Numerical Analysis of a Water Column and Structure Heave Velocity Relationship for a Floating Oscillating Water Column Wave Energy Device

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ABSTRACT

This paper investigates a method to determine the relative power production potential of a floating oscillating water column wave energy converter. This method focuses on determining the key characteristics of the parametric function relating the water column heave velocity to the structure heave velocity. The numerical investigation is undertaken using single frequency sinusoidal waves using WAMIT and OrcaFlex.

The paired velocities of the structure and the water column surface follow an elliptical function. The properties of this ellipse yields interesting information about the power produced by the OWC. It has been determined through investigation into the length and gradient of the major (long) and minor (short) axes of the bisector of the ellipse that relates the vertical water column heave velocity to the structure heave velocity that the power production potential is linearly proportional to the magnitude of of relative velocity between the water column and floating structure more so than a phase difference between these two velocities.

It has also been determined that the lengths of both axes of the ellipse are maximised, and hence system efficiency, when the forcing frequency is equal to approximately 90-100% of the of natural frequency of the water column of the system in question.

KEY WORDS: Energy; power; oscillating water column; wave energy converter; oscillating wave energy converter; power capture, OWC, WEC.

INTRODUCTION

An oscillating water column wave energy device usually consists of a chamber partially submerged, this chamber is open to wave excitation. Wave forces are used to move an air column within the chamber through a power takeoff device usually located at the top of the chamber. This power takeoff device is usually a turbine of some description. These devices can be fixed to the shore/sea bed or floating in the ocean. A two dimensional schematic of a floating system is seen in Figure 1 (Stappenbelt and Cooper, 2009).

Significant analytical investigation has been undertaken on fixed devices (Morris-Thomas, M. & Irvin, R. (2007); Mei (2011); Bull (2015)) and floating devices ((Sykes, R., Lewis, A. & Thomas, G. (2009); Szumko, S., (1989)).

Floating devices maintain one advantage over fixed devices, the structure is able to move. This additional degree of freedom can allow for an artificially longer chamber length and hence a larger volume. A longer chamber length will allow more air to be passed through the power takeoff device per cycle than a shorter chamber. Investigation into the relative movement of the structure and water column has not been extensively studied previously. Past studies have focused on achieving resonance of either degree of freedom with the forcing waves (Stappenbelt and Cooper (2009); Bayuomi et al. (2014)).

The power output of such a system is dependent upon a number of factors including the separation of the natural periods of the water column and structure, the ratio of the water column cross-sectional area to the structure cross-sectional area and the relative periods of the forcing wave (Stappenbelt and Cooper (2009)). Stappenbelt and Cooper (2009) concluded that with an appropriate system setup, the maximum power output occurs when the forcing period is approximately equal to water column natural period.