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PHYSICAL MODELLING OF THE WAVE FIELD AROUND AN ARRAY OF CENTRALLY CONTROLLED WAVE ENERGY CONVERTERS

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1 INTRODUCTION

To capture a substantial amount of wave energy, Wave Energy Converters (WECs) will be placed in arrays in a certain geometric configuration. WECs spaced closely together will interact, affecting the hydrodynamics of these devices and thus the total power absorption of the WEC array. These are called 'near-field effects'. Furthermore, a WEC array will also influence the wave field in the wake zone behind the farm, the so-called 'far-field effects'. This affects the coastline and other users of the sea near the WEC array. Both near- and far-field effects are caused by the modification of the incident waves due to wave radiation by and wave diffraction around the WECs. To understand these effects, it is therefore necessary to study the wave field in and around a WEC array. This study investigates the wave field modifications for an array of up to five heaving point absorber WECs that was tested at the Coastal & Ocean Basin Ostend. To optimize the absorbed power of the array, the Power Take-Off (PTO) devices are controlled using a centralized control algorithm, influencing the hydrodynamic behaviour of the WECs and hence the wave field. The research fits into the larger scope of the 'WECfarm' project, which has been initiated to address the lack of available realistic and reliable data covering large centrally controlled WEC arrays to validate numerical models (Vervaet et al., 2022).

2 EXPERIMENTAL SETUP

This study uses the WECfarm WEC (Vervaet et al., 2022). It is a truncated cylindrical buoy with a diameter of 0.60 m and a draft of 0.16 m. A permanent magnet synchronous motor is used as the PTO system. The rotary motion needed for the motor is obtained by converting the vertical motion of the buoy with a rack and pinion system. Every WEC is mounted to a truss structure via a square frame that has dimensions 1 m by 1 m. For this study two different array configurations are investigated. Firstly, a staggered five-WEC array is considered. It is shown in Figure 1 (left). The distance from the inner WEC to the outer WECs is 1.41 m. This is the minimum distance when placing the WEC frames corner-to-corner. By removing WEC D and WEC E from the array, a triangular three-WEC array is obtained as shown in Figure 1 (right). This is the second configuration tested.

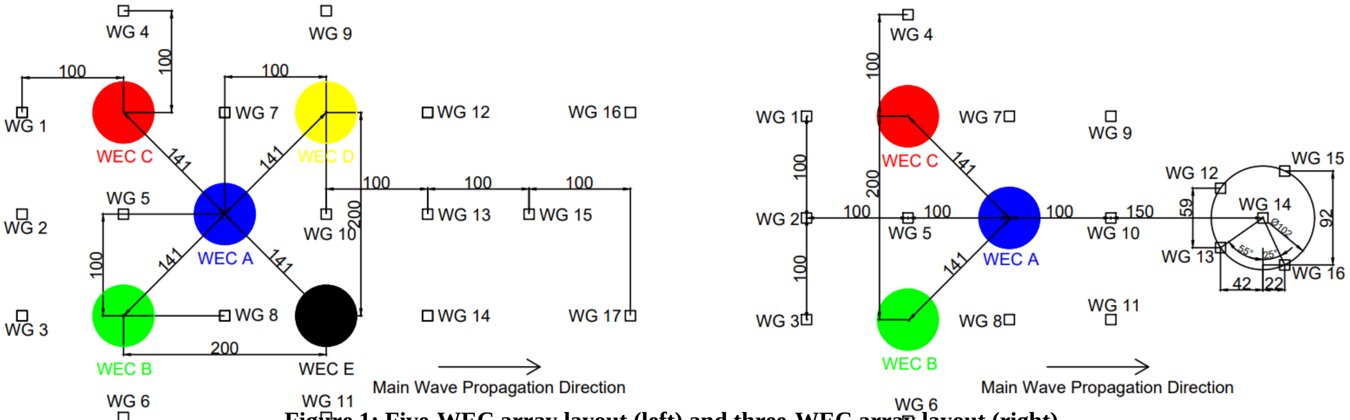

Figure 1: Five-WEC array layout (left) and three-WEC array layout (right).
The locations of the wave gauges to measure the wave field are indicated with squares. Dimensions are given in centimeter.

