Examining the merits of jack up platforms as foundations for the offshore wind industry

By Wally Lafferty

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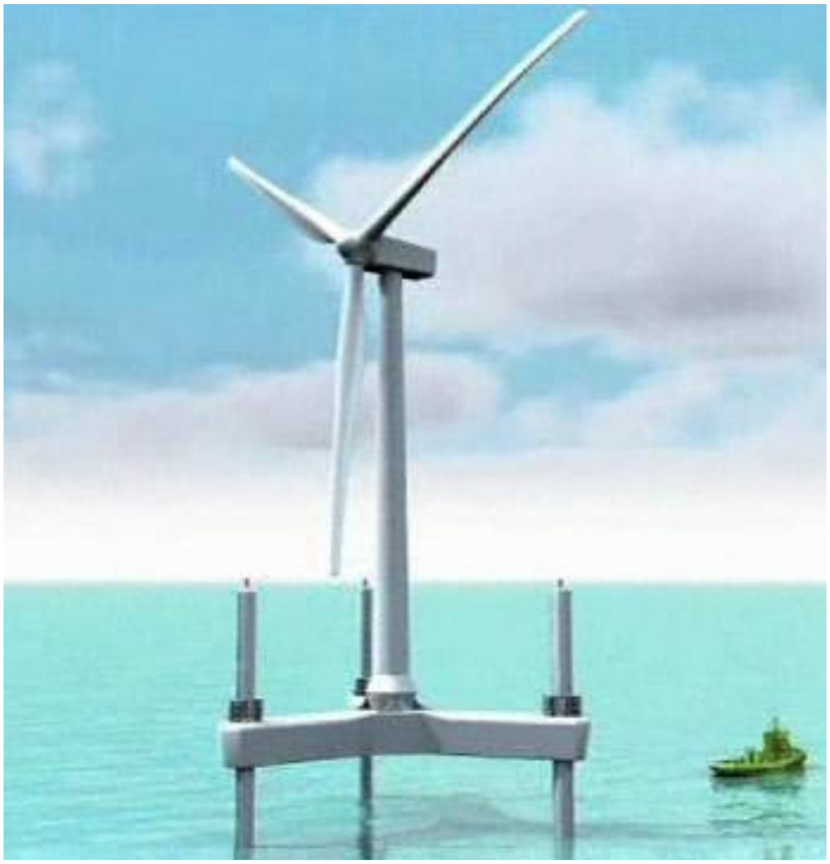


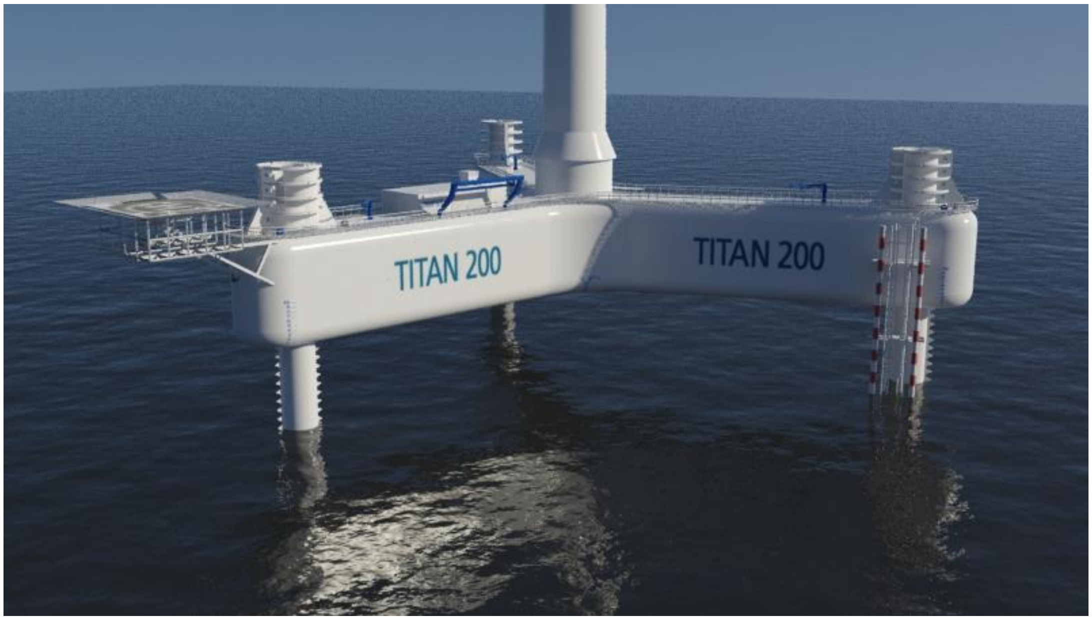
ABSTRACT

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 over 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 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.

