Gear Manufacturers Face Challenges in Growing Wind Energy Industry

Joseph L. Hazelton

East of San Francisco Bay, near the town of Rio Vista, 81 white towers stand 255 feet tall on rolling hills of dry grass harvesting a year-round crop: wind.

On each tower, blades 124 feet long rotate in the wind, transferring its energy to the gearbox inside the turbine nacelle. Sun and planet gears rotate around an internal ring gear, transmitting the energy to the nacelle generator, creating electricity. In total, the turbines generate 145 megawatts.

Installed this year, the wind farm represents an opportunity for the gear industry.

Wind energy is a growing international industry. The European Union added 4,493 megawatts of new capacity in '01, then added another 5,871 in '02. The United States installed 1,696 megawatts of new capacity in '01 and 410 more in '02.

A leading U.S. wind energy developer, FPL Energy alone is scheduled to install another 800 megawatts this year. Brent Reardon, the developer's technical manager for wind, says the company's goal is to install 750–1,000 megawatts each year for the foreseeable future.

More wind turbines means more wind turbine gears. Besides new manufacture, wind energy's growth means more chances for work repairing the gears and overhauling them.

But wind energy is also a challenge to the gear industry.

The challenge starts with turbines in the 1.5–2.2 megawatt range. In that range and higher, wind turbines use planetary gear drives. Their sun and planet gears aren't difficult to manufacture, but their internal ring gears are.

In that range, the internal ring gears have pitch diameters of 4- to 6-feet and quality levels of Q10–12 using AGMA standard 2000–A88.

Working with pitch diameters of more than 5 feet, manufacturers of wind turbine gears start to "bump up against" their machine limits, says Ed Hahlbeck, president of Powertrain Engineers, a consultancy based in Pewaukee, Wisconsin. Hahlbeck's company specializes in large wind turbines, and Hahlbeck himself serves on the AGMA Wind Turbine Gear Committee.

The challenge of the internals is everyday, though, because turbines in 1.5–2.2 range are commonplace at utility-scale wind farms.

"With any new installation, you're going to be working in that size range, with 1.5 as the lower limit," says Frank C. Uherek, engineering manager for Flender Corp. and Winergy Drive Systems of Elgin, Illinois. "That's where the market is sitting."

The new wind farm near Rio Vista is an example. Each of its 81 wind turbines generates 1.8 megawatts.

But the market won't be sitting in that range forever. Reardon expects the average wind turbine to be in the 1.5–3.0 range in the next two to three years, meaning gears' sizes would become "tremendously bigger."

Roland Ramberg, president of The Gear Works, estimates gears in 3.0 turbines would have to be about 30 percent larger than they are in 1.5 turbines.

Based in Seattle, Washington, Ramberg's gear job shop specializes in high-accuracy industrial gears. In the wind energy industry, The Gear Works mainly provides repair-and-replacement service to users of wind turbines. Through bidding, though, it also manufactures gears for new wind turbines, primarily the internal ring gears for turbines generating up to 1.5 megawatts.

Wind energy's market in the United States is growing, so wind turbines represent an opportunity for the gear industry.

His company wouldn't have any trouble making the external gears for the 3.0 turbines, but it would have to buy the machinery for the larger internal ring gear.

"The internal would require a major investment," Ramberg says. "It would be

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Tax Credit Promotes U.S. Wind Energy

"Unsteady"—Brian McNiff, president of wind energy consultancy McNiff Light Industry of Harborside, Maine.

"Very up and down"—Rick Walker, director of business development, wind energy developer AEP Wind Energy of Columbus, Ohio.

"On a roller coaster"—Mark Haller, vice president of technology, wind energy developer Zilkha Renewable Energy of Houston, Texas.

What are these wind energy people describing? Their industry's market in the United States.

U.S. wind energy was largely inactive during much of the 1990s. The industry started to revive five years ago, when installment of new capacity jumped from 11 megawatts in '97 to 233 in '98, then to 661 in '99.

But the U.S. revival has included very *large* fluctuations. After '99, installment of new capacity dropped to 53 megawatts in 2000, soared to 1,696 in '01, then dropped again to 410 in '02.

In contrast, the wind energy industry installed 4,493 megawatts of new capacity in the European Union in '01, the U.S. boom year. Wind energy followed up the next year with another 5,871 megawatts in the EU.

U.S. demand varies more than world demand because the U.S. government keeps letting its wind energy tax credit expire, says Christine Real de Azua, assistant communications director for the American Wind Energy Association, based in Washington, D.C.

