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DOCUMENTATION VERIFICATION AND VALIDATION OF REAL-TIME HYBRID MODEL TESTS WITH THE 10MW OO-STAR WIND FLOATER

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Layout

- Model testing: motivation and limitations
- Real-Time Hybrid Model testing
- OO-Star Wind Floater ReaTHM tests
- Verification
- Conclusion

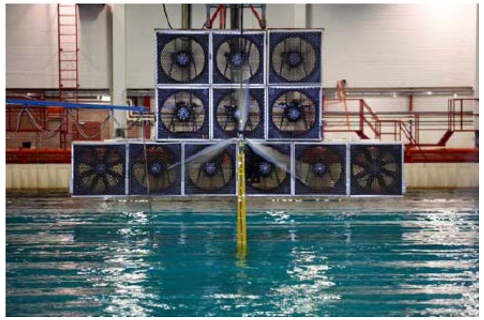
Motivation for model tests

- Common to all offshore structures
  - Significant investments should be de-risked and optimized
  - Some physical effects are not modelled correctly by engineering tools yet
  - Some physical effects are not known yet
- Specific to FOWT
  - Complex coupling between wind and wave loads, structure and blade dynamics.

→ Issue: the experiments must capture these couplings correctly

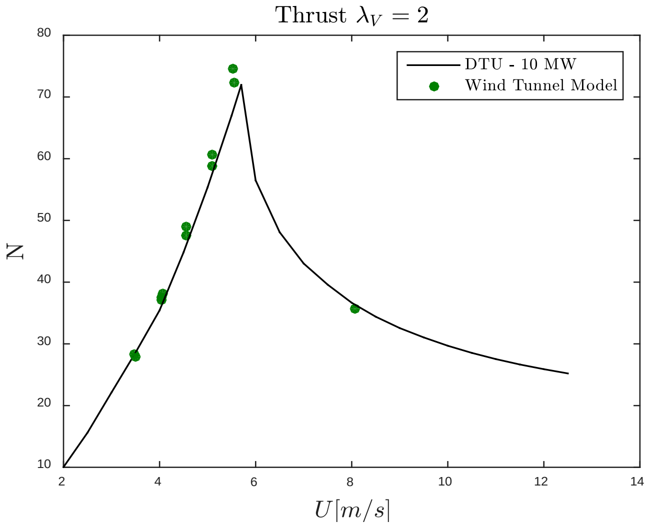
Limitations of classical approaches

- Tests in wave tanks, using fans to generate the aerodynamic loading
  - *Challenge 1:* ensure a correct wind field above the wave field → accuracy, repeatability, traceability
  - *Challenge 2:* ensure a correct mass distribution of the RNA model
  - *Challenge 3:* Froude/Reynolds scaling conflict, and rotor re-design by "Performance scaling"



Hywind demo, 2005

Politecnico Milano / 2016

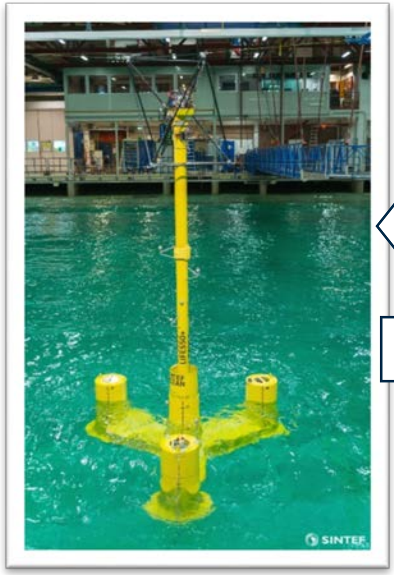


Real-Time Hybrid Model (ReaTHM®) testing

Model testing
(Ocean Basin)

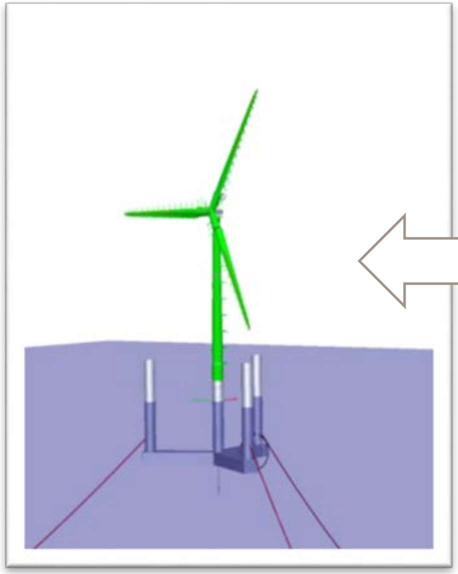
Aeroelastic simulation
(NREL's FAST code)

Waves & current



Actuated rotor loads

Measured platform motions



Wind

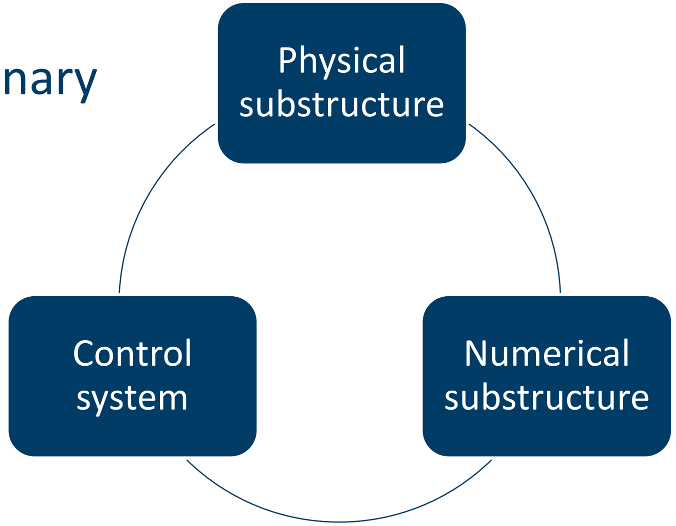
ReaTHM® testing

Strong points of ReaTHM® testing?

