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GICON® Firmengruppe

Development of a TLP substructure for a 6MW wind turbine based on development of a substructure for a 2MW turbine

A cooperation between industry and research institutions

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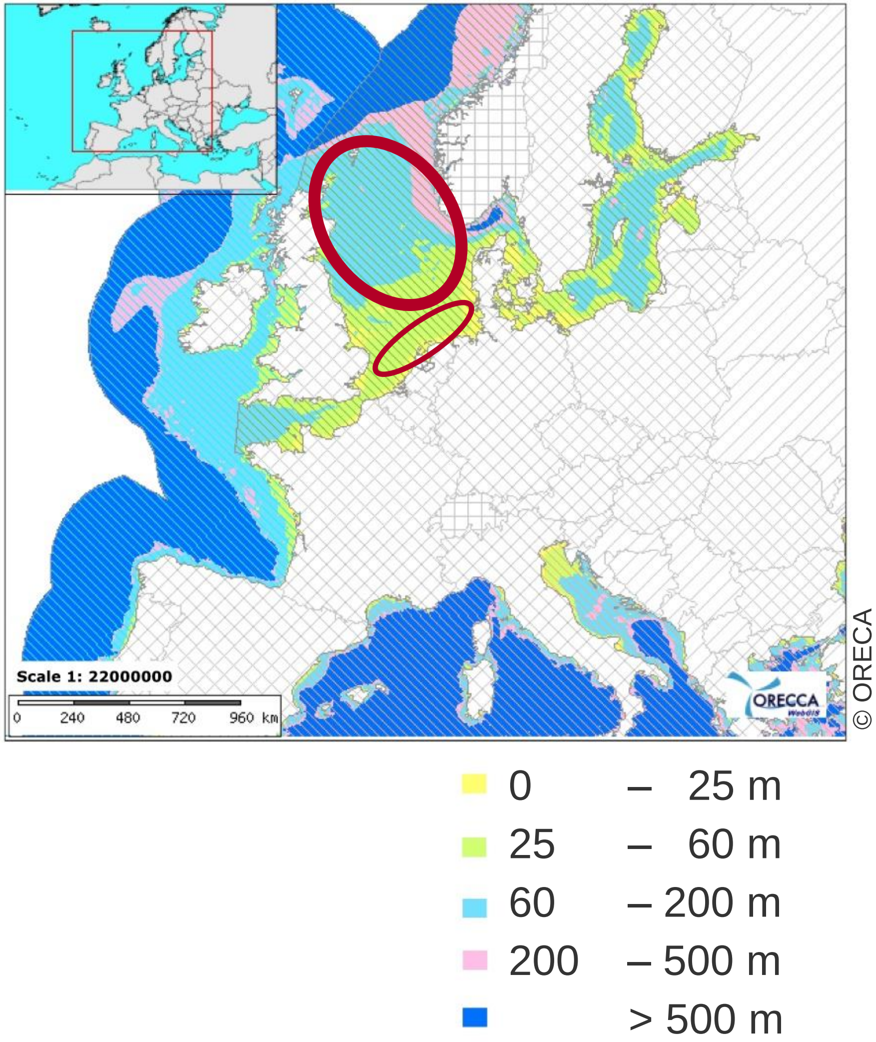
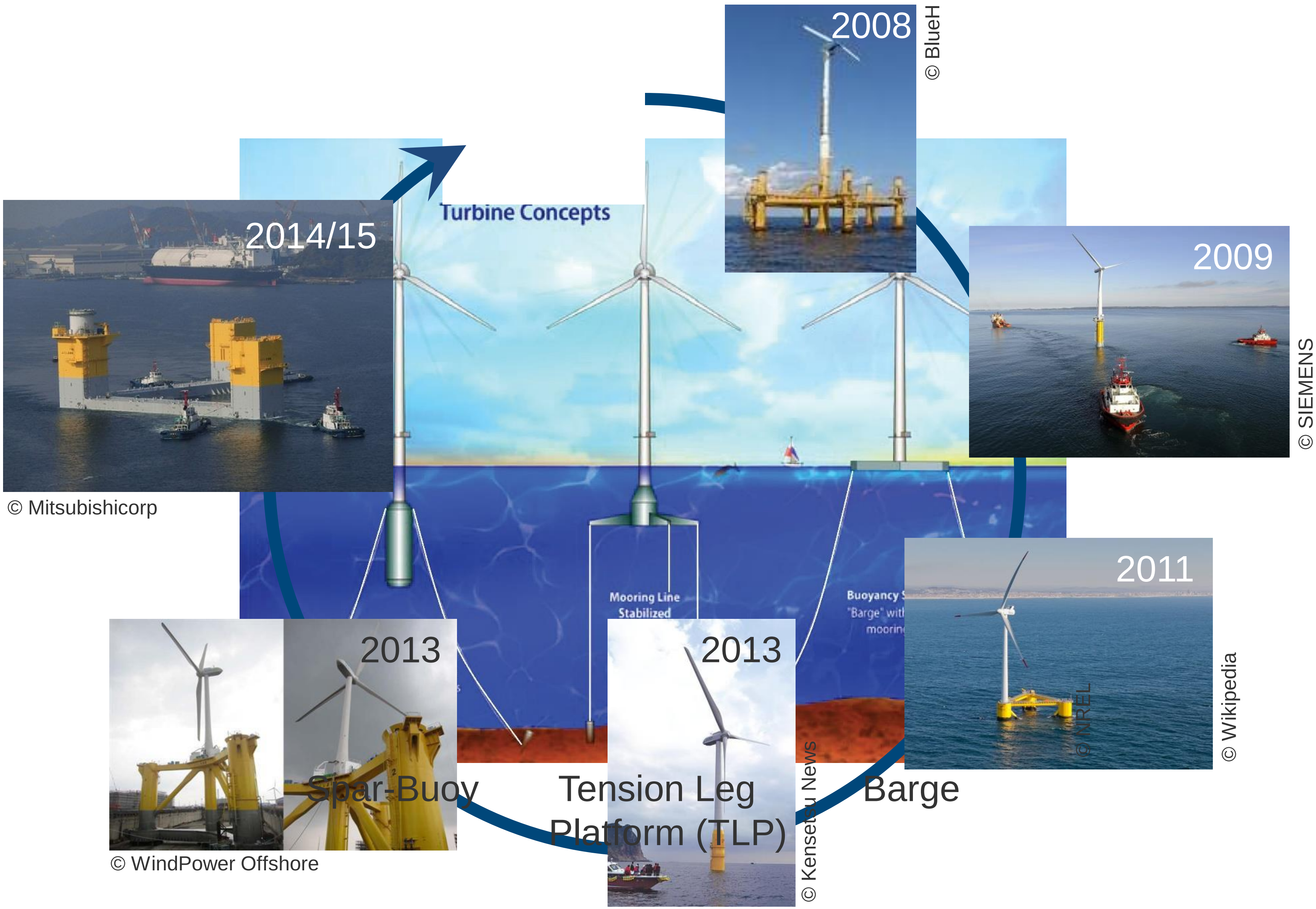
Offshore Wind R&D Conference 2015, Bremerhaven, 13.10. - 15.10.2015

