Concept design verification of a semi-submersible floating wind turbine using coupled simulations

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EERA DeepWind'2014, Trondheim, 22 January 2014

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Presentation outline

- Tri-Floater design
- Simulation approach
- Software and numerical model
- Simulation results
- Conclusions

Tri-Floater design

Wind turbine	NREL 5MW
Hub height above SWL	90 m
Control system	ECN
Radius to column centre	36.0 m
Column width	8.0 m
Design draft	13.2 m
Air gap to deck structure	12.0 m
Displacement	3627 t
Catenary mooring lines	3 x 750 m
Chain diameter	100 mm

Tri-Floater design

		operational			survival
		rated	above rated	cut-out	parked
significant wave height	[m]	4.5	4.5	6.5	9.4
wave peak period	[s]	7.5 – 10	7.5 – 10	9 – 12	11 – 14
wind velocity at hub	[m/s]	11.4	14.0	25.0	42.7
current velocity	[m/s]	0 – 0.6	0 – 0.6	0 – 0.6	0 – 1.2

- Operational inclination ≤ 10 deg
- Operational nacelle acceleration ≤ 3 m/s^2
- Safety factor mooring line ≥ 1.7

Simulation approach

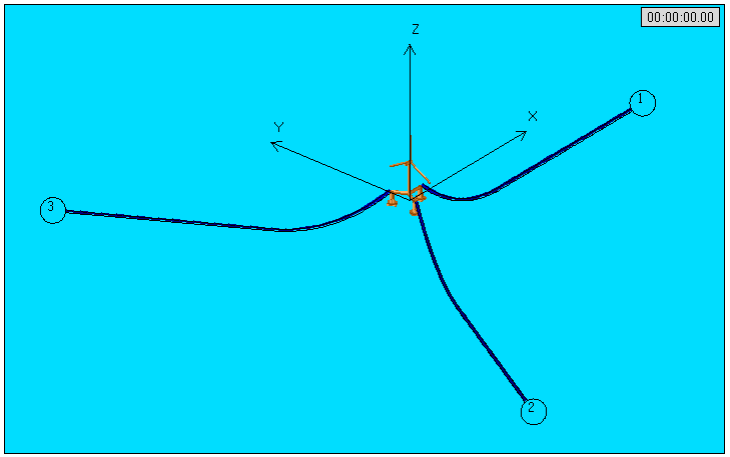
- Verify design requirements motions and mooring loads
- Concept design stage, so minimized computational effort

- Simulation duration: 1 hour
- Weibull distribution fitted to 50 % highest extremes
- Expected maxima determined for 3 hours by extrapolation

