Tube 2016:
FA 07 Monopiles – gigantic pipes for offshore wind farms

The energy sector is the biggest global market for manufacturers of steel pipes, with the main focus on two non-renewable resources: oil and gas. Yet pipes are equally indispensable for renewable energies. One particularly visible application is that of wind power in the form of wind turbine towers, built mostly in steel or concrete. What tends to be less conspicuous at an offshore wind farm is the facilities that can be found below the water level, where steel pipes or steel pipe structures are mainly used as foundations for the power generators that are visible high above the water.

After 2014, which had already been a record year in the German wind power sector, 2015 was yet another year with record figures. In 2014, 141 new turbines had been built, and offshore output had already doubled compared with 2013. But in 2015 the overall total increased further even further. In all, 546 offshore wind turbines were connected to the German grid, with a total output of 2,282.4 megawatts (MW). According to Deutsche WindGuard in its “Offshore Wind Power Expansion Status in Germany”, 792 offshore wind turbines were contributing power to the German grid at the end of December 2015, totalling 3,294.9 MW (2014:1,012.5 MW).

The energy sector had anticipated such record figures, due to quite a backlog of turbines, built earlier in 2015, yet without being connected straightaway. Although further growth is expected for 2016, we are unlikely to see even more records this year. This is because, at the end of 2015, another 41 turbines were completed, with an output of 246 MW, and these are now waiting to be connected to the grid. Also, 122 foundations have so far been set up for the installation of new offshore wind turbines. The sector is expecting roughly another 700 MW in 2016.

According to AG Energiebilanzen, about 8.2 TW hours of electric power were produced offshore in 2015. This covered the electricity demand of over 2 million households or 1.4 per cent of Germany’s gross power

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supply. So although offshore wind power has the smallest share in Germany’s power production (with the onshore volume being nearly 10 times as high), this sector is nevertheless an attractive one for the steel pipe industry, and indeed not just because of its good prospects for the future. After all, an offshore wind turbine requires considerably more crude steel than facilities on land.

More wind at sea than on land

On the other hand, building an offshore wind farm means spending far more time and money than the onshore equivalent. The increasing attractiveness of offshore turbines for the energy sector is partly due to the lack of acceptance of onshore facilities, though not only. There are also other plausible reasons. First of all, the wind at sea is not just stronger but also more constant and regular than on land – as has been confirmed by the 2014 Wind Energy Report for Germany of the Fraunhofer Institute for Wind Energy and Energy System Technology (IWES). Although both types of locations display seasonal differences (more in winter, less in summer) in the wind power supply, offshore wind is not as much dependent on the time of the day as onshore. This is because thermal convection has less of an impact on the open sea. In total, therefore, offshore wind turbines deliver far more energy than corresponding onshore wind farms. This is particularly true for the more recent farshore facilities which are situated further from the coastline.

A simple principle applies to turbines in general, whether onshore or offshore: the bigger the better. The rotor diameter plays a major role for the output and yield of a wind turbine, as the surface of the rotor determines the share of the available wind flow and the share that can be converted to electric power by the turbine. Moreover, depending on the location, an increase in height also means a higher wind speed. As the output generated by the wind is in proportion to the cube of the wind speed, the hub height has a major impact on the yield of the wind turbine.

Trends towards more performance and bigger turbines

This is accompanied by an increase in the nominal output of the wind turbines. According to IWES, the average nominal output of a newly installed offshore wind turbine has globally increased from 1.9 MW in

2000 to 3.6 MW in 2014. During the same period the hub height rose from about 60 to an average of 85 metres. Above all, there has been a continuous increase in the lengths of rotor blades on offshore facilities. In 2014 wind turbine rotors had an average diameter of 115 metres, compared with about 75 metres in 2000. New models in the 6-MW class even have diameters of 150 metres or more. In fact, the next generation of offshore wind turbines, which is currently under development, will have rotor diameters of over 160 metres, with a nominal output of 6 to 7 MW.

The foundation of an offshore wind turbine is impacted not only by a trend towards larger dimensions, but also by the water depth at the point of installation. Whereas the first wind farms were still built relatively close to the coast, where the water was quite shallow, today's offshore facilities are situated 21.5 kilometres off the coast, reaching 15.5 metres into the water. In 2014 turbines were built at about 21.1 kilometres from the coast, at a depth of 32.3 metres. According to IWES, German offshore turbines are situated, on average, 65 kilometres from the coast, reaching a depth of about 29 metres. Seen globally, this means that they are at the furthest distance from the coast.

As all offshore wind turbines operate under different conditions, a variety of solutions have been developed for the relevant foundation structures. In terms of quantity, the biggest share has always been that of monopiles and gravity foundations. Other construction methods are high-rise high pile caps, used in Asia, and, above all, timber-framed support structures (jackets), three-part foundations (tripiles, tripods) and floating foundations.

To put it in simple terms, the structure of an offshore wind turbine depends on its location. Gravity foundations, high-rise pile caps and monopiles are largely used in coastal and shallow waters. Tripod and tripile foundations are particularly suited at long distances from the coast and in deeper waters. Obviously, the boundaries between these categories are fluid and indeed continually shifting, particularly with regard to monopiles.

