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CENTRALE NANTES

Centrale Nantes Excellence in Science and Engineering

Centrale Nantes : key figures and keywords

> 2000 students
  - 1 500 engineer students
  - 220 PhDs
  - 230 Master students

> 30 % of engineer students in Double Diploma with foreign universities
> 25% of foreign students on the campus from 50 countries
> 115 partner Universities in 40 countries

> 550 academics, researchers and research engineers
> 150 administrative & technical staff
> 40 000 m2 buildings on a 160000 m2 campus



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Centrale Nantes : key figures and keywords

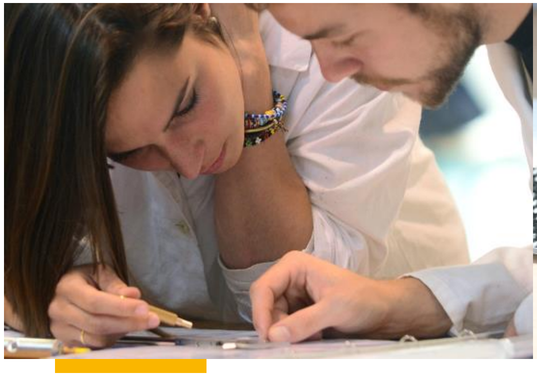
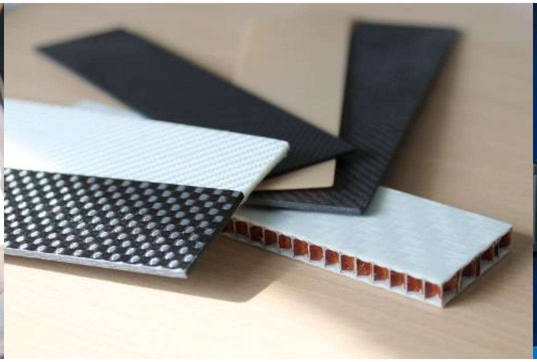
> Public Research and Higher Education Organisation

> Member of the ‘Ecoles Centrales’ network (Lille, Lyon, Marseille, Nantes, Paris and Beijing)

> Research at Centrale Nantes is organized around main themes:

- **Ocean engineering and MRE**
- Computer science and automation
- Robotics
- Energy and engines
- Manufacturing and additive manufacturing
- Bioengineering
- Civil engineering and innovative concrete
- Numerical simulation and high performance computing
- Materials and composites
- Urban environment
- Social sciences and humanities

> Created in 1919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6 Research laboratories labelled by CNRS

- GeM – Institut de Recherche en Génie Civil et Mécanique
- LS2N – Laboratoire des Sciences du Numérique de Nantes
- L.H.E.E.A. – Laboratoire d'Hydrodynamique
- Energétique et Environnement Atmosphérique
- ICI - High Performance Computing Institute
- Laboratoire de Mathématiques Jean Leray
- AAU – Laboratoire Ambiances, Architectures, Urbanités

GeM Institut de Recherche en Génie Civil et Mécanique

LS2N

Laboratoire de Mathémariques Jean Leray
UMR 6629 - Nantes

AAU ambiances architectures urbanités

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4 Research laboratories dealing with offshore wind energy applications

Wind & wave conditions

- Micrometeorology in complex coastal areas
- wind/wave interactions
- Wind turbine wake interactions

Grid integration

- Optimisation of power converters and storage strategies

Credit: NREL, 2014-2015 Offshore Wind Technologies Market Report

Structural design and materials

- Multiscale Modeling and Fatigue Analysis of cables (ombilical and mooring)
- Modeling of manufacturing processes for very large composite parts (blades)
- Soil structure interaction under cyclic loading

