TITAN PLATFORMS

Offshore Wind Power Systems of Texas

TITAN

Offshore Wind Power Systems of Texas

TM

The Future of Offshore Wind Energy is dependant on a good foundation

“The Titan 200 is Solid Footing to Build Upon”

Project references – UK Round 3

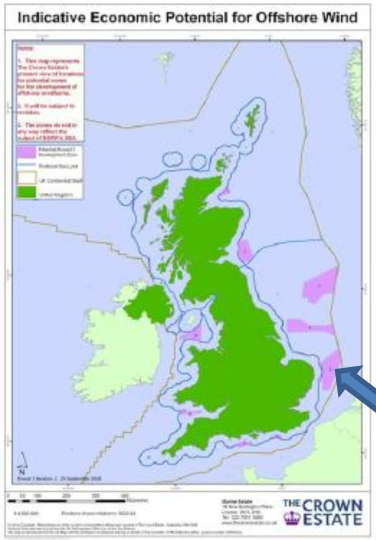


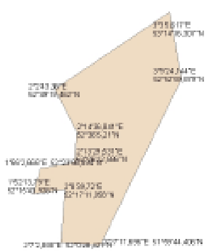
Figure 2.1 Round 3 areas

This document is a combined site assessment/design basis for the 9 Round 3 areas.

Design Basis

Project specific references

A. Carbon Trust, "OWA Offshore Wind Farm Foundation, UK Round 3, Design Basis, Version 1", May 2009,
B. Summary of Metocean design conditions based on respective the Offshore Technology Report 2001/010 model data and the DHI hindcast model data,
C. 2009-10-06 OWA Offshore Foundations: Revised design metocean conditions,
D. April 2009 – OWA Offshore WF Foundations UK Round 3 DRAFT Summary of loads,
E. E-mail 2009-10-28, PM "SV-data request",
F. May 2009 – OWA Offshore wind Farm Foundations UK Round 3 Design Basis, rev1,
G. E-mail 2009-10-21 "OWA Offshore Foundations: Revised design basis",
H. E-mail 2009-11-16 "Area 5. Tmo-Hs directional statistic1",
I. E-mail 2009-11-05 "Titan relative to Keystone.",
J. E-mail 2009-11-06 "Directional statistic Area 3 and 5." ,
K. 2009-11-12 "OWA Offshore WF Foundations UK Round 3 Summary of loads"



Industry specific references/codes

Design Basis Version 1UK Round 3 Offshore Wind Farm Foundations
Carbon Trust OWA

Page 12

4.1 Main Metocean design data. *Exposed wind/weather climate **Average wind/weather climate.

	Wind			Tidal					Waves							
									3h/50y	3h/1y	3h/50y, 30m+0.75TR			3h/50y,60m+0.75TR		
Area	$U_{10m,1h,50y}$	$U_{100m,1h,50y}$	$U_{100m,3s,50y}$	TR= HAT-LAT/ MSL(rel LAT)	0.75TR	Avg. Spring current	Max. spring current	Splash Zone Upper/ Lower rel. MSL	Hs/Tp	Hs/Tp	Hmax	Crest η_{max}/ u_{max}	Run-up R_{max} (rel LAT)	Hmax	Crest η_{max}/ u_{max}	Run-up R_{max} (rel LAT)
	m/s	m/s	m/s	m	m	m/s	m/s	m	m/s	m/s	m	m/ m/s	m	m	m/ m/s	m
1*	37.0	48.5	61.0	3.5/ 1.75	2.6	0.4	0.61	7.3/ -5.4	12.0/ 14.8	9.2/ 13.0	18.6	13.7/ 10.3	35.9	22.4	13.4/ 7.3	25.9
2	35.0	45.5	57.0	4.0 2.0	3.0	0.6	0.86	6.3/ -4.9	10.3/ 14.0	7.2/ 11.8	16.8	11.7/ 8.6	27.6	19.1	11.1/ 6.3	20.6
3*	37.0	48.5	61.0	2.5 1.25	1.9	0.4	0.55	6.7/ -4.9	13.0/ 15.3	9.1/ 12.8	19.7	15.0/ 12.0	44.4	24.4	14.7/ 8.3	30.3
4	36.0	47.0	58.0	4.0 2.0	3.0	0.9	1.20	6.6/ -5.0	10.9/ 13.9	7.6/ 11.6	17.5	12.6/ 9.5	31.7	20.3	11.8/ 6.7	22.4
5**	34.0	44.0	55.0	2.0 1.0	1.5	1.2	1.54	4.4/ -3.2	7.9/ 11.7	5.6/ 9.8	14.0	9.0/ 6.8	19.3	14.5	8.5/ 5.2	15.2
6	32.0	41.0	51.0	7.5 3.75	5.6	1.3	1.60	6.7/ -5.7	7.0/ 8.0	4.9/ 8.0	13.0	8.1/ 8.1	21.8	13.0	7.7/ 8.0	21.0
7**	34.0	44.0	55.0	4.0 2.0	3.0	1.5	1.89	5.4/ -4.2	7.7/ 8.0	5.6	14.3	9.1/ 9.7	28.2	14.7	8.7/ 8.5	23.7
8	36.0	47.0	58.0	9.0 4.5	6.8	1.6	2.26	9.8/ -8.1	12.0/ 15.6	8.9/ 13.5	19.3	13.3/ 9.0	30.8	22.4	13.2/ 6.9	24.6
9*	36.0	47.0	58.0	7.0 3.5	5.3	1.2	1.76	6.7/ -5.6	7.5/ 11.1	5.3/ 9.3	14.0	8.7/ 6.7	18.7	14.0	7.9/ 5.2	14.4

