THE BLUE GROWTH FARM PROJECT: SET-UP OF A 1:15 AT SEA EXPERIMENT ON A NOVEL MULTI-PURPOSE FLOATING PLATFORM

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KEY POINTS

- *EU project "The Blue Growth Farm" proposes an innovative multi-purpose floating platform concept*
- *BGF concept integrates offshore aquaculture with wind and wave energy production*
- *The paper presents the arrangement and planning of a 1/15 experimental campaign at sea*
- *It is aimed to demonstrate concept feasibility and to investigate coupled structure dynamics*
- *Details about platform scaling and sensor arrangement are also provided*

1 INTRODUCTION

Aquaculture and renewable energies have a big potential at sea, both in production and growth, but further progress is needed for multi-purpose platforms to be implemented in offshore environment. The Blue Growth Farm project, funded by EC under the programme H2020 (grant number 774426), aimed at developing and demonstrating an automated, modular, and environmentally friendly multi-functional platform for open sea farm installations, equipped with wind turbine, Wave Energy Converters (WECs) and aquaculture cages. The project, lasted almost four years, covered different aspects: from the technical challenges to the business plan, considering the social impact of such structures as well.

In this context, two experimental activities have been performed to study the platform dynamics, demonstrate the concept feasibility and validate the numerical models, focusing on the coupled effects due to the subsystems interacting among them and with the main structure. The former was carried out on a small-scale model (1/40) at ECN (Nantes, France) indoor facilities in October 2020. The latter was instead performed at sea, in the Natural Ocean Engineering Laboratory, NOEL (Reggio Calabria, Italy) on an aero/hydro outdoor prototype of the platform (1/15) in 2021.

Section 2 provides a brief the description of the prototype tested at NOEL. Section 3 reports an overview of the experimental campaign planning and the architecture of measuring system. Concluding remarks are reported in Section 4. Some results of the experiment are shown in a companion paper (*Ruzzo et al.*, 2022).

2 THE AERO-HYDRO OUTDOOR PROTOTYPE "AURORA"

The aero-hydro (a/h) outdoor prototype (named "Aurora") represents a scale model of the BGF concrete platform (see *Lagasco et al.*, 2019). The prototype has been designed accounting for scaling issues, safety, regulatory and environmental constraints. Due to the complexity of the platform, integrating different subsystems which generally follow different scaling laws, a review of the multi-physics scaling strategies for the subsystems usually embedded in multi-purpose floating platforms has been performed to define the geometry of the prototype to be tested at NOEL (*Ruzzo et al.*, 2021). In particular:

- the steel caisson-based platform represents a 1/15 Froude-scaled version of the full-scale platform in terms of geometry, mass and inertia characteristics;
- the aquaculture prototype system is composed of 6 cubic nets, designed by Froude-scaling the external dimensions and by tuning the twine length and diameter to preserve the net solidity ratio, while minimizing the alteration of the Reynolds number-dependent drag coefficient;

- the wind turbine is installed in the front-side of the structure. It represents a model of the DTU 10 MW reference floating offshore wind turbine, designed to achieve a Froude-scaled thrust under the design wind-wave conditions at NOEL site (performance scaling);
- the WECs are based on the patented REWEC3 concept and are installed on the front-side of the prototype. Again, a performance-scaling approach has been chosen, i.e. the external geometry represents the 1/15 scaled version of the full-scale and the internal dimensions have been determined so to absorb an amount of energy as close as possible to that expected at full-scale;
- the umbilical cable and its innovative connector have been tested just for demonstration purposes, being practically insignificant for the overall coupled dynamics, and have been hence over-scaled.

The scaling of the input loads has been obtained naturally, thanks to the exceptional conditions of the NOEL site in terms of wind, fetch, coast orientation and tides (*Boccotti, 2014*), resulting in the natural wind-induced generation of small sea states with significant wave heights H_s=0.2-0.8m, peak periods T_p=2.0-3.6s and JONSWAP-like spectra, representing Froude-scale models of the design conditions of the structure. Other local conditions, including swells and mixed sea states, are instead precious for broader frequency-domain characterization of the prototype.

