IEA Wind Annex 30 - OC4 Project

The **O**ffshore **C**ode **C**omparison **C**ollaboration **C**ontinuation

Fabian Vorpahl

Wojciech Popko

Simulation and assessment of wind turbines

Fraunhofer Institute for Wind Energy and Energy System Technology (IWES)

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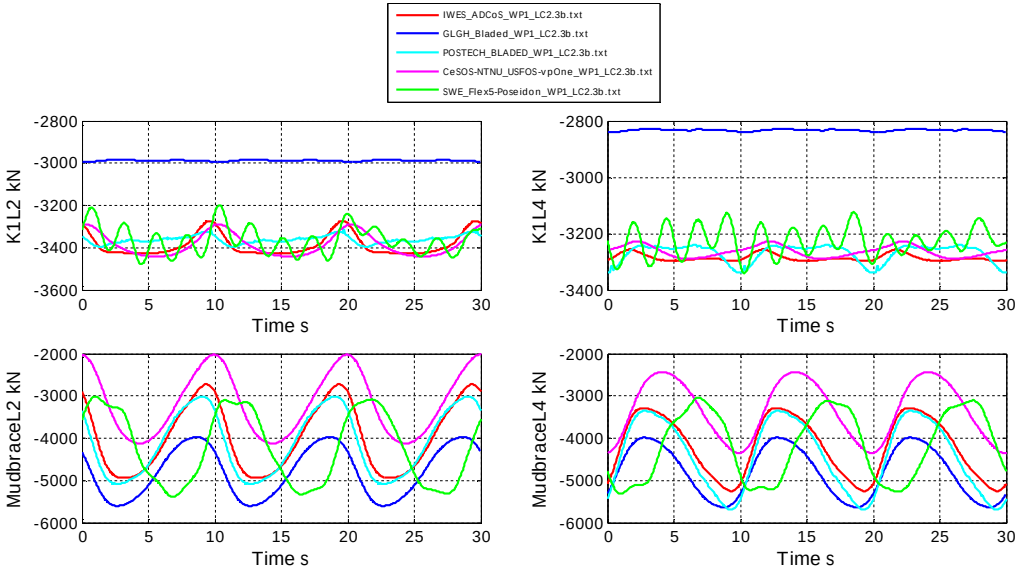
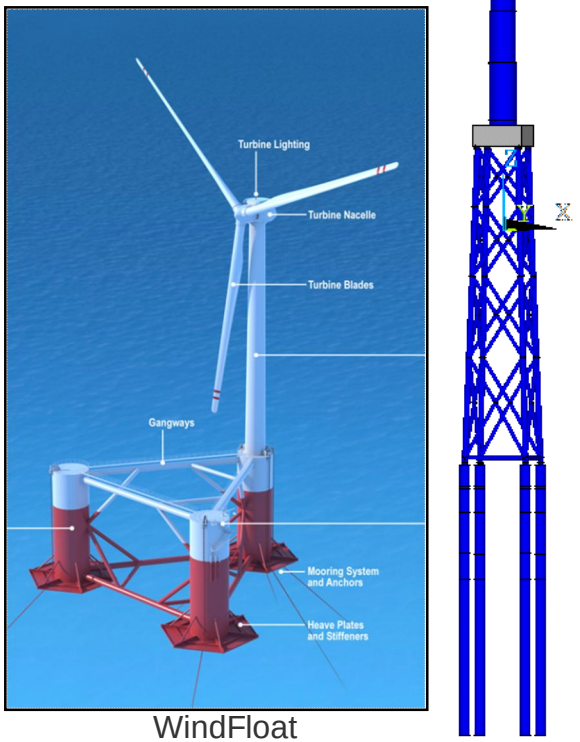
Outline

- OC4 project background and overview
- OC4 project organization
- Phase I: Turbine on jacket substructure
- Phase II: Turbine on floating semisubmersible

