International Journal of Scientific & Engineering Research Volume 10, Issue 5, May-2019
ISSN 2229-5518

Response and Motion Performance of Offshore 5MW NREL Wind Turbine Platforms Based On Gujarat and West Bengal Costal Ocean State

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Abstract—ThThe 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 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 programs, which is widely used in the offshore industry is adopted in this project to execute the Hydrostatic and hydrodynamic analysis. Two localities with different latitudinal and longitudinal extent are selected according to similar ocean floor depth without much undulation in bathymetric data. The entire localities selected are located in Indian coasts which are a few km away from the major ports in India. 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 there 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.

Index Terms—ANSYS AQWA, Floater Platforms, Hydrodynamic analysis, Hydrostatic analysis, Mini Tension Leg Platform wind turbines(MTLPWT), Offshore Tapping, Tension Leg Platform, National Renewable Energy Laboratory(NREL)

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1 INTRODUCTION

Wind energy is one of the most renowned source of renewable energy, with steep hikes in fuel prices, wind energy poses to be an attractive and environment friendly source of power generation. Most of world's metropolises are near shore and offshore wind energy offers the obvious advantage of no land usage and probably more reliable wind resource. Thus the project aims to study the tension leg platform feasibility and response in various localities. The vast deep water wind resource represents a potential to use offshore floating wind turbines to power much of the world with renewable energy. Many floating wind turbine concepts have been proposed, but dynamics models, which account for the wind inflow, aerodynamics, elasticity, and controls of the wind turbine, along with the incident waves, sea current, hydrodynamics, and platform and mooring dynamics of the floater, were needed to determine their technical and economic feasibility.Wind energy is one of the most renowned source of renewable energy, with steep hikes in fuel prices, wind energy poses to be an attractive and environment friendly source of power generation.Most of world's metropolises are near shore and offshore wind energy offers the obvious advantage of no landusage and probably more reliable wind resource.Thus the project aims to study the tension leg platform feasibility and response in various Indian coastal regions. Offshore structures should be able to stand up to the dynamic effects of environmental loads throughout their lifespan.

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These loads vary from temporary transient loads induced by earthquakes and ocean storms to continuous loads due to wind, waves, and ocean currents. Since floating offshore structures aren't supported directly by the ground, however, effects of earthquakes on floating structures have received less attention compared with those on fixed Structures. 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. Thetension leg platform wind turbine (TLPWT) is seen as a promising concept for this. Low production costs and limited motions give the TLPWT concept both economic and dynamic advantages. Previous studies regarding dynamic analysis of floating offshore wind turbines have focused on global dynamic analysis with a rigid hull. Due to the world's increasing energy demand and the depletion of fossil fuels, the importance of alternative energy production is increasing. In the past couple of decades, the offshore wind industry has developed from applications in shallow water to ever deeper, more remote locations with harsher environments.Various studies have focused on floater designs for this application and multiple prototypes have been developed.To gain access to areas with larger water depths, alternative bottom-founded structures have been developed. With this innovation the commercial applicability has been widened to water depths of 40 to 50m. These structures, however, typically require larger amounts of material, and still are not capable of covering most areas. With an increasing demand for wind energy, a solution for the application of wind energy in ever deeper waters is required, this could potentially be solves by the application of floating wind turbines.TLP floaters are categorized as mooring line stabilized structures. This type of floater typically possesses excess buoyancy, which is compensated by tension forces in pretension tethers that connect the floater to the seabed. These tensile forces have a stabilizing effect on both rotational movements and translational deflections.

2. METHODOLOGY

- Data collection
- Find and learn appropriate software

- Material properties selection
- Identifying the possible alternatives from existing offshore
- Fixing the most appropriate structure which is mini TLP
- Questing the existing design
- Fixing the four types of NREL TLP prototypes.
- Model four TLP prototypes from NREL in ANSYS AQWA
- Fix two localities which are around 100km from Indian coast.
- Obtaining bathymetric data
- Obtaining wind, wave and ocean current data
- Input the obtained data in to software for each locality
- Attain the aid of Hydrodynamic diffraction and response
- Analysis of model by software
- Interpretation of analysis results
- Conclusion

3. ANALYTICAL MODELLING

The structure is very simple comparing with normal tension leg platform. The major part of the structure is a draft. Four spokes are attached to this specific draft spokes are lesser in diameter compared to draft. Tendons are connected to the spokes and they are anchored to the sea bottom straight mooring system is adopted for mooring.The structure of mini TLP is basically a six degree of freedom system which possesses the mobility in six different directions. The structure mobility in all the different directions are related to the type of loading direction of loading and also the other costal conditions.Bathymetric data that is ocean floor depth have a significant impact on the motion performance. The cable properties like the cross section and the stiffness of the mooring cable etc are also providing a significant impact on the motion performance of the structure.

