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Sea Slot Cone Generator overtopping performance in 3D conditions

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ABSTRACT This note describes the influence of wave spreading, directionality and local bathymetry on the efficiency of the Sea Slot Cone Generator (SSG) wave energy converter pilot plant in Kvitsøy, Norway. This is an overtopping device i.e. its efficiency is directly proportional to the overtopping flows into the three reservoirs the device has one on top of each other. The overtopping flow rates have been measured separately for each one of them, together with incoming waves during physical model tests at Aalborg University. The influence of the significant wave height H_s and of the wave length L on the captured overtopping water is also described. It has been found that the performance of the SSG pilot plant will be negatively affected by spreading and directionality of the incoming waves as direct consequence of reduction on the overtopping flow rates of 10% - 35% compared to 2D conditions.

KEY WORDS: Wave energy; overtopping; breakwater; directional wave spectrum.

INTRODUCTION

Different Wave Energy technologies are competing in the Renewable Energy market after the huge energy potential they can benefit from has been proved. Developers´ efforts are lately concentrated on demonstrating the reliability of the devices and on lowering the price per kW of produced power.

The SSG is a wave energy converter of the overtopping type. It has a number of reservoirs one on the top of each other specially designed to optimize the storage of potential energy of incoming waves from a specific wave spectrum. Efficiency is then directly proportional to the overtopping water temporarily stored in the reservoirs. The SSG pilot plant is a 10 m wide (capturing width) structure with three reservoirs one on the top of each other and installed capacity of 190 kW. The water temporarily stored in the reservoirs on its natural way back to the sea passes through turbines spinning them up and generating electricity. The pilot project at the island of Kvitsøy in Norway has been partially funded by the European Union FP6 and has the purpose of demonstrating the functioning of one full scale module of the SSG wave energy converter, including turbines and generators in 19 kW/m wave climate (Margheritini et al. 2008). In this case the reliability issue has been initially solved by realizing an "on shore" device where loads on the structure (Vicinanza et al. 2006) are considerably smaller than offshore, while the cost per kW compares prices of electricity for remote areas supplied by diesel generators. Nevertheless, when going from offshore to shore the bathymetry can influence the overtopping flow rates i.e. the overall efficiency of the converter. Another promising application of the SSG concept is on breakwaters; but while the design of such structures is made to minimize overtopping and run up, the SSG design focuses on a combination of maximization of both these events. The purpose of the paper is to investigate the influence of 3D waves, irregular bathymetry and spreading on the overtopping flow rates for the 3 reservoirs of the SSG pilot plant at Kvitsøy location. The effect of H_s and L has also been investigated. The research has been done by mean of physical model tests in the deep wave tank of the hydraulic and coastal engineering laboratories at Aalborg University AAU equipped with 3D wave generator.

BACKGROUND OF THE STUDY

The overall efficiency of the device is the ratio between power output and the available wave power, given by the formula:

$$P_{wave} = \frac{\rho g^2}{64\pi} H_s^2 T_E \tag{1}$$

Where ρ=1020 kg/m^3, g = 9.82 m/s^2 and T_E is the energy period = m-1/m0, where mn is the n-th moment of the wave spectrum defined as:

$$m_n = \int_0^\infty f^n \Phi(f) df \tag{2}$$

Φ, is the frequency spectrum. It is possible to consider the efficiency of the SSG overtopping device as a combination of partial efficiencies for every one of which it is necessary an optimization of parameters. The hydraulic efficiency is defined as:

$$\eta_{hy} = \frac{P_{crest}}{P_{wave}} \tag{3}$$

Where:

$$P_{crest} = \sum_{j=1}^{3} q_{ov,j} R_{c,j} \rho G \tag{4}$$