This white paper will explore the key features and benefits of the wind turbine jack up platform and explain why the Titan may very well out perform other more familiar technologies in upcoming wind farm construction projects on the merits of technology, project planning and cost.



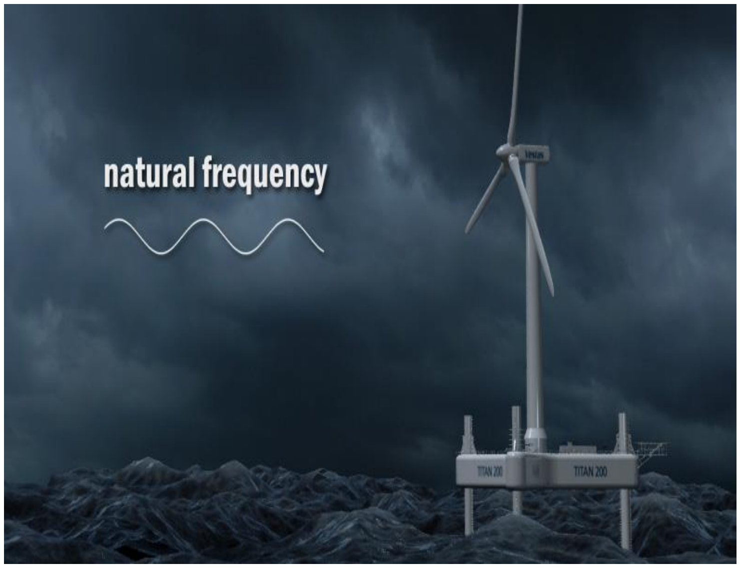
THE TITAN

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 – 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, by adding thickness to the hull plates, or by adjusting the height of the legs or making them thicker. There are even methods used to fine tune the natural frequency of the platform after installation if that becomes necessary.



DEPLOYMENT AND INSTALLATION

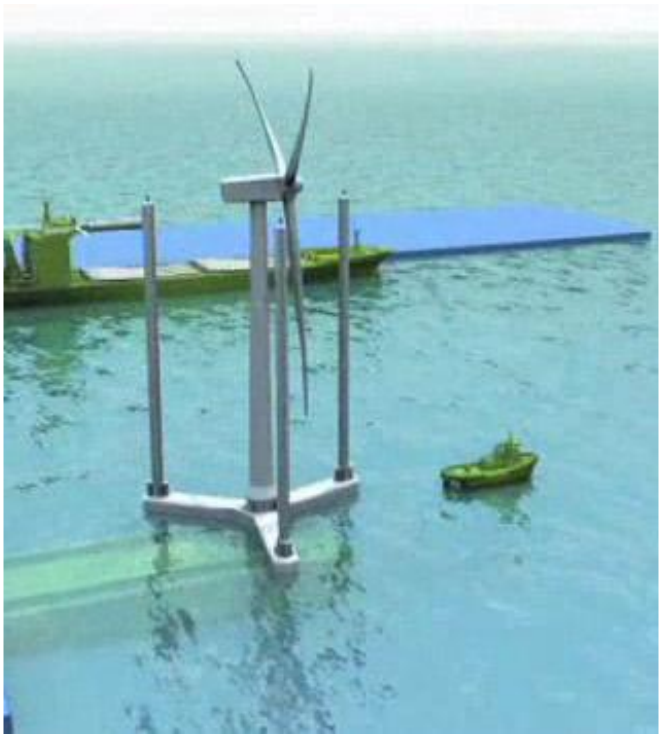
The Titan can be assembled either on a dock or in a dry dock, depending on available boat yard capabilities near the wind farm construction site. After assembly and certification of the jack up platform, the turbine is fully erected on the hull. This makes construction of the Titan platform and turbine 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 barge and the barge will be submerged. The Titan will float off the barge and can be moved to the check out staging area.

