Offshore wind: where next?

Words: Steven Peace, Director and the Chief Technical Officer, VertAx Wind Ltd.

VertAx Wind's 10 – 15 MW offshore turbine

The pace of the clean energy revolution is speeding up in an international effort to curb global warming and offshore wind power is set to play a pivotal role in achieving the CO_2 reduction targets of many of the world's coastal countries. It is widely perceived that offshore wind is set to grow by around 9,900% through to 2050 which, according to IRENA, the International Renewable Energy Agency, will take currently installed capacity of just over 10 GW to nearly 1,000 GW by 2050. This is a view widely shared by industry monitors, such as, DNV and the Global Wind Energy Council.

So, the future for the industry is looking good, but using current technology will they really be able to achieve these ambitious targets? According to WindEurope, the average size of wind turbine currently being installed offshore is 7.2 MW; that would mean 137,500 machines would be needed by 2050, or nearly 4,600 every year. It is true that the three main turbine manufacturers (Vestas, Siemens/Gamesa and GE) all have machines ranging between 14 – 15 MW in the pipeline, but these are not expected to be commercially available until 2024/25.

The machines currently in development are huge; with the GE 14 MW machine having a 220m rotor diameter and a single blade length of 107m; while the Vestas 15 MW machine is being designed to have a rotor diameter of 236m and a single blade length of 115.5m. Each blade takes 2 days and 100 men to produce and with their nacelles the size of a house and weighing in at around 600 tonnes; they are relatively slow to produce, averaging 1 complete machine a week.

The high level of demand, together with the desire to reduce costs further are the driving factors for the industry to continually try to develop ever larger machines. A wind turbines power output is directly related to the swept area of its blades and in turn the volume of wind it can capture. Larger turbines mean that fewer are needed to achieve a given power output and that equates to: fewer foundations, less inter array cable connections, lower installation costs and fewer machines to maintain.

Although there are other options, Horizontal Axis Wind Turbines (HAWT's) are currently the configuration of choice. Resembling a propeller on a tower, these machines' blades rotate on a horizontal shaft connected via a main bearing to their drive train housed within a nacelle. The nacelle is mounted on the top of their support towers and needs to be rotated into the direction of the wind by means of a

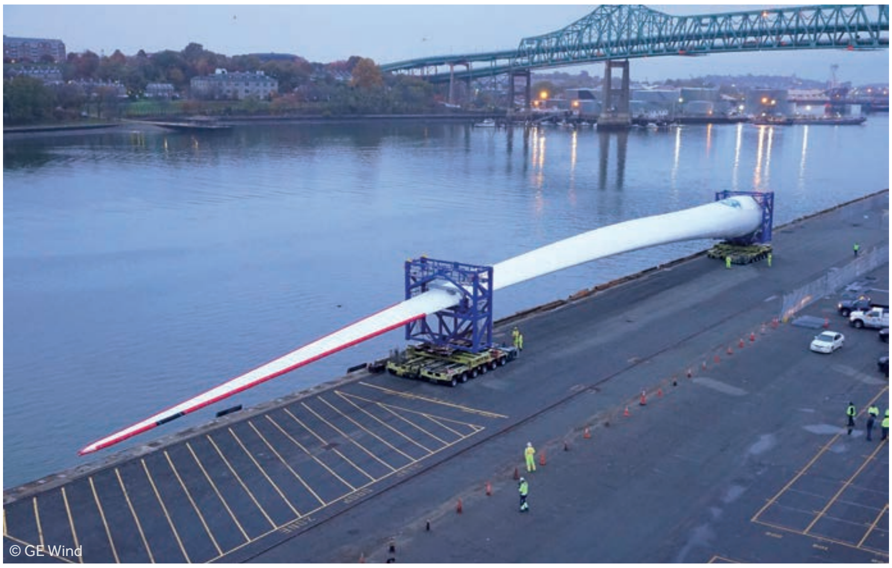
GE's Haliade-X 12 nacelle

yaw mechanism. To regulate the blades rotational speeds and to optimise power output, the blade's pitching angle is adjusted using positioning motors; which together with the yaw system, power generation, power conversion, nacelles environment and system monitoring functions, are controlled by a computerised system.

The loads exerted on the structural components of HAWT's are complex. The blades for example, have a constantly reversing gravitational load (55 tonnes each for the GE 14 MW machine), huge centrifugal forces on the blade tips and bending moments as the force of the wind tries to bend them back. All of these loads, together with the weight of the nacelle, are transmitted to the supporting tower and foundation with most of the wind load being exerted on one side of the tower at any given time.

