Validation of a Semi-Submersible Offshore Wind Platform through tank test

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ABSTRACT

The performance of a **scale model of a semisubmersible platform for offshore wind** has been identified through a varied **experimental tank test campaign**. Tests were performed by **TECNALIA** at the IHC wave tank in Santander within the framework of the **NAUTILUS** project.

The tested device consists in a **1:35 model** in a Froude scale of a four-column semi-submersible platform provided with heave plates and a ring pontoon at the bottom. The turbine held by the prototype is the NREL 5MW baseline wind turbine.

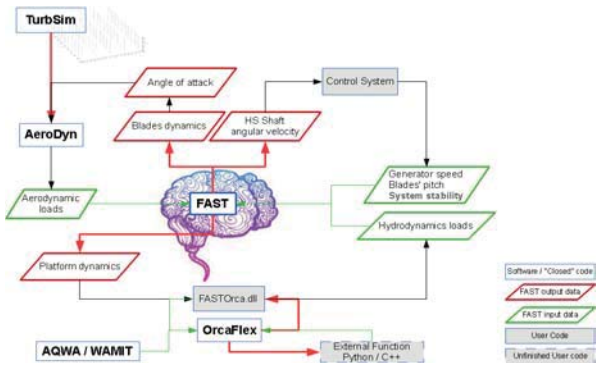
The campaign consisted in decay tests, but also tests in regular **waves** for determining the RAOs and tests in irregular waves simulating typical weather climate conditions of the Basque coasts. **Wind action** was also simulated with air fans and a rigid disk at the hub height. Different wind speed bins were tested. Finally wave, wind and **currents** conditions were replicated for extreme loads.

Outcomes in terms of hydrodynamic characteristics, RAOs, responses under irregular waves and **fairlead mooring loads** are herein reported and compared [1] with the results of numerical simulations obtained by coupling commercial and open source software (FAST and Orcaflex).

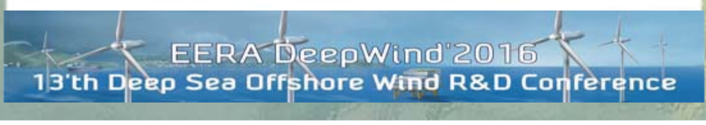
General specification	
Power rating	5 MW
Hull weight (steel mass)	1.700 tons
Total displacement	7.100 tons
WT weight	750 tons
Hub height	86 m
Hull draft	20 m
Depth	> 60 m
Catenary mooring	4 lines
Column diameter	9,5 m
Column distance	33 m
Freeboard	10 m

AERO-HYDRODYNAMIC COUPLING

The analysis of floating wind turbines (FWT) is more complicated than that of fixed-bottom wind turbines. For this particular case a **coupled aero-hydrodynamic simulator with FAST v7 and Orcaflex** has been used for simulating the response and aerodynamic performance of FWTs under wind, current and waves loads in the time domain.
For **aerodynamics**, an **unsteady BEM model and the (GDW) Generalized Dynamic Wake** has been used to calculate the aerodynamic loads and performance of the wind turbine.
For **hydrodynamics**, a **linearized BEM model** based on the frequency-dependent parameters obtained from the code AQWA has been used to calculate the hydrodynamic loads on the platform by solving the hydrostatic, **diffraction and radiation** problems.



The hydrodynamic study of the floater is **combined with an aeroelasticity and a control algorithm** model to obtain a **coupled aero-servo-hydro-elastic model**. Generalized inertia forces for floating wind turbine concepts have been described for tower, nacelle, hub, platform and blades. The generalized active forces have been described for aerodynamic forces, hydrodynamic forces, gravity force, drive train force and elastic forces