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 and industry regulations already exist for the conditions and loads involved. Main precautions for this mode address monitoring the weather forecasts, calculating pitch and roll angle at all oscillation periods, calculating heave accelerations, and studying the inertia loads anticipated during the tow. Physical precautions include support of the legs, watertight integrity of the platform, and stowage of cargo. Turbine blades and other operational gear are secured to prevent shifting or movement while under tow.



For transit, 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. This will also increase stability to compensate for waves and wind overturning moment. As the tow to site may take some period of time (from hours to days), the weather forecast will play a factor in how the system and cargo are configured for towing.

As the platform arrives at its permanent location, preparations are made to begin the jacking up mode. Wedges are removed from the leg guides, the jacking system is rechecked, ballast tanks and pumps are prepared to take sea water and temporary protection and securing devices are removed.

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. Once jacking is completed, this equipment is removed to be reused for installation of other platforms, saving cost in construction. Current, wave, and wind loads are also closely monitored.

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. No seabed preparation is required prior to installation.

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. At this point the soil has taken as much penetration as the dry weight of the platform will provide. 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. This added weight serves to drive the legs further into the soil, pinning the platform firmly into the seabed.

As the legs continue penetrating deeper into the soil and the weight of the platform continues to increase with added ballast, 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 the ballast water is discharged and the sea water inside the legs is evacuated. 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 that area. Throughout the jacking process, each leg is controlled separately to ensure that the hull 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. This standard maintenance procedure can be performed as often as necessary, although industry experience in the offshore oil fields has demonstrated that it’s a rare occurrence.

THE LIFTING SYSTEM

The Titan uses a well proven lifting jack system, one on each leg, each independently controlled. The legs are guided through the hull by a set of upper and lower vibration dampening guide bearings. Depending on the size and weight of the turbine, one or more intermediate guides may also be installed in the leg well. These guides maintain the position of the jacks to the lifting racks on each leg and prevent the lifting apparatus from transferring unwanted loads to the hull. The guides push against wear plates that can be replaced on site if it ever becomes necessary.

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

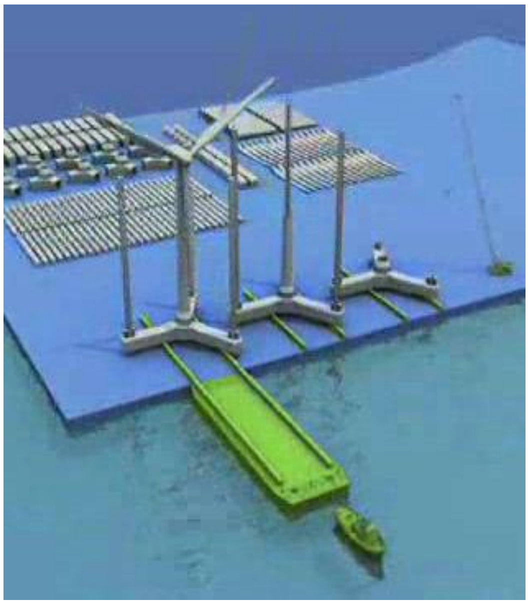
The Titan platform is structurally designed to carry significant loads under extreme conditions. Each arm of the hull extends 120-128 feet from the center, depending on the scale of the turbine. The arms are 21 feet in width and 22 feet in height.

The structural integrity of the platform is carried through the plates of the steel hull with load bearing members placed inside at intervals of 20 feet. This allows considerable open space inside the hull for ballast tanks, equipment rooms, a control room, crew quarters, and other uses.

The legs are 12 feet in diameter 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. The legs are not made to be longer than necessary.

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 sub-system 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.

The turbine manufacturer can also take advantage of space inside the Titan's hull to install sensitive electronics and electrical equipment (e.g., transformer, cooling systems, power electronics, controller, SCADA, etc.) in a clean environmentally controlled chamber. This will reduce O&M costs for the turbine equipment as these systems operate without daily exposure to spray and salt air. It is even possible to install the wind farm's operations center inside one of these platforms. Efficient use of the spaces inside the hull also helps to lower the vertical center of gravity and further reduce overturning moment on the system.