The Federal Wind Energy Production Tax Credit is meant to help level the playing field between companies providing electricity from wind power and those providing it from other sources, like gas, coal, oil and nuclear. Specifically, it's a per-kilowatt-hour tax credit for wind-generated electricity during the first 10 years of operation. This year, the credit is 1.8 cents per kilowatt-hour.

The credit was part of the Energy Policy Act of 1992 and had an expiration date of June 30, 1999. But wind energy's U.S. market was largely dormant until '98.

In the late '90s, state requirements for renewable energy sources led to increased development of utility-scale wind farms. The farms showed that wind energy could compete with other energy sources.

By then, the federal credit was approaching its expiration

Wind energy's U.S. market was mainly inactive during much of the '90s, but started to revive in '98 and had a record year in '01, when 1,696 megawatts of new capacity were installed.

date. On June 30, 1999, the credit expired. The U.S. government reinstated the credit in late '99, with a new expiration date, Dec. 31, 2001. The credit lapsed again at the end of '01, but was reinstated in March '02 and given its current expiration date, Dec. 31, 2003.

But the credit's short terms and lapses affect the wind energy industry. Installing a new utility-scale wind farm takes time. According to McNiff, wind farm projects will be suspended if turbines aren't being installed by Aug. 1 and the credit is set to expire Dec. 31 of that year. A member of AGMA's wind turbine gear committee, McNiff adds the projects won't resume until developers know the credit will be reinstated

"It tends to drive the production of wind turbines in a very cyclic manner," says Brent Reardon, technical manager for wind at FPL Energy, a leading U.S. wind energy developer based in Juno Beach, Florida.

In contrast, Europe's governments have long-term policies supporting development of wind energy and its countries steadily invest in wind energy, according to de Azua.

To make the U.S. market more stable, both Reardon and de Azua agree the federal credit should have a much longer life. For the AWEA, that life should be at least five years.

"It would help stabilize the wind industry for planning and development of future projects," Reardon says.

Internal ring gears for wind turbines generating 1.5–2.2 megawatts of electricity have 4- to 6-foot pitch diameters and AGMA quality levels of Q10–12.

millions."

Upgrading to manufacture 3.0 gears, a company might have to buy a larger CNC machining center for turning, milling and drilling; a larger gear-cutting machine—two if the company wanted to rough- and finish-cut separately; and a larger gear-grinding machine.

"Those would be the three major purchases," Ramberg says.

Such large machines could be bought from major machine tool manufacturers, but they'd be built to order.

"You're not going to go to the showroom and buy one off the showroom floor," Ramberg says. To indicate cost, he estimates the gear grinder alone would approach $2 million.

Equipping to manufacture larger internal ring gears is a problem for the future, though. Gear manufacturers are still dealing with a problem from the past: a general shift in wind energy from spur teeth to helical ones.

Ramberg noticed the shift several years ago, and both Hahlbeck and Uherek agree helicals are becoming more and more common.

Hahlbeck adds that cutting helicals on large internal gears is a special problem. He explains that the helicals are cut on shaping machines that generally aren't computer controlled, so the machines need special tooling, which increases manufacturing costs.

As wind energy grows, gear manufacturers face another challenge: higher volumes of production. To be more productive, they may have to replace their vitrified grinding wheels with CBN ones.

Describing the price difference as "huge," Hahlbeck says a set of roughing and finishing CBNs would cost several

New Wind Turbine Standard Is Ready for Growing Industry

The American Gear Manufacturers Association is preparing a 90-page standard on wind turbine gearboxes for its final reviews before publication.

After nine years of work, the AGMA Wind Turbine Gear Committee adopted the omnibus standard July 23. It will be the AGMA's first standard on wind turbine gearboxes.

The work started in January '94, with the committee's first official meeting. The original members were clear on the reason for organizing as a group.

"We were all seeing widespread failures in wind turbine gearboxes," says Jane Muller, an original member and the committee's vice chairwoman.

She's also a mechanical engineer with a gear consultancy, GEARTECH, located in Townsend, Montana.

"Wind turbines are a very demanding application for gears," says Brent Reardon, the committee's chairman. "They have to transmit very high and dynamic loads."

The committee started by creating an information sheet in conjunction with the American Wind Energy Association. The sheet, AGMA/AWEA 921-A97, provided recommendations for manufacturing wind turbine gearboxes and took effect in October '97. Since then, the committee has been expanding on the sheet to create a regular standard.

The standard is arriving at an opportune time. Mainly inactive for years, wind energy's U.S. market became more active in '98 and had a record year in '01, when 1,696 megawatts of new capacity were installed.

