PLOCAN. An offshore test site for ocean energy converters

Javier González, Vidina Monagas, Xabier Remírez, Angel Luque, Joaquín Hernández, Octavio Llinás
Oceanic Platform of the Canary Islands (PLOCAN)
Carretera de Taliarte s/n, 35200 Telde, Las Palmas, Spain
javier.gonzalez@plocan.eu

***Abstract*—The Oceanic Platform of the Canary Islands (PLOCAN) is a public consortium aimed to support R&D in the fields of ocean science and technology. PLOCAN manage a marine test site providing a set of infrastructures to facilitate the development of emerging ocean energy converters. This test site is placed at the East coast of Gran Canaria island covering a marine surface of 23 km2 and it will include in the close future an underwater electrical and communication grid. This grid is designed on medium voltage cables and a power capacity of 15 MW. The electrical infrastructure is expected to operate by the end of 2015.**

Keywords—ocean energy, test site, marine environment

I. Introduction

The Oceanic Platform of the Canary Islands (PLOCAN) is a multi-purpose platform to facilitate and accelerate the research, development and innovation in the field of ocean sciences and technologies. PLOCAN is included in the Spanish Roadmap of ICTS (Unique Scientific and Technological Infrastructures) and is supported by a joint consortium between the Spanish Government and the Autonomous Government of the Canary Islands, with the help of the European Regional Development Fund (ERDF). The PLOCAN consortium was created in 2007, with the aim to construct and operate an oceanic platform placed at the East coast of Gran Canaria island. This infrastructure provides the scientific and technological community with five strategic interdisciplinary areas: an integral observatory capable of exploring deep oceans and the atmosphere, an ocean test site infrastructure, a base for underwater vehicles, an innovation platform and a highly specialized training centre, these components, incorporating the applicable criteria that follow.

In order to carry out these activities, PLOCAN has set up a marine test site equipped with a complete underwater electrical and communication infrastructure and provides facilities for deployment, installation, experimentation, testing and decommissioning of prototypes during the trial stage.

Moreover, PLOCAN is helping developers to leverage public funds to minimize cross the funding gap between R&D and commercial stages, backing them up in the administrative permits procedures and bringing societal benefits, such as balancing the energy mix, growing marine industries and creating new marine jobs, skills and infrastructures for marine and maritime sectors.

II. Marine test site

A. Context

Testing in real operational conditions is a key phase during the development of any technology in order to meet the expected efficiency established in the design specification. The technological readiness level (TRL) is the scale to measure the maturity of a technology. This scale includes nine levels from TRL1 (concept) to TRL9 (successful operation). The framework of the ocean energy converters establishes the sea testing stage from TRL 5 to TRL 9 as shown in Table I [1].

In the case of marine technologies harnessing wave or marine currents energy, several characteristics should be tested in addition to gain efficiency in the production of energy. Those devices should be corrosion resistant, be stable within extreme meteorological and oceanic conditions and also the deployment/decommissioning should be feasible at a reasonable cost. All those aspects require specific testing operations in different timeframes and environmental conditions, and the results are the key input for the final commercial design and certification.

A large number of European companies are increasing the demand in berths for full scale grid connected ocean energy converters. Each type of technology is currently at a different stage of development, but all of them need specific ocean infrastructures that facilitate the test of prototypes from TRL 5 to TRL 9 to accelerate their commercial development.

TABLE I. TRL stages.

Stage / TRL	Description
Stage 1 TRL1-3	Concept validation. Prove the basic concept from wave flume tests in small scale
Stage2 TRL 4	Design Validation. Subsystem testing at intermediate scale, Flume tests scale 1:10, Survivability; Computational Fluid Dynamics; Finite Element Analysis Dynamic analysis; Engineering Design (Prototype); feasibility and costing
Stage 3 TRL 5-6	Testing operational scaled models at sea + Subsystem testing at large scale
Stage 4 TRL 7-8	Full-scale prototype tested at sea
Stage 5 TRL 9	Economic Validation; Several units of pre-commercial machines tested at sea for an extended period of time.

The PLOCAN test site started the activity in 2010 [2] showing competitive advantages such as excellent weather conditions, reasonable potential of wave energy, infrastructure and logistics, wide bathymetry range and an electrical substation near the coast to deliver the electricity generated.

PLOCAN contributes to the testing and demonstration phase, providing the site duly equipped with a complete underwater electrical infrastructure, a remote surveillance and monitoring services, an observation program including a real time data management system on land. It will allow the research, validation, demonstration, analysis and exploitation of innovative marine devices and technologies.

Moreover, the monitoring capabilities provided by the infrastructure allow the live observation of the prototypes and measurements of key environmental parameters.