Aerodynamics and control Smart rotors

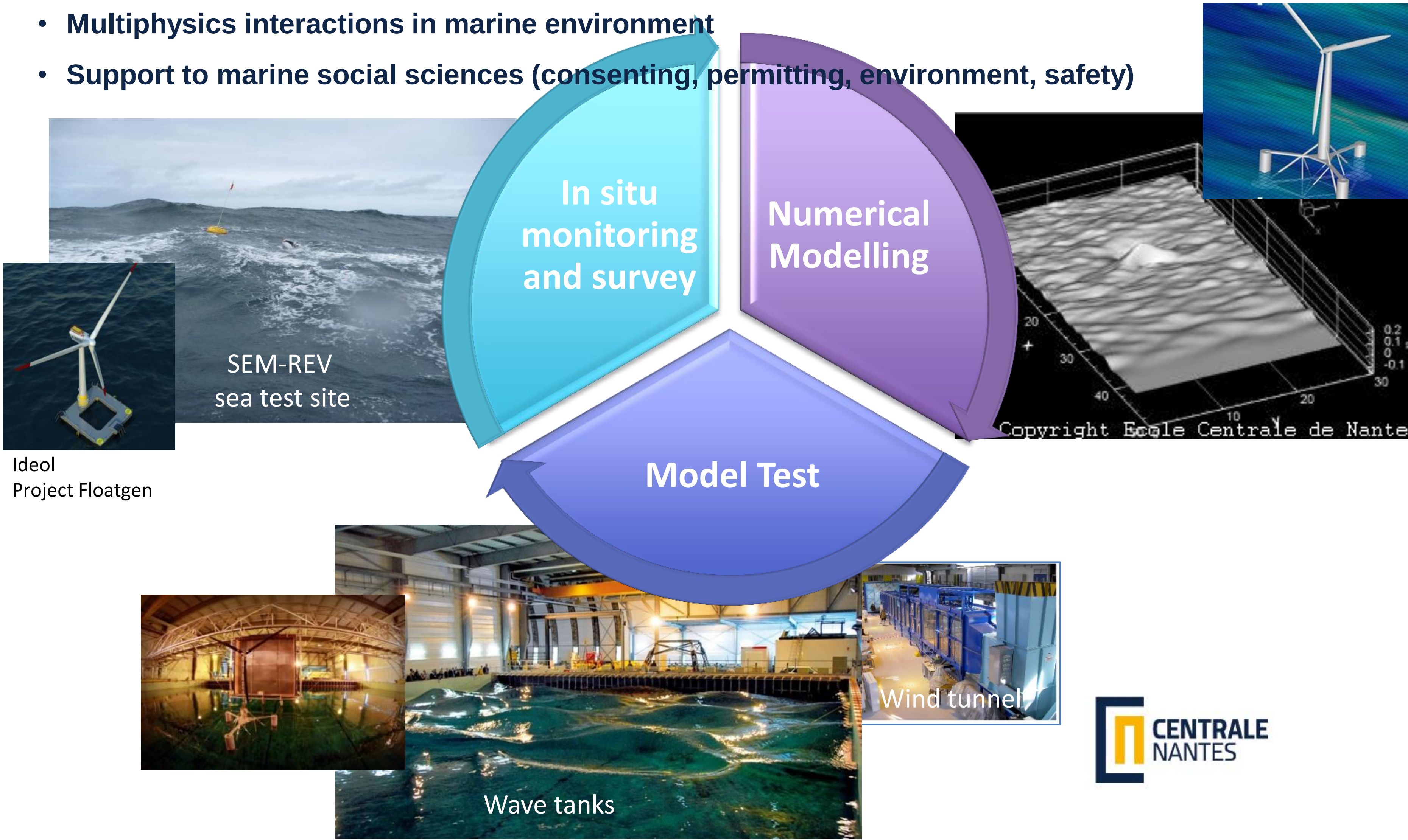
- Active flow control on blades
- Morphing blades

Offshore Wind Energy

- Floating wind turbine dynamic response
- Rotor control for floating wind turbines
- Floating wind farms
- Marine operations, safety/Security
- Environmental impacts
- Disruptive Concepts for far offshore wind energy harvesting

Strategy to support offshore Wind development

- Validation of numerical methods and model tests vs results in real conditions
- Multiphysics interactions in marine environment
- Support to marine social sciences (consenting, permitting, environment, safety)



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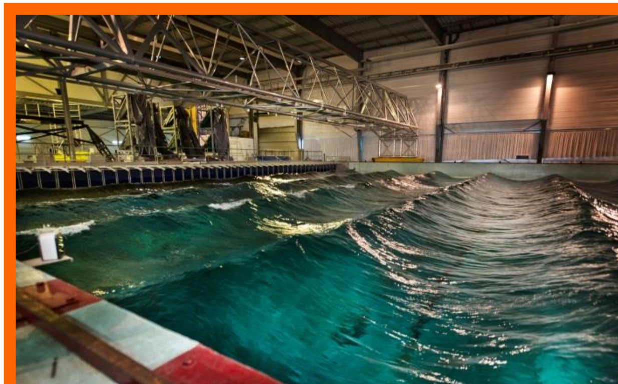
Experimental facilities

Ocean wave bassin



© Centrale Nantes

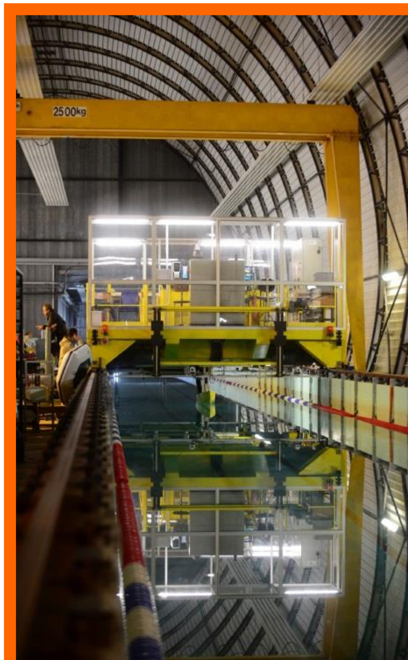
- 50 m x 30 m, depth: 5
- 48 flaps
- Regular and irregular waves
- monodirectional
- Crossed waves (≤ 90°)
- T = 0.5 ~ 5 s
- Hreg ≤ 1 m   Hs ≤ 0.6 m
- Typical scale: 1/1 à 1/100

Wind generation system for offshore wind turbine testing

© Centrale de Nantes

Towing tank

- 130 m x 5 m, depth: 3 m
- Equiped with a towing carriage to tow models up to 25 km/h
- Wave generation system