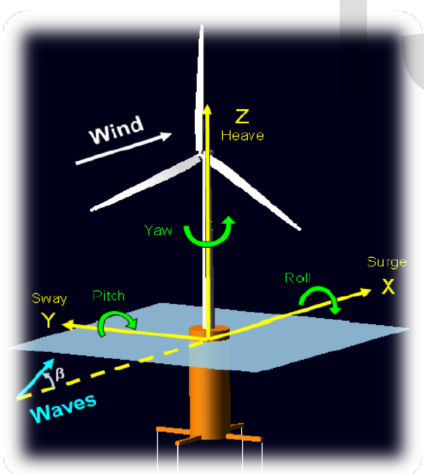

Fig -1. Mini Tension Leg Platform degrees of freedom

TABLE 1

PROPERTIESOFFOUR NREL PROTOTYPES MODELLED

PARAMETER S	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

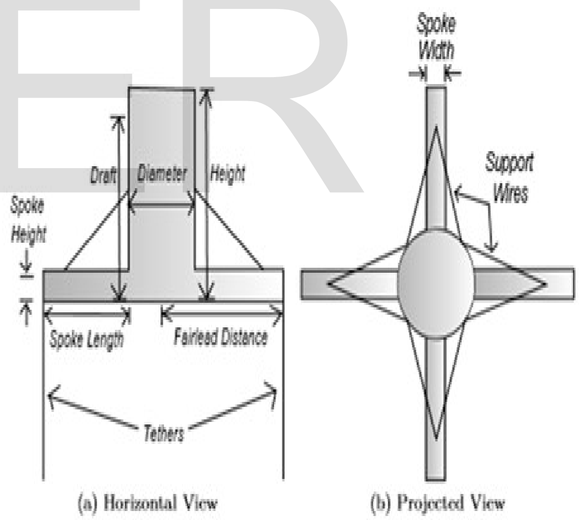

Fig -2.Mini Tension Leg Platform basic views

compared with those on fixed Structures Offshore structures should be able to stand up to the dynamic effects of environmental loads throughout their lifespan. These loads vary from temporary/transient loads induced by earthquakes and ocean storms to continuous loads due to wind, waves, and ocean currents. Since floating offshore structures aren't supported directly by the ground, however, effects of earthquakes on floating structures have received less attention.