In addition to these facilities provided by the test site itself, the users will benefit from previous experiences and lessons learned, logistics activities and simplified administrative procedures to install the prototypes, including environmental issues.

B. Location

The test site location has been selected to balance several requirements such as ocean energy resource, logistics, facilities in the nearby area, availability of the operational weather window and restriction of activities in the marine area (fisheries, maritime transport, marine protected areas, etc.). The test site is located at the East coast of Gran Canaria as shown in Fig 1.

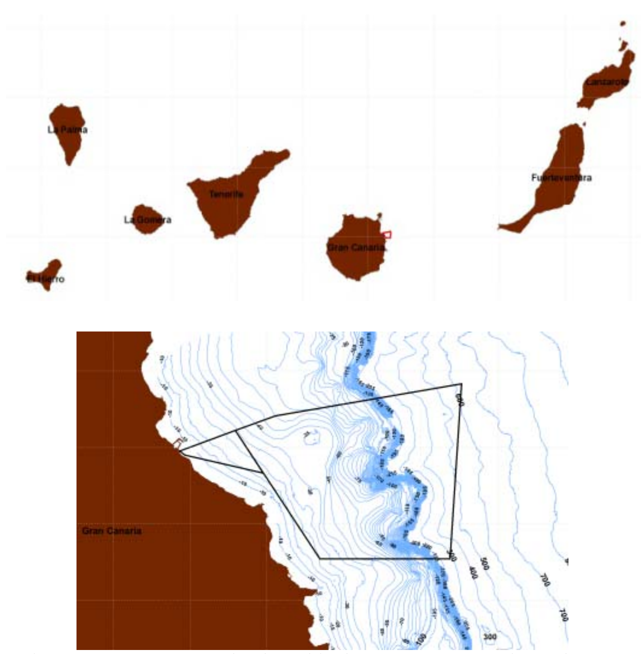

Figure 1. Top: Canary Islands archipelago. Bottom: test site at the East

C. Marine environment

Environmental sustainability must be assured along the testing process so it is necessary to know as much as possible about the marine environment conditions in the area where the activity will be developed. Additionally, the test site offers the possibility to implement environmental impact assessment methodologies and monitoring of environmental key target parameters.

Marine energy resource assessment conducted in Canary Islands shown in Fig. 2 [3] reveals that the East coast of the island has suitable conditions for a test site, with around 3000 equivalent hours of offshore wind and about 8 kW/m of wave power. However, it is shown that the best conditions for commercial exploitation of offshore wind are the Southern part of the islands, while the North coast shows the best location for harnessing wave energy. The test site is located in an area of compromise where both energy resources (wave and offshore wind) are balanced. Other advantages are the facilities of the ports close to the test site, a large operational weather window along the year, the availability of grid connection, etc.

Environmental base line studies have been conducted during the last years aimed to characterize the bathymetry, seabed sediments, geophysics, geotechnics, water quality, biodiversity and submarine noise, which will be used to set a permanent environmental monitoring program.

The results from several surveys related with seabed sediments are shown in Fig. 3. The test site bathymetry has been studied with a multibeam echo-sounder.

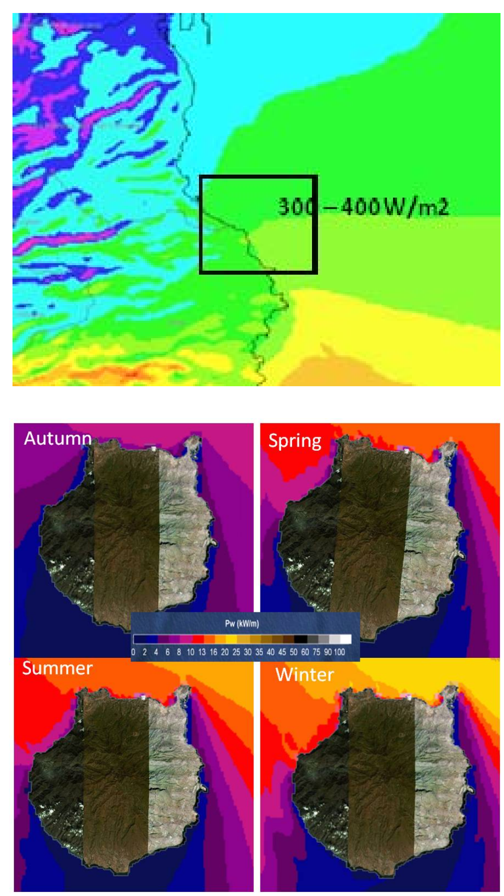

Figure 2. Top: Wind power at 80 meters height expressed in W/m2. Bottom: Average wave power expressed in kW/m.

