TITAN 200 OFFSHORE SUBSTRUCTURE FOR WIND TURBINES

OFFSHORE SOLUTIONS UNLIMITED

Exploring the Project and Cost Benefits

Offshore wind farms are becoming increasingly more difficult to install – employing larger wind turbines, moving into deeper water and penetrating irregularly contoured and rocky sea beds with variable to no soil cover while having to address ever more demanding statutory regulations. It's a simple fact that larger wind turbines lead to higher loads requiring deeper and heavier foundations. Yet, as foundations become larger, the increasing cost and the difficulty of logistics are making it harder for investors to justify. To reduce the cost of offshore wind farm installations, a wind turbine substructure is needed that will provide significant cost reductions and project benefits over today's conventional tubular steel monopiles and cross-member jackets.

The turbine substructures account for more than 25 percent of the material, engineering and construction cost of the project. With installation projects costing hundreds of millions EUR/USD, reducing the cost of substructures and installations must take center stage.

Fortunately, the extreme environmental and load demands experienced in the offshore oil fields have already driven the development of qualified solutions to many of the new challenges facing offshore wind. After many decades of experience in extreme ocean environments, oil field solutions have steadily improved and the costs have been well optimized. Yet, to date, the offshore wind industry has been slow to adapt the technical and economic advantages that are being employed in offshore oil substructure technology.

The offshore oil industry long ago chose the jack-up as the platform-of-choice to support the heaviest loads in the harshest ocean environments in the world. The jack-up has been known to carry loads that are far greater than any of today's largest offshore wind turbines. Its unique design elevates the entire substructure well above the waves reducing many of the hydrodynamic loads that wreck havoc on conventional wind turbine foundations.

The Titan 200 is a jack-up substructure designed specifically for the offshore wind industry by Dallas-based Offshore Wind Power Systems of Texas, LLC. The Titan 200 carries the design credibility earned by a team of professional structural marine engineers who have successfully designed these solutions for more than 30 years.

The design team's long and intimate familiarity with offshore engineering standards means the Titan's certification is ensured. Indeed, the American Bureau of Shipping, who has certified 95 percent of the world's operational jack-up platforms, has issued a letter of commitment stating that they are prepared to provide classification and statutory certification for the Titan.

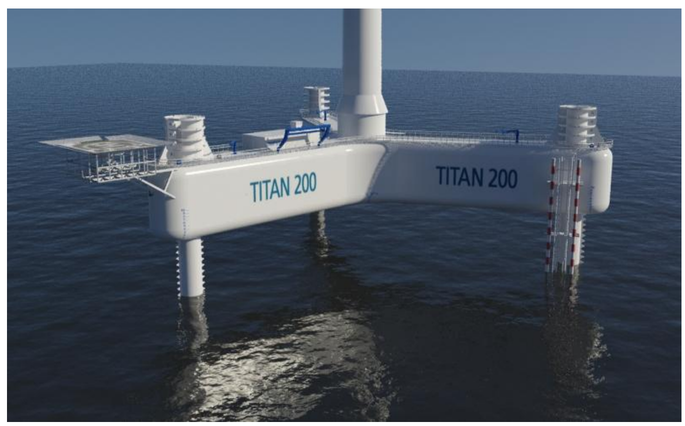
This report will explore at a high level the key advantages of the Titan 200 jack-up substructure for wind turbines. While specific cost estimates are not possible without specific project data, we will examine as far as we can the lifecycle project and cost advantages. Conventional foundations will be mentioned throughout the report to provide a comparison.

Titan 200 Offshore Substructure for Wind Turbines

EXPLORING THE PROJECT AND COST BENEFITS

INTRODUCING THE TITAN 200

The Titan 200 is an offshore jack-up substructure composed of a unique "Y" shaped hull with a horizontal radial "footprint" diameter slightly smaller than the radial diameter of the wind turbine's rotor. The Titan and wind turbine are fully assembled on land and then towed to the installation site eliminating the need for expensive offshore construction. Once the Titan arrives at the location where it is to be installed, the hull and turbine are raised together to stand on three legs using a jacking system capable of lifting the entire system well above the surface of the water. Once installed, the lifting system is removed from the substructure and used again on the next turbine installation.



Known as a Dutch Tri-floater design, the substructure cannot overturn while being towed to the installation site – if any arm of the hull begins to sink into the water, the weight of the other two arms bring the platform instantly back to horizontal. This inherent stabilizing feature makes the Titan an ideal substructure to move tall and load-sensitive turbines to their installation site.

Upon arrival at the installation site, the retracted legs of the Titan are lowered and embedded into the seabed and its hull is elevated to create up to a 25-meter air gap beneath the structure. The unique independently adjusting legs can be fitted with a variety of footings to accommodate a wide range of irregular sea floor contour, soil and rock conditions and will even stand securely on exposed bedrock. The Titan usually requires no advanced seabed preparation, using no concrete or aggregates.