- Goal of the German Federal Government → 50 % renewable energy by 2050
- Offshore-Windparks → one important role
- LCOE → depending on water depth
- Economical solution → floating foundations



Floating foundations for offshore - wind turbines



Objectives for floating offshore wind sub-structures

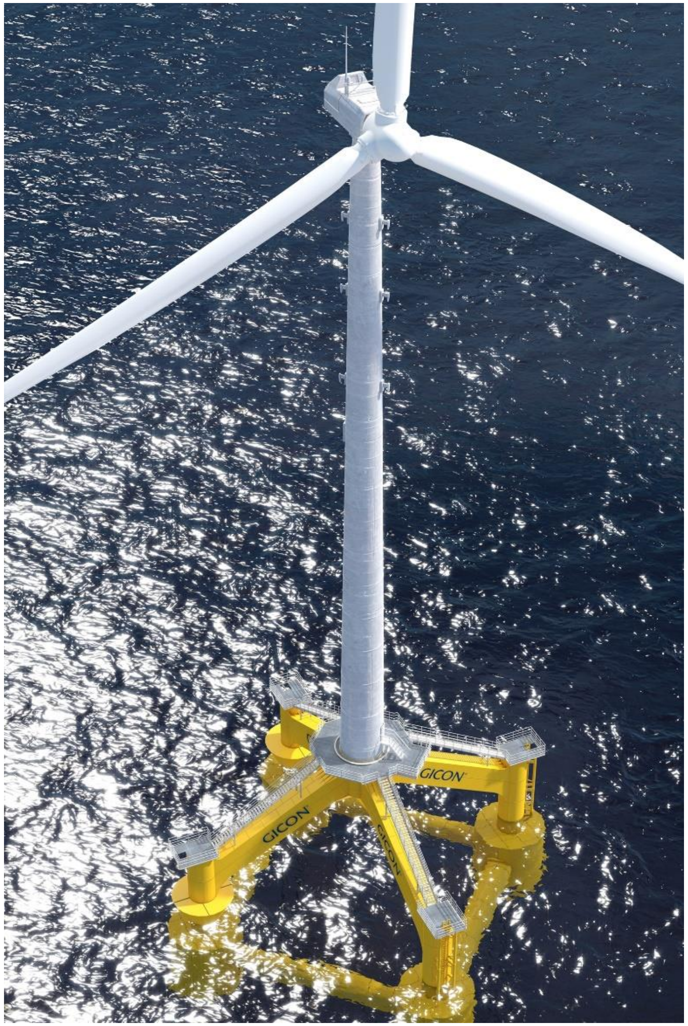
- Economical solution
  → Mass as low as possible

- Dynamic behavior
  → Parameter identification

- Boundary conditions
  → added mass (hydrodynamic mass)

- Scaled tests
  → Calibration of the calculation model

- Verification of the calculation



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TLP for OWT

Calculation-model

Verification of calculation

Pre-design 6 MW

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Examples for TLPs or TLBs

Tank tests 2012

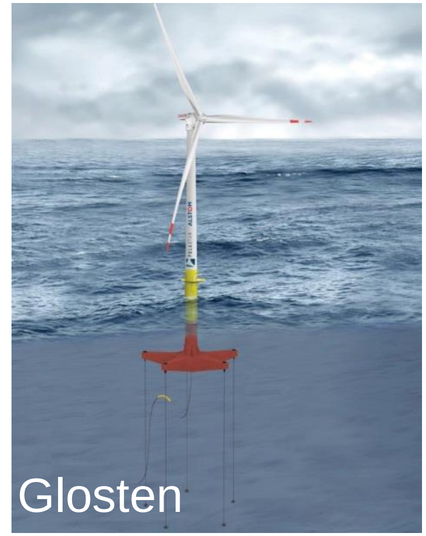
Vertical ropes

TRL 4

Tank tests 2013

Angled ropes

TRL 3



Tank tests 2013

Vertical ropes

TRL 4

Tank tests 2012-14

Vertical and angled ropes

TRL 4-5

Path of development

Mass in t	ca. 2000	2214	1790	**742**
Width in m	70	68	50	**32**
High in m	25	24	39	**28**