The incredible size, weight and strength of the latest HAWT machines pay homage to the leaps made in material technology and engineering. A few years ago, it wasn't even conceivable that blade technology would evolve enough to produce blades over 100m in length. But now, utilizing the knowledge gained, it is possible to produce blades in two thin glass composite half shells with imbedded carbon fibre stiffeners; which are then bonded together to produce one single blade of up to 115.5m long.

However, many believe we are nearly at the end of the road for the advancement of this technology, as although it may well be technically possible to stretch individual blade lengths beyond the 120m mark, the increased use of carbon fibre, the additional logistical problems and the extra loads on the turbines drive train and support structure, are likely to make HAWT's beyond 15 – 17 MW commercially unviable.



GE's 107m long blade

So what next?

Is there an alternative that could help us achieve the high targets set and contribute towards the curbing of climate change?

There is an alternative but lesser-known technology, that of the Vertical Axis Wind Turbine (VAWT). First conceived by Frenchman, Georges Jean Marie Darrieus, in 1925.These machines rotate around the vertical axis of their support tower, more like a carousel on a tower. The Darrieus aerodynamic lift, as opposed to drag type VAWT, originally had curved foil blades that attached at the top and bottom of a rotating column support tower, with a generator located at the bottom, looking rather like an egg whisk.

These types of machines were extensively used by a company called Flow Wind International on wind farms in the US during the 1980 – 90's.

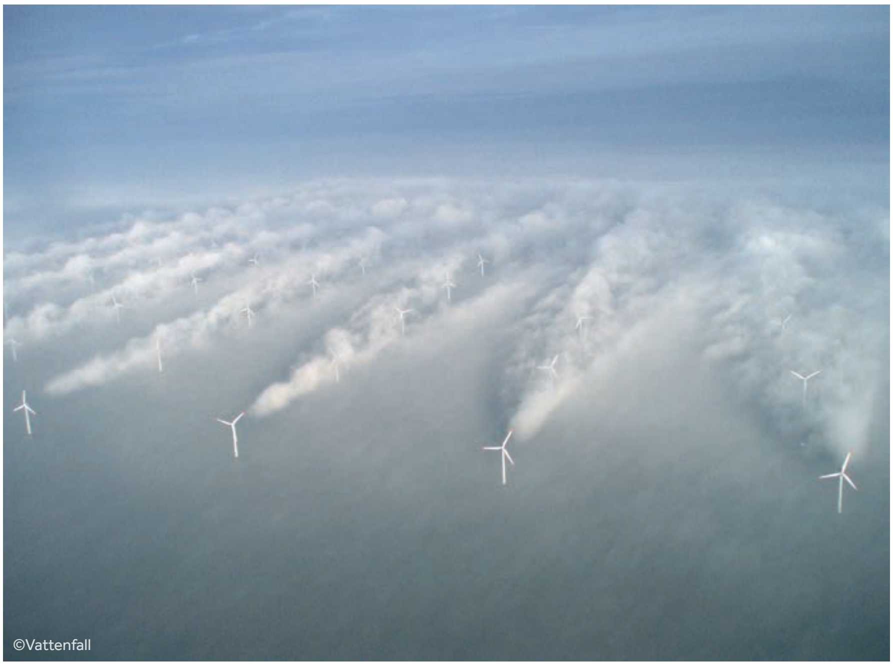
In the UK during the 1980's the Department of Energy funded further research led by Professor Peter Musgrove of Reading University into a straight bladed version of the Darrieus machine. The idea was to simplify and reduce fatigue in the blades, but Musgrove's first prototypes had complex variable geometry mechanical blade feathering (reefing) mechanisms to try and regulate their rotation and prevent them from over speeding. After extensive testing of a few prototypes, it was found that a straight bladed machine with a fixed geometry could self-regulate through the dynamic stall of the blades. These machines are now commonly known as H-Rotor VAWT's.


Dr P. Musgrove's variable geometry VAWT 450 machine

Although originally considered to be less aerodynamically efficient (hence the much slower uptake in the development of the technology), the efficiency differences are now considered marginal with modern designs. The H-Rotor version of the machine in particular, does have a number of significant benefits, some of which are only now being realised with advances in the technology.

For starters, they are omnidirectional, not needing to be orientated into the direction of the wind and therefore do not hunt for direction in turbulent wind flows. Their rotors and blades have a constant gravitational load and due to their generally lower rotational speed, they have lower centrifugal forces. The more manageable loads created by their blades are then more evenly distributed across their supporting structures, resulting in a lower centre of gravity and overturning moments.

