6. OFFSHORE WIND TURBINES: FROM FIXED-BOTTOM TO FLOATING TECHNOLOGIES

6.1 Introduction

6.2 Fixed-bottom technologies

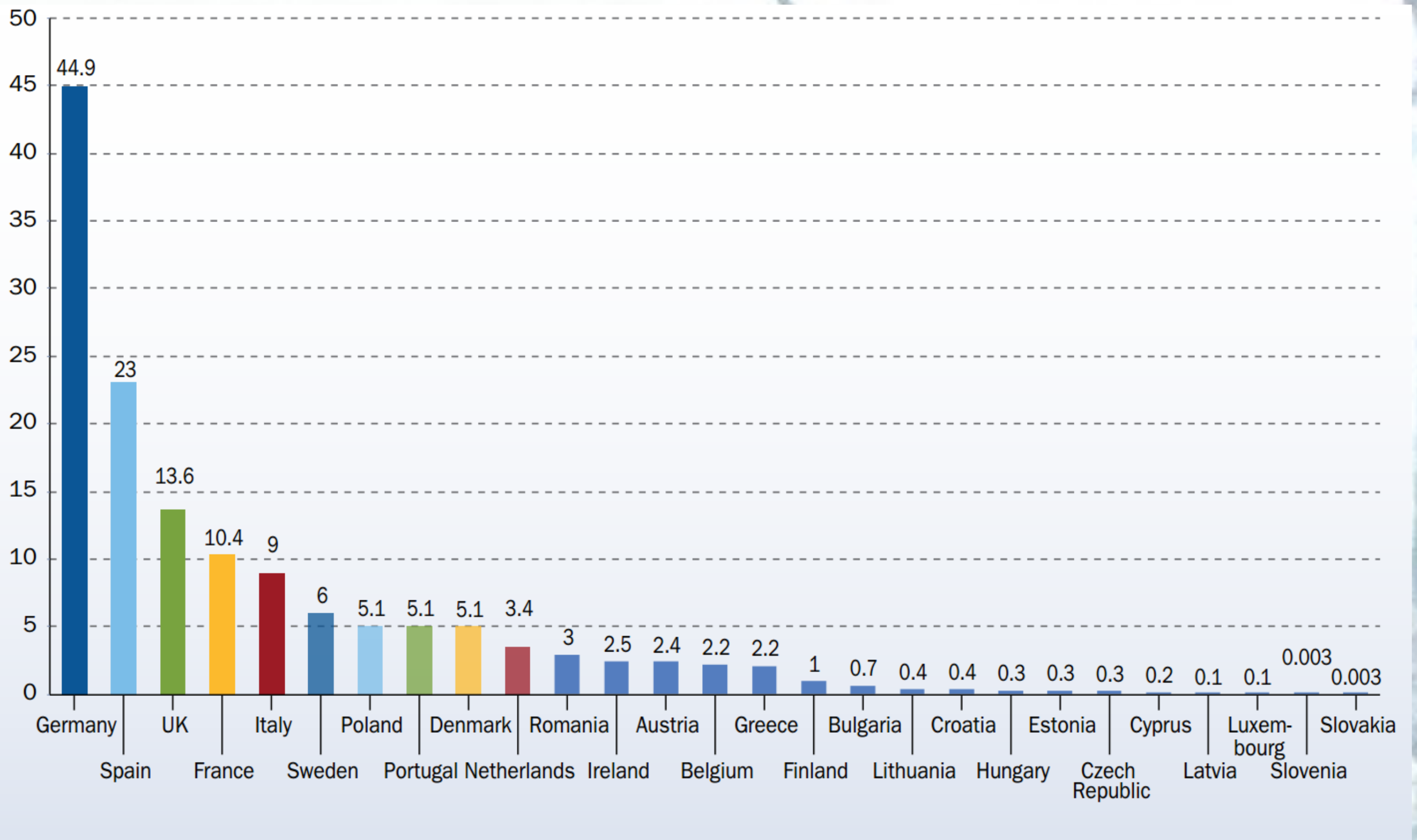
6.3 Floating technologies

6.4 Conclusions

6.1 Introduction
6.2 Fixed-bottom technologies
6.3 Floating technologies
6.4 Conclusions

Introduction

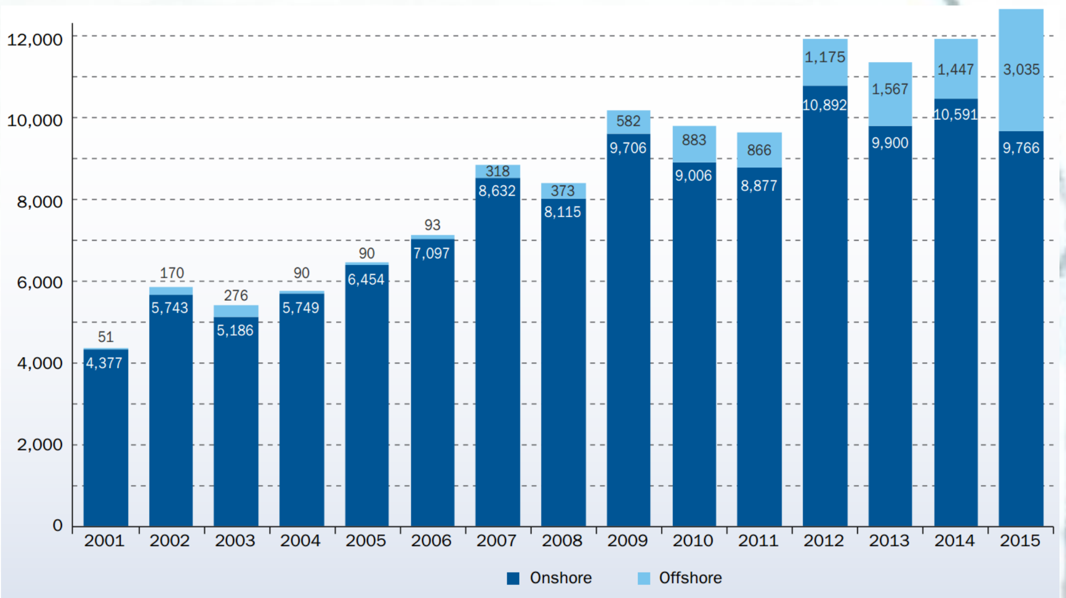
The wind energy in Europe



EU member state market shares for total installed capacity (GW). Total 141.6 GW [source: EWEA, 2016]

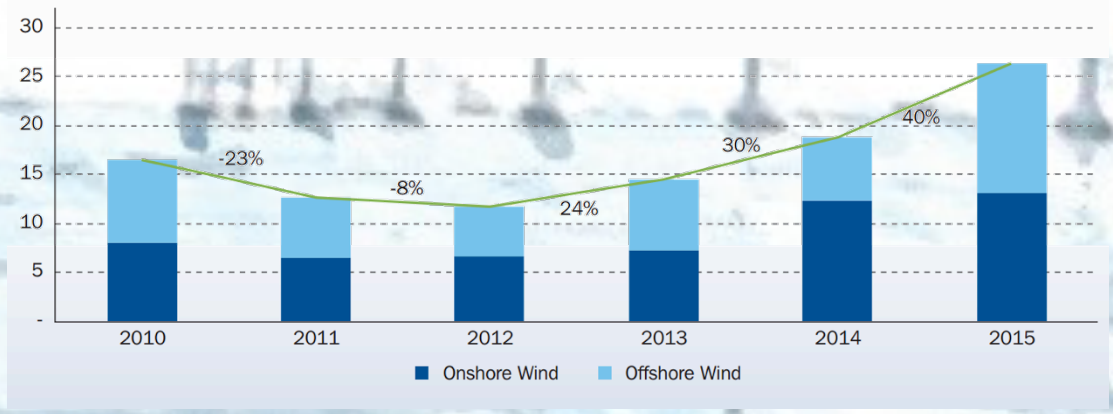
Fixed-bottom technologies

Onshore and offshore wind energy in Europe



- Increase of offshore installations
- Increase of offshore investments

Annual onshore and offshore installations (MW).
[source: EWEA, 2016]

