CRITICAL NATIONAL NEED IDEA

Alternative Energy Technologies

A Solution for the Critical

Technical and Manufacturing Challenges

Facing the Wind Power Industry

Submitted by:

REALLCo

Rockford Engineering Associates LLC

605 Fulton Ave.

Rockford, Il 61103

Office (815) 316 6377

Fax (815) 316 6379

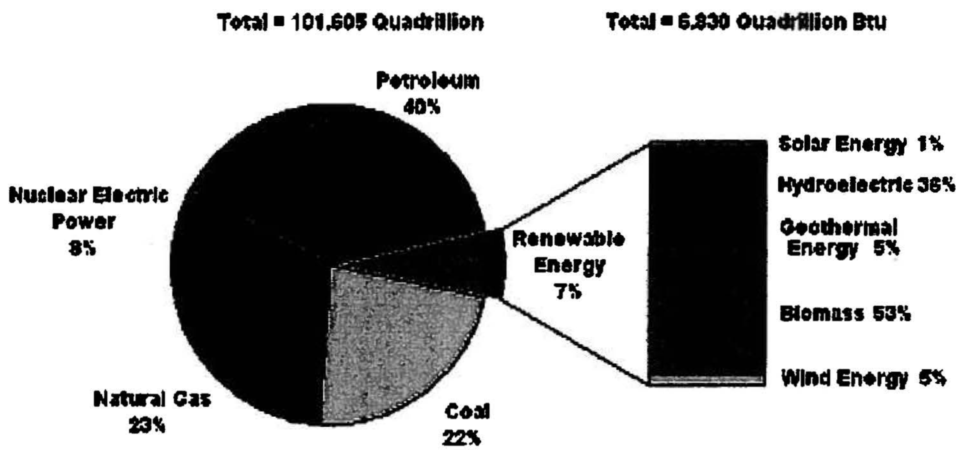
reallco@comcast.net

Contact:

Kanwar Singh

I. Overview

Arguably the most pressing problem faced today by American society is its near absolute dependence on fossil fuels. Renewable energy sources currently comprise only 7% of the energy consumed by the U.S. (See Figure 1). The remaining 93% of U.S. energy use is primarily coal, oil, natural gas and nuclear. The country is the world's largest consumer of oil, importing an estimated $700 B of oil each year. In addition to the economic impact, there are also serious environmental and foreign policy issues to be considered. However, the greatest impact is yet to come. Nearly all experts agree that recoverable oil reserves are declining and will continue to decline. The gap between production and consumption has significantly narrowed in the past decade as developing countries reach a level of industrialization where energy becomes the driving force in their economies. The result has been a steep rise in energy prices which is disrupting U.S. economy.



The Role of Renewable Energy Consumption in the Nation's Energy Supply, 2007

Figure 1

In recent years, within the U.S., a consensus has begun to develop for a national energy strategy. The most common version of this strategy is fundamentally focused on alleviating the country's dependence on foreign oil with a long term goal of eliminating most fossil fuels. It embraces the full range of existing energy technologies. This strategy ranges from increased drilling for fossil fuels within the country to conservation and includes a substantial investment in renewable energy sources such as wind,

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605 Fulton Ave.
Rockford Il 61103

nuclear and ethanol. These proven technologies can have a positive impact on the U.S. energy situation in the short term, say 5 to 10 years. Longer term technologies currently under development including cellulosic ethanol, solar, hydrogen and other bio-fuels offer solutions for the future.

Included in the short term focus are three renewable energy sources, wind, ethanol and biodiesel. In one sense these are mature technologies with well understood processes and an extensive installed base. However, viewing these technologies from an economic perspective raises serious questions about their long term viability. It can be argued that only with the support of government subsidies and tax incentives are these renewable energy sources economically viable. In the case of ethanol and biodiesel the "law of unintended consequences" has also played out with rising food prices as food competes with energy for agricultural production. However, wind power, one of the lowest cost renewable sources, is very likely to be a significant part of any national renewable energy program. Wind energy, with its global installed base of tens of thousands of turbines, should be economically viable and in theory should have an immediate impact on the U.S. energy equation. In fact, wind energy is also dependent on tax incentives and subsidies. Capital investment, manufacturing constraints and maintenance costs are today restraining this technology, preventing it from reaching its full potential.