Once installed and operational, the Titan is designed to withstand the worst storm conditions in the world with wave heights greater than 25 meters, water depths from 20 to 80 meters and Category 5 wind speeds gusting to more than 80 meters per second. The substructure is able to hold a tolerance of 0.01 degree in the horizontal plane keeping the wind turbine within a 0.02 degree vertical tolerance during a storm.

THE LEVELIZED COST OF ENERGY

Offshore wind is considered to be more costly per unit of energy than all other low-carbon energy technologies. With the levelized cost of energy (LCOE) for offshore wind doubling during the three-year period from 2006 to 2009 and continuing in an upward trend, many investors have shied away from long-term commitments to offshore wind. This has resulted in a considerable shortage of available financing for the offshore wind projects that are necessary to meet European renewable energy targets.

With this in mind, it is extremely important to lower the LCOE for offshore wind projects in every way that can have a significant impact. There are two areas where the Titan will have a significant positive impact on LCOE. First is by reducing the life cycle cost of the project from the earliest phase of installation all the way to end-of-life decommissioning. Second is by providing opportunities to increase the power output and capacity factor of offshore wind turbines in ways that are not achievable with other conventional foundations.

REDUCING THE COST OF THE PROJECT

There are several key areas where the LCOE of an offshore wind farm can be reduced by the Titan to improve the investment return. While there is some cost savings in the fabrication and manufacturing of the Titan compared to other conventional foundations, the most significant cost reductions are associated with the wind turbine, installation, project management, insurance and surety bonding.

Table 1 includes the U.S. Department of Energy's estimation (2013) of the significant project elements that contribute to the total LCOE for offshore wind. As the table illustrates, the DoE estimates that wind turbines contribute 32 percent of the total cost of energy over the wind farm's lifetime. The Titan substructure, due to the unique opportunities it provides to wind turbine manufacturers, can reduce the turbine's lifetime cost to the project by approximately 3 to 5 percent.

Table 1: Project elements that substantially contribute to LCOE for offshore wind and estimated reduction of lifetime costs using the Titan. Areas where LCOE are significantly impacted by the Titan are checked.

Elements that substantially contribute to LCOE	Contribution to total LCOE	Estimated reduction of lifetime cost using Titan substructure
Wind Turbines ✔	32%	~3-5%
Development	1%	-
Substructure ✔	18%	~1-3%
Project management ✔	2%	~20%
Port and staging	1%	-
Electrical infrastructure	10%	-
Assembly, transport and install ✔	20%	~6-10%
Insurance ✔	2%	~50%
Surety bond ✔	3%	~60%
Contingency	8%	-
Construction finance	3%	-

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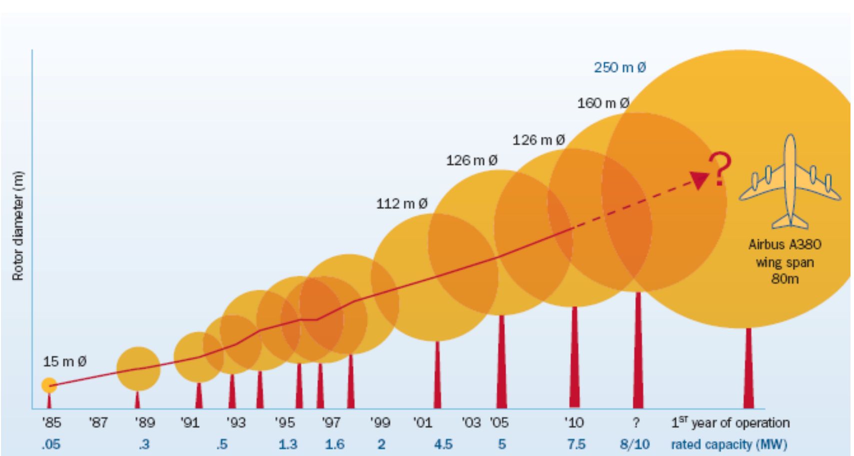
LCOE IMPROVEMENT - WIND TURBINES

The Titan substructure offers a unique opportunity for wind turbine manufacturers to increase the rated power output and capacity factor of their turbine. First, by allowing the turbine manufacturer to relocate many components to inside the Titan's hull, significantly reducing the weight of the turbine, the OEM may design a future turbine for a larger rotor and drive train to increase the turbine's rated power. Second, by elevating the rotor as much as 35 additional meters above the sea and into higher wind speeds, the capacity factor of any wind turbine can be improved. The combination of these advantages can substantially lower the LCOE of the wind farm by as much as 5 percent.