Grontmij | Carl Bro

AISC ASD-9th edition, "Manual of Steel Construction"
ASCE 7-05, "Loads on Buildings and Other Structures"
API RP-2A WSD, 2005, "Recommended Practice for Planning, Designing and Constructing Offshore Structures-Working Stress Design"
DNV RP-C203 – May 2000 – "Fatigue Design of Offshore Steel Structures"
ISO 19901 for general requirements for the determination and use of meteorological and oceanographic (metocean) conditions for the design.

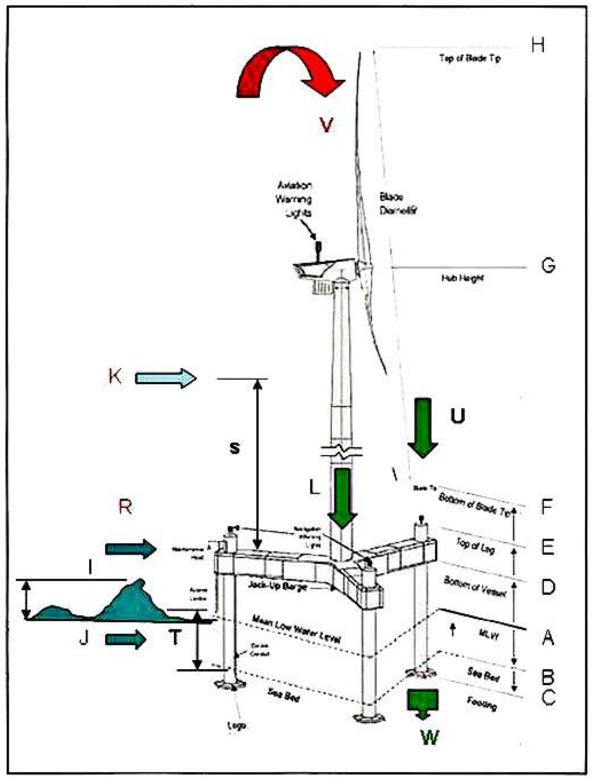
Structural Description

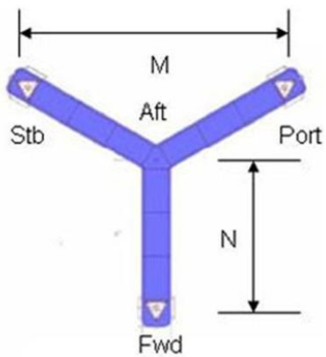
The layout of Titan 200 Mobile Self Installing Platform consists of a Y shape hull supported by three (3) independent legs.

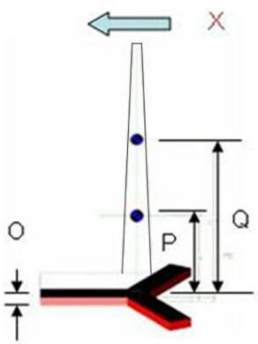
The foundation for the wind turbine is at the center of the Y hull.

