Novel Approaches for Physical Model Testing of Floating Wind Turbine Platforms

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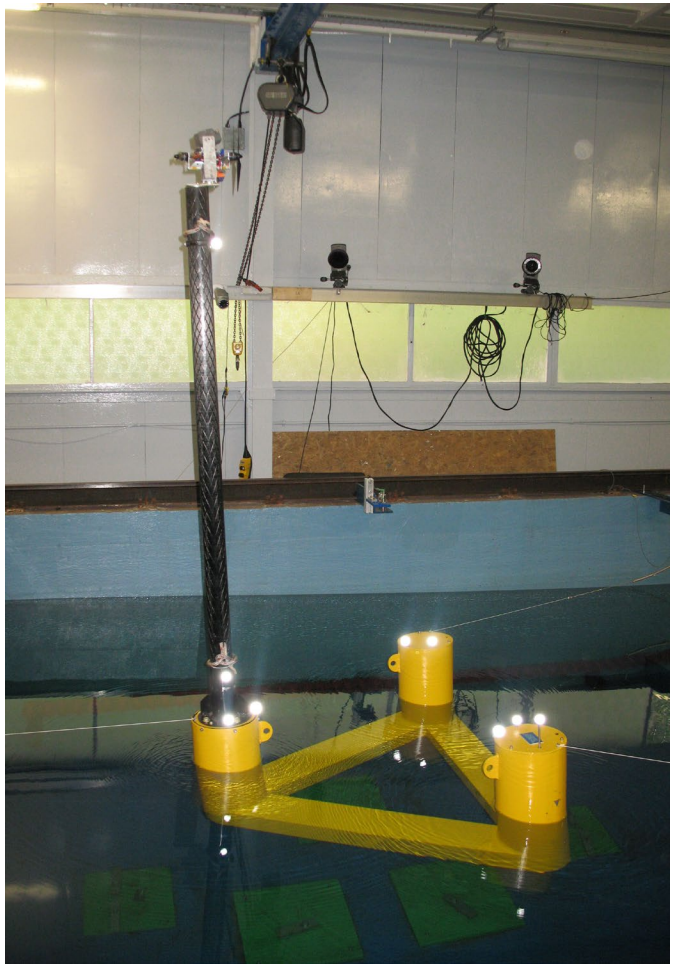
Background:

- *Scaling challenges for Aero-Hydrodynamic forces on FOWTs in model tests*
- *Growth in use of "Hybrid" model testing" for FOWTs, simulating effects of wind loading via software-controlled actuators*
- *Advantages in cost & size of models and equipment, scaling of complex behaviour, flexibility of test cases*



Challenges:

- *Complex approach due to coupling between aero and hydro effects*
- *Lack of standard procedures for validation & uncertainty estimation*
- *Lack of understanding of cost-benefit of different approaches*
- *Full SIL requires customised versions of standard codes (e.g. FAST)*
- *Latency issues*

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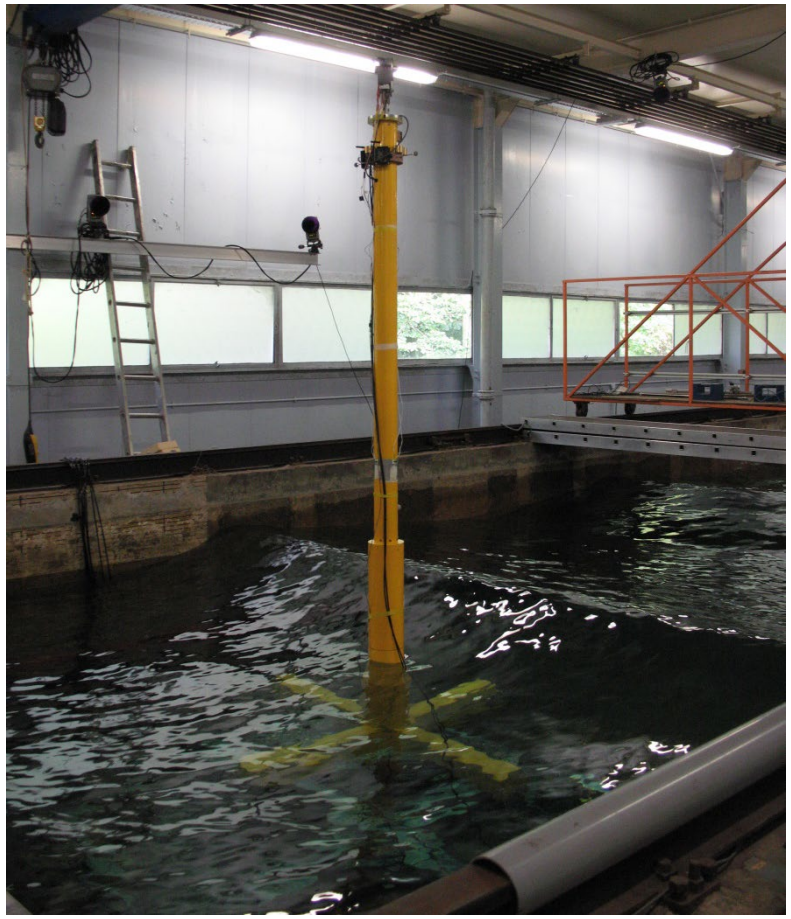
Aims:

- *Quantify benefits of using SIL and other hybrid testing approaches in testing of FOWT platforms*
- *Develop methodology and associated hardware for benchmarking performance of hybrid testing approaches*
- *Determine impact of system performance on simulation fidelity and uncertainty*
- *Develop metamodels for wind load simulation and test performance against "full" SIL approach*



Tasks :

- *Refine Hybrid system hardware*
- *Develop metamodels for wind load simulation (surge only)*
- *Develop benchmarking system hardware (1-DOF)*
- *Verify system and quantify uncertainty for metamodels v SIL*
- *Implement and demonstrate working metamodel-based system in small-scale model tests*
- *Compare with constant load and full SIL cases.*

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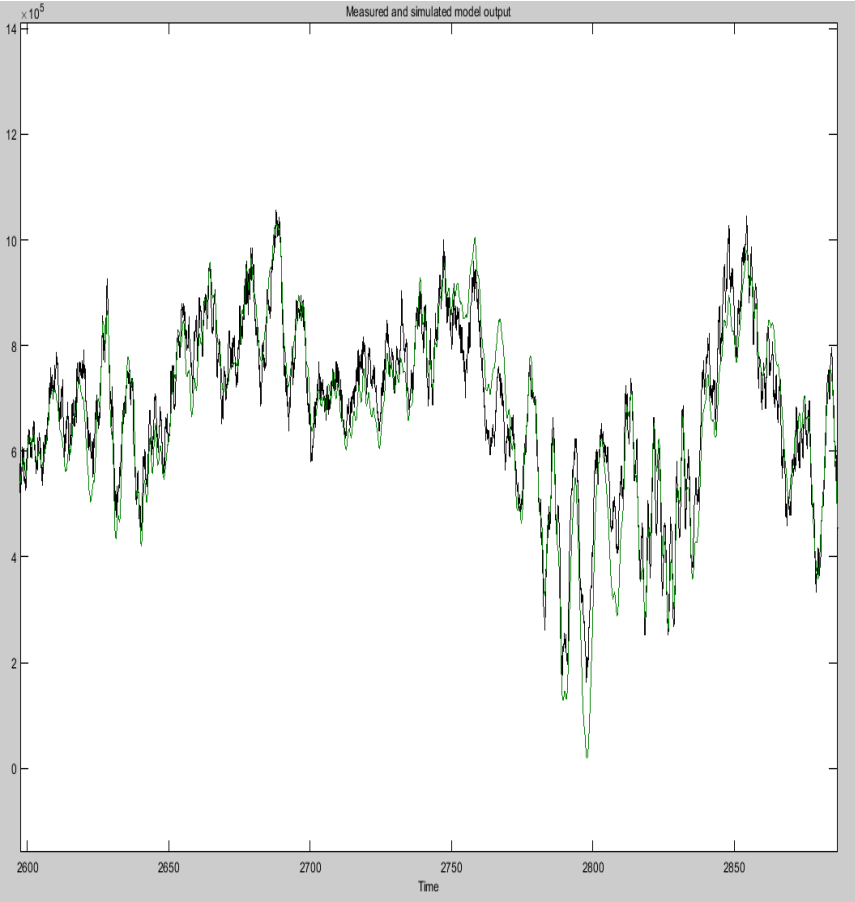
A range of different meta-modelling approaches were explored in the numerical trials. The models investigated included simple polynomials, ARx (UoS), neural networks (UoP) and state space (UoE) models

A well-known platform / turbine benchmark (OC3 Spar / NREL 5MW turbine) was chosen for the majority of the generation of benchmark data. Some studies were also carried out using a semi-sub platform.