The hull of the Titan offers a clean, vibration-free and atmosphere-conditioned indoor environment to house many of the wind turbine's power and electronic systems. The power transformer, power electronics, switchgear, control systems, cooling and atmospheric conditioning equipment can all be completely removed from the turbine and situated comfortably inside the Titan's hull. This provides an opportunity to better distribute the weight of the turbine's rotor and drive train reducing the loads on the bed plate and yaw drive. This also substantially lowers the center of gravity of the wind turbine and eliminates the need for special attachment fixtures and platforms inside the nacelle and tower. All of these advantages will have a positive cost impact to designing and manufacturing future offshore wind turbines.



Naturally, by significantly reducing the weight of the nacelle, it becomes more feasible to increase the height of the tower and the size of the rotor and drive train. Increasing the length of the blades from 72 meters to 78 meters, for example, will increase the turbine's energy production by as much as 8 percent as the increased rotor diameter directly increases the amount of power that can be converted from the wind. This represents a direct improvement to the levelized cost of energy.

Furthermore, the substantial air gap beneath the Titan's structure provides the added benefit of elevating the hub height of the turbine up to an additional 35 meters above the surface of the water. The wind's speed increases as the distance above the surface of the ocean increases, so by elevating a 90-meter hub to 125 meters the capacity factor of the turbine is naturally increased without requiring modification to the turbine.

A design effort on the part of the turbine manufacturer would be required to create a new turbine that relocates the power and electronics systems into the Titan's hull and increases the size of the rotor and drive train. However, the capacity factor of *all* currently-available offshore wind turbines would benefit from being elevated up to an additional 35 meters into higher wind speeds. Therefore, the Titan adds a production increase to all offshore turbines that are available on the market today.

LCOE IMPROVEMENT – THE SUBSTRUCTURE

The fabrication cost of any substructure is generally proportional to the structure's gross steel weight. While the simplicity or complexity of the design is also a factor, all of today's leading designs are roughly equivalent in the amount of labor required per ton of steel to produce a foundation. The Titan is no different in this regard.

Therefore, the fabrication cost of various substructures can be roughly compared by looking at the gross steel weight of the various systems including the gross weight all of the components necessary for full installation, such as the transition piece and piles. At this time the gross steel weights have not been made available for conventional XXL monopile, jacket, tripod, gravity base or floating substructures for 5 to 8 MW wind turbines in a water depth of 40 to 60 meters.


In the 5 to 8 MW class, for a water depth of 40 to 60 meters, the gross steel weight of the Titan is approximately 1,109 tons for the hull and transition adaptor. The legs and spudcans are approximately 1,124 tons depending on water depth and above-the-surface air gap requirements. This brings the Titan in at approximately 2,233 tons gross steel weight after installation.

It should be noted that an estimated weight and cost of any substructure can only be calculated in the context of an actual project after the wind, ocean and seafloor soil data have been obtained. With any substructure, the specific variables of the project, such as turbine size, type of soil, specific recorded wave heights and ocean currents will affect the cost.

As the Titan requires no piles or mooring systems, the gross steel weight of the structure is anticipated to compare favorably to other conventional designs when all required elements are taken into account.

LCOE IMPROVEMENT – PROJECT MANAGEMENT

Wind conditions are a significant factor in how long it takes to complete the installation of a wind farm. In most places in the world the wind conditions are driven seasonally which means there is typically only a limited window of opportunity spanning some number of weeks of the year where the wind is suitable to safely perform over-the-water construction operations. This suitable weather window represents the timeframe within which all offshore installation operations are possible.

Today's conventional foundations require a heavy lift vessel for placement of the foundation, the turbine tower and nacelle. Crane operations to lift these heavy components cannot be performed in wind speeds greater than about 12 meters per second or wave heights greater than 1.4 – 2.5 meters. Installation of the turbine rotor must wait for wind speeds below 8 meters per second. The installation phase of the project therefore can span multiple years if the acceptable seasonal weather windows are very short.

For floating turbines and for the Titan, where the substructure and the turbine are towed out to the site as a single complete system, the required installation timeline is significantly reduced providing a sizable reduction in LCOE. As the need for an offshore heavy crane is eliminated, the installation procedures are less sensitive to wind speeds that can cause foundation or turbine components to swing during lifting operations. Therefore, it is possible to increase the acceptable limits of wind conditions and thereby extend the available weather window, shortening the overall project timeline.

With floating turbines, however, the sea state remains a factor for installation of the mooring line anchors. The sea state must be very low to attach the mooring lines to the platform and stabilize the structure. These operations require different techniques depending on the water depth and force of the current.