The Renewable Electricity Production Tax Credit, a federal incentive, has encouraged a quadrupling of wind energy capacity over the past few years. This trend is continuing with current plans for the installation of over 2,000 new wind turbines throughout the country in 2009. Investors believe that the underlying wind turbine technology is well defined and proven by the thousands of existing installations throughout the world. Seven major companies currently produce wind turbines for the global market. However, there are underlying problems with scaling up production of wind power technology. This White Paper focuses on two critical problems that need to be addressed and offers ideas for developing solutions.

II. Wind Power Growth Restraints

This year the U.S. Department of Energy released a technical report called "20% Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply". Between now and 2030 wind power's contribution to the national energy mix must rise from its current 5% level to 20% to meet the objectives outlined in this report. This dramatic increase in wind power installations raises a number of economic, technical, environmental and manufacturing challenges. In this White Paper REALLCo has focused on two issues which it believes will have a significant impact on the growth plans of the wind power industry. The first problem is a manufacturing capacity problem which is rapidly becoming a recognized constraint on wind power growth. The second problem is a technical issue associated with existing wind turbine designs. It has become a major contributor to the rising cost of wind turbines and the capital required for wind power companies. In an interesting way, REALLCo believes that both problems are related.

A. Wind Turbine Manufacturing Capacity

While the critics complain about bird deaths, noise, and the impact on their views, there is a much larger barrier to wind power. Wind energy is becoming a victim of its own success. "The worldwide demand for wind energy equipment is outstripping supply," says John Dunlop, senior technical services engineer for the American Wind Energy Association (AWEA). Manufacturing lead times for turbines purchased today have moved out to 2011 or 2012. A large part of this demand is from the United States. The annual growth of wind energy in the U.S. was 29% for the 5 years ending in 2007 according to the AWEA. The real barriers to maintaining this growth are found in the engineering departments (turbine design issues are addressed in the next section of this White Paper) and on the factory floors of the turbine component manufacturers.

From a manufacturing perspective, wind turbine components have more in common with aerospace components than industrial ones. For example, wind turbine gear boxes are designed to be as light weight and compact as possible. Similar industrial gear boxes would be much heavier and more robust with a safety factor of at least 2.5 times the design specification. The light weight wind turbine gearboxes have very little safety margin and require very precise machining similar to aerospace components. Other major components such as the generator have similar machining requirements. These precision machining requirements demand that suppliers use high quality CNC machine tools, highest quality tools and the best manufacturing processes.

One of the key types of machines required for wind turbine component machining is the Vertical Turning Lathe (VTL), also sometimes known as a Vertical Turning Center. Modern VTL's are capable of both precision turning and in many cases, precision milling operations. This type of machine tool with its large horizontal rotary table is ideal for machining the hub and gearbox components along with other large heavy parts of the wind turbine drive train. With the increasing size of wind turbines, VTL's with a table diameter of 4 meters to 6 meters are required for these machining applications. Unfortunately there is a real shortage of these machines in the U.S. Over the past two decades, as U.S. companies outsourced work overseas, large numbers of big machine tools including VTL's were sold to China and other Asian manufacturers. We are now faced with a situation where the wind power industry is scrambling to find companies with the machining resources to meet its growing needs.

