Optimisation of a novel hybrid concept for wind-wave energy extraction

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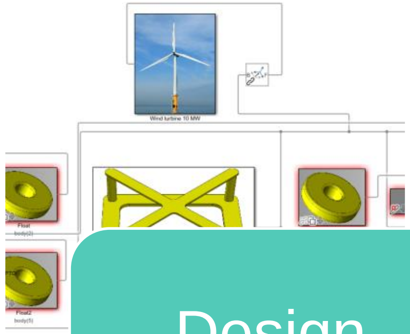
Roadmap

State of art of technology

- Wind&Wave platform description
- Advantages and disadvantages

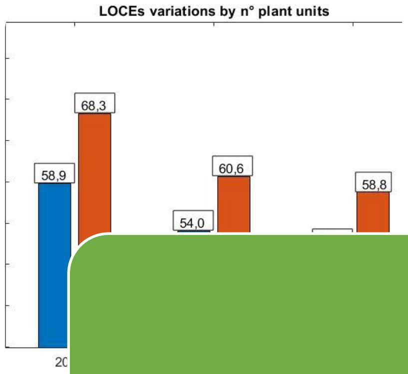


Design phase & Numerical Model

- Matlab & Simulink
- WecSim
- Ansys Aqwa

Case study application

- Belmullet (Ireland)
- Resource assessment



Conclusions

- Comparison between a FOWT and Hybrid system
- LCOE estimation

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Hybrid Wind & Wave Platform

A hybrid platform is a system capable of exploiting both **wind** and **wave resources**.

The system is usually made of:

- 1 or more **wind turbines**
- >1 **Wave Energy Converters**

Among the most used WECs there are:

- Point Absorbers
- Oscillating Water Columns
- Oscillating Wave Energy Converters.

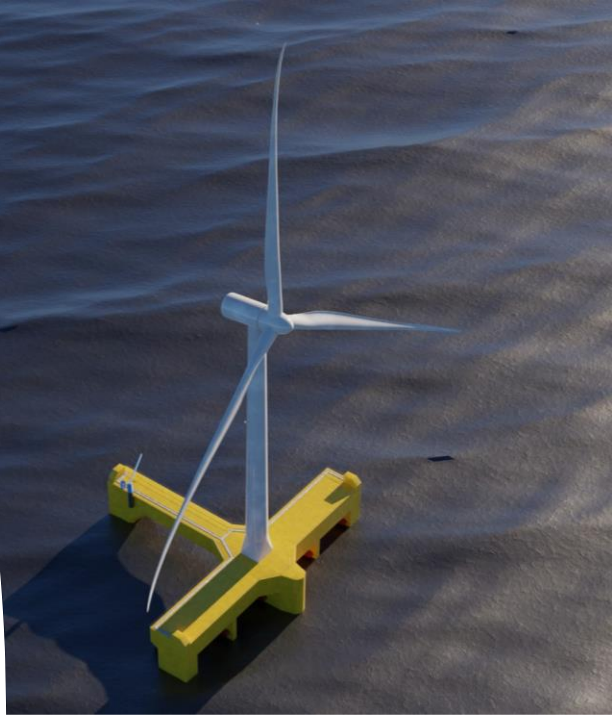
Hybrid Wind & Wave Platform

Main advantages:

- Shared platform, moorings and electrical grid
- Solution that prevents wind and wave variability
- WECs contribute to system stability

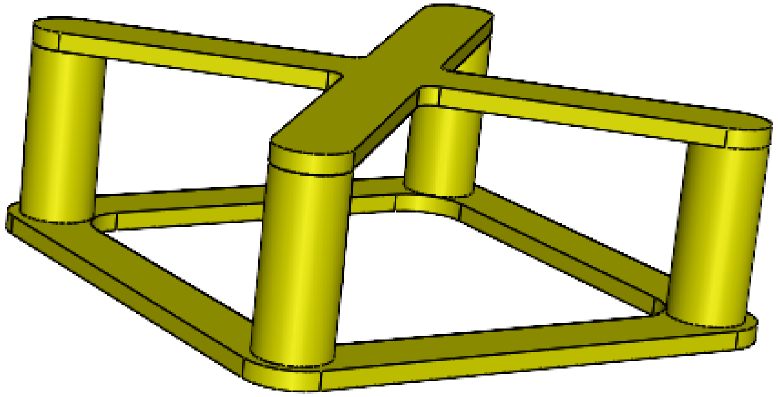
Main disadvantages:

