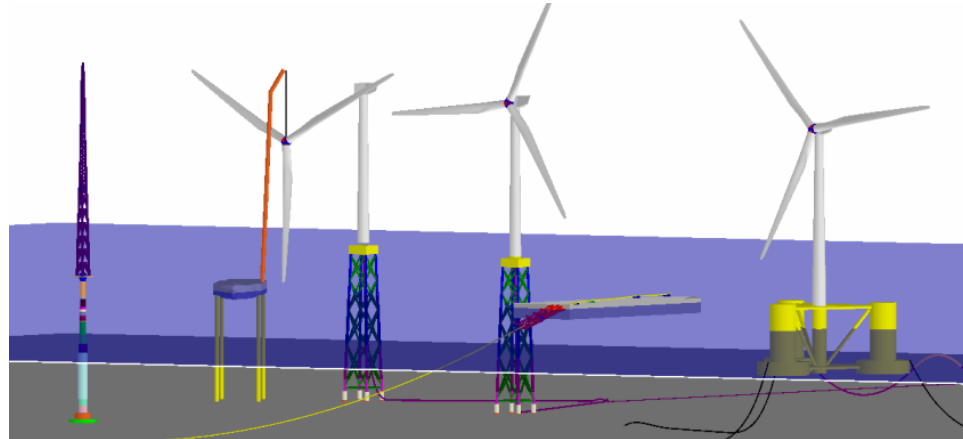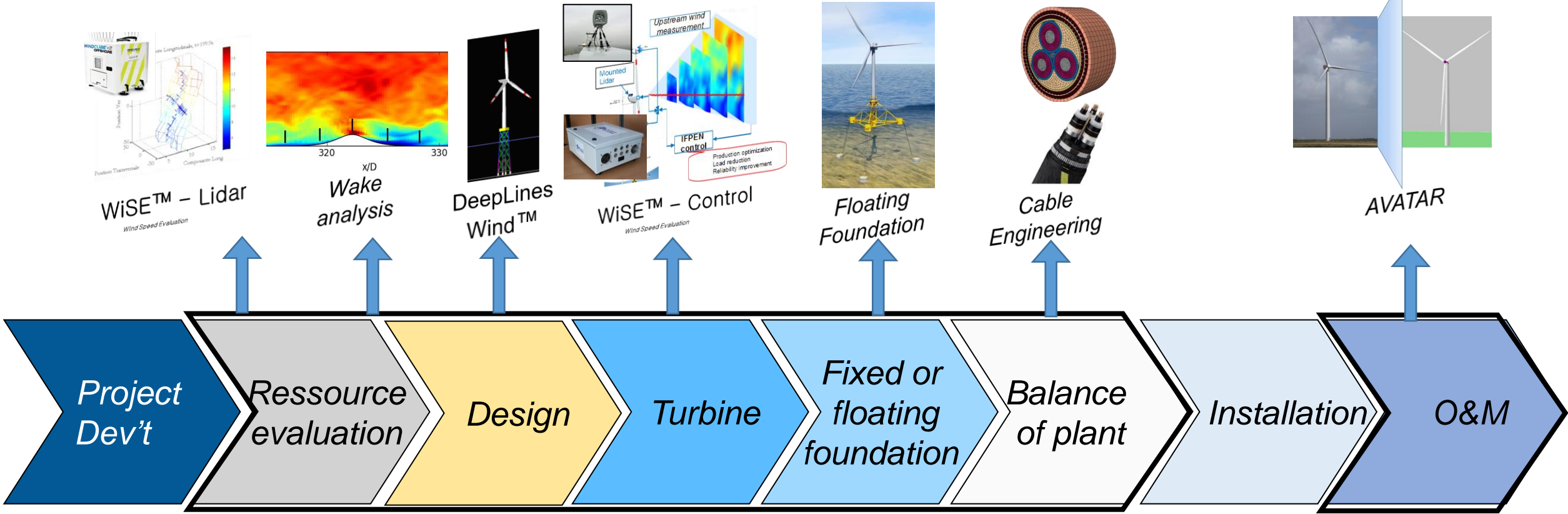# OFFSHORE WIND

IFPEN Solutions and Research activities

EERA DeepWind – 18/01/2018 – Pauline Bozonnet

IFPEN offers along the offshore wind value chain

● A broad range of industrial solutions

WiSE™ – Lidar
Wind Speed Evaluation

Wake analysis

DeepLines Wind™

WiSE™ – Control
Wind Speed Evaluation

Floating Foundation

Cable Engineering

AVATAR

| Project Dev't | Ressource evaluation | Design | Turbine | Fixed or floating foundation | Balance of plant | Installation | O&M |

● A strong international network

WiSE™ – Lidar improves site assessment methods
Wind Speed Evaluation

- Characterization of the wind resource = major driver of the economy of wind projects.

- The lidar is a sensor measuring wind speed, increasingly used in wind energy, especially offshore.