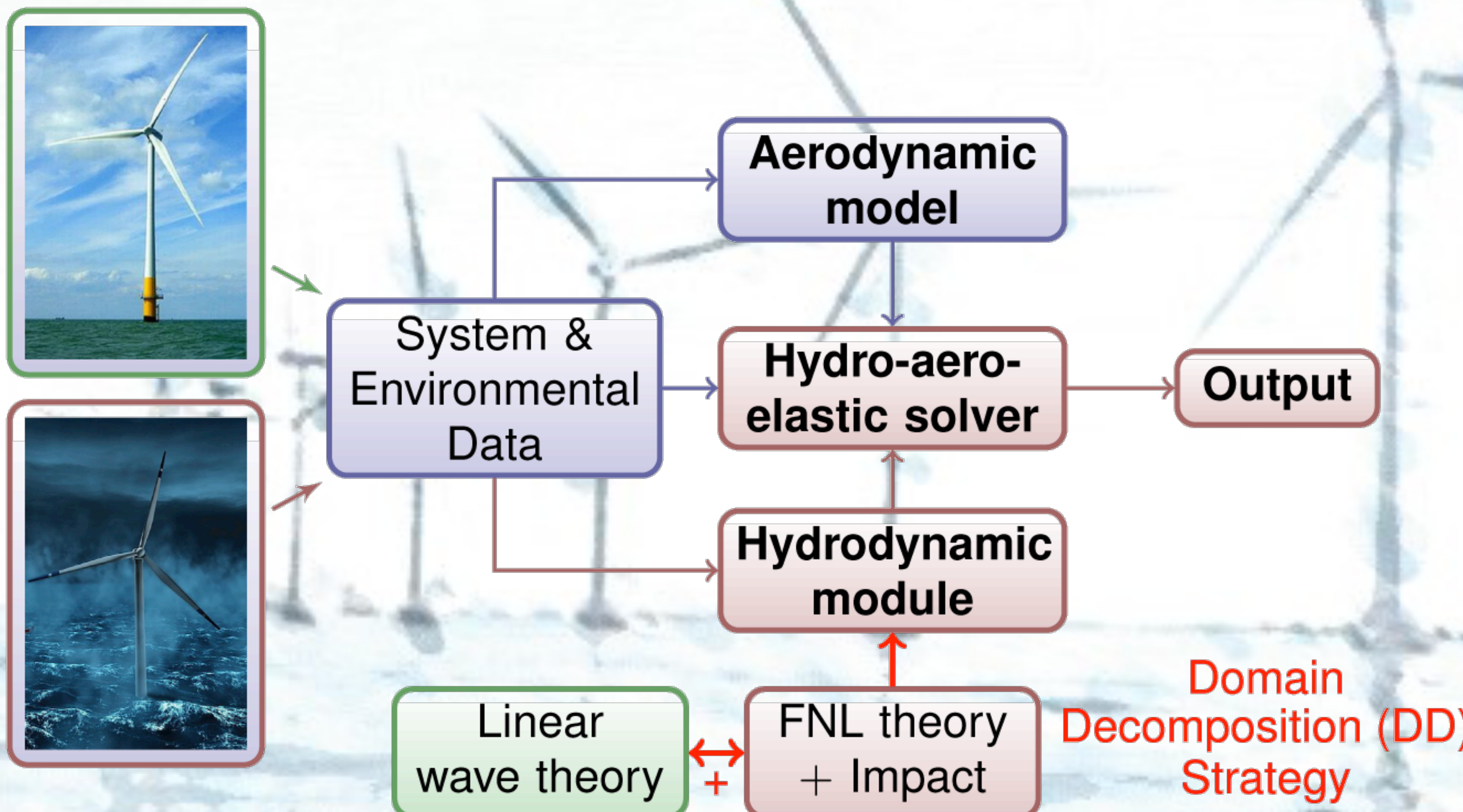


Total annual investments in wind energy 2010-2015. Figures include investments in new assets (€ BN).
[source: EWEA, 2016]

6.1 Introduction
6.2 Fixed-bottom technologies
6.3 Floating technologies
6.4 Conclusions

Fixed-bottom technologies

Proposed methodology to account for nonlinear waves



Proposed simulation scheme

Linear–Nonlinear transition scheme

Potential flow model (non-viscous, irrotational):
Laplace eq. with fully nonlinear kinematic and dynamic boundary conditions

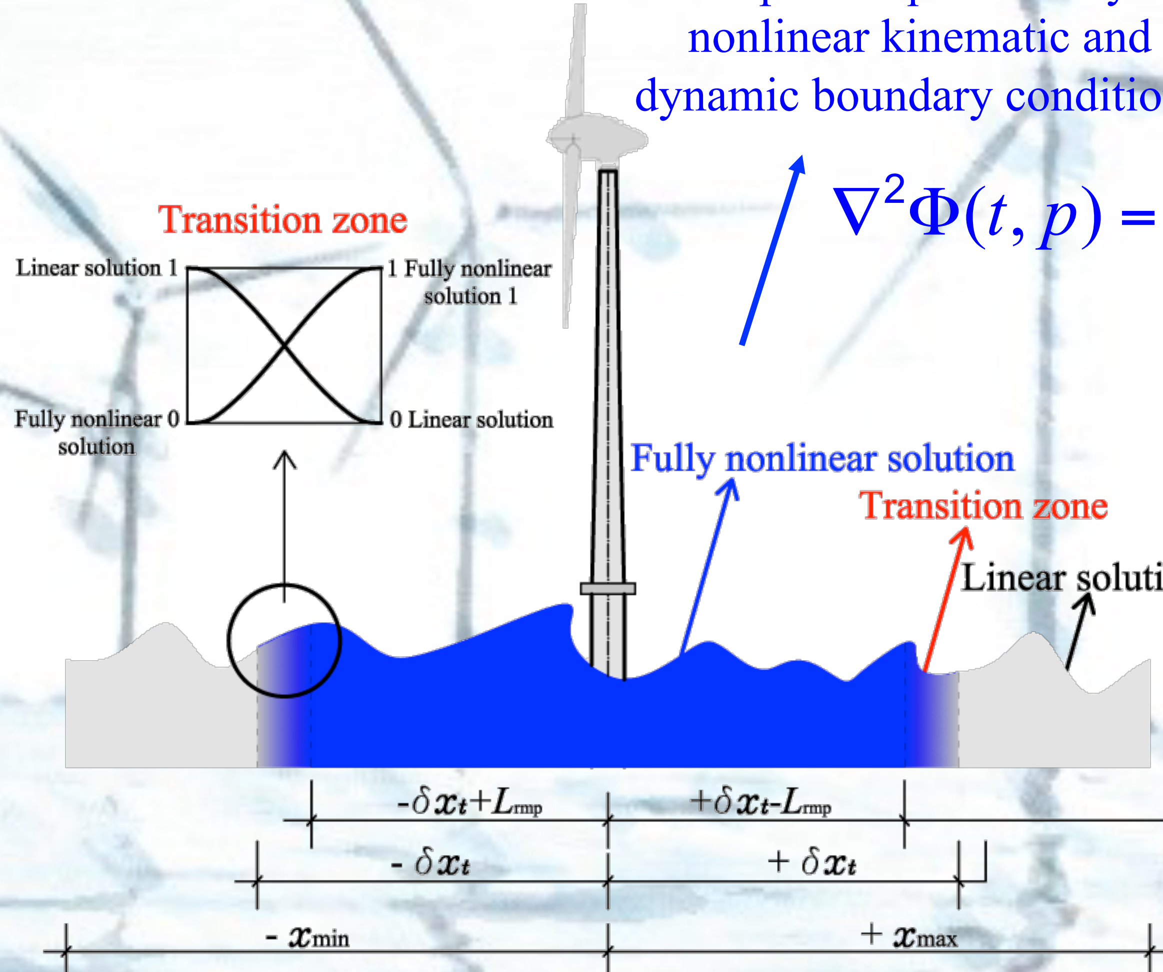
$$\nabla^2\Phi(t,p)=0$$

Efficient transition zone:

- Eulerian to Lagrangian description (and v.v.)
- Linear to nonlinear solution (and v.v.)

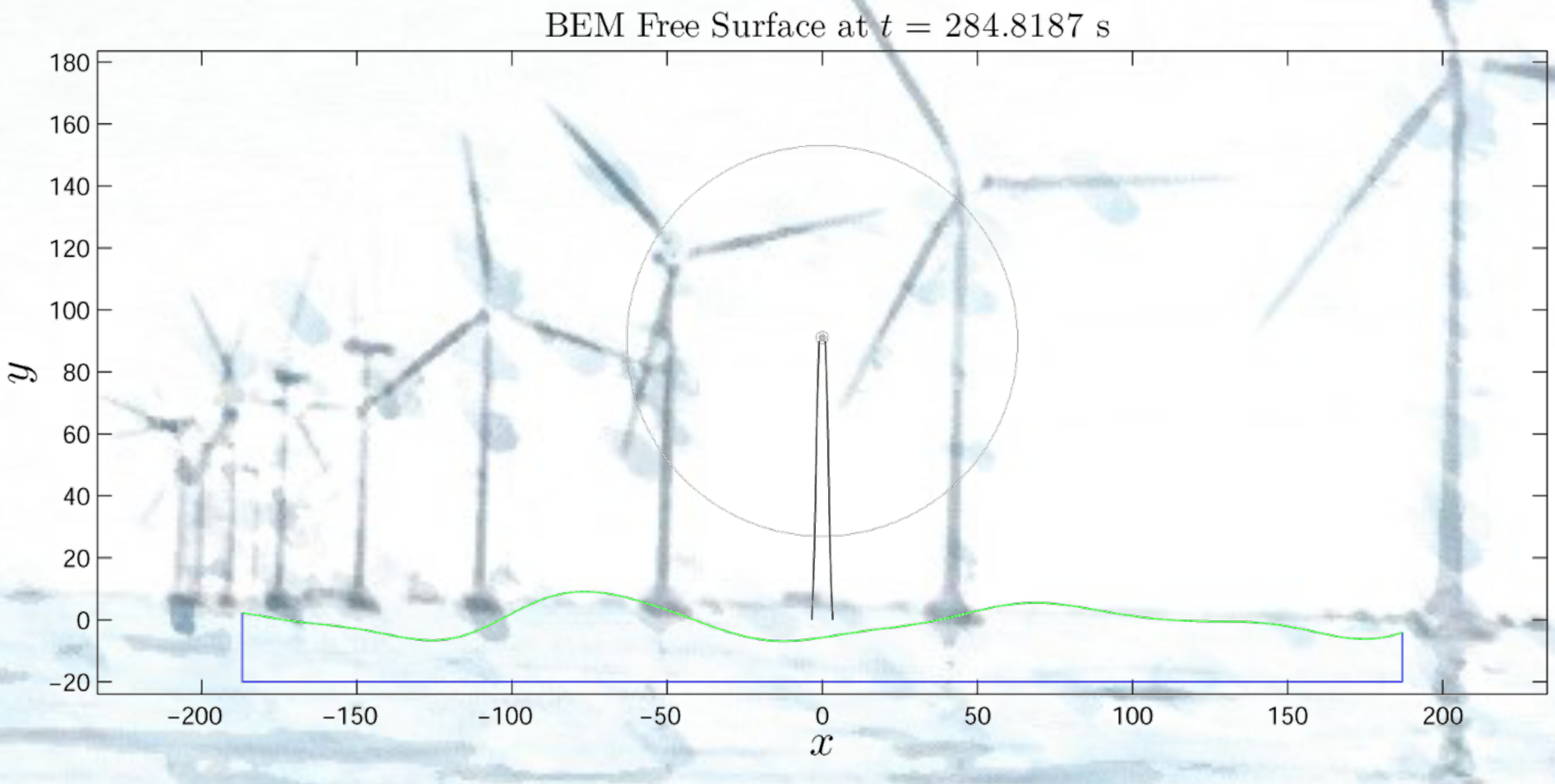
It assures:

- No reflection
- Long simulations



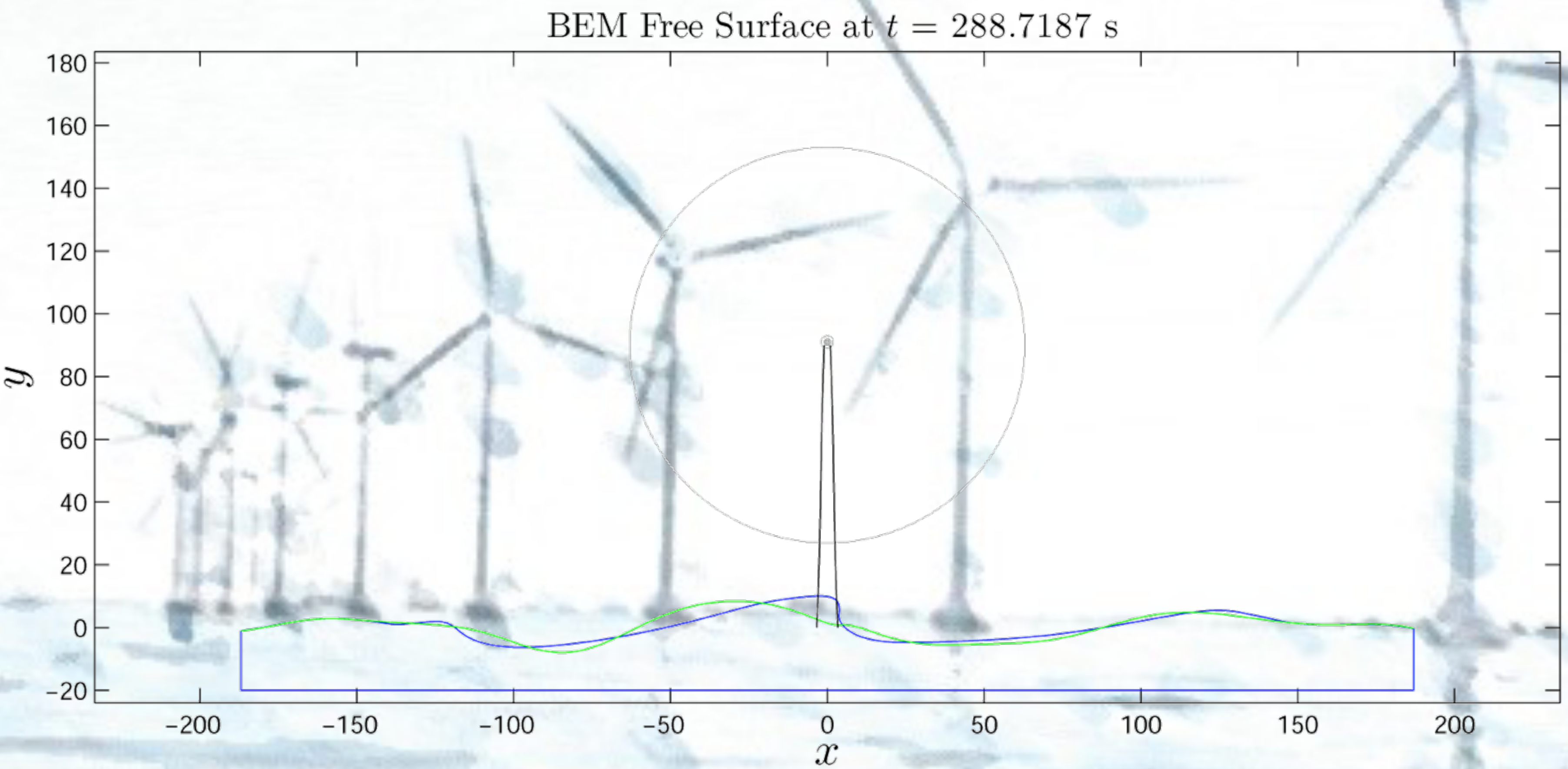
Proposed simulation scheme

Example: L vs. FNL breaking wave propagation I



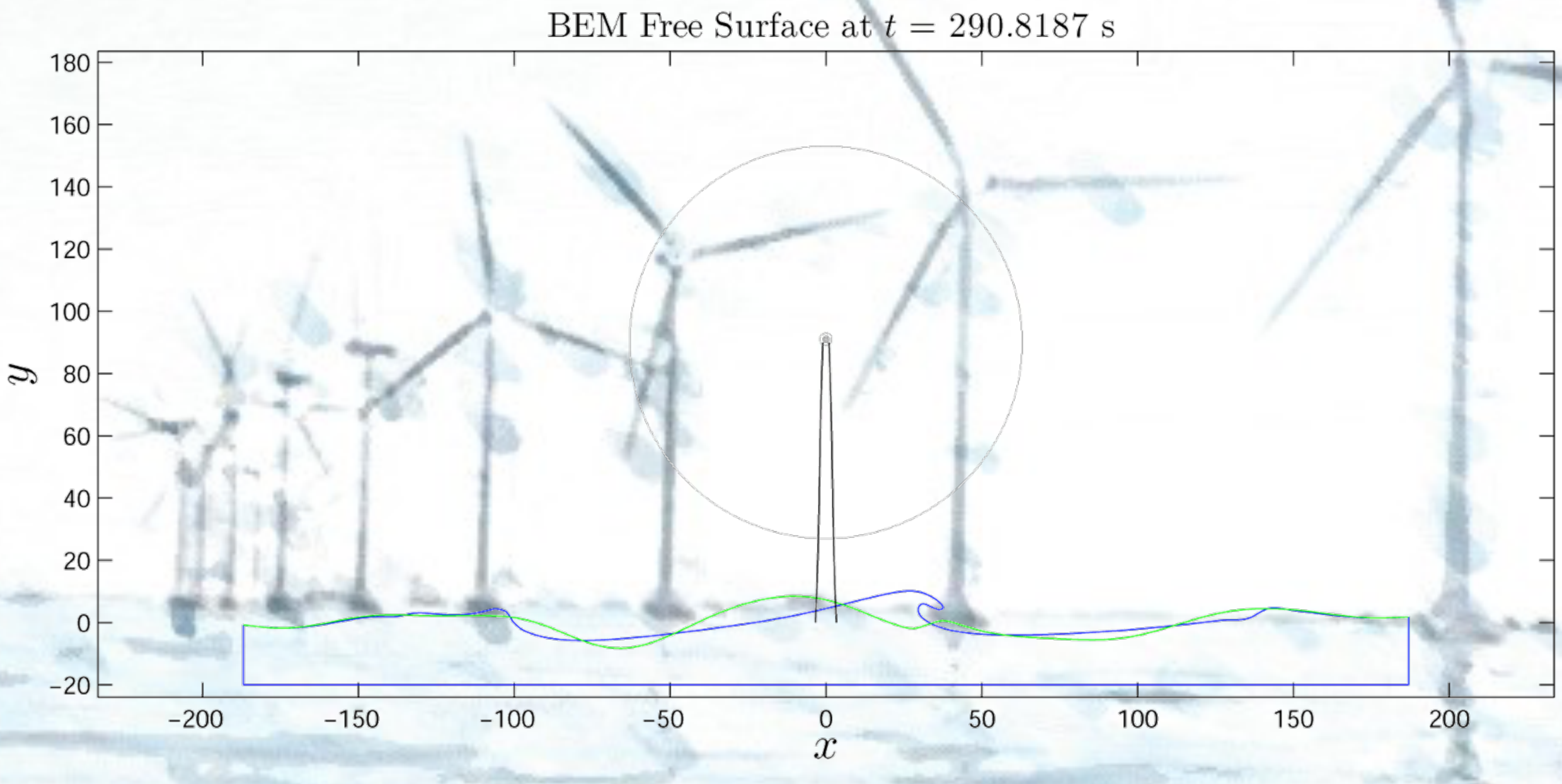
Proposed simulation scheme

Example: L vs. FNL breaking wave propagation II