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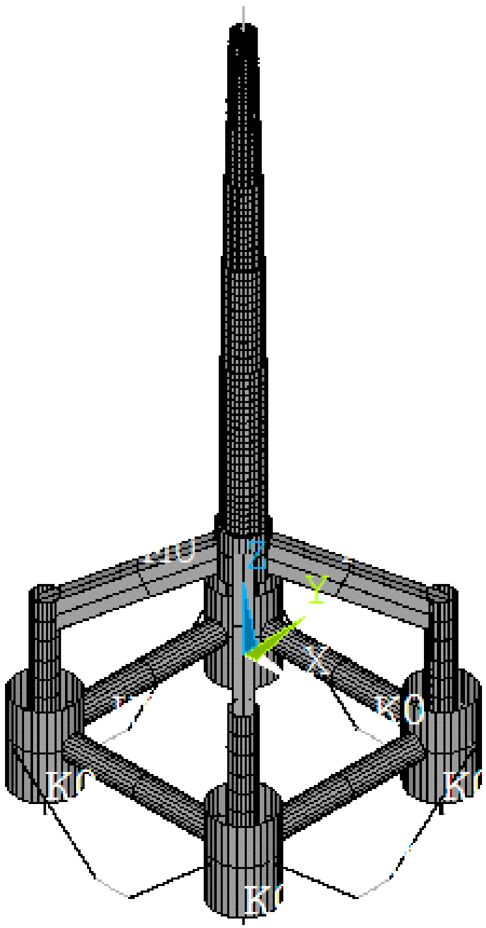
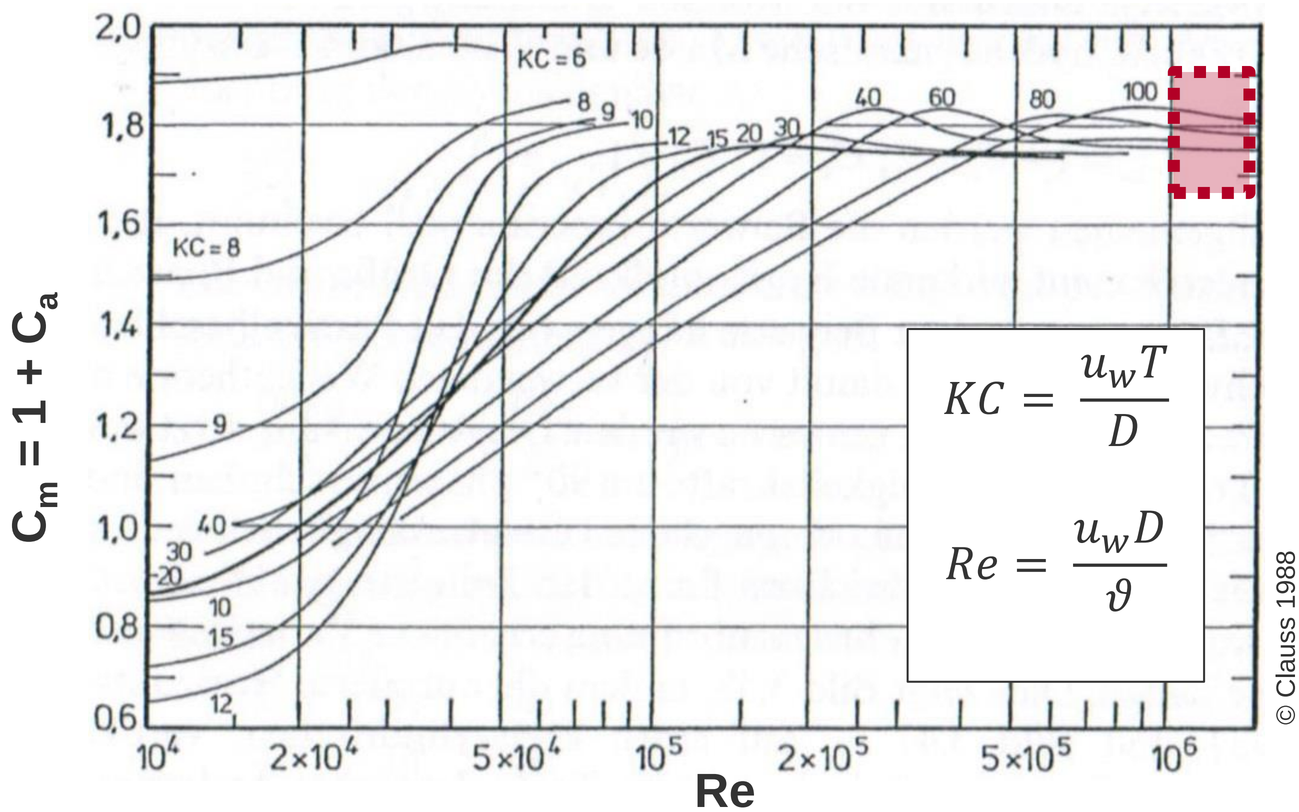
Calculation

- Analysis → FEM
- Tension Leg Platform → Beam elements (1D)
- Damping → Damping elements
- Ropes → Spring elements (only tension)
- MORISON-eq. → Wave loading [Borgman 1954]



KC and Re for cylinders

KC … Keulegan-Carpenter number Re … Reynolds-number



$$KC = \frac{u_w T}{D}$$

$$Re = \frac{u_w D}{\vartheta}$$

- For the chosen system **Re > 10^6, 6 ≤ KC ≤ 190** → **C_m = 1.8**

- Question: $\mathbf{C_m = 1.8}$?