Today, there are approximately 20 companies producing VTL's. Only 3 of these companies produce very large VTL's (table size > 6 meters). Within the size range required for wind turbine components there are perhaps 6 major suppliers. All of these suppliers use a similar mechanical bearing system for the rotary table. Typically the large horizontal table has a large diameter ball bearing that serves as the main thrust bearing. The table rotates around a central heavy duty roller bearing. There are two basic problems with this design. First, the maintenance of this large diameter load carrying bearing has proven to be problematic for many VTL users. When loading large heavy parts there is always the possibility of dropping the part and damaging the bearing. The second problem is the availability of the bearings. The lead time for these critical bearings has pushed VTL deliveries to over 24 months. Interestingly, this situation is partly due to pressure on bearing manufacturers resulting from the huge volume of large bearings consumed by the wind power industry. However, the main issue with these large bearings is their size, custom design and relatively low volume. There is little economic incentive for bearing manufacturers to tool up to produce higher volumes of these bearings. As a result, lead times for large VTL's can be expected to remain very high for the foreseeable future. This means that machining capacity for wind turbine components will remain seriously constrained for the foreseeable future.

REALLCo believes that switching the rotary table design to a fluid bearing system will not only solve the long lead time problem associated with mechanical bearings but will provide a table with a far more robust capability. Fluid bearings can be manufactured by the VTL builders thus eliminating the long lead times required by commercial bearing manufacturers. In addition, a fluid bearing based table with no metal to metal contact will normally operate in an unforgiving environment for many years with minimal maintenance. It is well known that large rotary tables (6 meters and larger) are designed with fluid bearings since there are no mechanical bearings of sufficient size and capacity for these applications. So, why are the midsized VTL's (4 meters to 6 meters) still designed with mechanical bearings? REALLCo believes that there are three primary reasons VTL manufacturers stay with mechanical bearing designs:

a. <u>Engineering Knowledge</u> – Many of the companies that produce the midsize VTL's have little or no experience with fluid bearing designs. Designing high performance fluid bearing systems requires extensive engineering knowledge and manufacturing skills unique to fluid bearings. Most companies choose not to attempt this technology due to the high risk associated with designs and manufacturing processes not well known to their engineering departments.

b. Sealing – Many customers avoid fluid bearing systems because of leaks, contamination of the fluid, and contamination of the environment. Sealing is a major consideration when designing fluid bearing systems.

c. Manufacturing Expertise – The components used in fluid bearing systems have tight tolerance requirements. Manufacturing these components requires precision machining and unique manufacturing processes. Many machine tool companies and their suppliers lack the expertise to produce these components.

REALLCo believes that ramping up the production of large machine tools, especially VTL's, will be necessary if wind power is to continue to grow at the rate required to reach the 20% goal by 2030. To accomplish the rapid growth of this critical manufacturing capacity, we need to break the logjam in VTL production. The problems associated with fluid bearing systems, although difficult, need to be addressed. A fluid bearing rotary table design needs to be developed for midsized VTL's if there is to be a real improvement in the availability of this critical class of machine tools. REALLCo believes that developing this type of large bearing system will attract the interest of VTL manufacturers currently suffering with the lead time and reliability issues associated with their existing mechanical bearing designs.

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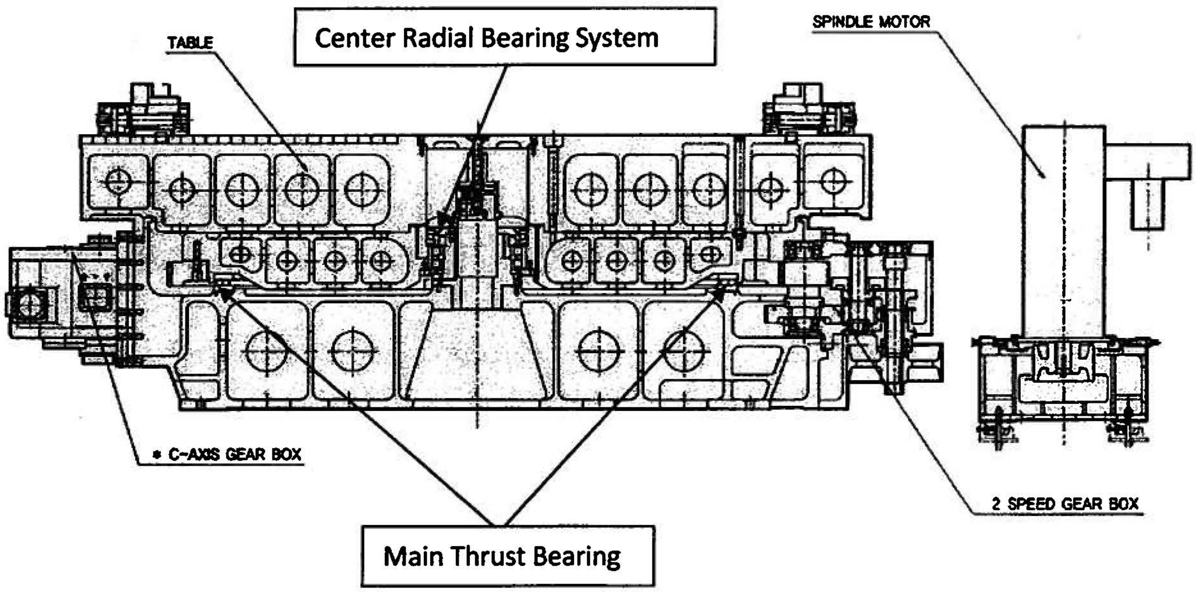
Rockford Il 61103