The overall dimensions of the unit are to be determined by the results of the analysis performed using given Design Basis.

All primary hull and leg strength materials used in the construction Of Titan 200 Jack-up rigs are ABS approved AISC rolled shapes (ASTM 992) and plate (ASTM 572 Gr. 50). Material has minimum yield strength of FY=50 ksi.







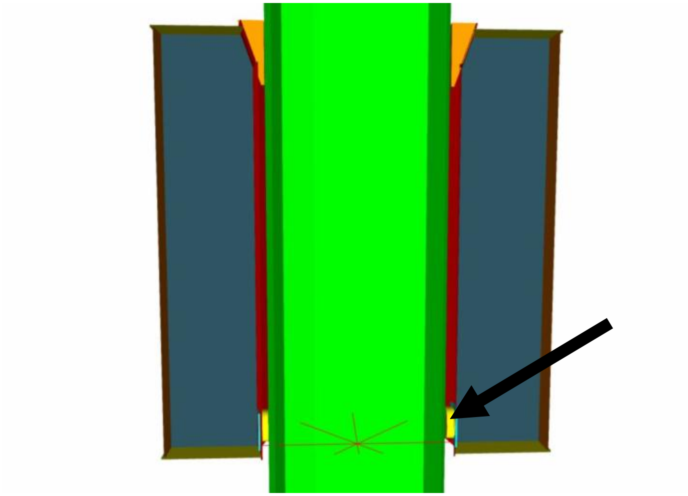
A-Mean Nominal Sea level
B-Water depth on site
C-Leg/spud can penetration
D-Air gap
E-Hull Depth
F-Clearance Blade Tip
G-Hob Height from Deck
H-Top Tip Blade
I-Wave Height (100 yr)
J-Current Force (kips)
K-Wind Force (kips)
L-Wt Turbine (kips)
M- Ctr. to Ctr. Legs
N-Ctr. to Ctr. Twr. To leg

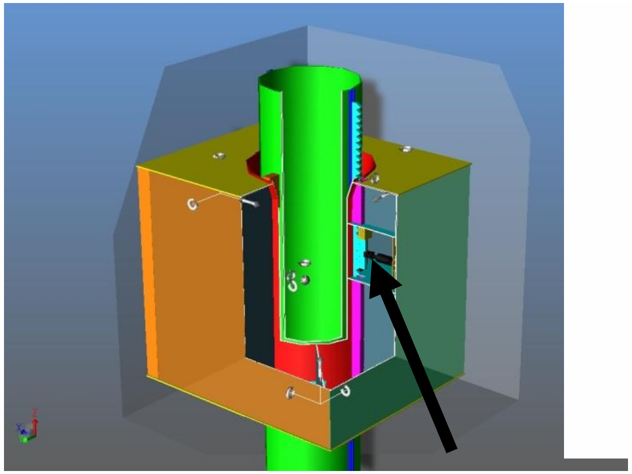
O-Vessel Draft
P-Ctr Gravity
Q-MC Height
R-Wave Force (kips)
S-Ctr. Wind Reaction
T-Ctr. Wave Reaction
U-Ballast Water (kips)
V-Overturning Moment
W-Fixity Spud can
X-East Wind Force (kips)

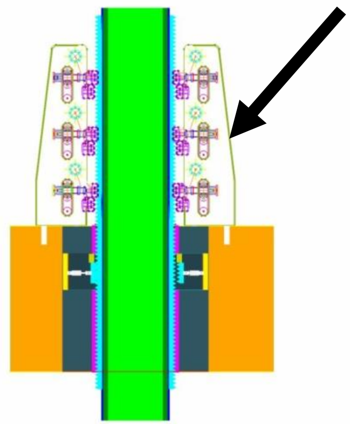
BLACK – Known Dim.
RED-Environm. Loads
GREEN-Induced Loads
BLUE-Calculated Values