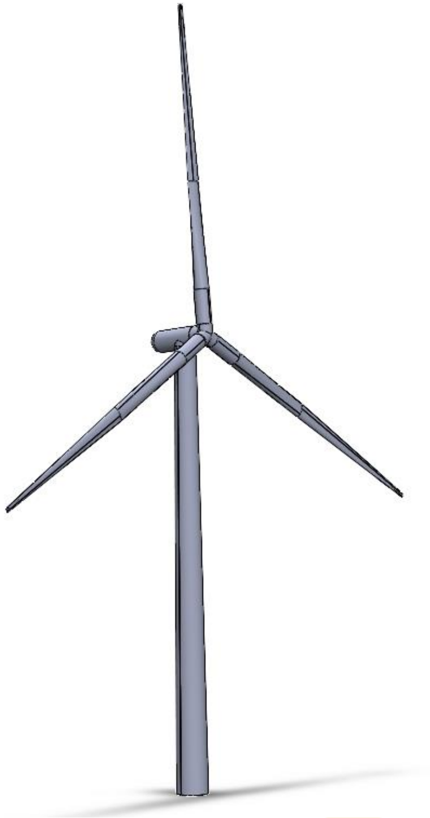
- Higher Capex and Opex
- Lower TRL of WEC devices

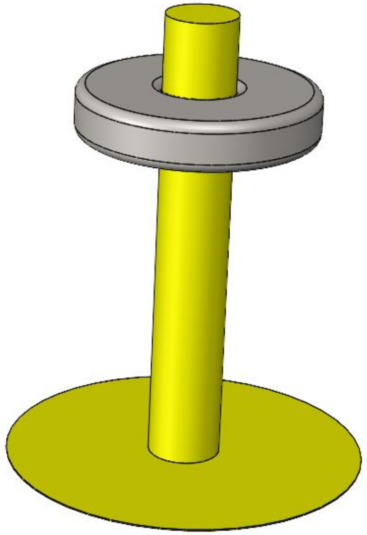


Hybrid Wind & Wave Platform

The wind&wave platform is made of:







- **Nautilus platform**
- **DTU 10 MW wind turbine**
- **4 Point Absorbers**

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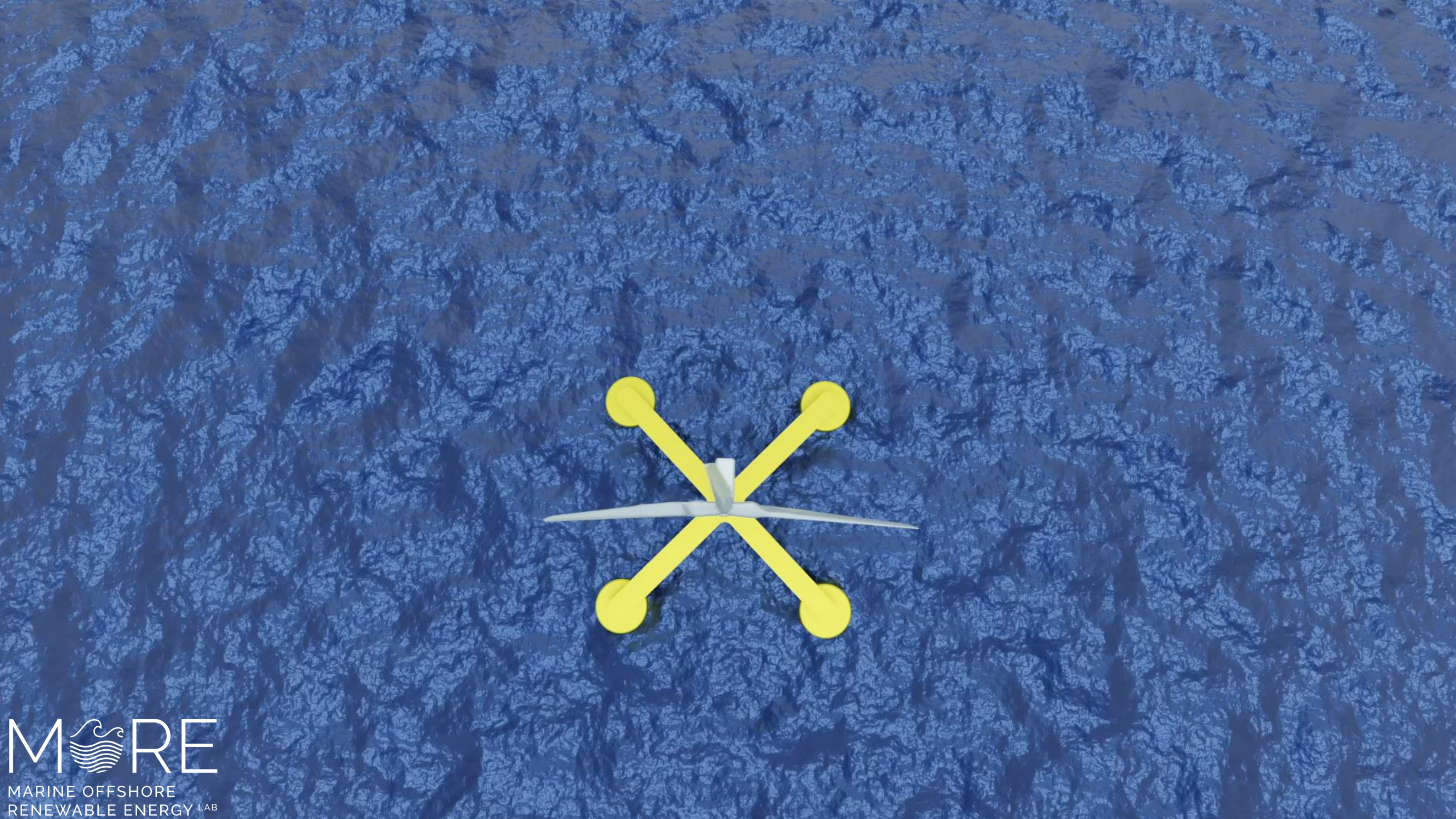
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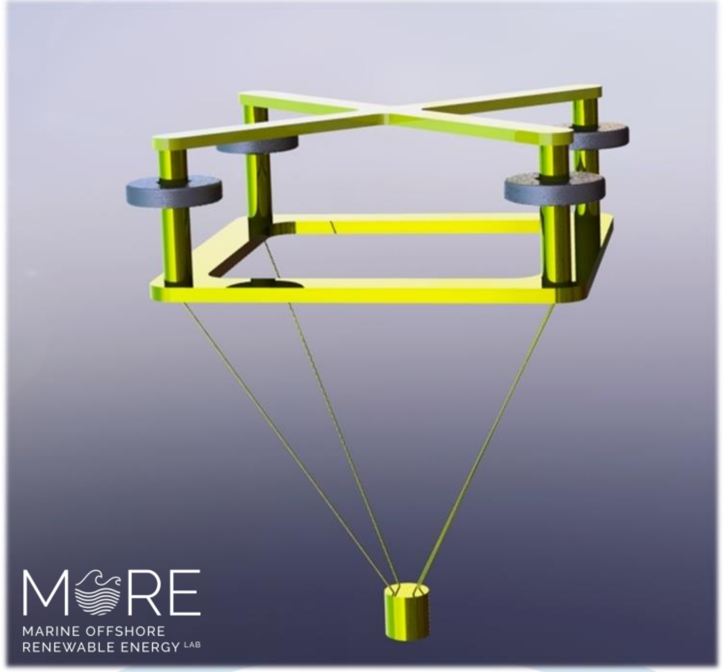
Design phase: the platform

Starting from the design of the semi-submerged **Nautilus** platform, a **preliminary design** of the system was made.

To ensure greater stability, it was decided to add a **counterweight** supported by 4 chains.