The steel floater of the aero-hydro prototype has been manufactured in Ancona and has been then towed on a pontoon to the Port of Reggio Calabria, where the the wind turbine and other equipment have been integrated before moving the prototype to NOEL lab (Figure 1). Once the aero-hydro outdoor prototype was moored, the remaining sensors and equipment have been installed and connected to the acquisition units on-board and the electrical connection with the land has been finalized. The connector and umbilical cable have been realized in Spain, moved to NOEL lab on a track and installed on the platform on July 2021, as well as the nets as detailed in the following section.

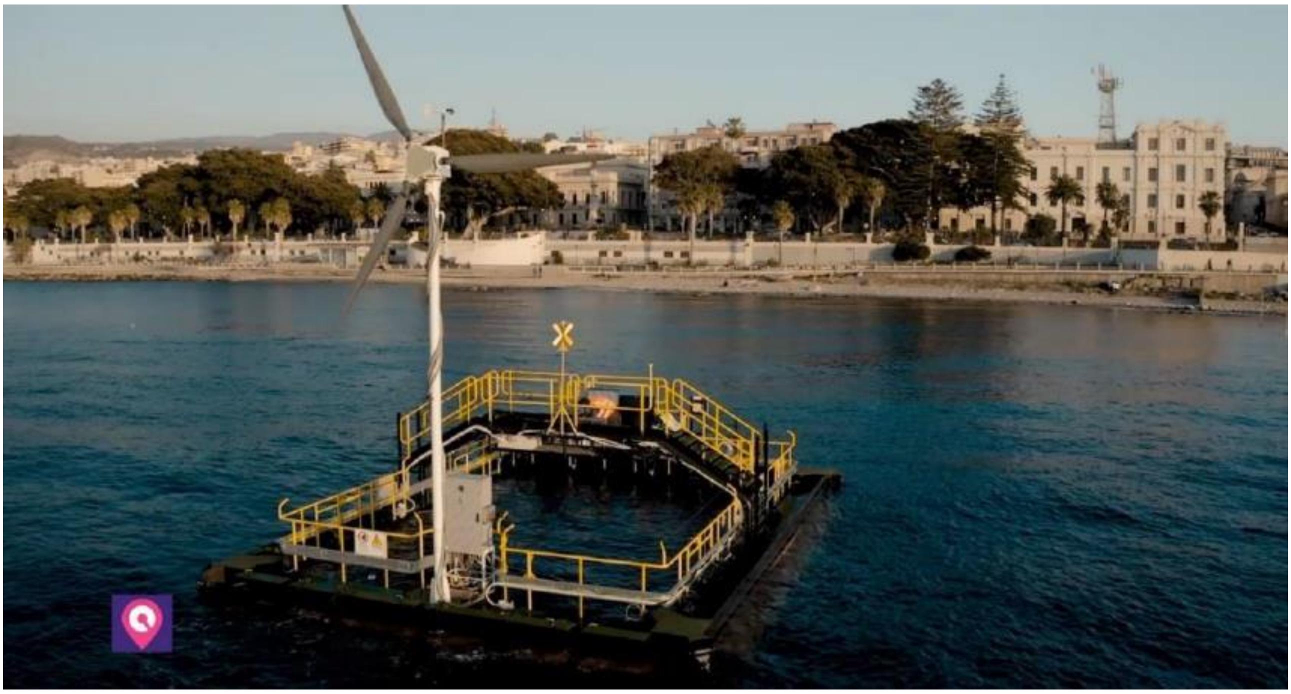

Figure 1. *Aero-hydro (AURORA) outdoor prototype drone view from sea.*

3 THE EXPERIMENTAL CAMPAIGN: AIMS AND PLANNING

The experimental campaign at NOEL lab lasted 9 months (from March 2021 to January 2022) and has been planned with a two-fold aim:

1. to demonstrate the feasibility of the concept at a relatively large scale in relevant environment (at sea), including the multi-technology functioning and integration;

2. to collect valuable field data about the fully-coupled structure dynamics, with and without any of its technologies. This will provide a deep insight on the complex physics of the interaction between the different sub-systems and will be crucial for the numerical model final validation.