- Realistic and controlled rotor loads
- Possibility to test extreme conditions
- Cost-effective and flexible

Any challenges?

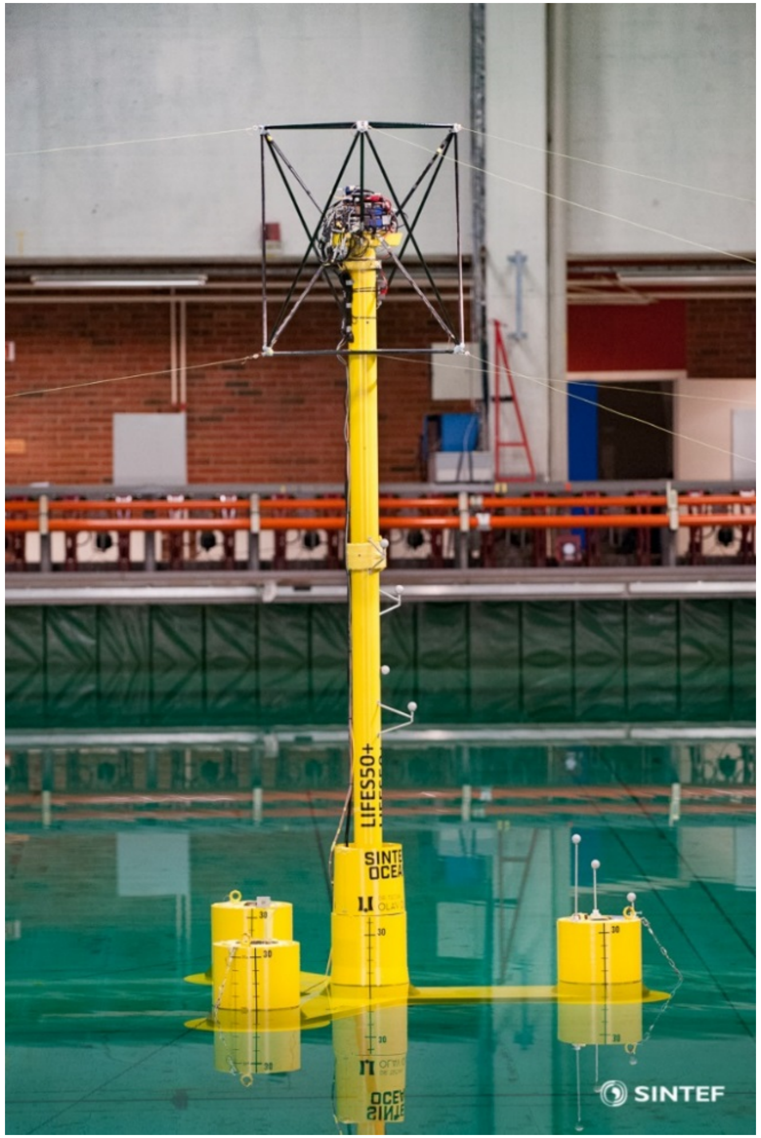
Multidisciplinary



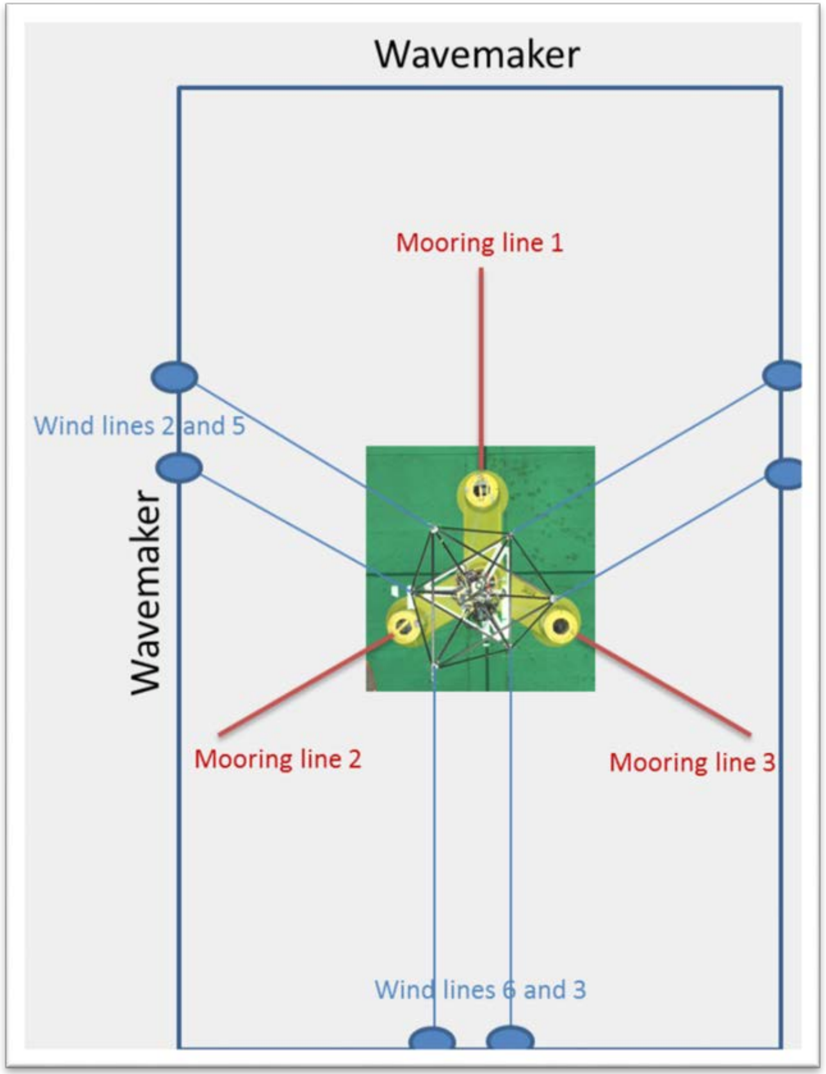
How to ensure high quality testing?

