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Local Digital Twin of an Offshore Wind Mooring Sensor using Reduced Order Modelling

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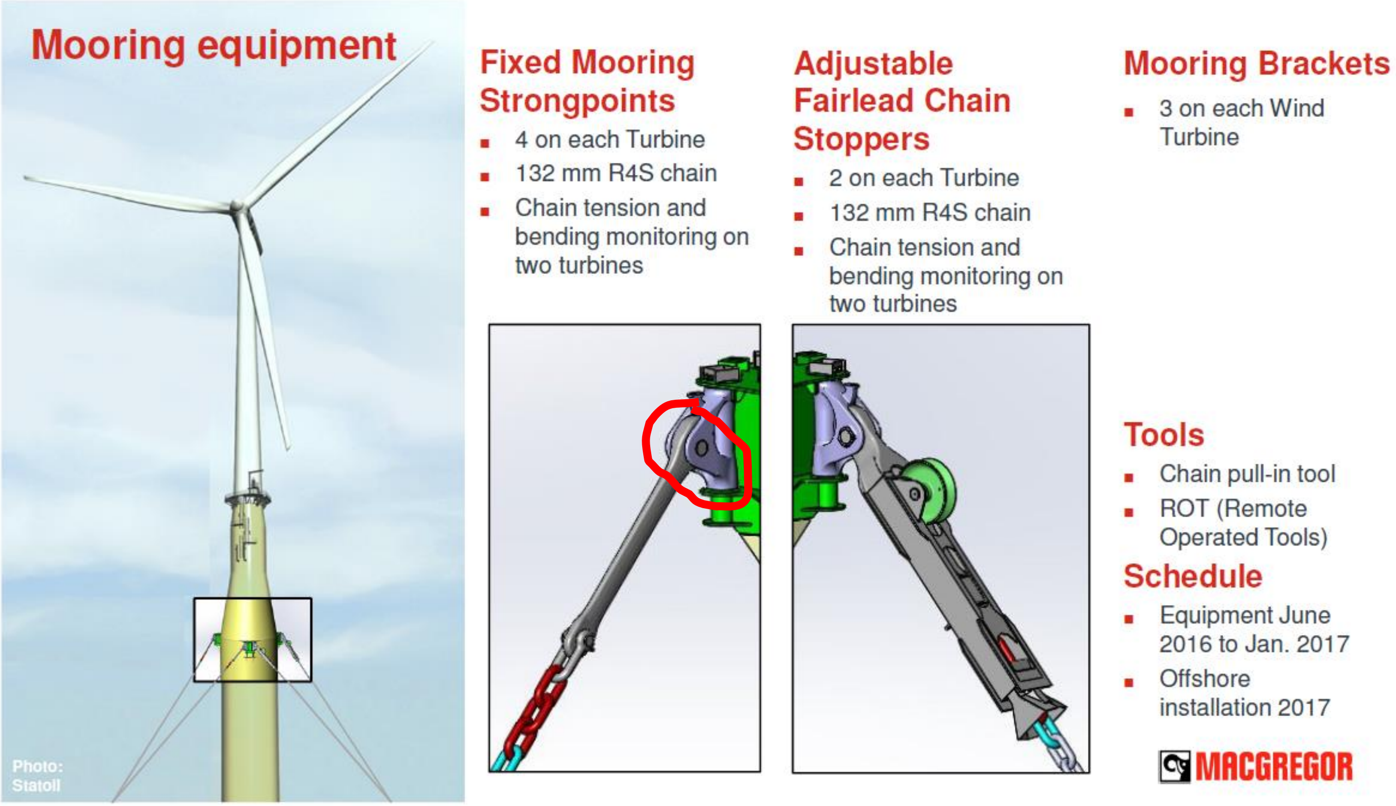
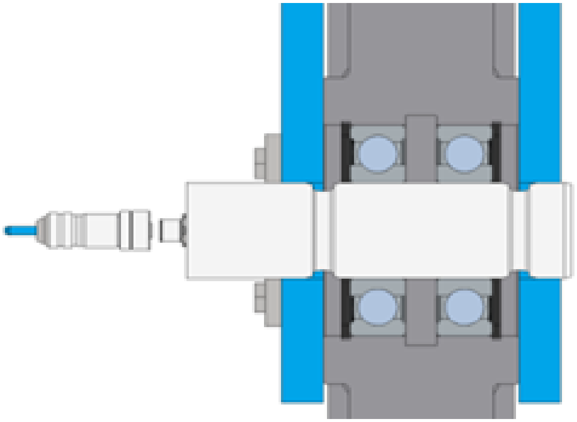
The introduction of floating Offshore Wind applications has resulted in new requirements and demands related to mooring installations. The mooring sensors need to be optimized for larger movements and changes in angle of attack.