- *A series of test cases comprising time histories of wind and wave environment, platform motions and turbine thrust were developed using the OpenFAST software.*
- *Cases included regular and irregular waves, & steady & turbulent wind.*
- *Data from these cases was used to train the modelling approaches and explore the accuracy of simulations using these models.*
- *All models tested had some success. The ARx approach was selected for further study due to good accuracy combined with ease of practical implementation in a real-time laboratory system.*

Figure shows a sample calculated FAST time history of thrust, and the corresponding ARx simulation in irregular waves & turbulent wind

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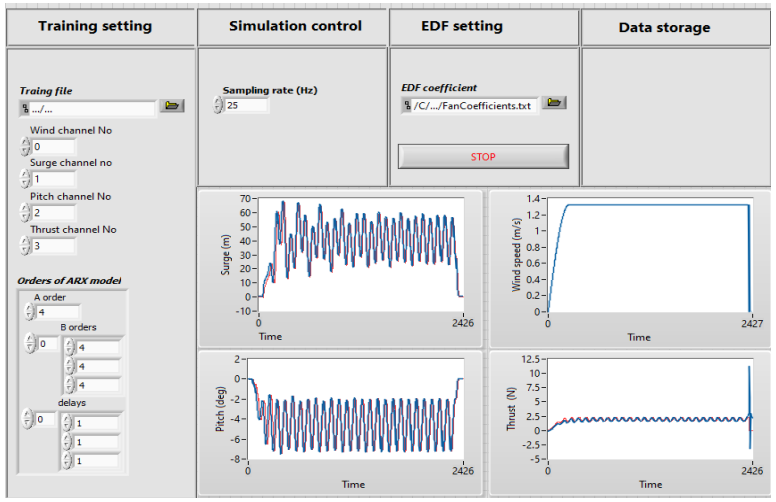
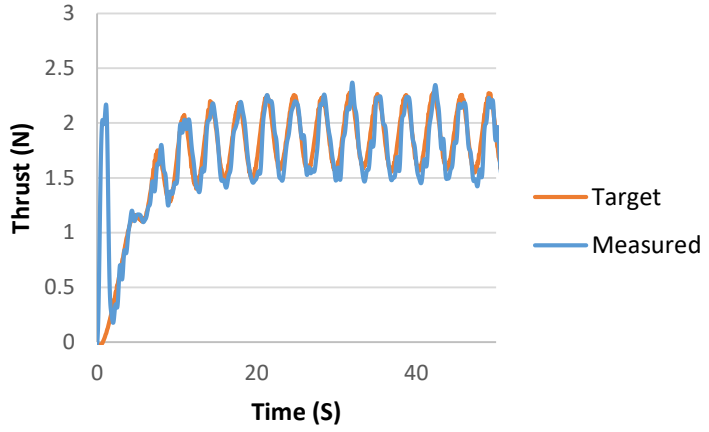
In order to quantify the performance of the ARx models in a practical setting, a model turbine was mounted on a motion platform and a series of 2-DOF (pitch and surge) platform motion trajectories were generated from a FAST simulation.





- *The use of the motion platform eliminated any coupling between the generated thrust and the platform motion.*
- *Hence predicted platform motions from the FAST simulation were unaffected by any errors in thrust simulation, allowing a meaningful comparison with FAST data.*
- *Motion was measured using the motion capture system used in the tank.*
- *A real-time Labview control programme was developed to drive the turbine thrust from the measured motion data using an electronic ducted fan (EDF).*
- *The measured thrust was compared with the FAST simulation of the thrust.*
- *Thrust results showed good agreement with target and demonstrated negligible latency.*