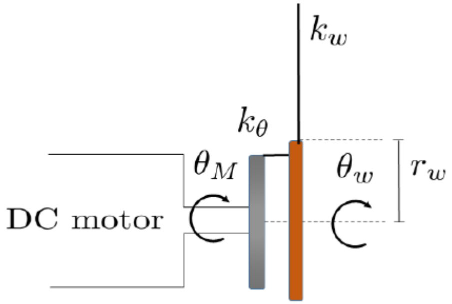
OO-Star Wind Floater model tests

- Lifes50+ H2020 project (http://lifes50plus.eu/)
- OO-Star Wind Floater with DTU 10MW turbine
- Tested in Nov 2017 in the Ocean Basin at SINTEF Ocean
- Scale 1/36
- Environmental conditions of Gulf of Main (depth 130m)
- Objectives:
  - Concept performance verification
  - Data for num. calibration
  - Develop hybrid methods



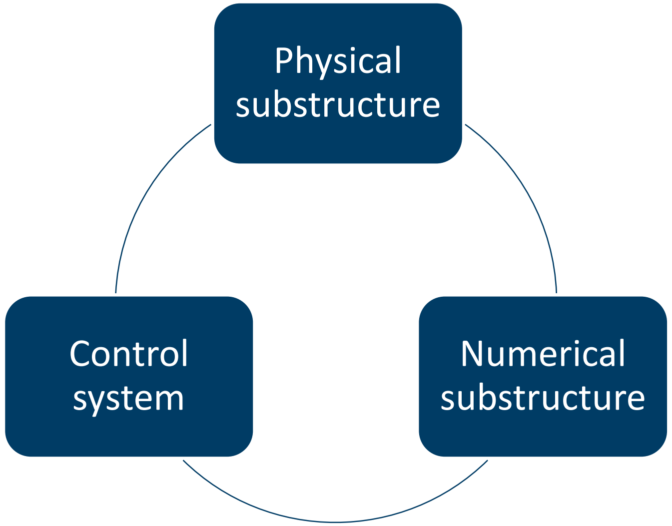
OO-Star Wind Floater model tests



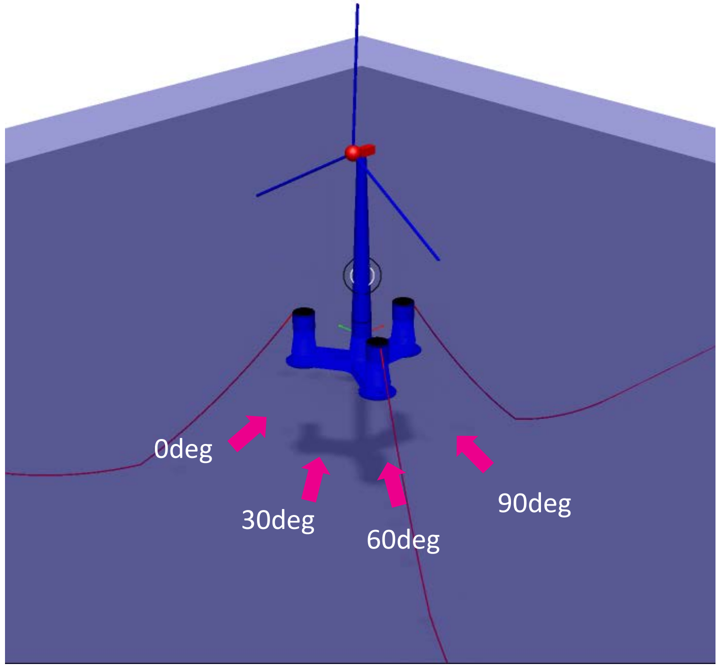


Verification: Stepwise approach

- General: Sensitivity study
- Substructure Verification
- Verification of complete system



Verification: Sensitivity study



- How important are each of the turbine load components for operational and parked conditions?
- Realized by use of Riflex-SIMO-Aerodyn, where rotor loads are modified one by one.
- Sensitivity to
  - aerodynamic sway, heave, pitch, and yaw
  - Gyro moments/centrifugal forces
  - Vertical and horizontal directionality
- 16 loading conditions

Description	Unit	EC1	EC2	EC3	EC4
Wind	m/s	8.0	11.4	20.0	44.0
TI	%	12.7	12.4	9.5	11.0
Wind model	-	NTM	NTM	NTM	NTM (EWM)
Power law coeff.	-	0.14	0.14	0.14	0.11
H_s	m	2.3	2.5	3.6	10.9
T_p	s	9.7	9.8	9.9	16.0
Wave spectrum	-	PM	PM	PM	PM