- Limited capacities for Turbulence Intensity evaluation, which drives:
  - Wind turbine selection
  - Production evaluation

- WiSE™ – Lidar developed by IFPEN, marketed by LeoSphere, is a **signal processing software for lidar measurements**.
  Wind Speed Evaluation
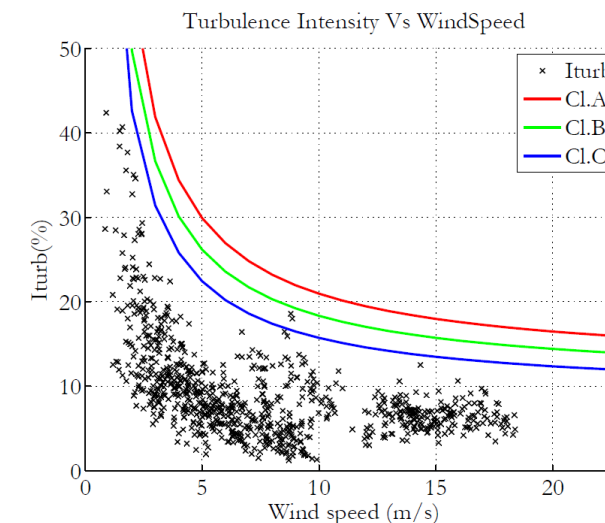
Turbulence Intensity Vs WindSpeed

WiSE™ – Lidar improves site assessment methods
WInd Speed Evaluation

- **WiSE™ – Lidar** reduces the uncertainty on the measurement of turbulence intensity
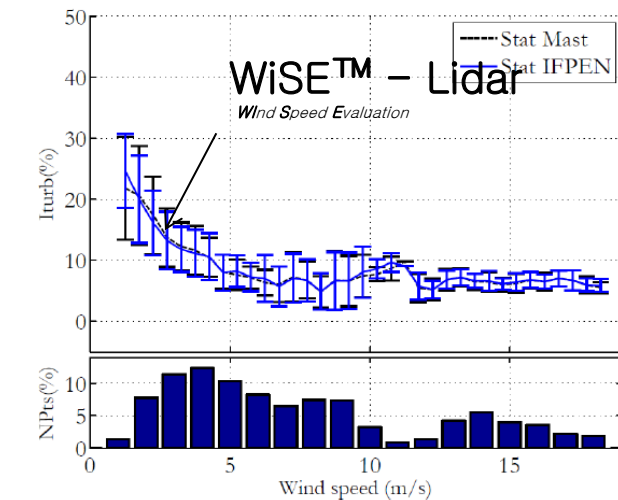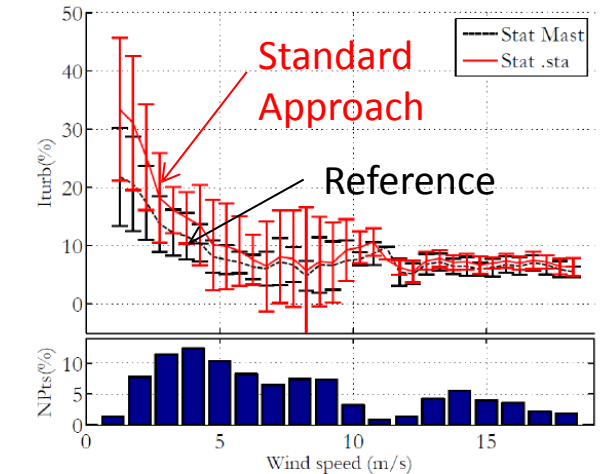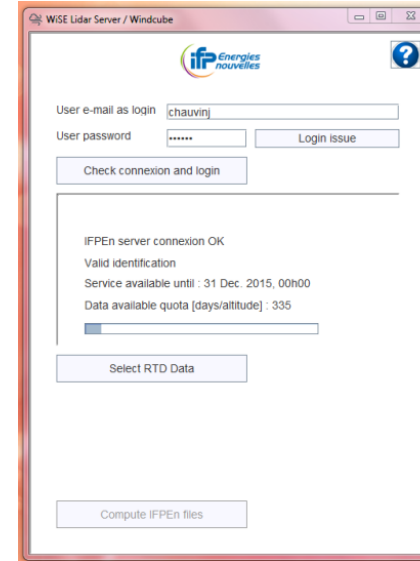 WInd Speed Evaluation

- Currently tested
  - by several pilot customers
  - through the participation to IEA-Wind Task 32

