

Analysis of the power output and the far-field effects of a 50-WEC farm using a novel coupling technique

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To reduce the likelihood of catastrophic effects of climate change, there is an urgent need to decarbonize of the world electricity supply. Consequently, all viable renewable energy sources need to be investigated for their potential to contribute to the electrical power mix. Ocean waves provide an exciting potential for clean, reliable energy, yet this source is still too costly to be commercially exploited at present.

As has recently occurred with offshore wind, a significant cost reduction of electricity from waves will come from aggregating large numbers of wave energy converters (WECs) in farms. Given the practical constraints on the size of individual WECs derived from first principles, it is likely that an electrical node comparable to the size of a large offshore wind turbine will be provided by an array or cluster of closely spaced WECs. Therefore, the most likely scenario for commercial WEC farms will be one of multi-array farms consisting of sparsely spaced WEC arrays of densely packed WECs. However, unlike single WEC turbines, the power output of the arrays and the WEC farms will change depending on the layout of both the WECs and the WEC arrays because of hydrodynamic interactions in these arrays.

One of the problems in studying the impact of large WEC farms is choosing an appropriate level of granularity in the numerical simulation of the hydrodynamic effects. Resolving too many equations leads to a loss in computational efficiency while fast approaches such as spectral models do not provide a sufficient level of detail and do not resolve the phase relationships that lead to large fluctuations in power output.

Our novel solution is to couple a BEM code in the areas immediately surrounding the WECs and propagate the perturbed waves to the surrounding farm area and beyond a wave propagation model [1]. The BEM solver utilized in this study is NEMOH [2], while the wave propagation model is the mild-slope equation package MILDwave [3]. A novel 2nd order precision iterative technique is used to calculate the wave field for a wave farm composed of several arrays [4].

In this presentation, we demonstrate the results of a numerical study which traces the effect of various layouts to the power output of a wave farm composed of several clustered arrays. The study utilizes a staggered configuration of shallow draft heaving buoys to mimic a realistic clustered WEC array. The effect of varying array separation distances and wave incidence angles are demonstrated for many regular and irregular wave conditions.

The effects of changing the incident wave conditions and the layout on the WEC farm are explained in a qualitative and quantitative way. The former via demonstrating the perturbed wave field in the WEC farm and the latter via a table and plot of the power output for the various configurations considered.

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References

- [1] P. Balitsky, G. Verao Fernandez, V. Stratigaki y P. Troch, «Coupling methodology for modelling the near-field and far-field effects of a Wave Energy Converter,» de *Proceedings of the ASME 36th International Conference on Ocean, Offshore and Arctic Engineering (OMAE2017)*, Trondheim, Norway, 2017.
- [2] A. Babarit y G. Delhommeau, «Theoretical and numerical aspects of the open source BEM solver NEMOH,» *Proceedings of the 11th European Wave and Tidal Energy Conference. Nantes, France*, pp. 1-12, 2015.

- [3] P. Troch y V. Stratigaki, «Phase-Resolving Wave Propagation Array Model,» de *Numerical Modelling of Wave Energy Converters*, 2016, pp. 191-216.
- [4] P. Balitsky, G. Verao Fernandez, V. Stratigaki y P. Troch, «Assessing the Impact on Power Production of WEC array separation distance in a wave farm using one-way coupling of a BEM solver and a wave propagation model,» de *Proceeding of the 10th European Wave and Tidal Energy Conference (EWTEC 2017)*, Cork, Ireland, 2017.

Keywords: WEC array; WEC farm; wave farm; power output; farm effects; array effects; hydrodynamic interaction; wave propagation model; coupling; mild-slope equations; Boundary Element Method; numerical modelling

BOOK OF ABSTRACTS



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PREFACE

This is the 'Book of Abstracts' of the 18th edition of the VLIZ Marine Science Day, a one-day event that was organised on 21 March 2018 in the MEC Staf Versluys in Bredene.

This annual event has become more and more successful over the years. With almost 400 participants and more than 100 scientific contributions, it is fair to say that it is the place to be for Flemish marine researchers and for the end-users of their research. It is an important networking opportunity, where scientists can meet and interact with their peers, learn from each other, build their personal professional network and establish links for collaborative and interdisciplinary research.

Marine scientists from all Flemish universities and scientific institutes – and representing all marine science disciplines – have contributed to this volume. The book thus illustrates the diversity, quality and relevance of the marine sciences in Flanders (and Belgium): it provides a beautiful and comprehensive snapshot of the state-of-the-art of marine scientific research in Flanders.

Pre-doc and post-doc scientists present their research in an exciting way and communicate their fascinating science – and its importance to society – to the wider public. We thus hope to demonstrate the excellence of Flemish marine science and to increase its national and international visibility.

The volume of research that is presented here holds a great promise for the future. It shows that marine science is a very lively discipline in Flanders, and that a new generation stands ready to address the grand challenges and opportunities that our seas and oceans represent.

For the second year, the Brilliant Marine Research Ideas are awarded, an initiative sponsored through the philanthropy scheme of VLIZ. We are proud to announce that last year's winners present their results here at the VLIZ Marine Science Day.

I want to congratulate all participants with their contributions, and I invite them all to become members of VLIZ and to actively participate in our events and activities in the future.

Bredene, 21 March 2018

Prof. Dr Jan Mees

General Director VLIZ

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