Deeper water installations will require longer and heavier mooring lines with significantly larger anchors. These installations must be conducted from a mooring system installation vessel where the operations will be affected by sea state and wind conditions and therefore must be performed within a limited weather window. Shallow installations that require shorter mooring lines and smaller anchors may be performed from a self-propelled installation vessel that is slightly less dependent on the sea state.

Installation operations for the Titan can be performed in a much wider range of sea state conditions which extends the weather window considerably. The Titan with the turbine installed can be towed in wind speeds of up to 20 meters per second, a head current of 1 meter per second and wave height of 5 meters in accordance with industry standards. This places the Titan's installation window in terms of sea state conditions in a maximum range of 5 to 8.

While nominal towing speed is estimated at 3 meters per second (6 knots), each Titan substructure and turbine installation can be completed in one or two days from start to finish. Without the need for specialized construction vessels it is possible to deploy and install 3 to 5 Titans and turbines concurrently in a single day.

Naturally, the length of the installation window will have a significant impact on the cost of the project. Heavy specialized vessels present an enormous cost even on the days when they remain idle due to unfavorable wind conditions. With the self-installing Titan eliminating the need for these vessels and opening the suitable weather window to wind speeds nearing 20 meters per second, a significant reduction in the cost of the project will be realized. Furthermore, the ability to complete a substructure and turbine installation at a rate of 3 to 5 systems every couple of days shortens the overall installation project immensely.

LCOE IMPROVEMENT – PORT AND STAGING, ASSEMBLY, TRANSPORT AND INSTALL

The construction and installation of foundations and turbines account for 13 to 20 percent of LCOE for the wind farm. The logistics of preparing the seabed, moving the support structures, lifting them and installing them at sea and then returning again to install the turbine towers, nacelles and rotors is a significant driver of the wind farm's levelized cost.

The average time to install a conventional foundation and a 6 MW turbine together is approximately one operational week. This means 2,000 boat days are required for a single heavy lift vessel to install 1 GW of capacity. To install this capacity in four years, an average of three concurrently operating heavy lift vessels would be required.

Of course, the largest unknown variable in offshore construction cost is the vessel's day rate that must be paid even on days when the weather prevents performance of construction operations. There is no way to calculate how many days will have to be paid while the vessel sits in port.

At a day rate of more than $100,000 for a modest heavy lift vessel, the project cost could conceivably exceed $250 million for the use of a single class of vessel for a 1 GW project. In 2008, the *Service Jack*, a 110 meter long self-propelled installation vessel, was commissioned for three years to install foundations and turbines at Sheringham Shoal. The day rate for the *Service Jack* was estimated to be $330,000. Its sister ship, the Service Jack 2, was also commissioned for nine months at an estimated day rate of $380,000.

This does not take into account the cost of other vessels needed for dredging, scour protection, barge transport, tugs, diving support and crew vessels. Even the smallest of these vessels are contracted for day rates ranging from $3,500 to $100,000. Naturally, the day rate for all vessels varies widely depending on the season. A small crew boat may rent out at $3,000 per day in January but command $6,000 per day in April.

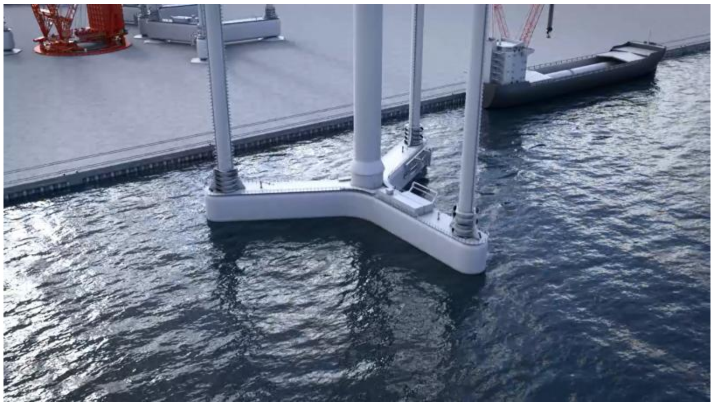
Exacerbating the mounting cost of these specialized vessels is the fact that XXL monopiles, jackets and tripods are now beginning to exceed the practical size limit for shipping mobility and installation. The challenges for XXL monopiles – those greater than 6 meters in diameter and more than 80 meters in length – require new manufacturing processes and installation techniques be developed.

While plate fabrication, rolling and welding techniques for large tubular structures are well-understood, these welded super-tubes present enormous challenges for transportation, lifting at sea and driving into the seabed. With few vessels capable of working with these structures, and no larger vessels being developed today, the cost of handling these foundations is going to be substantial and the project risks very high.

Jacket structures and tripods face a similar set of challenges. It is not possible to assemble and weld these structures at the point of installation, so each one must be transported and installed complete. Today's vessels can only handle one or two of these structures at a time which increases the amount of work expected of them.