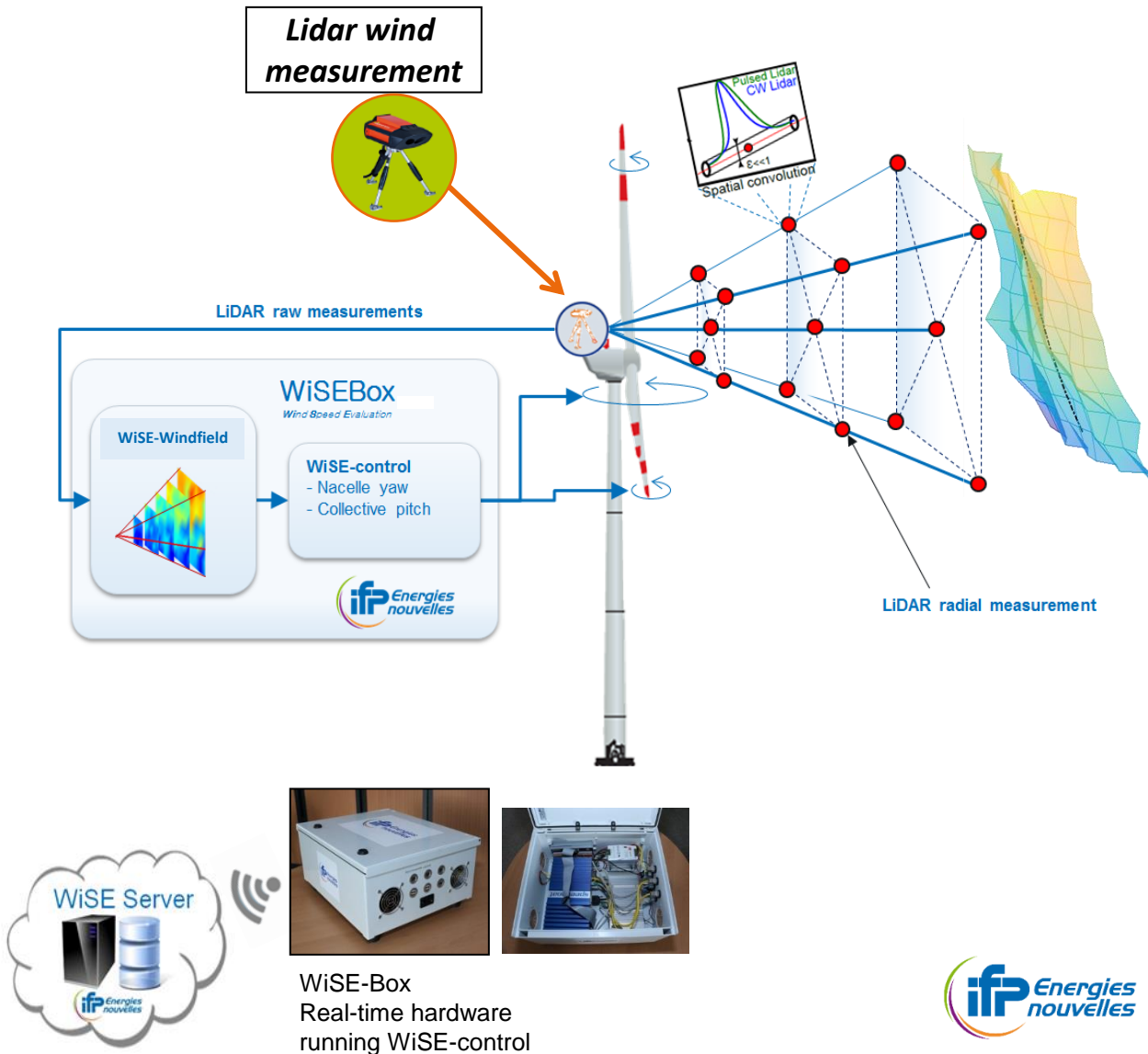- It will be available online to LeoSphere customers and for specific studies through IFPEN

- R&D version planed for floating lidars

WiSE™ – Control optimizes wind turbine production and reduces LCOE using Lidar based active control

WInd Speed Evaluation

- Most modern wind turbines:
  - real-time blade pitch and nacelle yaw control
  - to optimize production and mitigate loads

- Based on feedback from the turbine sensors, only react afterwards

- Nacelle based lidars: long distance wind measurements ➜ control anticipation capacities

- WiSE™ – Control is a system featuring control strategies developed by IFPEN to take advantage of this anticipation

WInd Speed Evaluation

Lidar wind measurement

LiDAR raw measurements

Pulsed Lidar
CW Lidar
Spatial convolution

WiSEBox
Wind Speed Evaluation

WiSE-Windfield

WiSE-control
- Nacelle yaw
- Collective pitch

IFP Energies nouvelles

LiDAR radial measurement

WiSE Server

WiSE-Box
Real-time hardware
running WiSE-control

IFP Energies nouvelles

WiSE™ – Control optimizes wind turbine production and reduces LCOE using Lidar based active control