Structural Description

LEG TO HULL CONNECTION CONCEPTUAL DESIGN







SPRING BEARING AT LOWER GUIDE

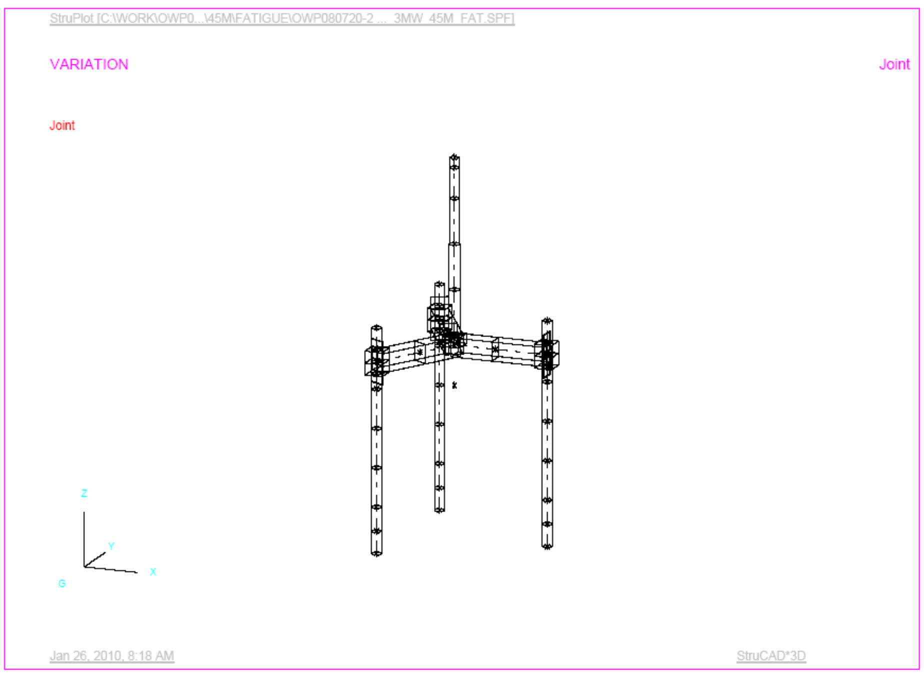
RACK LOCKING SYSTEM

ASSY WITH RAISING JACKS

Structural description

DESIGN CASES

	1 Baseline	2	3	4
Power (MW)	5.0	5.0	3.6	3.6
Depth (M)	45	35	45	35



The layout of Titan 200 Mobile Self Installing Platform consists of a Y shape hull supported by three (3) independent legs.

The foundation for the wind turbine is at the center of the Y hull.

Basic Design

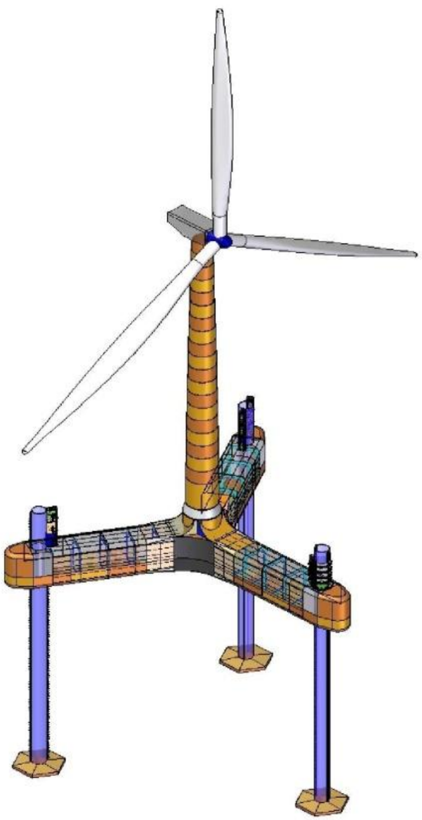
Titan 200 Mobile Self Installing Platform, Area 5

Basic Structure Information for Each Case

Case	Turbine	Water	Leg			Hull Dimensions		Material
	Size	Depth	Dia	Thick	Dist to Hull Ctr	Width	Depth	Yield
	(MW)	(m)	(mm)	(mm)	(m)	(mm)	(mm)	(MPa)
1 Base	5.0	45	3,660	28.7/38.1	36.58	7,600	8,230	420
2	5.0	35	3,810	28.7/38.1	36.58	7,600	8,230	420
3	3.6	45	3,660	28.7/38.1	36.58	6,700	7,300	420
4	3.6	35	3,350	28.7/38.1	36.58	6,400	6,850	350

