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Short Communication

Response and Motion Performance of Offshore 5MW National Renewable Energy Laboratory Wind Turbine Platform Based on Nicobar Costal Ocean State

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P A P E R I N F O

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A B S T R A C T

Wind turbines on floating support platforms are designed to be installed in a deep offshore environment several miles off the coast and in water depths greater than 60m. Effects from sea ice, varying mean sea level, and marine growth constitute additional loads that must be considered in a real design process. Design Modeler is the ANSYS tool used to create geometry for hydrodynamic systems. Surface bodies are only supported by ANSYS AQWA thus entire solid body which is created using the design modeler is transformed in to surface body. Four different mini Tension leg platforms were prepared all the dimensions and standards are followed from the guidelines of national renewable energy laboratory United States. This paper focused on the motion performance of tension leg platform supported wind turbine prototypes in Nicobar coast of India. The wind, wave and ocean current data were obtained and inputted in to the AQWA modules and the result is validated with respect to time domain.

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INTRODUCTION

The design for a floating offshore wind turbine tension leg platform (FOWT-TLP) is economical, technically feasible and experiences less motion compared to other floating structures, especially in deep water. In the past decades, the offshore wind industry has developed from applications in shallow water to ever deeper, more remote locations with harsh environments. In these progressively large water depths, bottom founded support structures become no longer applicable and floating support Structures could provide a viable alternative. Various studies have focused on floater designs for this application and multiple prototypes have been developed. A requirement for deep-water floating offshore wind turbines is the development of reliable, viable floating-platform support structures. To develop cost-effective, high-performance floating wind turbines with structural and dynamic integrity and reliability onshore and shallow-water fixed-bottom offshore turbine loads mainly are dominated by aerodynamics [1, 2]. For offshore floating turbines, hydrodynamic loads become more important. The dynamic response of a floating wind turbine depends on several elements, such as the aerodynamic loads on the rotor, the hydrodynamic loads on the floater, the restoring effect of the mooring lines and the structural properties of the turbine and floater [3, 4].

Offshore wind turbines are subjected to combined wind and wave loadings. Severe environmental condition is probable to happen in marine areas when the wind speed and the wave height is high. Offshore wind turbines require to be stable and not to fail dynamically in severe environmental conditions. Environmental pollution and global warming has increased demand for renewable energy. In this regard, different studies and majors have focused on renewable energies. Among different sources of renewable energy, wind energy is the most reliable and practical type of renewable energy which can be generated using wind turbines [4, 5].

MODEL DESCRIPTION AND INPUT

The demand of electrical energy is getting higher around the world every other passing day and India is no such exception. With limited non-renewable resources of energy to generate electricity, India is slowly shifting its focus towards renewable resources of energy like solar and wind to produce electricity. Here in this project we majority focuses on the design and response of the floater platforms which carry 5MW wind turbines as floating

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entity. which carry 5MW wind turbines as floating entity. A major breakthrough in the offshore wind turbine research is the introduction of mini TLP's which are very much small and cost effective than normal TLP's for wind extraction purposes. ANSYS AQWA a commercial suite of hydrodynamic program, which is widely used in the offshore industry is adopted in this project to execute the hydrostatic and hydrodynamic analysis.

Nicobar locality with latitudinal and longitudinal extent is selected according to similar ocean floor depth without much undulation in bathymetric data. Such offshore floating innovations are totally unknown for Indian community and no such projects are proposed or commissioned till now in India even Indian costal wind have much intensity. Here comes the relevance of the work. The parameters like wind, wave, ocean current etc. will vary according to variation in localities and their variations are considered from INCOIS portal and inputted in to AQWA. Such modern innovations will definitely become an add up to the energy demands of a developing entity India. The Horizontal and projected view of the wind turbine floater TLP modeled is shown in Figure 1. Four modeled National Renewable Energy Laboratory (NREL) tension leg platforms are shown in Figure 2.

