Form of Written Discussion at the 27th ITTC Conference

Discusser	
Name	Arthur M. Reed
Affiliation	David Taylor Model Basin (NSWCCD, USA)

Name of Technical Committee or group to be discussed	Specialist Committee on Hydrodynamic Testing of Marine Renewable Energy Devices

Written Discussion (within 1,000 words of length)

The Committee mentions briefly the gyroscopic effects of the turbine of a floating offshore wind turbine. Could the Committee comment on the significance of including these gyroscopic effects on the results of a motions in waves test, and on what would be lost if these effects are not included. This question is motivated by my knowledge of a "benchmark" model test for a floating offshore wind turbine that was performed ignoring the gyroscopic effects of the turbine.

Response

The committee would like to thank Dr Reed for his question.

If a floating horizontal-axis wind turbine is oriented so that the wind and waves are collinear in what would be described as "head seas" in ship terms, then the gyroscopic effect would result in the generation of yaw moments from wave-induced pitching. Similarly, if a floating vertical axis turbine were in the same condition, then the pitching motion would induce roll motions.

It is difficult to generalise about the significance of these gyroscopic effects (or what would be lost by neglecting them); the response of the horizontal axis device in yaw will depend upon the mooring-induced stiffness and the hydrodynamic damping of the floating platform in yaw, whilst the corresponding response of the vertical axis device will depend upon the transverse stability and roll damping of the floating platform. More complex issues could arise in principle if the gyroscopically-induced motions are not accounted for in the design of the turbine controller and consequently couple in some way into the turbine control system.

This serves to emphasise the complexity of the system being modelled in tank test, and the high level of difficulty of performing these tests to the state of the art.

Form of Written Discussion at the 27th ITTC Conference

Discusser	
Name	Maurizio Collu
Affiliation	Cranfield University

Name of Technical Committee or group to be discussed	Specialist Committee on Hydrodynamic Testing of Marine Renewable Energy Devices

Written Discussion (within 1,000 words of length)

There have been some recent studies investigating "hardware-in-the-loop" test techniques, where the aerodynamic forces are modelled through a numerical model implemented into a servo-motor system and controller, and this system impose the forces on a scale model of the, for example, floating support structure of an offshore wind turbine.

Even the opposite (wind tunnel test of a wind turbine scale model coupled with a servo-motor system simulating the dynamics of the floating support structure) has been tested.

What are the comments of the Committee about these techniques?

Response

The committee would like to thank Dr Collu for his interesting question.

We are aware of several studies of floating offshore wind turbines which have utilised the "hardware-in-the-loop" idea to generate some of the forces in a model test, usually with the aim of simulating forces which cannot be scaled correctly in a model test. Examples in recently published literature include tests in which the unsteady aerodynamic thrust force in a hydrodynamic test is generated by a speed-controlled fan based on measurement of the instantaneous velocity at the nacelle (e.g. Zamora-Rodriguez *et. al.*, 2014) or those in which the hydrodynamic motions of a floating platform are simulated in a wind tunnel using a hexapod (Bayati *et. al.* 2014).

This type of technique (which is also sometimes referred to as "software-in-the-loop") is certainly not unique to this application, and has previously been used in the simulation of mooring systems for deep-water offshore structures, and indeed in the simulation of PTOs in wave energy converters.

The technique clearly has some merit in terms of overcoming challenging scaling problems, such as the issues related to discrepancies between Reynolds and Froude scaling for the aerodynamic and hydrodynamic forces on a floating offshore wind turbine. There are obviously some conventional technical challenges which must be overcome in order to implement these approaches, such as achieving appropriate mass distributions, generating adequate forces in each direction of interest, and obtaining sufficiently rapid response of the actively-controlled system.

Furthermore there is always the limitation that the response of the controlled system is at best only as good as the mathematical model used to control it, and thus the model test lacks the completely physical nature of a conventional test. Nonetheless, given that these techniques are only used in cases in which a fully physical model test already involves scaling compromises, they appear to offer an interesting and promising route to improved testing methodologies.