The Titan is currently planned to be fabricated in South East Asian shipyards. These yards, while known for their affordability, are the most experienced working with jack-up vessels and the special steel needed to fabricate the legs and lifting racks. Transportation from the shipyard to the wind farm's staging and assembly site can be conducted transporting up to 20 units on a single shipping vessel, dramatically reducing the per unit cost of shipping. On a sizable wind farm construction project, a delivery of 20 units can be achieved every 45 days, significantly reducing the unit cost of shipping. In contrast, XXL monopiles, jackets and tripods must be shipped at a maximum of one, two or three at a time.

By conducting all final assembly operations on land, it is planned to complete final assembly for four Titan substructures at one time employing a single circular rail-crane. Assembly of the substructures and the wind turbines occur together.



Once launched, the substructure and turbine will be elevated and checked out dockside. Many pre-commissioning activities can be conducted with convenient near-shore access. Once completed, the system can be towed to a nearby holding area to await favorable installation conditions or it can be towed directly to the wind farm and installed.

Installation of the fully assembled substructure and turbine requires only the use of standard towing vessels – one or two vessels per unit depending on sea conditions. Additionally, a single support vessel will be deployed per installation to carry personnel and equipment and support the self-installing process. The same support vessel will be used to retrieve the lifting jacks and return them to be used again for installation of another substructure. The elimination of all specialized excavation, heavy lifting, transportation and pile-driving vessels represent a savings of as much as 6 to 10 percent of LCOE.

LCOE IMPROVEMENT – INSURANCE

Another significant cost of offshore wind installations is insurance. With high-risk safety and equipment concerns, projects are required to purchase insurance to cover personnel safety, capital equipment, vessels and crew, transportation, construction and installation. The cost of insurance comes to as much as 2 percent of the total LCOE of the wind farm. Furthermore, as installations are becoming more challenging, the cost of insurance is naturally trending upward.

The Titan requires no over-the-water construction operations and so eliminates the need for insurance to cover mishaps during these operations. While at the time of this writing insurance underwriters have yet to determine the cost of a policy for deployment of the Titan, it is predicted that the cost of insurance will reflect the substantially reduced risk. This could reduce insurance premiums by as much as 50 percent compared to the cost of insurance for the installation of other conventional foundations.

LCOE IMPROVEMENT – SURETY BOND

Amounting to as much as 3 percent of the project's overall cost, a surety bond is required to be held by the developer of offshore wind farms that ensures funds are available to remove all structures and clear the site at the conclusion of the lease.

For wind farms that employ conventional monopile, jacket or tripod foundations, the surety bond represents a sizable burden for the project's investors. The bond must be held throughout the life of the wind farm to cover the cost of specialized vessels, blasting, diving operations, and all work involved with removing the wind farm and returning the environment to its natural condition. Even for floating turbine structures, the bond must cover the cost of removal of all mooring anchors and anti-scouring systems.

For projects employing the Titan substructure, the surety bond is reduced by nearly two thirds. All decommissioning operations are performed without the use of specialized construction vessels, and no seafloor debris removal is necessary. Once the Titan has been towed back to shore, the seafloor immediately returns to its natural condition without the need for remediation efforts.

WIND AND CLEAN WATER – AN ADDITIONAL REVENUE OPPORTUNITY

Today, more than one billion people live in areas where water is scarce. Based on mid-range population projections, the demand for water for agriculture alone could rise to exceed 70 percent of total human demand. This suggests that the global consumption of water could rise by 60 percent in the next ten years. With cities growing by 2 to 5 percent per year, there is expected to be fierce competition between cities and the agriculture sector over the available water resources.

A unique and compelling design option for the Titan 200 is the inclusion of a utility-scale water desalination plant inside the substructure's hull. Powered by the wind turbine, this hybrid wind and water system can provide both electricity and drinkable or agricultural-grade water to coastal and island communities.

The sea water that's fed into the system situated several kilometers offshore is relatively free of solid sediments and is much easier to filter and process resulting in a higher water production yield than that provided by onshore or near-shore water desalination systems. This naturally reduces the frequency of filter and maintenance service.

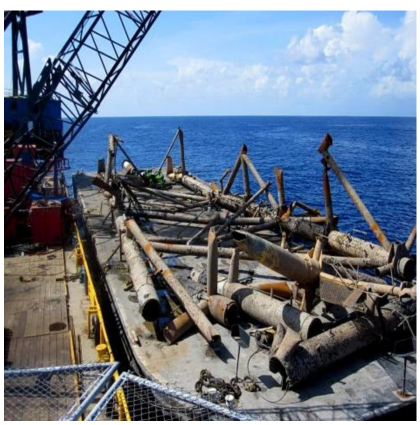
Utilizing the same industry-standard sea recovery systems as those that service thousands of offshore oil and gas rigs, a single Titan wind and water hybrid system can produce one million gallons of drinking water per day utilizing less than half a megawatt of energy from the wind turbine. By installing a simple water line to shore along with the power export cable, the installation cost of the integrated system can be further optimized while creating a significant additional revenue stream for the system.