The range of depths included in the test site goes from coast to 600 meters. The seabed morphology has been analyzed with a side scan sonar and grab sampling, showing some heterogeneity, with areas of sand and areas of rocks. The unconsolidated sediment layer thickness was characterized using a subbottom profiler TOPAS. This survey reveals areas with a sediment layer thickness up to 12 meters suitable for drag embedded anchors.

Biodiversity shown in Fig. 4 has been characterized with a submarine video camera and grab sampling. Maërl communities have been identified although they are not well conserved. This community is formed by *Lithothamnium coralloides* and *Phymatolithon calcareum* species. The algae *Avrainvillea canariensis* is represented in the area being a species of interest for the Canarian ecosystems according to the Regional Environmental legislation.

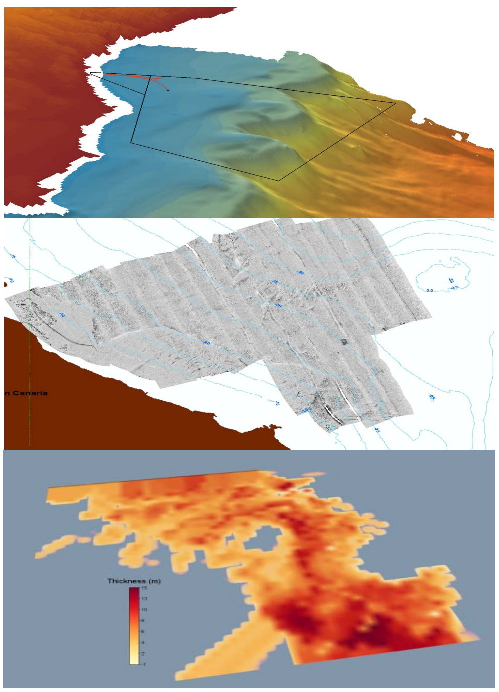

Figure 3. Top: Bathymetry. Middle: Seabed morphology from side scan sonar survey. Bottom: Seabed sediments: Unconsolidated sediment layer thickness measured with a subbottom profiler.

Figure 4 Benthic communities. Top left: Maërl (*Lithothamnium coralloides* and *Phymatolithon calcareum)*. Top right: *Avrainvillea canariensis*. Bottom left: *Anapagarus laevis*. Bottom right: *Eunice vittata*

The magnetic field shown in Fig. 5 has been characterized using a marine magnetometer in order to detect metallic objects in the seabed. The only anthropogenic anomaly is related with the shipwreck ARONA, a vessel of 70 m length placed at 30 m depth.

The water quality is seasonally analyzed on 12 stations studying parameters as temperature, salinity, pH, nutrients, dissolved oxygen, heavy metals, hydrocarbons and turbidity. The ocean temperature ranges from 22ºC at the surface to 8ºC at 1000 meters depth as shown in Fig. 6.

III. GRID CONNECTION

Ocean energy converters undergoing trials in the area require a marine electrical transmission system and cable routes to evacuate the electricity and transmit data in real time. In this context PLOCAN will provide an electrical and communication grid connection that will consist of an underwater section, as shown in Fig. 7 and a short land section to allow the connection of the marine infrastructure to the national transmission grid on land. The connectors in the cables tail are located at a distance from the coast of about 5 km. It will ensure minimum loss of power during the transmission and the use of medium voltage cables. The electrical infrastructure will operate at 13.2 kV and is capable of delivering 15 MW of power within the range of ±1% of 50Hz. The developers shall be able to operate its devices with an export power factor of 0.8.

