Outside the Box
highlighting the out-of-the-ordinary within the realm of structural engineering

More Wind Power Requires Taller Towers – Taller Towers Require Innovation…

By Peder Hansen

Maximizing tower height is very important for the wind power industry. One major reason is a phenomenon called wind shear, sometimes referred to as wind gradient, which is a difference in wind speed over a relatively short distance in the atmosphere. As the wind blows across the landscape, it is slowed down by trees and buildings. As altitude increases, wind speed increases and turbulence decreases above the boundary layer close to the ground. This effect is especially pronounced in the Midwestern part of the US.

By installing turbines on taller towers, potential power output from a wind turbine increases. The difference in wind speed from 80 to 100 meters is roughly 8%, resulting in a typical 15% energy increase; this is without any additional turbine grid interconnection cost. The typical extra cost by going from an 80-meter conventional tower to a 100-meter tower is roughly $300,000 (depending on wind turbine size), including delivery (500 miles) and pre-assembly. Using typical power purchase agreement (PPA) numbers, this extra cost is paid back in about four years of operation.

Can Wind Turbines Get Any Bigger?

Yes! But it requires innovation. What is obvious is that wind turbines continue their evolutionary path. These larger and more efficient turbines increase the demands on materials. Starting a few years ago, towers with hub heights of 80 meters and turbines with capacities greater than 2 MW were becoming the rule, not the exception. There has been an influx of market demand for larger units, and that trend seems likely to continue for the foreseeable future.

The hub height of the turbines is a significant factor in terms of power production. Lower wind speed sites are currently being reconsidered, as many prime wind locations have already been developed. As typical turbine capacities inch closer to the 3 MW mark, rotor diameters get close to and above 100 meters; turbines will continue to increase demands on towers as well.

There are two options for managing loads from these massive turbines. The first is to increase the wall thickness of the structure, and the second is to increase the bottom diameter of the tower, thus enabling a continuous or increasing taper towards the foundation. Option one is used almost exclusively at the moment because transportation restrictions dictate the maximum diameter allowed.

As the requirement for larger turbines increases and the market demands more of them, there is an urgent need for an up-scaling of innovation, manufacturing capacity, trucking capability, and handling methods. With bottom diameters reaching 14.5 feet and weights exceeding 100,000 pounds, towers have reached the limits of all transportation restrictions and a multitude of permits are needed to move them over the road.

The Challenge

What is the best way to develop a structure similar to a conventional, round, painted tower while at the same time reducing the weight and allowing for taller hub heights and increased bottom diameters?

Northstar Wind Towers' (NWT) engineering team was tasked with developing a tower system that can efficiently handle the ever-increasing loads induced by expanding rotor sizes and multi-megawatt turbines. Another key development requirement was to increase safety margins by incorporating an added level of redundancy into the tower connection design. Other objectives included lowering installed tower costs by 10 to 15%, and enabling automated manufacturing and painting processes.

The Solution

Towers with a continuous taper or an increasing taper are, by design, the most efficient way to handle wind turbine loads. A modular, field-assembled panel eliminates the transportation restrictions and therefore allows for a much more efficient tower design. Panels can be added to increase the tower diameter and height. The increase in diameter allows for thinner walls – the result is a more efficient use of steel.

Segmented flanges at the tower top and base allow for a conventional interface with the turbine and foundation. The bottom flange is modeled using the same mounting criteria as on conventional towers. The bottom diameter, however, creates new options for the foundation design. It is now possible to make foundations wider, which results in less depth.

100 meter tower.

This also eliminates the need for costly embedment rings often used within the foundation to distribute the load from the turbine.

Another common area of concern is the dimensioning and manufacturing of the door area. In relatively narrow towers, the door takes up a larger percentage of the overall diameter, thus requiring substantial and costly reinforcement of the door frame. The larger diameter tower has a larger area at the base, and therefore the door makes up a smaller portion, keeping more steel in the critical load path.

Modular towers must be reassembled before erection. Rather than trying to design a new fastening system or connection method for these segments, Northstar Wind Towers' engineers went searching for connection styles used in other cyclically loaded structures. They also studied various methods used in the previous generation of wind turbine towers. It became apparent that a connection method that excluded the load passing through the bolt is the most optimal. These types of connections are collectively called slip-critical or "friction" connections. As STRUCTURE readers probably know, friction connections are tried-and-true and are in use in bridges as well as high-rise buildings where post-inspection is limited. This method has also been used in multiple wind turbine towers over the years.

Panel construction, combined with bolted slip-critical connections, reduces the amount of welding needed by an average of 85 to 90%, as compared to an equivalent conventional tubular tower. This in turn reduces manufacturing time and cost further. An added benefit of using a turn-of-the-nut fastening system is that calibration of tension tools is no longer required, as this method is not based on torque. This reduces risk related to installation error and enables a relatively short turnaround on section pre-assembly.

The modular tower is still roll-formed and painted like tubular towers, only on a modular scale. Once installed, the tower is similar from a visual point of view to a conventional tubular tower. The modularity of the design, and the relatively smaller size of individual components, enables a paint system that utilizes state-of-the-art, in-line, automated material preparation and paint application.

Transportation

The increasing demands on shipping companies that are able to haul traditional towers have placed a growth constraint on the industry. By contrast, tower modules can be transported on standard trailers. The lower tower sections are bolted together in the field. Top sections are shipped pre-assembled and do not require additional field attention. The average to-site cost of the modular tower is just 25 to 35% that of a comparable tubular tower shipped the same distance.

Market Acceptance

It is obviously not advantageous to have the tallest and least expensive tower if no one wants to buy and use it in their wind developments. It has therefore been important to ensure the complete cooperation of the major turbine manufacturers. First, the concept was introduced to manufacturers through several Q&A meetings to understand their concerns, wants, and needs for tower design. Detailed load information for specific turbine designs were procured. After matching their frequency, fatigue, and buckling criteria, as well as obtaining a third party design certification, the next step was to introduce the findings to their respective commercial teams.

In Q4 2010, Northstar plans to erect a 23 meter prototype tower near their headquarters in Blair, Nebraska, showcasing the manufacturing, transportation and construction features

NWT standard trailer loaded.

of their design. They are in the process of securing agreements to install a fully operational 100 meter demonstration tower planned for the summer of 2011 and the company anticipates full scale tower production beginning in 2012.

Future

Today, modular 80-meter towers are competitive with current welded towers. However, it is the promise of going even higher that is really exciting. Partnering with key wind turbine manufacturers, work is continuing to bring the standard hub height above 110 meters cost-effectively, while keeping all modules within standard transportation dimensions.▪

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