WiSE™ – Control
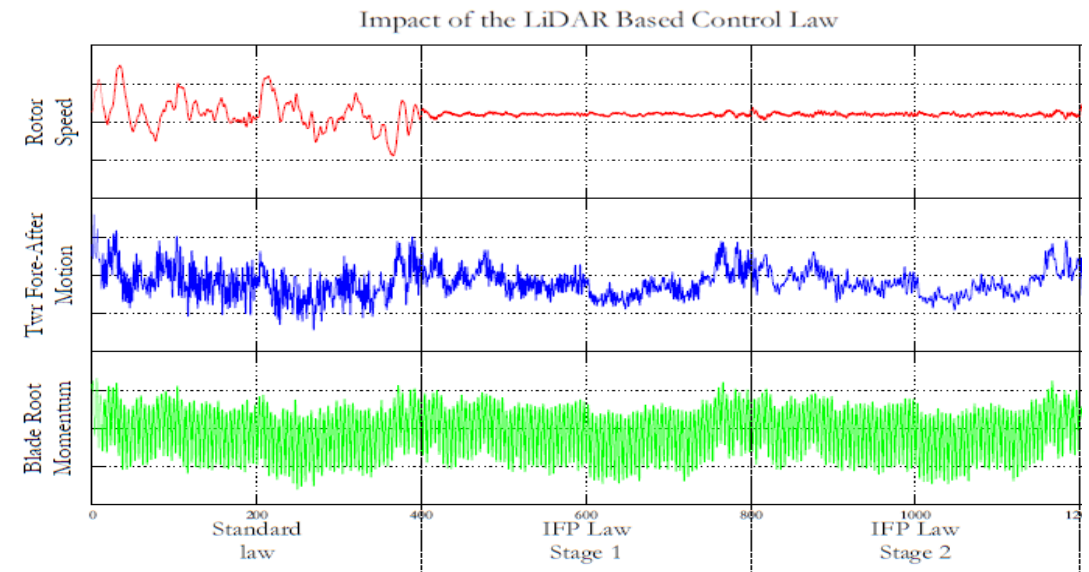WInd Speed Evaluation

- **WiSE™ – Control** features control strategies
  WInd Speed Evaluation
  leading to :
  - 20 % reduction of tower and blade extreme load
  - Fatigue lifetime increase by 5 to 10 years → Reduced maintenance
  - 3 to 4 % increase of production thanks to an improved yaw control and transition management
  - A potential LCOE decrease of 5%

- The ANR funded SmartEole project will allow a semi-numerical validation on onshore wind turbines (2016-2017)

- Full-scale demonstration project in preparation

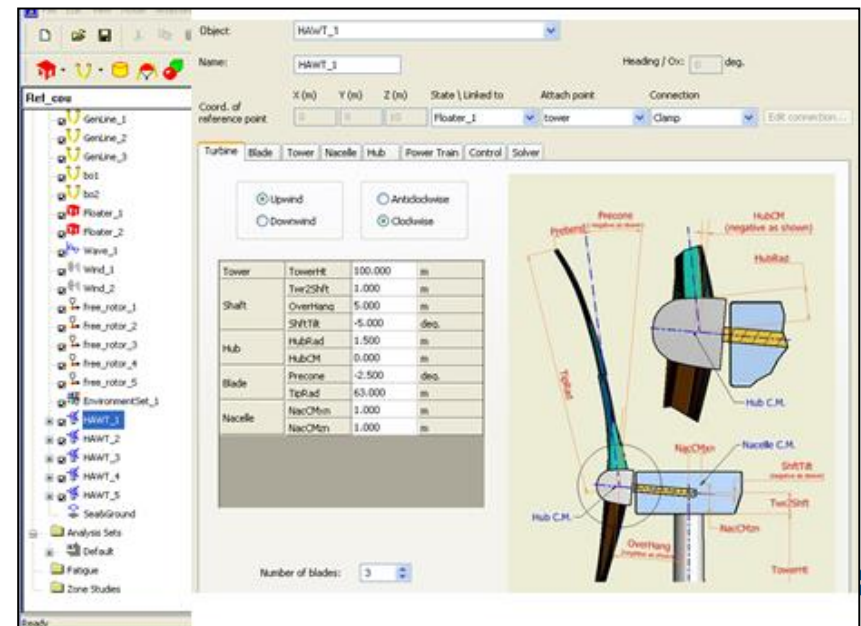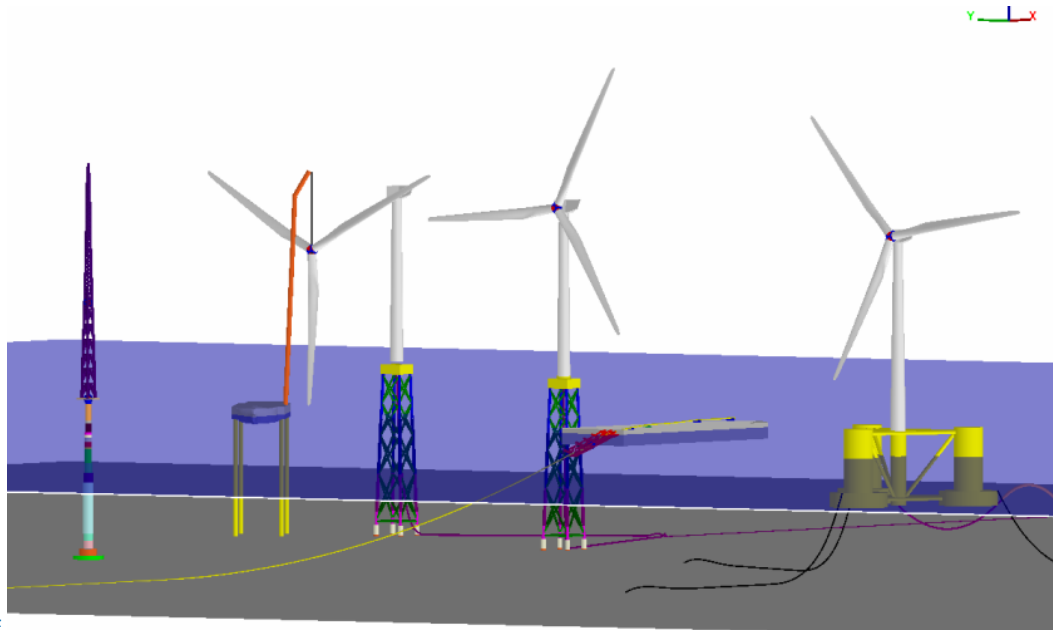- Extensions to floating wind and farm control ongoing