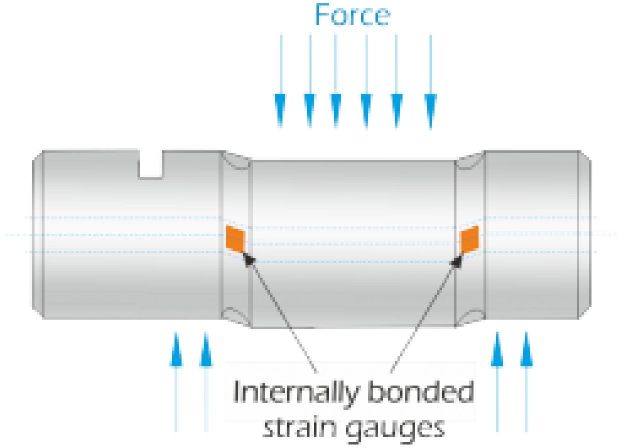
A Digital Twin, using reduced order FEM calibration (IFEM) and test results from a downscaled 1/30 Windmill structure, can be used to optimize sensor performance.

All combination of applied forces can be efficiently tested with the help of accelerated FEM simulations based on physical measurements.

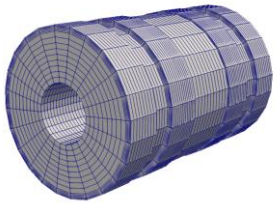
Mooring load sensor

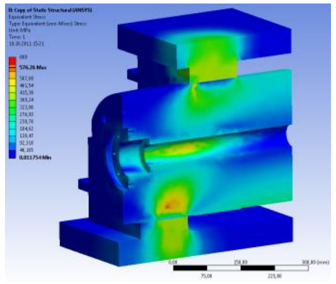




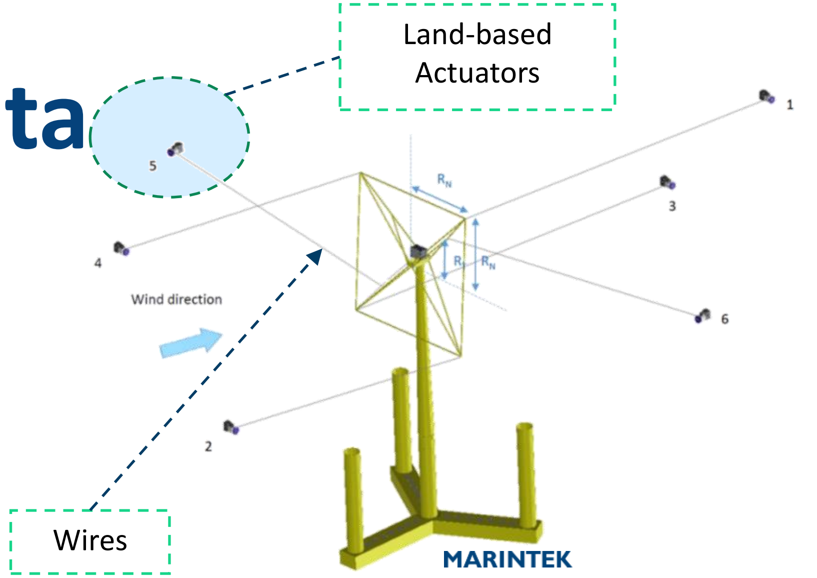


Optimized FEM model for IFEM
Simulation of all variable load cases





Experimental data



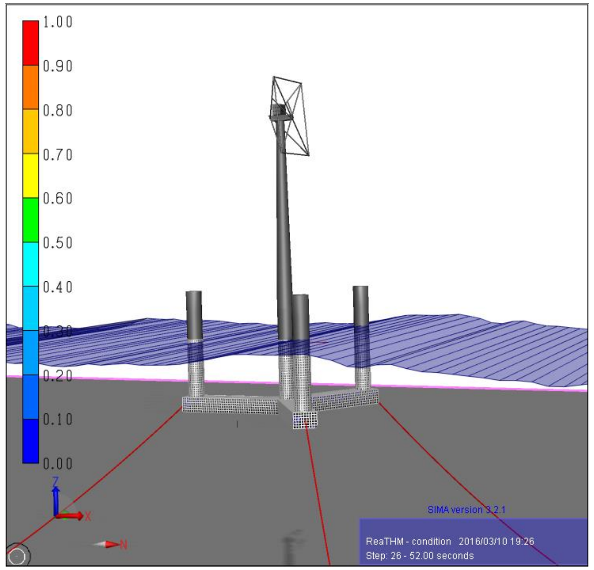