© Centrale Nantes

Examples of tests

Tests of Marine current turbines with the towing tank,

© Centrale Nantes

Tests of the Wave energy converter S3 (on the left) and Pelamis (on the right)

SBM OFFSHORE

ADEME

© Centrale Nantes

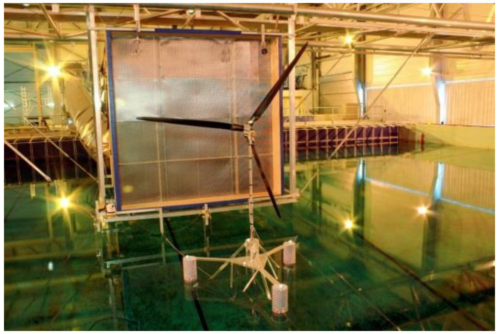
© Centrale Nantes

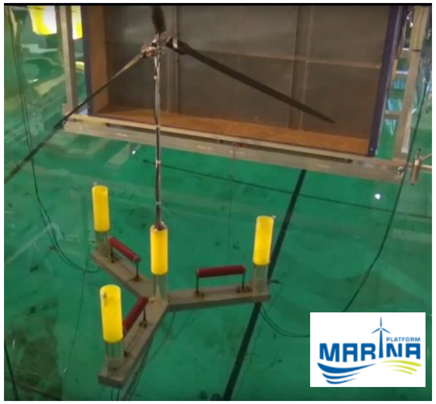
Physical modelling of FWT @ Centrale Nantes

- PhD thesis, A. Courbois (2013)

Experimental study of the dynamic behaviour of a FOWT subject to wind and wave forcing

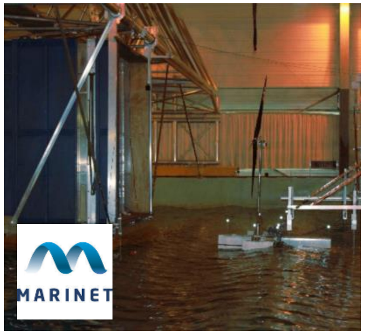
  - NREL 5MW 50th scale model
  - wind generation system
  - Study done with Dutch trifloater.

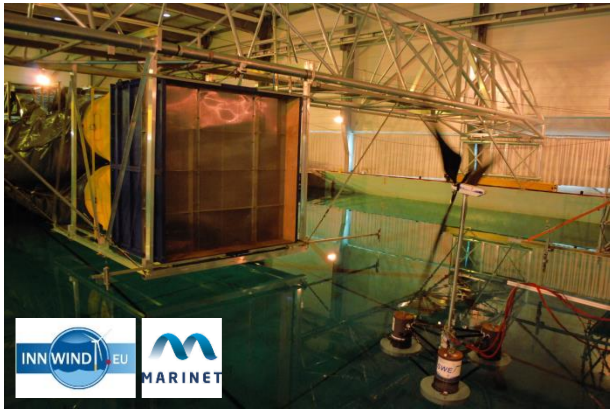




- Testing of **various FWT& hybrid systems through FP7 Marinet EU program**:
  - InnWind (Fr scaled rotor, Re scaled rotor, SIL, 2014)
  - FPP (2015)

- Testing of **hybrid wind-wave concepts in FP7 EU MARINA project** (2014)

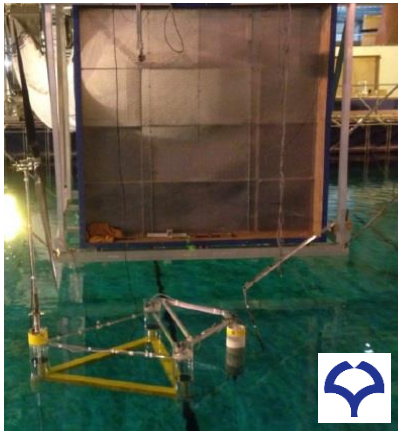




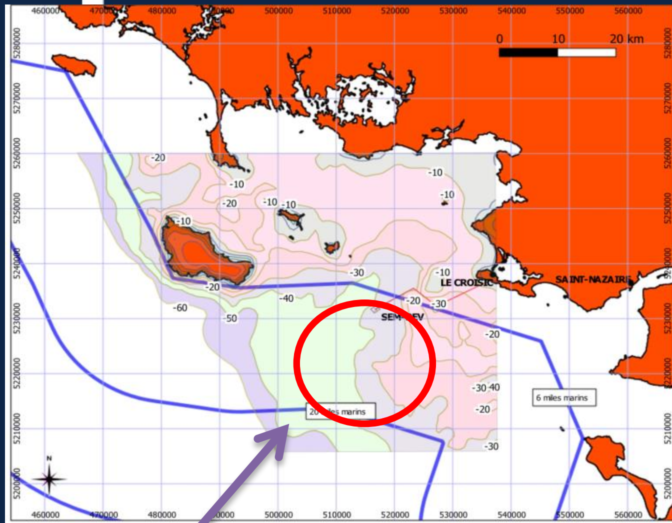
- Testing of **VAFWT: MOQUA project** (2015)

- Testing of **SPM FWT in collaboration with Osaka Univ**.(2015)

