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Editor

Britannia breaks the 9 MW barrier

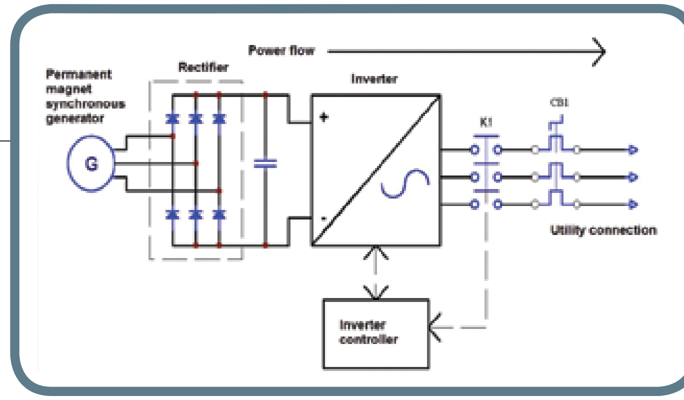
Getting 10-MW from a wind turbine will take a permanent-magnet generator with four independent sections, a gearbox lighter than those on smaller turbines, a 150-m diameter rotor, and more.

A 10 MW offshore turbine is in the works that addresses the growing demand for reliable and efficient offshore wind energy. Over its lifetime, each Britannia from Clipper Windpower is expected to displace the use of two-million barrels of oil and offset the need to dispel 724,000 tons of CO_2 into the atmosphere. It will initially deploy in European waters.

The 10 MW design is an evolution of Clipper's 2.5 MW wind-turbine architecture introduced in 2003. The overall design concepts were introduced by Jim Dehlsen, a pioneer in the wind energy industry for more than 30 years, as well as an experienced wind engineering team that had been involved in the development of four generations of wind turbines –ranging in size from early 550 kW turbines up to the 1.5 MW models.

"We plan to achieve the same tower mass as current 5 MW machines, while using larger diameter blades to bring the cost-of-energy down for offshore operation," said Amir Mikhail, PhD. Senior Vice President of Engineering at Clipper Windpower. "The design concept is to produce twice as much power for the same mass." He explains that the project targets a lighter nacelle (the enclosed drive train and associated equipment at the top of the tower) which will also translate into lower balance-of-plant (BOP). Some aspects of the Clipper Liberty 2.5 MW machine are being scaled up to the Britannia, however a raft of additional innovations are being introduced to make this concept work in the real world.

The 10 MW Britannia from Clipper Windpower



The electrical system provides redundancy for offshore applications. For example, the design calls for multiple generator windings, rectifiers, down-tower conductors, and inverters.

Design Evolution

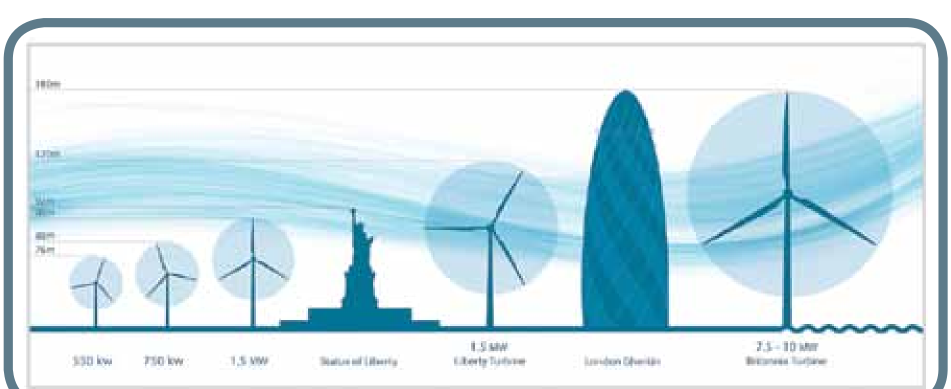
The company spent many years working with the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) in Golden, Colorado to prove out the early stages of the 2.5 MW design. In fact, NREL's National Wind Technology Center provided a grant to help develop and test the initial Liberty concept.

Modern gearboxes typically use two-stage planetary and one parallel-shaft stage with helical gears which are attached to a single generator. However, this necessitates massive gear casings that stretch the capabilities of traditional manufacturers, and places enormous loads on the bearings. Wind turbines have grown from an average of 700 kW to over 2 MW in the past decade, and some 5 MW models are currently in operation. As a result of this shift in orders of magnitude, the three-stage gearing concept suffers too many failures due to excessive loads. Clipper has spent many years refining a lightweight two-stage helical design using four permanent magnet (PM) generators instead of the usual single-wound rotor-induction generator. This was then validated during extensive testing at NREL which evolved into the company's 2.5 MW turbine.