Experimental case

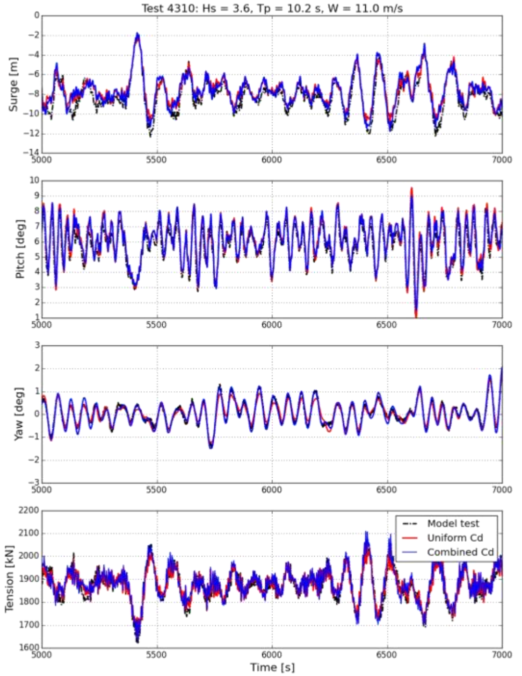
- The FWT:
  - 5MW CSC turbine
  - Floater designed by C.Luan for the NOWITECH project
  - 5 MW NREL rotor-nacelle-assembly
- Froude scale 1/30
- Water depth: 200m
- 3 chain-chain mooring lines

Experimental Setup: Instrumentation

- Position of model by optical measuring system
- Measure linear acceleration and angular velocity at hub
- Actuated force («wind lines»)
- Mooring line tensions
- Shear forces and bending moment at base of tower
- Shear forces and bending moment at base of column 3
- Ultra thin instrumentation cable under the model

