Wind Turbine Towers Establish New Height Standard and Reduce Cost of Wind Energy

Challenge

Wind energy is an important part of the global push for clean, renewable energy alternatives. Over the past fifteen years, the wind industry has successfully reduced the cost of wind-produced electricity by, among other advances, increasing turbine capacities from 0.2 Megawatts (MW) to 2 MW+. At the same time, towers have increased in height from 65 meters (m) to today's mammoth 80m towers that can weigh as much as 225 tons. Taller towers are desirable because winds are stronger at higher altitudes, thereby producing more power for each turbine installed. However, tower height stalled at 80m due to unacceptable economics with taller tubular towers. The opportunity to achieve 12% more power output per installed-turbine could not be realized without addressing these key height issues:

- Weight scalability with height: There are greater overall forces acting on a 100m tall tower compared to an 80m tower, just as there would be on a taller vs. shorter building structure. Conventional tubular-steel towers combat these forces by adding lots of steel mass to increase stiffness. As a result, the cost of steel towers grows exponentially with tower height, making taller towers economically impractical.
- Transportation limitations: The cost of transporting large, tubular-steel wind towers is high. The towers come in four sections with the heaviest weighing over 50 tons. Highly specialized $500,000 trailers are needed to move each section, which makes the resulting tower transport costs $140 to $180 per mile.
- Construction challenges: Due to the immense weight of steel tube towers, ultra-large crawler-cranes are required to install the towers and turbines. The 600-1,000 ton cranes needed to erect turbines at 100m height are in scarce supply and exceedingly expensive. The high "mobilization/demobilization" cost for the largest cranes is a key inhibitor of smaller, community wind projects, and a recurring problem for wind turbine heavy maintenance operations. Finally, the excessive 32-foot wide roads-footprint required by large crawlers engenders significant community opposition in many areas due to the amount of woodland clear-cutting required.

Innovating Solutions

A DOE EERE SBIR Phase I grant received in 2002 enabled Wind Tower Systems (WTS) to run thousands of computerized optimization routines to analyze a 1.5 MW turbine at tower heights of 62.5m, 80m, and 100m. The following year, WTS received a Phase II grant to explore new tower designs that would be height-scalable, less expensive, and more easily deployed than tubular-steel towers. Initially exploring the possibility of a lightweight, all-composite tower, WTS' research and development (R&D) efforts eventually led to a modular, steel tower design that is lighter than a tubular steel tower, more transportable, scales linearly in cost vs. height, and features an integrated crane-free lifting system.

Initial research showed that, while a composite tower would reduce weight, it would not be able to achieve the required stiffness levels and thus would be subject to unacceptable resonance oscillation forces. The company applied its learning and adapted the composite design to a highly innovative steel Space Frame structure that achieved all of the design objectives.

The final Space Frame design is the most weight- and cost-effective tower design on the market, scaling to 100 meters in a linear cost relationship. Notably, the 100m tower with integrated lifting systems carries the same lifetime installed cost as today's 80m tubular/crawler crane solutions, thereby lowering the cost of wind energy by up to 12%. The current tower and lifting systems designs are applicable to turbines up to 3 MW nameplate capacity (i.e., the maximum rated output).

DOE Small Business Innovation Research (SBIR) support enabled Wind Tower Systems to develop the Space Frame tower, a new concept for wind turbine towers. Instead of a solid steel tube, the Space Frame tower consists of a highly optimized design of five custom-shaped legs and interlaced steel struts. With this design, Space Frame towers can support turbines at greater heights, yet weigh and cost less than traditional steel tube towers.

Wind Tower Systems LLC (now Wasatch Wind LLC) was founded in Heber City, Utah, in 2002 to research, develop, and commercialize lighter-weight, taller, readily-deployable modular wind turbine towers for utility-scale, multi-megawatt turbines. The company provides innovative, taller wind turbine towers and crawler crane-free installation systems, enabling wind energy projects to reduce electricity cost and execution risks.

www.wasatchwind.com

A case study from the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy SBIR program, providing competitive grants for scientific excellence and technological innovation to advance critical American priorities and build a strong national economy – one small business at a time.

Taller Tower Breakthrough for Large Wind Turbines

The Space Frame design opens new heights and locations to wind energy by significantly reducing the costs associated with manufacturing, transporting, and installing the towers, both on land and offshore. Tower cost is reduced because the Space Frame cost grows linearly with height rather than exponentially as with steel tube towers. The Space Frame structure is covered with a non-structural, architectural fabric that mimics the aesthetics of tubular towers and addresses concerns over avian perching and mortality. Transportation cost is reduced because the modular Space Frame tower ships on standard flatbed trucks, eliminating the need for expensive transportation permits and shipping carriers.

To address construction challenges, WTS developed a crane-free wind tower erection system. Inspired by the process used to erect broadcast towers, the WTS system employs an integrated tower-climbing "gin-pole" device to erect the tower sections, and a tower-top mounted Hi-Jack lifting frame for raising the heavy turbine nacelle and rotor components. The company's system removes tower height limitations imposed by crane height and reduces wind farm construction expenses. As a result, the system enables smaller community wind projects and is very attractive for projects in less-developed nations.

WTS has filed multiple patents globally covering the design of specific system components and processes. The firm's wind farm development division is leveraging opportunities enabled by the technology to build wind farms in areas where competition is low and returns for investors are high. These sites include ridge tops, developing countries, and remote locations such as islands.

SBIR Impacts

Potential Benefits of the WTS Space Frame Towers vs. Conventional Steel Towers (per tower)[1]

Energy	Increased energy generation due to taller tower	10%
Economic	Reduced cost of energy	12%
	Reduced cost of installation	$164,000

Potential Benefits of Wind Power vs. Conventional Electricity Generation[2]

Environmental	SO_X emission offset from a 1.5 MW wind turbine	8 million lbs/year
	NO_X emission offset from a 1.5 MW wind turbine	23 million lbs/year
	CO_2 emission offset from a 1.5 MW wind turbine	11 million lbs/year

Innovation

The Space Frame Tower and Hi-Jack Systems increase the attractiveness of wind power by:

- reducing tower weight by 30–50% compared to conventional tubular-steel towers
- reducing wind project developers' cost of building wind farms by 3% to 5% for the same size installation
- reducing transportation and construction risks via non-specialized transportation and elimination of crawler cranes
- taking advantage of the stronger winds available at 100 meters height
- enabling economical development of small and hard-to-access wind sites

Company Success

SBIR funding was critical for WTS' proof-of-concept work, invention, and development of the Space Frame Tower and, subsequently, the Hi-Jack Lifting System. Design flexibility afforded by the DOE's SBIR grant set it apart from similar programs—the project had to take a new direction when WTS discovered that the initial design for an all-composite tower was too costly.

Wasatch Wind is commercializing the Space Frame Tower and Hi-Jack Systems and is in the process of transitioning from a research company.

The wind energy industry typically has long development times that involve many years of research, development, and refinement before a product reaches the market. The duration of the SBIR grant was not long enough for WTS to develop and construct a completed demonstration tower, but it provided the resources necessary to complete a final engineering design. It also provided a business advisor who facilitated communication with potential investors and helped open the door to funding to support the Space Frame's path to commercialization. It also positioned WTS for a $1.5 million matching grant from the California Energy Commission (CEC), that supported construction, testing, and certification of the new tower with a commercial turbine as well as development of the crane-free erection system.

[1] Energy and economic benefits of WTS Space Frame tower based on data on the Wasatch Wind website (http://www.wasatchwind.com).
[2] Environmental benefits calculated using EPA and DOE emissions and power generation data.

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