END-OF-LIFE DECOMMISSIONING

Decommissioning liability is estimated to be about 5 to 10 percent of the capital costs of the wind farm as traditional monopiles and jacket foundations present costly problems for removal. Again, heavy lift vessels are required for disassembly and removal of the wind turbine. For safety, this operation must be performed during an acceptable weather window.

Offshore cutting rigs are often employed to cut the foundations or piles 5 meters below the mud line leaving a considerable amount of steel embedded in the sea floor. Then the substructure is cut into manageable pieces to be lifted out by a crane onto a barge. Concrete anti-scouring pads must sometimes be blasted and removed along with all aggregates.

In most markets, the cost of decommissioning is affected by the terms of the offshore lease. In the United States, for example, BOEMRE regulations on decommissioning require that the removal of all structures and obstructions be completed within two years of the end of the lease. As the acceptable weather windows for removal operations are in most cases seasonal, this may present only two limited seasonal opportunities for removal of the entire wind farm.


While decommissioning operations tend to be low-tech and routine usually only requiring a couple of days per structure, the operations for decommissioning a wind farm will have to be completed over large spatial dimensions. The decommissioning of a modest 400 MW wind farm, for example, will have activity levels similar to an entire year of oil and gas structure removals. Since these activities must fit within the acceptable weather constraints for offshore operations, the decommissioning methods are likely to be time-driven rather than cost-driven in order to comply with the regulatory timelines.

The Titan presents the fastest and least costly decommissioning scenario of all substructure types. To decommission the Titan, all systems and components will be secured as they were during the earlier transit mode. The interconnection cable will be disconnected and removed from the substructure. The jacks are reinstalled and the substructure is jacked down to its buoyant position. Natural sea water is used under pressure to remove the soil and break the suction from the embedded legs and spudcans and the legs are raised. The fully intact system, with the turbine, is then towed back to shore without the use of lifting vessels or demolition operations. Once again, these operations can be performed in a much wider acceptable weather window, allowing for more cost-effective decommissioning strategies.

ENVIRONMENTAL IMPACT

The Titan presents, by far, the lowest environmental impact of any offshore substructure. Seabed preparation is rarely required for installation of the Titan, even accounting for sloped or irregularly contoured terrain, so normally no concrete or aggregates are used. No drilling into bedrock is required. There are no piles to drive into the sea floor, so there is no driving noise or vibration introduced into the environment during installation.

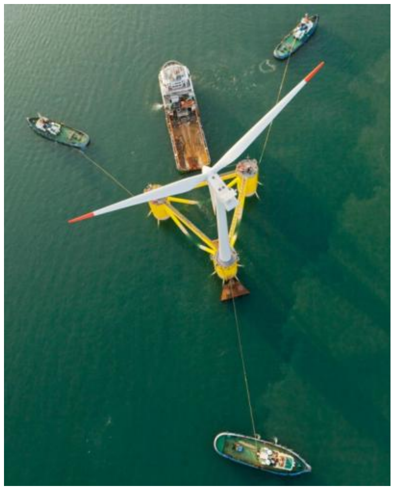
Mooring lines that are hazardous to large sea mammals are not used with the Titan. This leaves important migratory routes free of tangling hazards. The legs are large enough and are far enough apart that they present no entrapment risks to sea life.

As nothing is permanently installed into the seabed, decommissioning leaves no steel embedded in or lying about on the sea floor. There will be no underwater demolition. Since there is no need for concrete, no heavy cleanup will be required. Once the Titan is removed, there is no residual evidence of the Titan's installation and the seabed returns immediately to its pristine natural condition.

A WORD ABOUT FLOATING TURBINES

Considerable discussion has been generated over the prospect of floating wind turbines in deeper water. While this technology may one day evolve to become a viable solution in some markets, floating turbines present their own significant set of challenges.

In a floating wind farm of considerable size, the mooring lines are going to be problematic. As the water depth increases, the mooring lines will be longer and must reach farther from the turbine to the sea floor. By regulation, mooring lines cannot be crossed which means the spacing of the turbines will likely have to be increased, reducing the nameplate capacity of the lease.



Since a broken mooring line will allow the turbine to move with the ocean current, and a free turbine could potentially float into the proximity of another turbine, a redundant pair of mooring lines are going to be required extending from the platform in at least three directions. A wind farm of 100 turbines, each with three pairs of mooring lines extending from the surface to the seafloor, will create a considerable hazard for large sea mammals. As some sites for wind leases reside within the primary migratory route for endangered large sea mammals, it is predicted that environmentalists will resist the installation of floating turbines.

