What are the Challenges and Innovations in Offshore Wind Design and Development?

By James Lawson, Contributor | August 22, 2011

Given that around a quarter of the cost of an offshore turbine is in the foundations, what is being done to reduce foundation cost and installation time, plus cope with deployments and other issues?

LONDON -- Although still only a tiny fraction of the world's installed wind capacity, offshore wind is about to explode. BTM Consult predicts that more than 16 GW of new offshore will be installed by the end of 2014, with a global total of 75 GW by 2020.

As turbine foundations comprise a quarter to a third of the overall cost of an installed offshore turbine, depending on water depth, turbine size and who you talk to, today's foundation designers have a tough remit: develop new designs and installation procedures to cope with deeper water challenges - while simultaneously reducing the cost of manufacture, deployment and operation.

Fatigue load, installed strength, resistance to dynamic loadings and cost per installed-MW are four important metrics, but there are many others such as resistance to scour and corrosion plus ease of maintenance and even decommissioning. Water depth, the turbine size and the nature of the seabed - rock, sand or clay, for instance - all inform which type of substructure and footing is used.

Seabed fixings or footings can include piles, drilled and grouted holes, and innovations like in-line and pre-piling which help improve strength and reduce installation time. There's also the suction bucket or suction caisson where a vacuum is used to suck a footing into the seabed, dispensing with the need to pile or drill.

At the start of 2011, some 889 of the world's 1,318 offshore wind turbines used monopiles. This reflects the preponderance of shallow water locations and the trust placed in this proven design, though there have been some recent problems. Almost the default choice in up to 25 metres of water with a firm seabed, the monopile's shape makes for simple calculations and many monopiles can be packed tightly onto a barge for deployment. They typically weigh around 500 tonnes, though on deeper sites they can weigh up to 810 tonnes and are up to 69 metres long.

Gravity Base Foundations are another proven shallow-water design choice used at early developments like Vindeby in Denmark. The weight of the base and the rest of the structure holds the wind turbine in place with no need to pile or drill into the seabed. Concrete is the normal material, though steel is also an option.

Cape Wind, the only US project so far permitted to build in federal waters, plans to use standard monopiles in the relatively shallow waters of Nantucket Sound, while gravity bases are one option for Freshwater Wind's 19 metre-deep Lake Erie project.

"All of the data we have: sonar, soundings, vibra-core and borings indicate that a gravity base would be best," says Dr Lorry Wagner, head of project sponsor Lake Erie Energy Development Corporation. "One issue for monopiles is that the glacial till has minimal strength and the bedrock is 60-90 feet from the lake bed. We are also considering twisted jackets and a variation of a suction pile. Finally, we need a foundation that will perform under lake ice conditions, most likely with an ice cone. We will continue to study the area and make a final decision after all of the data is in."

Soft seabed conditions are also a challenge in China. Here most offshore wind farms will be built in intertidal zones which will see the foundations exposed during low tide, becoming submerged in about 5-15 metres of water during high tide. The only offshore wind farm outside Europe, Donghai Bridge in Shanghai, used a multi-pile foundation structure to cope with the soft ground, with 8-10 legs on concrete piles joined by a concrete deck.

IN DEEP WATERS

As water depth increases, both gravity bases and monopiles become less attractive. Monopile dimensions increase rapidly to cope with deepwater loadings, and attract high hydrodynamic loads from the water, affecting the structure much more than, for instance, a jacket built from many smaller diameter tubes. The amount of ballast required for gravity bases in deeper water becomes uneconomic, though they have been used as deep as 28 metres in Phase 1 of the Belgian Thornton Bank field. Modern designs aim to increase this depth further without undue cost increases.

Foundations for mid-to-deep water fields (30-60 metres) are now the challenge in Northern Europe, currently the crucible of offshore wind development. With the Beatrice Wind Farm Demonstrator Project, Talisman Energy and Scottish and Southern Energy were the first to prove that a deepwater offshore wind farm was feasible. Completed in 2007, two 5 MW turbines are located 22 km offshore in 45 metres of water. The two platforms employ jacket foundations.

