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Foundations for the Offshore Wind Industry

The Merits of *Jack-Up Platforms*

By Wally Lafferty

A new type of offshore wind foundation has emerged from the offshore oil fields and is rapidly gaining attention. It may be one of the most innovative and promising turbine foundation technologies to come along in years. It is certainly one of the most proven. **The venerable jack up platform is showing promise to be a leading contender in the Crown Estate's upcoming 3rd round of UK offshore wind projects.**

The jack up platform has been well proven for more than 60 years in the harshest of ocean environments. It has been known for its ability to lift a significant amount of weight – far more than would be required to lift the largest offshore turbines. Its unique design lifts the entire turbine and platform well above the waves, dramatically reducing many of the environmental loads.

Designed and produced specifically for the offshore wind industry by Offshore Wind Power Systems of Texas, LLC, the Titan 200 carries the design credibility earned by a team who has designed jack up platforms for offshore oil and gas fields for more than 30 years. The team's intimate familiarity with the IEC 16400-3 design and verification standards will ensure that industry certification of the Titan will be straight forward. Indeed, the American Bureau of Shipping has already issued a letter stating that they are prepared to provide classification and statutory certification for the Titan. ABS was responsible for certifying 95% of the world's operational jack up platforms.

THE TITAN

The Titan is an offshore jack up platform composed of a unique "Y" shaped hull with a diameter slightly smaller than the wind turbine's rotor, standing on three legs with a lifting system. Known as a Dutch Tri-floater design, the platform cannot overturn while being towed to the installation site – if any one arm begins to dip into the water, the other two arms push down to bring it back to horizontal. This inherent stabilizing feature makes the Titan an ideal platform to move tall heavy turbines around on the water.

The platform is towed to the installation site with the wind turbine already completely installed. Upon arrival, its legs are lowered and embedded into the seabed and its hull is elevated to provide a stable foundation capable of withstanding extraordinary environmental loads. A typical modern drilling jack up is capable of working in the worst storm conditions in the world with wave heights up to 80 ft, wind speeds in excess of 100 knots and in water depths up to 500 feet.

The Titan is specifically designed to lift the heaviest wind turbine in up to 300 feet of water. The installed platform will endure Category 5 storms and continue operation after the wind turbine has been inspected. The platform is able to hold a tolerance of 0.01 degree in the horizontal plane, which means that the wind turbine will remain within a 0.02 degree vertical tolerance during a storm. The hull is elevated to

allow storm waves as high as 60 feet to pass harmlessly beneath. The legs are pinned into the seabed at a sufficient depth to compensate for the overturning moment of its turbine load in wind speeds exceeding 40 meters per second (more than 83 knots). The Titan can be designed to meet all European and US offshore environmental conditions.

The natural frequencies of the Titan can be tuned in multiple ways, by shortening or lengthening the reach of the hull, there are even patented methods used to fine tune the natural frequency of the platform after installation if that becomes necessary.

DEPLOYMENT & INSTALLATION

The Titan can be assembled either on a dock or in a dry dock, depending on available boat yard capabilities near the wind farm construction site. After assembly and certification of the jack up platform, the turbine is fully erected on the hull. This makes construction of the Titan platform and turbine less costly since land-based equipment is all that is employed for final assembly.

If the system is completed inside a dry dock, then the dock is filled with water and the platform is floated to a nearby staging area where the system is jacked up and fully tested with convenient near-shore access. If the system is completed on a dock, the finished assembly will be moved on rails onto a launch barge and the barge will be submerged.

Once check out testing and certification is complete, the hull is lowered back into the water, the legs are raised, and the Titan is towed to the site. A tug boat is the only vessel required for deployment and installation.

Jack up platforms operate in three modes: transit from one location to another, jacking up or down, and elevated on its legs. Each mode has specific precautions and regulatory requirements to be followed to ensure smooth and safe operations.

The transit mode occurs when the platform and turbine are being moved from one location (the dock) to another (the site). The physics involved in moving jack up platforms under heavy loads is well understood, the turbine blades are positioned as "bunny ears" with one blade secured to the tower and the other two blades tethered to the platform. Though the legs of the platform must be raised to ensure clearance of the seabed during tow, the legs will be lowered as the water depth permits to lower the vertical center of gravity and reduce leg inertia loads due to tow motions.

As the platform arrives at its permanent location, preparations are made to begin the jacking up mode. Jacking occurs in stages where the soil density below the feet (spud cans) is closely monitored using parametric acoustic (echo sounding) transducers installed inside the bottom of each leg. Soil information and predicted penetration curves beneath the spud cans are calculated and understood before installation begins and is updated throughout the jacking operation.

When the Titan is precisely positioned, the legs are lowered to the sea floor where the spud cans penetrate the top layer of soil and begin to bear the load of the platform. The spud cans are designed to optimize soil penetration and allow the unit to be installed on uneven or sloping bottoms.