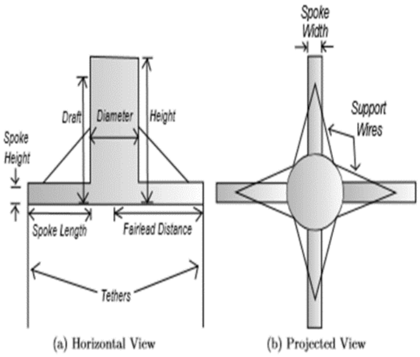


Figure 1. Horizontal and projected view of the wind turbine floater TLP modeled

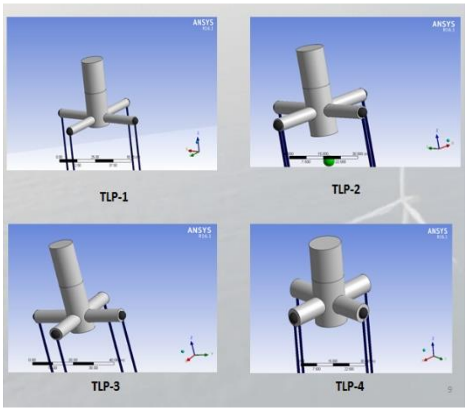


Figure 2. Four modeled National Renewable Energy Laboratory (NREL) tension leg platforms

In this paper, a thermodynamic model of ethanol-gasoline fueled SI engine is provided to predict engine performance and emissions. The model is sufficient for all range of fuel composition from pure gasoline to pure ethanol. Provided model is calibrated and obtained data are validated via experiments; then, the model is used to investigate the effects of engine inlet parameters such as engine speed, equivalence ratio and the proportion of ethanol in fuel, on performance and emissions. The design point of each study is introduced due to engine's best performance.

All data about wind, wave, ocean current etc. are collected from the portal online the corresponding directions of the parameters are also inputted in to ANSYS AQWA. The properties of modeled tension leg platforms are summarized in Table 1. The ocean state data of locality are shown in Table 2.

TABLE 1. Properties of modeled tension leg platforms

Parameters	TLP-1	TLP-2	TLP-3	TLP-4
Draft Diameter	15m	12m	12m	15m
Draft Length	40m	35m	45m	30m
Spoke Diameter	5.5m	6m	7m	8m
Spoke Length	25m	20m	18m	15m
Gravity Point	(0,0, −32.988)	(0,0, −35.426)	(0,0, −41.681)	(0,0, −36.857)
Total Mass *T*	1468632 kg	1868740 kg	1644921 kg	2648716 kg
Number of Spokes	4	4	4	4

TABLE 2. Ocean state data of locality

Ocean state properties	Value
Latitude	6.5ºN to 7ºN
Longitude	92.5ºE to 93ºE
Depth (bathymetric data)	3286
Wave height	2.5m
Wave direction	20ºN E & 20ºS W
Short wave period	8s
Long wave period	9s
Wind speed	4m/s
Wind direction	45ºN W
Current velocity	0.6m/s
Current direction	20ºN W

Locality selected based on latitude and longitude is shown in Figure 3. Wave data collected for Andaman is shown in Figure 4. The wave period data collected for Andaman is illustrated in Figure 5; while the wind data collected for Andaman are shown in Figure 6.