- Comparison of the measured values with the calculated results (natural frequencies)

- Target value search: $|f_b - f_m| \rightarrow 0$ with $f_b = f_b(C_{a\_Rohr}, C_{a\_AK})$

- Variation of:
  - $\mathbf{0.0 \leq C_{a\_pipe} \leq 0.8}$
  - $\mathbf{0.0 \leq C_{a\_BB} \leq 0.8}$

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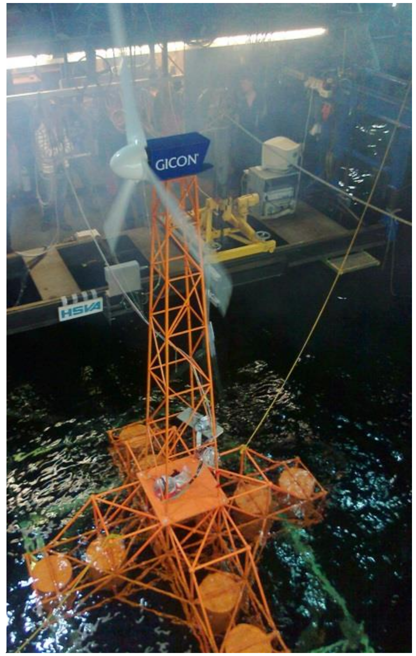
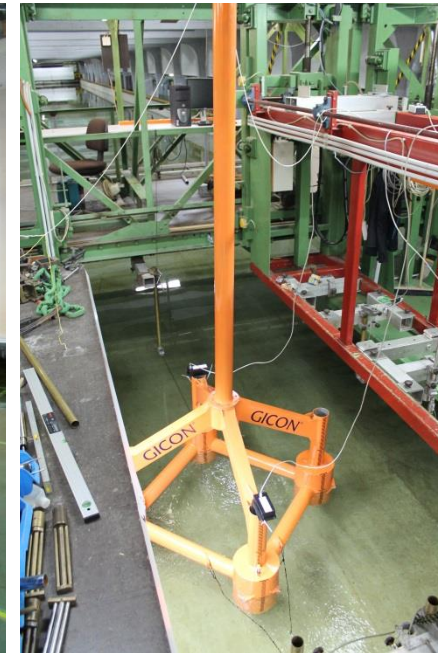
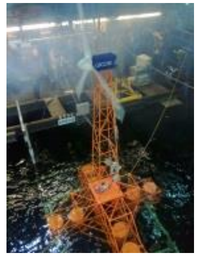
Tested sub-structures





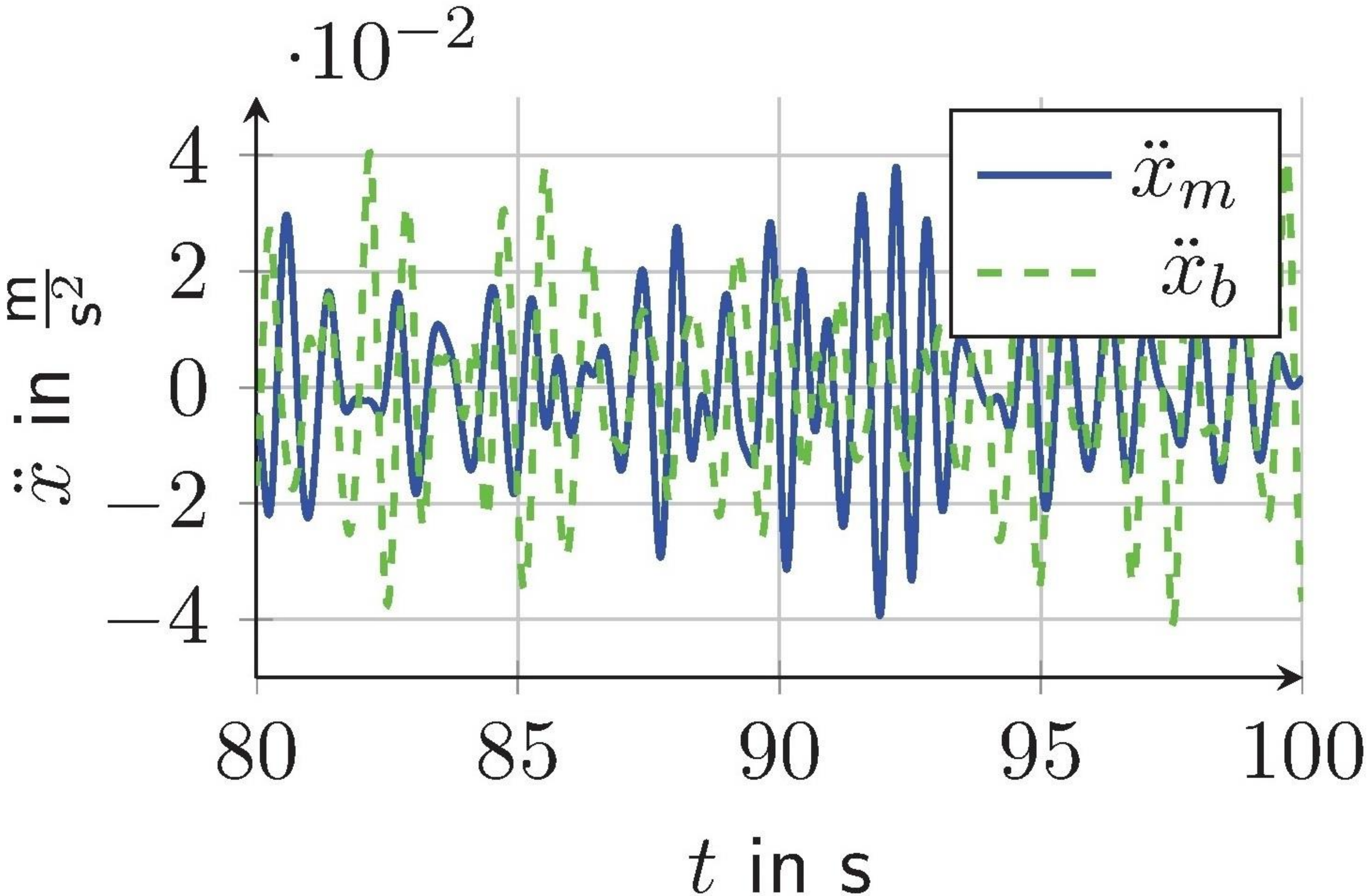
Facility	HSVA	MARIN	DST
Water depth in m	30	21	21
Scale	1:25	1:37	1:25
Mooring lines	**PE–rope**	**PE–rope**	**Flat springs**