Calibration of Numerical Tools





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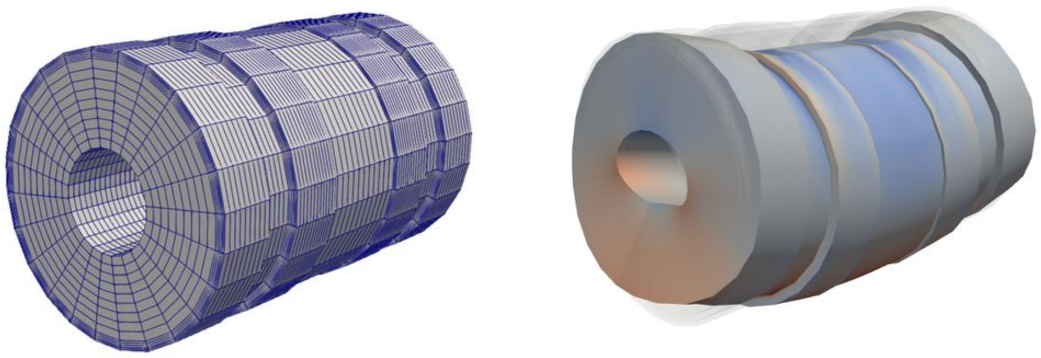
Numerical modelling

Full Order Model (FOM)

IFEM: Isogeometric Finite Element Module



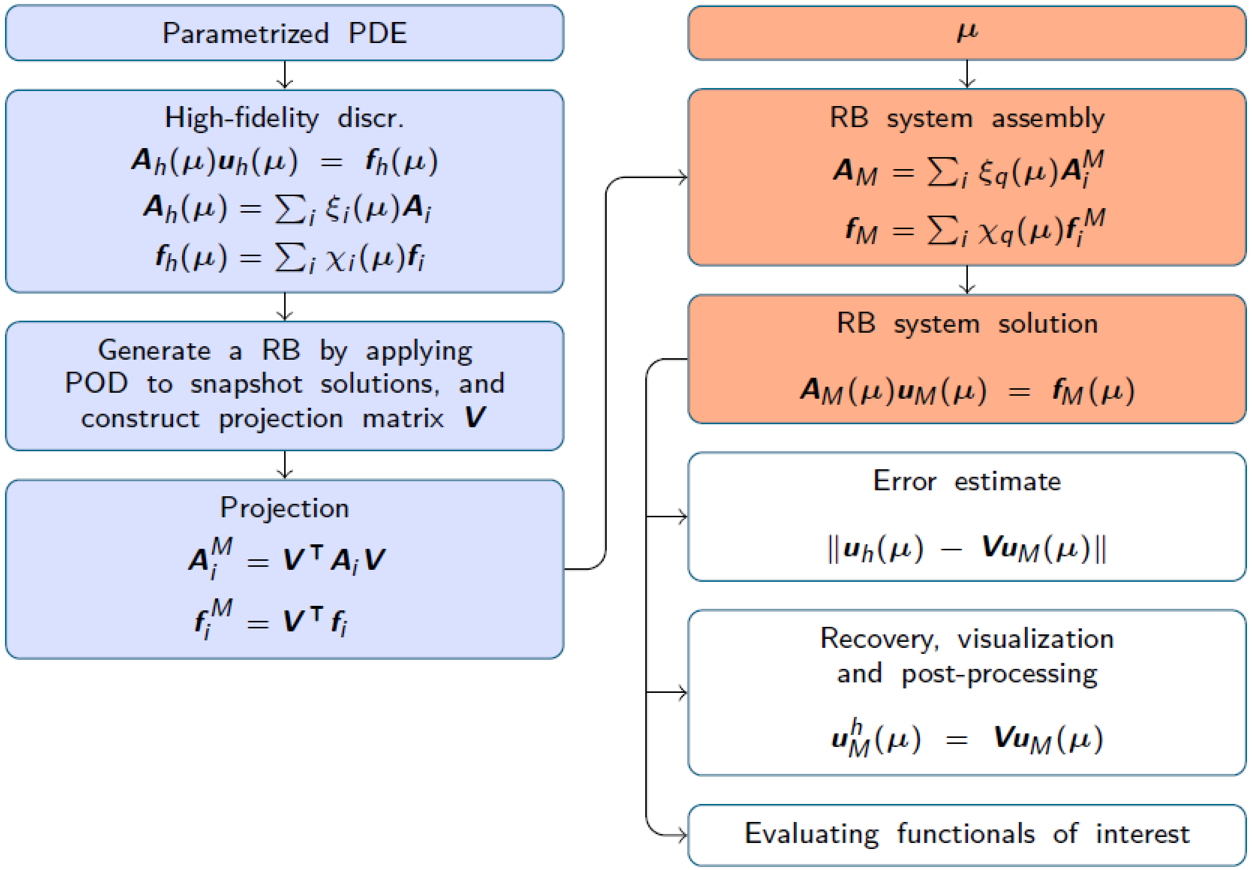
- FOM: 18 000 dofs - 1 month total CPU
- ROM: 15 dofs - 6 minutes total CPU