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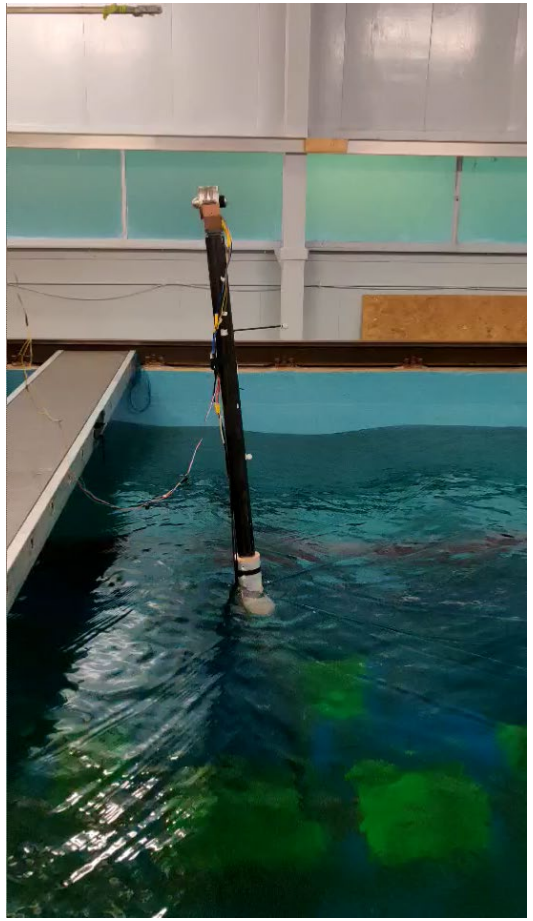
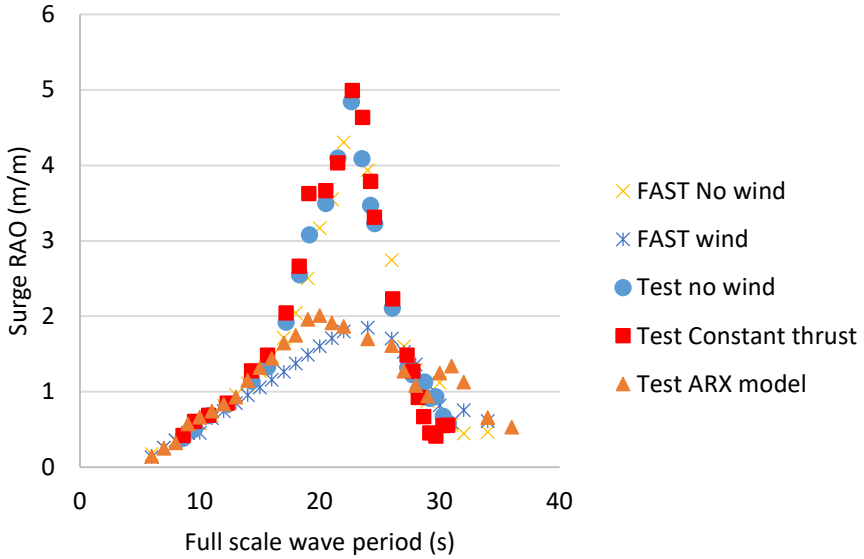
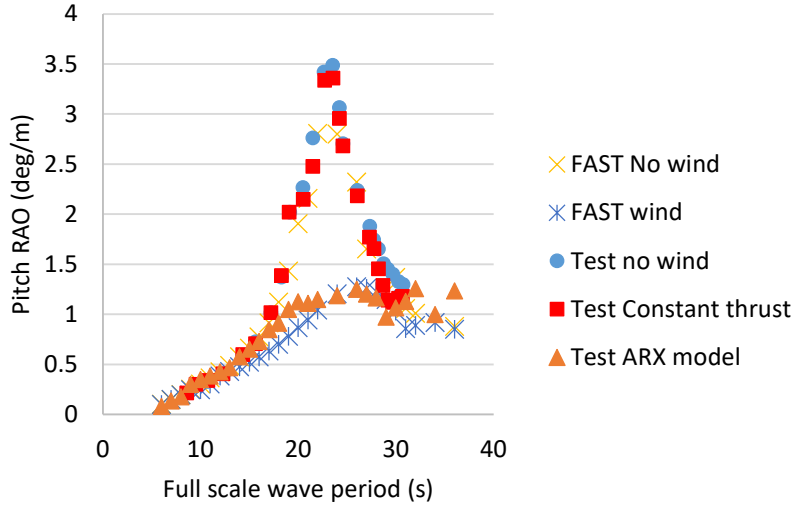
In order to explore the impact of correct aerodynamic modelling on platform motion results obtained from tank tests, a series of comparative studies were carried out using an existing 74th scale model of the OC3 spar.







- *Tests compared the platform motions under conditions of no wind load, constant thrust and unsteady wind load generated using the ARx model*
- *Unfortunately it did not prove possible to compare with full SIL model in this campaign; instead results are compared with FAST simulations*
- *Results suggest that, as expected, the turbine aerodynamics has a significant impact on platform motions and that the ARx model successfully reproduced the aero-hydrodynamic coupling.*

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Key Conclusions

- *Correct modelling of turbine aerodynamics can have a significant impact on platform motions. Constant thrust is not adequate to capture the aero-hydrodynamic coupling effects.*
- *The use of a meta-model allows realistic representation of the turbine thrust based on modelling of data rather than direct calculation.*
- *The ARx model successfully reproduced the aero-hydrodynamic coupling in the numerical simulation over a range of realistic test cases including regular & irregular waves and steady & turbulent wind. Other models also showed potential to successfully reproduce the thrust.*
- *Some more complex models demonstrated slightly improved performance in the numerical simulation over the ARx model, but were more difficult to implement in a real-time system.*
- *The ARx model was successfully implemented in a practical real-time system in the laboratory, and thrust time histories showed good agreement with target values*
- *The use of a motion platform to test the physical system was successful in allowing thrust to be decoupled from platform motion, allowing a direct comparison to be made between simulated and measured thrust data, & quantitative assessment of system performance*
- *The approach was successfully implemented in a series of tank tests, demonstrating the practical application.*
- *This research is expected to lead to a range of opportunities for participation by the facilities involved in this project in further funded research studies involving novel floating wind turbine systems and also to allow more reliable and sophisticated tests to be carried out on a commercial basis for system developers, hence generating impact in the wider industry.*

Further studies will address different platform types, practical implementation of more complex metamodels, more complex environmental conditions, and direct comparison with SIL approach