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Solving the Maintenance Challenge in Wind Power

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The past 20 years have brought amazing advances in wind power technology. The American Wind Energy Association states that wind is the world's fastest growing energy source on a percentage basis (with an annual increase approaching 32%) and its growth is forecast to continue a double-digit pace into the next decade. As a result of these advances the cost has been reduced, making it more competitive with other traditional resources. The world has long been in search of a non-polluting, renewable energy that is as cheap as coal and oil. Major contributors to the affordability of wind power have been low operating and maintenance costs. It is essential for these costs to remain low in order for this environmentally friendly energy resource to remain competitive.

The Process of the Wind Turbine

The process of the wind turbine is a fairly simple one. The wind is used to generate mechanical power or electricity. A range of different wind speeds passing over the blades is converted into mechanical power. Wind turns the blades and the power from the rotation of the wind turbine rotor is transferred to the generator through the nacelle that houses the gearbox, low and high speed shafts, generator, controller, and brake. The electricity generated can be used directly or fed into a transmission grid. A wind turbine's power increases exponentially with wind speed; should wind speed double, the result is a power increase of as much as eight times. Wind turbines are best utilized with wind speeds that allow the turbine to run at its full rated power.

There are many criteria that aid in wind power production such as local support, availability of transmission, distance to load centers, as well as wind capacity. Future installation considerations are to take place off-shore to maximize wind consistency. Capacity factors increase approximately 40% from inland wind turbines to off-shore turbines. Just as capacity factors increase from inland to offshore, so do the operating and maintenance costs. This calls for even more efficient control of mechanics and lubrication. Remote monitoring of turbine components and operation is essential to keeping maintenance costs manageable and productivity high.

Wind Power Benefits

The benefits of wind powered energy are numerous. They include issues of cost savings to environmental gains. A fact sheet released in June 2004 by the American Wind Energy Association states the following:

> Development of 10% of the wind potential in the 10 windiest US states would provide more than enough energy to displace emissions from the nation's coal-fired power plants and eliminate the nation's major source of acid rain. If wind energy were to provide 20% of the nation's electricity – a very realistic and achievable goal with the current technology – it could displace more than a third of the emissions from coal-fired power plants, or all of the radioactive waste and water pollution from nuclear power plants.

Wind farms are groups of large wind turbines that can range in size from a few megawatts to hundreds of megawatts in capacity. Wind farms usually consist of small individual modules (the turbines). Turbines can be added as electricity demand grows, solving the problem of outages during peak usage. In order to keep wind power as a cost-effective renewable energy resource the wind turbine must remain operational.

The following table created by the American Wind Energy Association compares the costs of major energy sources with wind energy. The figures are from the California Energy Commission's 1996 *Energy Technology Status Report*, which examined the costs and market readiness of various energy options[1]. The CEC calculations do not include subsidies or environmental costs.

Fuel Levelized costs	**(cents/kWh)** (1996)
Coal	4.8-5.5
Gas	3.9-4.4
Hydro	5.1-11.3
Biomass	5.8-11.6
Nuclear	11.1-14.5
Wind (without PTC*)	4.0-6.0
Wind (with PTC*)	3.3-5.3

*PTC – Federal Production Tax Credit

The cost of natural gas has increased since 1996, so that the levelized cost of gas–fired power plants would now be considerably higher. In January 2001, the cost of natural gas generated power was running as high as 15 to 20 cents per kWh in certain markets. In this same time period, the cost of wind power has declined significantly.

Maintenance of Wind Turbines

The maintenance of wind turbines is always a concern- not only because of their growing remote locations, but the high cost and degree of difficulty in reaching the nacelle. *Orbit*, a technical publication produced and distributed by Bently Nevada, states: "…bearing and gear wear, if not caught in time, will often progress to more serious collateral damage affecting the other parts of the drivetrain and the generator. This necessitates far more costly repairs than simply replacing a bearing or gear at the end of

[1] California Energy Commission (CEC) *Energy Technology Status Report 1996*. Sacramento. All CEC estimates are in constant dollars as of 1993, with costs "levelized over a typical lifetime (usually 30 years) beginning in 2000". p. 57.

its useful life. When a $1,500 bearing fails unnoticed, it can lead to a $100,000 gearbox replacement, a $50,000 generator rewind, and a $70,000 crane to access the failed components (and even more expense if it is an offshore location)."[2]

Gearbox failures account for the largest amount of downtime, maintenance, and lost production capacity – usually totaling 15-20% of the price of the turbine. For these reasons, wind turbine and, more specifically, gearbox reliability is imperative. The gearbox generally has six or more gears and rolling element bearings that must have a well-designed lubrication protocol. Most gearbox failures are believed to be directly related to poor lubrication and lack of routine maintenance. The easiest way to prevent failures is by keeping the lubricating oil as contaminant-free as possible[3].

Factors that affect gear lubrication[4]:

Factor	Requirements
Gear Type	Number of teeth in contact and load carrying capacity
Gear Speed	The higher the speed of meshing gears, the higher the sliding/rolling of individual teeth, requiring low viscosity oils
Reduction Ratio	The number of reduction and ratios determine the speed differential between the low and high speed gears and its viscosity requirements
Operating Temperature	Oil viscosity must be selected considering the lowest starting temperature and maximum operating temperature
Transmitted Power	As load is increased, the viscosity of the lubricant must be increased to maintain the same oil films
Surface Finish	Rougher surfaces require thicker oil films to obtain complete separation. Smoother surfaces can be lubricated with lower viscosity oils
Load Characteristics	Excessive loads may rupture oil film, this condition generally requires the use of extreme pressure EP oils
Drive Type	Electric motors and turbines produce uniform torque and gear loading. Reciprocating engines produce variable torque
Application Method	Oil film formation may be less effective in splash systems and require higher viscosity oils.
Water Contamination	Determines the use of rust and oxidation inhibitors and demulsifying additives.
Lubricant Leakage	Special characteristics to resist leakage

With a trend in wind farms moving offshore so as to capture maximized wind speeds and therefore, run more efficiently, maintenance will increasingly become more difficult. This emphasizes the importance of proper gearbox lubrication. To date, very poor maintenance of wind turbine lubrication has been seen in the field. To combat this, the lubrication performance has been monitored and ways are being researched to improve the fluids.