"The Liberty's multiple-drive path design radically decreases individual gearbox component loads, which reduces gearbox size and weight," said says Bob Thresher, director of NREL's National Wind Technology Center. "The new generators significantly reduce component mass by eliminating much of the copper that would be required for windings in the rotor. The machine will also take advantage of advanced feedback controls to reduce load excursions in turbulent wind conditions and optimize pitch schedules to reduce drive train loads and improve energy capture." Apart from reducing loads, this approach is aimed at boosting turbine uptime.

Also under development is a way to improve the variable-speed technology used in most modern wind turbines. Variable-speed designs maximize energy capture from the wind by continually adjusting the rotational speed of the blade to match prevailing wind conditions. The Clipper design harnesses the latest generation of transistors and switches to achieve full power conversion which is more suited to modern grid requirements such as low-voltage ride through and grid stabilization in a simpler way, about half the cost of full speed conversion. The company has been granted many patents in this area.

This all adds up to weight reduction. Many modern gearboxes in MW-scale wind turbines weight 50 to 70 tons. By comparison, Liberty's gearbox weighs in at only 36 tons, including gearbox, brakes, and housing.



The profiles give an idea of the scale of the Britannia.

Britannia

Some of these concepts are being carried over to the Britannia 10 MW model. It will use permanent magnet (PM) generators, and will incorporate an advanced gearbox system and control systems. But due to its scale, most components will have to be redesigned to accommodate much greater loads and operate well in a challenging marine environment.

"The 500 working Liberty machines have proven the variable speed concept, which can be migrated directly into the Britannia," said Mikhail. "We also took the idea of dividing the load and carried it to a higher level."

Four generators atop a 10 MW wind tower would require a more complex connection to the gearbox. So instead of four PM generators, the load will be separated into four outputs inside the drive train to make it more compact. Result: a single medium-speed generator with multiple windings. The medium speed makes it possible to use a two-stage gearbox rather than the 3-stages commonly used in the industry. As a general rule of thumb, with fewer stages, there are fewer reliability issues, and efficiency is higher.

A 30-year life span was another novel idea introduced to the market by the Liberty as opposed to the typical 20 years offered in the industry. The Britannia Project is also targeting a thirty-year span.

Similarly, the Liberty's two pre-loaded, low-speed tapered-roller main bearings are being scaled up. These bearings help absorb the massive thrust loads and mitigate problematic axial motion as well as main shaft misalignment often associated with low-speed bearing failures.

A major effort has been made to reduce unscheduled maintenance costs for the proposed turbine. Doubly-fed induction generators, in contrast, require replacing brushes, while other U.S. concepts require rotating rectifiers and exciters which are generally placed in the rotor hub. So like the Liberty, there are no moving brushes, rotating rectifiers, or exciter parts in the generator's rotor. The PM generator also eliminates the need for brushes on the shaft as there is no need to excite the rotor.

"The total weight of the Britannia's nacelle is currently targeted at 500 tons, which is comparable to current machines which are half the capacity" said Mikhail. "Lower weight translates directly into lower costs for the machine and the balance of plant which ultimately translates into lower cost of energy."

Blades

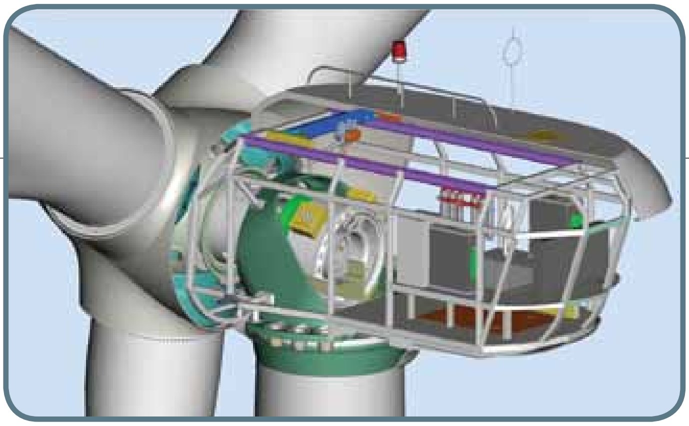
While what goes on atop the tower is of vital importance, the blades can make or break turbine performance. Mikhail explains that energy production is proportional to the square of the blade diameter, and loads increase with the cube of the swept area.

Over the years, then, OEMs have made their nacelles larger as more features were added to mitigate loads. This trend can not continue indefinitely and so Clipper has opted for a two pronged approach: reduce the weight of the machine and lengthen the blades to capture more energy while introducing innovation into blade design to lessen their loads.