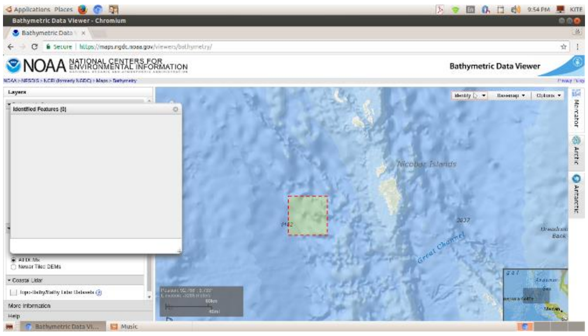


Figure 3. Locality selected based on latitude and longitude

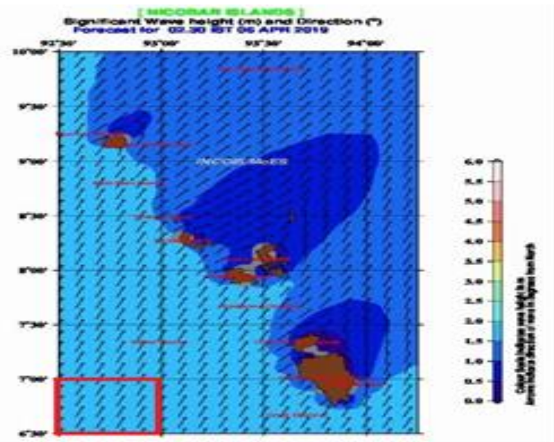


Figure 4. Wave data collected for Andaman

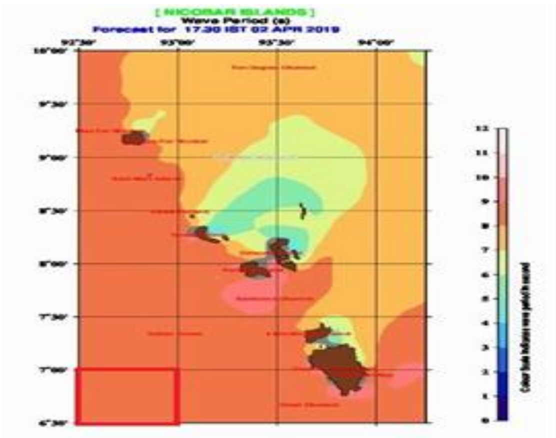


Figure 5. Wave period data collected for Andaman

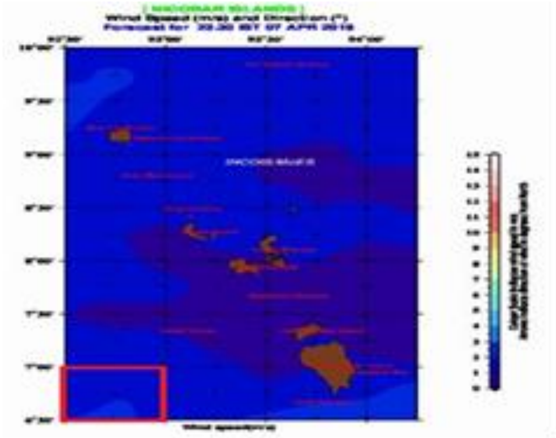


Figure 6. Wind data collected for Andaman

RESULTS AND DISCUSSION

Hydrostatic results obtained from ANSYS AQWA are provided below. Motion performance of four NREL TLP Supported wind turbines are done hydrostatic analysis and hydrodynamic response studies are done.

Figure 7 illustrate the ocean current data collected for Andaman. The hydrostatic results of TLP-1 Andaman locality is shown in Figure 8. The hydrostatic result TLP-2 Andaman locality is demonstrated in Figure 9. In addition, Figure 10 shows the hydrostatic result TLP-3 Andaman locality. Figure 11 demonstrate the hydrostatic result TLP-4 Andaman locality.

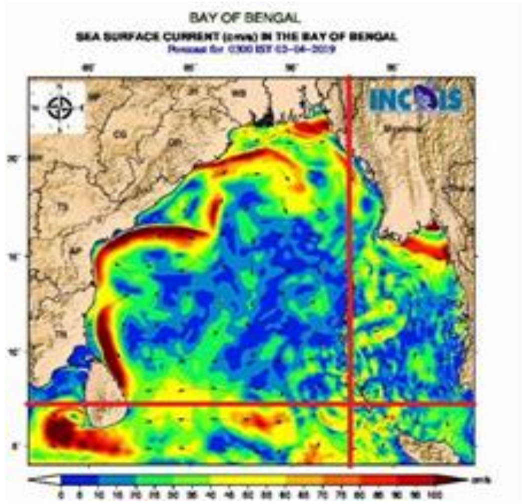
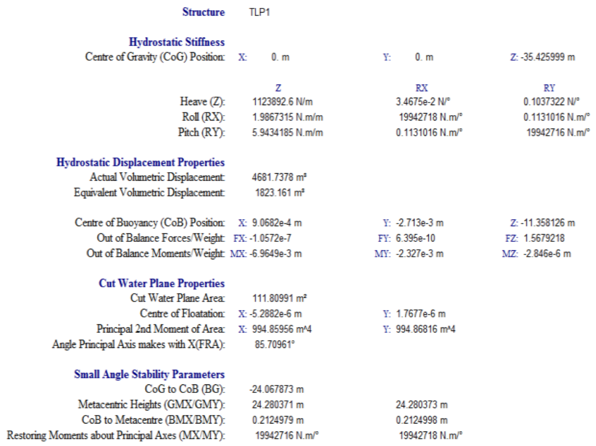