As increasing load is brought to bear on the soil, the legs continue to penetrate until the soil reaches maximum bearing pressure and the hull begins to lift. The legs and several ballast tanks inside the hull are then filled with sea water to increase the weight of the platform well beyond the maximum loads of the operational system.

As the weight of the platform continues to increase with added ballast and the legs continue penetrating deeper into the soil, the hull is never allowed to raise more than a couple of feet above the natural buoyant state of the hull. If a leg encounters a "punch through", where the leg suddenly penetrates a layer of soft soil or an underground cavity, the risk to the platform and turbine are minimized as the hull's own buoyancy will compensate and absorb the sudden shift. If a leg encounters an obstacle, such as a boulder, the legs can be retracted, the platform can be rotated or moved, and the process can begin again.

Once the soil's maximum bearing pressure is again reached under the additional weight of the platform with its full ballast, the legs reach their maximum penetration depth and the system is considered to be anchored sufficiently to overcome all maximum operational loads. At this point all the ballast water is discharged. The platform can then be jacked up to its operational height above the water, leaving an air gap underneath the platform of about 60 feet. The platform is lifted higher than the highest recorded storm wave for the location. Throughout the jacking process, each leg is controlled separately to ensure that the hull

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remains level at all times during the lift.

Upon completion of the jacking mode, the system is secured in the elevated mode for operation. The jacking system is stopped, the brakes are set, and the leg locking system is engaged. The cabling is brought on board using an industry standard J-tube installed in one of the legs.

Since the water has been removed from inside the legs, the J-tube and cable splice remain fully man-accessible. All operational systems are thoroughly checked out before the turbine blades are un-tethered and released.

The jacking system and echo sounding equipment are removed and put back on the boat to be returned and used on the next installation. In the event the legs settle further into the soil over time, the jacking system can be reinstalled and the platform leveled.

THE LIFTING SYSTEM

The Titan's patented lifting jacks are designed to be removed and reused on other platforms. Therefore, only one or two sets of jacks (leased to the developer) are required for installation of the wind farm. After completion of the wind farm, it will only be necessary to retain one set of lifting jacks for long term maintenance of the site.

DIMENSIONS

The Titan platform is structurally designed to carry significant loads under extreme conditions.

The structural integrity of the platform is carried through the plates of the steel hull with load bearing members placed inside at spaced intervals. The legs are designed with cross members spaced inside the leg from top to bottom. These cross members resist deformation of the leg so the lifting jacks always remain in position for the lifting pinions. The height of the legs is determined by the water depth of the site.

DOCK SIDE ASSEMBLY

Final assembly of the Titan is performed in a boat yard closest to the location of the wind farm. This work includes integration of all subsystem components, assembly of the platform, and test and verification. The Titan is fully certified prior to installation of the wind turbine, which also occurs on the dock.

All of this assembly work provides jobs for the local community.

Wind turbines up to 10 MW can be accommodated in the current Titan design. The turbine is assembled on the hull and fully erected before the system is floated. Thus, all construction is performed using land-based lifting equipment.

ENVIRONMENTAL IMPACT

The Titan presents the lowest environmental impact of any offshore foundation.

No seabed preparation is required. No mooring lines are used that could introduce an unwanted hazard to whales or other migratory sea life. There are no piles, so decommissioning leaves no steel embedded in or lying about on the sea floor.

There will be no underwater cutting or demolition. There is no need for concrete on the sea floor, so no cleanup will be required.

COST ADVANTAGES

When the Titan was submitted to the UK Carbon Trust as a contender for Round 3, the economics showed it to be very favorable. The cost per megawatt based on a 5 MW turbine in 35-45 meters of water falls well

within the range of the Carbon Trust's goal for innovative and affordable solutions ($0.8 M USD/MW).

There are several comparative cost drivers that should be examined that demonstrate a solid business case for the Titan. These include lower installation costs, shorter project timelines, reduced liability insurance, elimination of preparation and stabilizing materials, fewer decommissioning expenses, the ability to make repairs, and competitive fabrication costs. Installation of the Titan and wind turbine can be completed without the need for expensive specialized vessels. A standard service vessel may be employed to tow, carry supplies, parts, and personnel back and forth. The elimination of all specialized construction vessels represents a significant cost savings to the project. The Titan's ability to take on ballast and lower its legs during towing and jacking operations – thereby lowering the center of gravity and extending the metacentric height of the platform and turbine –makes the platform more stable in higher winds and waves. This opens the acceptable installation weather window significantly, thus shortening project timelines.

In the event of serious storm or ship damages to the platform or a gearbox or generator needs to be replaced, the Titan can be brought back to the dock for repairs; jacket and monopile foundations cannot, and the maintenance work can be performed using land-based equipment.