Design Process

TITAN 200



To meet the operational goals, design process is as follows:

- **Natural Frequency.** The rig is arranged and sized to meet goals of natural frequency, in particular avoidance of the wind turbine 1P and 3P frequency bands

- **Strength.** The platform must meet the site maximum environmental criteria (wind, wave, current) criteria within tolerances for allowable stress and deflection

- **Fatigue.** Key connections must meet the fatigue life goal of 25 years for the project wind and wave fatigue load criteria

Area 5 Analysis Data – Weights

WEIGHTS

	Ref	3.6MW-45m	3.6MW-35m	5.0MW-45m	5.0MW-35m	Units
Hull	D, ssht	807,00	761,00	923,00	869,00	MT
Legs	D, ssht	847,00	664,00	875,00	875,00	MT
Total rig (less tower)	Calc	1 654,00	1 425,00	1 799,00	1 744,00	MT
Tower	5, T8.1	190,00	190,00	300,00	300,00	MT
Nacelle and rotor	5, T8.1	220,00	220,00	410,00	410,00	MT
Total turbine	Calc	410,00	410,00	710,00	710,00	MT
Grand total	Calc	2 064,00	1 836,00	2509,00	2 454,00	MT

Natural frequency

Titan 200 Mobile Self Installing Platform, Area 5

Frequency band requirements

		3.6 MW		5.0 MW	
Rotor diameter	m	107		126	
Tip speed	m/s	80		90	
Rotor speed range (min/max)	rpm	7.5	15.0	6.9	13.7
Rated speed	rpm	13.0		12.0	
1P rated speed	Hz	0.22		0.20	
3P rated speed	Hz	0.65		0.60	
3P min/max speed	Hz	0.38	0.75	0.35	0.69
Allowed system frequency band	Hz	0.27	0.31	0.25	0.29
	Hz	> 0.9		> 0.82	
Prohibited 1P frequency band	Hz	0.17	0.27	0.16	0.25
Prohibited 3P frequency band	Hz	0.31	0.90	0.29	0.82

The Titan 200 Mobile Self Installing Platform along with the wind turbine and tower is sized to meet the natural frequency requirements.

In particular the fundamental sway (fore-aft and transverse) and torsional (about vertical axis) modes are considered.

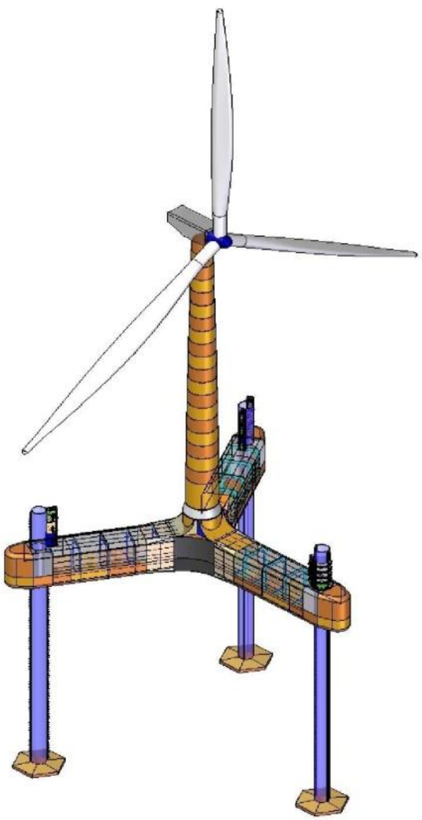
The rig can be tuned by adjustment of leg size and spacing, i.e. center of leg to center of tower. Spring Bearing stiffness will also be adjusted to complete fine tuning. Fine tuning, strength and fatigue requirements will be met by altering material thickness.

NATURAL FREQUENCY ANALYSIS TECHNIQUE

The global analysis model for the strength check is utilized to check natural frequencies. A modal analysis is performed on the structure utilizing same geometry and mass. Since the primary rig modes are sway (fore-aft and transverse) and torsion, lateral movement will mobilize some water mass in and around the legs. These masses are included as “added mass” in the analysis. The first several mode shapes and frequencies are calculated. However the ones of interest are the first 3, surge, sway (both same frequency) and torsion.