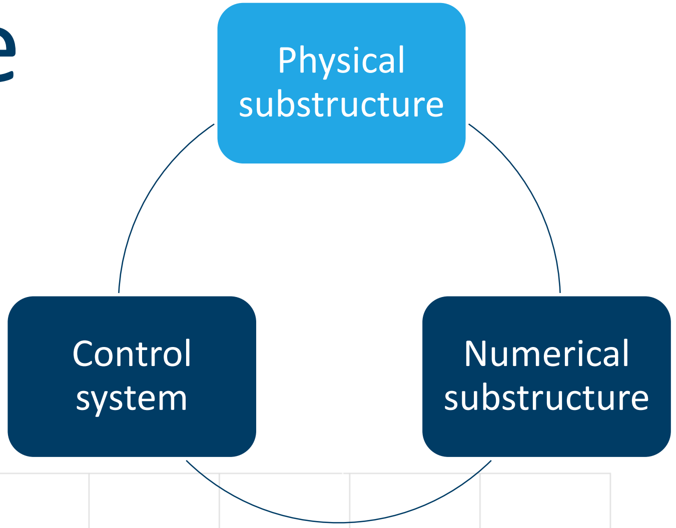
Verification: Sensitivity study

- Influence on standard deviation for quantities of interest (DOF1-6, mooring line tensions, BM and SF)

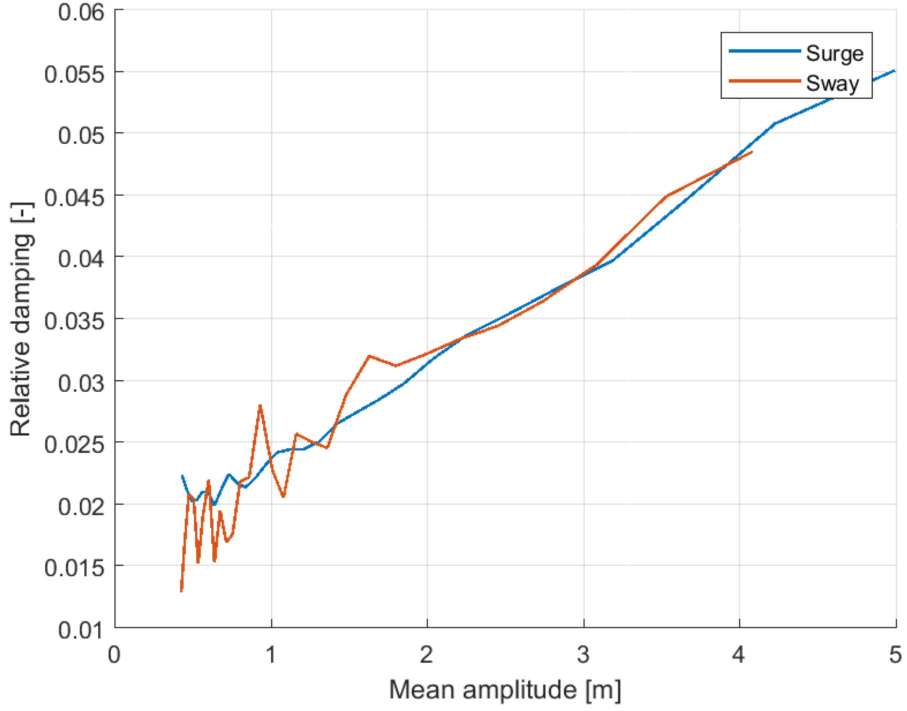
Removed	**Operating (EC1-3)**	**Parked (EC4)**
Aerodynamic sway	small	15% tension and 8% yaw and pitch
Aerodynamic heave	small	12% tension
Aerodynamic pitch	+18% pitch and +10% SF	+22% pitch and +22% BM
Aerodynamic yaw	-85% on yaw (small)	small
Vertical directionality	small	7% pitch and 15% tension

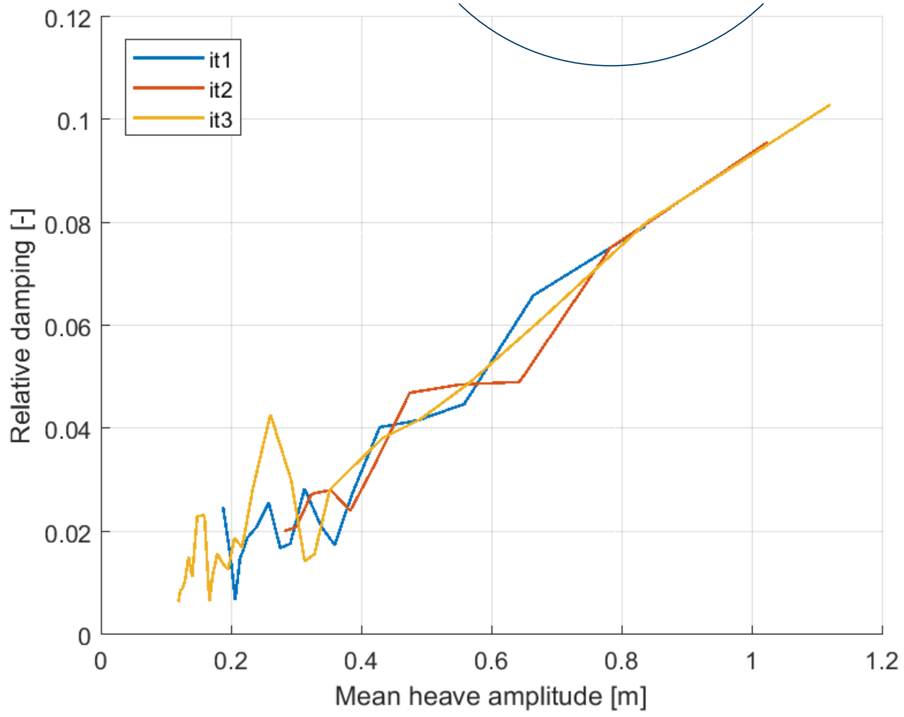
=> 6 actuators in two parallel horizontal planes to apply all loads except heave

