Proceedings of the 9th International Conference on Physical Modelling in Coastal Engineering (Coastlab24)
Delft, Netherlands, May 13-16, 2024

Extended Abstract, DOI: 10.59490/coastlab.2024.718

PHYSICAL MODELLING OF A CENTRALIZED CONTROLLED ARRAY OF FIVE WECFARM WAVE ENERGY CONVERTERS

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KEYWORDS: wave energy converter (WEC); WEC array; WECfarm; physical modelling; centralized control

1 INTRODUCTION

Point absorber wave energy converters (WECs) closely placed in array hydrodynamically interact through wave radiation and diffraction. The power absorption by these WECs is optimised by altering the WEC dynamics through the control of the Power Take-Off (PTO). As the WEC dynamics are changed, the hydrodynamic interactions change as well. Therefore, the PTO control should be optimized taking all these interactions into account, referred to as centralized control. The 'WECfarm' project has been initiated to study WEC arrays, and to address the research gap on available realistic and reliable data on WEC array tests to validate numerical models (Vervaet et al., 2022). This work discusses the experimental design, implementation and testing of a centralized controlled array of five 'WECfarm' heaving point absorber WECs, tested at the Coastal and Ocean Basin Ostend.

2 EXPERIMENTAL SETUP

The 'WECfarm' point absorbers have a truncated cylindrical buoy with radius 0.30 m and draft 0.16 m. The motion is restricted to the heave direction, and the PTO system of each WEC is designed as a rotary permanent magnet synchronous motor (PMSM) connected to a gearbox, which drives a linear rack and pinion system (Vervaet et al., 2022). Figure 1 (left) shows the planview of the five-WEC array, with dimensions in m. A staggered five-WEC array layout is considered for which each of the outer WECs has an identical distance of 1.41 m to the inner WEC. This distance corresponds to $\sqrt{2}$ m, when the 1 m by 1 m steel frames are placed corner to corner, as displayed in Figure 2 (right). In the staggered five-WEC array layout, the inner WEC can act as a proxy of a WEC surrounded by other WECs in a multi-dimensional infinite staggered WEC array, illustrated in Figure 1 (right).

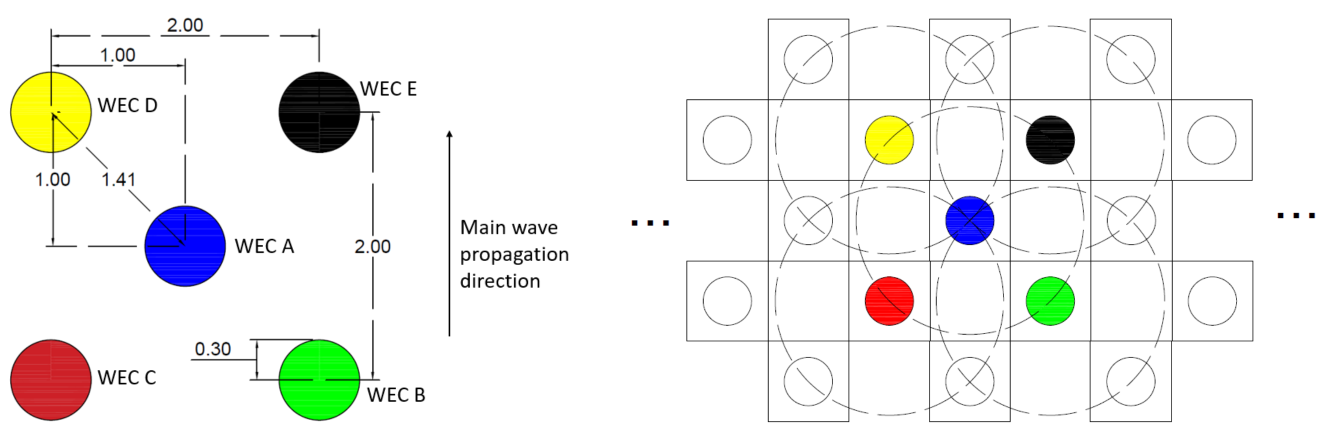

Figure 1. Planview of the five-WEC array layout tested at the Coastal and Ocean Basin Ostend, dimensions in m (left), and definition sketch of a multi-dimensional infinite staggered WEC array (right).

The experimental campaign took place at the Coastal and Ocean Basin Ostend in Belgium. Figure 2 shows a picture of the setup as built in the wave basin, with an overview on the left and a detail on the right. The WECs are attached to a truss construction. The main wave propagation direction, as indicated on Figure 1, corresponds with wave generation from the right to the left on Figure 2.

