Design criteria for an offshore wind farm installation jack-up

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The global search for cleaner energy sources has led to increasing support for offshore wind farm installations. This development has significant implications for the marine industry, as discussed in this article.
The recent emergence of offshore wind farming as a new maritime industry is something to which the traditional shipping and shipbuilding industries, and especially the offshore sector, are having to adjust. Past attempts of designers to deal with the particular challenges of this new reality were not taken overly seriously. However, in light of the intensifying worldwide debate on global warming and CO₂ emissions, governments around the world are showing genuine interest, and are giving concrete support to the new offshore wind industry.

In Europe, an initiative to subsidize offshore wind projects with approximately EUR 4 billion has been launched by the European Union. Leading European utilities engaged in eight offshore wind projects during 2009, providing a combined output of more than 0.5 GW. In 2010, according to the European Wind Energy Association (EWEA), ten more offshore wind farms with an aggregate output of 1 GW will be built. In the USA, investments in this new industry have also started. In June 2009, four offshore wind park projects off the coasts of New Jersey and Delaware, with a combined output exceeding 1 GW, received regulatory approval.

It is not the innovativeness of wind turbine designers alone that is opening the door for this impressive growth in offshore wind harnessing activities. Rather, it is the combined innovative efforts by designers of virtually all the equipment used in the offshore wind value chain. This includes the designers of specialized vessels to install wind turbines, tailored feeder vessels to supply wind turbine components to installation vessels, and dedicated vessels required to operate and maintain offshore wind farms.

Wärtsilä and its Hamburg-based partner IMS Ingenieurgesellschaft, kicked off the development of a new generation of offshore wind farm installation vessels in late 2007. This resulted in a crane jack-up tailored to, and optimized for, the installation of the next generation of offshore wind turbines that can be operated all year round. Two years later, RWE Innogy, the renewables arm of the utility RWE, ordered two Wärtsilä/IMS designed jack-ups from the South Korean shipyard Daewoo Shipbuilding & Marine Engineering (DSME).

At first glance, the Wärtsilä/IMS offshore wind farm installation jack-up is an ugly square metal box with legs and a crane. However, the beauty of the design lays under its skin in solutions that perfectly match the operating requirements with the technical possibilities. Notably, the jack-up is no larger than necessary, no heavier than necessary, and also no more complicated than necessary. This represents precisely the competitive edge of innovative, high-end Western European design in these days of global competition.

The design process started with the definition of some crucial main particulars, such as crane capacity and dimensions, followed from the dimensions and weights of the latest generation of 6 MW offshore wind turbines, which were just on the drawing board at that stage.

As a next step in the design process, different ship concepts were evaluated, ranging from mono- and multi-hull solutions to semi-submersible concepts (see Figure 1). Taking also building costs into account, the box-shaped jack-up was decided upon.

![Fig. 1 – Types of mobile offshore units for wind turbine installation and maintenance.](image-url)
Fig. 3 – FE analysis of hull and legs / leg wells in selected areas.

Displacement
STEP = 1
SUB = 6
TIME = 1
DMX = 16.51

Fig. 2 – 3D structure drawing of the hull.

NODAL SOLUTION
STEP = 1
SUB = 4
TIME = 1
SEQV (AVG)
BOTTOM
DMX = 1223
SMN = .647703
SMX = 2779
From there, the design process continued with the basic geometry of the jack-up’s steel structure, with its compartments and its longitudinal and transverse subdivisions. While detailing this steel structure, “keeping things light” was the overriding philosophy, with girders and openings rather than solid steel walls (see Figure 2).

Then, in several loops, the steel structures were dimensioned according to the results of numerous finite element analyses of the complete vessel with legs. Various other details, like the crane foundation, the leg wells, and of course the legs themselves, also were assessed (Figure 3). In this way, the vessel was designed to meet customer requirements within the bounds of all technical possibilities.

Since the Wärtsilä /IMS jack-up is designed for renewable energy installations, extra attention has been given to its energy efficiency. The USA’s EPA emission standards have been taken into account for the diesel generating sets. In order to push energy efficiency well above 50%, the waste heat from both the exhaust gases and the cooling water of the diesel generating sets is recovered (Figure 4).

The jack-up’s main particulars are impressive. The free deck surface almost matches the dimensions of a football field. Its’ crane can accurately position the nacelle of a latest generation 6 MW offshore wind turbine, with a weight of approximately 500 tonnes, at a height of 100 metres above the water surface, onto the wind turbine’s turret. The vessel’s jacking system can reliably raise 15,000 tons of steel, the vessel’s own weight and that of its cargo, 20 metres above the water surface at water depths of up to 45 metres.

Upon completion of the construction at DSME, the unit will be able to efficiently set up an offshore wind farm with some 80 wind turbines, including their foundations, in one season. This is substantially better than with a jack-up that is not tailored to the specific requirements of the offshore wind industry, and also substantially better than what can be achieved by today’s offshore wind farm installation jack-ups. ➔
This is primarily the result of correctly defining the jack-up’s operational envelope, i.e. its ability to cope with the conditions that can be expected to be encountered where offshore wind farms are likely to be located.

The jack-up is able to position itself in significant wave heights up to 2.5 metres. Tidal currents of up to 3 knots, which are not unusual in for example the Irish Sea, can be coped with. Once jacked-up, it is able to conduct installation work in significant wave heights of up to 5 metres and with wind forces of up to Beaufort 7.

Whilst today’s jack-ups can only work under relatively favourable wind, wave and current conditions during summer time, the Wärtsilä/IMS designed jack-up is capable of coping with nearly all weather conditions throughout the entire year.

The first of the two Wärtsilä/IMS offshore wind farm installation jack-ups is scheduled to be delivered from DSME in the middle of 2011, and the second one slightly later in 2011. From then on, the emerging offshore wind industry will finally have the tailored equipment it needs.