Dimension	Value	Units
External Square Length	90	$[m]$
Internal Square Length	70	$[m]$
Diameter of columns	6	$[m]$
Height of columns	28	$[m]$
Draught	21	$[m]$
Platform and ballast material (Steel)	7700	$[kg/m^3]$
CoG Coordinates	$(0;\ 0;\ -40)$	$[m]$
Pendulum ballast mass	6126	[tons]
Total mass	11395	$[tons]$

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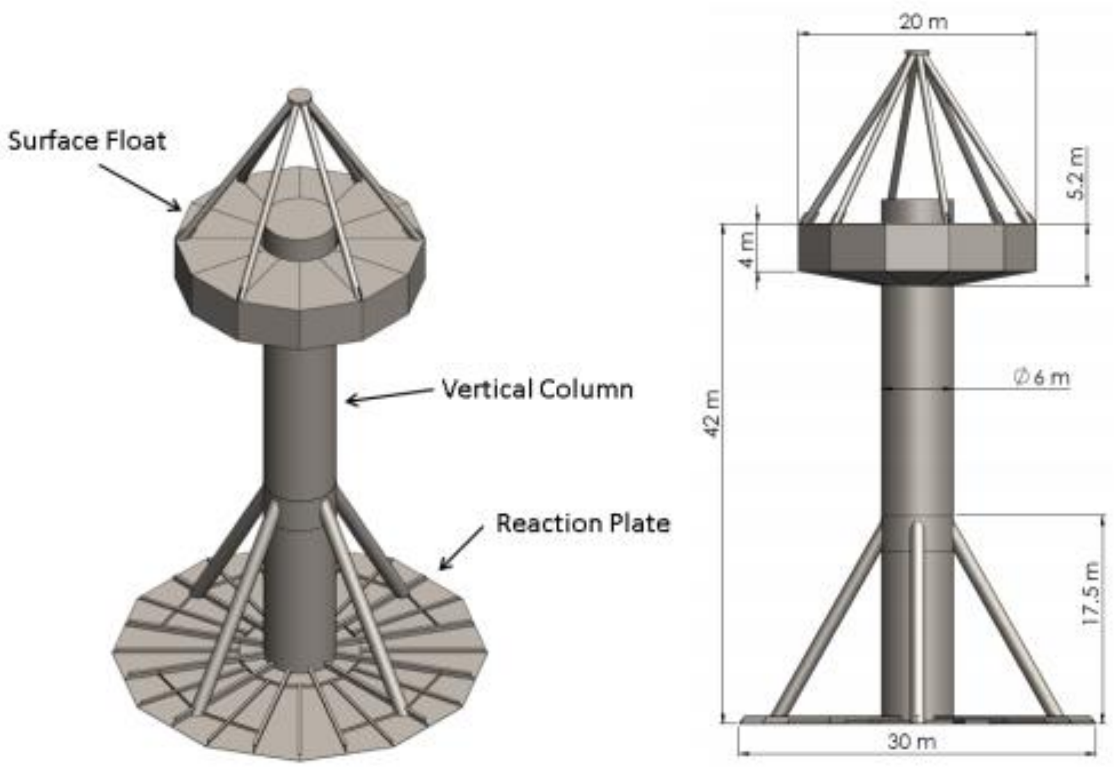
Design phase: the RM3 WEC

The **RM3** point absorber design consists of a surface float that oscillates with wave motion relative to a vertical spar buoy connected to a subsurface reaction plate.

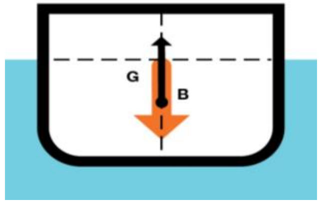
The floating platform has been adapted to accommodate a WEC for each of the 4 columns of the structure.