Impact of the LiDAR Based Control Law

Rotor Speed

Twr Fore-After Motion

Blade Root Momentum

0   200   400   600   800   1000   12

Standard law   IFP Law Stage 1   IFP Law Stage 2

Deeplines Wind™: a fully coupled solution for simulation of fixed and floating wind turbines

ÉNERGIES NOUVELLES

- Fixed / floating wind turbine modeling software
 - Based on DeepLines™ solver:
    - Finite element solver
    - Hydrodynamic loadings
  - Aerodynamic loadings
    - Computed in a dll (modularity)
    - Commercial library: based on BEM
    - In-house libraries: 2D and 3D vortex solvers

Fully coupled simulation: Aero-servo-hydro-elastic coupling

PRINCIPIA

iFP Energies nouvelles

Deeplines Wind^{TM}: a fully coupled solution for simulation of fixed and floating wind turbines

- Modular aerodynamic library
  - Commercially available version:
    - BEM based
    - Used for the design of Hywind Scotland, Provence Grand Large, …

- Advanced simulation capacities (aerodynamics, wake) are available inside IFPEN for specific studies
  - Vortex Methods
    - Free-wake, lifting-line flow model CASTOR
    - 2D and 3D
    - HAWTs and VAWTs
    - Accurate load/near-wake predictions

PRINCIPIA

HEXICON
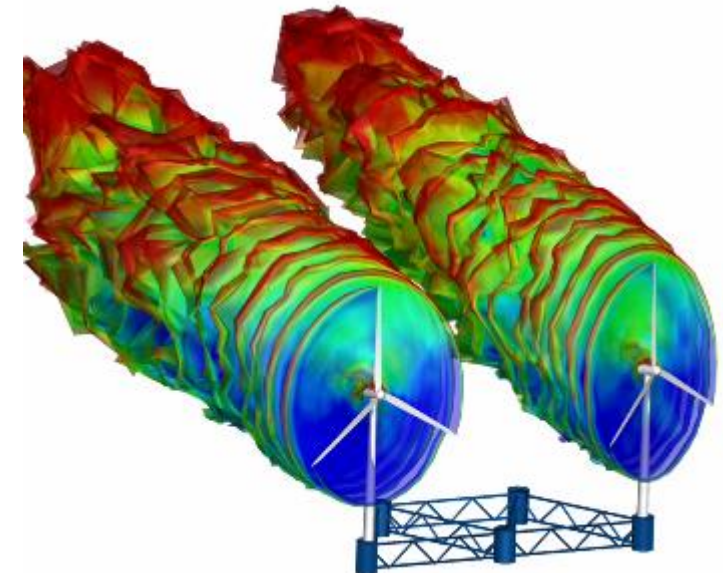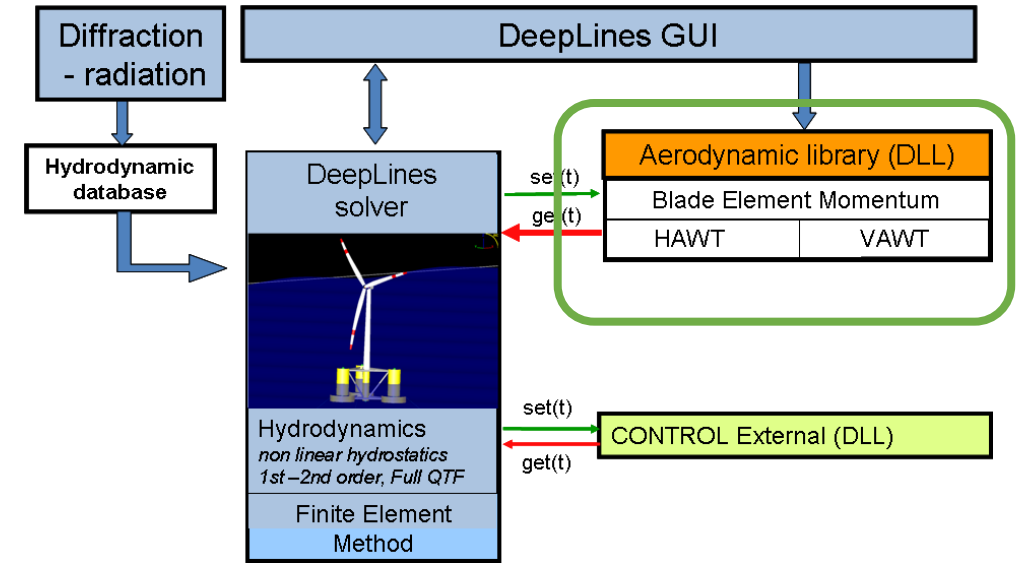
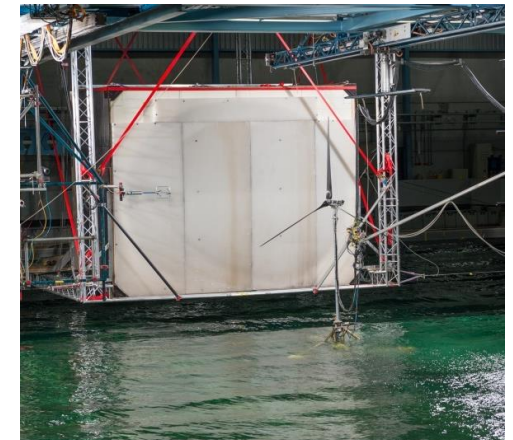# Deeplines wind validation

