FIELD TESTING IN ON-SHORE OWC WAVE POWER PLANTS

[1]AITOR J. GARRIDO, [2]AMPARO VILLASANTE, [3]IZASKUN GARRIDO

Automatic Control Group, University of the Basque Country
E-mail: [1]aitor.garrido@ehu.es

Abstract - Ocean wave energy has de potential to satisfy 15% of EU energy demand, cutting 136 MT/MWh off the CO2 emissions by 2050, as stated by the EU Energy Road Map. Analogously, the Spanish Renewable Energies Plan specifically highlighted the Spanish marine energy potential with special emphasis in wave energy. In this context, Oscillating Water Column (OWC) converters are maybe nowadays the most promising wave energy converters, with the potential capability of sea energy harnessing from diverse on-shore and floating structures. This paper presents an analytic modeling of the wave capture chamber for a fixed on-shore OWC wave power plant. The model is particularized and parameterized for the case of the Mutriku MOWC wave power plant, located in the Spanish Basque Country coast, and then validated using both measured real wave entry data and experimental generated output power from the plant

Keywords - Modelling, Capture Chamber, Measured Data Series, Experimental-Data Validation, Wave Energy.

I. INTRODUCTION

Ocean Energy Europe has highlighted that wave energy could harness over 3000TWh/year. In particular, major efforts are being made in the Spanish Basque Country through the Nereida MOWC experimental/commercial Project developed in Mutriku[1].It consists of 16 18.5kW turbines that provide a total power of 296kW, reaching the 2.4GWh milestone in 2021 (see Fig 1).



Fig. 1. Turbo-generator modules in Mutriku wave plant

II. MUTRIKU MOWC PLANT DESCRIPTION

OWC-based converters are devices which basically turn the mechanical energy of the waves into electrical power by means of a capture chamber and a turbo-generator module.

This capture chamber consists of a fixed structure whose lower part is opened to the sea and it always remains under the Still Water Level (SWL), as shown in the scheme of Fig. 2. In this way, sea waves generate an oscillatory air flow by pushing and pulling inner air, which compresses and decompresses it. This creates a pressure difference between both sides of the turbine that makes the turbine spin. This pressure drop dp can be defined by means of the following equation [2,3]:

$$dp = C_a \frac{\rho b l_1 n}{2} \frac{1}{a_1} (v_t^2 + (r \cdot \omega_t)^2) (1)$$

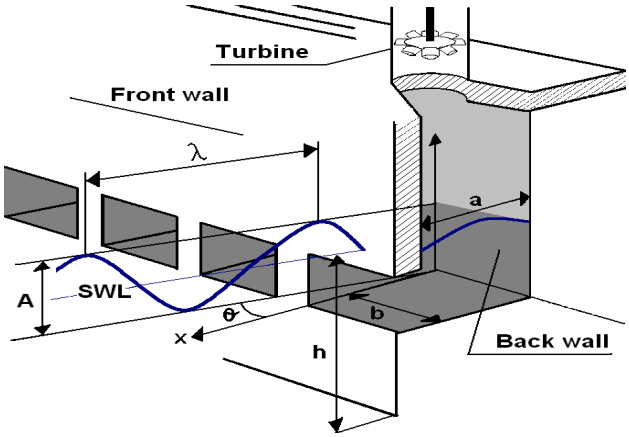


Fig. 2. Mutriku MOWC breakwaterscheme

The turbo-generator module consists of the turbine and an induction generator (usually DFIG) [4]. Despite of the airflow direction, the rotational movement of the turbine does not change due to the geometry of the turbine (see Fig 3). The mechanical equation describing the dynamics of the turbo-generator block can be expressed as follows:

$$H\dot{\omega}_t + F\omega_t + T_e = T_t (2)$$

III. MODEL STATEMENT

In order to obtain an appropriate model different system modelling approaches may be used [5]. In any case, as it may be seen from (1), input waves directly affect the airflow speed. That, considering the geometry of the chamber, it is possible to be computed as:

$$v_t(t) = \frac{8awc}{\pi D^2} \cdot \sin\frac{\pi l}{cT} \cos\frac{2\pi}{T} t (3)$$



Fig. 3. Wells turbine at Mutriku wave plant

In addition, the rotational speed related is also needed. This speed depends on the torque applied by turbo-generator module that must be obtained from (2), so that one has:

$$T_t = C_t Kr[v_t^2 + (r\omega_t)^2], (4)$$

In turn, the turbo-generator rotational speed ω_r is obtained from the well-known DFIG equations [28].
Summing up the above relationships in (1), jointly with the Torque Coefficient (Ct) and Flow Coefficient (ϕ) obtained by means of the characteristic curves of the turbine [6,7], the expression of the pressure drop through the turbine as a function of the wave entry may be obtained as follows:

$$dp = f\left(\frac{v_t}{r\cdot\omega_t}\right)\cdot\frac{\rho b l_1 n}{2}\frac{1}{a_1}\left(\left(\frac{8awc}{\pi D^2}\cdot\sin\frac{\pi l}{cT}\right)^2\cos^2\frac{2\pi}{T}t + r\cdot\omega t2\right) \quad (5)$$

IV. EXPERIMENTAL VALIDATION

Now, the OWC plant model is implemented and then validated by means of experimental data. To do so, the model is feed with real wave surface data series collected at the Mutriku plant breakwater using an acoustic Doppler current profiler RDI 600, in order to obtain the theoretical predictedpressure drop. The results can be then compared with in situ measured experimentaldPdata provided by the Mutriku OWC plant (Basque Energy Board/EVE - BIMEP) for the same time period.
As it may be observed from Fig. 4, results show an excellent matching rate between the values predicted by the model and experimental measured data.

V. CONCLUSION

This paper presents a holistic approach to the modeling and simulation of on-shore OWC. The proposed concept builds upon the relevant previous experience, and constitutes an advance that involves state-of-the-art engineering expertise and addresses control aspects.

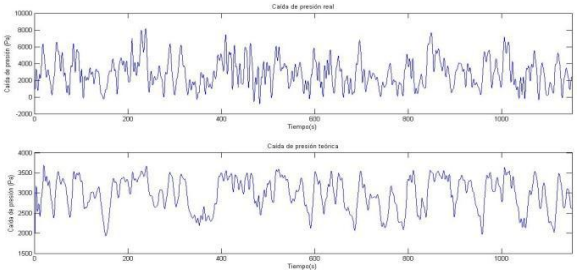


Fig. 4. Pressure drop comparison on May 12th, 6 a.m.

Results have been particularized for the case of the Mutriku's MOWC powerplant and then validated by means of experimental data.
The model contributes to integrate the wave, chamber and turbo-generator module, paving the path for its validation by means of experimental data. Results show an excellent matching between the values predicted by the model and experimental measured data, allowing further research towards digital twin and advanced control schemes implementation.

ACKNOWLEDGMENT

The authors would like to thank the collaboration of the Basque Energy Board/EVE - BIMEP through Agreement UPV/EHUEVE23/6/2011. They would also like to thank the colleagues of WAKE European project and the BIMEP for their collaboration and help.

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