LUBRICATION OF WIND TURBINES IS ANYTHING BUT A BREEZE

Since antiquity, a wide cross-section of people around the globe successfully harnessed the remarkable renewable energy of the wind. Wind energy impelled boats down the iconic Nile River as far back as 5000 BCE. By 200 BCE rudimentary windmills in China were pumping water, while vertical–axis windmills with woven reed sails were grinding grain in Persia and in the Middle East. Many ancient cultures associated the element of air and, thereby, wind, with spirit. Thus, the Egyptian Goddess Isis was known as the controller of the winds and the "living north wind." For, although, these forces are invisible, they are palpable and powerful, and we are inextricably moved by their presence. Just as we breathe air to live, the wind animates a sail and puts it into nearly-miraculous motion.

Figure 1: Wind Energy (Source: U.S. News & World Report: 5 Graphs About Wind Energy, July 17, 2014)

The sheer sublimity of meteorological phenomenon has fascinated civilization for thousands of years. Ancient Greek mythology is an example of elements of weather being personified as deities. Today, while we view the wind through a more scientific lens, we are no less enamored of, and dependent upon, its awesome propulsive possibilities.

Before we focus on the state of wind turbines today, and examine their unique advantages and challenges, let's take a sail down memory lane and pinwheel back to the more recent history of wind energy: New modes of harnessing energy from the wind flowed around the globe. By the 11th Century, people in the Middle East employed windmills extensively for food production. Returning merchants and crusaders who were blown away by this idea then carried news of it back to Europe. The Dutch, the people who are, perhaps, most closely identified with the monolithic imagery of the mighty windmill, refined the device and adapted it for draining lakes and marshes in the Rhine River Delta. When settlers took this technology to the New World in the late 19th Century, they started using windmills to pump water for farms and ranches and later to generate electricity for residences and business.

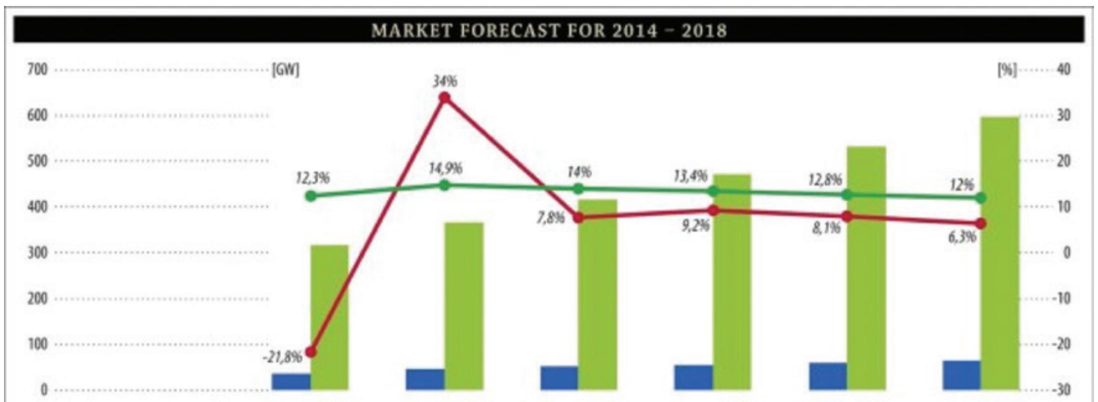
American colonists used windmills to grind wheat and corn, to pump water and to cut wood at sawmills. The nascent rise of electric power saw wind energy finding new applications in lighting buildings remotely from centrally generated power. Throughout the 20th Century, small wind plants, suitable for farms and residences, and larger utility-scale wind farms, that could be connected to electricity grids, were developed.

The oil shortages of the 1970s revamped the energy landscape for the U.S. and for the world at large. It fueled a demand for alternative energy sources, opening the floodgates for the reemergence of the wind turbine to produce electricity.

During the time period of 1974 through the mid-1980s, the U.S. government worked with industry to advance the technology and enable development and deployment of massive commercial wind turbines. Large-scale research wind turbines were developed under a program overseen by the National Aeronautics and Space Administration to create a utility-scale wind turbine industry in the United States. With funding from the National Science Foundation and later followed by monetary support from the U.S. Department of Energy, 13 experimental turbines were put into use utilizing four major wind turbine designs. This research and development program preceded several of the multi-megawatt turbine technologies active today. The monolithic wind turbines developed under the auspices of this program set several world records for diameter and power output.