Figure 1 also shows the locations of the wave gauges. Wave elevations in and around the five-WEC array are recorded using an array of 17 wave gauges (WGs) to characterize the wave field. A similar wave gauge layout is used for the three-WEC array. It consists of 16 wave gauges, of which five are placed in a CERC 5 wave gauge array in order to measure the wave directionality in the wake zone of the three-WEC array. Figure 2 shows the full experimental setup of the five-WEC array (left) and the three-WEC array (right) at the Coastal & Ocean Basin Ostend.

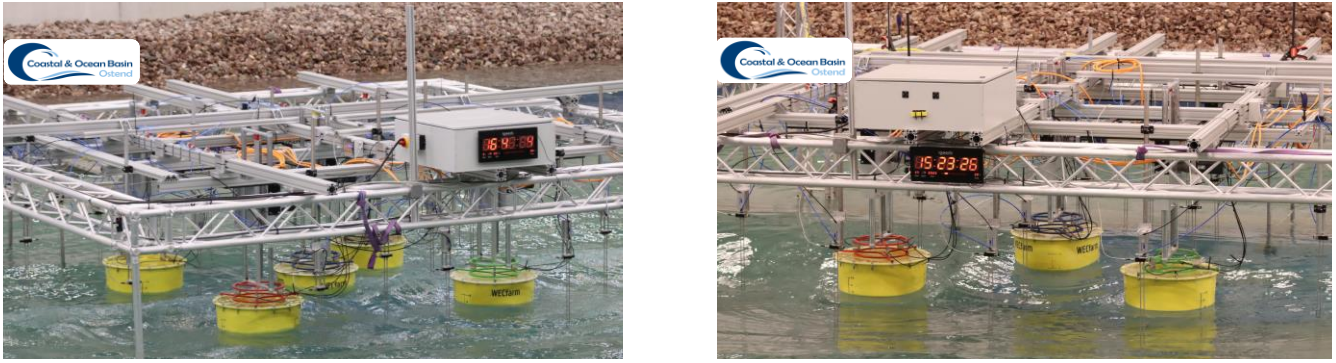

Figure 2: Experimental setup of the five-WEC array (left) and three-WEC array (right) at the Coastal & Ocean Basin Ostend

3 DESIGN OF EXPERIMENTS

The wave field is studied for irregular long-crested and short-crested waves, resembling both realistic operational and extreme conditions. Six irregular long-crested wave conditions are selected, of which the peak periods T_p, significant wave heights H_s and wave lengths L are summarized in Table 1. The long-crested waves are characterized by a JONSWAP spectrum with a peak-enhancement factor $\gamma = 3.3$ and follow the main wave propagation direction as indicated in Figure 1. The peak period of the first sea state corresponds to the resonance period of the WEC. Moreover, the WEC hydrodynamics, and thus the wave field, are influenced by the PTO controller. Both an independent Proportional (P-) controller, considering no hydrodynamic interaction, and a centralized P-controller, considering the full hydrodynamic model of the array, are tested. Controllers are most useful in cases where the wave periods are larger than the resonance period of the WEC and that is why only wave conditions with peak periods larger than 1.07 s are selected. Sea state 5 resembles an extreme sea state. Finally, two irregular short-crested wave conditions are also considered. These are obtained by multiplying the JONSWAP spectra of sea state 1 and 4 with a spreading function.

Table 1: Overview of the irregular long-crested wave conditions tested

	Sea state 1	Sea state 2	Sea state 3	Sea state 4	Sea state 5	Sea state 6
T_p [s]	1.07	1.20	1.50	1.80	2.00	1.35
H_s [m]	0.12	0.12	0.16	0.16	0.30	0.14
L [m]	1.79	2.24	3.40	4.59	5.36	2.80

4 CONCLUSIONS AND OUTLOOK

PTO control is used to optimize the power absorption of WEC arrays. This control affects the WEC hydrodynamics and therefore control influences how the wave field changes in and around WEC arrays. This study investigates the wave field modifications for a three- and five-WEC array for an independent and centralized P-controller. Six irregular long-crested and two irregular short-crested wave conditions are considered, resembling operational and extreme wave conditions. Additional irregular short-crested wave conditions could be tested in a future experimental campaign along with more advanced PTO controllers. Ultimately, the data from this study will serve to validate numerical models.

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