Apart from their use in the turbulent wind flows found in a built-up environment, none of these benefits are significant on machines smaller than a few megawatts, but these differences can be very significant and come into their own when looking at machine sizes of 10 – 15 MW and above.



Horns Rev wind farm

The final report produced by Musgrove's work (later VAWT Ltd) for the UK Department of Energy in 1991, concluded that H-Rotor VAWT's would become more viable with scale and that their future lies in multi-megawatt offshore wind farms. A view which was reinforced by the UK's Energy Technologies Institute in its final remarks on its offshore wind studies in 2011, when it said that; 'the future is far offshore, deep water, floating multi-megawatt (i.e. 15 MW plus) VAWT's.'

Modern designs of VAWT demonstrate that, given the greatly different way in which a VAWT functions when compared to a HAWT and its generally consequential lower and constant loads, their blades can be far simpler. They can be made to a uniform aerofoil profile with parallel leading and trailing edges with no twists or tapers. They can be produced in sections and manufactured using mechanised production methods with lower cost, lightweight materials. If supported at more than one point over their length, there is little technical reason that limits their size and studies have shown that VAWT's of up to 30 MW rated output are likely to be possible.

Furthermore, their lower centre of gravity and overturning moments make VAWTs ideal for use on floating platform foundations.

There is another reason why the industry should seriously look at a change in orientation…wind turbine wake and overall wind farm density.

A wind turbine's wake is the disturbed air flow that is the result of the wind blowing through its rotating blades. After having passed through a turbine's rotor, the wind has a lower velocity, is very disrupted and turbulent and in turn this has a detrimental effect on the efficiency of other downstream turbines in a wind farm array.

On a typical HAWT, the wake spirals out from the whole circumference of the machine's blades and funnels for some distance. Eventually the wake dies down and a more stable wind flow returns; providing the steady flow required for the efficient operation of the next wind turbine in the farm.

Current spacing of HAWT's in an offshore wind farm is typically between 8 – 10 wind turbine diameters apart. With the latest HAWT's having rotor diameters of 220m or more, that could amount to a distance of over 2 km between machines taking up a large area of seabed.

The wake from a VAWT is different, insofar as the disrupted air flow is in the vertical plain and is predominantly created by the half of the machine where the blades shed vortices in the downwind part of their rotation. Studies show that in this scenario the wind recovers quicker, and therefore theoretically, VAWT's in a wind farm setting can be spaced closer together, typically 4 -5 rotor diameters or less.

Furthermore, there is a growing body of evidence from a number of recent studies*, which suggest that counter rotating VAWT's sited close to each other in clusters can interact positively, so increasing the performance of the individual machines. The wakes from these counter rotating machines combine, and to some degree, cancel each other out; potentially meaning that the spacing between clusters of VAWT's on a wind farm can be further reduced.

Therefore, it is conceivable that in the future, clusters of 3 machines producing up to 90 MW or more could be installed within a wind farm with spacing's similar to those of a single 12 MW HAWT today. A higher density of wind farm would not only provide cost saving benefits, but it would have a reduced impact on the seabed's ecosystem and be less disruptive for both shipping and radar.

The British company, VertAx Wind Ltd, is one of the companies working in the multi-megawatt offshore VAWT arena. Their patented conceptual design is for a fully modular wind turbine that utilizes largely common components to assemble machines in the 10 – 15 MW + range.

The machine incorporates many innovations including sectional blades supported by two, or more hubs, each with its own novel segmented ring generator. The size, weight and modularity of its components will allow VertAx to move away from the traditional supply chains and to mass produce the machine' components, in relatively normal sized factory units, using largely mechanised methods of production and generally lower cost materials.

The machines' components would then be easily transported for assembly at either a land-based site, or on a floating platform foundation at the quayside before final deployment offshore. These machines have been designed with longevity in mind and will offer unprecedented levels of redundancy and ease of maintenance.

www.vertaxwind.com

* For example: https://www.brookes.ac.uk/about-brookes/news/vertical-turbines-could-be-the-future-for-wind-farms/ and https://link.springer.com/article/10.1007/s10546-018-0368-0

Bio

Steven Peace is a director and the Chief Technical Officer of VertAx Wind Ltd. He has over 30 years' experience in wind and other renewable energy industries and is one of the founding architects of the VertAx wind VAWT concept.