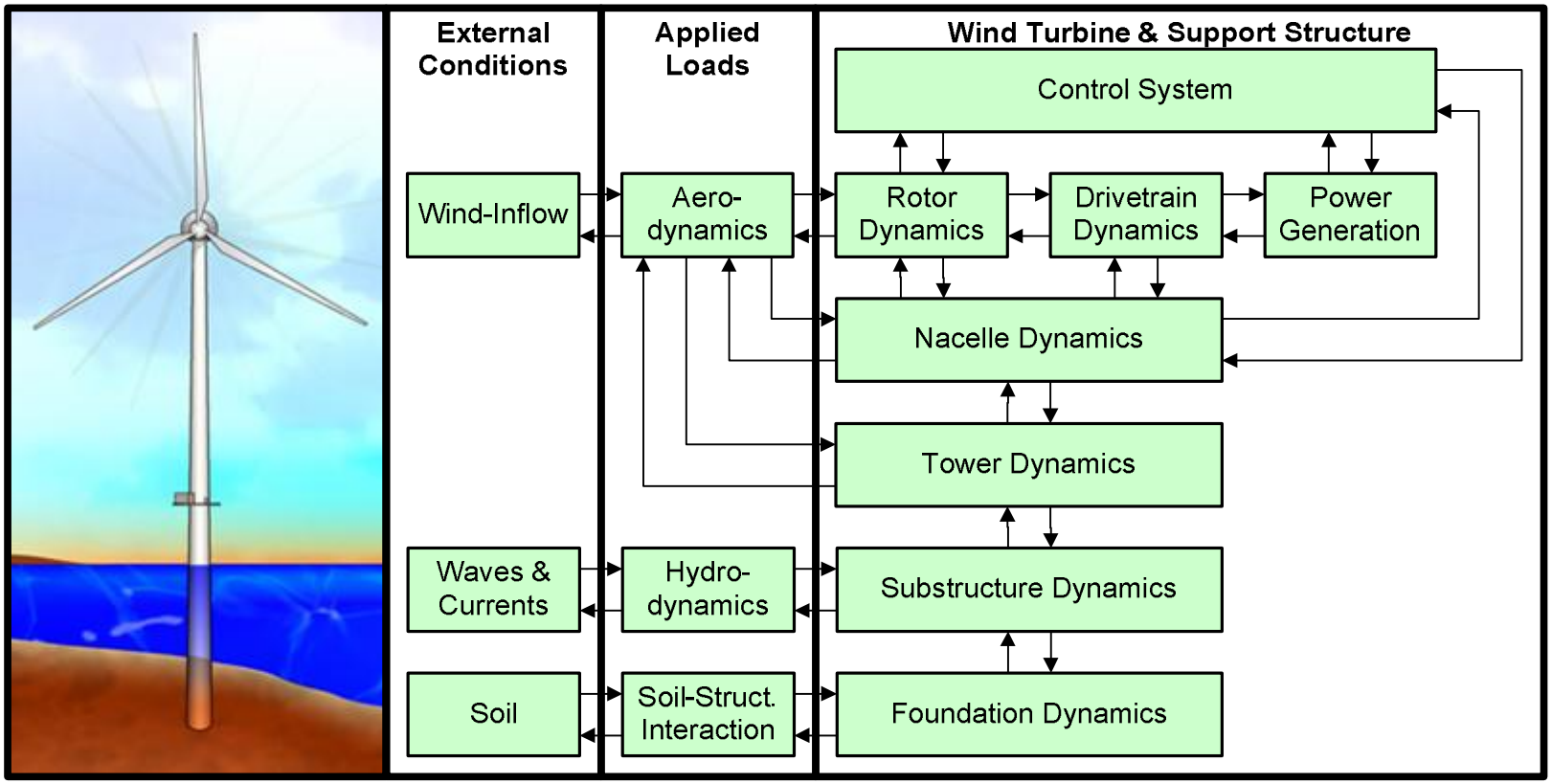




WindFloat
(Image: D. Roddier, PPI)

OC4 Project Background and Overview: Fully-coupled Simulation

Aero-hydro-servo-elastic tools currently used for loads simulation



Source: NREL

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OC4 Project Background and Overview: Verification / Validation Problem

- Fully-coupled tools are used for loads simulation
- Turbines are certified based on the calculated loads and components are designed based on those loads
- Offshore Wind Turbines are further developed (Turbine size, new Support Structure types…)
- Tools are further developed to account for characteristics of new Components / Designs (wave loads on 'braced' structures)

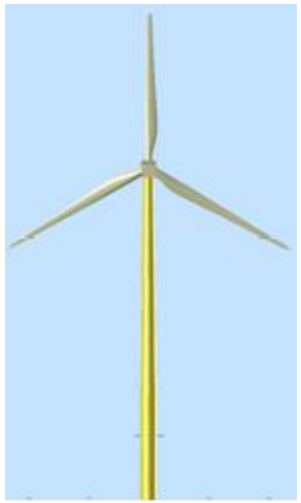
- Tools must continuously be verified and validated because of:
  - Importance of the simulated loads and
  - New challenges for tools / new features of tools

OC4 Project Background and Overview: Verification / Validation Problem

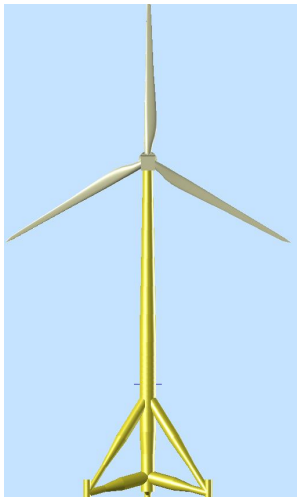
- Straightforward solution: Tool validation against measured data
- Drawbacks:
  - Immense effort of large measurement campaigns
  - Bottleneck due to confidential data necessary for model setup
  - Complex real world load cases make it hard to trace back errors in codes / models
- Verification in code benchmark projects
  - OC3 project as code verification project dedicated to Offshore Wind Turbines (IEA Annex 23, 2005 to 2009), focused on different support structure types
  - Still open issues and need for further research → setup of OC4 project

OC4 Project Background and Overview: From OC3 to OC4

- New support structure types
- Local structural dynamics in jacket
- Complex hydrodynamics calculations for semi-submersible



Source: University of Stuttgart, SWE



Source: University of Stuttgart, SWE

Source: StatoilHydro

OC3

Source: NREL

OC4

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OC4 Project Background and Overview: Project setup

- New IEA task 30 setup in 2010
  - Only one project in this task: OC4
  - Based on OC3 results and experiences
  - Investigation of new aspects and new structures
- 2 work packages:
  - Phase I – Jacket substructure (led by Fraunhofer IWES, Germany)
  - Phase II – Semisubmersible (led by NREL, USA)
- 3 years life span
- Including former OC3 participants and new project members

