Tube 2018:

FA 09 Tripods, Jackets and Tripiles: Innovative Tube Systems for Offshore Wind Energy Systems

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Steel tubes or steel tube systems are among the most frequently used constructive elements for the foundations of offshore wind energy systems. In addition to the size and the weight of a wind energy turbine, water depth plays a primary role when it comes to choosing the type of foundation, and it normally increases in line with the distance to shore. In the “Wind Energy Report Germany 2014” published in mid-2015, the Fraunhofer Institute for Wind Energy and Energy System Technology in Kassel (Fraunhofer Institut für Windenergie und Energiesystemtechnik, IWES) says that the most important offshore countries increasingly rely on a further extension of their farshore energy systems, i.e. offshore sites with a distance from shore of at least three nautical miles or 5.5 kilometres.

Especially in Germany, most offshore wind farms are realised in higher water depths and distances from shore to avoid any negative impact on the marine environment in the Wadden Sea National Park. According to IWES, the offshore wind energy systems added worldwide in 2014 were built in an average distance of 21.1 km from shore and a water depth of 32.3 m. In contrast, German offshore farms are located at an average distance of 65 km from shore and in a water depth of approx. 29 m - the international comparison thus shows that these systems are located farthest away from shore.

High diversity of support structures

The trend of constructing offshore wind farms in increasingly deep waters has a profound impact on the support structures deployed (i.e. the structure used to anchor the turbine foundation on the seabed). After initially deploying gravity foundations and mono piles, other structures are now used increasingly. In addition to the high-rise power caps deployed in Asia, latticed support structures (jackets), tri-sectional foundation foundations (tripiles and tripods) as well as floating foundations, suction buckets and artificial islands should be mentioned in this context.

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According to IWES, the various designs are suitable for differing on-site conditions. Gravity foundations, monopiles and high-rise pile caps are primarily used in nearshore and shallow waters. The tripod and tripile types of anchoring foundation are deployed at an average distance of 96.5 km and thus farthest away from shore. Floating structures are deployed in an average water depth of 78 m and must still be considered as being in a test phase. As regards monopiles, it must be added that their manufacturers develop larger and larger models which may also be used in deeper waters.

Offshore wind energy farms must have an especially high stability and robustness to withstand the powerful forces of nature throughout their lifetime of 20 years or more. In addition to high wind speeds, the turbines are particularly impacted by waves, ocean currents, tides and floating ice. In addition, there are the dynamic loads generated by the wind turbines themselves. Support structures based on steel tubes are capable of withstanding all loads and of reliably carrying their superstructures for decades.

Tripods: Three-legged support structures for offshore wind turbines

A tripod consists of three steel tubes welded together at an angle of 120° to form a tripod which then carries a precisely centred central tube. A tower is than fitted on this tube. The tubes of the tripod construction have a diameter of 1 to 2.5 m each and require a triangular base surface of 200 to 300 m². Each leg may have a single pile or consist of several tubes. Similar to jackets, centring sleeves are mounted at each end of the tripod structure to support the foundation pile driven into the seabed. The piles are interconnected by horizontal struts and joined to the central tube by a diagonal brace.

The ground surface should be level and free of too many stones, as the structure is anchored to the seabed at a depth of several metres using pile driving machines. Tripods offer high stability even in rough sea areas and - with the current state of the art – they are suitable for water depths of 20 to 80 m. The tripod support structures especially developed for the offshore wind industry were first deployed in 2009, when the German “Alpha Ventus” offshore test site was built.

Jackets: Latticed steel tube structures for large depths

For decades, jackets have been proven support structures for offshore platforms even at large water depths. In this case, the anchoring structure consists of a spatial lattice, which is made of steel tubes and similar to the latticed towers used for high-voltage power lines. The four feet of the foundation end in sleeves housing the foundation piles driven into the seabed. Because of their high resistance, jackets are suitable for offshore wind parks up to a water depth of 70 m. The “Alpha Ventus” test site did not only have tripod structures, six other wind turbines were installed on jacket foundations.

Compared to tripod foundations, a jacket is supposed to require a third less steel. Furthermore, the latticed support structure of the jacket is supposed to lead to benefits in terms of both capital expenditure and the logistics of the installation. On the other hand, jackets have a large number of welded connections with many edges and struts, which require regular maintenance because of their significantly higher corrosion risk, and may therefore lead to higher operating cost.

Tripiles: Lightweight and low-cost

Just as tripods, tripile foundations were especially designed for offshore wind farms. Tripiles consist of three individual steel tubes which carry a tripod crosspiece at the water surface to install the wind turbine. Compared to monopiles, the individual tubes are of a smaller diameter and more easily driven into the seabed. Tripiles are anchored in the seabed using a pile-driving template. The three steel tubes are then fitted with a tripod crosspiece to carry the wind turbine. The installation process is considered to be relatively demanding, as the piles have to be driven in with great accuracy so that the supporting crosspiece can be precisely installed.

Tripiles are suitable as foundations for water depths of up to 50 m and, according to the manufacturing data they are less expensive and lighter than other support structures. It is supposedly possible to adapt the wall thicknesses and lengths of each tube specifically to a given site. The first tripiles were realised in the BARD Offshore 1 wind farm in the North Sea and in the nearshore Hooksiel wind farm.

Hexabase: Steel tube foundation with a hexagonal layout

Two recent developments in the support structures of offshore wind farms are the hexabase foundation and the texbase hybrid gravity foundation which is based on the same principle. Hexabase, a steel tube foundation with a hexagonal layout. supposedly has major advantages compared to the more traditional structures: it is more efficient and more economic in production and installation. Compared to conventional jackets or large monopiles, it promises reductions of up to 20% in weight and up to 20% savings on manufacturing cost. Furthermore, it supposedly has a particularly high adaptability to various water depths and wind turbine types. The hexagonal lattice structure consisting of tubes with comparatively small diameters and wall thicknesses is said to show a particularly good absorption capacity for the dynamic forces generated by wind turbines.

According to ThyssenKrupp, an important prerequisite for realising these savings is that a majority of the tubes used is made of hot-rolled wide strip. It is said that hot-rolled wide steel strip can be more easily processed to structural tubes than the quarto sheets, which have been used so far. The welded tubes have a uniform diameter and the nodes are also standardised for the welding robots to automatically connect the tubes and nodes. According to its developers, the process promises faster and cost efficient production and consistent weld quality because of the computer-operated welding process.

Texbase: A “lightweight” hybrid gravity foundation

Based on the hexabase principle, the texbase structure was developed as a hybrid gravity foundation combining the properties of a lightweight steel structure and a gravity foundation. A hexabase standard structure is mounted on the base structure of ballast tanks which are made of particularly durable water-permeable synthetic fibres and filled with 2,000 to 4,000 tonnes of sand. The base consists of a frame of steel tubes which is then covered with geotextile fabrics and evenly transfers the load into the ground.

With a weight of 450 to 700 tonnes before installation, the weight of a texbase structure is similar to a traditional foundation. The foundation supposedly requires only a minimum of soil preparation and may be

installed with simple construction machinery and little noise. According to the developing community, this innovative gravity foundation is easy to transport, and after it has been installed in a water depth of up to 50 m, it also guarantees a firm stand even for the largest wind turbines of at least 8 MW power.

Innovations from the tube and pipe industry will be presented at Tube Düsseldorf from 16 to 20 April 2018 at Düsseldorf fairgrounds.

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