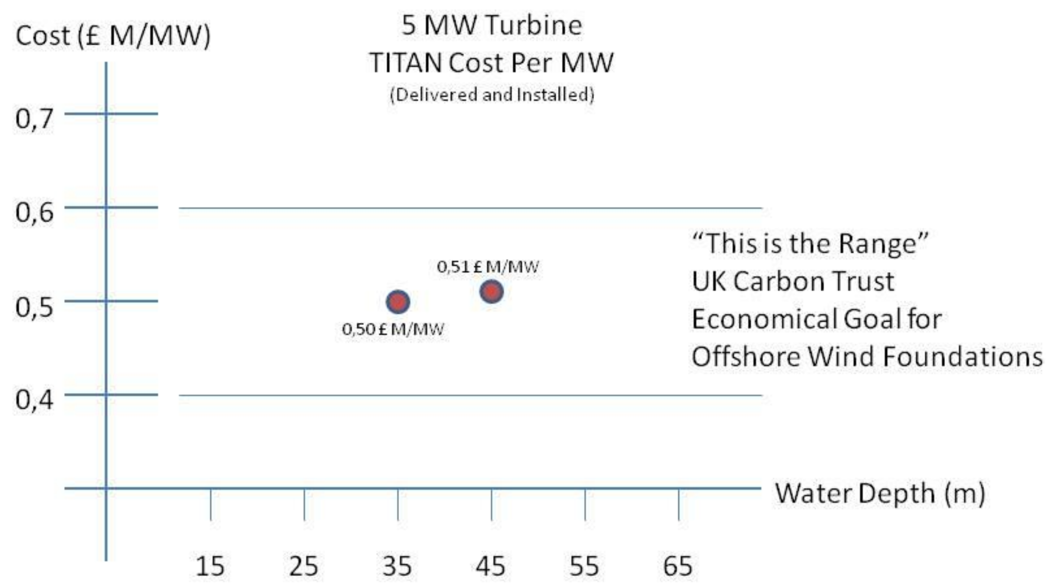
ENVIRONMENTAL IMPACT

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.

Removal requires that all systems and components be secured as they were during the earlier transit mode. The platform is jacked down to its buoyant position. Sea water is used to blast the soil away from the embedded legs and the spud cans and the legs are raised. Once the Titan is removed, there is no residual evidence that the Titan was there and the seabed returns to its pristine natural condition.

COST ADVANTAGES

When the Titan was submitted to the UK Carbon Trust as a contender for Round 3, the economics showed to be very favorable. As the following figure illustrates, 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.



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.

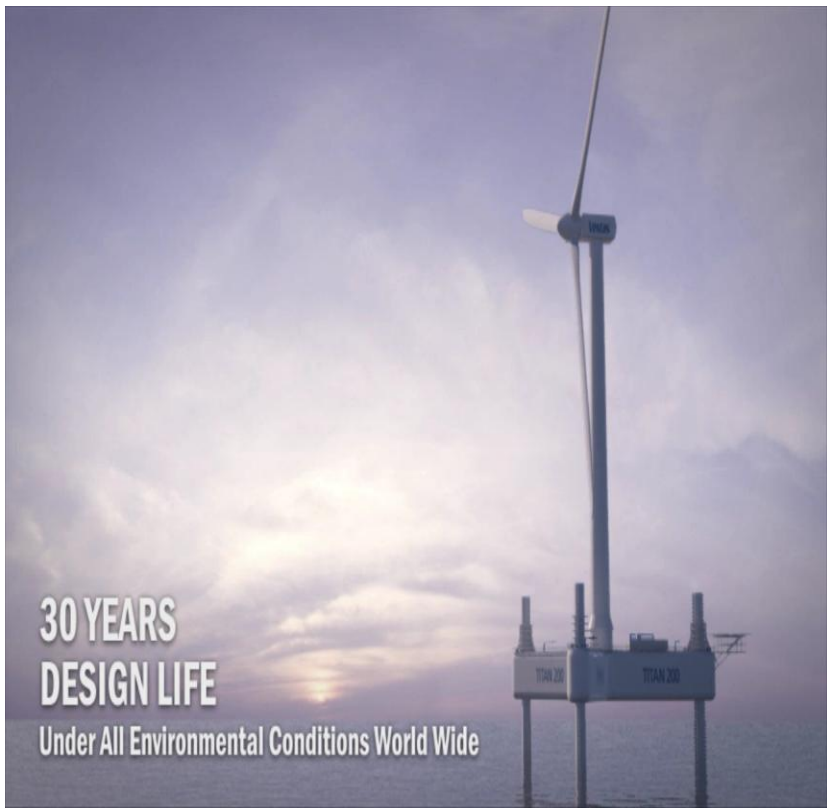
Installation of the Titan and wind turbine can be completed without the need for expensive specialized vessels. A tug boat is used to tow the Titan and wind turbine to its location in the wind farm. A standard service vessel may be employed to carry supplies, parts, and personnel back and forth. But the elimination of all specialized construction vessels represents a significant cost savings to the project.