Anemic oil prices threatened to render electricity from wind to be cost prohibitive in the 1980s and 1990s. However, thanks, in part, to federal and state tax incentives implemented in the 1980s, wind energy managed to thrive in California. These incentives

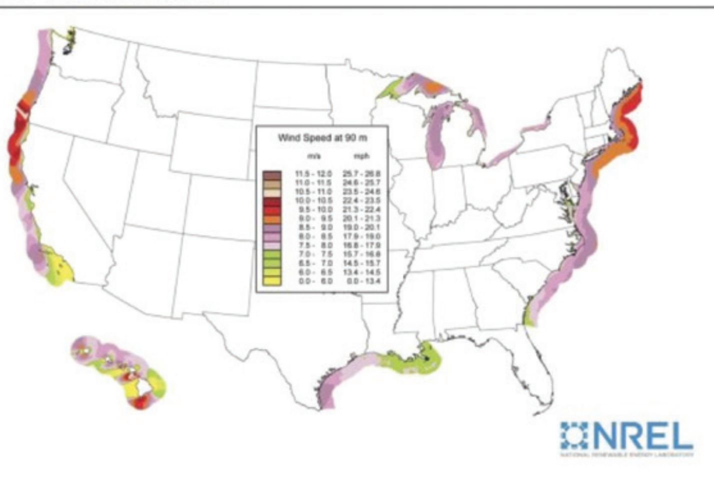
Figure 2: Isis The Goddess of Fertility (Source: Ask Aladdin: Your Egypt Travel Experts)



	2013	2014	2015	2016	2017	2018
Cumulative [GW]	318,1	365,4	416,4	472,1	532,3	596,3
Cumulative capacity growth rate [%]	12,3%	14,9%	14,0%	13,4%	12,8%	12,0%
Annual installed capacity ([GW]	35,3	47,3	51,0	55,7	60,2	64,0
Annual installed capacity growth rate [%]	-21,8%	34,0%	7,8%	9,2%	8,1%	6,3%

Source: GWEC

Figure 4.14 Offshore Wind Resources



Notes: • Data are annual average wind speed at 90 meters. • m/s = meters per second. • mph = miles per hour.

Web Page: For related information, see http://www.nrel.gov/gis/maps.html. Source: This map was created by the National Renewable Energy Laboratory for the Department of Energy (January 10, 2011).

bankrolled the premiere major use of wind power for utility electricity. Aggregated in commodious wind resource areas, these turbines would be considered inconsequential and economically undesirable by current wind farm development protocols.

Although, wind energy's expansion in the U.S. halted dramatically, after tax incentives were waived in the late 1980s, wind energy continued to flourish in Europe buttressed partially by a revival of environmental concerns in light of scientific studies alluding to the potentially deleterious impact on the global climate if the use of fossil fuels continued to escalate without compunction.

Wind-powered generators currently exist in a variety of size ranges: From small turbines, employed for battery charging at remote locations, to large, virtually-gigawatt-size offshore wind farms which power national electric transmission systems.

Wind turbine gearboxes being placed in desolate locales, at steep heights, and under harsh conditions are some of the major challenges that counterbalance wind power's many advantages. In addition, routine maintenance, such as compulsory gearbox oil changes to protect components from the corroding effects of micropitting and wear also requires substantial upkeep. In light of these dilemmas, sufficient equipment lubrication is mandatory, as it can aid in safeguarding system components, diminishing unscheduled downtime, cutting costs, prolonging oil drain intervals, and reducing risk of injury, or even fatality, through lessened human-to-machine interaction.

The diligent use of high quality synthetic lubricants is one of the key elements required to get the most out of wind turbine equipment. It should be kept in mind, when it comes to choosing which lubricant will be most appropriate, that one of the most overlooked aspects is finding a balanced formulation. Employing optimal base stocks and a customized additive package, which meets, or exceeds, the specified needs of the wind industry, such as aiding in life extension of oil in spite of difficult operation factors is a critical component to successful wind equipment reliability.

Case in point, a quotidian wind turbine lubricant will have an oil drain interval of three years, while a superior synthetic lubricant, orchestrated specifically for wind, can facilitate the longevity of those intervals even more dramatically. For instance, one Mobil synthetic lubricant derived especially for wind turbine gearbox and bearings has been demonstrated to increase oil drain intervals in turbine applications for as long as 7 years. For this reason, and for many more, lubricant formulation is the single most important ingredient to cogitate when choosing a lubricant.

In order to adequately parse the importance of a balanced constitution, it is necessary to consider a few salient equipment stumbling blocks that wind operators are grappling with today:

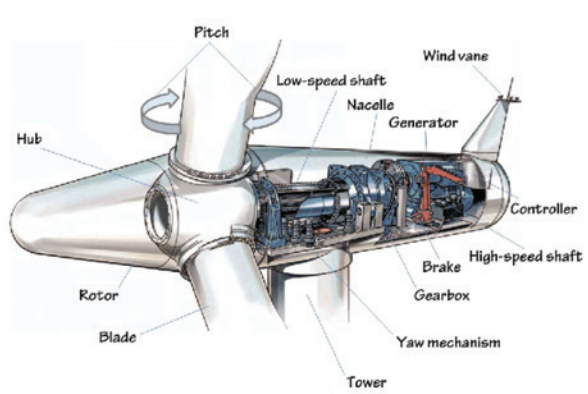
Firstly, let's consider a predictable stumbling block for wind turbine operators: micropitting. Micropitting can form on surface-hardened gears within the initial several hours of operation, should the gearbox not be adequately lubricated; thus, resulting in lessened gear tooth exactitude. To mollify this effect, operators should look for oils formulated with a micropitting additive package, like typical extreme pressure additives, in addition to employing a gear finish as specified by American Gear Manufacturers Association's AGMA 6006 standard. After which, an oil formulated with advanced base fluids, that offer a high viscosity index – typically 160 or higher – and lower traction coefficient, can also help. The higher viscosity index can provide a thicker lubricant film at operating temperature, and the lower traction coefficient can help improve energy efficiency.

Another factor which must be taken into account is water contamination; this can have a profound effect on wind turbine performance, most notably in offshore environments where water exposure is greatly increased. Water, when found in oil, can result in additive depletion, stable emulsions and higher viscosity. It can also cause equipment issues, like filter blockage and faster wear of system parts. Lubricants concocted with particular additives can help mollify the effects of these contaminants by strengthening the oil's defense against water contamination and also bettering its wet oil filterability.

Foaming is yet another wind turbine issue which must be tackled by operators. As foam bubbles up and crashes through a shaft seal, it leaks inside the nacelle (the generator and gearbox "shell" with rotator shaft on a horizontal axis wind turbine), creating a safety hazard for slippage. Furthermore, as foam forms on the surface of the oil, it may cause a problem with the oil level float switch, causing a faulty reading which could even set off an alarm. Also, if foam enters the oil circuit, a temporary decrease of oil pressure or flow can transpire, also engendering alarm. All these occurrences would likely result in costly loss of time which could have otherwise been avoided.

A wind energy system, as would be expected with any mechanical system, requires sufficiently-tailored lubrication to function optimally. Vibration, heavy mechanical loads, dampness and contamination are all hazards to bearing and gear service life. Wind turbines can also be difficult and exorbitant to service since they extend more than 100 meters off the ground in addition to being situated in remote locations. A possible solution to these predicaments is to implement an automatic lubrication system. Automatic lubrication systems, unlike manual ones, provide unctuousness more predictably and accurately to moving components in the nacelle. By delivering the most minimal, yet effective, dose of lubricant reliably to all friction points, while the machine is running, automatic lubrication systems decrease friction inside bearings and help to prevent contamination.

Diagram 2. The major components of a wind turbine

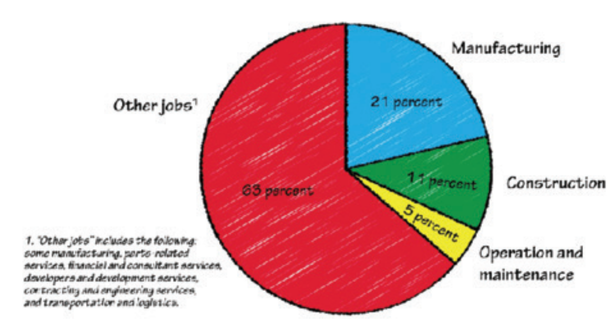


SOURCE: Center on Globalization, Governance, and Competitiveness, Duke University

Wind turbines have been used in one way or another for more than 7,000 years, and while that is unlikely to change any time soon, wind turbine lubrication exists at the far extreme of industrial gear applications in terms of temperature, load weights, bearing wear, maintenance, accessibility and basic lubricant performance. Increasingly, for offshore applications, synthetic and biodegradable fluids are being developed. Furthermore, turbine gear oil specifications are starting to mirror the demand for higher lubricant performance through testing for enhanced oxidation and corrosion resistance, as well as for greater bearing and long-range operational performance.

Despite wind power's obvious challenges including the following: High cost of initial investment; remote locations required; use of large amounts of land which could be better utilized; noise and aesthetic "pollution"; and possible damage to wildlife.Conversely, there are several advantages of this form of power. For example, land-based utility-scale wind is one of the lowest price energy sources available today, and wind creates jobs. In fact, the U.S. wind sector employed more than 100,000 workers in 2016, and wind turbine technician is one of the fastest-growing American jobs of the decade. Wind also enables U.S. industry growth and competitiveness. Wind is a clean fuel source since wind energy doesn't pollute the air. It is a domestic source of energy and sustainable, as well.

Chart 1. Jobs in wind power, 2009



SOURCE: American Wind Energy Association

Paradoxically, wind power harkens back to the dawn of civilization, yet still manages to be an intriguing growth-oriented and ever-evolving industry at the vanguard of renewable energy advancements. Developments of cutting-edge lubricants and maintenance strategies for this extreme application are making tremendous strides toward a new standard in gear and bearing lubrication, which may even one day blow away the competition in the sphere of alternate energy.

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