Natural frequencies

						
x_{trans}	0.270	**0.270**	0.637	**0.625**	0.308	**0.279**
y_{trans}	0.254	**0.254**	0.637	**0.625**	0.298	**0.281**
z_{trans}		**1.130**	2.111	**1.955**		**1.264**
x_{rot}	0.425	**0.425**	1.150	**1.160**	0.608	**0.675**
y_{rot}	0.387	**0.387**	1.150	**1.160**	0.667	**0.742**
z_{rot}	0.490	**0.490**	1.308	**1.304**		**2.511**

- Agreement for $C_{a\_BB} = 0.2$ and $C_{a\_pipe} = 0.6$
- Added mass coefficient → validated for ALL models
- Deduced from the hydrodynamic semi-transparent structure

Time domain


$\cdot 10^{-2}$
4
2
0
−2
−4
$\ddot{x}$ in $\frac{\mathrm{m}}{\mathrm{s}^2}$
$\ddot{x}_m$
$\ddot{x}_b$
80
85
90
95
100
t in s

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Requirements for the 6 MW sub-structure

Mass (incl. sec. steel) ≤ 1200 t

Floating stability for the sub-structure and anchor incl. wind turbine

Fabrication – 1 ½ sub-TLPs/week

Aim: 80 TLPs/year

Economical solution for water depths ≥ 30/35 m – comparable with fixed sub-structures

