. greater than 140 and pour points below -30 C. "Again, synthetic base stocks are necessary."

Bartz also underscored the difficulty in inspecting and maintaining remote wind power plants, especially in offshore farms. "You need to use a helicopter or ship to get out there," he noted. "Will that be done just to get a one-liter oil sample?" In many cases, he suggested, online sensors may be the only option for monitoring the equipment condition.

**Formulate Like the Wind**

So where does the industry stand with wind turbine gear oil development? Afton Chemical is among those actively involved in meeting the new challenges, and it has worked with OEMs to address the issues of bearing

*Continued on page 24*

## What Makes the Wind?

Wind is caused by a number of factors, the main one being the sun. For example, daytime sunshine over land causes air to heat and expand upwards, which creates an area of lower pressure. Then cooler, denser air that may typically be over water moves in to fill the low pressure area, and this air movement is wind. For this reason, shoreline locations work well for wind turbines, including locations along the North American Great Lakes. Wind direction is a bit more complicated and is related to a number of factors, including Earth's rotation, the temperature differentials at the poles vs. the equator, and the global distribution of warm ocean waters and larger land mass. —*Ray Bergstra*

*Continued from page 23*

fatigue, micropitting and anticorrosion, and also to ensure that seal compatibility and antifoaming requirements are maintained.

Each of these performance areas is important but "handling all simultaneously is the real challenge," states Ian Macpherson, industrial marketing manager for Afton North America in Richmond, Va. "The technical challenges of wind turbine lubrication have caused a revolution in the formulation style of industrial gear oils. This revolution has increased performance by orders of magnitude, and made industrial gear lubrication one of the most dynamic areas in our industry today."

With the large new gearboxes in place, what types of lubricants are now available to do the job for these bad boys of wind power? ISO 320 grades using mineral base oils are the lowest-cost products, and in many instances, can provide adequate protection, especially in the smaller land-based installations. For example, wind farms in southern Alberta, Canada, today run with typical oil change intervals of six months to one year, but oil condition monitoring may allow further extensions.

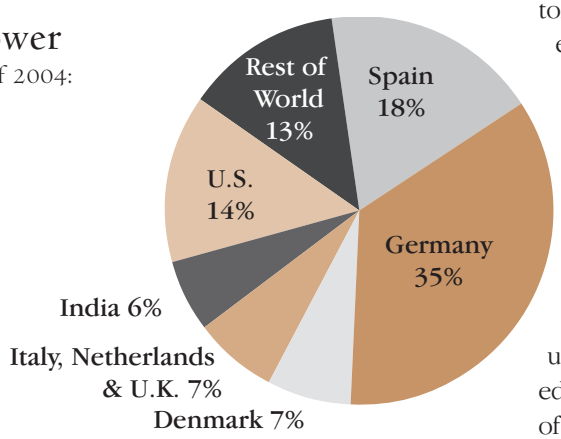
However, as wind turbines are increasingly located in remote or offshore locations, all forms of maintenance become more significant. For lubrication, this is leading to increased use of premium base fluids with extended drain capability. A review of online product information shows that some, but not all, of the major oil suppliers offer industrial gear oils specifically designed for the higher demands of wind turbines. Anderol, Castrol, Dow, ExxonMobil, Kluber and Total, for example, all supply ISO 320 products that meet the latest specifications of the gearbox OEMs, using synthetic base fluids such as polyalphaolefins, esters, PAG and combinations thereof.

With the advances in wind turbine technology and the increasing high cost of fossil fuels, it is not difficult to understand the high growth rate of wind turbine installations. This growth is often stimulated by government support, such as the U.S. wind energy Production Tax Credit that supports the target of fulfilling 10 percent of electricity needs from renewable sources by 2020. The Global Wind Energy Council has members from every region, and each has dedicated efforts to expand their capacity for this renewable form of energy. And as long as the earth turns and the sun shines, there will be wind. ∎

*Raymond Bergstra, Ph.D., head of MTN Consulting Associates in Edmonton, Alberta, Canada, last wrote about synthetic hydrocarbons for* Lubes'n'Greases, *in our May 2005 issue. He can be reached by phone at (780) 436-3993, or visit www.mtnconsulting.ca.*

## Share of Global Wind Power

Total at End of 2004: 47,317 MW




*Source: Global Wind Energy Council*