Challenges & Rewards for Engineers in Wind

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Notwithstanding the sluggish pace of the economic recovery and the cost of nearly everything seemingly on the rise, renewable energy production continues to be an important sector of the global economy. The adverse consequences of climate change, together with the shared global reality of governments, businesses, and individuals feeling a collective pain at the pump due to high oil prices, are spurring society to find ways to reduce fossil fuel consumption and develop alternative energy sources. While advances in traditional and alternative energy production are occurring, large utility scale wind energy is currently the most viable renewable solution available. Today, engineers looking to make an impact in the world need look no further than the challenges and rewards facing the wind energy sector.

There are many advantages that wind brings to the energy mix. For one, wind turbines do not produce combustion byproducts and can generate electricity for comparatively low costs, in many cases comparable to some of the lowest cost traditional methods such as natural gas fired combined cycle power plants. Some additional advantages for large utility scale wind energy include revitalization of rural communities, fewer government subsidies, free fuel, price stability, cost effective electricity production, and significant job creation. Wind energy projects create new short- and long-term jobs. Employment includes developers, surveyors, meteorologists, structural engineers, assembly workers, lawyers, bankers, and technicians to name just a few. Per unit of electricity generated, wind creates nearly 1/3 more jobs than a coal plant and nearly 2/3 more than a nuclear power plant.

Wind energy can diversify the economies of rural communities, adding to the tax base and providing new income. All energy systems are subsidized, and wind is no exception. However, wind receives considerably less than other forms of energy. The Government Accountability Office determined that fossil fuels received nearly five times as much in tax incentives as renewable energy did between fiscal years 2002–2007, with \$13.7 billion going to fossil fuels compared to \$2.8 billion for renewables.[1]

Unlike other forms of electrical generation, wind generates electricity at the source of fuel. Wind does not need to be mined or transported, removing expensive elements from energy costs. The cost of wind-generated electricity has fallen from nearly 40¢ per kWh in the early 1980s to 2.5-6¢ per kWh today depending on wind speed and project size.

Modern land based utility scale wind turbines are in the 1.5-3.0 MW range. They consist of large structures designed to handle extremely high loads, and unusually high fatigue cycles. They must also operate over a wide range of environmental conditions, have a low maintenance requirement, and most importantly – they must be low cost. Comparison of the estimated cost of a helicopter and wind turbine blade highlights the difference in cost requirements; helicopter blades are about \$1000 per pound compared to \$5 to \$20 for a wind turbine blade.

A model by Electric Power Research Institute, Technical Advisory Group (EPRI – TAG), is commonly used to calculate cost of energy (CoE) of utility scale wind turbines.

$$\text{Cost of Energy} = \frac{\text{FCR} \star \text{Cost}_{\text{Capital}}}{\text{Annual Energy Production}} + \text{Cost}_{\text{O\&M}}$$

Where: FCR = Fixed charge rate, $\text{Cost}_{\text{Capital}}$ = Total capital cost of the project, and $\text{Cost}_{\text{O\&M}}$ = Operations and maintenance cost per unit of energy.

From this relationship, FCR, Capital Cost, and O&M must be as low as possible, and at the same time the AEP should be as high as possible. Using 9% cost of money and assuming installed 2.5MW turbine example levels of Capital Cost, O&M, and AEP of \$1.43M/MW, \$25/MWh, and 8300 MWh respectively, the resulting CoE is about \$64/MWh. If this example turbine was in an area where retail electricity cost consumers \$80-90/MWh, the wind turbine owner would stand to make a healthy profit, even without government subsidies.

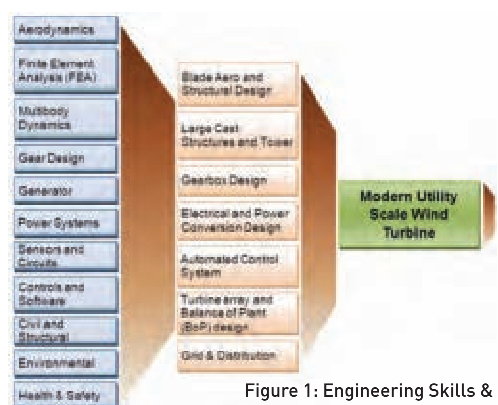

Figure 1: Engineering Skills & Wind Turbine Design

Many opponents of wind energy try to point to the intermittency of wind and the need to provide backup power or storage. Fortunately, with a holistic systems level view of the grid, this argument doesn't stand up. In fact, large and abrupt changes in demand for electricity can and do adversely affect the output of conventional electric generation sources – such as grid operators facing the sudden loss of a large power plant – whereas wind output changes are typically more gradual and predictable. This is easily understood by thinking of the continuous parade of storm fronts day to day, moving generally west to east in many regions, with wind plant after wind plant in the path of these storms taking their turn to spin up and generate electricity.

Designing and maintaining a wind turbine is a challenging task, requiring close interaction between engineers of many different disciplines. The fundamental challenge in designing a wind turbine is for it to operate reliably and safely for twenty years or more; produce as much power as possible, and with the lowest possible initial and life cycle costs.

Wind turbines are often referred to as three blades on a stick. "I can understand why engineers have that perception. The reason is usually a lack of understanding of complexities and challenges involved in wind turbine design" says Clipper's Sandeep Gupta. He relates this perception to this own personal experience. "As an engineer with aerospace background, I was in the same boat once. When I joined the University of Maryland for my doctorate program, my advisor offered me a research project on wind turbine aerodynamics. My first reaction was disappointment. However, I decided to give it a shot and that was one of the best decisions I ever made. As I got to understand the complexities of wind turbine technology and the challenges involved, I fell more and more in love with the technology."