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[2] Bauer, Richard. Clark, Timothy. Rasmussen, James. Orbit. Bently Nevada 2nd Qtr 2004, p.21-23, 26-27.
[3] Deirdra Barr, Ethyl Petroleum Additives Ltd., "Modern Wind Turbines: A Lubrication Challenge". *Machinery Lubrication* Magazine. September 2002
[4] Noria Corporation. *An Introduction to Machinery Lubrication, Contamination Control and Oil Analysis Best Practices*, 2003. (p. 179).

Another new and immediate solution to the lubrication dilemma in wind turbines is purification of the fluid. Removal of the contamination will reduce oxidation and gear wear and tear. It has been proven that small particles circulating in the fluid cause most of the contamination problems. Wear, oxidation, viscosity levels, and lubricant surface tension are all products of small particulate contamination.

Finding the Right Fit for Particle Removal

Oil filtration is an absolute necessity as a first step in protecting gearbox machinery. Filters, while good at removing medium and large sized particles, are not the answer for removing small particulates. The cost of a filtration system might seem attractive at first glance but the following problems result when small particles are not removed:

- Increased maintenance
- Turbine downtime
- Parts replacement
- Reduced oil quality
- Oil waste and removal

Water removal, air release, and sludge removal all remain costly issues when filtration is used alone, not to mention the man hours used in transportation to/from the turbine. Filtration will ultimately result in increased wind turbine maintenance that should be reduced or eliminated.

The same can be said for the use of electrostatic precipitators as another method of particle removal. This process involves charging all of the particles either negatively or positively, creating an unbalanced charge. A grounding plate with opposite polarity is then used to isolate particles from the system. Replacing and cleaning the grounding plate may also result in extra maintenance. Electrostatic precipitators also require high voltages (between 75,000 and 100,000) and have very low flow rates. A wind turbine operator would waste valuable maintenance time, resulting in an inefficient lubrication treatment.

Balanced Charge Purification

The seemingly ideal answer to minimal maintenance of wind turbine gearboxes is a patented technology called Balanced Charge Purification™ (BCP). ISOPur Fluid Technologies has developed a unique process that removes sub-micron contamination. BCP is the only technology to efficiently remove and prevent sludge buildup. Another added benefit of ISOPur purification is that the unit can be monitored remotely, as most wind turbine farms have their own local area network. This network allows for controls and other instrumentation systems to be linked together, as well as linked to a local or remote operation’s center. Weather and turbine location are no longer concerns for maintenance crews, thanks to remote monitoring. Created with control room operation in mind, the ISOPur system is equipped with SmartPak™, an easily programmable logic controller that provides the following:

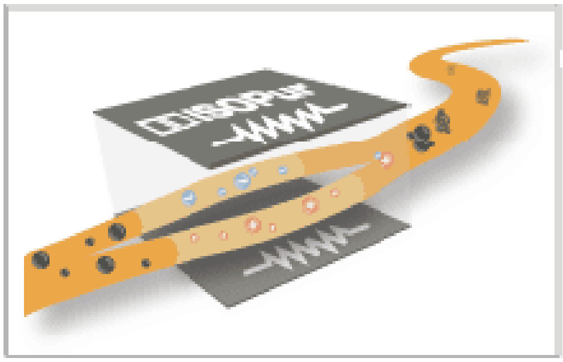
- Optimizes flow rate to changing fluid conditions
- Monitors fluid temperature
- Fluid pressure
- Fluid flow

Alarms and automatic reminders also help to alert wind turbine operators of unusual flow or pressure within the ISOPur system. This would streamline turbine maintenance, saving valuable time and money.

How BCP Works

The fluid is split into two streams and a positive and negative charge is placed on the contamination within the oil. Once a balanced charge is achieved, the opposite charges attract and the sub-micron particles agglomerate, making them easily removable with standard filtration (as shown in Figure 1).

Figure 1 Balanced Charge Purification (BCP)



The key to this process is separating the fluid into two streams and charging the particles with an equal amount of positive and negative charge to ensure that the overall system remains neutral. Details on this patented technology may be found in US Patent 5,788,827 published in 1998.

While particles are being charged, the lubricant base stocks and additives remain unaffected. Numerous case studies show consistent sludge and varnish removal from the internals of the machinery. This saves thousands of dollars in on-site maintenance resulting in a rapid return on investment.

ISOPur currently has begun testing in Europe with one of the largest manufacturers of wind turbines. With the results, ISOPur hopes to expand this money and fluid saving technology here in the United States in order to promote the advancement of wind power as a valuable, renewable energy source.

About the author: Gerald Munson is co-founder and chief technology officer at ISOPur Fluid Technologies, Inc. For additional information about ISOPur and its patented industrial fluid cleaning technology solutions visit www.isopurfluid.com, call toll-free at (888) 270-9889, or email info@isopurfluid.com. ISOPur is headquartered at 70 Inwood Road, Rocky Hill, CT 06067.