Verification of Physical Substructure

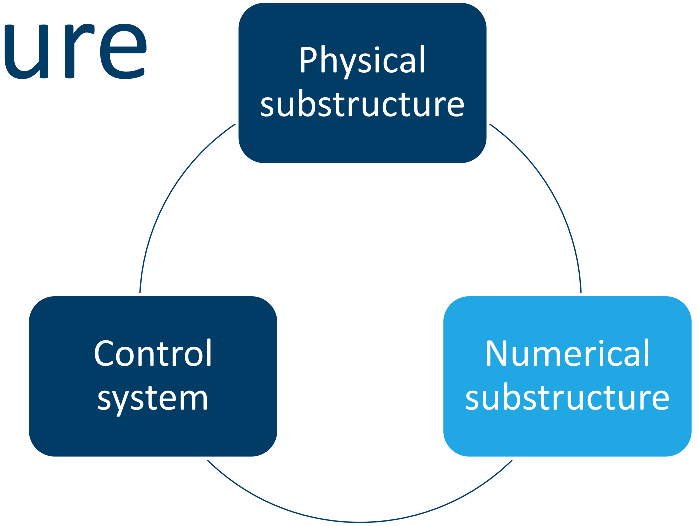


- Pullout
- Decay
- Repetitions



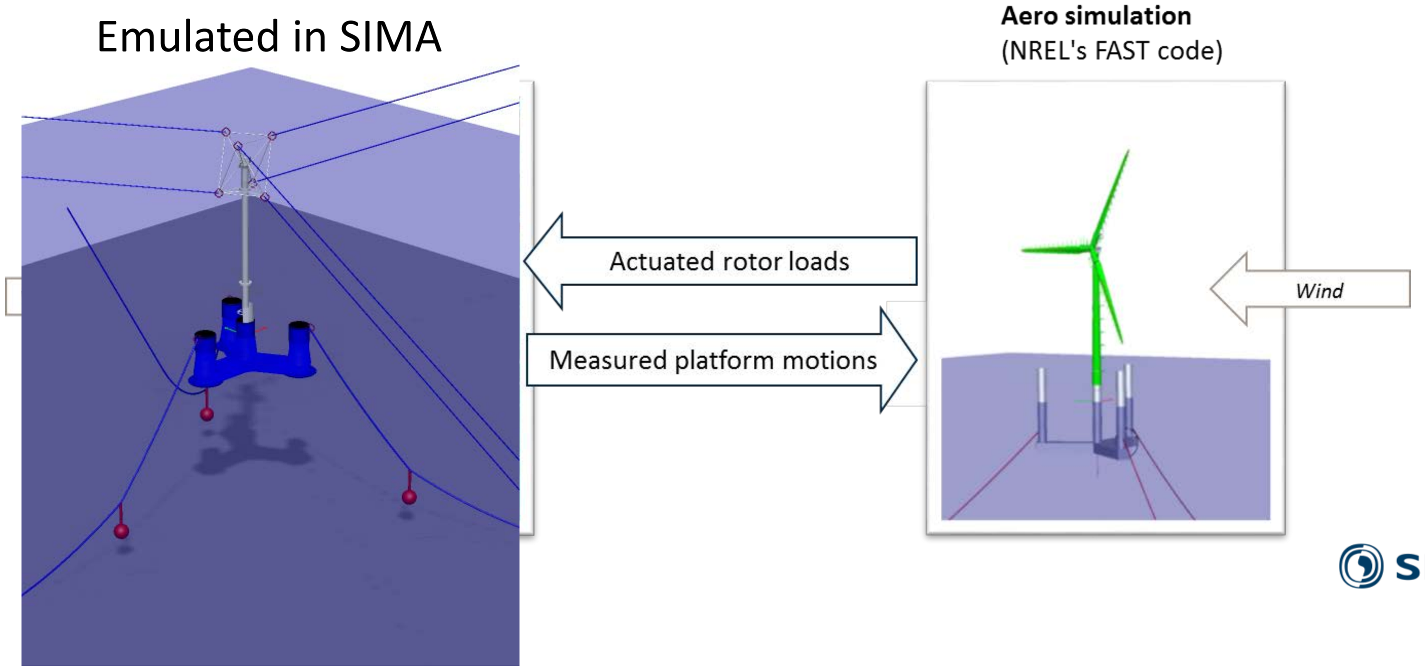


Verification of Numerical Substructure

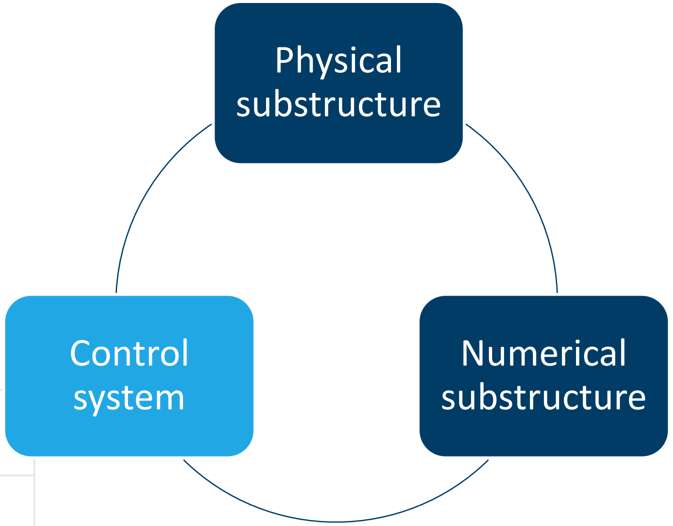


Physical part of the experiments emulated in SIMA for verification of

- Allocation (rotor loads->forces on actuators 1-6)
- Scaling
- Applied actuators forces