Figure 7. Ocean current data collected for Andaman

Structure	TLP1		
Hydrostatic Stiffness			
Centre of Gravity (CoG) Position:	X: 0. m	Y: 0. m	Z: -32.987999 m
	Z	RX	RY
Heave (Z):	1761432.9 N/m	-6.3309e-2 N/°	-7.0939e-2 N/°
Roll (RX):	-3.05439 N.m/m	21608276 N.m/°	-0.1177863 N.m/°
Pitch (RY):	-4.0645313 N.m/m	-0.1177863 N.m/°	21608272 N.m/°
Hydrostatic Displacement Properties			
Actual Volumetric Displacement:	6139.1934 m³		
Equivalent Volumetric Displacement:	5432.8118 m³		
Centre of Buoyancy (CoB) Position:	X: 5.3875e-4 m	Y: 2.8378e-4 m	Z: -13.323456 m
Out of Balance Forces/Weight:	FX: -4.2311e-7	FY: -5.9778e-7	FZ: 3.2847118
Out of Balance Moments/Weight:	MX: 1.2071e-3 m	MY: -2.3235e-3 m	MZ: -1.9864e-5 m
Cut Water Plane Properties			
Cut Water Plane Area:	175.23528 m²		
Centre of Floatation:	X: 2.3075e-6 m	Y: -1.7346e-6 m	
Principal 2nd Moment of Area:	X: 2443.6523 m^4	Y: 2443.6597 m^4	
Angle Principal Axis makes with X(FRA):	-84.80558°		
Small Angle Stability Parameters			
CoG to CoB (BG):	-19.664543 m		
Metacentric Heights (GMX/GMY):	20.062584 m	20.062586 m	
CoB to Metacentre (BMX/BMY):	0.3980413 m	0.3980425 m	
Restoring Moments about Principal Axes (MX/MY):	21608276 N.m/°	21608278 N.m/°	

Figure 8. Hydrostatic result TLP-1 Andaman locality



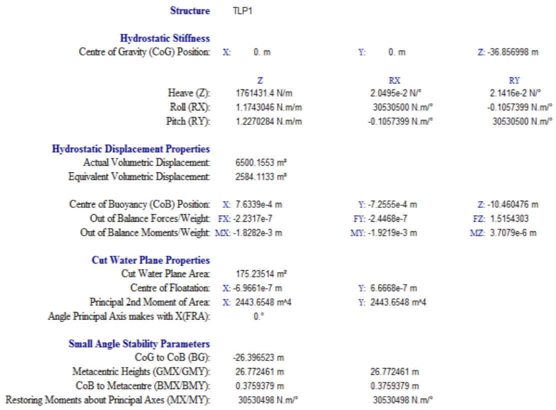
Structure	TLP1		
Hydrostatic Stiffness			
Centre of Gravity (CoG) Position:	X: 0. m	Y: 0. m	Z: -35.425999 m
	Z	RX	RY
Heave (Z):	1123892.6 N/m	3.4675e-2 N/°	0.1037322 N/°
Roll (RX):	1.9867315 N.m/m	19942718 N.m/°	0.1131016 N.m/°
Pitch (RY):	5.9434185 N.m/m	0.1131016 N.m/°	19942716 N.m/°
Hydrostatic Displacement Properties			
Actual Volumetric Displacement:	4681.7378 m³		
Equivalent Volumetric Displacement:	1823.161 m³		
Centre of Buoyancy (CoB) Position:	X: 9.0682e-4 m	Y: -2.713e-3 m	Z: -11.358126 m
Out of Balance Forces/Weight:	FX: -1.0572e-7	FY: 6.395e-10	FZ: 1.5679218
Out of Balance Moments/Weight:	MX: -6.9649e-3 m	MY: -2.327e-3 m	MZ: -2.846e-6 m
Cut Water Plane Properties			
Cut Water Plane Area:	111.80991 m²		
Centre of Floatation:	X: -5.2882e-6 m	Y: 1.7677e-6 m	
Principal 2nd Moment of Area:	X: 994.85956 m^4	Y: 994.86816 m^4	
Angle Principal Axis makes with X(FRA):	85.70961°		
Small Angle Stability Parameters			
CoG to CoB (BG):	-24.067873 m		
Metacentric Heights (GMX/GMY):	24.280371 m	24.280373 m	
CoB to Metacentre (BMX/BMY):	0.2124979 m	0.2124998 m	
Restoring Moments about Principal Axes (MX/MY):	19942716 N.m/°	19942718 N.m/°	