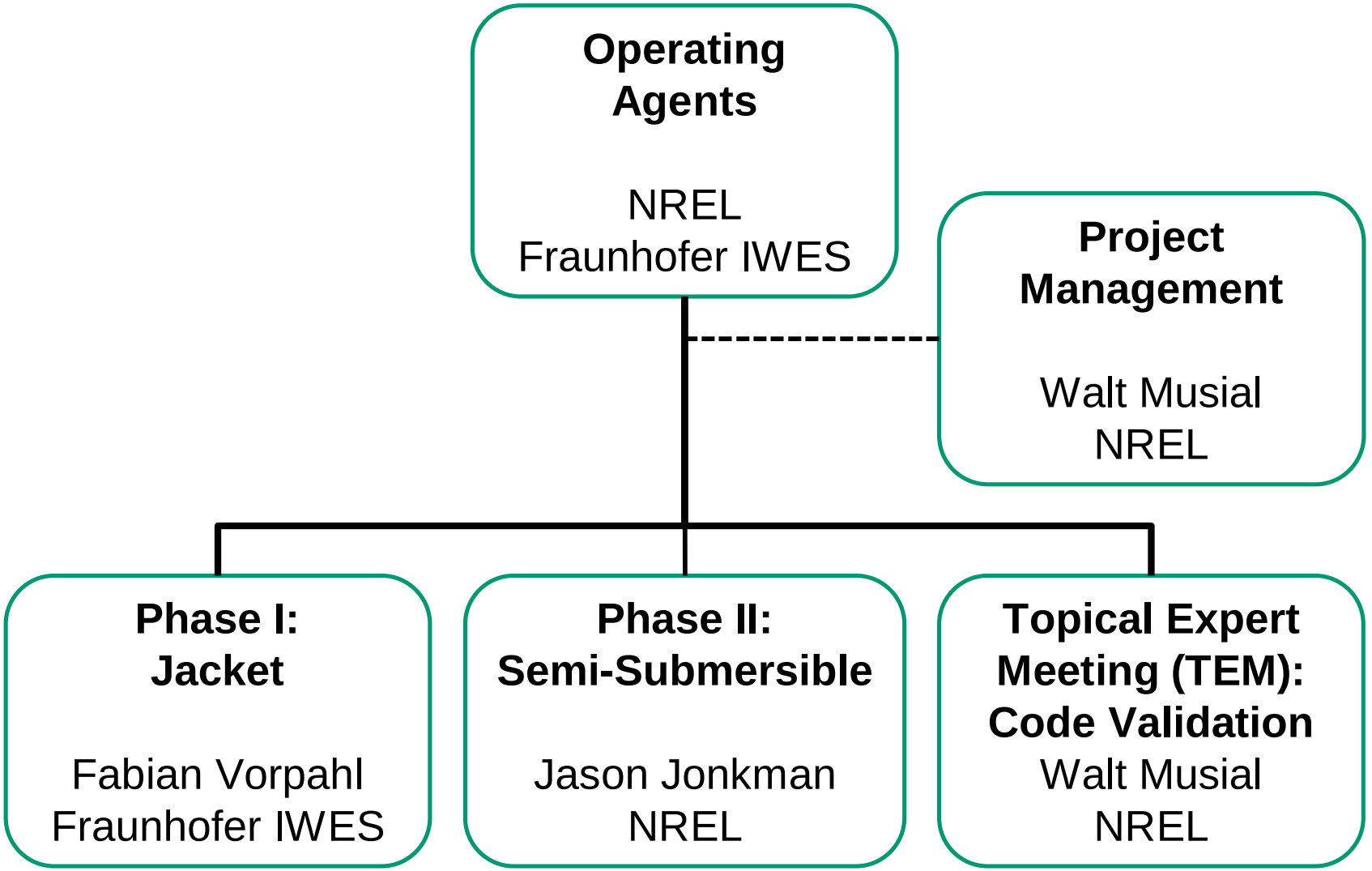
OC4 Project Background and Overview: Goals

- To benchmark and verify the codes in terms of their simulation capabilities of different sub-structures
- To asses the accuracy and reliability of obtained results
- To increase confidence in results and allow for decrease of safety factors
- To predict loads more accurately by reducing uncertainties
- To find out capabilities and limitations of implemented theories
- To refine and investigate existing analysis methods
- To initiate further Industry codes development and their optimization
- To train new analysts how to run and apply codes correctly

OC4 Project Organization: Activities

- Monthly net-meetings: Ongoing
- Biannual physical meetings: 2 already held
- 1 experts meeting in the 2nd year
- 1 expert-meeting report
- 1 conference paper for each Phase planned
- Final report

OC4 Project Organization: Structure



OC4 Project Organization: Country commitments

- IEA Wind Task 30's biggest challenge has been getting country commitments
- Currently: 5 countries joined the task
- Netherlands will be joining soon
- Active partners in Korea and Sweden: Commitment expected soon

Country	Response
Austrailia	No response
Austria	No response
Canada	Considering
Chinese Wind Energy Association	Considering
Denmark	Committed
European Commision	Declined
Euopean Wind Energy Association	Declined
Finland	Considering
Germany	Committed
Greece	No response
Ireland	Considering
Italy	No response
Japan	No response
Korea	Pending
Mexico	No response
The Netherlands	Pending
Norway	Committed
Portugal	No Response
Spain	Committed
Sweden	Pending
Switzerland	Declined
United Kingdon	Declined
United States	Committed

