IHC Offshore & Marine had to develop a very distinct version of a known design, a vessel with her own propulsion, DP-2 capability, and one of the largest cranes and accommodation capacities ever installed on such a platform.

**NEPTUNE:**
turbine transport and installation self-elevating heavy-lift jack-up vessel

Sustainable and renewable energy are developing markets, stimulated by governments in their efforts to reduce CO₂ emissions. The European Union, for example, intends to use renewable sources (also known as renewables) for 20% of its energy requirements by 2020. In practice, this implies the building of sizeable wind and solar power farms. It also suggests that a recently delivered innovative Royal IHC vessel, designed for the installation of wind turbines, will be extremely busy in European waters over the next few years.
Onshore wind energy has some limitations, and consequently it seems advantageous to generate wind energy at sea. Key players in this field are the countries surrounding the North Sea: the United Kingdom, Germany, Denmark, The Netherlands and Belgium. There are plans to install between 52 and 88GW offshore wind farms by 2020. Depending on the size of wind turbine generators (WTGs), these plans require the installation of up to 17,000 turbines and foundations of various types and sizes. The reliability, lead time and cost of the installation of these turbines are important factors in the construction and subsequent exploration and maintenance of offshore wind farms.

These activities appear to be challenging because turbines can be installed in water depths of up to 50m and up to 200km offshore. The consequences for the technology and the logistics are great. Large and heavy constructions, such as monopile foundations, gravity-based foundations, jacket or tripod foundations, floating units, nacelles and rotor blades for example, must be transported over substantial distances and installed on the sea floor and high in the air.

Dimensions and weights are astonishing. Monopiles can measure 5-7m in diameter and have masses of well over 800t, for instance, and jackets may have dimensions of approximately 20 by 20 by 80m. Turbines of 5MW at 3.3kV have already been installed. These boast rotor diameters of approximately 130m and hub heights of nearly 100m above sea level. In the future, 10MW turbines are considered feasible. These mastodons are expected to have weights of over 1,000t and rotor diameters of about 150m.

It is evident that efficient seaport and construction capacity for the construction of these huge structures, as well as sufficient and reliable installation capacity for both turbines and foundations, are strategically important conditions for the mobilisation of wind energy [1]. This is where GeoSea enters the scene (figure 1).

A subsidiary of the Belgium-based Dredging, Environmental & Marine Engineering (DEME) Group, GeoSea focuses on offshore works around the globe. It specialises in the drilling or hammering of large diameter piles, the erection of intricate offshore structures in a wide variety of environments, sophisticated soil investigations from bathymetric surveys to vibrocoreing, and service and maintenance activities.

It is involved in nearly every aspect of the oil and gas and renewables sectors, including: management, support, logistics, survey, inspection, maintenance and repair services. Its variety of skills, technology and equipment, staff and experience make the company, supported by the synergetic structure of the DEME Group, an ideal partner in wind energy farm erection and maintenance.

It is therefore no surprise that GeoSea/DEME is an active shareholder in the large C-Power project, also known as the far shore wind turbine farm at Thornton Bank off the Belgian coast. Other partners include EDF Energies Nouvelles, Z-Kracht, RWE Innogy, Socofe and SI2W Environment.

A host of prominent technology designers and manufacturers are involved, too. DEME companies are engaged in the construction of gravity-based foundations (GBFs) in the port of Ostend, the accurate dredging, flattening and refilling of foundation pits up to the consistent layers of the sea floor, the heavy lift work, transportation and positioning of the GBFs, the trenching, laying and backfilling of the cable network and construction of shore landings.

After completion, Thornton Bank will comprise 54 wind turbines at mutual distances of 500-700m, located 30km from the Belgian coast in average water depths of 16m. The project is expected to generate 1,000GWh of electricity annually, the equivalent of the power consumption of 600,000 people, transferred to the coast by cables measuring 38.7m. Nacelles as such have masses of 316mT, whereas a complete wind turbine amounts to 695mT. Beside the GBFs for the deepest locations, which mass up to 3,000mT each, considerably lighter, dividable jacket foundations are applied for the locations at lesser depths.

The optimum vessel

The installation costs of wind farms form a considerable part of the total capital expenditures (capex) and consequently have considerable influence over their operational expenditures (opex). This situation calls for the most efficient, reliable and all-weather method of installation [1].

GeoSea has a good solution for this challenge by applying the jack-up vessels VAGANT, GOLIATH and BUZZARD, which, in combinations, could offer all transportation, stability and lift capacity required. The experience with these vessels ultimately and almost naturally led to the requirement for a vessel that could unite all functionality in one unit: full DP-2 propulsion capability, a stable working platform, heavy lift capacity and a large free deck space of sufficient strength.

With a clever sequence of loading and unloading the turbine parts: pylon in two parts, nacelle and complete rotor, such an innovative vessel could do the whole thing autonomously. To build the vessel, the company found an ideal partner in IHC’s Offshore division, which built similar vessels in the first decade of the 21st Century, the PAULINE and the VAGANT.