Aerodynamic libraries

- BEM/Vortex Methods: MexNext project
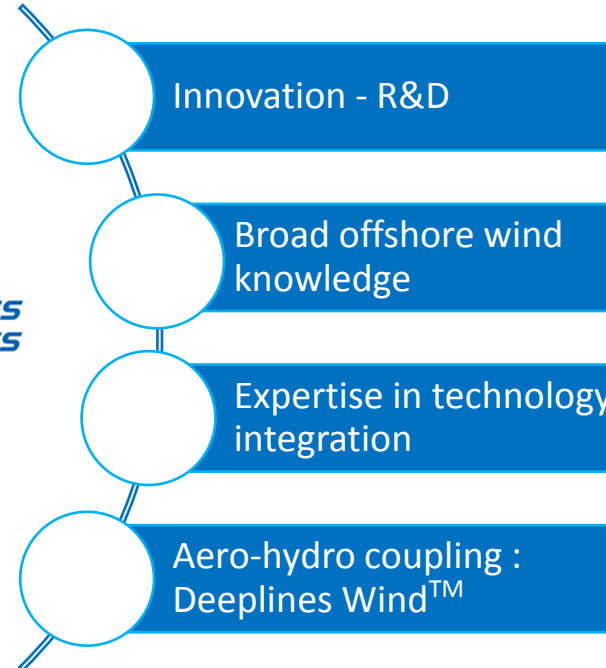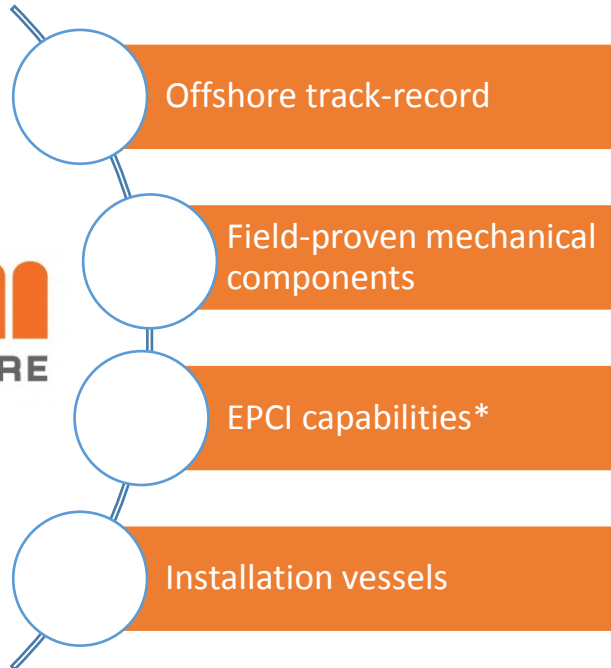 - Blade loads, near-wake velocities
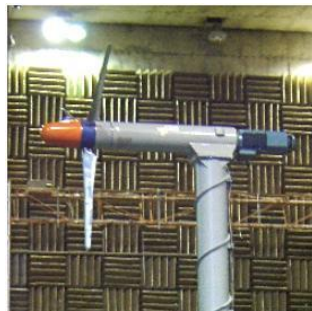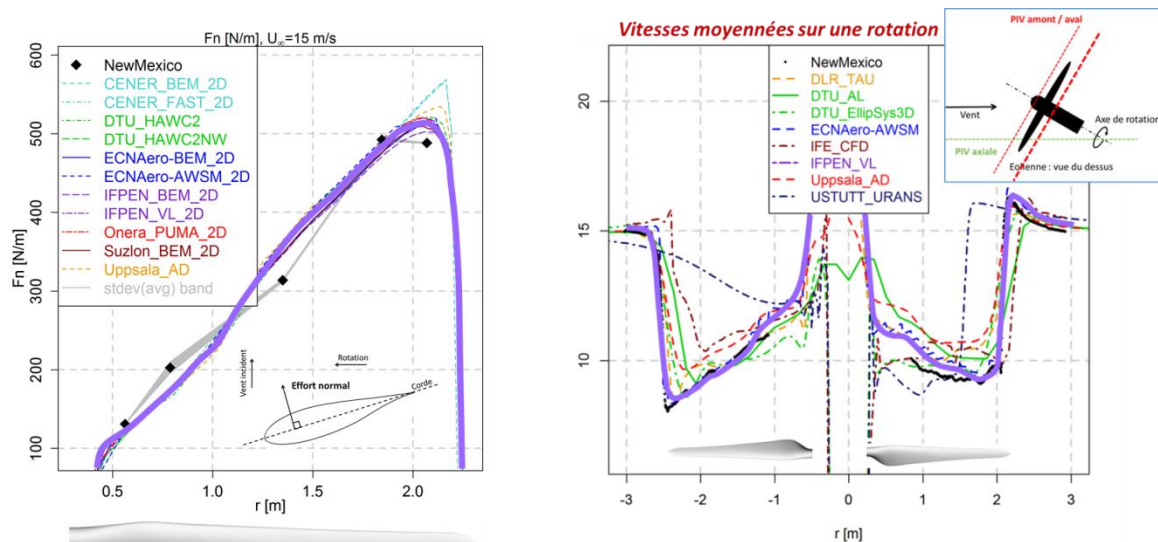
Coupled simulations