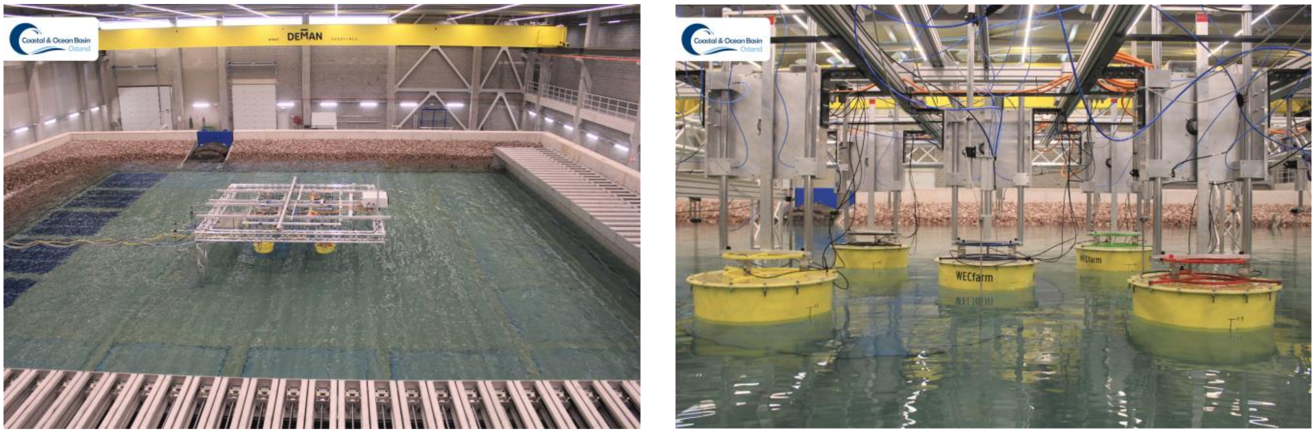

Figure 2. The experimental setup of the five-WEC array the Coastal and Ocean Basin Ostend: overview (left) and detail (right).

3 DESIGN OF EXPERIMENTS

A causal impedance matching Proportional (P) controller is used, approximating the complex conjugate of the intrinsic impedance of the WEC array in the peak wave frequency of the design sea state (Coe et al., 2021). The 5x5 intrinsic impedance matrix is obtained by executing forced oscillation system identification tests (Bacelli et al., 2017). The PTO force vector for the five-WEC array is given in Equation (1).

$$\begin{bmatrix} F_{PTO,A} \\ F_{PTO,B} \\ F_{PTO,C} \\ F_{PTO,D} \\ F_{PTO,E} \end{bmatrix} = -\begin{bmatrix} C_{AA} & C_{AB} & C_{AC} & C_{AD} & C_{AE} \\ C_{BA} & C_{BB} & C_{BC} & C_{BD} & C_{BE} \\ C_{CA} & C_{CB} & C_{CC} & C_{CD} & C_{CE} \\ C_{DA} & C_{DB} & C_{DC} & C_{DD} & C_{DE} \\ C_{EA} & C_{EB} & C_{EC} & C_{ED} & C_{EE} \end{bmatrix} \begin{bmatrix} \dot{z}_A \\ \dot{z}_B \\ \dot{z}_C \\ \dot{z}_D \\ \dot{z}_E \end{bmatrix} \quad (1)$$

In case no hydrodynamic interaction is considered, quoted as independent control, the PTO force F_{PTO} for each WEC is calculated as its heave velocity $\dot{z}$ multiplied with a damping coefficient *C*. A minus sign is added as F_{PTO} should oppose $\dot{z}$. For independent control, the non-diagonal elements of the 5x5 damping coefficient matrix are equal to zero. In case the hydrodynamic model of the full array is considered, quoted as global or centralized control, these non-diagonal elements differ from zero, and yield a F_{PTO} for each WEC which depends on the velocity of all the WECs. Short- and long-crested irregular waves are used to obtain realistic operational and extreme sea conditions.

4 CONCLUSIONS AND OUTLOOK

To optimize the power absorption of WEC arrays, the PTO control of the WEC array can take the occurring hydrodynamic interactions between the WECs into account, referred to as global or centralized control. In the presented experimental campaign with an array of five ‘WECfarm’ WECs, the power absorption for independent control is compared to the one for centralized control, for a causal impedance matching P controller, for a range of short- and long-crested irregular waves. Future testing should target higher effectiveness for broadband waves, as the performed experimental campaign limits the impedance matching approach to the peak wave frequency of the sea state.

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