- Testing of **fixed offshore WT with rigid and flexible models**, wind loads simulated using controlled fan (2016)



Sea tests site description



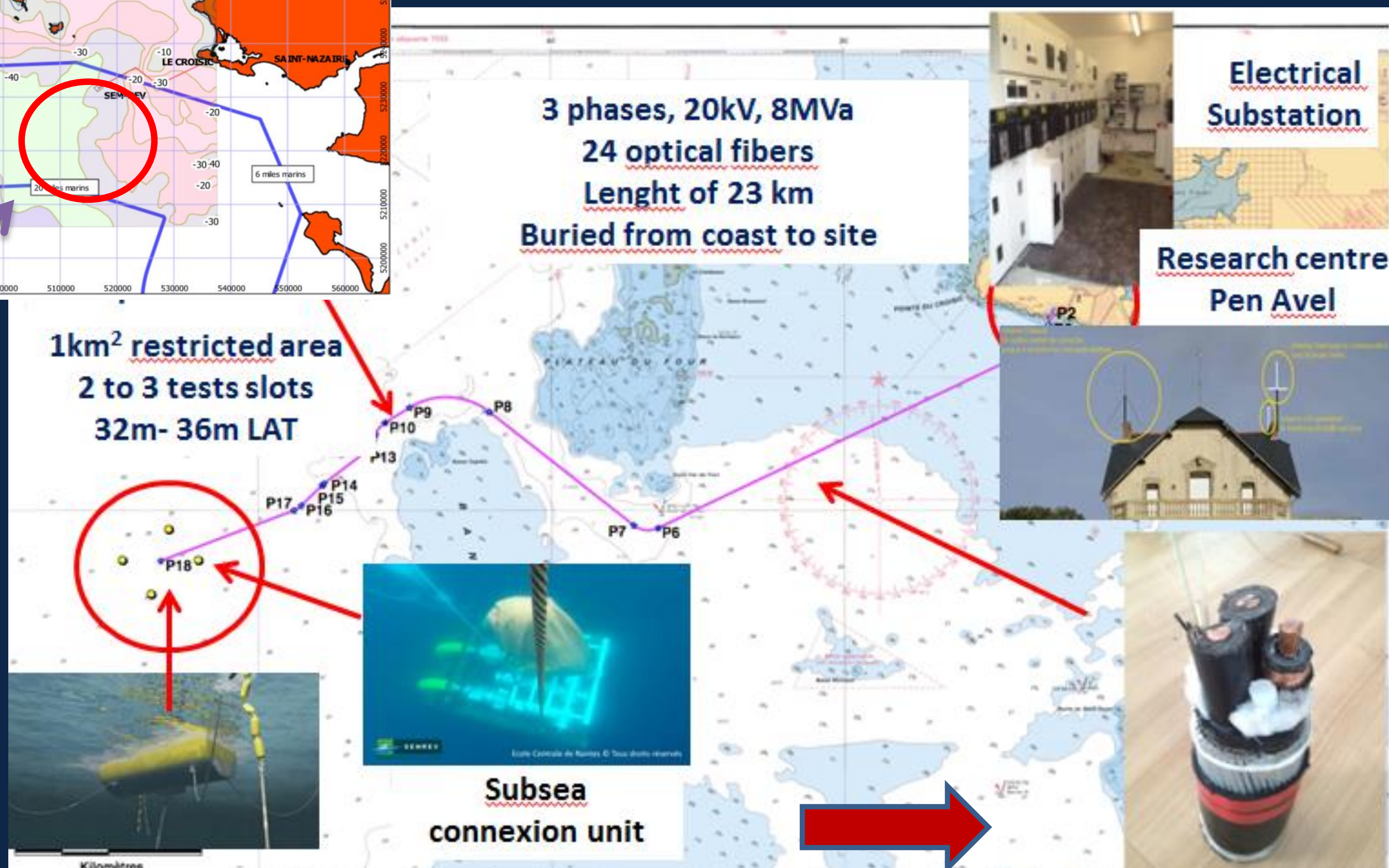
3 phases, 20kV, 8MVa
24 optical fibers
Lenght of 23 km
Buried from coast to site