Degrees of Freedom (dofs)

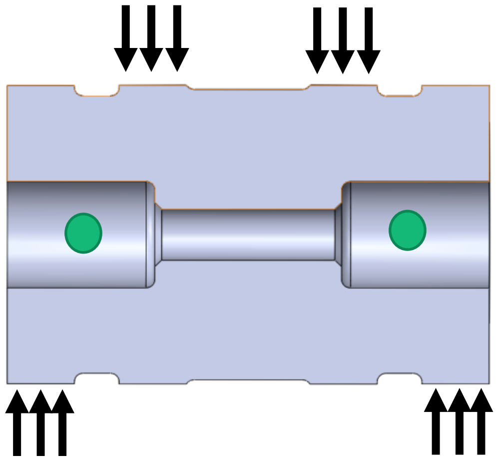
Speedup: 8000

Reduced Order Model (ROM)

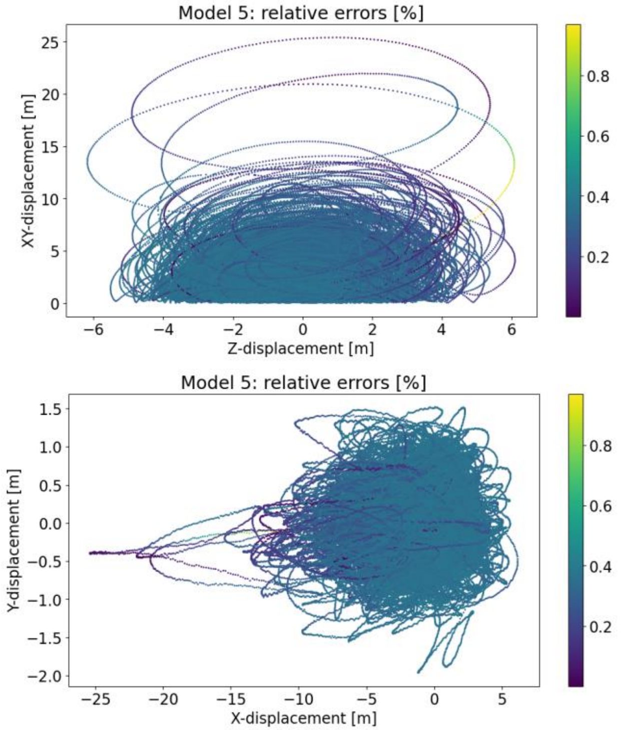
AROME: Adaptive Reduced Order Module



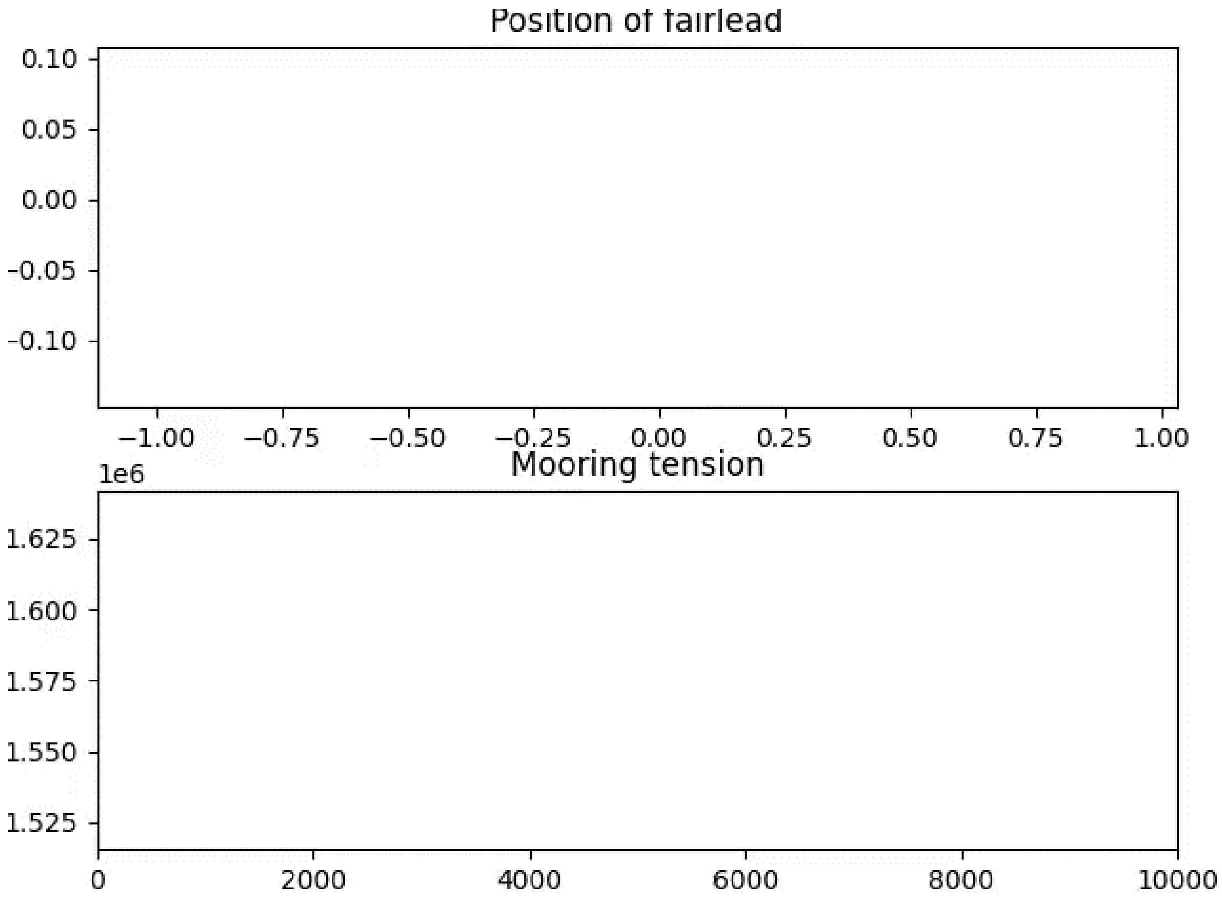
Variation in measured strain vs load directions



Position of shear strain gauges with calibration in one load direction



Calibrated Sensor error vs variation load directions



Summary

The introduction of floating Offshore Wind applications has resulted in new requirements and demands related to maritime installations. Suppliers with experience from the oil and gas industry have adjusted and customised their technologies to fit the new specifications. The mooring installations are no longer using winches to adjust the pretensions and the sensors need to be precise even with large movements of the floating structure.

In 2015 SINTEF Ocean (earlier MARINTEK) and NTNU designed and tested a 1:30 model of a 4-column semisubmersible platform, which support the NREL 5MW wind turbine. The physical model comprises the hull, tower, and rotor-nacelle-assembly model for the hybrid test situation. The goal was to qualify the global performance of the system while being tested in the wave basin. The forces and their directions applied to the mooring wires was measured and has now been used in a local digital twin simulation of a mooring sensor.

A reduced order model has been used to simulate all load cases during the original physical testing in the basin made by SINTEF Ocean. The simulation efficiency of the reduced order model has made this possible, covering a large amount of load cases. In this case the reduced order method is 8000 faster than a full order FEM model.