Laconic origins

According to the technical specification, the laconic description of GeoSea’s request from IHC was a “four-legged general purpose self-elevating unit, Gusto Marine Structure Consultants (Gusto-MSC) type SEA2500, arranged for installation of a pedestal mounted heavy lift crane and suitable for future installation of a helideck for operation of a Super Puma or equivalent.”

“The unit basically consists of a hull, four circular legs and four hydraulic jacking systems. Prime movers are to be provided to supply power for auxiliary propulsion, positioning, jacking, crane operation and domestic purposes. One 600 tonne/26m heavy lift crane is to be arranged on a pedestal at starboard of the vessel.”

“The unit is equipped to remain self-contained in an offshore environment for 15 days with respect to fuel, lubricating oil, water and food for a full complement of 60 people.”
Dracconic efforts

This concise description, however, required rather lengthy and draconian efforts from IHC Offshore & Marine (IHC O&M). The request sounded simple enough, but: “between dream and reality, laws and practicalities stand in the way”, to paraphrase renowned Flemish author Willem Elsschot (1882-1960), who would know from experience. He worked in the shipbuilding industry for years under his real name, Alfons de Ridder, and was actually employed by a predecessor of GustoMSC, the Gusto shipyard in Schiedam, The Netherlands, a ‘founding father’ of IHC Holland from 1943 to 1965.

These great efforts concerned both technology and the building schedule. To begin with the latter: the contract for the detailed design, construction and delivery of the vessel was signed between GeoSea and IHC on 16 September 2010 and the keel was laid on 25 March 2011. She was launched on 23 September 2011 (figure 2).

From the date of her naming as NEPTUNE (after the ancient Roman god of the sea) on 7 March 2012 in the port of Ostend, the yard... the yard shall produce all required detailed section and arrangement plans as well as necessary calculations and hand them over for approval to the Owners and to the ABS (American Bureau of Shipping).”

So IHC O&M had to develop a very distinct version of a known design, a vessel with her own propulsion, DP-2 capability, and one of the largest cranes and accommodation capacities ever installed on such a platform, leaving nevertheless the largest possible workable deck space of 1,600m² for an allowed load figure of 10mT per metre squared. And all that on an extremely tight schedule to allow the vessel to participate in the Thornton Bank activities. And it has to be said: IHC O&M succeeded triumphantly.

Technical highlights

Jacking-up system: at the corners of the platform, four proven GustoMSC hydraulic, positive engagement jacking systems have been installed. The systems are similar to the ones applied on other GustoMSC jack-up units in operation and fully comply with ABS regulations.

Every system is built in a so-called jack-house and comprises a set of two rings, flexibly suspended from the hull. The upper ring has a connection to the upper deck of the jack house and the lower ring is suspended from the upper ring by heavy hydraulic cylinders (figure 3). Both rings have been equipped with a set of hydraulically operated locking pins, which fit in boreholes in the circular legs.

By (automatic) sequential operation of the pins and rings, upward and downward steps of the platform can be initiated, as well as preloading of the sea floor. The system can achieve climbing speeds of approximately 0.7m per minute.

A special feature of the MSC design/IHC Hytop hydraulic system/IHC Vremac cylinder arrangement is that the NEPTUNE’s legs can be preloaded in diagonal pairs to the full capacity of 2,750mT in order to verify the bearing capacity of the sea floor with GeoSea-developed leg penetration models. If the preloading holds, the other pair of legs is tested.

Subsequently, all four legs are standing on the seabed and the total load is reduced to a safety factor of two times the preload. This is a very important feature for undisturbed installation of turbines.

One operator can fully operate the jacking system. Integrated inclinometers ensure the level position of the platform and redundancy in the design guarantees continued operation in the event of a failing hydraulic pump. Rubber pads, used in the flexible suspension, protect the legs and rings from mechanical damage and provide a kind of play that prevents extreme forces. Full lifting tests during harbour trials have attested the perfect working of the system (figure 4).

Propulsion and DP-2 capability: sometimes platforms like the NEPTUNE have some kind of propulsion for positioning them in the working area. In such cases, however, escorting tugs are always needed to provide communications and other nautical functions. GeoSea and IHC O&M opted for a more innovative solution, by promoting the propulsion arrangement from being an auxiliary into a full main propulsion system, with even a full Class 2 Dynamic Positioning (DP-2) System (figure 5).

Four non-retractable 1600kW full-azimuth thrusters are arranged at the bow and stern of the NEPTUNE. They run at constant speed while variable thrust is obtained by controllable pitch. Each thruster is directly driven by a single diesel engine. Cooling of the diesel engines is provided by means of one combined LT/HT box cooler per engine.