Many of today's floating structure designs will use an active ballast system to move water from one ballast tank to another. This is required to ensure the stability and vertical orientation of the turbine when the wind shifts direction to push on a different side of the turbine. If a ballast pump failure results in an imbalance of the platform and causes the turbine to tilt, the asymmetrical loads on the turbine's main rotor bearing could easily exceed the bearing's allowable load tolerance potentially causing failure of the rotor bearing. Therefore the ballast system must include a redundant pumping system in the event a pump fails.

Taking this problem to the extreme condition, floating turbine designers are well aware of the need to design for the 100-year maximum storm wave and its associated loads. But storm troughs, which are statistically as likely as storm waves, present a unique hazard of similar magnitude for which there is no solution. A trough that forms beneath a floating structure will cause the structure to fall, if only briefly, in an uncontrollable orientation. When the trough disappears, the floating structure will regain its buoyancy and lift itself back to its proper orientation. However, there is no known design that will prevent these loads from translating through the main rotor bearing of the turbine.

In contrast, the Titan offers the same advantage that a floating turbine has in eliminating over-the-water construction and at-sea installation of the turbine. However, the Titan stands solidly on the seafloor and positions the substructure well above storm waves and troughs, virtually eliminating these loads.

COMPARISON OF SOLUTION TYPES

There are many comparisons that can be made between the various conventional support structures and the Titan. Table 2 shows the key comparisons that have the greatest positive or negative impact on LCOE.

Table 2: Overall comparison of solution types as affecting LCOE

	XXL Monopile	Jacket	Tripod	Suction Bucket	Gravity Base	Floating	Titan 200
Project Management	Significant restrictions on weather and sea states for all phases of construction	Significant restrictions on weather and sea states for all phases of construction	Significant restrictions on weather and sea states for all phases of construction	Significant restrictions on weather and sea states for many phases of construction	Significant restrictions on weather and sea states for all phases of construction	Significant restrictions on weather and sea states for all phases of construction	Much broader weather and sea state conditions resulting in shorter project timelines
Installation time per structure (boat days)	2-6	2-5	2-5	3-8	3-8	1-4	1-2
Installation time per turbine (boat days)	2-5	2-5	2-5	2-5	2-5	0	0
Required at-sea operations	Seabed preparation, heavy lift, pile driving, installation of transition piece, grouting and installation of turbine	Seabed preparation, heavy lift, pile driving, installation of transition piece and installation of turbine	Seabed preparation, heavy lift, pile driving, installation of transition piece, grouting and installation of turbine	Seabed preparation, at-sea evacuation of atmospheric air to sink the structure and pumping to create suction, heavy lift, installation of transition piece, possible grouting and installation of turbine	Seabed preparation, at-sea evacuation of atmospheric air to sink the structure, heavy lift, transportation and installation of ballast, installation of transition piece and installation of turbine	Seabed preparation, heavy lift, installation of mooring anchors and cables, towing, removal of securing systems and connection of mooring lines to platform	Towing, elevating the structure, removal of securing systems and removal of lifting jacks
Transport	Vessel carry of concrete/ aggregates, monopile, transition piece and turbine components	Vessel carry of concrete/ aggregates, jacket, transition piece and turbine components	Vessel carry of concrete/ aggregates, tripod, transition piece and turbine components	Vessel carry of concrete/ aggregates, transition piece and turbine components, tow	Vessel carry of concrete/ aggregates, transition piece and turbine components, tow	Vessel carry of concrete/ aggregates, anchors and mooring cables, tow	Tow, vessel carry of lifting jacks
Maximum wind speed for installation (m/s)	12 m/s for foundations, turbine tower and nacelle, and 8 m/s for the rotor	12 m/s for foundations, turbine tower and nacelle, and 8 m/s for the rotor	12 m/s for foundations, turbine tower and nacelle, and 8 m/s for the rotor	12 m/s for foundations, turbine tower and nacelle, and 8 m/s for the rotor	12 m/s for foundations, turbine tower and nacelle, and 8 m/s for the rotor	Unknown	<20 m/s
Likely maximum turbine size (MW)	8	8	8	5	5	6	10
Maximum water depth (m)	40-50	60	40-50	40	40	Unlimited	60-100
Stability	High	High	High	High	High	Poor: Storm troughs and waves present considerable risk to the turbine	High
Environmental impact	Disrupts sea bed around the structure, noise and vibration due to pile driving operations	Disrupts sea bed around the structure, noise and vibration due to pile driving operations	Disrupts sea bed around the structure, noise and vibration due to pile driving operations	Disrupts sea bed around the structure, noise and vibration due to pile driving operations	Disrupts sea bed around the structure, noise and vibration due to pile driving operations	Disrupts sea floor around anchor points, mooring lines impose significant hazard to migratory sea life	Minimal