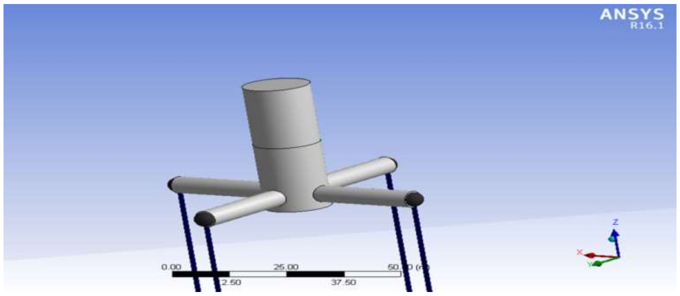

Fig -3.TLP-1 modeled in ANSYS AQWA

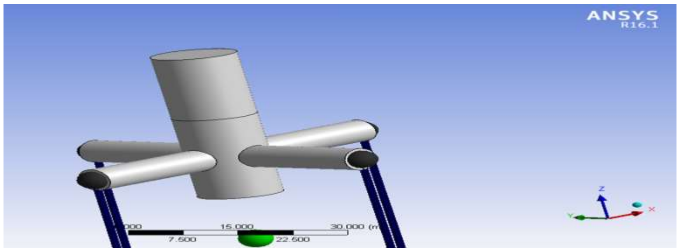

Fig -4.TLP-2 modeled in ANSYS AQWA

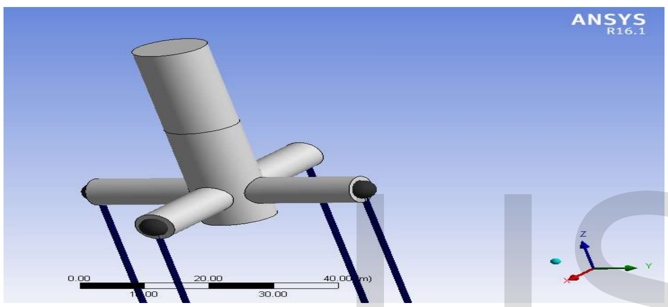

Fig -5.TLP-3 modeled in ANSYS AQWA

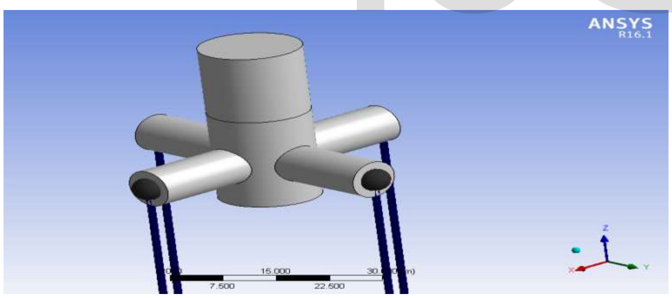

Fig -6.TLP-4 modeled in ANSYS AQWA

4. DISCUSSION OF INPUT

The environmental parameters like wind, Wave, Current have significant impact on the structure. All the data required for input are collected by the portal of government of India named "INDIAN NATIONAL CENTER FOR OCEAN INFORMATION SERVICES ".They provide real-time data of the of the environment and climate. They also provide a toolset for forecasting the upcoming ocean state for the upcoming months. The portal provides all the required inputs for each and every location according to latitude and longitude.

The exact ocean depth will be provided if we provide the ocean latitude and longitude. . Two localities which are of constant ocean floor depth are selected without undulations. Two localities are fixed with a particular latitude and longitude gap which locates around hundred kilometers from the coastal areas of major costal states of peninsular Indian subcontinent. The localities extent over both bay of Bengal and Arabian sea.

TABLE 2

DATA COLLECTED FOR GUJARATLOCALITY

PARAMETER	MAGNITUDE OR DIRECTION
LATITUDE	21^{o}N to 22^{o}N
LONGITUDE	66^{o}E to 67^{o}E
BATHYMETRIC DATA	2090m
WAVE HEIGHT	1.5m
WAVE DIRECTION	N 20^{o} E & S 20^{o} W
SHORT WAVE PERIOD	6s
LONG WAVE PERIOD	7s
WIND SPEED	6m/s
WIND DIRECTION	N 88^{o} E
CURRENT VELOCITY	0.2m/s
CURRENT DIRECTION	S 45^{o} W

TABLE 3

DATA COLLECTED FOR BENGALLOCALITY

PARAMETER	MAGNITUDE OR DIRECTION
LATITUDE	20^{o}N to 21^{o}N
LONGITUDE	88^{o}E to 89^{o}E
BATHYMETRIC DATA	122m
WAVE HEIGHT	1.8m
WAVE DIRECTION	N 30^{o} E & S 30^{o} W
SHORT WAVE PERIOD	5s
LONG WAVE PERIOD	6s
WIND SPEED	10m/s
WIND DIRECTION	N 45^{o} E
CURRENT VELOCITY	1m/s
CURRENT DIRECTION	S 45^{o} E

Both the localities selected to implement the NREL platforms are at peak locations of Indian peninsular region one is around hundred kilometers from Bengal coast and other is hundred kilometers from Gujarat coast.

International Journal of Scientific & Engineering Research Volume 10, Issue 5, May-2019
ISSN 2229-5518