Considerable strain on offshore wind turbines

Offshore wind turbines generally need to be more stable and robust than onshore. This is because they are exposed to more and bigger forces. As well as their own weights and high wind speeds, they need to cope with waves, currents (including high and low tides) and floating ice. Their foundation structures must be designed and dimensioned in such a way that they can withstand all the forces to which they are exposed, and indeed over several decades and without tilting.

The simplest way to anchor an offshore wind turbine in the seabed is to use monopiles – a long cylindrical pipe which is usually driven into the bottom of the sea by an installation vessel. Monopiles can be installed within a very short period of time – i.e. several hours – and are therefore very cost-effective. As a rough guideline, about half of the pile must be embedded below the bottom of the sea to ensure sufficient stability.

As pile-driving is extremely noisy (with a level above 160 dB or more), suitable precautions must be taken to protect marine life. Nowadays, however, there are a number of alternatives to pile-driving, such as injection and vibration piling. This reduces the noise level and also the mechanical impact on the foundation pipe.

To bear the enormous weight of an entire structure, the pipes must have thick walls and large diameters (several metres). At a 5-MW facility, for instance, the gondola with its rotor and hub alone weighs between 300 and 400 tonnes, sometimes more. In addition, there are several hundreds of tonnes for the wind turbine and the transition piece between the foundation and the turbine.

XL and mega monopiles

To cope with such large volumes and to use monopiles at ever-increasing depths of water, specialist pipe manufacturers are continually entering new territory in terms of dimensions. At the beginning of the millennium it was possible to produce pipes of about five metres in diameter for plant engineering purposes. Today, however, the standard diameter of a pile is over six metres, and the pile can be used at a depth of about 30 metres.

The Dutch Sif Group believes it should be possible to increase the length of a monopile to 120 metres, its diameter to 11 metres, and its weight to 2,000 tonnes. Anticipating such developments, the company has been expanding its production capacities, so that it can eventually produce such pipes in series. In the near future, however, Sif believes that it is sufficient to make foundations with 9-metre diameters which are 100 metres long and weigh 1,500 tonnes.

Other manufacturers, too, are now opting for the production of such XL, XXL or mega monopiles. EEW Special Pipe Constructions GmbH in Rostock produces large, longitudinally welded pipes, with thick walls, up to 10 metres in diameter, up to 120 metres in length and up to 1,500 tonnes in weight. This is currently the most cost-effective foundation structure for offshore wind farms with turbines in the 5-to-8-MW class, at a depth of up to 40 metres. According to the manufacturer, this allows savings of up to 30 per cent on foundations compared with a jacket design. Such savings are apparently substantial, as foundations account for 20 to 25 per cent of the total cost in an offshore project.

Mega monopiles are also being studied by a workgroup at Dillinger Hüttenwerke which has worked with the company’s subsidiary Steelwind Nordenham on setting up a special manufacturing facility for such foundations. The first monopile that was produced in Nordenham in September 2014 had a diameter of 7.8 metres and weighed around 1,000 tonnes. It was also the biggest of its kind. Yet it is possible to build monopiles up to 10 metres in diameter, up to 120 metres in length, up to 150 millimetres in wall thickness and up to 1,500 tonnes in weight. Such piles can apparently be used at a water depth of up to 45 metres.

Tough, high-strength steel is required

Dillinger Hütte is also one of the main suppliers of heavy plates for the production of monopiles. To make these, the company has developed steels with thicknesses far above 100 millimetres and in a strength category of up to 500 MPa (megapascal). Preference is given to firmer, mechanically rolled steels, in particular. Foundation structures require steels that are extremely tough, robust and weldable.

This is because welding is one of the main stages required in the production of a monopile. To put it in simple terms, the sheet metal is formed into lengths of pipe segments, using 3- or 4-roller bending machines. The inside and outside longitudinal seams of the individual lengths are then welded on a welding line,

and the finished individual lengths are taken to a production line where they are welded together into a single large segment. Alternatively, it is possible to pre-mount smaller segments consisting of two or three lengths and then to combine them on the same large-segment production line.

Highly automated production routines

Having reached this so-called growing line, the final component is then assembled. The individual lengths or small segments are aligned with one another, using special turning and alignment tools, and the components are stapled together. The inner and outer circumferential seams are then welded together, using a column and boom and applying a submerged arc welding technique. In this way the components are gradually assembled to form the actual monopile which is taken to the next manufacturing stage, i.e. finishing and coating. Continuous, highly automated production warrants a good level of capacity utilisation and cost-effective manufacturing of offshore wind turbine foundations.

Wind farms are unlikely to be on display at the next Tube trade fair. However, there will be plants and machinery for the cost-effective manufacturing of monopiles and other foundation structures. Moreover, where wind energy technology is concerned, it makes perfect sense to combine this leading international pipe and tube fare with the world's biggest wire and cable trade fair, *wire*. *Tube* and *wire* will be held at the Düsseldorf Exhibition Centre from 4 to 8 April 2016.

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