Structural Integrity

TITAN 200



The design basis consists of Client requirements for the site and OWPST usual structural configurations for the turbine support system. Particulars required for this feasibility study are extracted from the references and displayed in the following presentation.

The objective is to show on bottom stability and structural strength in the extreme environment. Other sections will address natural frequency and fatigue life.

A global analysis computer model is created to capture:

- Hull shape and basic main member sizes of the hull branches and legs,
- Transfer of load from top of leg to upper and lower hull plating,
- Tower members (OD and thickness) to capture weight and wind loading on tower, turbine and nacelle and transfer them along with their overturning moment to the hull,
- Water depth, air gap, leg penetration,
- Wind loading on tower,
- Wind on hull and legs calculated ,
- Wave and current loading on legs including marine growth,

The model is solved and reviewed for resulting

- Stress to insure reasonable members can meet the requirements
- Deflections
- Overturning stability

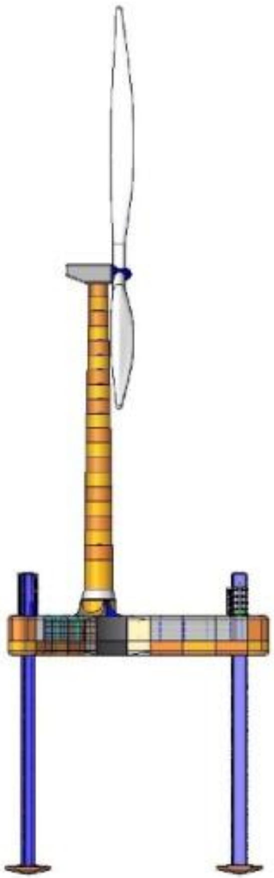
Fatigue evaluation

A fatigue analysis to determine fatigue life at critical locations in the rig are made on:

• Tower foundation (weld of foundation base plate to tubular column supported by hull)

• Leg girth weld at point of max bending (at hull bottom plate)

The rig is analyzed based on loading provided in Ref. 7. The directional probability was used to address loading at the various angles of attack (i.e. 0 degree, 60 degree, etc).

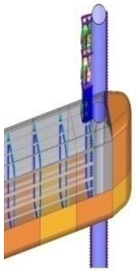


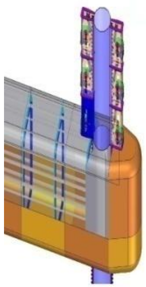
Fatigue Analysis, Loads and Results

Titan 200 Mobile Self Installing Platform, Area 5

Fatigue Case Results – Summary

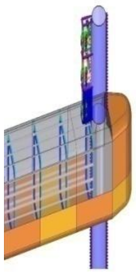
Case	1, Baseline	2	3	4
Turbine, MW	5.0	5.0	3.6	3.6
Water depth, M	45.0	35.0	45.0	35.0
Material yield (reference), Mpa	420.0	420.0	420.0	350.0
Material thickness				
Tower foundation, mm	50.0	50.0	50.0	50.0
Leg local reinforcement. mm	125.0	70.0	100.0	100.0
Cumulative Damage				
Tower to hull, %	93.7	92.5	97.6	97.6
Critical leg girth weld, %	96.5	96.1	98.4	94.2





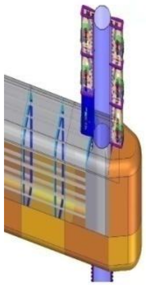
Stability Analysis

Basic stability calculations have been performed for each platform configuration according to classical Principles of Naval Architecture. The object is to determine elevation of the platform center of gravity (CG) and the metacentric height (MC) to insure the MC is higher than CG, a stable configuration.