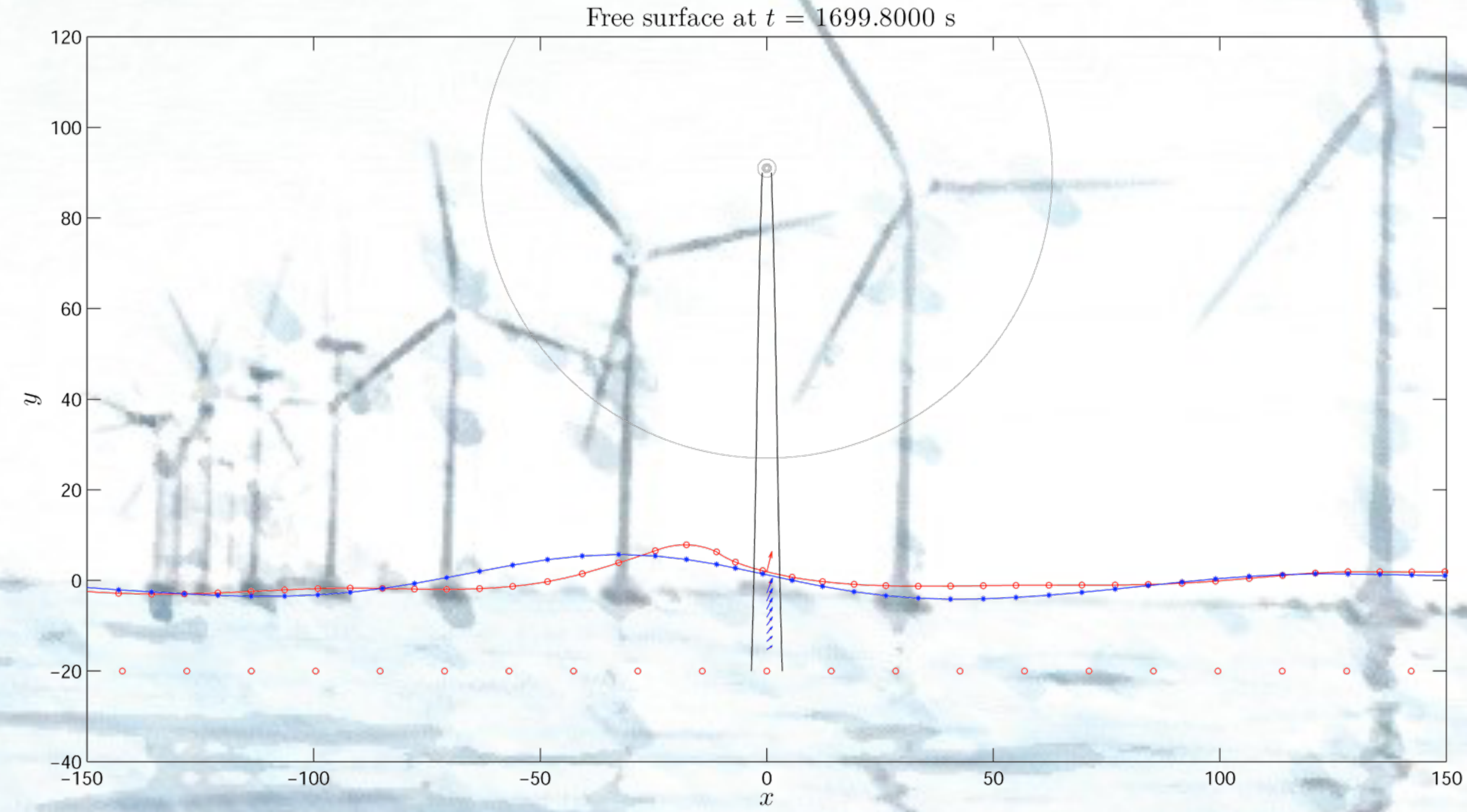
Proposed simulation scheme

Example: L vs. FNL breaking wave propagation III



Proposed simulation scheme

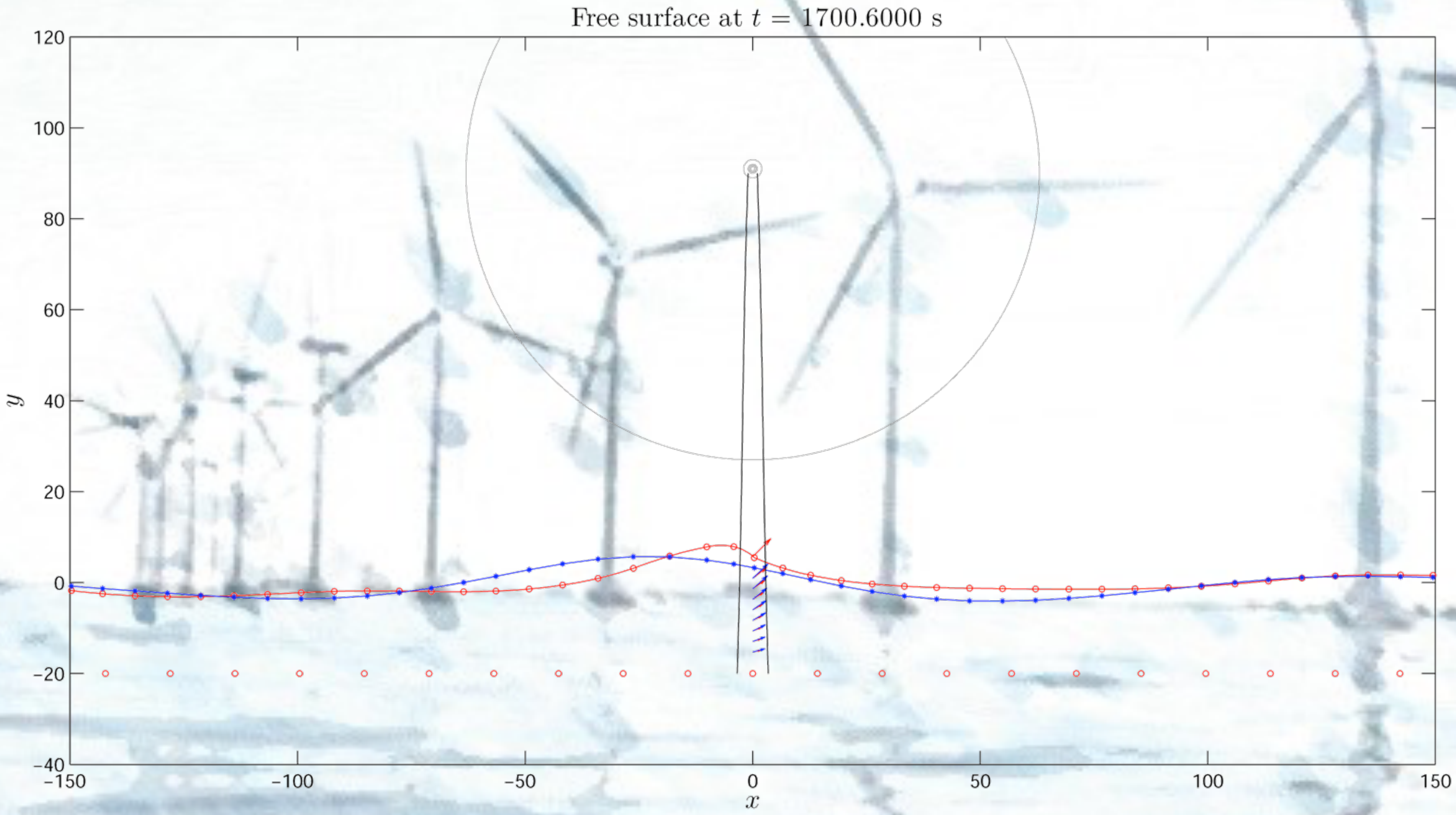
Example: L vs. FNL non-breaking wave propagation I