Figure 1 shows major components of a wind turbine design and the associated engineering skills required. As can be seen, the engineering skills required cover a wide range of engineering disciplines, including mechanical, electrical, aeronautical, civil, controls and software, to name just a few.

If we begin considering a wind turbine from the ground up, we start with the turbine foundation. Wind turbines are exposed to massive over turning moments, requiring a well designed foundation, containing thousands of yards of concrete and hundreds of tons of steel. Figure 2 shows a few of these design considerations.

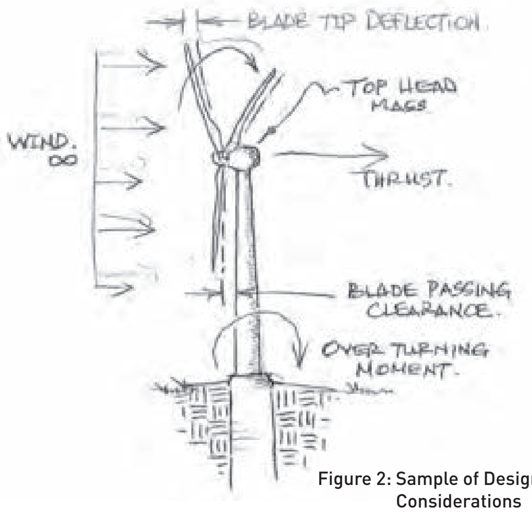

Figure 2: Sample of Design Considerations

The tower, which transmits the turbine loads to the foundation, must meet the extreme loads and fatigue life requirements of the turbine, as well as stability requirements. The tower comprises a large portion of the cost of the wind turbine due to the large amount of steel required for fabrication, and due to the high costs required to transport the tower to the site. These costs are driving innovation in wind turbine towers, which have evolved from lattice type construction in the early days of wind, to the tubular steel construction which is most common today. Examples of newer tower technologies include concrete pre-tensioned segments; lattice towers with architectural covers, which lower transportation costs; towers with vibration damping systems that increase the fatigue life of the tower and reduce materials costs; and self-erecting tower technologies to reduce construction costs. Towers are also growing taller to access higher speed wind, which will require additional innovation in order to meet the load carrying and life requirements while not increasing CoE.

As we continue to move up the turbine, we come to the bedplate, typically a ductile iron casting that supports the turbine drivetrain and rotor. The bedplate is also exposed to large extreme loads and to a challenging fatigue load environment, and often must be relatively stiff to ensure the correct alignment of drivetrain components. The bedplate supports the drivetrain, which typically consists of a gearbox and a generator.

The purpose of the gearbox is to increase the speed at which the generator turns in order to reduce the cost of the generator. It is here that we begin to see the collaboration required between the mechanical engineers who design the gearbox and the electrical engineers who design the generator, as the design of each component affects the other. The higher the gearbox ratio, the higher the cost of the gearbox (with lower the reliability due to increased part count) and lower the cost of the generator.

The challenge for the design team is to produce a drivetrain system that has the lowest overall costs and highest reliability, and to recognize the effect that each component has on the balance of the system. Wind turbine drivetrain reliability has been an issue in the past, and is spurring a large amount of innovation in drivetrain topologies. Some of the latest drivetrain technologies include direct drive generators, low speed generators with a simple gearbox (a compromise between current high speed technology and direct drive technology) and hydraulic speed increasers as an alternative to a gearbox.

From the drivetrain, we move to the rotor blades, the most visible part of the turbine, and perhaps the component requiring the most interaction between engineering disciplines. A rotor blade must be as efficient as possible, quiet, and relatively insensitive to fouling from insects and dust. It must have at least a 20 year fatigue life, withstand hurricane force winds and lightning strikes, and have sufficient stiffness to avoid striking the tower under any operating condition.

Meeting these requirements requires the participation of aerodynamicists, structural analysts, materials engineers, process engineers, and controls engineers, each of whose design decisions affect those of other members of the rotor, turbine, and Wind Power Plant (WPP) design teams.

A formal coursework in wind turbine engineering in the United States has been relatively scarce until recently. University of Massachusetts, Amherst has a long history of providing formal education in wind energy. In addition to this, Texas Tech University, University of Colorado at Boulder and University of California, Davis also offer focused programs for wind energy research. With the increase in funding for basic research in wind energy and the rapid growth of wind energy, the last few years have seen a substantial increase in the number of universities offering courses focused on wind energy, making it easier for engineers to meet the challenges and reap the rewards in wind.

The growth of large utility scale wind power is fast paced and generating unprecedented demand for engineers and technicians. For those heeding the call – The technical challenges and rewards are second to none. ✻

References

1. "Federal Electricity Subsidies: Information on Research Funding, Tax Expenditures, and Other Activities That Support Electricity Production," *GAO*, October 26, 2007.

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Welcome to San Antonio!

As the 7th largest city in the United States, San Antonio, Texas, has much to offer! From affordability to food and fun, San Antonio promises to be an exciting location for Turbo Expo 2013. The city was recently named to the "Top 10 Budget Destinations for 2012" (*Budget Travel,* Dec. 2011) as well as "America's Best Cities for Foodies" (*Travel & Leisure,* Sept. 2011) for its barbecue.

In addition, *Forbes* magazine also listed San Antonio among "America's Best Downtowns": "The city is more than just home to one of the most famous historical sites in the West [the Alamo]. The San Antonio River Walk is perhaps the most beautiful part of the city, creating a verdant pathway lined with colorful café umbrellas that winds its way through downtown, offering up a bevy of shops, restaurants, and bars on the way." (October 2011)

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