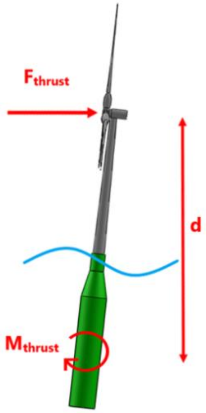
Source: U.S. Department of Energy

Hydrostatic Stability

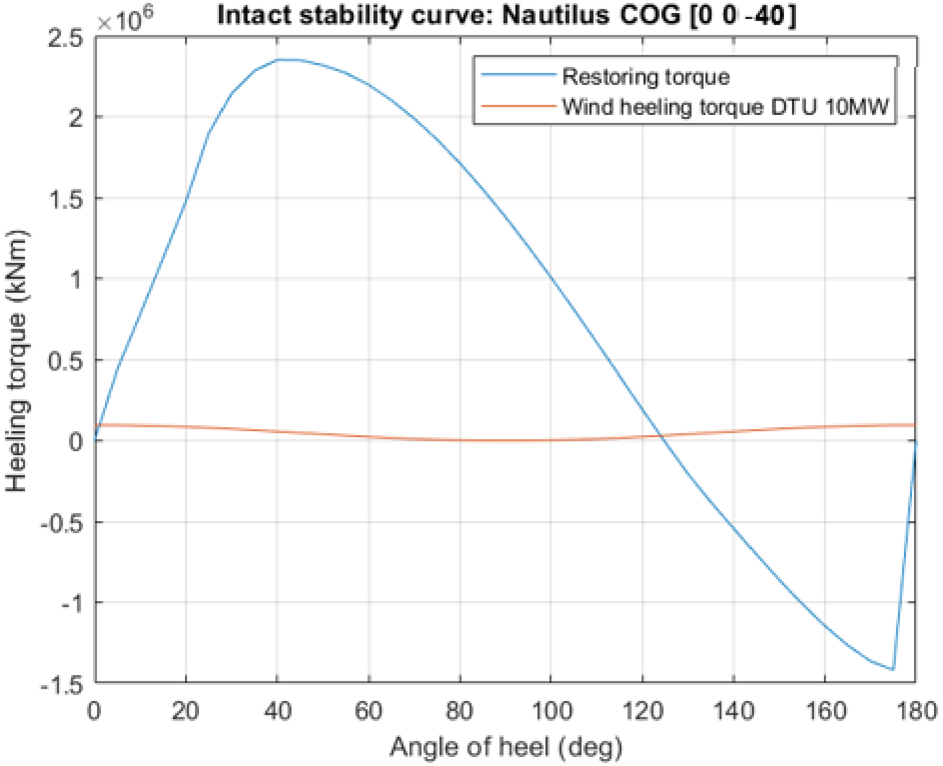
After dimensioning the system, the static stability was verified, calculating both the **metacentric height** of the platform and the **GZ curve**.