- Floating wind, validation on model tests data:
  - OC3, OC4, OC5
  - VALEF2: French project similar to OC5
  - TLP model test campaign

- Aero-Elastic vortex Methods: EU Inflow project
 - Blade loads, 600 kW VAWT

IFPEN-SBM partnership

SBM OFFSHORE

- Offshore track-record
- Field-proven mechanical components
- EPCI capabilities*
- Installation vessels

IFP Energies nouvelles

- Innovation - R&D
- Broad offshore wind knowledge
- Expertise in technology integration
- Aero-hydro coupling : Deeplines Wind^{TM}

Joint technology development

IFPEN carries out coupled analysis studies for SBM (ex PGL)
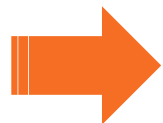
Become a leader on floating wind emerging market

(*) EPCI: Engineering – Procurement – Construction - Installation

Floating wind : our solution

Mooring lines are inclined to cross slightly above nacelle
➔ Fixed point
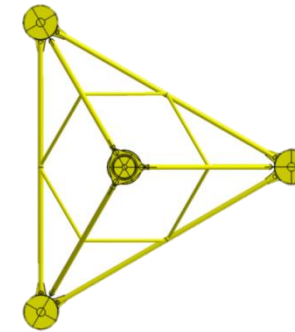
Distributed buoyancy
➔ Stability during towing

Minimal area at the surface
Submerged buoyancy
➔ Decreased wave loads, decreased tide and current effects

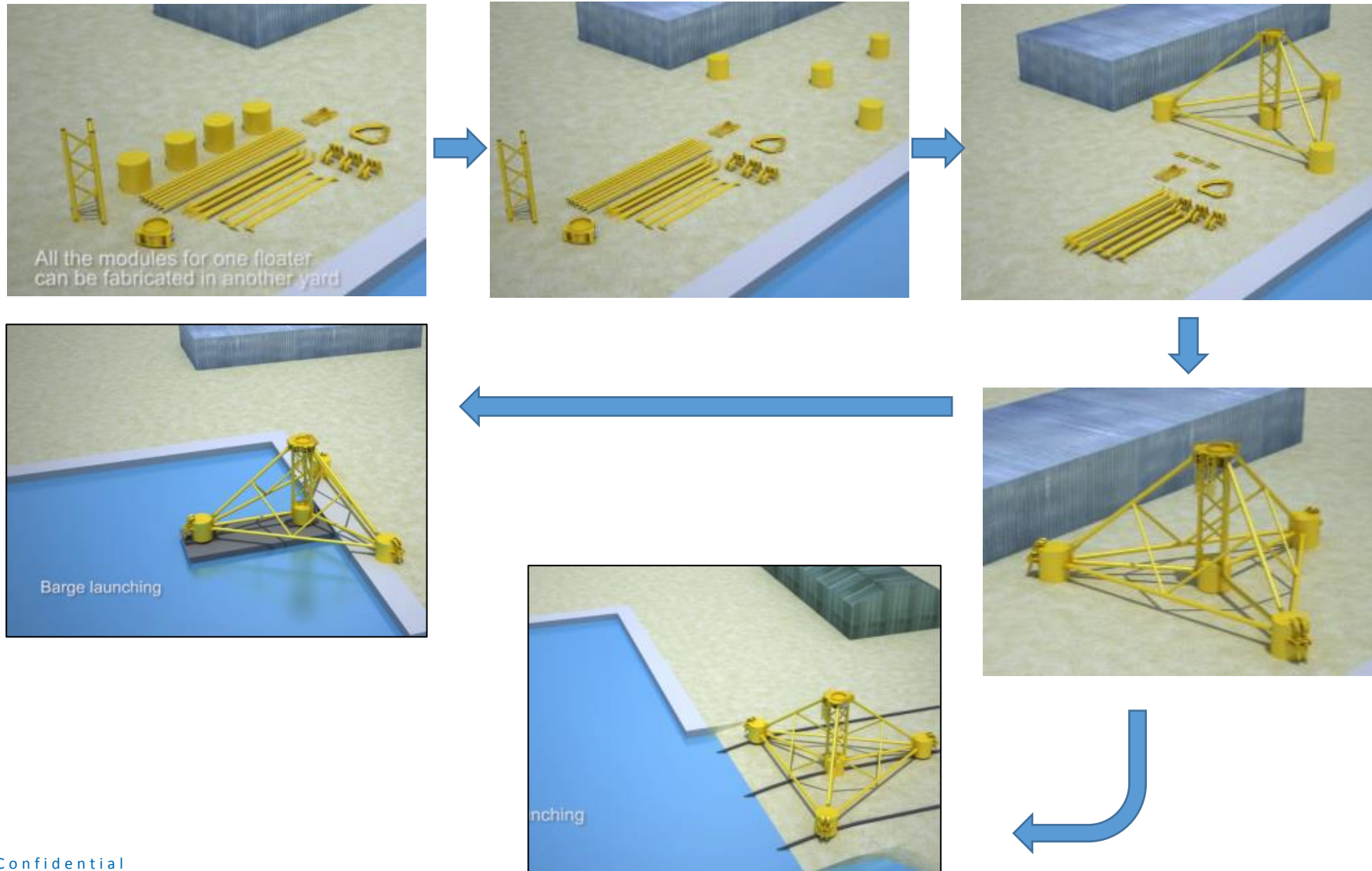Catenary electrical cable configuration thanks to limited motions

