Educational

The Gearbox Problem

July 2009

GEARBOXES: COSTLY REMNANTS OF OUR ENERGY PAST

For decades, wind turbine design has been based on a conventional gearbox architecture. Indeed many turbines manufactured new today still use the old gearbox designs and many of today's wind farms are full of gear-driven wind turbines.

But the need to move away from gearbox-laden designs is well-known throughout the industry. High failure rates have had far-reaching effects and caused concern for many years.

> *"Over 80% of the profit warnings in the wind turbine manufacturing industry have come from gearbox issues, primarily malfunctioning bearings but also unforeseen issues with various gearbox designs."* *Merrill Lynch Wind Industry Overview, August 2007*

Extending back to the late 1990s, the US Department of Energy commissioned a subcontract project (YCX-1-30209-02) to identify, design, and test a megawatt scale drivetrain with the lowest overall life-cycle cost. In fact, Northern Power Systems played a major role in the project. The company's revolutionary gearless wind turbine design is due in large part to that work.

In a 2007 conference paper, the National Renewable Energy Laboratory (NREL) commented that "Despite reasonable adherence to these accepted design practices, wind turbine gearboxes have yet to achieve their design life goals of twenty years, with most systems requiring significant repair or overhaul well before the intended life is reached. Since gearboxes are one of the most expensive components of the wind turbine system, the higher-than-expected failure rates are adding to the cost of wind energy."[1]

In 2007 NREL launched its **Gearbox Reliability Collaborative (GRC).** This multi-year program was designed to find out why gearboxes fail earlier than other turbine components.[2] This year, the US Department of Energy dedicated $2.5 million to the GRC, and plans to ask for another $2.5 million in 2010 to continue its important work. So the work toward an industry solution continues, but it is not likely to result in fast or easy fixes.

WHAT CAUSES GEARBOXES TO FAIL?

Gearboxes are problematic by the very nature of the numerous moving parts and subsystems that are required for their operation and the demanding nature of the wind turbine application itself. **Bearings** have also been targeted as a possible weak link. A 2007 NREL conference paper notes that the majority of gearbox failures originate at the bearing level. The Gearbox Reliability Collaborative work is ongoing and the next set of reliability data is expected to be available this fall.[3] Whatever the continuing investigations reveal, it is generally accepted that the complexity and multiple moving parts of gearbox-driven designs are creating more opportunities for failure, more maintenance requirements and costlier fixes.

It actually shouldn't be surprising that gearboxes have so many failures, especially if you think about it in terms of something we all know – car transmissions. A car transmission is functionally similar to a wind turbine's gearbox. Expecting a wind turbine's gearbox to last for 20 years of continuous operation would be like expecting a car's transmission to last for 4 million miles. Most would agree that is an unreasonable expectation.

---

1 S.Butterfield and W.Musial, National Renewable energy Laboratory, 2007 European wind Energy Conference paper, 2007

2 "A Public-Private Project Seeks clarity in the conversation," John Clapp, North American Windpower, May 2009

3 Ibid

Northern POWER SYSTEMS

Educational

The Gearbox Problem

WHAT OTHER PROBLEMS DO GEARBOXES PRESENT?

Even in the year when a turbine's gearbox has not failed, owners of gear-driven wind turbines are presented with other serious and costly issues. Of greatest impact are noise and continuing maintenance.

- **Noise**: A turbine's gearbox is a major contributor of machine noise. According to Fraunhofer Institute, "One reason is the tooth mesh of the gear wheels. The structure born noise generated by the tooth mesh propagates through the roller bearings to the gearbox and through the impact noise insulation to the nacelle bedplate and finally to the tower. The large surface area of the tower radiates the noise to the environment."[4] While somewhat problematic in large wind power production facilities, turbine noise is a much more serious issue in community-based wind power applications where turbines are sited in the places where people live and work.
- **Frequent and complex maintenance**: Often multiple times per year, maintenance crews need to be dispatched to care for the gearbox. Hydraulic fluids, bearings, slip rings, pumps and clutches necessitate a somewhat complex maintenance and operational support program.