The delivered, uninstalled cost of the Titan appears to fall below the cost of a delivered, uninstalled jacket foundation designed to carry similar loads (if you include the weight of the jacket's four steel piles and the transition top piece). Fabrication of the Titan for a 3.6 MW turbine uses roughly 1,400 tons of steel.

The Titan's weight for a 5 MW turbine only increases slightly to 1,800 tons, and for a 10 MW turbine the weight rises to only 2,000 tons. This puts the Titan at around $4M USD installed for a 5 MW turbine in 40 meters of water.

These figures assume that the Titan platforms are shipped 20 at a time. Project delivery windows will vary, but it is easily conceivable to ship as many as 20 foundations every 45 days.

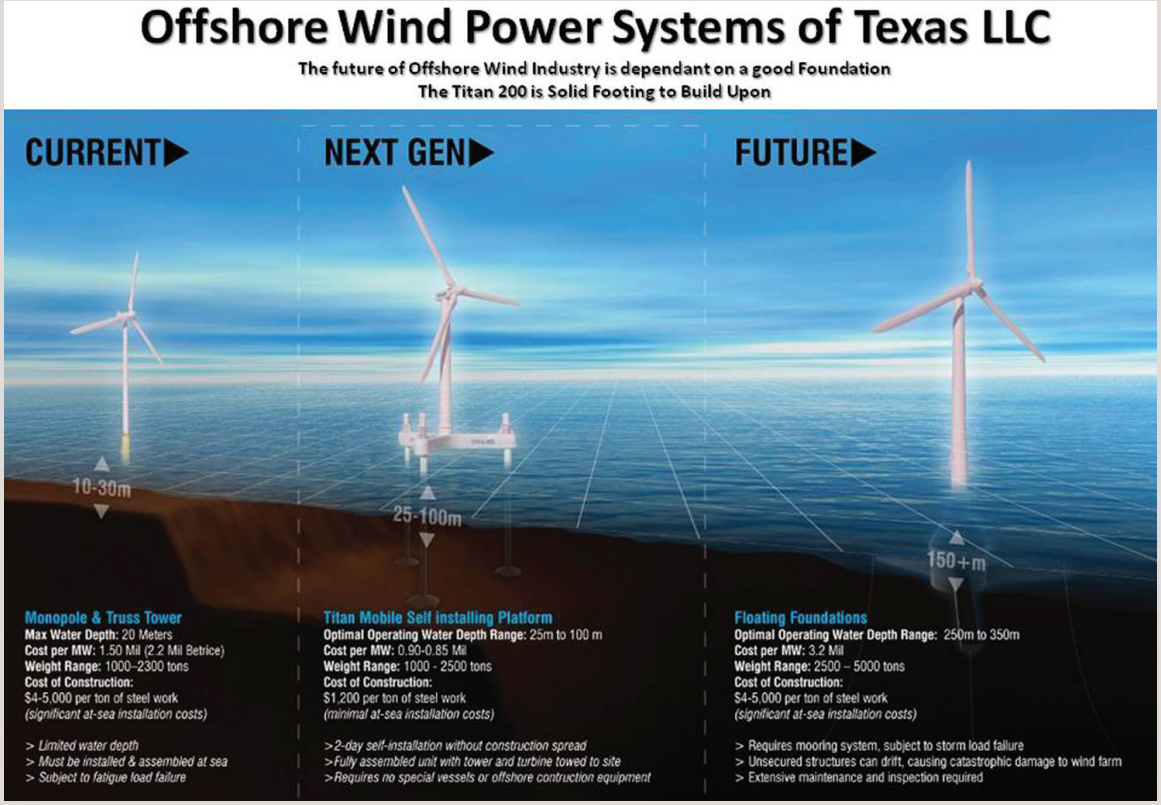
There is one more cost advantage that should be mentioned, the developer can use the Titan to his advantage in two ways. First, he can purchase a Titan platform designed for the turbine he intends

to install later. He can install the met mast on the platform and use it to take wind measurements for a year. After the wind measurement task is completed, he can bring the Titan back to the dock, remove the met mast from the platform and replace it with a turbine, recovering the cost he would have otherwise spent on a met mast foundation. The Titan is flexible enough to accommodate such a change.

SUMMARY

The Titan provides an exciting opportunity to change the game for offshore wind farms and investors. The advantages are plentiful, and the technology itself is very mature. And don't underestimate the importance of mature regulatory statutes already in place for platforms such as these, as this helps to minimize the investment risk to the project.

The highest cost drivers on other foundations are more difficult to estimate due to the unpredictable nature of the weather. But the Titan eliminates the cost of over-the-water construction equipment and their associated liability insurance costs, and reduces the unpredictable cost of paying for equipment while waiting for the weather to improve.



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