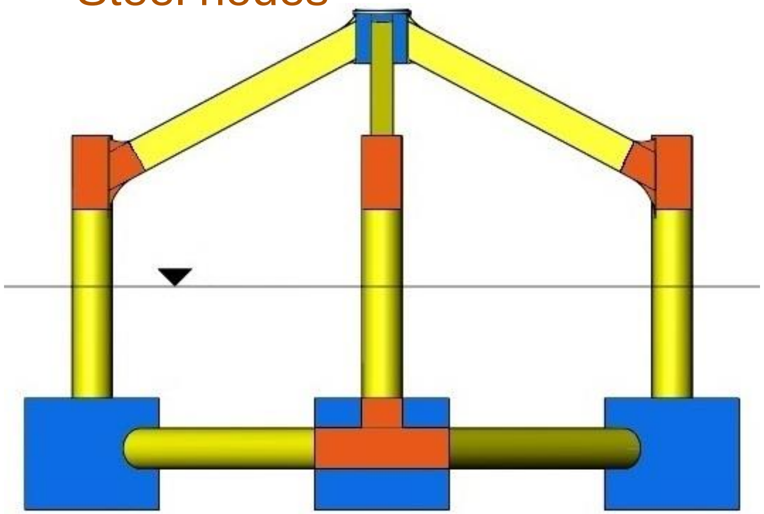
Mass (incl. sec. steel) ≤ 1200 t

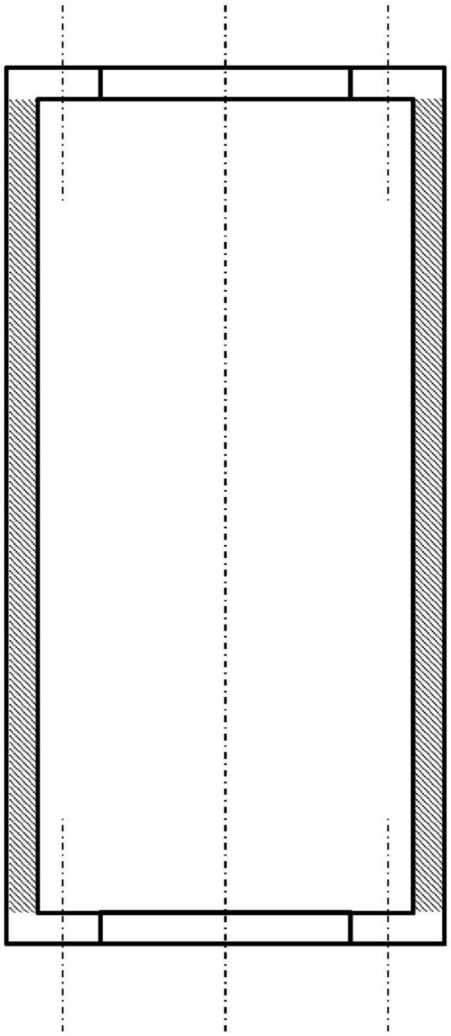
Concrete

Steel-Concrete-Composite

Pipes

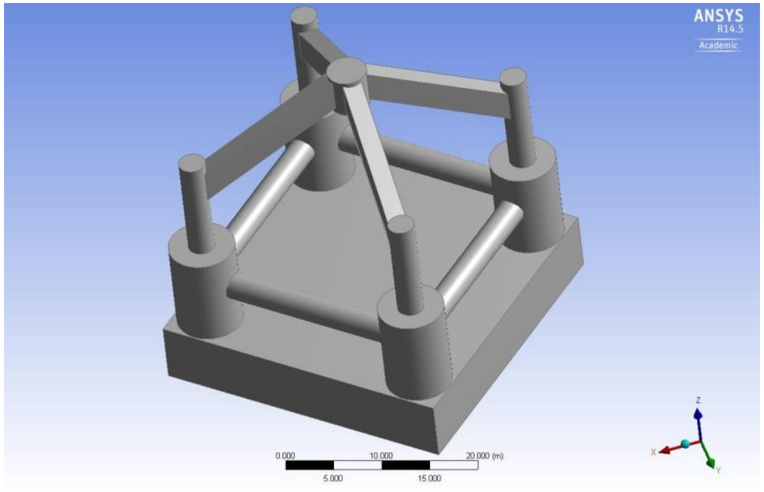
Steel nodes





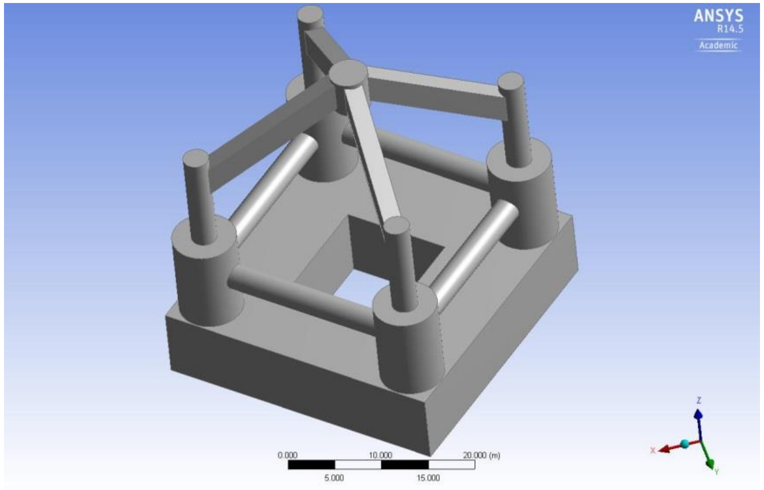
Floating stability incl. Wind Turbine

	DeviationMaximum				
	Acceleration (ms^-2)			Rotation(Degree)	
Angle ofAttack	X	Y	Z	RX	RY
180	-0,616	-0,155	-3,014	0,058	0,716
135	0,385	-0,495	-2,799	0,078	0,855
90	-0,017	-0,661	-2,716	0,164	-7,970
45	-0,384	-0,496	-2,801	0,040	0,736
0	0,617	-0,155	-3,017	0,098	4,268



Mass	5000t
WaveFreq	0.1Hz
WaveHeight	2m