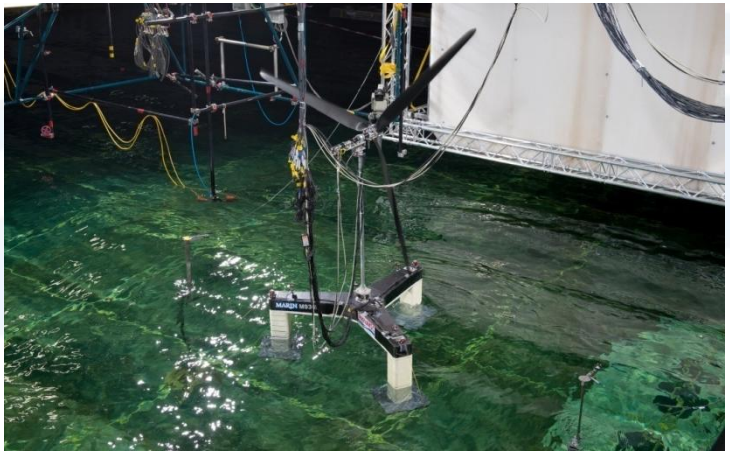
- Time step and seed dependency studied

Software and numerical model

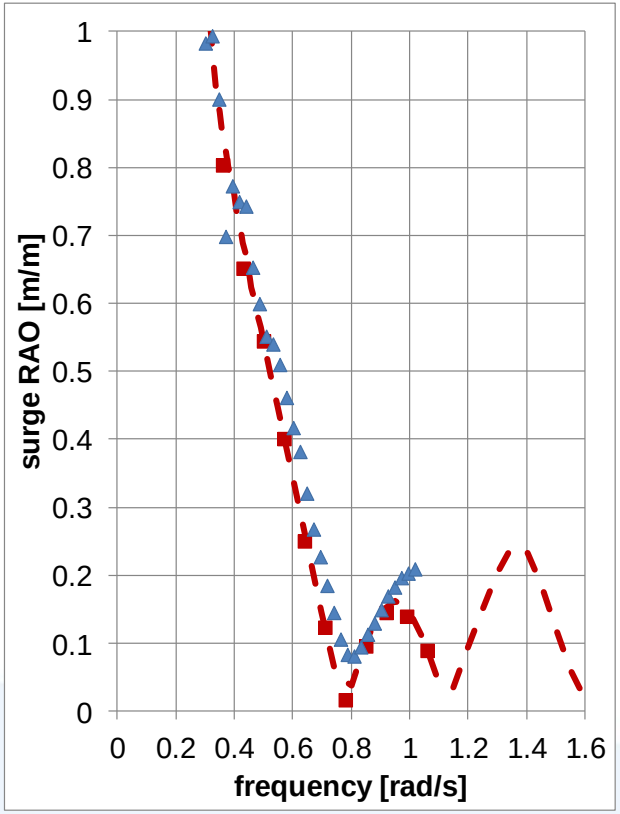
- AQWA (Ansys)
  - Hydrodynamics (1st and 2nd order)
  - Mooring
- PHATAS (ECN)
  - Rotor aerodynamics
  - Rotor and tower structural dynamics
  - Drive-train and control systems