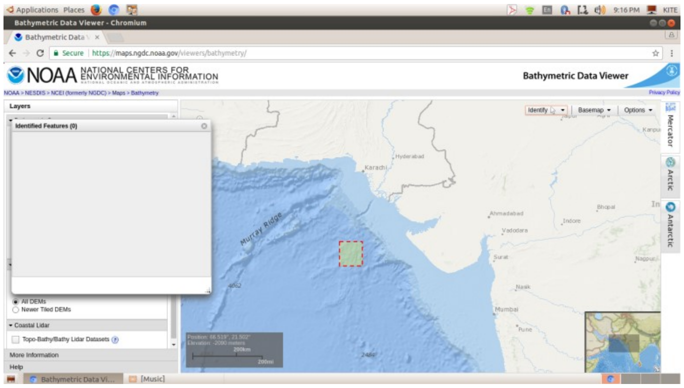

Fig.7.Gujarat locality NOAA data

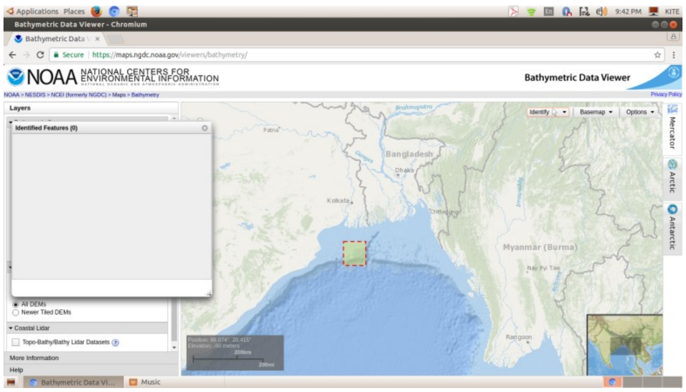

Fig.8.West Bengallocality NOAA data

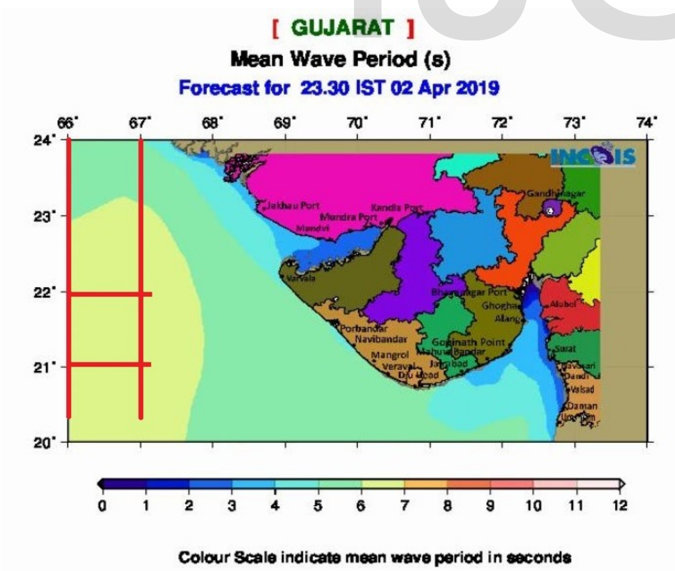

Fig.9.Gujarat locality Wave period data

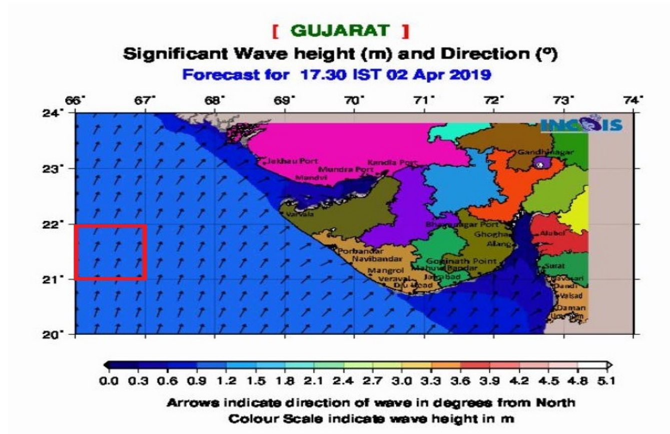

Fig.10.Gujarat locality Wave height and direction data