Figure 9. Hydrostatic result TLP-2 Andaman locality

Structure	TLP1		
Hydrostatic Stiffness			
Centre of Gravity (CoG) Position:	X: 0. m	Y: 0. m	Z: -41.681 m
	Z	RX	RY
Heave (Z):	1123891. N/m	1.2862e-2 N/°	-4.2162e-2 N/°
Roll (RX):	0.736936 N.m/m	25853688 N.m/°	-0.1425482 N.m/°
Pitch (RY):	-2.4157121 N.m/m	-0.1425482 N.m/°	25853688 N.m/°
Hydrostatic Displacement Properties			
Actual Volumetric Displacement:	5703.2759 m³		
Equivalent Volumetric Displacement:	1604.801 m³		
Centre of Buoyancy (CoB) Position:	X: -1.4908e-3 m	Y: 6.8028e-4 m	Z: -16.016405 m
Out of Balance Forces/Weight:	FX: 3.7776e-8	FY: -3.7679e-7	FZ: 2.5538907
Out of Balance Moments/Weight:	MX: 2.4318e-3 m	MY: 5.2825e-3 m	MZ: -3.1112e-6 m
Cut Water Plane Properties			
Cut Water Plane Area:	111.80975 m²		
Centre of Floatation:	X: 2.1494e-6 m	Y: 6.557e-7 m	
Principal 2nd Moment of Area:	X: 994.85315 m^4	Y: 994.85699 m^4	
Angle Principal Axis makes with X(FRA):	-77.481247°		
Small Angle Stability Parameters			
CoG to CoB (BG):	-25.664595 m		
Metacentric Heights (GMX/GMY):	25.839029 m	25.839031 m	
CoB to Metacentre (BMX/BMY):	0.1744354 m	0.1744361 m	
Restoring Moments about Principal Axes (MX/MY):	25853688 N.m/°	25853688 N.m/°	

Figure 10. Hydrostatic result TLP-3 Andaman locality

Panel pressure of four NREL TLP's located at Andaman locality is shown in Figure 12. The hydrodynamic motion characteristics are summarized in Table 3.



Structure	TLP1		
Hydrostatic Stiffness			
Centre of Gravity (CoG) Position:	X: 0. m	Y: 0. m	Z: -36.856998 m
	Z	RX	RY
Heave (Z):	1761431.4 N/m	2.0495e-2 N/°	2.1416e-2 N/°
Roll (RX):	1.1743046 N.m/m	30530500 N.m/°	-0.1057399 N.m/°
Pitch (RY):	1.2270284 N.m/m	-0.1057399 N.m/°	30530500 N.m/°
Hydrostatic Displacement Properties			
Actual Volumetric Displacement:	6500.1553 m³		
Equivalent Volumetric Displacement:	2584.1133 m³		
Centre of Buoyancy (CoB) Position:	X: 7.6339e-4 m	Y: -7.2555e-4 m	Z: -10.460476 m
Out of Balance Forces/Weight:	FX: -2.2317e-7	FY: -2.4468e-7	FZ: 1.5154303
Out of Balance Moments/Weight:	MX: -1.8282e-3 m	MY: -1.9219e-3 m	MZ: 3.7079e-6 m
Cut Water Plane Properties			
Cut Water Plane Area:	175.23514 m²		
Centre of Floatation:	X: -6.9661e-7 m	Y: 6.6668e-7 m	
Principal 2nd Moment of Area:	X: 2443.6548 m^4	Y: 2443.6548 m^4	
Angle Principal Axis makes with X(FRA):	0.°		
Small Angle Stability Parameters			
CoG to CoB (BG):	-26.396523 m		
Metacentric Heights (GMX/GMY):	26.772461 m	26.772461 m	
CoB to Metacentre (BMX/BMY):	0.3759379 m	0.3759379 m	
Restoring Moments about Principal Axes (MX/MY):	30530498 N.m/°	30530498 N.m/°	

