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WAVE TANK EXPERIMENTS OF A NOVEL FLOATING PHOTOVOLTAIC SYSTEM

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1 INTRODUCTION

Solar photovoltaic (PV) energy, alongside other renewables, is expected to lead the energy sector. However, large-scale ground-mounted PV generation requires a significant amount of land, prompting conflict with other uses. On these grounds, floating PV (FPV) technology is gaining interest (Rosa-Clot and Tina, 2020). While commercial FPV is already being deployed on freshwater bodies, efforts are being undertaken towards harnessing solar energy on the untapped surface of the ocean (Oliveira-Pinto and Stokkermans, 2020). The main challenge is to develop a cost-effective technology capable of withstanding extreme environmental conditions whilst ensuring platform stability, to minimize misalignment of the solar panels that could result in significant efficiency loss (Claus and López, 2022). Several marine concepts have been proposed, with most of them leaning towards flexible design strategies, similar to those applied in freshwater (Claus and López, 2023).

Researchers at the University of Oviedo, Spain, are developing a novel FPV system that is specifically designed for marine conditions, following a rigid design approach (Figure 1). The concept leverages the combination of two distinct elements: a double-axis solar tracker, maximizing solar energy generation, and a tension-leg platform (TLP), ensuring structural performance and stability. This research showcases the wave tank experiments, under regular wave action.

Figure 1. Conceptual design of the marine FPV system, HelioSea (left), alongside a real photo of the experimental setup (right).

2 EXPERIMENTAL SETUP

To advance the technology readiness level of the proposed device, physical modelling was essential to characterize its performance in waves. The concept was tested at the wave basin of the Hydraulics, Water Resources and Environment Division of the Faculty of Engineering of the University of Porto (Figure 2). This wave basin measures 12 × 28 × 1.2 m, with an additional 1.4 m of water depth in its central pit. These dimensions were considered in conjunction with the Froude approach to establish the scale of the model and the desired wave conditions, at a 1:30 scale.

A total of 27 combinations of wave heights and periods were generated with a wave-maker system that comprises 16 piston-type wave paddles. During the experiments, the water surface elevation was monitored using 8 resistive-type wave probes. Furthermore, the model's 6-degree-of-freedom (6-DoF) motions were tracked using an optical motion capture system, utilizing 3 fixed infrared cameras and 4 markers on the model for this purpose.

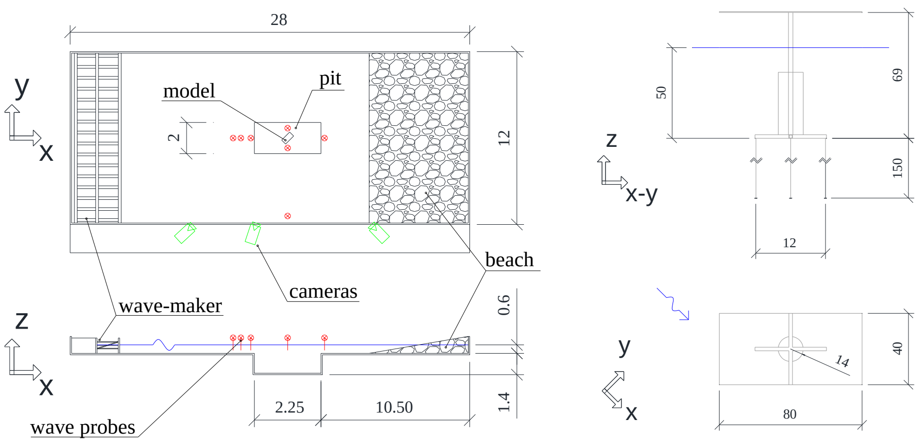

Figure 2. Plan view of the wave tank and the setup (left, units in [m]) and dimensions of the physical model (right, units in [cm]).

3 MAIN RESULTS, CONCLUSIONS AND FUTURE WORK PERSPECTIVES

The experimental tests allowed for the characterization of the floating system's response to waves, including the impact of key wave parameters on its behavior (Table 1). Several noteworthy conclusions are summarized below.

- As expected for a platform of its type, vertical motions – i.e. pitch ($R_{y'}$), roll ($R_{x'}$), and heave (z') – were negligible. This aspect is paramount, as pitch rotations ($R_{y'}$) have a negative impact in the electricity generation.
- In the proposed concept, yaw rotations ($R_{z'}$) are unrestrained and may lead to misalignments of solar panels. However, low motion amplitudes were observed. In fact, the corresponding response amplitude operator presents values below 3°/m for all the periods tested.

Future work should incorporate hydrodynamic numerical modeling to gain insight into the device's response and to optimize its design. The latter will contribute to a reduction in the structure's cost and the overall levelized cost of energy.

Table 1. Motion amplitudes for selected tests (in prototype scale with respect the CoG).

H [m]	T [s]	surge, x' [m]	sway, y' [m]	heave, z' [m]	roll, $R_{x'}$ [°]	pitch, $R_{y'}$ [°]	yaw, $R_{z'}$ [°]
1.8	8	0.54	0.05	0.04	0.20	0.12	0.23
1.8	16	2.60	0.18	0.09	0.24	0.28	0.90
2.4	8	0.72	0.06	0.06	0.26	0.16	0.30
2.4	16	3.40	0.24	0.12	0.32	0.37	1.20

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