6.1 Introduction
6.2 Fixed-bottom technologies
6.3 Floating technologies
6.4 Conclusions

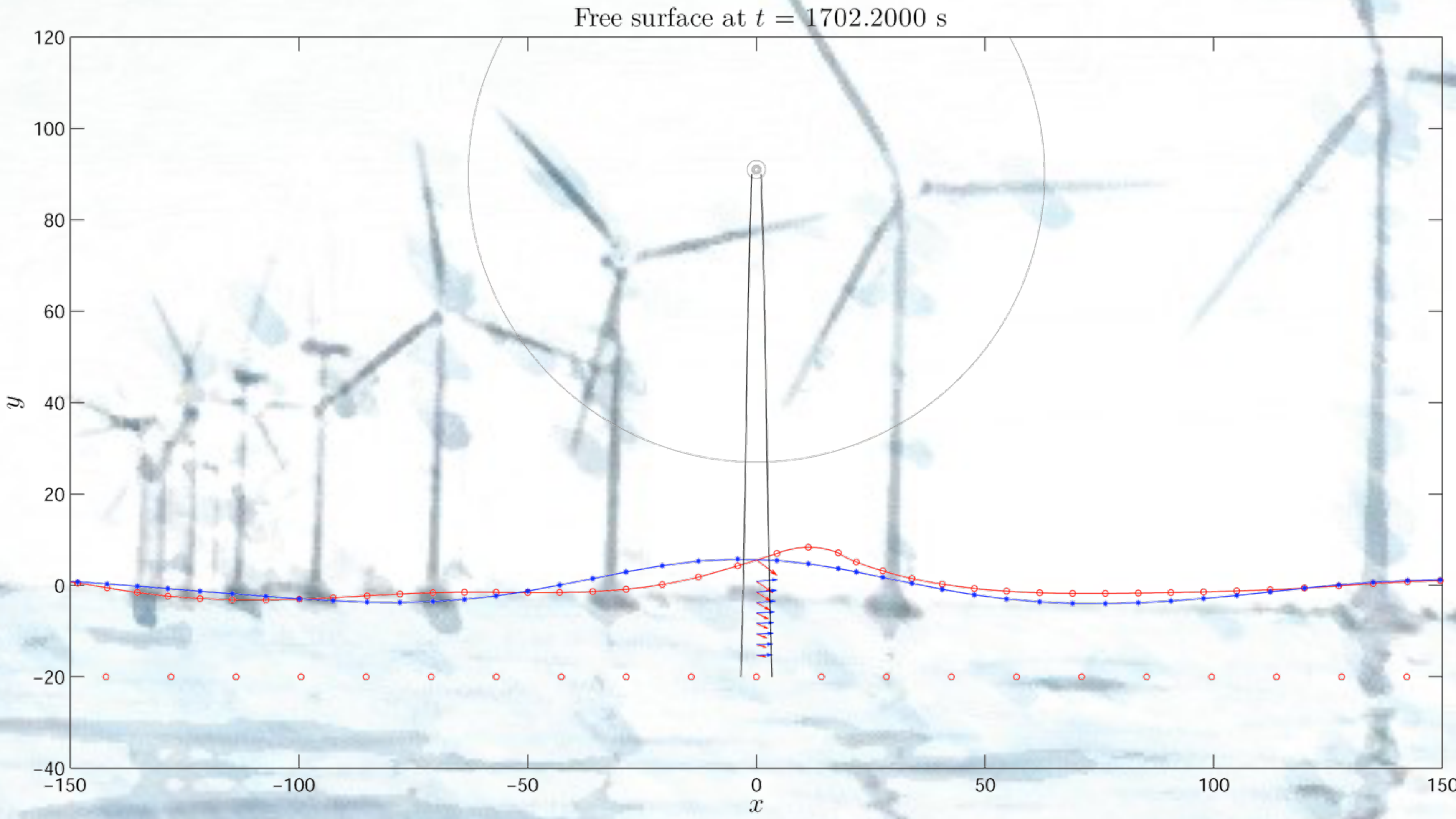
Proposed simulation scheme

Example: L vs. FNL non-breaking wave propagation II



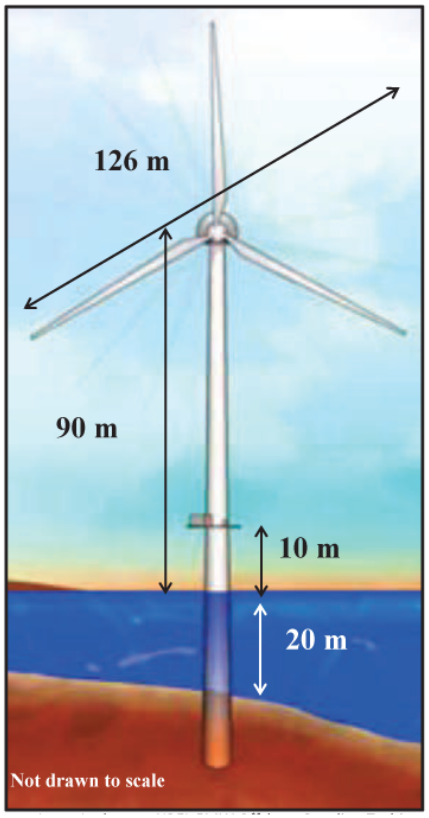
Proposed simulation scheme

Example: L vs. FNL non-breaking wave propagation III

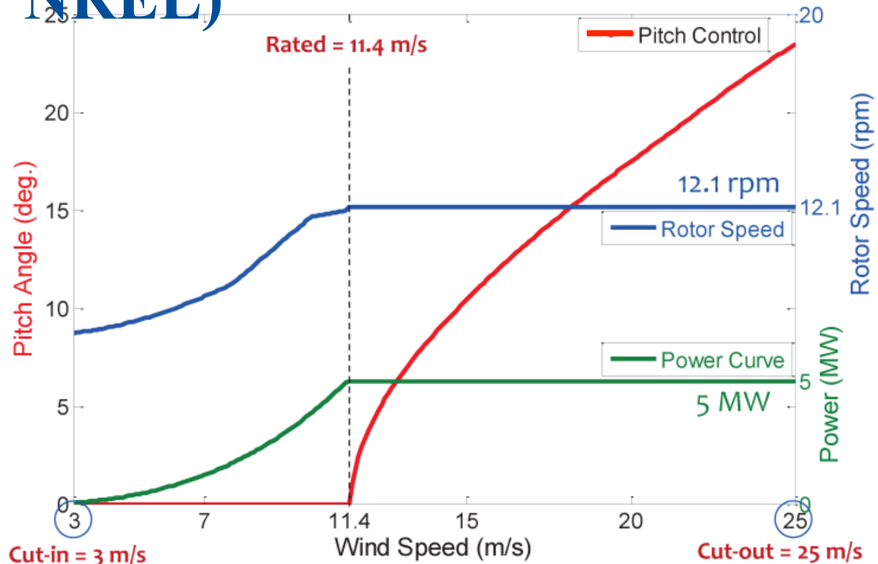


Aero-hydro-elastic simulations

5-MW NREL Baseline turbine model (simulations with FAST, NREL)



(courtesy of NREL)



Above cut-out: parked state

Sea state:

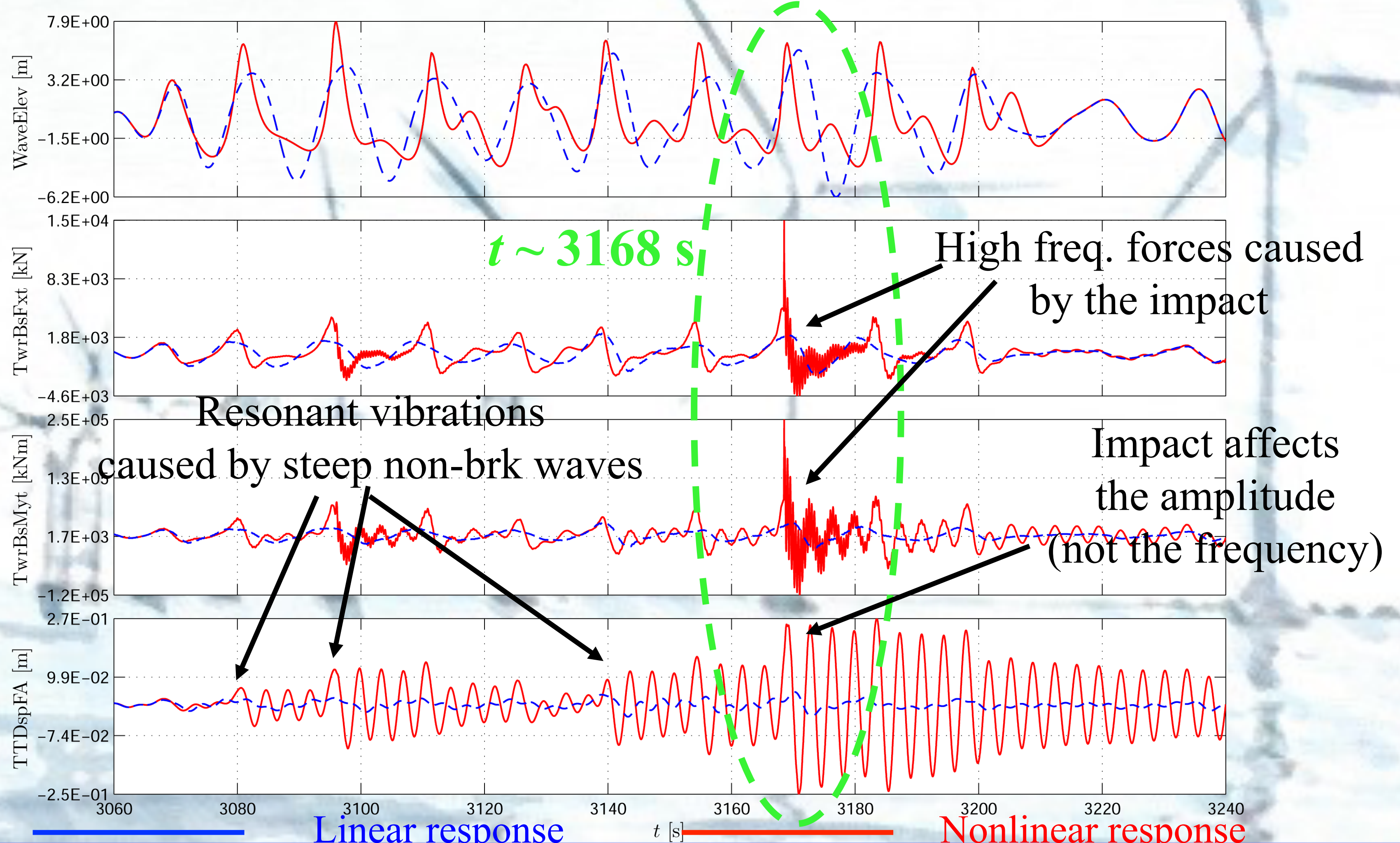
H_s [m]	T_p [s]	HH Wind vel. [m/s]
7.5	15	33