Electrical Substation

Research centre Pen Avel

1km² restricted area
2 to 3 tests slots
32m- 36m LAT

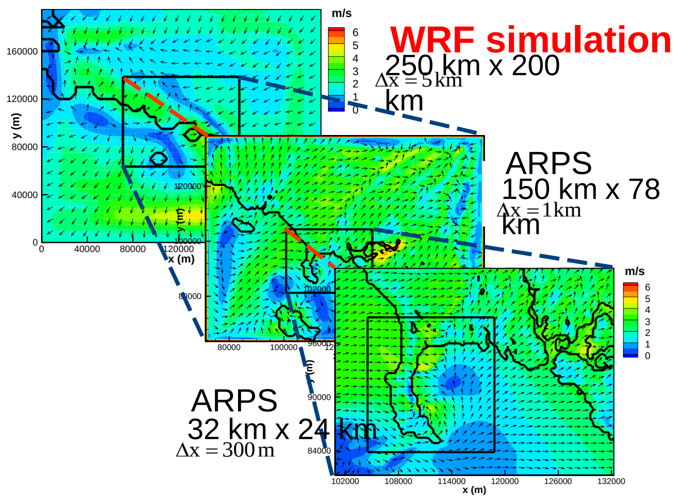
Subsea connexion unit



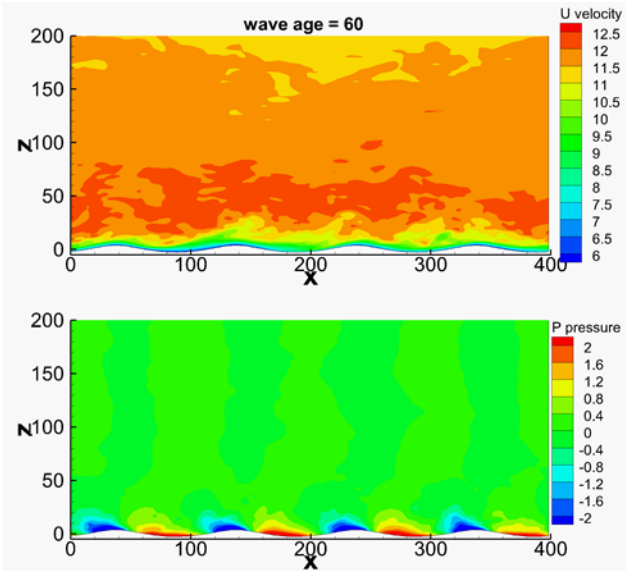
Wind & wave conditions

Micrometeorology in complex coastal areas

Exemple of Quiberon bay, France

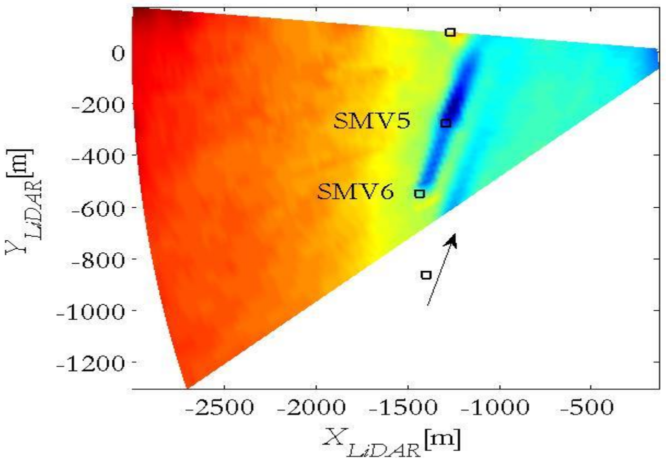


wind/wave interactions



LES Atmospheric code Coupled with HOS code for waves
(P. Sullivan, NCAR) (LHEEA)

Wind turbine wake interactions



Scanning LiDAR measurements of WT wakes
French project SMARTEOLE

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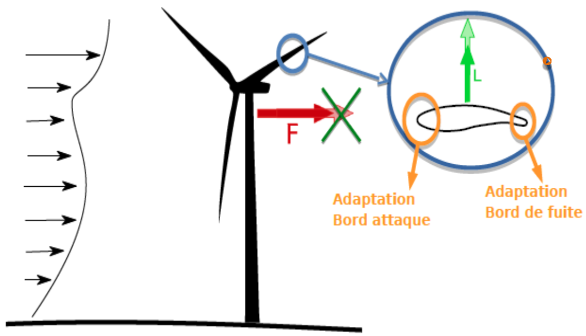
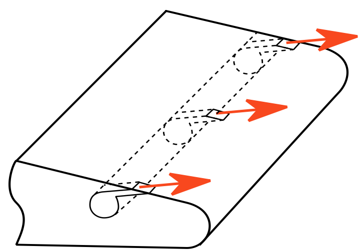
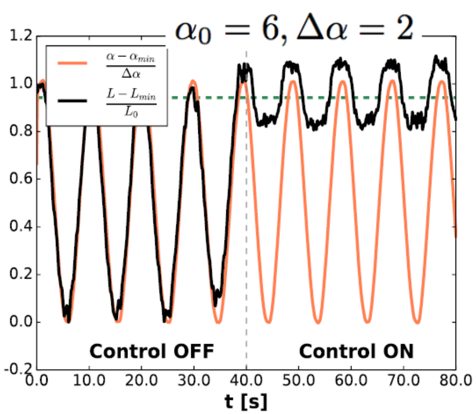
Aerodynamics and control
Smart rotors

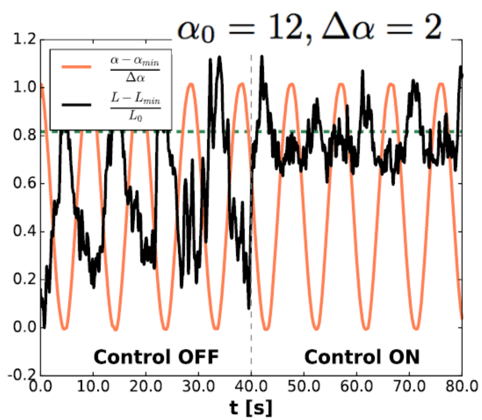
Active flow control on blades with blowing jets