$$F_B - F_G = \rho g V - mg = 0$$



$$\alpha_{maximum\ pitch} = \frac{M_{thrust}}{C_{55}} \leq 5°$$



Towards Hydrodynamic Analysis

Hydrostatic Analysis → **Hydrodynamic Analysis**

Excel

SOLIDWORKS

ANSYS

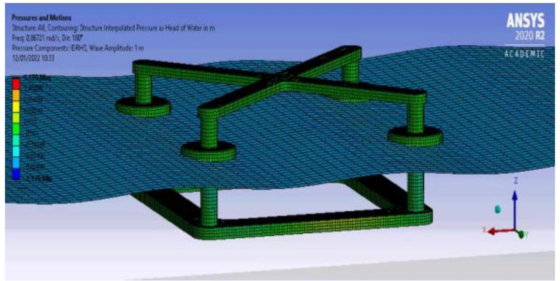
MATLAB
SIMULINK

Numerical Model of a Wind&Wave Platform

Pre-processing

ANSYS

BEMIO

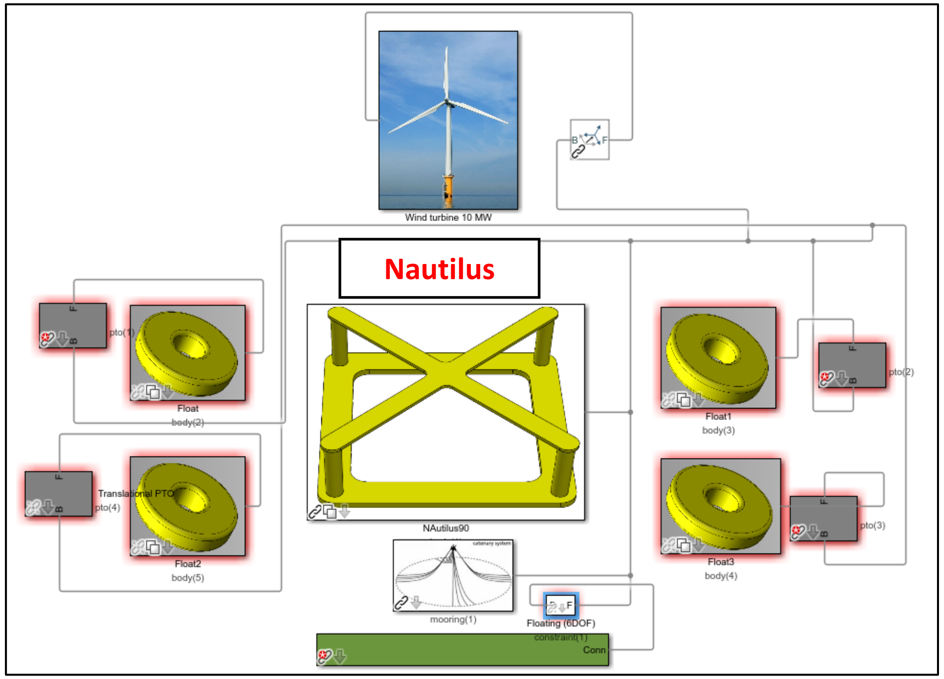


Input Geometry details stl files

MATLAB SIMULINK

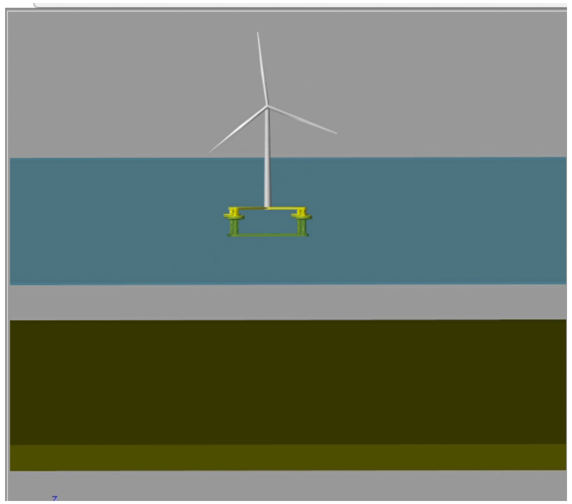
$$m\ddot{X} = Fext + Frad + F_{PTO} + Fv + F_B + Fm$$

Wind turbine 10 MW



Mooring system

Mechanics visualization



Output :

- Power,
- Position, Velocity and Acceleration
- Loads.

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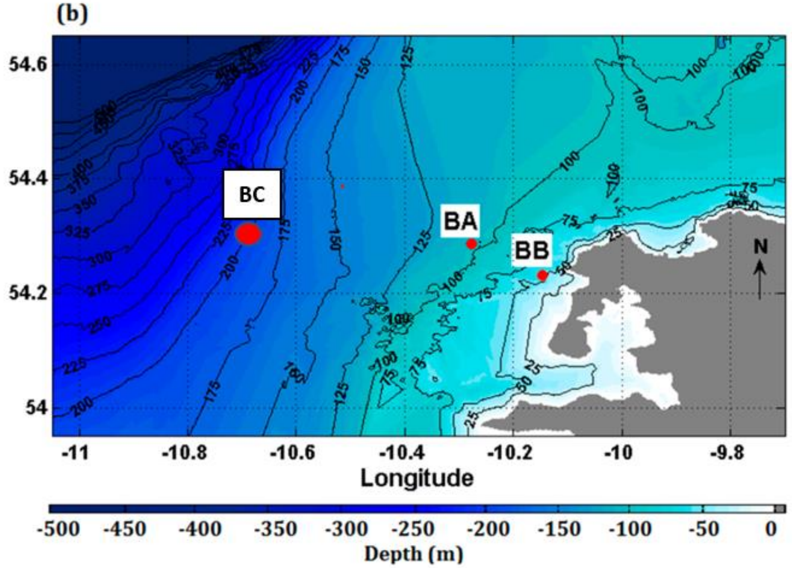
Belmullet Case Study