HIGH FINANCIAL RISKS FOR DEVELOPERS

The frequent maintenance requirements and multiple (and costly) gearbox replacements have certainly proven problematic for developers of large wind power production facilities. Most wind farm developments today have maintenance teams in place to maintain and replace gearboxes. Many economic models factor in total gearbox replacements every 5-7 years on each turbine. The financial risk gearboxes represent is only somewhat mitigated by the large number of turbines in a major wind power production facility and developers' ability to amortize personnel, equipment and consumables costs across a fleet of turbines.

> *"One recent report says retrofits of gearboxes were necessary at all 30 turbines in an offshore farm - after less than two years. In another case many turbines were already on their second or third gearbox retrofit after only 5 years. Gearbox replacement costs are as much as $300,000 per failure."* North American Windpower June 2006

CRIPPLING EFFECTS FOR COMMUNITY WIND APPLICATIONS

Demanding gear-laden wind turbines pose great challenges to the community scale adoption of wind turbines for schools, private businesses, municipalities, and farms. The costs associated with maintaining gear-driven wind turbines create an insurmountable burden to these community wind applications, which typically host only 1 or 2 wind turbines and cannot afford to employ maintenance crews or fund costly gearbox assembly replacements. Turbine down time can also lead to poor public perception for your wind project.

> *"Gearbox failures account for the largest amount of downtime, maintenance, and loss of power production. These costly failures can total 15-20% of the price of the turbine…"* Renewable Energy World, September 2008

Gearbox turbines were simply not designed with the community application in mind—they are noisier, costlier and require more support. The adoption of wind power in communities has been historically slow because of the lack of a low-maintenance, next-generation wind turbine technology.

Northern POWER SYSTEMS

4 "Active vibration absorber for gear box noise reduction in wind turbines", conference proceedings, 5/27/2007, Illgen, A.; Drossel, W.-G.; Wittstock, V.; Schirmer, W.; Wiedemann, L., Fraunhofer Institute, http://publica.fraunhofer.de/starweb/servlet.starweb?path=pub0.web&search=N-58370

Educational

The Gearbox Problem

A GEARLESS FUTURE

Our country and the world face a new energy landscape. Today's wind power production facilities and community wind applications require a new technology – one that far surpasses the antiquated and inefficient wind turbine designs of the past. With more than 30 years in the wind industry, the Northern Power Systems team embraced these challenges and the idea of a streamlined and elegant turbine architecture based on the idea that less is more:

Less subsystems, more reliability

Less moving parts, more energy

Less maintenance, more savings

It is this philosophy that formed the basis for the advanced gearless technology of the NPS 100 & NPS 2.3 wind turbines. By eliminating the gearbox architecture and the need for the many subsystems that supports its functions, Northern introduced a vastly simplified and ultra-reliable gearless technology that results in better energy capture, quieter operation and significantly lower operation and maintenance costs—an ideal combination for the community wind application.

One indication of the superior reliability of Northern Power Systems' Permanent Magnet Direct Drive (PMDD) technology lies in our company's design approach. Northern Power wind turbine were originally designed according to the IEC 61400-1 standard for a 30-year life at an IEC WTGS Class I site (i.e. 10m/s average hub height wind speed). Given that most new wind turbines are designed to a 20-year life in less rigorous Class II conditions (8.5 m/s average), Northern Power wind turbines stand head and shoulders above other turbines – and especially used or refurbished turbines – from a reliability standpoint.

FOR MORE INFORMATION

- NREL 2007 conference paper - improving wind turbine gearbox reliability: http://www.nrel.gov/wind/pdfs/41548.pdf
- 2009 gearbox study lead by NREL: http://www.nrel.gov/features/20090417_wind.html
- Renewable Energy World Article: NREL study aims to grease wind powers future: http://www.renewableenergyworld.com/rea/news/article/2009/04/nrel-gearbox-study-aims-to-grease-wind-powers-future
- March 2009 renewable energy focus article on gearbox maintenance issues: http://www.renewableenergyfocus.com/view/1396/improving-wind-turbine-gearbox-reliability-with-om/
- Conference abstract from Fraunhofer re: gearboxes causing noise: http://publica.fraunhofer.de/starweb/servlet.starweb?path=pub0.web&search=N-58370
- Northern Power Systems web page on technology and design http://www.northernpower.com/technology/index.php

Northern
POWER SYSTEMS