DP-2 classification requires that no single failure may result in loss of the specified position. The single failure is defined as any failure in the total chain of power generation, power conversion, propulsion means and control equipment, except for flooding or fire of a complete space (the latter two belonging to DP-3 classification). The implication of such requirements is that not only the DP control computers and interrelated equipment such as GPS systems, gyrocompasses, etc. must be executed as redundant, but also that as a maximum only one of the diesel engines, couplings, gearboxes may fail due to electric or hydraulic failures, for example.

IHC and GeoSea have ingeniously solved this requirement by designing each engine/propeller combination as fully independent of the rest of the engine room systems. That means that for the rest of the engine room, redundancy is no
issue and in case of electric mains failure, the thrusters will still be available and controllable from the bridge.

To be independent of other engine room components, the engine/propeller combinations have been equipped with, for example, direct-engine driven or hydraulic auxiliary systems for propeller pitch and azimuth angle control, ventilation, cooling and lubrication, fuel supply and fuel return. In this way, the vessel could achieve ABS DP-2 classification as a MODU unit. ABS is the world’s principal classification bureau for jacking units and drilling platforms. MODU is a generic term for several classes of self-contained floatable or floating units such as jack-ups, semisubmersibles and submersibles.

During operations, the NEPTUNE does not need any assistance from propelled vessels for positioning herself in the correct working area. The DP system and the azimuth thrusters are able to position the platform, after which the legs can be lowered to the sea floor. In shallow waters, where the thrusters are less effective, additional positioning capacity can be delivered by four hydraulic mooring winches with a maximum pulling force of 450kNm, mounted on top of the jack houses. A CCTV system provides a direct view on these winches from the wheelhouse.

Cooling water provision: the generator sets for power provision to the jack-up system, the crane, HVAC and other auxiliary systems are too large for the usual air-cooled diesel engines, they have to be water-cooled. A clever solution has been developed for the cases in which the NEPTUNE is elevated from the water. This consists of a system of buffer tanks, hose reels and submersible pumps. The latter are automatically suspended from the main deck as soon as the vessel loses contact with the water and can provide unrestricted cooling capacity up to the NEPTUNE’s main deck elevating up to 25m above sea water level.

Crane rest: the 600mT pedestal-mounted fully revolving crane from Huisman Equipment, located forward of the starboard aft jack-house, delivers a main hoist capability of 600mT at 26m of outreach. This wind turbine installation crane consequently has a main hoisting boom of 85m in length. Of course, it considerably protrudes from the NEPTUNE’s bow and must be supported during sailing.

As a challenge, the boom rest had to be positioned around the beam’s centre of gravity with all its consequences for dynamic forces, oscillations and fatigue behaviour. It has been solved by a boom rest, some pre-tension on the main hoist and a ‘garage’ for the hoisting blocks, which is integrated in the boom itself (figure 6).

First operations and perspective
NEPTUNE has already proven her efficiency on the Thornton Bank project (figures 7 and 8). A complete cycle of loading a turbine, sailing to the offshore location under own propulsion, and mounting the complete turbine and sailing back to Ostend fitted well within budget duration targets. These results are promising for the subsequent works in, amongst others, the German North Sea and the Baltic Sea. The comments in industry periodicals have been equally positive: “The Neptune will leave a definite mark as crucial renewable energy enabler within the frame of the European renewable energy commitment.” [2, 3].

References

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**Principal characteristics NEPTUNE**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Builder</td>
<td>IHC Offshore &amp; Marine</td>
</tr>
<tr>
<td>Owner</td>
<td>GeoSea, member of DEME Group</td>
</tr>
<tr>
<td>Classifications</td>
<td>American Bureau of Shipping (ABS) A1, Self-elevating Unit + ABS - AMS - DP-2 + ABCU, Self-propelled under MODU</td>
</tr>
<tr>
<td>Length overall (hull)</td>
<td>60m</td>
</tr>
<tr>
<td>Breadth</td>
<td>48m</td>
</tr>
<tr>
<td>Depth</td>
<td>6m</td>
</tr>
<tr>
<td>Design operational draught</td>
<td>3.5m</td>
</tr>
<tr>
<td>Operational water depth</td>
<td>4.45m</td>
</tr>
<tr>
<td>Jacking legs</td>
<td>4 pcs. Ø1.5x80m (Ø2m)</td>
</tr>
<tr>
<td>Jacking preload capacity</td>
<td>2,750mT</td>
</tr>
<tr>
<td>Jacking speed maximum</td>
<td>0.7m/min</td>
</tr>
<tr>
<td>SWL wind turbine installation crane</td>
<td>600mT @ 26m</td>
</tr>
<tr>
<td>SWL auxiliary crane</td>
<td>10mT @ 25m</td>
</tr>
<tr>
<td>Main deck</td>
<td>1,600m², max allowed load 13m²/m²</td>
</tr>
<tr>
<td>Helideck preparation</td>
<td>Suitable for Super Puma or equivalent</td>
</tr>
<tr>
<td>Total installed power</td>
<td>8,962 kW</td>
</tr>
<tr>
<td>Accommodation</td>
<td>60 people, including all usual facilities</td>
</tr>
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