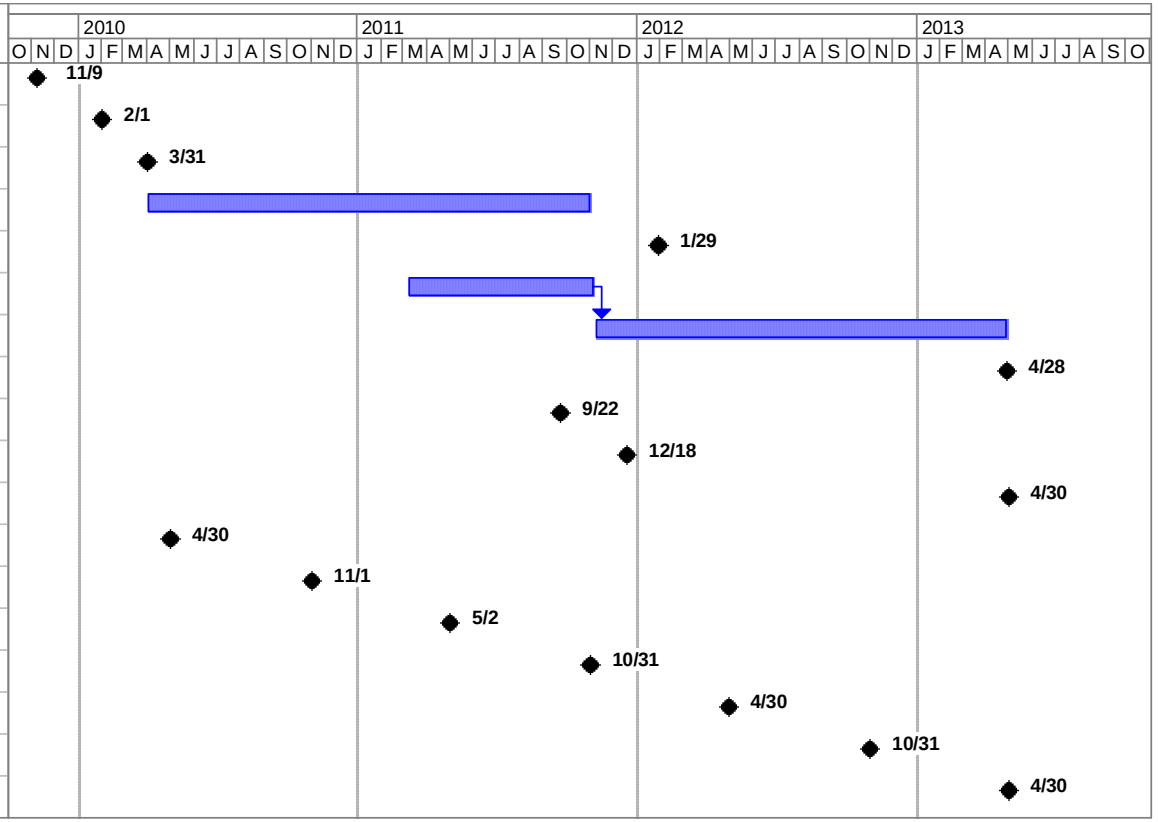
OC4 Project Organization: Partners and codes

Participant & Codes

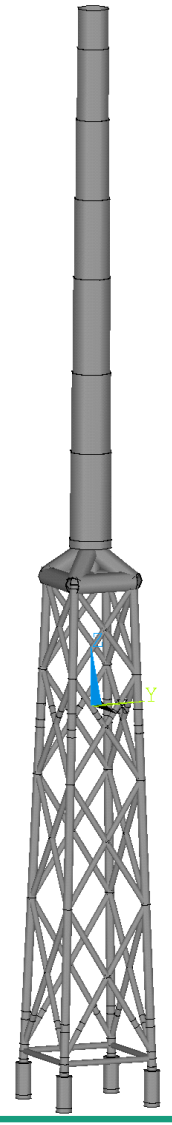
3Dfloat
ABAQUS
ADAMS-AeroDyn-HydroDyn
ADAMS-AeroDyn-WaveLoads
ADCoS-Offshore-ASAS
ANSYS-WaveLoads
Bladed
Bladed Multibody
DeepC
FAST-AeroDyn-HydroDyn
FAST-AeroDyn-NASTRAN
FAST-AeroDyn-TimeFloat
FEDEM-AeroDyn
FLEX5
FLEX5-Poseidon
HAWC2
PHATAS
SAMCEF
SESAM
SIMPACK-AeroDyn-HydroDyn
USFOS-VpOne

OC4 Project Organization: Schedule

ID	Task Name
1	ExCo Approval of Annex 30
2	Receive Commitment Letters
3	Receive Funds
4	Jacket Code Comparison - Work Package 1
5	Publish Paper or Report on Jacket
6	Establish Floating Design Concept
7	Floating Platform - Work Pakage 2
8	Report on Floating Structure
9	Code Validation Data Comparison Workshop
10	Report on Workshop
11	Final Report
12	Kickoff Meeting #1
13	Meeting #2
14	Meeting #3
15	Meeting #4
16	Meeting #5
17	Meeting #6
18	Meeting #7

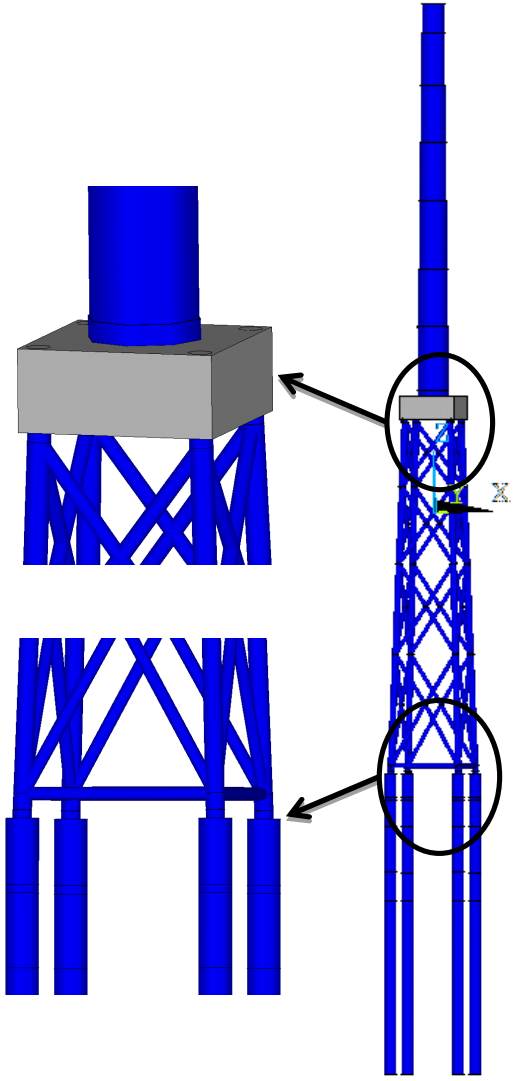


Phase I: Turbine on Jacket Substructure



Phase I: Turbine on Jacket Substructure

- Support structure with jacket sub-structure designed by Rambøll A/S for the NREL 5-MW Reference Turbine in the UpWind project (WP4)
- Four legged, fixed bottom jacket sub-structure with piles, transition piece and tower defined
- Concrete Transition Piece (TP) and 4 central piles
- Water depth of 50m
- Elevation of the yaw bearing at 88 m from MSL