	DeviationMaximum				
	Acceleration (ms^-2)			Rotation(Degree)	
Angle ofAttack	X	Y	Z	RX	RY
180	-0,705	-0,101	-3,281	0,104	11,971
135	-0,411	0,590	-3,205	0,105	12,232
90	0,002	-0,717	-3,246	0,556	-0,487
45	0,408	0,591	-3,209	0,043	12,426
0	0,705	-0,101	-3,282	0,013	11,979



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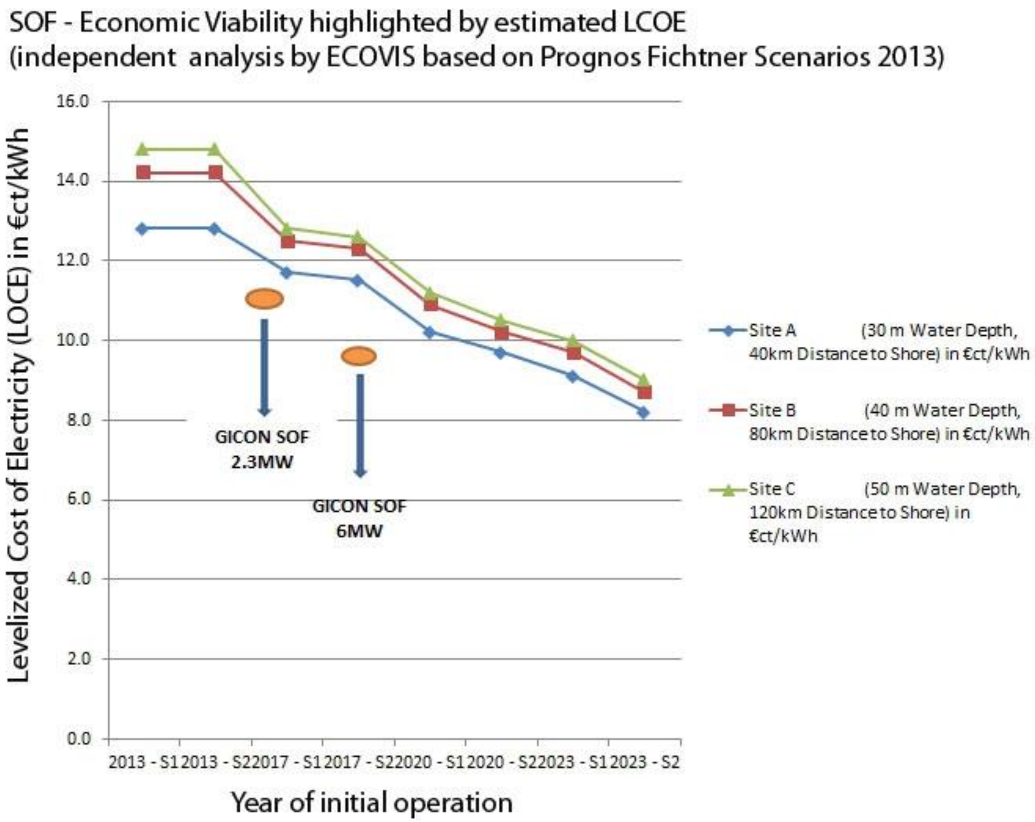
Conclusion

Summary

- First results show the technical feasibility of the 6 MW system
- The system will be an economically viable solution



Thank you for your attention

Quellen

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