The ability to lower the center of gravity of the platform and turbine system during towing and jacking operations opens the acceptable installation weather window significantly, thereby shortening project timelines. Where tall over-the-water crane vessels can operate in only a very narrow acceptable weather window, the self-installing Titan can manage with a much wider acceptable range of wind speeds and wave heights.

The elimination of high over-the-water construction will result in lower liability insurance costs for the project. Insurance on hazardous specialized vessels and construction crews is not needed.

Installation of the Titan does not require the use of offshore concrete or aggregates to stabilize the foundation. Transportation and costs for such materials are eliminated.

Decommissioning and removal of the Titan is simple and requires no expensive clean up effort.



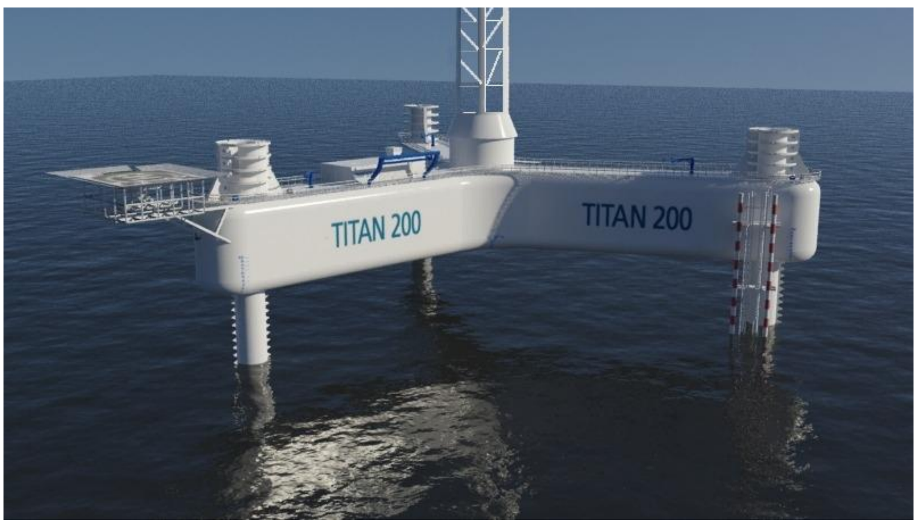
In the event of serious storm or ship damages to the platform, the Titan can be brought back to the dock for repairs; jacket and monopile foundations cannot, as they must be scrapped and replaced. Likewise, in the event a gearbox or generator needs to be replaced inside the turbine, the Titan can be brought back to the dock using a single tug vessel 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. The small difference in the Titan's structural weight is the result of only a minor extension to the length of the hull's reach. With fabrication rates in Southeast Asia currently at around $1,500 USD per ton, the Titan compares in delivered cost alone very favorably to other foundation technologies. 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 as it reflects the truly innovative nature of a platform as flexible as the Titan. All wind farms will require a period of time before construction begins for taking wind measurements. This is usually done offshore by installing a meteorological measurement tower (known as a met mast). The met mast will take wind measurements for a minimum of a full year so the developer can better quantify the predicted energy yield of the wind resources at the site throughout the seasons.

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.



Another option is that the developer can install a meteorological measurement system on a Titan platform and reuse it from project to project. This approach allows the developer to amortize the cost of the wind measurement system over multiple projects. It is also possible for the developer to lease the complete Titan Wind Measurement Platform System from Offshore Wind Power Systems of Texas, paying only for the period of its use.