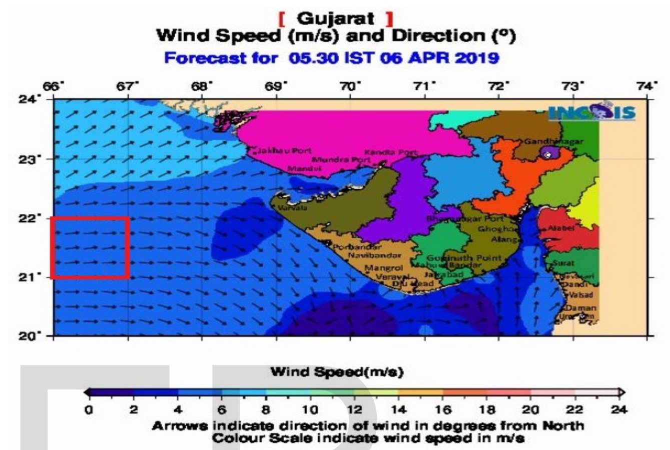

Fig.11.Gujarat locality Wind Speed and direction data

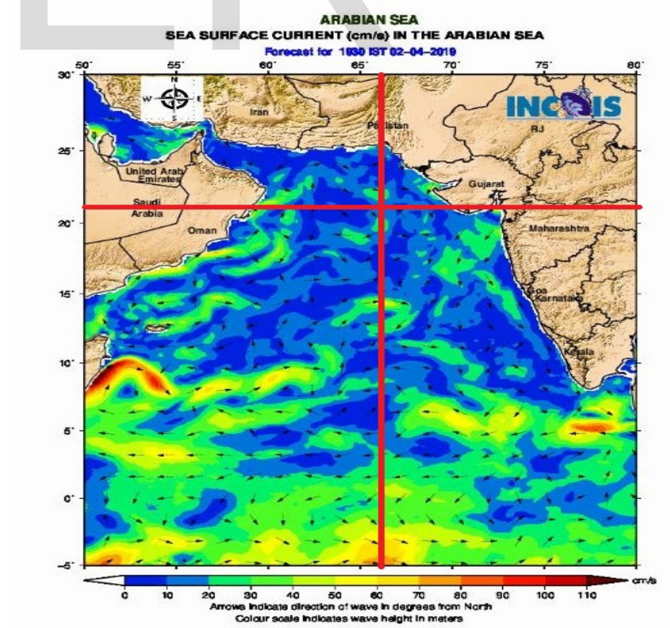

Fig.12.Gujarat locality Ocean current and Direction data

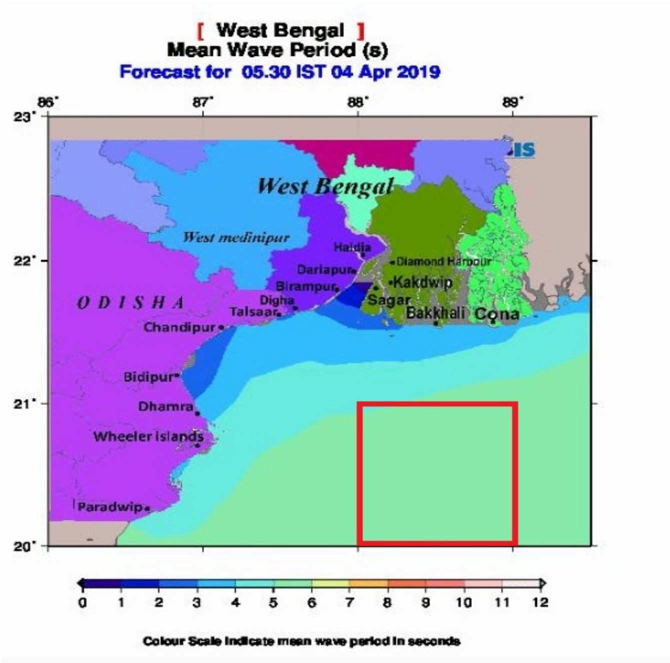

Fig.13.Bengal locality Wave period data

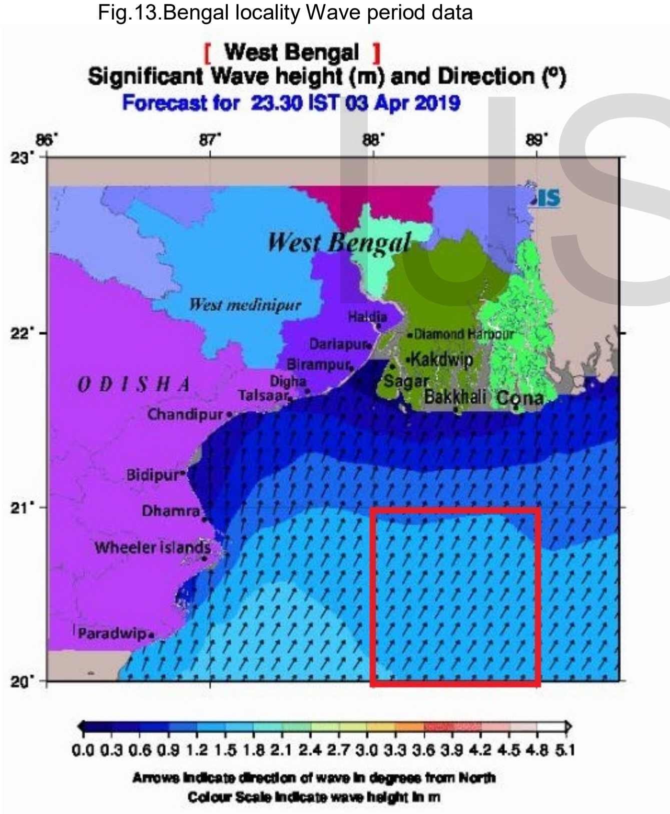