Phase I: Turbine on Jacket Substructure

Phase I project plan:

- Implementation of the UpW
  5MW NREL Reference OW
- Preliminary check of mass
- Simulation of different loac
  - Eigenanalysis – LC set 1.
  - Rigid offshore wind turbir
  - Land based turbine – LC
  - Flexible offshore structure
  - Fully-fexible OWT – LC set 3.x

Load Case	Enabled DOF	Wind Conditions	Wave Conditions	Analysis Type	Initial Conditions
2.1	None	No air	Still water	Static simulation including gravity and buoyancy to MSL	
2.2	None, Rotor speed and blade pitch via controller	Steady, uniform, no shear: $V_{hub} = 8\,\mathrm{m/s}$	No water	Periodic time-series solution	$\Omega = 9\,\mathrm{rpm}$ $\Phi = 0\,\mathrm{deg}$ $\Theta = 0\,\mathrm{deg}$
2.3a	None	No air	Regular Airy: $H = 6\,\mathrm{m}$, $T = 10\,\mathrm{s}$	Periodic time-series solution	wave simulation starts from crest at $x = 0$, $y = 0$ (global system)
2.3b	None	No air	Regular stream function (Dean, 9th): $H = 8\,\mathrm{m}$, $T = 10\,\mathrm{s}$	Periodic time-series solution	wave simulation starts from crest at $x = 0$, $y = 0$ (global system)
2.4a	None: Rotor speed and blade pitch via controller	NTM (Kaimal): $V_{hub} = V_r = 11.4\,\mathrm{m/s}$ $\sigma_x = 1.68\,\mathrm{m/s}$ $\sigma_y = 1.34\,\mathrm{m/s}$ $\sigma_z = 0.84\,\mathrm{m/s}$ $L_{k,x} = 340.20\,\mathrm{m}$ $L_{k,y} = 113.40\,\mathrm{m}$ $L_{k,z} = 27.72\,\mathrm{m}$ $L_c = 340.20\,\mathrm{m}$ Wind shear: $\alpha = 0.14$	No water	PDFs, DELs, power spectra	$\Omega = 12.1\,\mathrm{rpm}$ $\Phi = 0\,\mathrm{deg}$ $\Theta = 0\,\mathrm{deg}$
2.4b	None: Rotor speed and blade pitch via controller	NTM (Kaimal): $V_{hub} = 18\,\mathrm{m/s}$ $\sigma_x = 2.45\,\mathrm{m/s}$ $\sigma_y = 1.96\,\mathrm{m/s}$ $\sigma_z = 1.23\,\mathrm{m/s}$ $L_{k,x} = 340.20\,\mathrm{m}$ $L_{k,y} = 113.40\,\mathrm{m}$ $L_{k,z} = 27.72\,\mathrm{m}$ $L_c = 340.20\,\mathrm{m}$ Wind shear: $\alpha = 0.14$	No water	PDFs, DELs, power spectra	$\Omega = 12.1\,\mathrm{rpm}$ $\Phi = 0\,\mathrm{deg}$ $\Theta = 0\,\mathrm{deg}$
2.5	None	No air	Irregular Airy: $H_s = 6\,\mathrm{m}$, $T_p = 10\,\mathrm{s}$, Pierson-Moskowitz wave spectrum	PDFs, DELs, power spectra	

Phase I: Turbine on Jacket Substructure

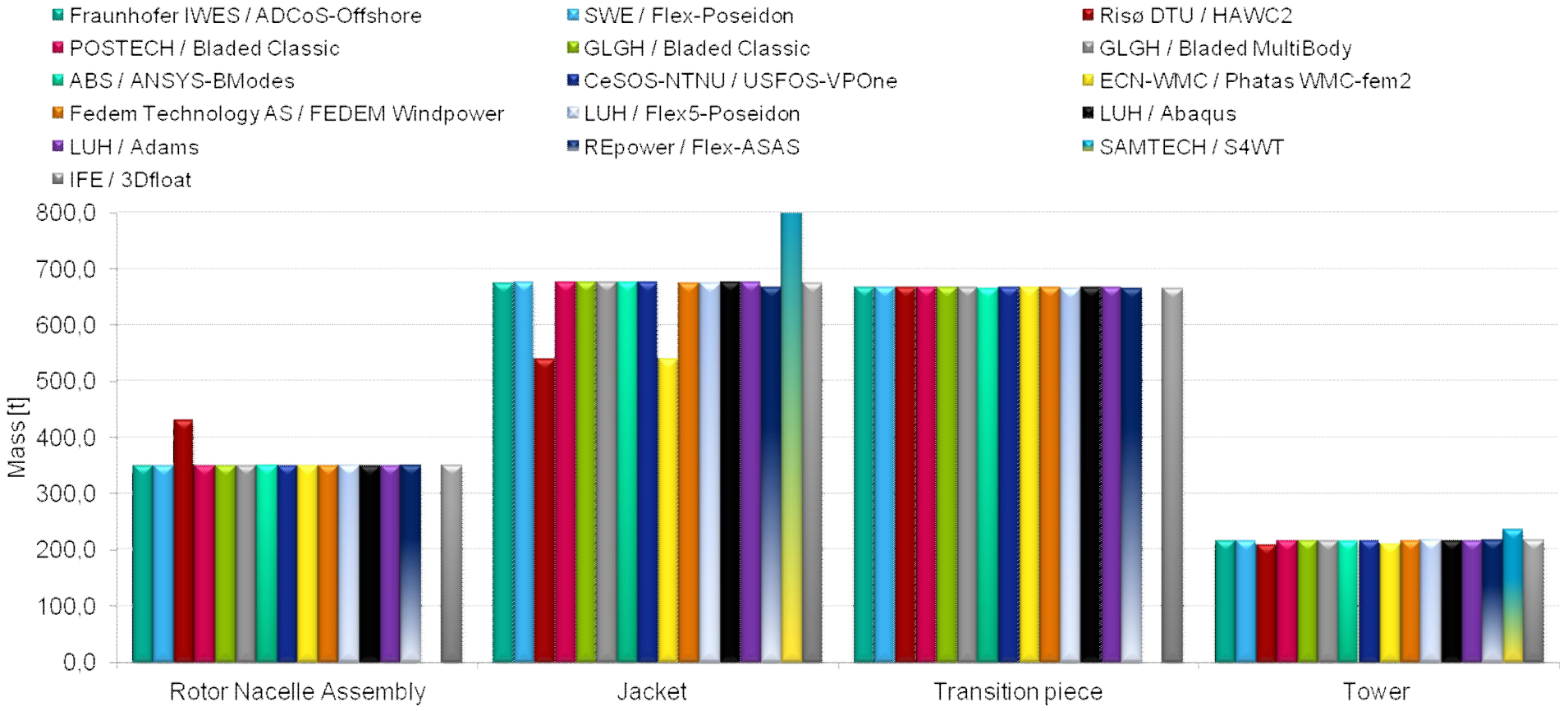
Accomplished tasks:

- ✓ Implementation of the UpWind jacket sub-structure and the 5MW NREL Reference OWT
- ✓ Preliminary check of masses and eigenfrequencies
- ■ Simulation of different load cases with increasing complexity
  - ✓ Eigenanalysis – LC set 1.X
  - ✓ Rigid offshore wind turbine – LC set 2.X **(in process, partially done)**
  - – Land based turbine – LC set 3.X
  - – Flexible offshore structure – LC set 4.X
  - – Fully-fexible OWT – LC set 5.X

Phase I: Turbine on Jacket Substructure

Exemplary results (15 partners):

✓ Preliminary check of masses



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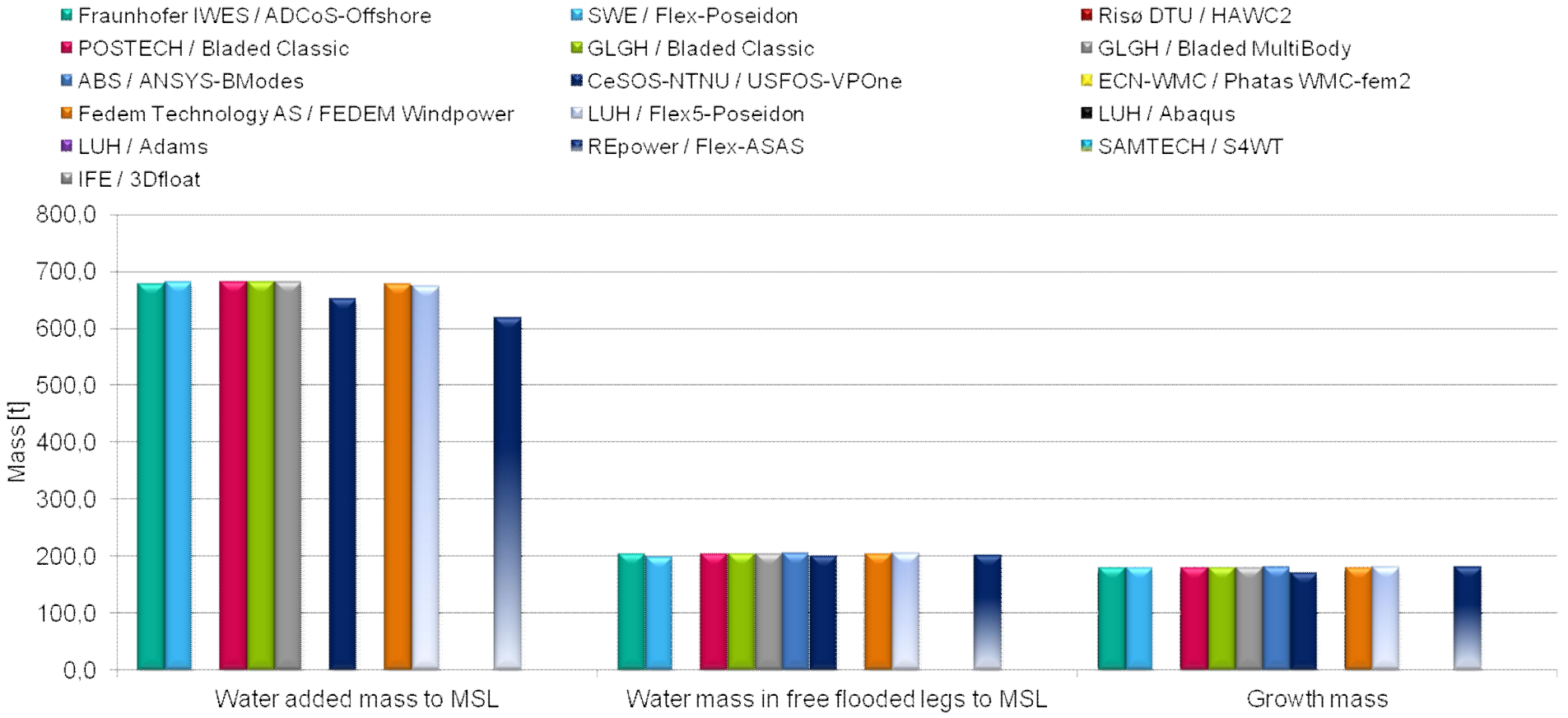
Phase I: Turbine on Jacket Substructure

Exemplary results:

✓ Preliminary check of masses



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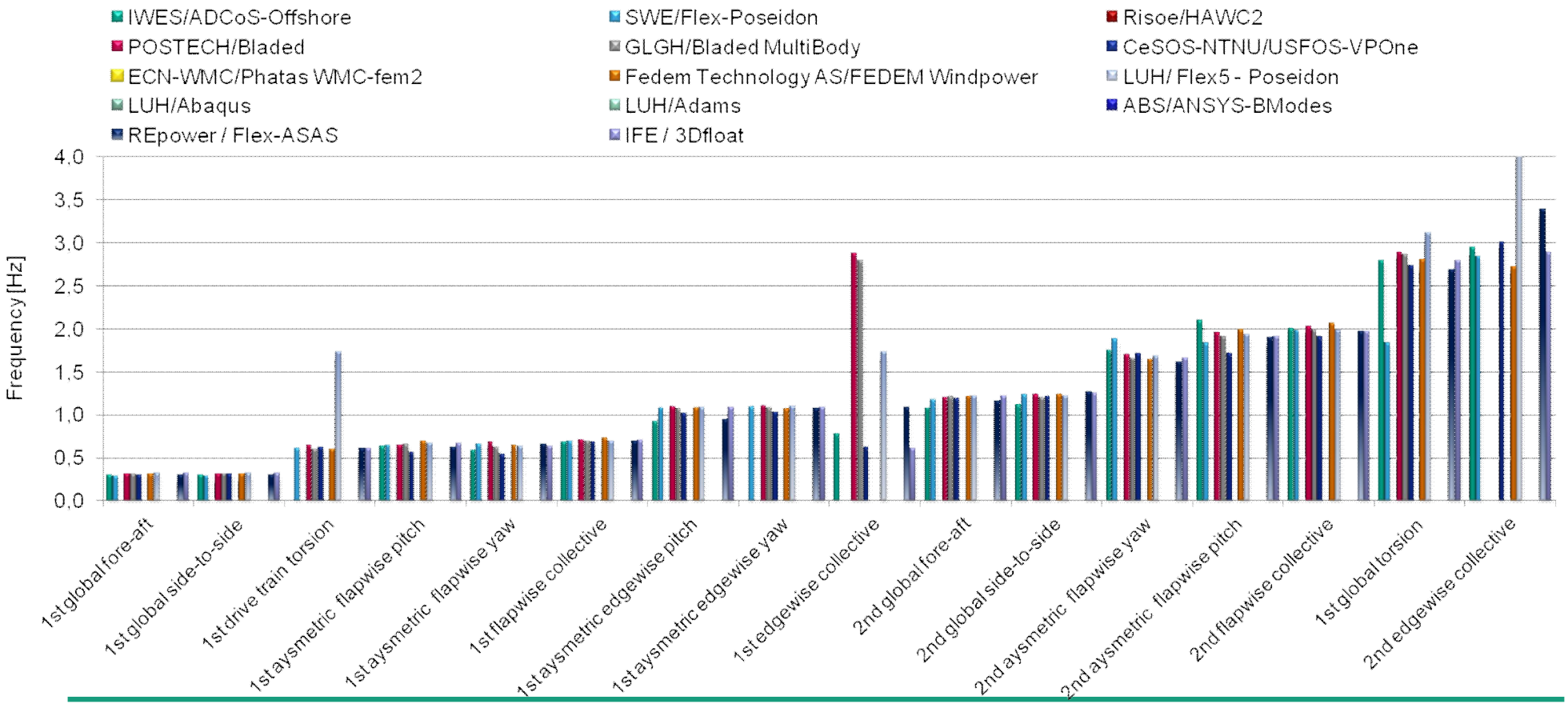
Phase I: Turbine on Jacket Substructure

Exemplary results:

✓ Eigenanalysis – LC 1.0b (no gravity and no struct. damping)