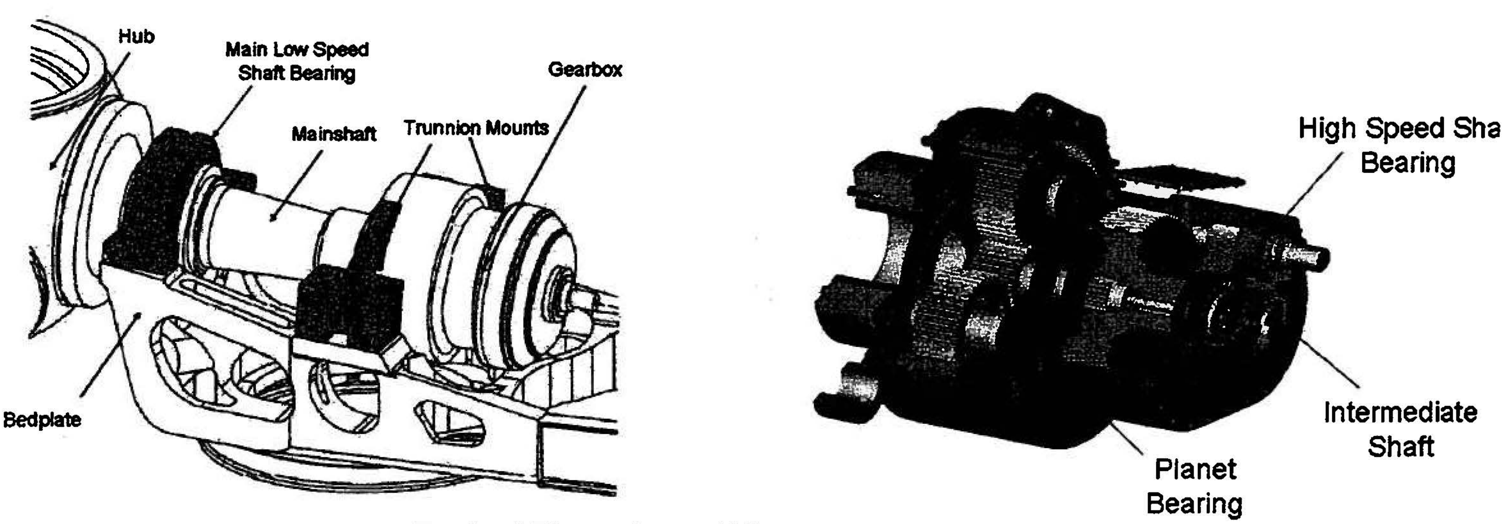


Typical VTL, Large Rotary Table and Table Bearing System

Figure 2

B. Wind Turbine Gearbox Reliability

A 2007 report by the National Renewable Energy Laboratory (NREL) identified very high gear box failure rates as a primary issue with modern wind turbines. A high gearbox failure rate has been experienced by the wind energy industry since its inception. Early gearbox designs were problematic due to design and manufacturing deficiencies. However, over time, wind turbine manufacturers working with bearing manufacturers, gear designers and lubrication experts improved the reliability of this key component. However, today the gearbox remains the most expensive component of the wind turbine system, largely because of its higher than expected failure rate. The NREL said that "The future uncertainty of gearbox life expectancy is contributing to the price escalation of wind turbines". As wind turbines have increased in size, gearbox reliability has continued to suffer. To some extent the problem has been masked by the OEM's warranty. As wind turbine warranties expire the problem becomes more apparent and a drain on the operator's resources. Not only are the replacement components costly, but the time and effort to repair or replace a gearbox located hundreds of feet above ground are quite expensive. Today, gearbox rebuilds are often a wind facility's most costly maintenance item.



Typical Three Stage Wind Turbine Gearbox

Figure 3

According to the NREL, a majority of wind turbine gearbox failures appear to begin in the bearing systems. Bearing reliability remains a problem, in spite of the fact that most gearboxes have been designed using the best bearing design practices available. The bearing problem is quite serious since bearing damage often leads to multiple gear failures dramatically escalating the repair cost. According to the NREL, the wind industry has reached a point where the best design practices for gear boxes still do not result in sufficient life for wind turbines to be an economical source of electricity.

The NREL has chosen to attack the bearing problem by initiating the Gearbox Reliability Collaborative. This collaboration of gearbox supply chain companies is focused on investigating the design level root causes of gearbox failures. The objective is to find design and manufacturing solutions that will lead to higher gearbox reliability. It is hoped that suppliers, who often use proprietary design information, will cooperate to identify the underlying failure modes of the overall design.