Load reduction on blades with closed-loop control





Morphing blades

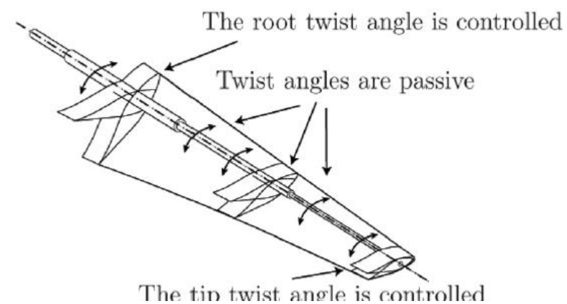


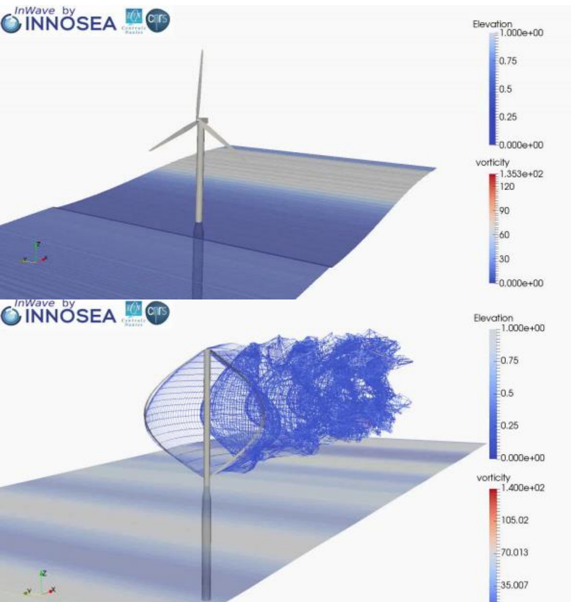
Table 3 AEP of the wind turbines as a function of the average wind speed

	FPB	MB		BPC	
$\bar{v}$ (m/s)	AEP (MWh/y)	AEP (MWh/y)	Percentage increase	AEP (MWh/y)	Percentage increase
5.0	24.0	29.9	24.5	29.5	22.7%
6.0	33.7	43.6	29.4	42.8	27.1%
7.0	41.6	57.2	37.4	56.0	34.5%
8.0	48.0	70.1	45.9	68.6	42.7%
9.0	53.2	81.7	53.5	79.9	50.1%
10.0	57.5	91.6	59.4	89.6	55.9%
11.0	60.7	99.4	63.6	97.3	60.2%
12.0	63.1	105.0	66.4	103.0	63.1%
13.0	64.5	108.0	68.1	106.0	65.0%
14.0	65.1	110.0	69.2	108.0	66.2%
15.0	64.9	110.0	69.7	108.0	66.9%

Wang et al. A Simplified Morphing Blade for Horizontal Axis Wind Turbines. *Journal of Solar Energy Engineering*, 2014, 136 (1),

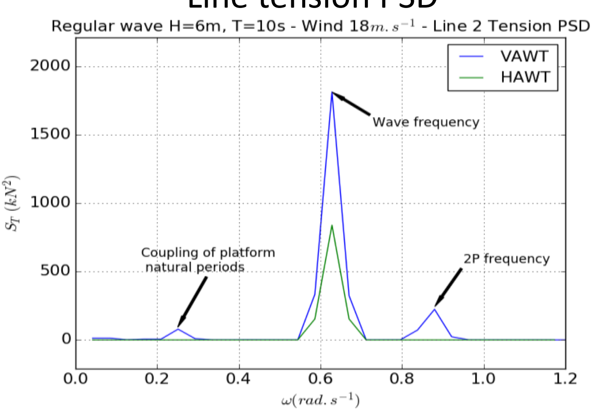
Offshore Wind Energy systems / Dynamic response

Simulations
HAWT vs. VAWT

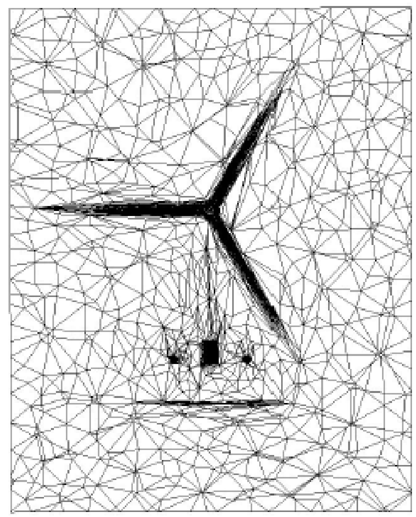


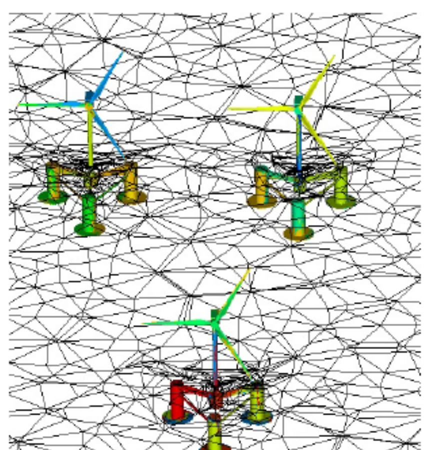
V. Leroy et al. In Proc. 36th OMAE Conference (2017)