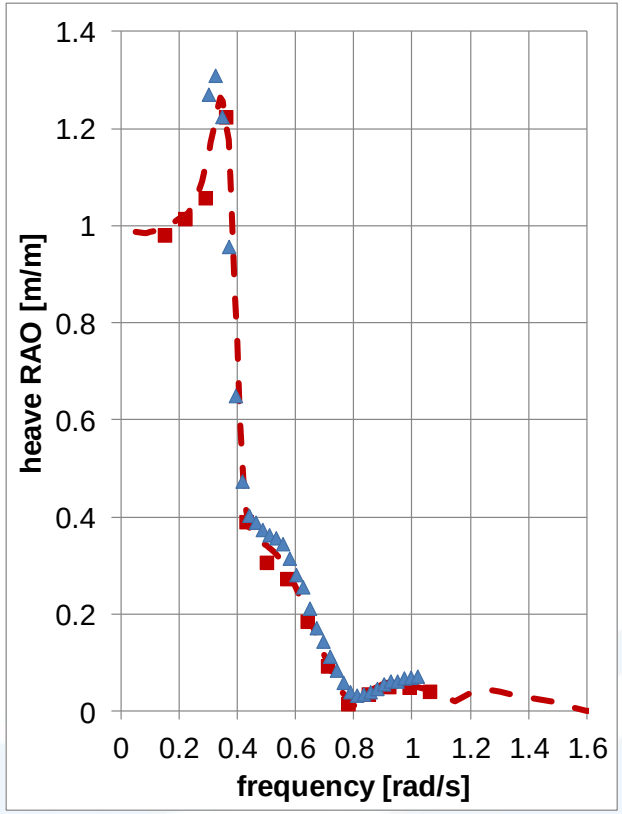


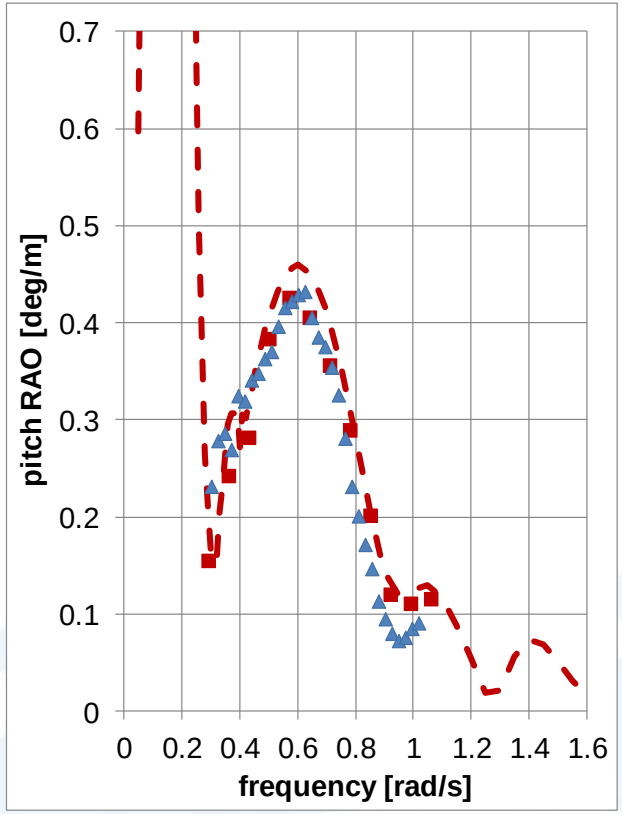
- Benchmarked with OC3 spar
- Hydrodynamic model validated with model tests