However, throughout the history of wind turbine gearbox design there is evidence of a basic design issue. Engineers have consistently been unable to predict the variable loads that wind places on the bearings and gears. The new larger turbines have amplified the problem. Their very large blades produce massive torque loads through the typical three stage gearbox. In attempt to accommodate these torque requirements manufacturers have developed huge costly ring gears and large diameter roller bearings. Associated with these mechanical systems are complex lubrication systems. REALLCo believes that a fresh approach to the bearing problem is needed. Rather than continuing with large complex designs based on mechanical bearings, REALLCo believes that the wind industry should consider the use of fluid bearings.

Over the years, the machine tool industry has applied fluid bearing technology to applications where enormous loads and torques are applied to both linear motion and rotating systems. Fluid bearings have certain inherent characteristics that are uniquely suited to wind turbine gearboxes.

a. Load – Fluid bearings are well suited to applications with extremely high loads, both static and dynamic loads. They can easily accommodate the large variable loads that are common in wind turbine drive systems. With certain types of fluid bearing systems a bearing with virtually infinite stiffness can be produced..

b. Wear – With no metal to metal contact, there is essentially no wear in a fluid bearing system. Not only is this a benefit for bearing life but it also eliminates the possibility of debris from bearing wear entering the gears causing additional wear or damage.

c. Damping – Fluid bearing systems are highly damped which can mitigate vibration that might be introduced into a gear system. Vibration resulting from blade flutter or minor unbalanced conditions can be suppressed by a properly designed fluid bearing system.

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As with any advanced technology there are also significant challenges:

a. Fluid Bearing Power Supply – Fluid bearings require a power unit to provide pressurized fluid (typically 800psi to 1000 psi) to the bearing pads. Typically the power unit consists of an electric motor, pump and oil reservoir.

b. Seals - Fluid bearing systems must be sealed to contain the bearing fluid and to prevent contaminates from entering the fluid. In addition to seals, some fluid bearing systems utilize a suction pump to remove the fluid from the bearing.

REALLCo believes that technology can be developed to address both areas for a wind turbine environment. Existing gearbox designs generally have sophisticated lubrication systems. Many of these systems use pressurized oil requiring a pump and oil reservoir of 60 gallons or more and are similar in some respects to the power unit required for a fluid bearing system. Although there are significant problems associated with the development of a fluid power supply for the wind turbine environment, REALLCo believes it is possible to develop an effective and reliable solution.