Line tension PSD

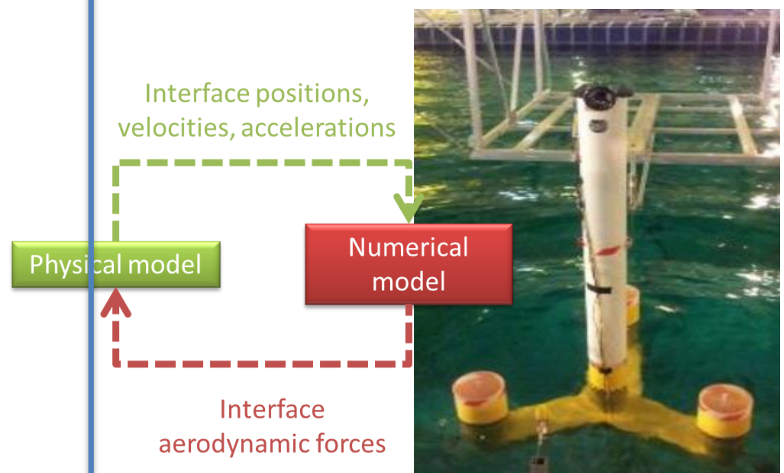


Massively parallel direct CFD
FOWTS (EOS project)



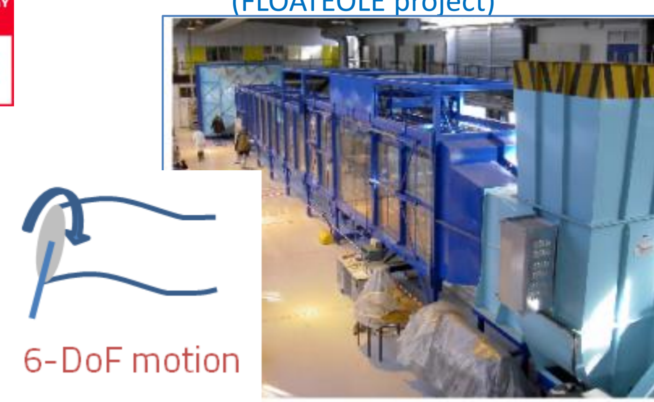


Software –In-the-Loop to emulate aerodynamical loads and study floater dynamics
(Softwind project)



WEST ATLANTIC MARINE ENERGY CENTER
Research, Education & Innovation in PAYS de la LOIRE

Emulation of floating motion to study WT wake dynamics
(FLOATEOLE project)



Offshore Wind Energy : From reality to dreams…

1st floating WT prototype in France
Installed on ECN sea test site SEME-REV

FLOATGEN

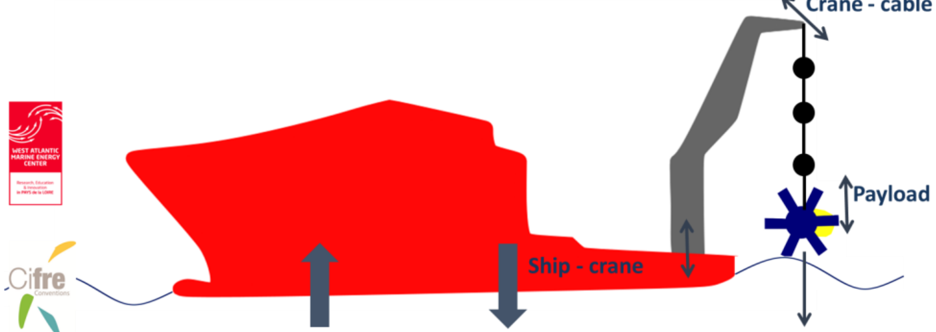
Safety/security

Risk analysis vs marine traffic
Maritime surveillance
Survey of MREs components

Marines operation

Met-ocean predictions
O&M Monitoring
On-board numerical models for decision making

Modelling of marine operations
FRyDOM



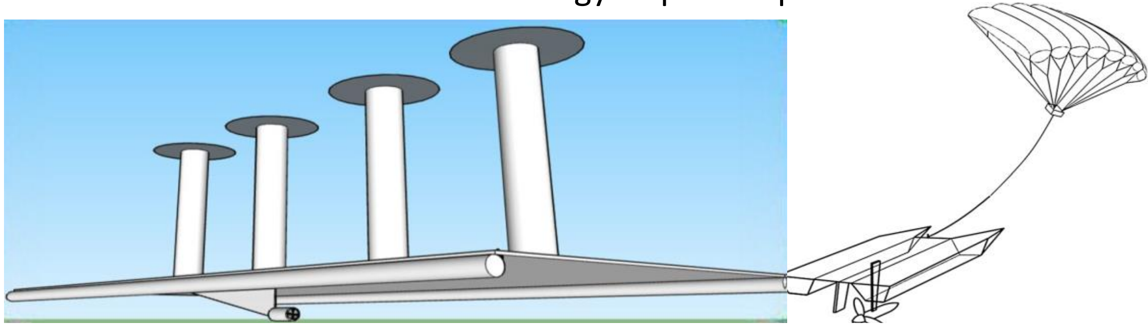
INNOSEA

P-Y Wuillaume et al. *In Proc. of the 23ème Congrès Français de Mécanique* (2017)