In order to study the influence on the technologies installed on-board on the overall dynamics and obtain useful information for the validation of the numerical model, different prototype configurations have been tested during the experiment (Table 1). When WECs are closed (configuration A), the numerical model should include only the water mass trapped inside them, while when they are operative (configurations B, C), the WECs-structure dynamic interaction should be considered to take into account the energy absorption.

With respect to the wind turbine, in parked conditions (configurations A1, B1, C2) its interaction with the structure is given only by its weight and wind loads on the tower and the parked rotor. When the wind turbine is operative (configurations A2, B2, C1, C3), the numerical model should take into account the mutual dynamic interactions between the wind turbine and the structure. During the experiment, the wind turbine has been controlled from onshore. The presence of the fish cages (configuration C), introducing a further damping mechanism around the platform moonpool, has been tested as well.

Configuration		WECs	Nets	wind turbine	umbilical cable
Configuration A	A1	Closed	No	parked	no
	A2	Closed	No	rotation on	no
Configuration B	B1	Open	No	parked	no
	B2	Open	No	rotation on	no
Configuration C	C1	Open	installed	rotation on	no
	C2	Open	installed	parked	installed

Table 1. AURORA experimental campaign configurations.

The measuring system employed is quite complex and made up of several independent measurement stations, each with its own sensors and acquisition systems (Table 2):

1. metocean stations, aimed at measuring wind, waves and current in undisturbed field, to characterize the natural uncontrolled input environmental conditions;
2. NOEL/WAVEIT station, aimed at measuring platform motions, mooring loads, moonpool wave elevation, wave pressure field all around the structure and internal WEC pressures;
3. POLIMI station, dedicated to the measurement and real-time control of the wind turbine model;
4. RINA-C station, dedicated to the structural health monitoring (SHM) of the platform.

The measured data from each station have been acquired on-board and transmitted to the land via optical fiber, thanks to media converters. On land, data have been pre-processed, monitored in real-time for demonstration and diagnostic purposes, and memorized on dedicated hardware and on the cloud.

	Measured parameters	Sensors / Devices	Location
Platform dynamics	6-DOF rigid body motions	AHRS inertial platforms	On board
	Structural Health Monitoring (5-DOF rigid body motions included)	Optical strain gauges	On board
		Optical inclinometers	On board
		Optical accelerometers	On board
		Optical temperature sensor	On board
	Mooring loads	Load cells	On board
	Moonpool wave climate	Pressure transducers	On board
		Ultrasonic probes	On board

WECs	Water column behavior	Pressure transducers	On board
Wind Turbine	Tower deformation	Strain gauges	On board (wind turbine)
	Motions	Accelerometers	On board (wind turbine)
	Blade bending	Strain gauges	On board (wind turbine)
	Rotor speed	Encoder	On board (wind turbine)
	Blade pitch angles	Encoder	On board (wind turbine)
	Meteo	Wind-meteo station	On board (wind turbine)
Undisturbed field	Current	Current profiler	At sea
	Wave climate	Pressure transducers	At sea
		Ultrasonic probes	At sea
	Meteo	Wind-meteo station	On land
Structure surveillance		Optical+Thermal camera	On board
		Ordinary cameras	On land

Table 2. Sensors and devices employed in the experimental campaign.

In parallel to the data acquisition, two demonstrations activities have been planned and successfully performed, i.e. the test of device-to-cable connection of the umbilical cable and the connector and the test of the surveillance and security system.

4 CONCLUSION

The realization of open-sea experiments is extremely important when dealing with floating platforms, since it allows to collect useful information and valuable data to validate the numerical tools needed to describe their dynamic behaviour. In this paper, the outdoor tests of an aero-hydro 1/15 prototype of an innovative multi-purpose platform concept, developed within H2020 "The Blue Growth Farm" (BGF) EU project, are introduced. The tests were realized at sea in the Natural Ocean Engineering Laboratory (NOEL) of Reggio Calabria (Italy) from March to January 2022 on different structure configurations. Collected data were pre-processed and stored to feed further analyses, currently ongoing, including the validation of the numerical model developed within the project activities. Demonstration activities were successfully carried out as well. Results of the experiment will be presented in future publications, while a brief preview is proposed in a companion paper (*Ruzzo et al.*, 2022).

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