There are also a number of challenges associated with the development of the fluid bearing systems required to support the gearbox main shaft and the drive shaft. The fluid bearing system must have sufficient stiffness to accommodate the large and variable loads produced by the blades. Ideally, the fluid bearing design should fit within the constraints of existing gearboxes and should not impact existing nacelle designs. REALLCo believes that it can produce bearing designs that will meet these objectives.

Sealing this type of bearing system has always been a challenge for designers. In the wind turbine environment it is particularly important that an effective seal system be developed. The bearings must operate for long periods of time with only minimal maintenance and therefore cannot allow any fluid leakage. Also of concern is contamination of the environment. There can be no leakage of the bearing fluid into the environment. REALLCo believes that there are innovative solutions to the seal issue that can meet the requirements of fluid bearing applications for wind turbines. REALLCo has a new approach to this problem that can meet these goals.

It is unlikely that the wind power industry will develop a fluid bearing system given the limited knowledge of this technology within its engineering community. Throughout the history of wind turbine gearbox design the focus has never changed. Even with all of the aforementioned problems, the wind industry has continued to pursue a mechanical bearing solution. However, even with the most modern bearing technology, gear design and lubrication technology, gear box reliability still does not meet the industry requirements. In spite of this fact, the industry has maintained its single minded focus on a mechanical bearing solution.

III. Justification for Government Attention

Wind energy is one of the lowest cost renewable energy sources and has the greatest potential for changing the U.S. energy equation in the short term. With government backing, the industry is targeting a 20% share of U.S. energy consumption by 2030. However, even with strong financial support and government incentives, it is unlikely this goal will be reached. As outlined in this White Paper, there are two primary issues blocking this growth. Interestingly, REALLCo believes both can be solved by the same technology. Using the fluid bearing technology proposed in this paper, the logjam in VTL production can be broken and the wind turbine gearbox reliability problem resolved. REALLCo has on its staff some of the country's leading fluid bearing designers. They are quite confident that the problems identified in this White Paper can be successfully addressed using fluid bearing technology.

REALLCo believes that government funding and support are needed to overcome the challenges outlined in this White Paper. The manufacturing capacity problem (resulting from the long lead times associated with VTL production) and the wind turbine bearing reliability problem both are constrained by similar problems. Although fluid bearing technology could solve both problems, there is a serious lack of engineering knowledge within these industries when considering this technology. Their engineers often are unaware of the potential of fluid bearing technology or are reluctant to utilize the technology due to their limited knowledge of its requirements. Similarly, management is reluctant to embrace a difficult technology due to its perceived risk and development costs. Companies with fluid bearing expertise (primarily smaller companies like REALLCo) are not directly associated with wind energy. They have little incentive to spend their limited resources to develop fluid bearing technology specific to wind energy applications. What both the VTL and wind power industries require is a demonstration of how fluid bearing technology can be applied to their critical needs. A demonstration of the technology for their specific applications along with supporting engineering data can be expected to have a profound impact on their product design decisions.

Without direct government support, it is doubtful either the end-user or the technology suppliers will take the initiative to develop fluid bearing applications for the challenges outlined in this White Paper. As a result, the wind power industry will likely continue to struggle to meet the goals outlined in the U.S. Department of Energy report.

Manufacturing capacity can be expected to constrain the industry's ability to produce wind turbines. Lead times for turbine production of three years will continue to be the norm and may even increase as more countries turn to wind power for short term solutions to their renewable energy needs. Gearbox reliability, although significantly improved from early designs, has resisted the wind industry's best efforts to reach an economically viable design. As a result, turbine costs have remained high and maintenance costs are limiting the profitability of wind power. Without continued government incentives, private investment in wind power will become problematic.

REALLCo believes that, with government support, fluid bearing technology can be developed and applied to these critical challenges facing the wind power industry.

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