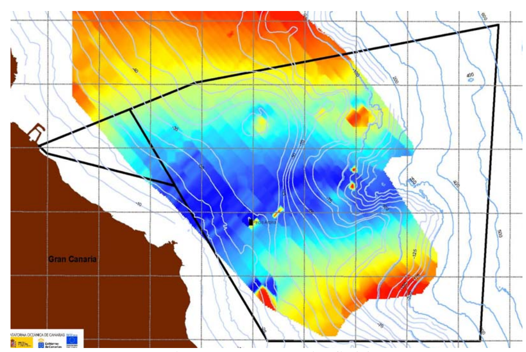

Figure 5. Magnetic field

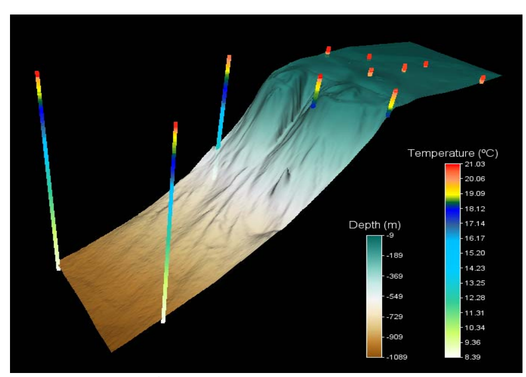

Figure 6. Ocean temperature

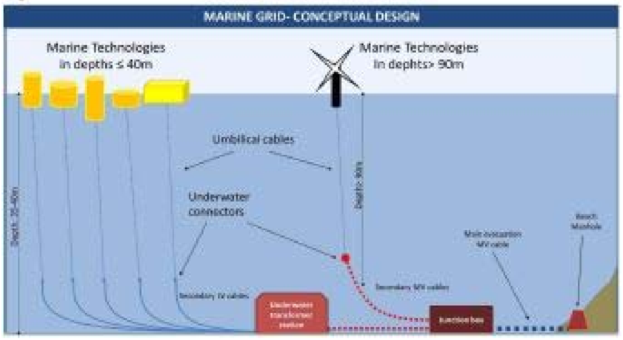

Figure 7. Electrical grid

The offshore infrastructure connects the prototypes in the sea with the shore station trough a beach manhole where the transition from the submarine cable to the land cable is done. The offshore grid essentially comprises two hybrid cables (5 MW, 13.2 kV, 50Hz, copper AC/DC and optical fibers), an electrical connection system (underwater dry-mate hybrid connectors), an underwater power transformer station and auxiliary elements, such as hardware and software for data analysis and buoys to delimitate the deployment area.

The onshore grid essentially comprises an underground power cable (15 MW, 13.2 kV, copper AC/DC, optical fiber), a 13.2/66 kV power transformer with associated switchgear and power factor correction equipments to ensure delivery to the grid within technical specification, an associated research control centre for data monitoring and processing and other auxiliary elements, such as hardware and software for monitoring the electrical equipment in the substation.

PLOCAN started in 2013 a tendering process for the construction and installation of the submarine electrical grid. The cables are expected to operate by the end 2015.

IV. REGULATORY FRAMEWORK

A severe national regulation and administrative legislation must be accomplished in order to obtain the consenting from the National and Regional authorities to install the underwater electrical infrastructure and also to obtain the regular permission required to undertake the deployment, installation and the anchoring of marine infrastructures.

During the administrative procedure a large number of government agencies and public bodies are involved in the evaluation of the project. The main bottlenecks are the lack of a single consent process for project approval and the uncertainty of timeframes. These aspects make an obstacle to the development and commercial evolution of the marine energy sector in Spain. PLOCAN initiated in 2012 the consenting process established by the National and Regional regulations. The process finished in March 2014 with the permit corresponding to the marine space occupation. The permits obtained include the administrative authorization issued by the General Directorate of Industry from the Canarian Government, the environmental impact declaration issued by the General Directorate of the Nature Protection from the Canarian Government, the test site area reservation issued by the General Directorate of Coast and Sea Sustainability of the Spanish Ministry of Agriculture, Food and Environment and the permit to connect the infrastructure to the national grid issued by the transmission agent and operator of the Spanish electricity system.

V. PROJECTS

The WELCOME project was leaded by the Spanish company PIPO Systems during 2012 [4]. This project tested a scaled 1:5 wave energy converter prototype at PLOCAN test site. At the moment, the project UNDIGEN is underway [5] partially funded by the Spanish Government and leaded by the Spanish company WEDGE GLOBAL. The aim of the project is the construction and testing of a wave energy converter prototype. It has a 200 kw PTO installed in a 30 m long device, with a dry weight of 140 tonnes. It was deployed at sea in March 2014. It was constructed in Cantabria (Spain) and assembled at Las Palmas port in Gran Canaria.

Figure 8. UNDIGEN prototype deployed in the test site

ACKNOWLEDGMENT

This work has been partially supported by the European Regional Development Fund (ERDF acknowledgments in the unnumbered footnote on the first page.

REFERENCES

[1] OES IA Document No. T02-00 (2010). Development of Recommended Practices for Testing and Evaluating Ocean Energy Systems.

[2] J. González, J. Hernández, O. Llinás: PLOCAN: Toward establishing an oceanic testbed for ocean energy converters, 3rd International Conference on Ocean Energy- ICOE 2010, Bilbao.

[3] Instituto para la Diversificación y Ahorro de la Energía (IDAE) (2007). www.idae.es

[4] WELCOME Project (Wave Energy Converter Multiple Lift Spain): 1:5 scale. Demonstration System PISYS APC-technology applied to observing systems offshore marine environment (2009). PIPO Systems. Ref PEN-120000-2009-25.

UNDIGEN Project: Wave Power Generation Functionality Systems (2011) Global Wedge. Record IPT-2011-1770-920000.