The Titan Wind Measurement Platform System is designed to carry a retractable met mast that reaches to 200 meters above the water. The tower is secured with guy wires attached at the end of each arm of the hull. The measurement instruments are placed at regular intervals and will take measurements to the maximum height of the turbine's rotor.

The Titan Wind Measurement System can be powered by undersea cables or it can be self powered. The Titan can carry a combination of photovoltaic solar energy cells, a small wind turbine, and a diesel generator to produce power for the electronics. Measurement data and system faults can be recorded on board, sent to an onshore receiving station by cable, or a broadband radio can transmit data to a receiver on shore.

Additionally, the Titan can be fitted with a wave measurement instrument that will record wave heights throughout the measurement period.

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.

To recap, these are some of the key advantages that are unique to the Titan.

- The platform hull and turbine are elevated on its legs well above the waves, significantly reducing environmental loads on the platform structure. Severe waves and storm troughs pass harmlessly beneath the platform.
- The legs of the jack up platform are designed to embed themselves deep into the seafloor, pinning the structure solidly to the earth and compensating for the most extreme overturning moment.
- The entire system comprised of the jack up platform, the turbine, and all auxiliary equipment, is installed and fully tested dock side, using less expensive land-based equipment.
- The fully tested and certified system is floated and towed out to the site where installation is completed in as few as 1-2 days with an additional day needed to connect cabling.
- The jack up platform is self-installing, requiring no expensive specialized construction vessels.
- Since specialized vessels are not required, and no over-the-water construction will be performed, the weather window for installation is much greater, enabling a better project timeline.
- Having eliminated over-the-water construction, the Titan presents the lowest risk to personnel safety in the offshore construction environment, resulting in lower project liability insurance costs.
- The hull of the jack up platform can be configured to house maintenance crews and equipment.
- There is sufficient space inside the hull of the jack up platform to house the turbine's sensitive electronics and electrical equipment (e.g., transformer, cooling systems, power electronics, controller, SCADA, etc.) in a clean weather-protected chamber, improving long-term operational maintenance costs.

- Utilization of space inside the hull lowers the vertical center of gravity and overturning loads on the system. There is sufficient space inside the hull to create quarters for maintenance personnel, rooms for equipment and storage, and a control room.
- Replacement of large heavy components (e.g., gearboxes or generators) can be performed less expensively by towing the system back to the dock and conducting the repairs on land.
- In the event of serious storm or ship damages to the platform, the Titan can be taken back to the boat yard where repairs can be performed on the dock.
- Leveling adjustments to the platform can be performed as frequently as necessary.
- No seabed preparation is required. Uneven or sloping seafloors are acceptable.
- The Titan presents the lowest environmental impact of any offshore foundation, leaving no steel or concrete to clean up.
- Boarding the jack up platform can be accomplished by boat using a ladder or crane/lift, or by helicopter landing platform.
- The jacking system and echo sounders can be removed and reused on other platforms, saving a significant amount of cost for installation and maintenance.
- The Titan's 30-year design life is the longest in the industry.

About the author

Wally Lafferty is the former Vice President and Managing Director for Vestas Wind Systems, responsible for Technology R&D in North America. He is a member of Offshore Wind Professionals and a contributor to the Wind Power Expert Network. He currently consults with offshore wind companies globally from his location in Houston, Texas. Wally also writes a blog, A Sustainability Minute which you can find at asustainabilityminute.com. For further information about this article, Wally can be reached at wally.lafferty@yahoo.com.

About Offshore Wind Power Systems of Texas LLC.

The company was formed to leverage experience in offshore oil field technology gained over the last 30 years. This, combined with extensive knowledge of energy projects in the US, Asia and Europe, has allowed the company to pursue opportunities in the development of a business element for offshore wind farms. OWPST's newly patented Titan Wind Turbine Platform (US Pat. 7163355 & several Intl. Patents for Mobile Wind-Driven Electric Generating Systems and Methods) was designed to solve the deepwater dilemma for wind turbines. Questions may be forwarded to: Sales@offshorewindpowersystemsoftexas.com

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