Fig.14.Bengal locality Wave height and direction data

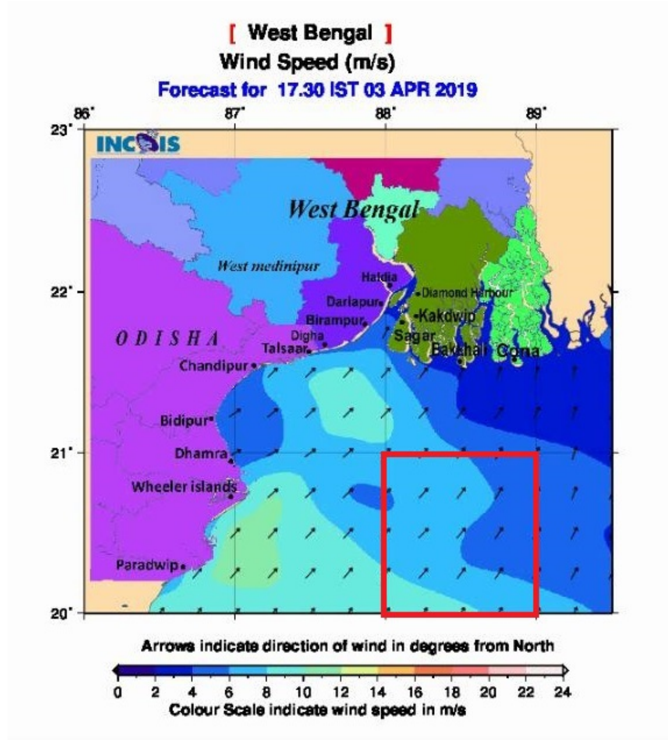

Fig -15.Bengal locality wind speed and direction data

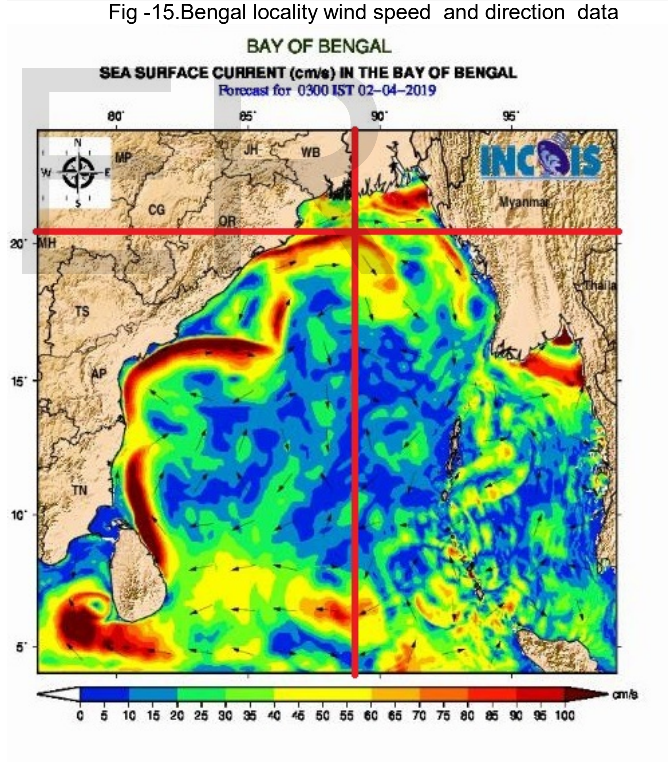

Fig.16.Bengal locality ocean current data

5. RESULT AND DISCUSSION

Hydrostatic analysis results and hydrodynamic analysis results are provided below.