Software and numerical model

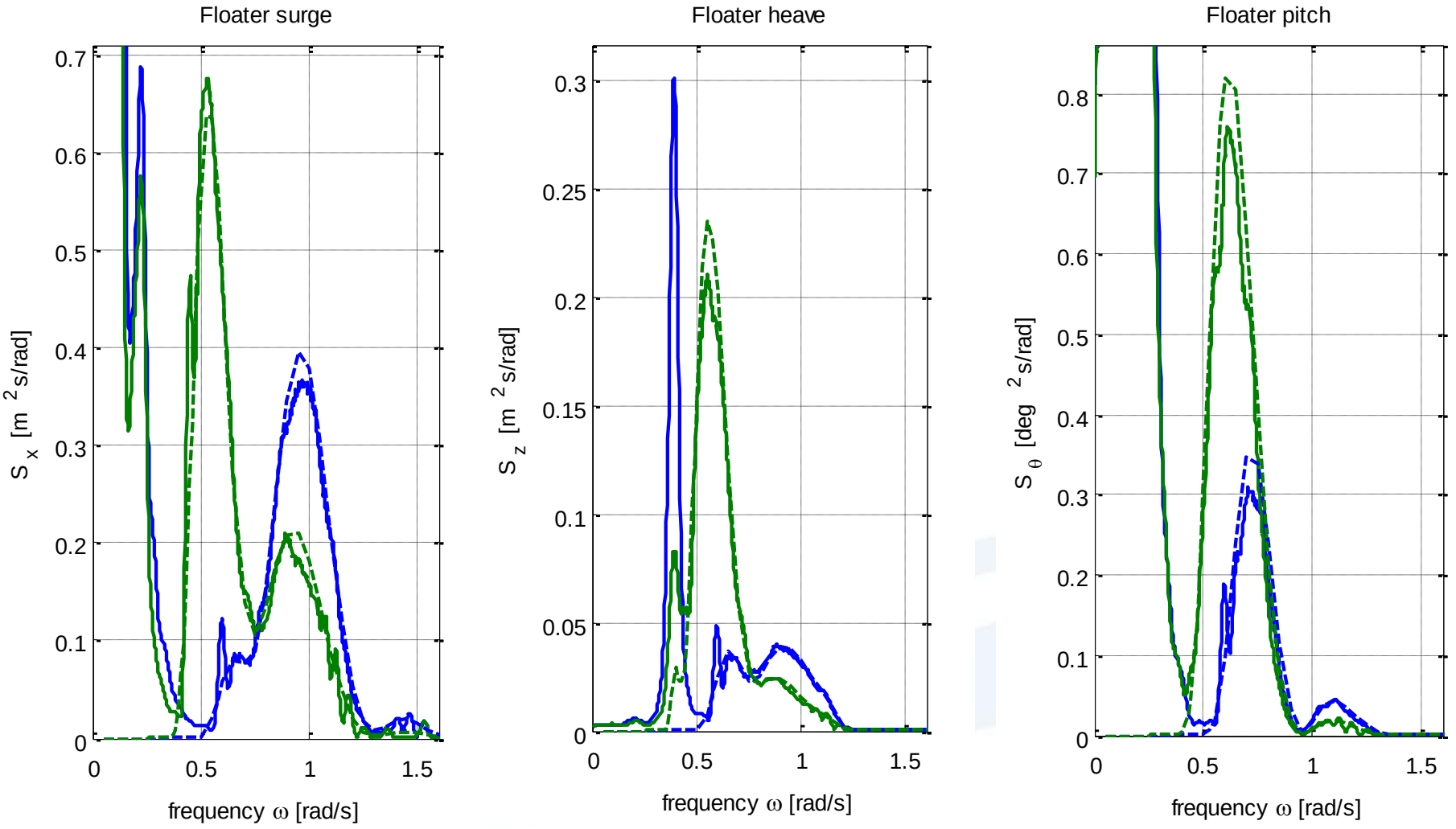




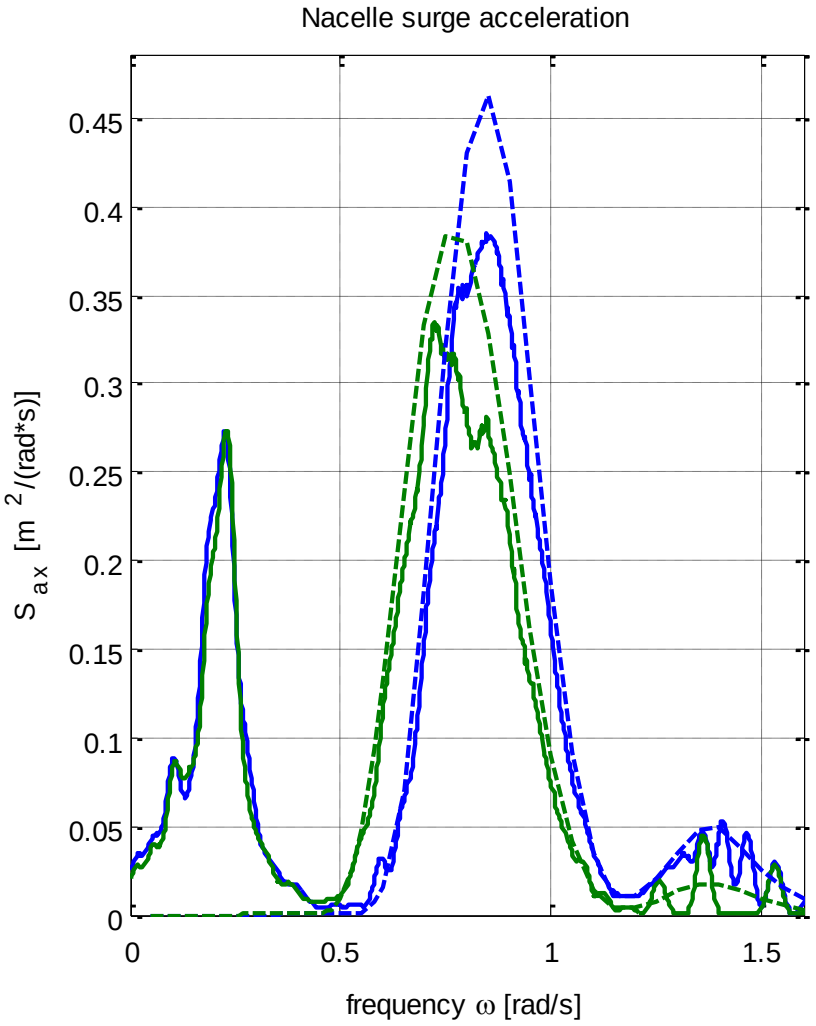


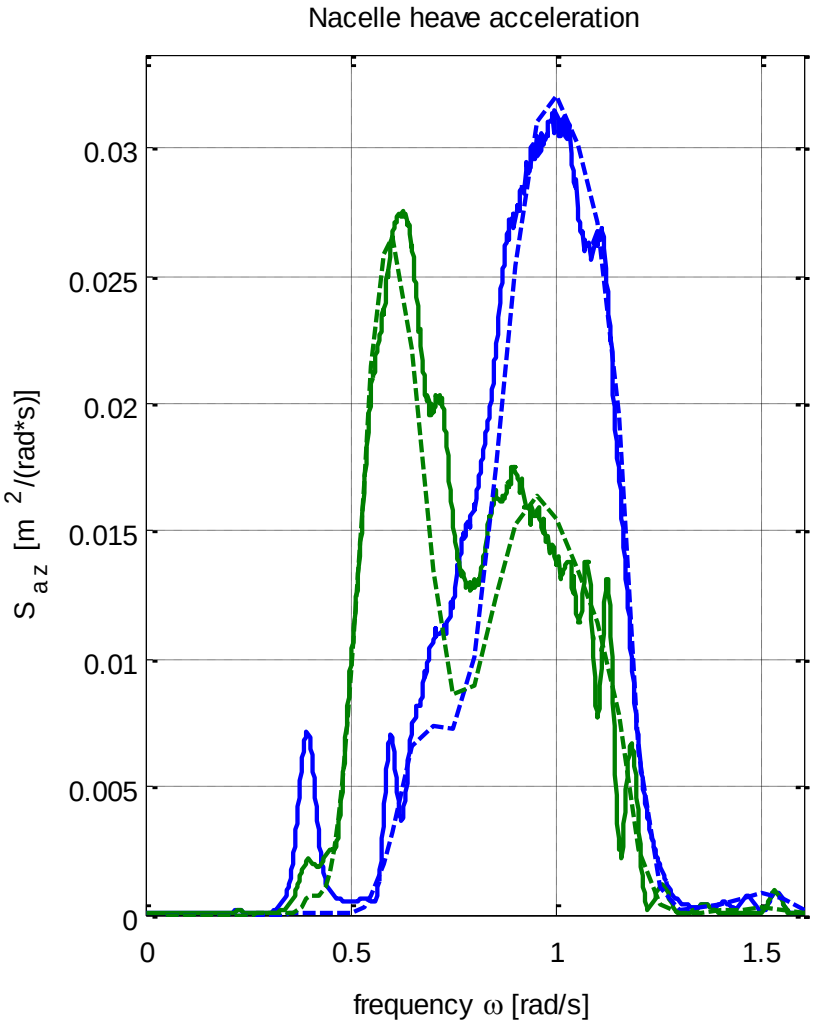
- Frequency domain motion analysis
- Coupled simulations in regular waves
- Model test in white noise

Simulation results



Simulation results





TD sim. Tp 7.5 s

FD calc. Tp 7.5 s

TD sim. Tp 10 s

FD calc. Tp 10 s

Simulation results

	operational			survival
	rated	above rated	cut-out	parked
floater inclination [deg]				
mean	**3.5**	2.9	1.7	3.4
3-hour extreme (90%)	7.4	**8.5**	6.1	11.1
nacelle hor. acceler. [m/s^2]				
mean	**0.7**	0.6	0.6	0.8
3-hour extreme (90%)	2.4	2.5	**3.0**	3.1

Conclusions

- Tri-Floater fulfills design criteria

- Low frequency motions are dominant
- Wave frequency motions are well predicted by uncoupled frequency domain motion analysis

- Such analysis is useful to assess global floater motions in early design stages and optimize the floater design
- Coupled simulations are however indispensible in later design stages

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