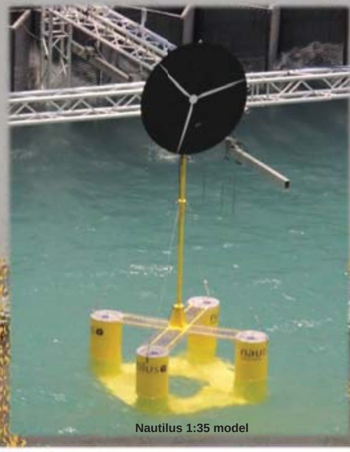
TEST CAMPAIGN 1:35 SCALE MODEL

The **test campaign** carried out **included**:

1. Inclining test
2. Decay test
3. Force oscillation
4. Mooring system forces
5. Towing in regular waves
6. Regular waves
7. Wave grouping tests.

Each one had a specific **target**:

1. Stability curve
2. Eigen periods
3. Added mass and damping
4. Mooring stiffness
5. Drag coefficient
6. RAO's
7. Drift force



Nautilus 1:35 model

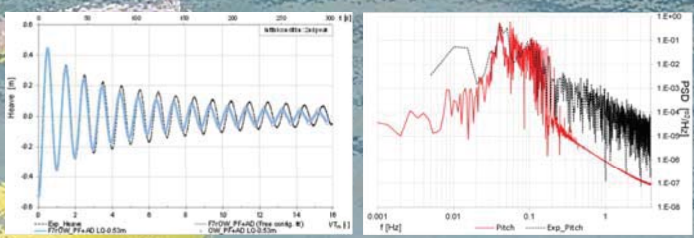
Data below shows some results from decay test (natural frequencies and calibration), validation for wave grouping and figures of operational and survival test.

Surge	Sway	Heave	Roll	Pitch	Heave
101.65 s	101.75 s	18.90 s	23.92 s	24.30 s	70.55 s

Eigen period results from decay test

Test results					
	Operational		Survival		
Hs	1.88		14.12		m
Tp	9.15		15		s
Vwind	11.5		50		m/s
Vcurrent	0		0.9		m/s
	Offset	Peak to peak	Offset	Peak to peak	
Surge disp.	9.71	4.38	8.51	6.31	m
Heave disp.	86.5	0.47	89	5.34	m
Pitch disp.	-0.76	3.01	-0.71	3.56	deg
L1 loads	91.35	5.55	82.39	86.80	ton
L3 loads	32.21	1.46	35.73	10.45	ton
	Offset	Max	Offset	Max	
Acceleration X	0.20	0.65	0.46	1.47	m/s²
Acceleration Z	0.09	0.29	0.47	1.41	m/s²
Acceleration Pitch	0.12	0.47	0.27	0.90	deg/s²

Result from operational and survival conditions



(Left) Lineal-quadratic heave calibration and (right) pitch numerical model validation for 3m significant height wave spectra.

CONCLUSIONS

- Results were **satisfactory** with expected accelerations and motions below most wind turbine manufacturer **requirements**.
- Free decay and forced oscillation test are essential for **model calibration**.
- Hydrodynamic **numerical model and test results fit** for wave excitation. Working on coupling with aerodynamic reliable model.
- Reliable numerical model **enables the simulation** of design load cases for certification.

REFERENCES

[1] Nava,V., Aguirre, G., Galvan, J., Sanchez-Lara, M., Mendikoa, I., Perez-Moran, G., Experimental studies on the hydrodynamic behavior of a semi-submersible offshore wind platform, 2015, Renewable Energies Offshore - 1st International Conference on Renewable Energies Offshore, RENEW 2014, 24-26 Nov. 2014, Lisbon, Portugal, ed. Taylor & Francis Group, pp. 709-715.
[2] Definition of the semisubmersible Floating System for Phase II of OC4; A. Roberson. NREL
[3] Integrated Dynamic Analysis of Floating Offshore Wind Turbines; Bjorn Skaare; Hydro Oil & Energy
[4] Modeling aspects of a floating wind turbine for coupled wave–wind-induced dynamic analyses; M. Karimirad; NTNU