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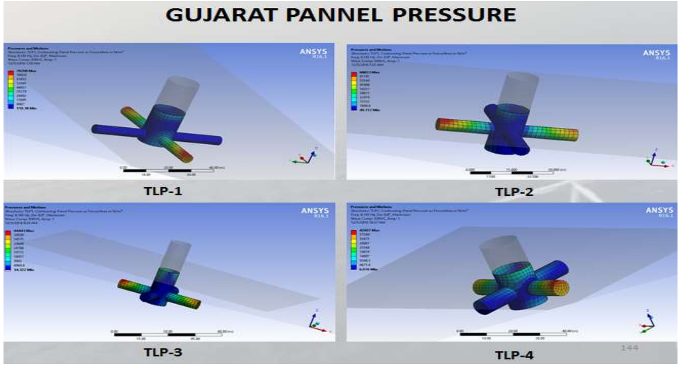

Fig.17.Panel pressure distribution Gujarat TLPS

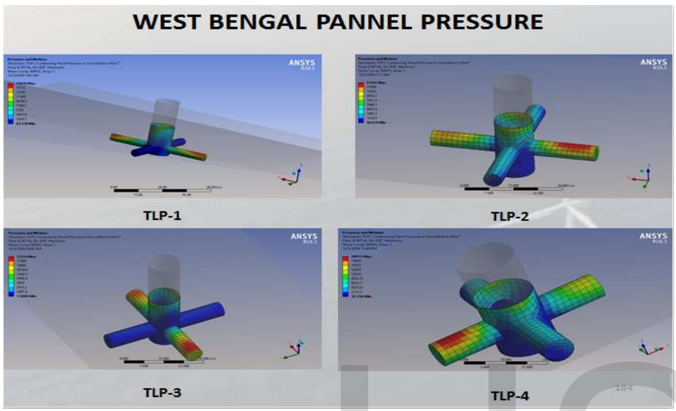

Fig.18.Panel pressure distribution Bengal TLPS

TABLE 4

HYDODYNAMIC RESULTSFROM GRAPH ANALYSIS

LOCATION	SURGE	SWAY	HEAVE	REMARKS
GUJRAT TLP-1	0.00025	0.000125	-22.564	
GUJRAT TLP-2	0.000625	-0.002	-28.046	SWAY DEVIATING
GUJRAT TLP-3	-0.00115	0.0006125	-31.127	
GUJRAT TLP-4	0	-0.005	-14.5	SURGE AND SWAY HIGHLY DEVIATING

Hydrostatic and hydrodynamic analysis are carried out possible outcomes are analyzed. From the Actual response plots from the ANSYS AQWA we can fix the motion performance and response of the platform in the provided ocean state

TABLE 5

HYDODYNAMIC RESULTS FROM GRAPH ANALYSIS

LOCATION	SURGE	SWAY	HEAVE	REMARKS
WEST BENGAL TLP-1	LARGE DEVIATIONS	LARGE DEVIATION	LARGE DEVIATION	LARGE DEVIATION
WEST BENGAL TLP-2	LARGE DEVIATIONS	LARGE DEVIATION	LARGE DEVIATION	LARGE DEVIATION
WEST BENGAL TLP-3	LARGE DEVIATIONS	LARGE DEVIATION	LARGE DEVIATION	LARGE DEVIATION
WEST BENGAL TLP-4	LARGE DEVIATIONS	LARGE DEVIATION	LARGE DEVIATION	LARGE DEVIATION

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	-5.3309e-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: 1432.8118 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: -1.734e-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/°

Fig.19.Sample hydrostatic result TLP1 Gujarat

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	-5.3309e-2 N/°	-7.0939e-2 N/°
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Fig.20.Sample hydrostatic result TLP1 Bengal

CONCLUSION

Motion performance of four NREL TLP Supported wind turbines are done hydrostatic analysis and hydrodynamic response studies are done.

- Two tension leg platforms among eight ones are feasible.
- TLP1 of Gujarat locality is feasible.
- TLP2 ofboth localities are not feasible.
- TLP3 of Gujarat locality is feasible
- TLP4 of both localities are not feasible.

- India has huge possibilities of wind energy extraction.
- Deep sea solutions will constructively catalyze this sector in the near future.
- Bathymetric data have a significant impact in the motion performance of TLPWT
- Panel pressure varies according to loading direction

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