Figure 11. Hydrostatic result TLP-4 Andaman locality

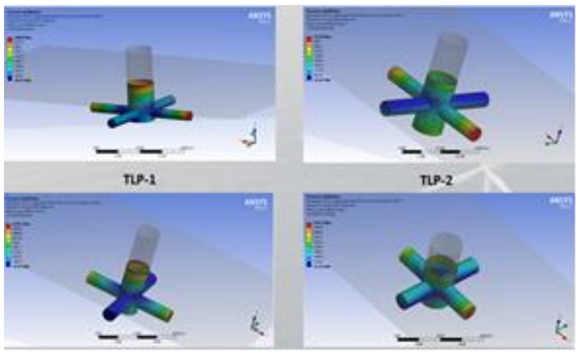


Figure 12. Panel pressure of four NREL TLP's located at Andaman locality

TABLE 3. Hydrodynamic motion characteristics

Location	Surge(M)	Sway (M)	Heave (M)	Remarks
Nicobar Tlp-1	0.000075	0.00015	-19.5577	Tlp With Best Surge Perfomance
Nicobar Tlp-2	0.0008	-0.0023	-25.47	
Nicobar Tlp-3	-0.001375	0.0006	-27.406	Surge Deviate Slightly
Nicobar Tlp-4	0.0008	-0.0005	-25.6	

CONCLUSION

All the tension leg platforms except the third one will give satisfactory regular response but the third tension leg platform fails due to deviation in the surge. The surge motion response with respect to time gives a deviating output hence the structure will not be stable in the given condition. The wind industry has developed very fast in recent years, moving from onshore to offshore in shallow water and then in deep water. Many floating wind turbine concepts have been proposed for water depth larger than

100-200 m. Tension leg platform wind turbines (TLPWTs) are among the concepts that are under consideration for deeper water. There is an increasing interest in using offshore wind turbines in deeper waters. The tension leg platform wind turbine (TLPWT) has seen as a promising concept for this purpose. The TLP-1 resulted in the best surge performance among four prototypes.

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Persian Abstract

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چکیده

توربین های بادی در سکوهای پشتیبانی شناور به گونه ای طراحی شده اند که در یک محیط عمیق دریایی چند مایلی ساحل و در عمق آب بیش از ۶۰ متر نصب شوند. تأثیرات ناشی از یخ دریا ، متوسط سطح دریا متفاوت است و رشد دریایی بارهای اضافی را تشکیل می دهد که باید در یک فرایند طراحی واقعی در نظر گرفته شود. طراحی مدلهمانند ابزاری ANSYS است که برای ایجاد هندسه برای سیستم های هیدرودینامیکی استفاده می شود. بدنهای سطح فقط توسط ANSYS AQWA پشتیبانی می شوند بنابراین کل بدنه جامد که با استفاده از مدل ساز طراحی ایجاد می شود به بدنه مسطح تبدیل می شود. چهار سکوی مختلف با کمترین تنش پا آماده شده است که تمام ابعاد و استانداردها از دستورالعمل آزمایشگاه ملی انرژی تجدیدپذیر ایالات متحده پیروی می شود. در این مقاله تمرکز بر عملکرد حرکتی سکوی ساق پا ، نمونه های اولیه توربین باد در سواحل نیکوبار هند است. داده های جریان باد ، موج و اقیانوس به ماژول های AQWA وارد شدند و نتیجه با توجه به دامنه زمانی اعتبار می یابد.