	XXL Monopile	Jacket	Tripod	Suction Bucket	Gravity Base	Floating	Titan 200
Opportunity for collateral revenue stream	X	X	X	X	X	X	Water production, natural gas production
Opportunity to improve power output	X	X	X	X	X	X	Turbine OEM can move power and electronic systems into the hull reducing the turbine's weight, making it possible to install a larger rotor
Opportunity to improve capacity factor	X	X	X	X	X	X	Elevates the turbine 30 meters above the sea into higher wind speeds
Insurance	Over-the-water construction	Over-the-water construction	Over-the-water construction	Over-the-water construction	Over-the-water construction	Over-the-water construction	No over-the-water construction
Decommissioning	Monopile must be cut off at sea floor, steel remains embedded in the soil, anti-scour system must be removed, divers are required, lifting vessel, demolition support vessels and barge are required	Piles must be cut off at sea floor, steel remains embedded in the soil, anti-scour system must be removed, divers are required, lifting vessel, demolition support vessels and barge are required	Piles must be cut off at sea floor, steel remains embedded in the soil, anti-scour system must be removed, divers are required, lifting vessel, demolition support vessels and barge are required	Foundation and anti-scour system is blasted and recovered, demolition support vessels, lifting vessel and barge are required	Foundation and anti-scour system is blasted and recovered, demolition support vessels, lifting vessel and barge are required	Anchors must be removed, anti-scour system must be removed, robotic system or divers are required to attach lifting system to anchors, lifting vessel, demolition support vessels and barge are required	Pumping vessel is required to release suction from around the legs, support vessel to deliver jacking system. Nothing is left on sea floor.

SUMMARY

The Titan offshore wind turbine substructure provides a significant opportunity to change the game for offshore wind farms and investors. The potential for reducing the LCOE for offshore wind may easily exceed 10 percent. The advantages are plentiful and the technology itself has matured for more than 60 years in the offshore oil fields. In fact, most of the necessary regulations for fabricating, transporting and installing these structures are already in place in every market.

The projected cost for projects that employ XXL monopiles, jackets or tripods for large turbines in deeper water is more difficult to estimate due to the unpredictable nature of the weather and its impact on project timelines. As the global climate continues to warm, we have seen more unpredictable weather patterns globally and this bears heavily on the anticipated cost of offshore wind installations. But, the Titan eliminates the cost and risk of over-the-water construction, the associated liability insurance costs and the unpredictable cost of paying for equipment while waiting for the weather to improve.

Furthermore, the opportunity the Titan presents to wind turbine manufacturers is profound. A direct improvement of the capacity factor of any currently available turbine may lower the LCOE by as much as 2 percent. The additional opportunity the manufacturer has to redesign the turbine to reduce weight and increase the rotor diameter offers the potential for a significant increase in rated power, reducing LCOE by another 3 to 4 percent or more.

In addition to reducing the levelized cost of energy, the Titan also dramatically shortens the project installation timeline. By allowing for installation operations in wind speeds up to 20 meters per second and significant wave heights of 5 meters, the available installation weeks per year will more than double in many cases. The project’s installation phase could be shorted by 50 percent or more.

No other substructure offers the opportunity to create an additional revenue stream for the developer. By installing a water desalination plant in the Titan’s hull powered by the wind turbine, the Titan wind and water hybrid system can provide electricity with more than one million gallons of clean water per day to coastal and island communities.

Finally, the environmental impact of the Titan is the most attractive in the industry. With no seabed preparation, no mooring line hazards to sea mammals, no drilling or driving vibrations, and fast and simple decommissioning, the Titan provides the most attractive environmental profile of all solutions.

Reducing the LCOE for offshore wind will unlock a significant amount of investment capital for new projects. While many elements in the supply chain are working feverishly to do their part, it is unlikely that any other single element can make as significant a contribution to lowering the levelized cost of energy than the employment of the Titan.

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Editorial Note: While multiple resources often provide differing information, conservative values have been used throughout this report. It is quite possible for actual cost reductions to be greater than those asserted in this report. A more complete estimate will be possible by calculating the costs based on actual project data for a specific project. We encourage the commission of a six-month FEED study to determine the realistic cost of deploying the Titan for any specific project.

About Offshore Wind Power Systems of Texas LLC.

The company was formed to leverage the team's 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 international patents for Mobile Wind-Driven Electric Generating Systems and Methods) was designed to solve the deepwater dilemma for larger wind turbines. Questions may be forwarded to: Sales@offshorewindpowersystemsoftexas.com

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