While most turbine rotors today have less than 100-m diameters (the largest currently has a 126-m diameter), the Britannia Project targets a 150-m rotor diameter. Carbon fiber will be used to reduce weight and boost energy production. This is being accomplished with a proprietary airfoil design that makes the blade as light as possible and a novel structural layout.

"Carbon fiber is expensive so we are making judicious use of it, particularly to change the geometry of the spar and to maintain the stiffness requirements of the skin in certain areas," said Mikhail. "These brand new blades will each weight 30 tons and be 72 meters long."

He adds that they were designed to have a higher tip speed which means they will have to deal with a high Reynolds number. This represents a type of flow to which



Tower-head mass of the Britannia compares to that of current 5 MW class turbines. The unit, intended for 30 year life, reduces O&M costs by letting technicians easily change out onboard components. All heavy key components can be swapped out with an onboard crane, including the generator rotor, or stator, or both.

these proprietary airfoils are suited. These flat-back airfoils allow for more structural rigidity with minimal performance loss.

The company expects major energy capture gains. Clipper verified the performance using a model of the intended blade in the DLR Wind Tunnel in Braunschweig, Germany.

Prototyping

To execute this project, Clipper has established a Centre of Excellence for Offshore Wind in Blyth in the northeast of the UK in conjunction with the Blyth-based New and Renewable Energy Centre (NaREC). NaREC is one of five centers of excellence set up by the North East regional development agency, One NorthEast. It includes a range of research, testing, and development facilities for verifying components before they are assembled on the prototype wind turbine.

NaREC is providing a full-scale test support package for engineering and a drivetrain test laboratory, including blade testing facilities. OneNorthEast funding has already established a blade test stand. This will be expanded to cope with the 72-m long blades. Further test stands will be erected in the near future for gearbox and generator testing.

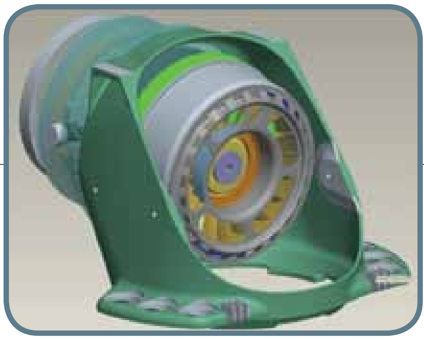
Engineering for the project is being directed by Clipper's Advanced Technology Group in California while the company operations in Blyth will handle sthe Balance of Station which includes foundation, assembly, and erection. Funding provided by the Department of Energy and Climate Change (DECC) also will support the development of Clipper's turbine supply chain and related manufacturing facilities. This has already been set in motion. For example, following successful modeling in Germany and subsequent blade plug development, Clipper signed a lease agreement with the Shepherd plant in the Northeast of England to produce the blades, starting with those intended for the prototype. This new 4,000-m^2 facility recently broke ground near Newcastle.

The first machine will be based near shore for easier testing. "The Britannia prototype will run at 7.5 MW on land," said Mikhail. "However, we will ramp it up to 10 MW for testing to ensure it is operating as planned." While everything will essentially be the same as the intended offshore model, the tip speed will be limited occasionally to keep noise levels down.

Before it is erected, however, the timeline calls for the NaREC gear box testing facility to be ready by the middle of 2011 to allow testing of that system. Mikhail says he intends to conduct thorough and realistic tests of the drive train before moving forward with prototype construction. The plan is to test key components before putting up the turbine in the Blyth area, currently targeted for the second quarter of 2012.

That model will have to include a host of redundancy and marine-worthy features to ensure it can cope with the tough demands of the North Sea. Mikhail said the this includes multiple features to increase reliability and cut down on required maintenance for the simple reason that an offshore turbine can be hard to reach due to weather and sea conditions. Accordingly, it includes four different lines of power output (each 2.5 MW), fully redundant sensors, and other key parts. So even if one part of the turbine does go offline, it can continue to operate at 7.5 MW until repairs are safely carried out.

The nacelle will be fully enclosed to keep the air inside free from salt and humidity. In addition, a dehumidifier will maintain air quality. These features have been extended to include areas of the tower that house equipment. **WPE**



The medium speed, permanent-magnet generator, dubbed MegaFlux, is rated for 10.6 MW. The unit is 98.3% efficient, a 1% improvement over the Liberty and 2 to 4% over conventional induction generators. The medium speed will generate fewer natural frequencies to dampen compared to the company's Liberty quad generator. Multiple independent output windings per generator provide the same quad redundancy in the electrical system as the Liberty design.