"It's a growing, fluid industry," Muller says.

As an example, she refers to the late '70s and early '80s. Back then, utility-scale wind farms used wind turbines that might generate 120 kilowatts. Today, new utility-scale wind farms commonly use turbines generating 1.5 megawatts. And more powerful turbines are commercially available.

"Just the basic design of the gearbox is changing quite rapidly," Reardon says.

As design and manufacture guidelines, the standard is the work of a committee that has expanded since it created its information sheet.

"We're up to 50 members attending every meeting. There are over 10 countries involved in this committee," Muller says. "It represents everyone involved in wind energy."

As a cross section, the committee includes several industry heavyweights. Reardon, its chairman, is from FPL Energy, a leading U.S. wind energy developer. Its members are from NEG Micon, Flender, MAAG Gear, Timken, SKF Industrial, Castrol Industrial, and Exxon Mobil.

Other members come from the U.S. National Renewable Energy Lab and Institut für Maschinenelemente Technische, connected to the Gear Research Centre at the Technical University of Munich, Germany.

In total, members' companies manufacture, purchase, operate and service wind turbines; manufacture the gears, bearings, lubricants and lubricant components used in them; provide monitoring equipment for them; and consult on their gears.

Many committee members are from companies in Europe, where wind energy is a larger industry than it is in America.

The AGMA is in the final stages of preparing for publication its first standard on wind turbine gearboxes.

According to Muller, they had commercial and general interests in contributing to the standard. American wind farms often use European wind turbines. Muller says the Europeans also contributed to do "the right thing" for the wind energy industry. She adds the standard benefited from the Europeans.

Reflecting the members' expertise, the standard includes a range of fields related to wind energy. It covers specifying, selecting, designing, manufacturing, procuring, operating and maintaining of wind turbine gearboxes. It also covers bearings, lubrication and condition monitoring of the boxes.

The standard has nine annexes, as well. They include wind turbine architecture, environmental considerations, wind turbine load description, quality assurance, operation and maintenance, minimum purchaser and gearbox manufacturer ordering data, lubrication selection and condition monitoring.

On Feb. 12, the committee approved the standard for a general ballot. The standard was then distributed to AGMA members for review and suggested changes.

Like other AGMA standards, this new standard will be voluntary. Its title is "Standard for Design and Specification of Gearboxes for Wind Turbines" and is designated AGMA/AWEA 6006-AXX. When published, the "XX" will be replaced by the publication year.

On July 23, the committee met in Big Sky, Montana, decided which suggested changes to include, and voted to submit the standard to the AGMA Technical Division Executive Committee.

The standard still has a ways to go before publication, though. After TDEC, the standard will be reviewed by the AGMA board of directors and then the standards council for the American National Standards Institute. After all three groups approve the standard, then the AGMA will publish it.

Manufacturers of wind turbine gears may have to push the limits of their machinery to create the internal ring gears needed by wind energy's larger turbines. Another manufacturing challenge is the general shift from spur teeth to helical ones.

thousand dollars, but the vitrifieds would cost only a few hundred.

However, Hahlbeck adds gear manufacturers tend to sell their wind turbine gearboxes to projects where the number of gears can be in the hundreds. In those cases, CBN wheels could be a cost advantage through higher productivity and greater consistency.

Uherek says serial production is key to CBN use: "If you're going to make 40 of something, CBN pays; if you're going to make one of something—forget it."

Serial production also takes advantage of CBN's longer life compared with vitrifieds, making the price difference more bearable.

Given these manufacturing challenges, it isn't surprising that Bernard Vukovic of MAAG Gear uses "expensive" when describing gear manufacturers' involvement in the wind energy industry. Vukovic is a gear engineer in the wind turbine gearbox division of MAAG, based in Winterthur, Switzerland.

Besides the high cost of the machines for manufacturing large wind turbines' gears and gearboxes, he mentions the expense of the cranes for removing malfunctioning gearboxes from erected turbines and the costs that can result from shipping the gearboxes back to manufacturing plants for repair.

So he advises gear manufacturers curious about entering the wind energy industry: "Unless you have really, really big pockets, then don't."

He also cautions companies interested in supplying just the sun, planet and parallel-axis gears, not the internal ring gears. He says an important question is: Who's responsible for what parts? That question becomes important when gearboxes malfunction and companies have to decide who's responsible for possibly expensive repairs.

"They can make or break somebody," Vukovic says.

Photos courtesy of AEP Wind Energy, the American Wind Energy Association, FPL Energy and The Gear Works.

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