SEVENTH FRAMEWORK PROGRAMME

INVESTISSEMENTS D'AVENIR

Concept studies for far offshore wind energy harvesting
Performance of Energy ship concepts



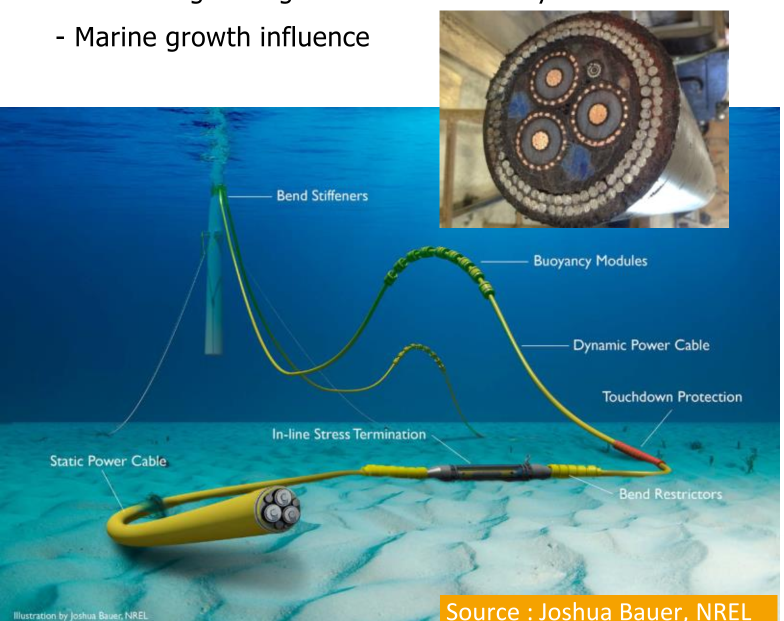
Scanning LiDAR installed on the FOWT
to measure the wind resource and the wake
(project FLOATEOLE 2019)

Structural design and materials

Dynamic cable for marine energy (project OMDYN)

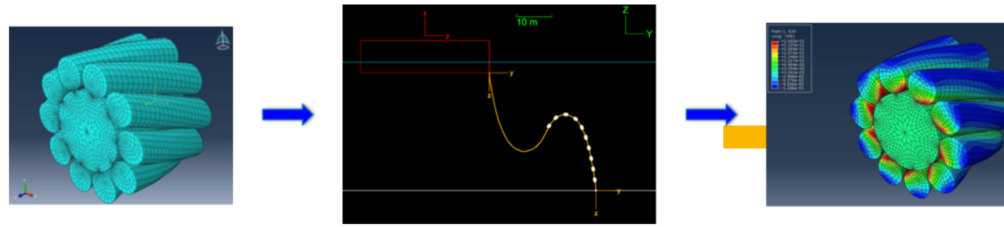
Objectives :

- Mechanical characteristics of cable components,
- Numerical modeling of the global configuration and cross section
- Experimental analysis of thermo-mechanical fatigue,
- Monitoring throughout the cable life cycle
- Marine growth influence

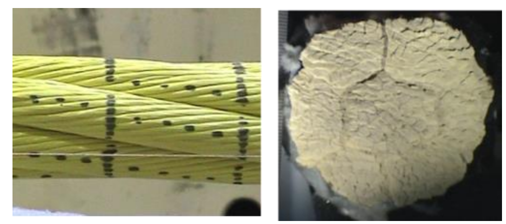


Multiscale Modeling and Fatigue Analysis of cable

- *Umbilicals (joint work with Innosea, LHEEA and IFSTTAR)*



- *Mooring Lines (joint work with IFREMER and LHEEA)*
  Model updating from in-situ measurements (Floatgen)



Soil structure interaction under cyclic loading

- *Swallow and pile foundations of offshore wind turbines*
- *Development of macro-elements (jointwork with IFSTTAR)*

Modeling of manufacturing processes for very large composite parts

- *Experimental analysis and modeling of the liquid resin infusion of thick thermoplastic composites (wind turbine blade)*

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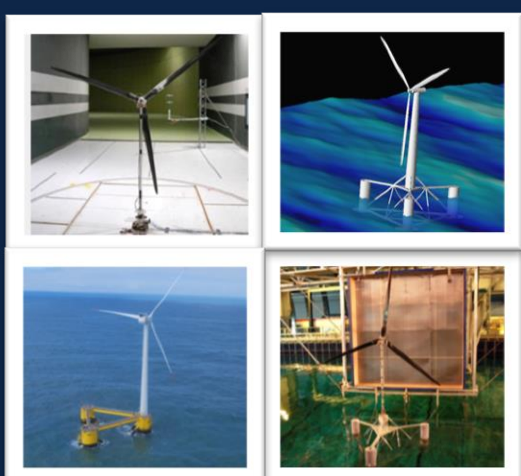

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