Gravity based, piles or suction anchors
➔ Compatible with all soil conditions

© SBM Offshore

All the modules for one floater can be fabricated in another yard

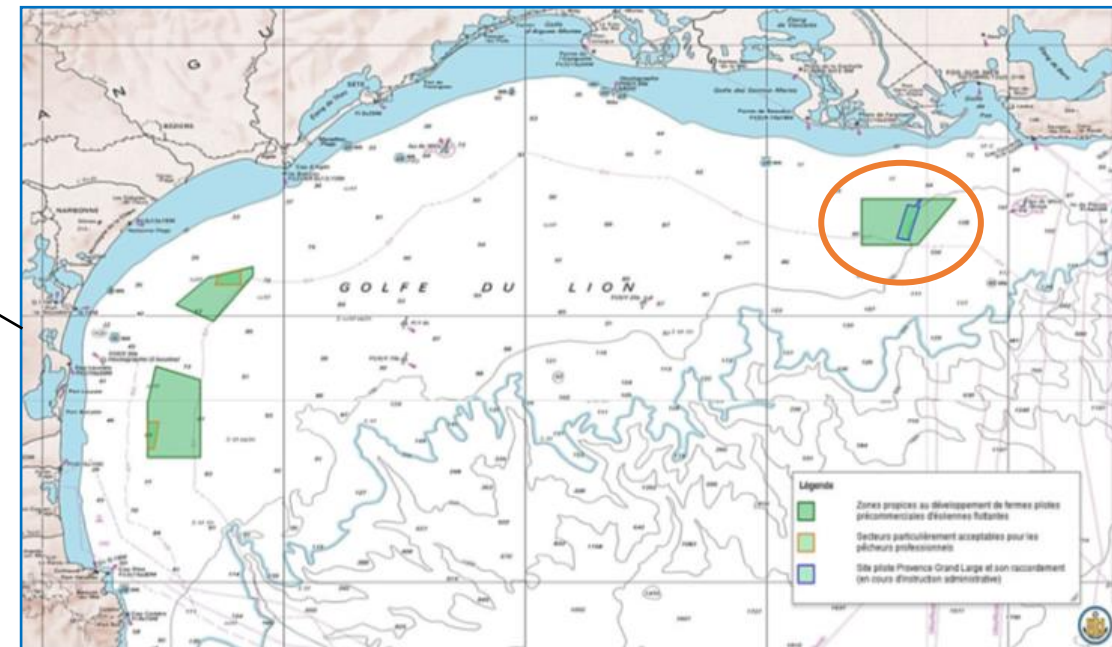Barge launching

SBM Offshore – IFPEN technology selected by EDF-EN
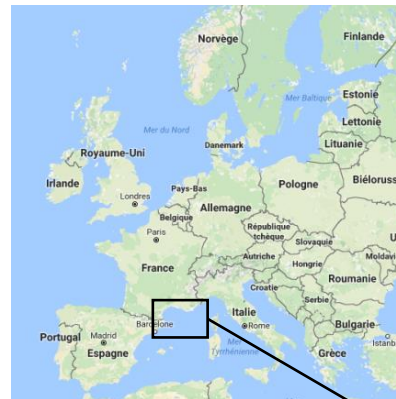
SBM Offshore & IFPEN **were selected in 2016 by EDF-EN** to design, build and install 3 floaters for a floating wind pilot farm offshore France (subject to the project achieving committed financing)

Turbine SWT 8.0-154 (8MW)

Provence Grand Large project:
3 SBM Offshore floaters equipped with 8 MW
Siemens wind turbines
(at sea in 2020)

Innovating for energy

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