H_S: significant wave height; T_P: wave spectral peak period

Aero-hydro-elastic simulations - Tower

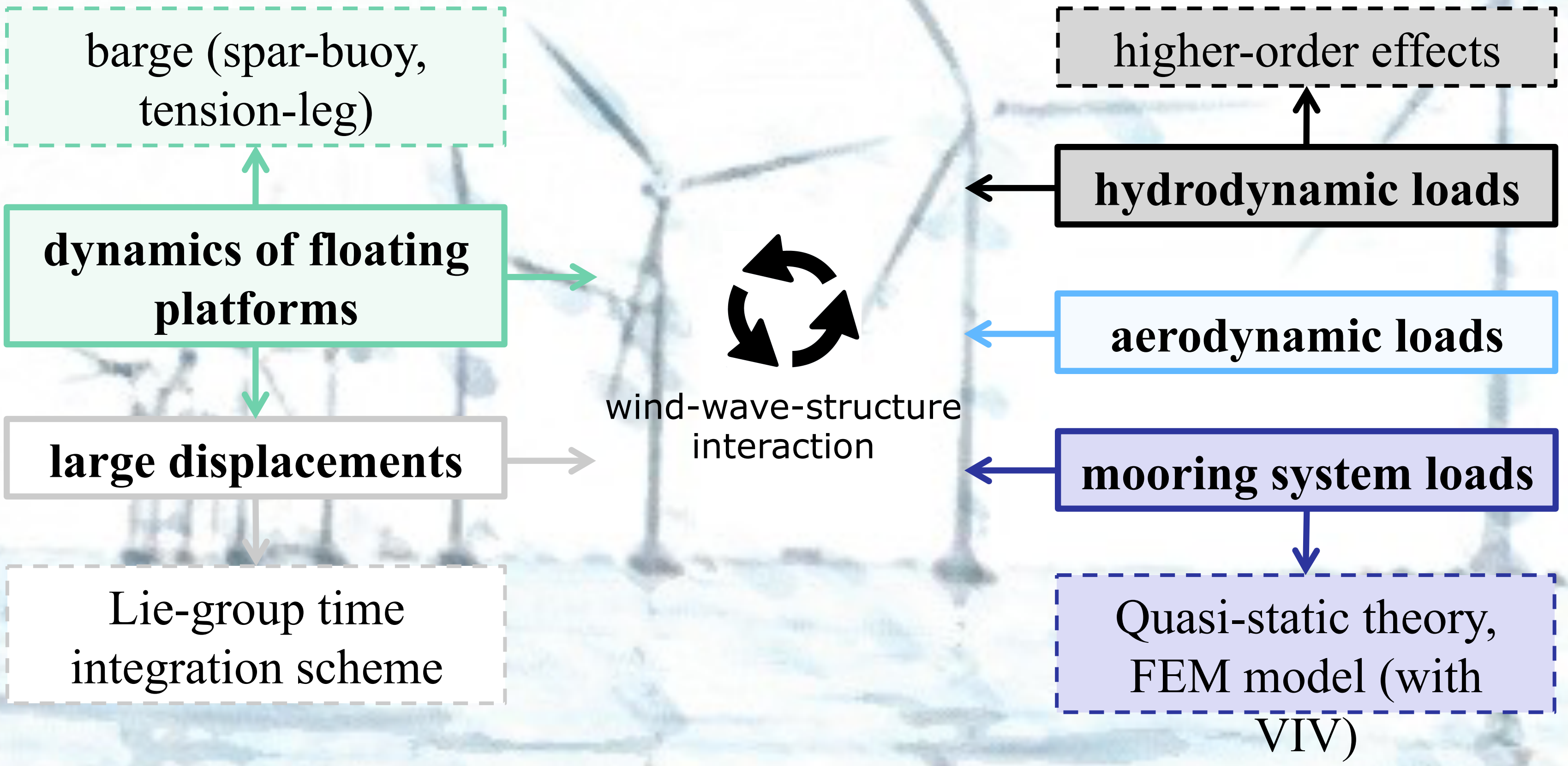
FNL vs. L wave kinematics and tower response

f_{tower} = 0,28 Hz



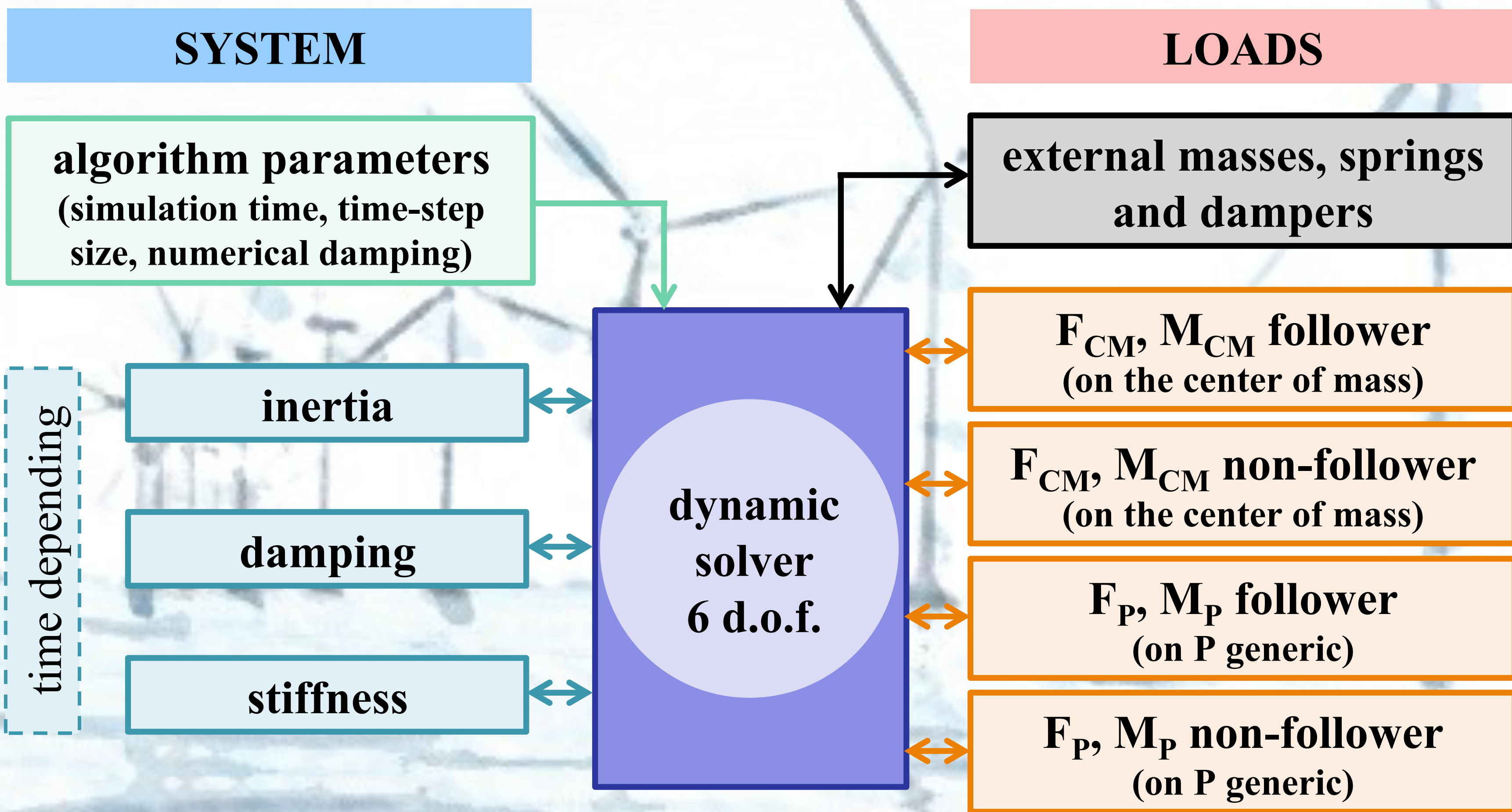
Floating technologies

Wind-wave-structure interaction problem



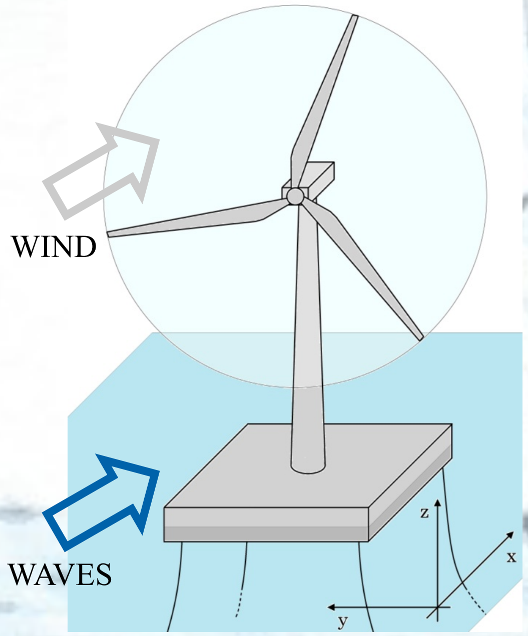
Floating technologies

Floating platform dynamics: numerical model



Floating technologies

Hydrodynamic problem



→ Potential-flow theory

→ First-order hydrodynamics, i.e. superimposition of:

- hydrostatics
- radiation
- diffraction

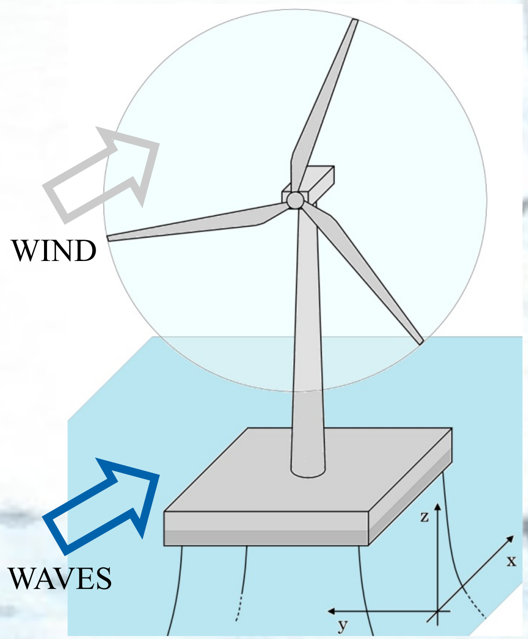
→ Coupling with the dynamic solver:

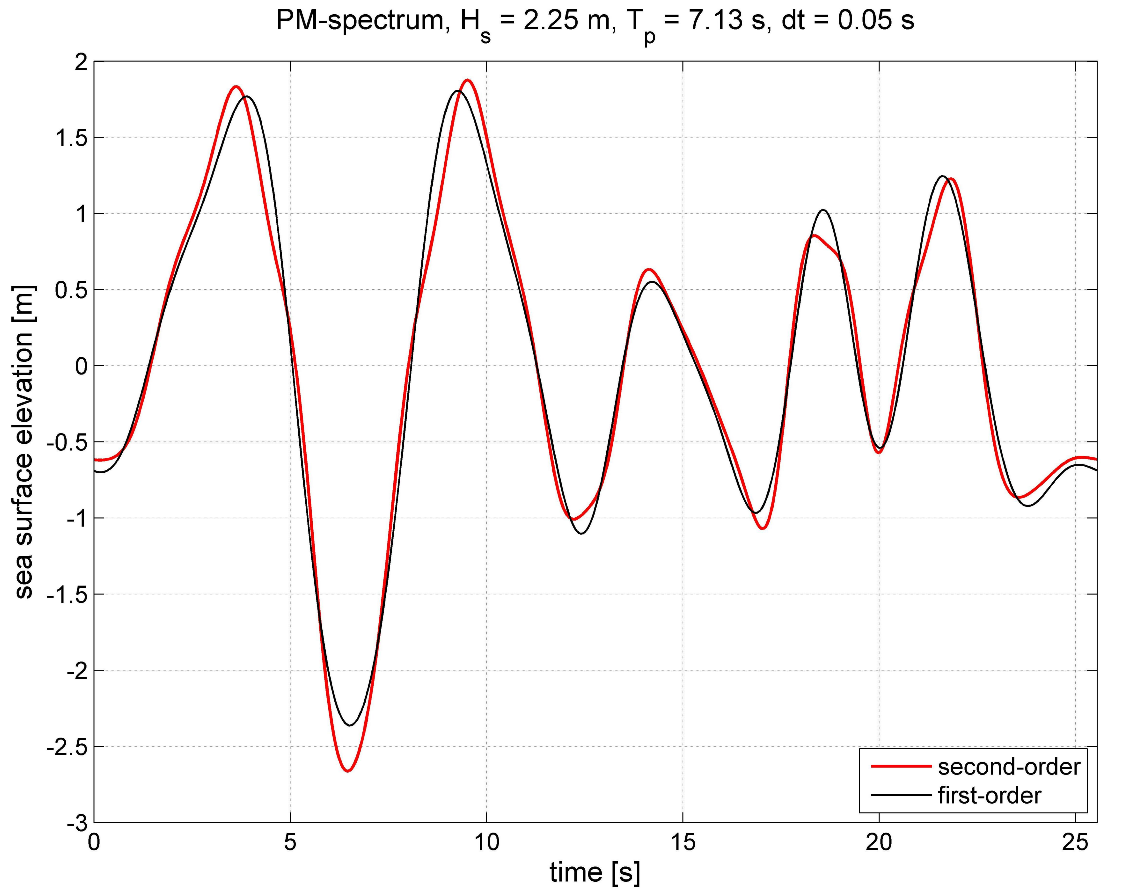
- configuration-depending loads
- additional mass, damping and stiffness

→ Higher-order effects (next step)

Floating technologies

Hydrodynamic problem





Comparison between the first-order and the second order wave kinematics (obtained using the same random phases).

Mooring Lines

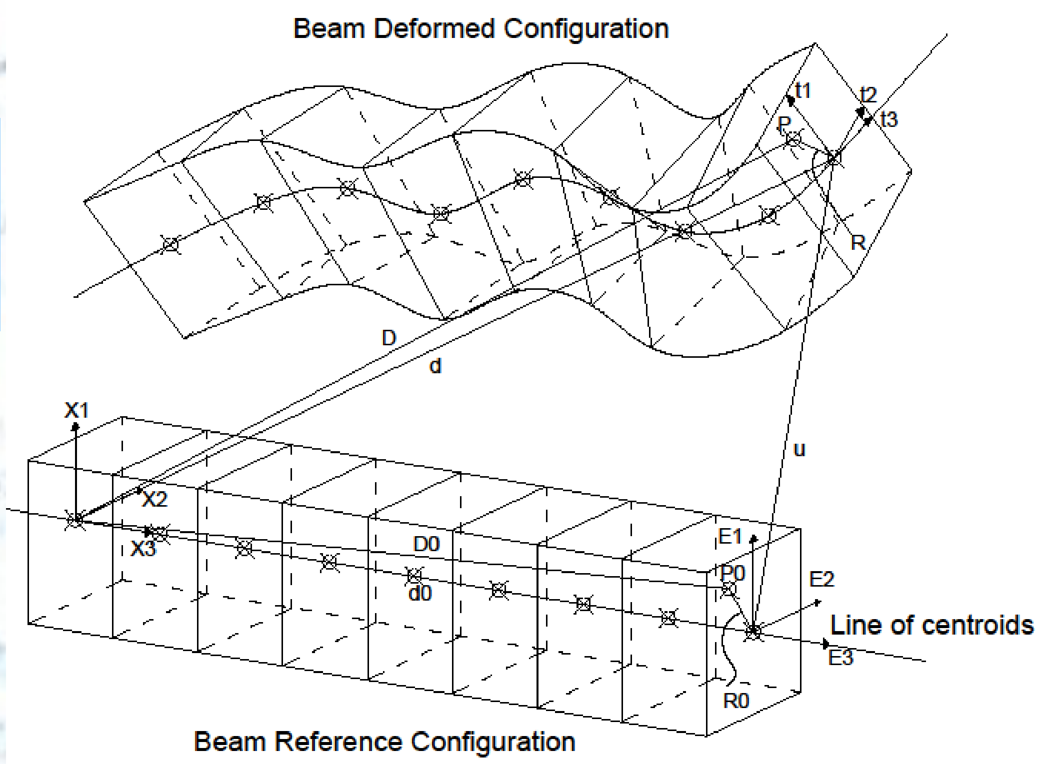
Structural Dynamics

The dynamics of each mooring line is fully reproduced discretizing the structure with a dynamic finite element technique.