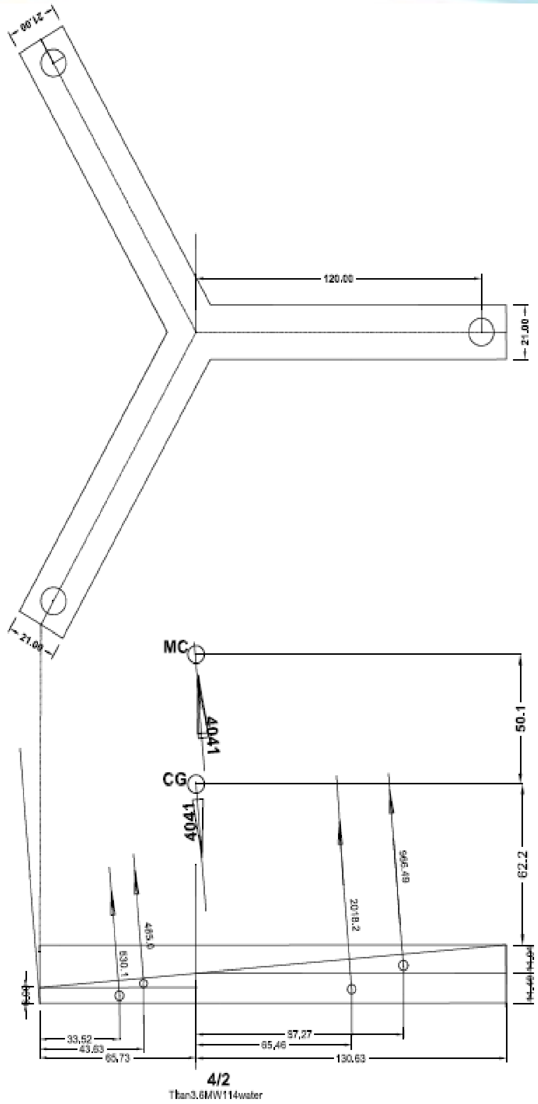


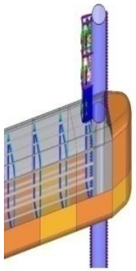
STABILITY

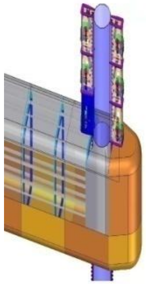
	5.0MW, 45M	5.0MW, 35M	3.6MW, 45M	3.6MW, 35M
CG Elevation above main deck, M	24.9	22.4	19	19
MC Elevation above main deck, M	34.9	36.1	34.3	34.3



Stability Analysis





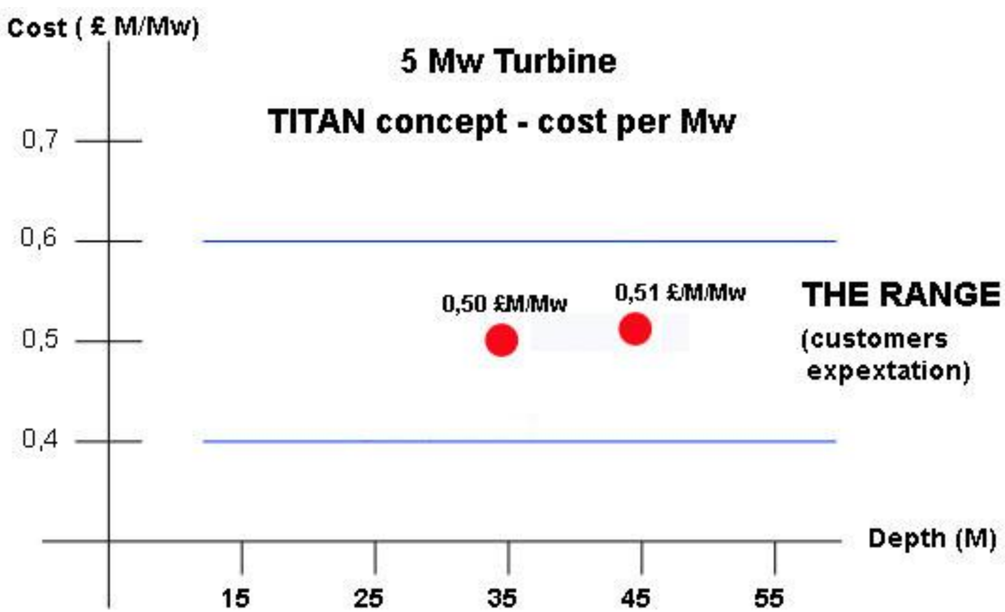


TITAN concept vs economics

Carbon Trust - Offshore foundations
The goal described is to develop novel forms of wind turbine foundation with potential for lower capital and installation costs than designs currently in use, including consideration of deep water sites.