As mid-depth foundations have moved from prototypes to full commercial deployments, the jacket in all its various forms appears to be the established champion. For example, US developer Deepwater Wind has cited its use of 'proven, state-of-the-art jacket foundation technology' as one reason why it should be selected to build two proposed wind farms off Rhode Island and New Jersey. Jackets can take a number of forms with various footing options, but those deployed so far have been four-sided, A-shaped, truss-like lattice structures resting on piles and typically weighing around 600 tonnes.

"It's still not yet clear what the standard will be in deeper waters and saying any particular design is the absolute best is impossible," says Allan MacAskill, business development director at SeaEnergy Renewables. "It's about confidence in trusted technology and the risk associated with new designs. The conversations I listen to have the jacket as the perceived standard and everything else is competing to usurp its position."

Norwegian designer OWEC Tower designed the Beatrice jackets and subsequently developed the OWEC Quattropod Jacket as used on Alpha Ventus and the UK's Ormonde field. There are many other jacket options such as the Atkins/BiFab design, which is claimed to be cost-competitive with monopiles in depths beyond 15 metres, and Windsea's modular design which allows smaller vessels to install the lower weight modules.

"We have done benchmarking, and found that jacket-based structures are lighter and cheaper than any alternatives we have seen so far," explains Per Bull Haugsøen, managing director at OWEC Tower.

Tripiles, tripods and jackets all play a part in Germany's offshore fields. Alpha Ventus, Germany's first offshore windfarm, employed six REpower jackets mounted on six Areva tripods in 30 metres of water. The tripod expands the monopile's seabed footprint, with its legs (secured on piled footings) supporting a central cylinder that connects to the turbine base. Though there are far fewer welded connections compared to a jacket, the tripod is much heavier, more vulnerable to scour and its joints are complex to fabricate.

The Borkum West II development, adjacent to Alpha Ventus, will use 40 tripod foundations to support its Areva 5-MW turbines.

"The tripod design is well understood and proven," says Stefan Dorfeldt, lead project engineer at designer OWT. "The tripod is heavier than the jacket for the same water depth, which makes the jacket slightly cheaper 'at the quayside,' but it's about the overall cost. The tripod is more robust, is easier to inspect and protect against corrosion, and needs one less pile than a jacket."

Bard champions IMS's tripile design which, like the tripod, can be seen as an extension of the monopile design. Instead of a single tube, three piles are driven, and are connected to a transition piece using grouted joints. Used on the Bard 1 field in 40 metres of water, tripiles are lighter (490 tonnes) than jackets or tripods. Construction starts next year on the Dutch Buitengaats field which will deploy 60 Bard tripiles in 30 metres of water.

Though these are all proven mid-depth designs, further reductions in foundation fabrication and installation costs are essential to improve the cost-effectiveness of offshore wind. At least a 10 percent cost reduction was the goal for the initial 104 entrants to the Carbon Trust's Offshore Wind Accelerator (OWA) competition. Beating the benchmark costs of the monopile and jacket designs means reducing or eliminating expensive processes like piling and crane lifts. Now, OWA manager Phil de Villiers says that all of the four shortlisted designs will be prototyped. 'We've now got a very accurate picture of the overall costs to build and install the designs,' he noted.

Two employ suction bucket foundations. Though a bucket failure in 2005 during the installation of an Enercon demonstration turbine set back caisson research somewhat, a prototype off Frederikshavn in Denmark has not budged since its installation in 2002, while a met mast with a suction bucket foundation was successfully installed at Horns Rev 2 Offshore Wind Farm in March 2009.

Like the suction bucket and the jacket, Keystone's Inward Battered Guide Structure comes from technology pioneered in the oil industry. It features three supporting legs angled around a central pile, hence it is also known as the 'Twisted Jacket'. With around a third of the components of a conventional jacket, it is faster and cheaper to build and also promises to be easier to install. The Twisted Jacket will be prototyped in 30 metres of water next year to support a met mast on the UK Hornsea field.