Bayati, I., Belloli, M., Ferrari, D., Fossati, F. & Giberti, H., 2014, ‘Design of a 6-DoF Robotic Platform for Wind Tunnel Tests of Floating Wind Turbines‘ Energy Procedia, Vol 53, 2014, Pages 313–323

Zamora-Rodriguez, R., Gomez-Alonso, P., Amate-Lopez, J., De-Diego-Martin, V., Dinoi, P. & Souto-Iglesias, A., 2014, ‚Model Scale Analaysis of a TLP Floating Offshore Wind Turbine‘, Proceedings, 33rd Int. Conf. on Ocean, Offshore & Arctic Engineering, (OMAE2014), OMAE2014-24089, June 8-13, 2014, San Francisco, California, USA

Form of Written Discussion at the 27th ITTC Conference

Discusser	
Name	Maurizio Collu
Affiliation	Cranfield University

Name of Technical Committee or group to be discussed	Specialist Committee on Hydrodynamic Testing of Marine Renewable Energy Devices

Written Discussion (within 1,000 words of length)

Levelled cost of energy for offshore a wind farm is very high, and one possible solution to this problem that is being investigated is to couple wind and wave energy devices.

Do you foresee specific guidelines to test these devices? What is the status at the moment?

Response

The committee would like to thank Dr Collu for this interesting comment. The idea of utilising more than one type of renewable energy in a given device is superficially attractive, with the potential to allow sharing of costly components such as cabling and mooring systems. We briefly mentioned the SKWID hybrid wind and current device in the report. This device utilises vertical axis wind and current turbines sharing a common axis and generator, and allows the current turbine to “kick-start” the wind turbine. This degree of integration is more difficult to achieve with wind / wave devices. One issue which is often raised anecdotally is the trade-off in costs between the additional energy generated by the wave energy device and the additional hydrodynamic loading on foundations or moorings it causes.

A very recent review of the status of hybrid wind-wave devices can be found in Pérez-Collazo *et. al.* (2015). The authors classify the various devices proposed based on the degree of itnergration and discuss two aspects which are descibed as challenging: the substructures and the wave energy conversion.

Nonetheless the idea is still potentially interesting. However it is not immediately obvious that separate guidelines would be required for testing hybrid devices, as the guidelines adopted for stand-alone wave energy devices and offshore wind turbines cover the vast majority of the key issues.

Pérez-Collazo, C., Greaves, D., Iglesias, G., 2015, “A review of combined wave and offshore wind energy”, Renewable and Sustainable Energy Reviews, Volume 42, Pages 141–153

Form of Written Discussion at the 27th ITTC Conference

Discusser	
Name	Marc Vantorre
Affiliation	Ghent University, Belgium

Name of Technical Committee or group to be discussed	Specialist Committee on Marine Renewables

Written Discussion (within 1,000 words of length)

Referring to §6.1, last sentence: “It can also be noted that there is a clear lack of suitable experimental validation data”, it is suggested (to the new committee!) to mention the “WEC Wakes” EU FP7 project (Stratigaki *et al.*, 2014) on the physical modelling of large arrays of up to 25 generic point absorber WECs.

The WEC values database will be publicly available in less than 6 months and the purpose of the WEC wakes project is exactly to cover the knowledge gap of what is mentioned in the report as “a clear lack of suitable experimental validation data”.

Response

The committee would like to thank Prof Vantorre for his helpful comment. We believe that this study provides some valuable information for validation of numerical codes. Unfortunately the paper was published after the cut-off date for inclusion in our report. Nonetheless the main challenges we identified remain; in order to build a large array (such as that described in this study) in any available facility, it is necessary to use devices which are relatively small at full scale (typically point absorbers) and model them at relatively small scale, leading to challenging issues of uncertainty as described by Lamont-Kane *et. al.* (2013). Whilst this study clearly provides a step in the right direction, experimental validation for device types other than point absorbers and at larger scales is still generally lacking.

Lamont-Kane, P., Folley, M. & Whittaker, T., 2013, “Investigating Uncertainties in Physi-cal Testing of Wave Energy Converter Arrays”, Proceedings, 10th European Wave and Tidal Energy Conference (EWTEC 2013), Aalborg, Denmark

Stratigaki V., Troch, P., Stallard T., Forehand D., Kofoed J. P., Folley M., Benoit M., Babarit A., and Kirkegaard, J. 2014, “Wave Basin Experiments with Large Wave Energy Converter Arrays to Study Interactions between the Converters and Effects on Other Users in the Sea and the Coastal Area”, Energies 2014, 7(2), 701-734