Verification of Control System

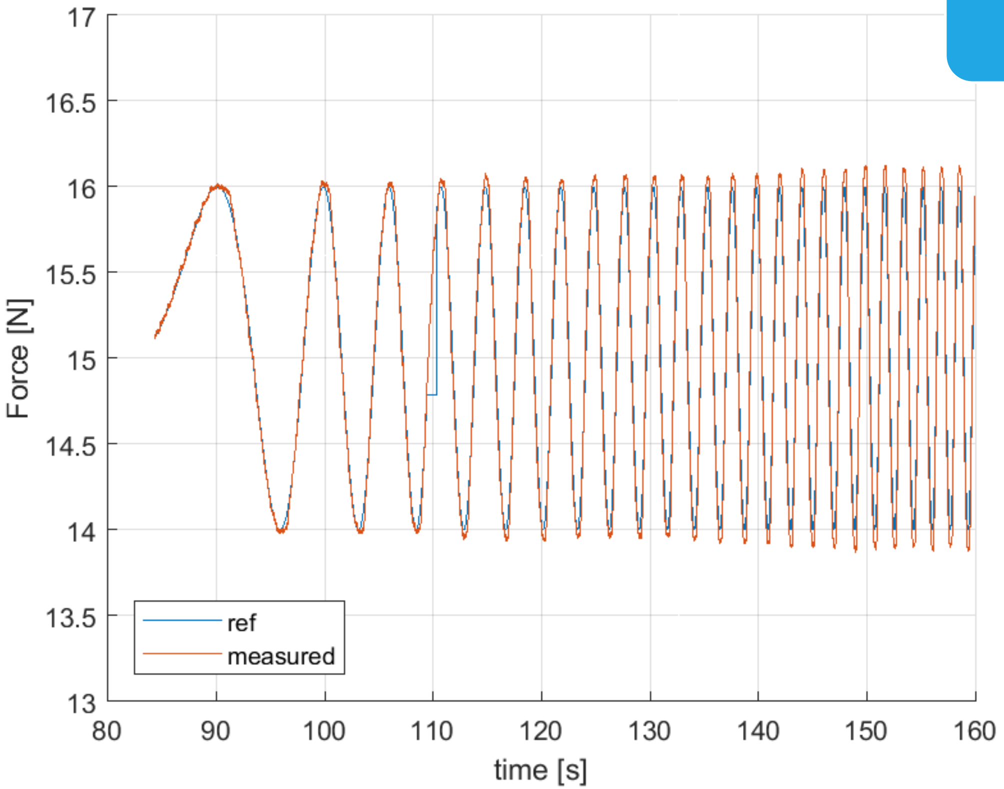


Main objectives:

- Reference tracking
- Disturbance rejection

Through:

- Chirp tests
- Following tests



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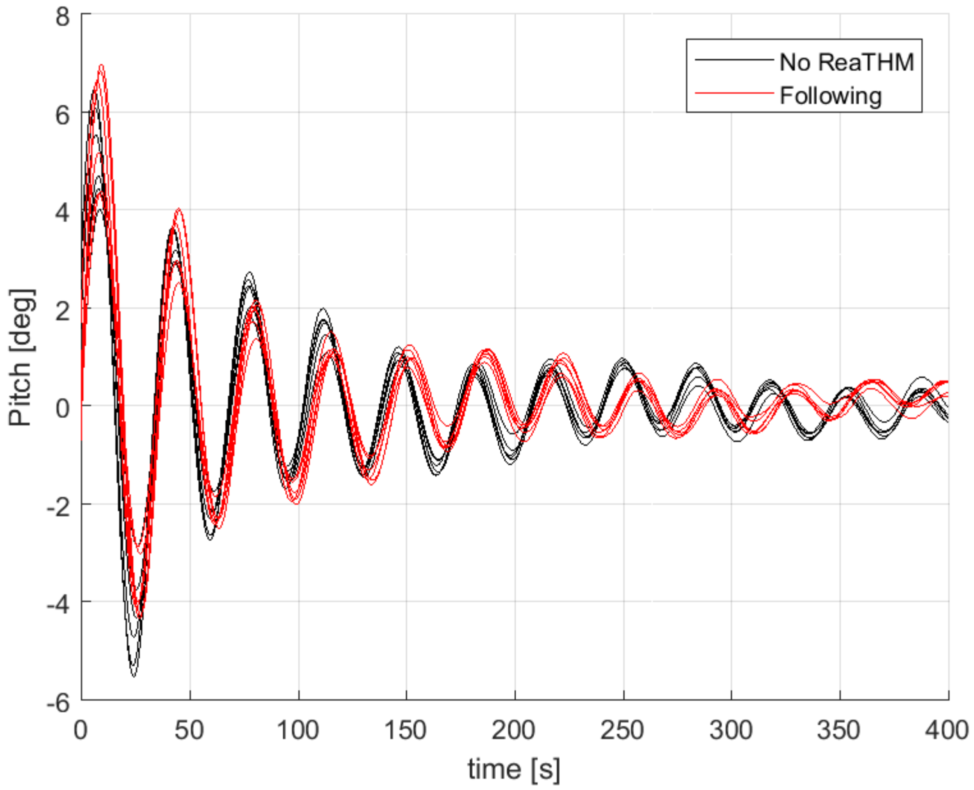
Verification of Complete System: Decay