The GBF consortium's gravity base foundation is designed for production line manufacture using concrete slip forming techniques. Intended for waters 30-45 metres deep, the turbine and tower are assembled onshore and the entire structure deployed on a purpose-built barge.

Developed by Aalborg University, the MBD Universal Foundation is a suction bucket monopod. It employs hundreds of high-pressure water jets on the bottom edge of the caisson skirt so that an operator can vary the jet pressure in order to 'steer' the bucket into the desired orientation as the vacuum sucks it into the ground. Unlike the monopiles it resembles, the wide foundation means this design works more like a gravity base and can cope with up to 55 metres of water.

The fourth shortlisted entry is SPT's Self-Installing Wind Turbine, an asymmetric braced monopod design that uses three suction bucket footings. Built up in harbour, the assembly goes by standard barge to its location in 20-60 metres of water.

'We also considered the decommissioning costs,' says de Villiers. 'The suction bucket can be decommissioned quite easily, though we are likely to need different foundation designs for different soil conditions.'

Turbines in deep water (over 60 metres) can take advantage of the even higher and more consistent winds found far offshore in areas like the US east coast, Norwegian waters and west of Shetland, UK, with various designs coming into play as water depths increase. At these depths a floating, rather than fixed, foundation is required, and there are many ongoing design projects.

FLOATING PLATFORMS

There are three main types of floating turbine platforms: ballast-stabilised designs that resemble a floating vertical pole with ballast in the lower end; tension leg platforms (TLPs) that tether the floating platform very tightly to the seabed and so virtually eliminate vertical movement; and buoyancy-stabilised platforms resembling a conventional semi-submersible rig.

Floating turbine projects are still at the prototype stage, with one notable exception: Statoil's Hywind project. Coming to the end of a two-year test programme off Bergen, this ballast-stabilised, spar-type design requires very deep water as it extends 100 metres beneath the sea's surface. Able to cope with sea depths up to 700 metres, the Hywind design employs ballasted catenary anchors, created by hanging multiple-tonne weights from the midsection of each anchor cable, reducing the movement of the floating platform. 'We are working on setting up a demo park of three to five Hywinds together,' says Statoil spokesman Per Arne Solend.

Principle Power's Windfloat has moved from the design and tank testing stage to prototyping and is working with its partners to build and deploy a prototype carrying a 2 MW Vestas turbine at Agu√ßadoura off the coast of Portugal. 'This is stage one of a three-stage process,' explainss chief business development officer Craig Andrus. 'In the next pre-commercial phase, we will build six units carrying three 3 MW and three 6 MW turbines.'

As the three-legged, semi-submersible prototype is designed to cope with mid-depth waters (minimum 40 metres) yet is also suitable for depths over 100 metres, it is relevant to today's developments as well as future far-offshore fields. 'The only change is the length of the anchor chain,' says Andrus. 'It is logistically and cost-competitive with a fixed jacket in 40 metres of water.'

Blue H Technologies has a number of deepwater initiatives to its credit. As well as deploying a TLP prototype in 2008, it is currently working on a second TLP design slated for deployment in 2012 with a larger pre-production floating turbine planned for 2014. The company also led the UK's Deepwater project, which looked at the feasibility and costs of a TLP design in water 70-300 metres deep.

'Deepwater showed that a floating platform for a 5 MW turbine is technically and economically feasible,' says Andrew Scott, programme manager for offshore wind at the Energy Technology Institute (ETI). 'A TLP works extremely well in 60-100 metres of water.' A prototype is the next step. 'We're going to publish RFPs in the next couple of months and the ETI is going to put in considerable funding,' states Scott.

Optimising foundation design for far offshore turbines while trimming costs is a huge and ongoing challenge. As shown by the substantial industry support for initiatives such as the Carbon Trust's Offshore Wind Accelerator programme, governments, businesses, academics and many others in the wind energy community have responded with an unprecedented burst of innovation, collaboration and investment. Success will reduce financing costs, speed of deployment and, eventually, reduce the energy cost to consumers.

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http://www.renewableenergyworld.com/rea/news/article/2011/08/what-are-the-challenges-and-innovations-in-offshore-wind-design-and-development