Belmullet site (Ireland)



The site considered is the BC:

- Average sea depth of **200 m**
- **41 km** far from the coast

Meta-oceanic data extraction

ECMWF

	Start	Step	End
TpClass	3.5	3	16.5
V0Class	0.5	2,5	30.5
HsClass	0.5	2	6.5

$$P_{wave} \cong 0.5 \cdot H_s^2 T_e$$

$$P_{wind} = \frac{1}{2} \rho A V^3$$

1) Data set extraction form ERA5

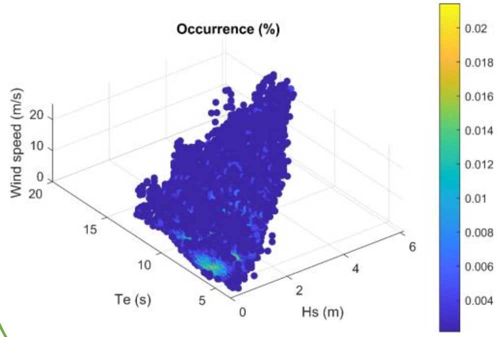
- Putting geographical coordinates into python script

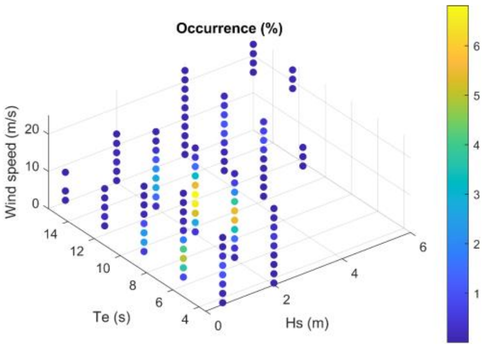
2) Filtering by triples class

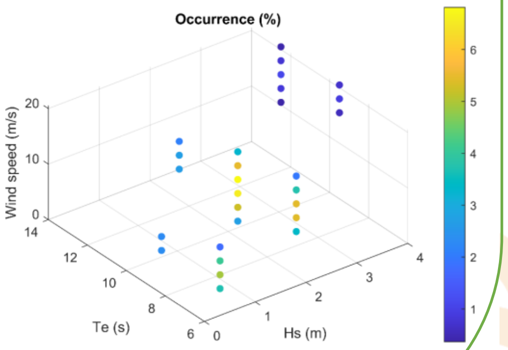
- Performing filtering using MATLAB script

3) Filtering by rating energy source potential and occ

- Obtaining the final data set







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Tecno-Economic Analysis

$$LCOE = \frac{I_0 + \sum_{t=1}^{n} \frac{A_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{M_{el}}{(1+i)^t}}$$

CAPEX and OPEX identification

$$Cost_{manuf} = mass_{platform} * price_{steel}$$

AEP estimation

$$AEP = \sum P_{tot}(i) \cdot f(i) \cdot 8766$$

Ipothesis:

- Operational lifetime = **25 years**
- WACC = **8%**
- Wind Farm composed by **2, 10, 25** hybrid systems