The TITAN concept surpasses the goal and accommodates 5 Mw as well as 3,6 Mw turbines with advantages at all levels in depths of 15 to 50 meters.

- **Construction Costs**
- **Deployment Costs**
- **Mass production – lower costs**
- **Storm resistance**
- **Maintenance costs**
- **Insurance savings**
- **Decommissioning costs**



- **Cheaper to build in bulk**
- **Cheaper to transport**
- **Cheaper to install**
- **Cheaper to maintain**
- **Cheaper to decommsion**

Experienced Engineers

Designed and analyzed by professionals

CLIENT PROJECT:	Titan 200 Feasibility Review for Carbon Trust Area 5
LOCATION:	
CLIENT JOB #:	
FCE JOB #:	OWP080720-2T
FCE REGISTRATION #:	TEXAS BOARD OF PROFESSIONAL ENGINEERS Registration #F-8419

Prepared By:	M. Freeman	Date:	01 Sept 2009
Reviewed By:	C. Mandella	Date:	01 Sept 2009

Experience

The Titan 200 provides the international offshore wind industry with proven versatile tool for the development and production of power in most world regions economically.

The TITAN 200 is according to classification by the American Bureau of Shipping and built in accordance with the latest MODU Code established by the IMO Resolution A.649(16).

When required by the customer, the unit can be manufactured to meet the requirements of the United States Coast guard, The Netherlands Department of Mines or other regulatory bodies.

We have been providing this same service to our clients for over 30 years on a World Wide bases meeting the most stringent design requirements, we design, certify, manufacture and service

Why Chose the TITAN

Issue	Titan 200 Highlights
Installation cost	The Titan 200 is self installing. It requires only a tug to bring to location and a workboat to bring installation aids (jacks, etc.) back to shore base. • Fully assembled unit with tower and turbine towed to site • No derrick barge or other offshore construction equipment • No dredge or other site preparation rigs • No special purpose vessel or equipment to deliver to location • No pile driving or suction piles • True 2-day installation without construction spread
Construction cost	• Mass production of hulls and legs in a low cost location in far east. This activity takes place year-round. • Transport to TAG yard near installation site, 25 platforms at a time (3 shipments per season = 75 platforms). • Structural unit cost (price/weight) is approx 25% of UK prices. • Tower installation and final assembly at UK yard near installation site • Installed price goal per megawatt is comfortably achieved.
Site irregularities	Not a factor for installation: • Sand waves • Subsoil boulders or other obstructions (if more than 20 m below mudline) • Scour
Verticality	• Platform is continuously adjustable at time of installation to insure verticality of tower. Level seafloor not required. • In event of long term loss of verticality, platform can be easily leveled by temporarily re-installing installation jacks. • No need to un-install tower to adjust • No serious construction project to adjust
Personnel access	• Fully IMO approved boat landings and ladders (retractable) • Optional helideck • Optional stairs • Optional man-loaded crane

Maintenance access	• Davit at each leg for cargo and jack handling • Optional crane of any size (nominal 40-50 tonne suggested) • A-frame davit for installation/removal/change-out of containerized control room, power and other deck equipment
Range of locations, common design	• Robust family of designs for various water depths and environments • Standard designs for 3.6 MW and 5.0 MW turbines in 35 to 45 M water depth • Natural frequency can be fine-tuned for the site by adjusting leg reaction pads rather than by total redesign • All platforms in a field will have same design, easily adjustable for variations in water depth. • Economy of scale is assured.
Performance and life	• Design by collaboration of US and European engineers and scientists with 100's of years combined experienced in the hull form and European offshore wind market • State of the art design taking advantage of all aspects of dynamic design including adjustable mass, spring rates and damping to assure optimized design meeting the site requirements. • Thorough fatigue analysis and design details for the life of the facility.
Regulatory	• Standard design to ABS requirements. • Optional submittals and approvals by other agencies such as DNV or Lloyds • Safety systems to IMO and other requirements Note: Platform is unmanned except for occasional maintenance procedures.

TITAN PLATFORMS

Offshore Wind Power Systems of Texas

The Future of Offshore Wind Energy is dependant on a good foundation

"The Titan 200 is Solid Footing to Build Upon"