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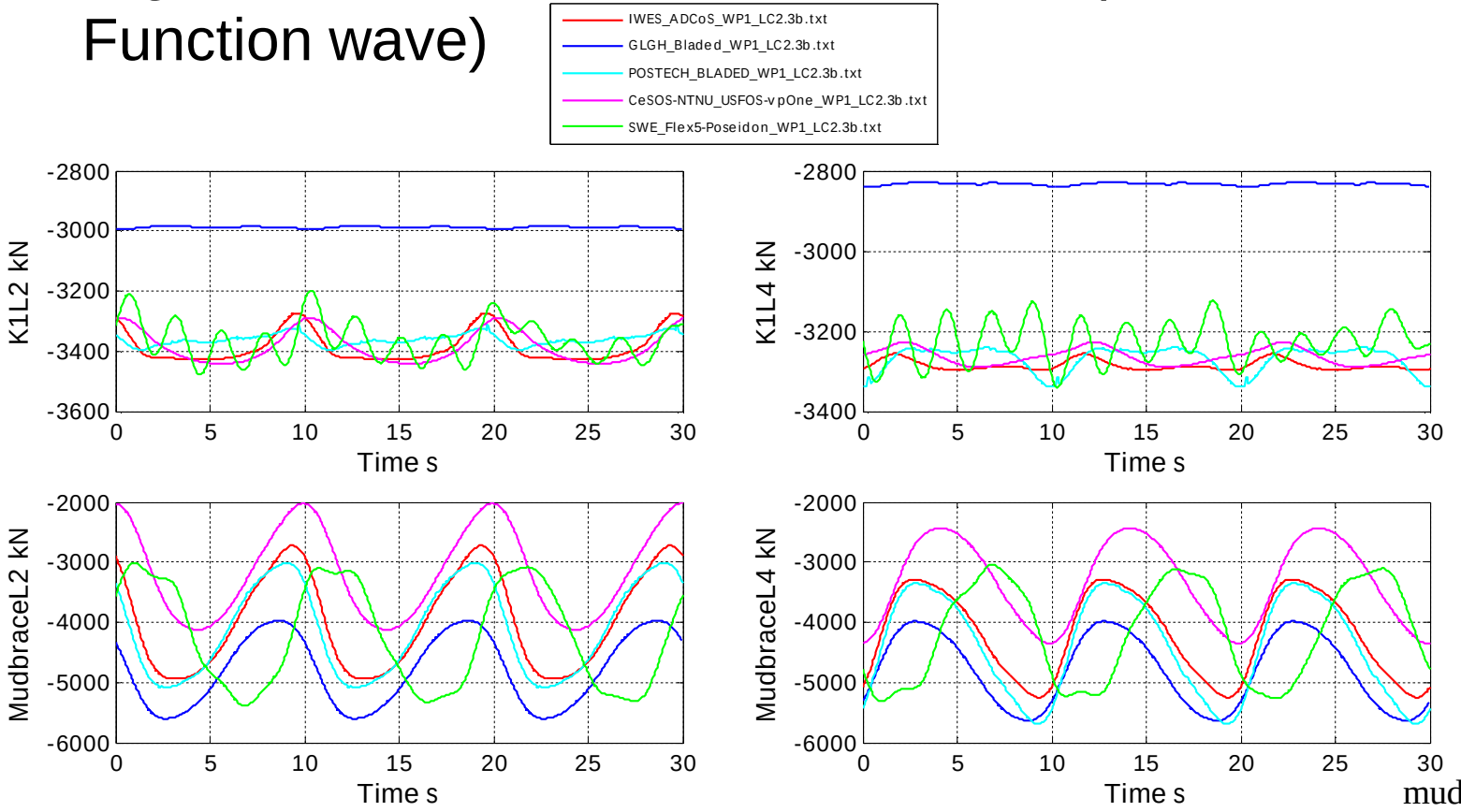
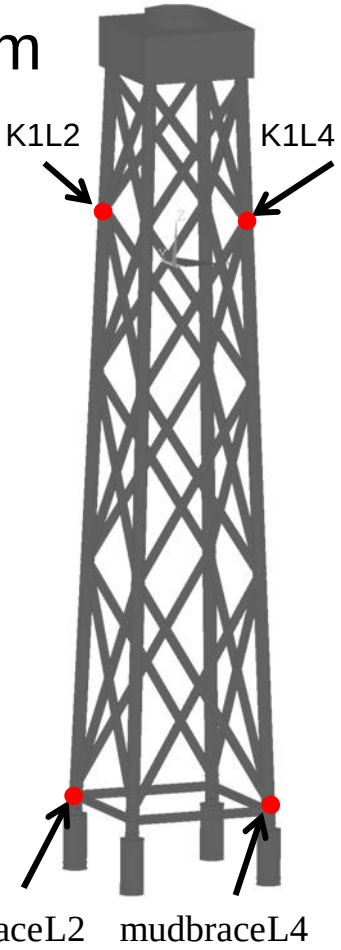
Phase I: Turbine on Jacket Substructure

Exemplary results:

✓ Rigid offshore wind turbine – LC 2.3b (no wind, Stream Function wave)





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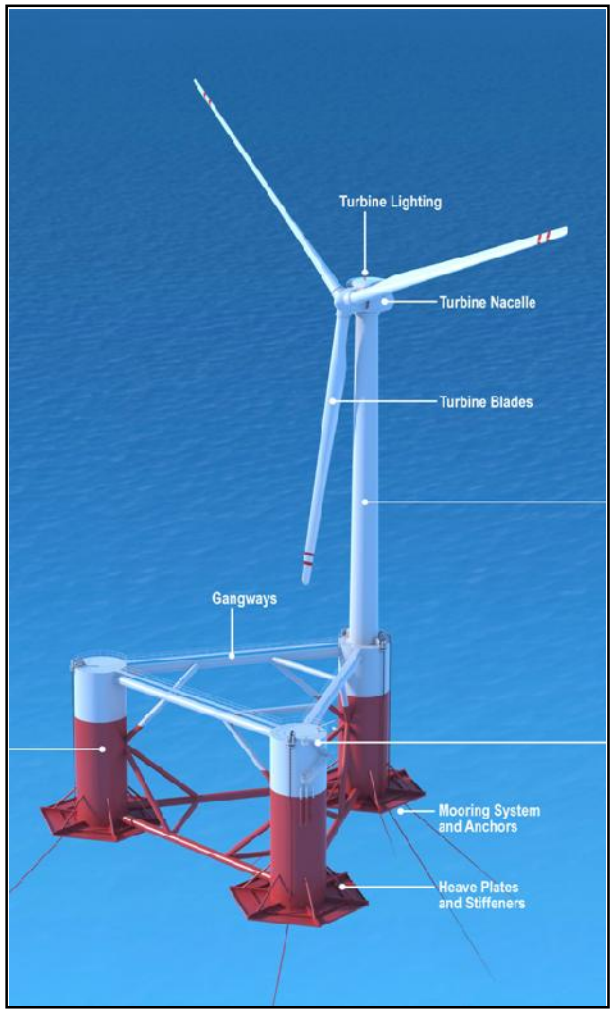
Phase I: Turbine on Jacket Substructure: Wrap-up

- High international interest in Phase I (15 participants delivered data for the preliminary comparison study)
- Detailed model description based on NREL baseline turbine and Upwind jacket available
- Setup of groups of test cases in the OC4 committee done
- First results obtained so far show reasonable agreement
- Further revisions of the results are on the agenda

Phase II: Turbine on floating semi-submersible

OC4 participants will choose between Principle Power Inc.'s (PPI) WindFloat & DeepCwind generic semi-submersibles:

- PPI WindFloat is a patented commercial system with first full-scale installation scheduled for mid 2011
- DeepCwind is a generic publically available design to be wave-tank tested at 1/50th scale in 2011
- Decision making still ongoing



WindFloat
(Image: D. Roddier, PPI)

Thank you for your attention