Structural Model

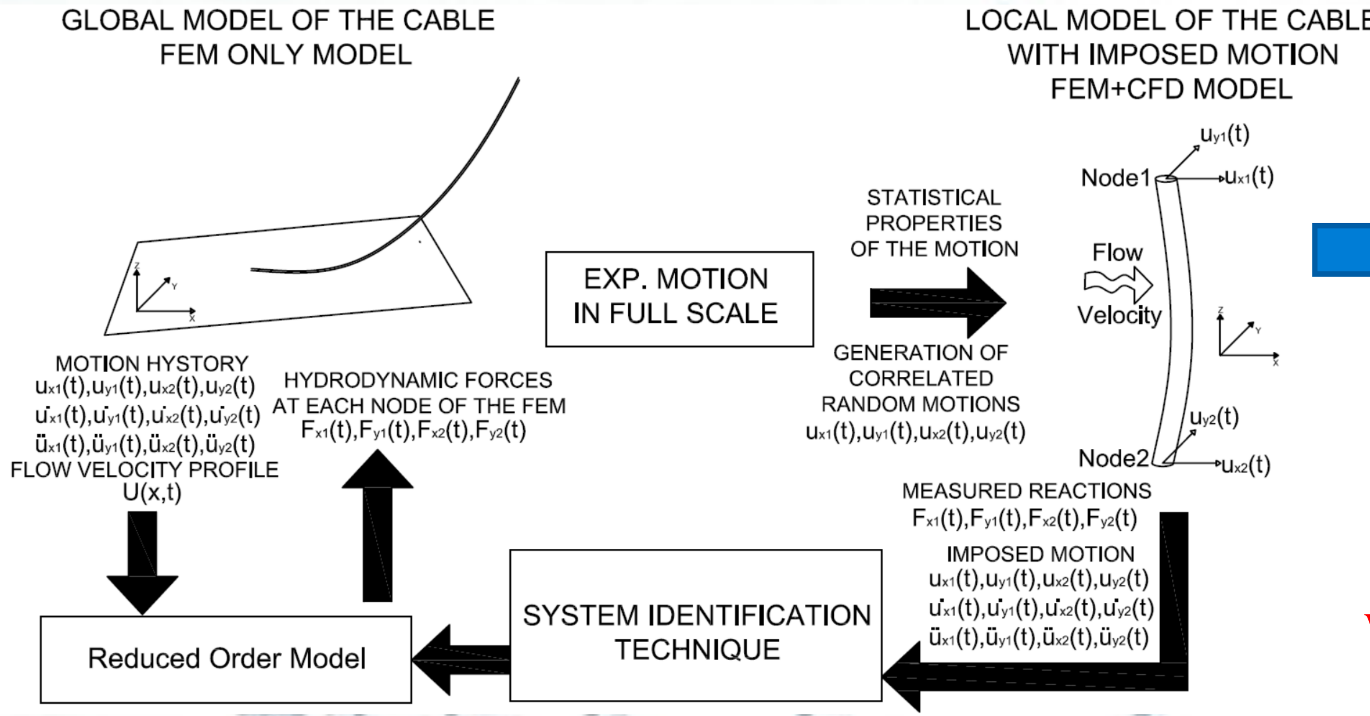
Structure discretized with Geometrically-exact beam elements (SIMO)

Time integration performed with a generalized-alpha method

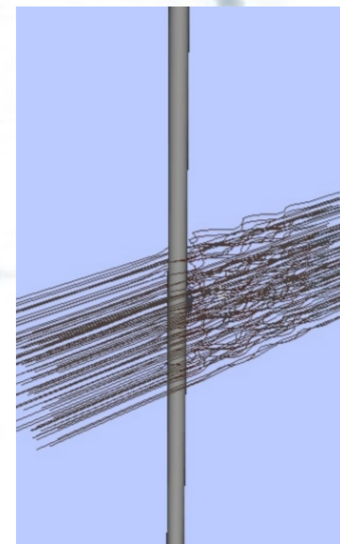


Mooring Lines

Hydrodynamic Model



High fidelity model



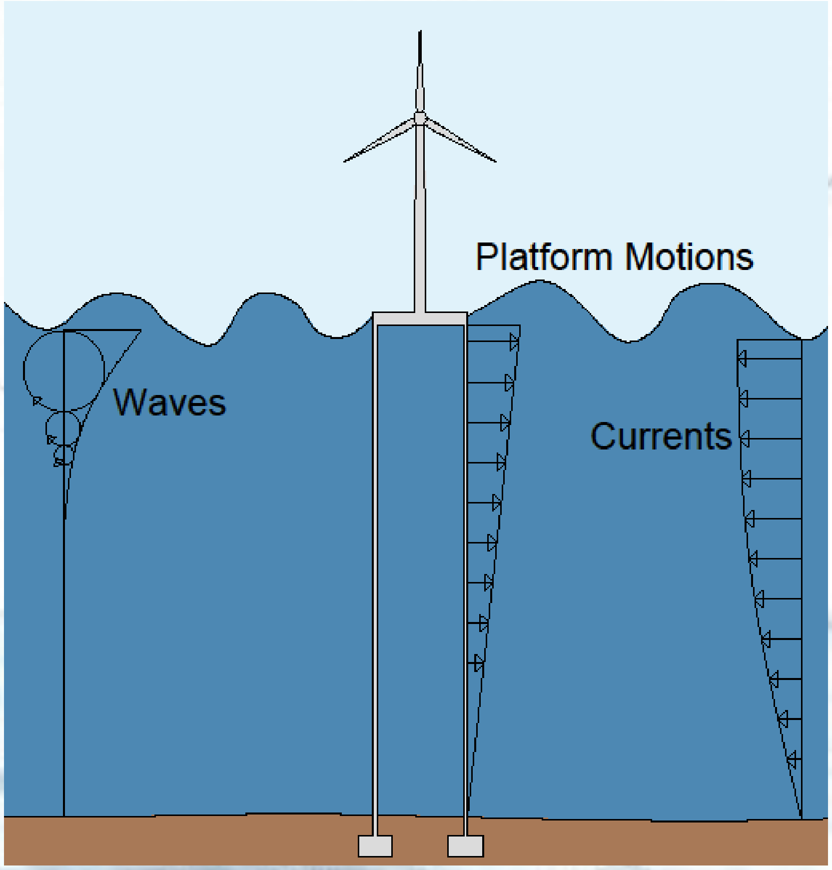
Coupling of a CFD solver with a geometrically exact FEM solver

The hydrodynamic model is based on an efficient reduced order model (ROM) suitable for long term simulations in time domain but able to capture complex phenomena such as vortex induced vibrations. Parameters of the model are calibrated using results from high fidelity FSI simulations conducted on a reduced domain size.

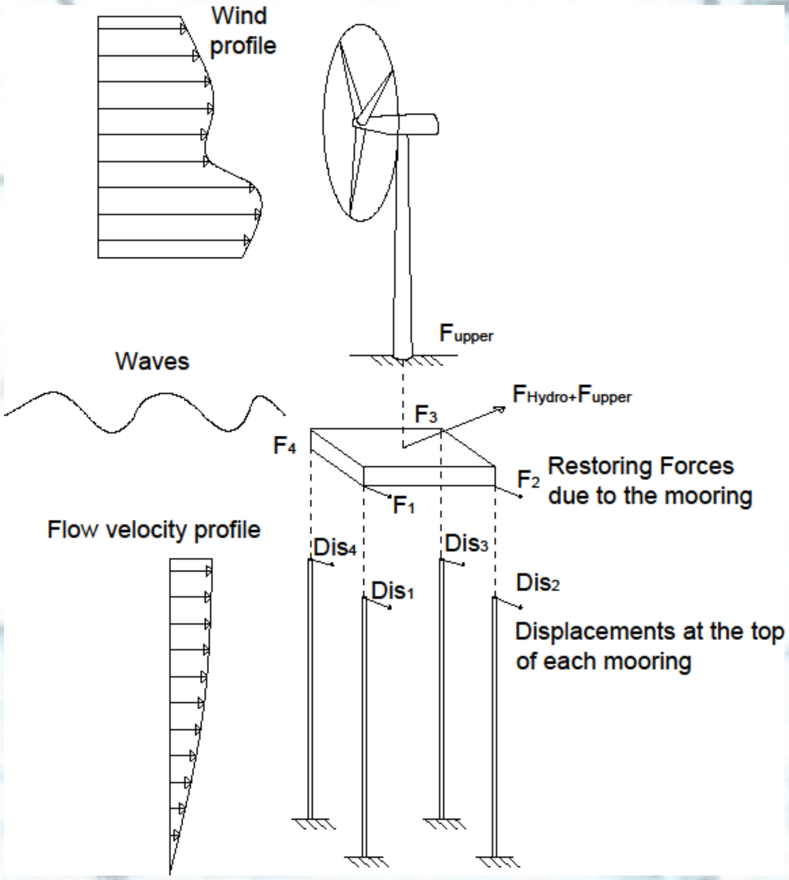
Mooring Lines

Coupling with the platform solver

Actions on the moorings



**Coupling Procedure:
Block Gauss-Seidel Algorithm**



Conclusions

Fixed-bottom substructures

- In severe sea states, resonant vibrations can be triggered by high-order nonlinear waves contributions.
- Such vibrations cannot be captured when the standard linear wave theory is used.

Floating platforms

- Development of a dynamic solver based on large-displacement approach.
- Cable's loads: from quasi-static theory to ROM for geometrically exact FEM solvers.

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6.2 Fixed-bottom technologies
6.3 Floating technologies
6.4 Conclusions

Thank you for your kind attention!