	20 MW	100 MW	250 MW	UNITS
CAPEX	116.6	471.8	1124.4	M€
OPEX	1.8	8.7	13.1	M€
AEP	86600	433000	1085000	MWh

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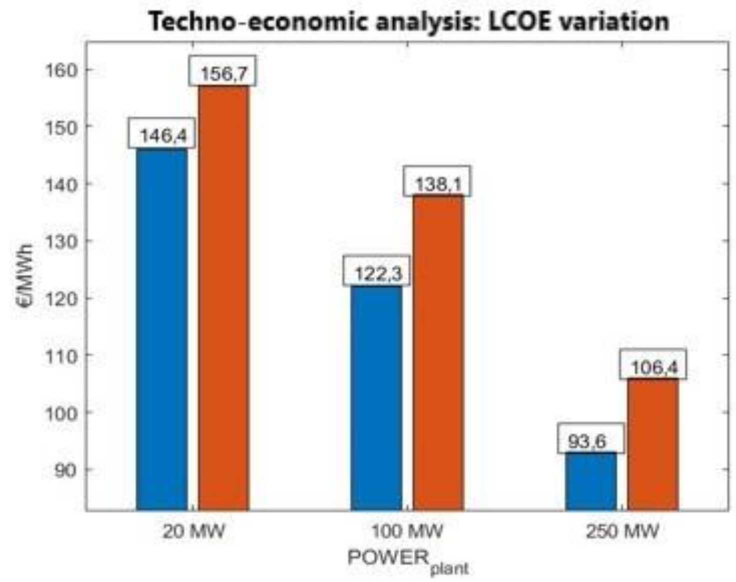
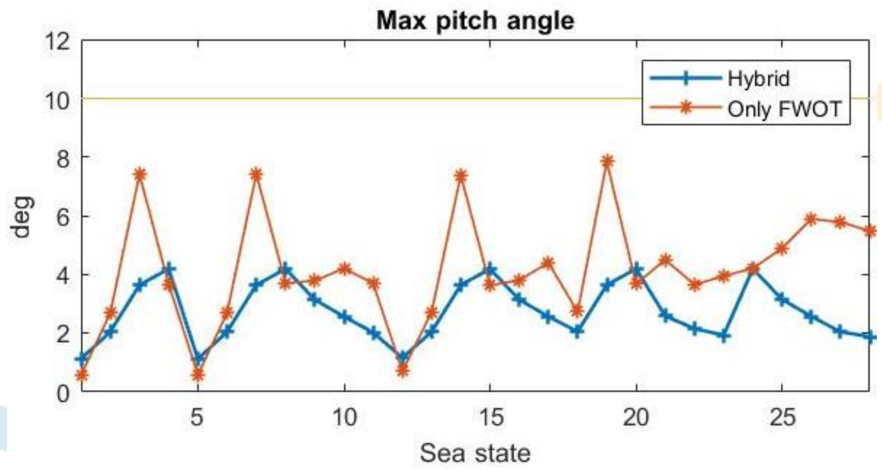
Hybrid vs FOWT system

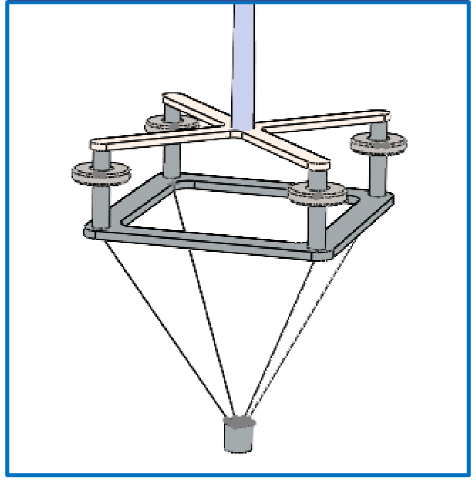
LCOE variation difference by units of farm

Comparison between dynamic stability

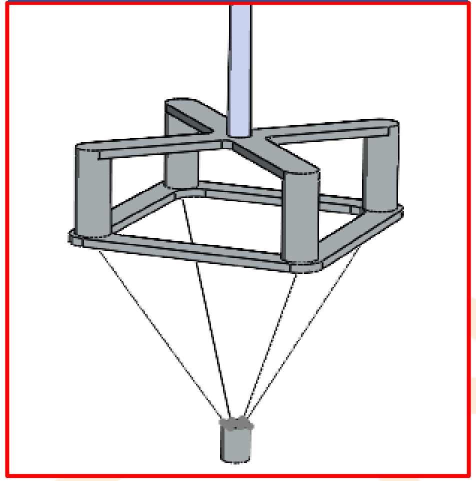




Hybrid



FOWT



Conclusions

To sum up…

- Pre-design of geometry is **reliable** and **scalable** for hybrid solution;
- The **hybrid** solution is the **best solution both in term of LCOE and in dynamic stability;**

Further works

- Simulate **more triplets** and investigate in other profitable sites;
- Get **more configuration** of hybrid integrations

Thank you for attention!

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