Pitch decay test without ReaTHM system and with the system in following mode



	Tn Pitch [s]
No ReaTHM	34.9
Following	35.8
Rel. Diff [%]	2.5

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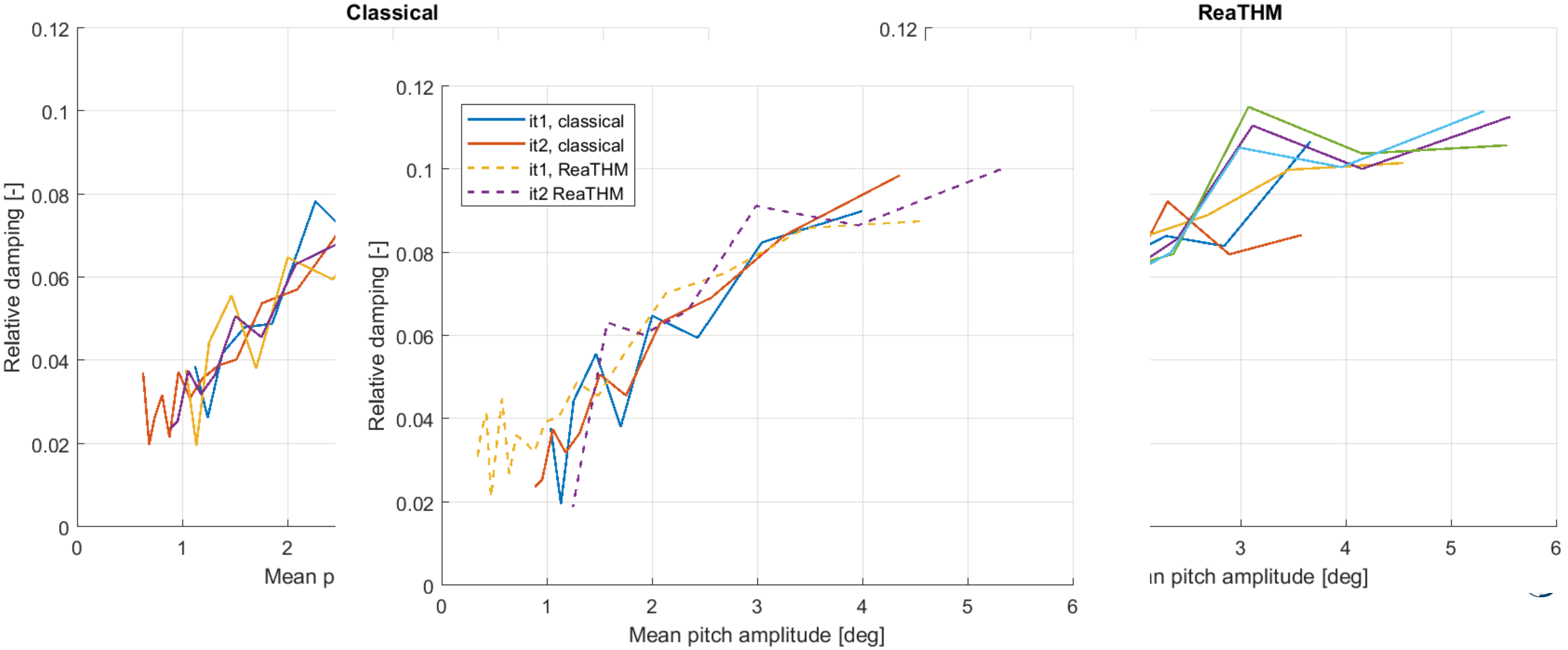
Verification of Complete System: Decay

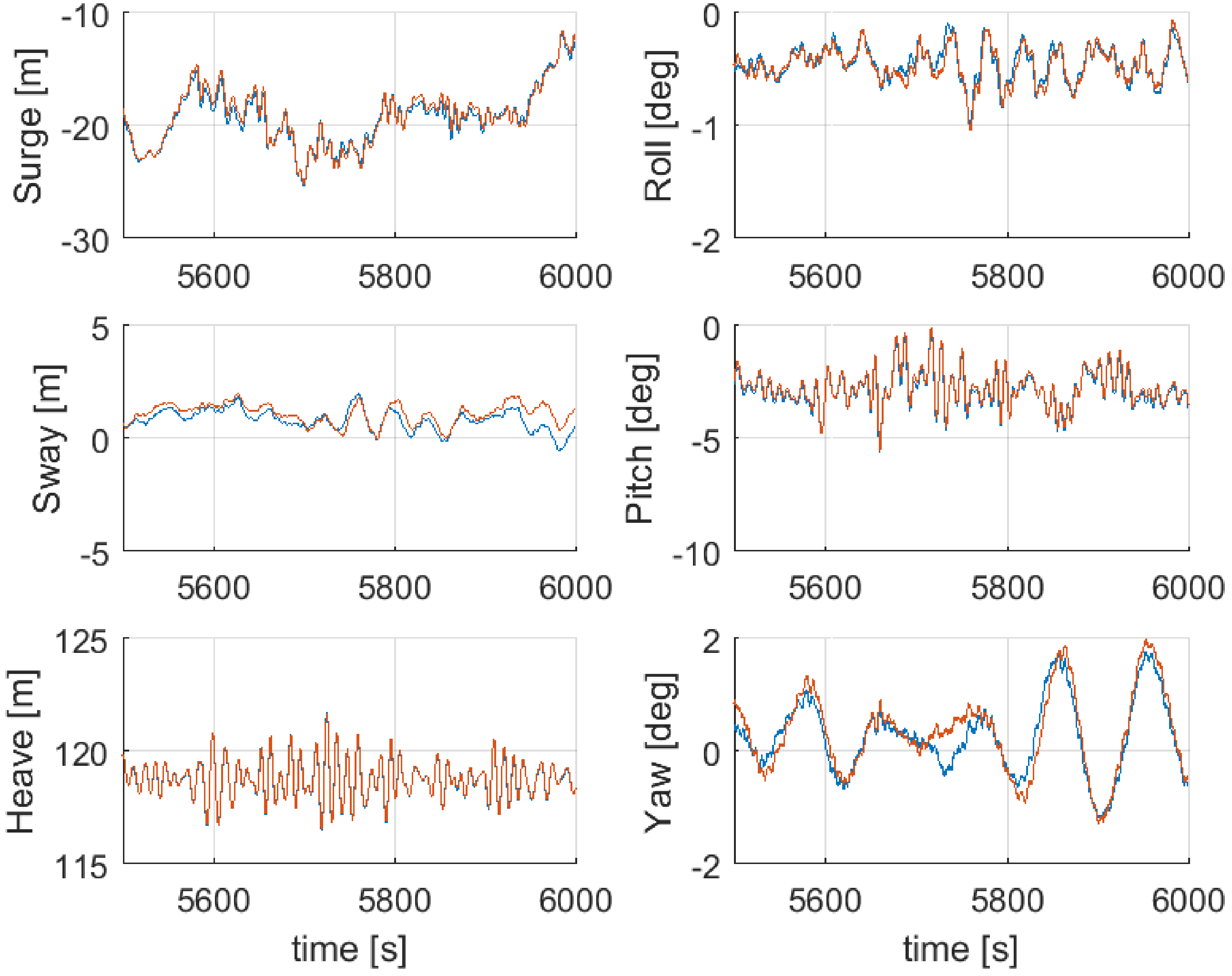
Pitch decay test without ReaTHM system and with the system in following mode



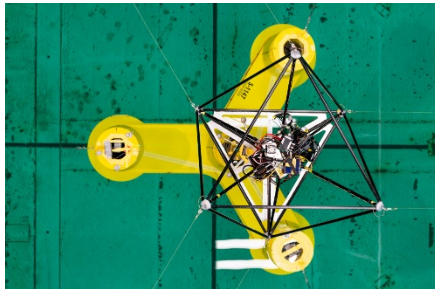
Verification of Complete System: Repetition

Test repetition:

- DLC 1.6
- Waves: Pierson-Moskowitz Hs=7.7m and Tp=12.4s
- Wind: NTM 8m/s

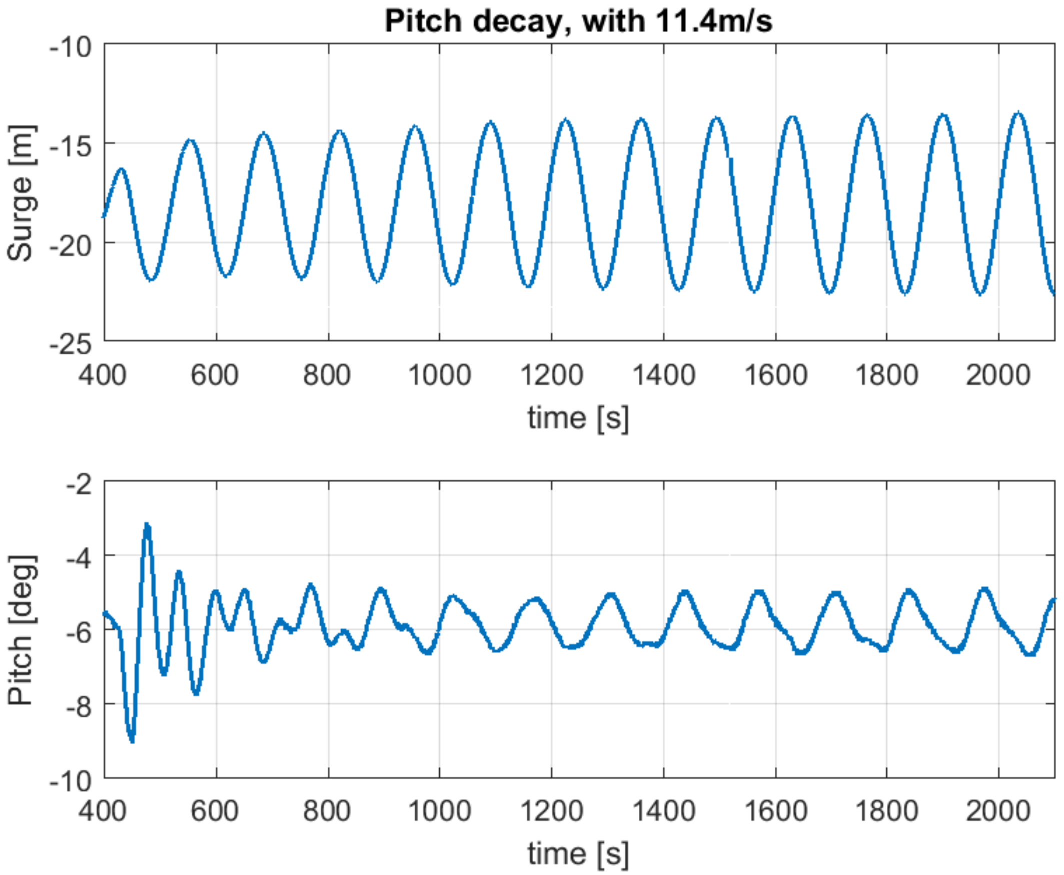


Collinear wind and waves



Conclusions

- ReaTHM® testing is a multidisciplinary method
- Sensitivity analysis is key in the design process
- New verification and documentation methods developed for substructures and complete system
- Examples shown from Lifes50+ with OO-Star Wind Floater
- More work needed to address experimental uncertainty of hybrid tests -> Phase 2 of Lifes50+ in March 2018 *(Nautilus-DTU10)*



Acknowledgments

LIFES50+

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HYBRID KPN

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Teknologi for et bedre samfunn