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Efficient Frequency-Domain Analysis of Dynamic Response for the Multi-Body Wave Energy Converter in Multi-Directional Waves

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ABSTRACT

In this paper, a multi-body wave energy converter is studied in the frequency domain. The device consists of a semisubmersible platform and 21 buoys. A mode expansion method, with total number of 27 modes, is used to formulate the dynamic motions. Moreover, An idealized form of power take-off mechanism is considered. Ocean environment and its directionality is modeled by using a JONSWAP wave spectrum with directional spreading according to Mitsuyasu. The objective is to assess the performance of the device in absorbing the wave energy and its dynamic behavior in ocean waves with/without considering the effect of power absorption mechanism. The current analysis method has been found to be computationally efficient and easier to interface with structural code compared to the available standard procedures by means of multi-body analysis approach.

KEY WORDS: Wave energy converter; dynamic response; mode expansion; frequency domain; multiple floating bodies; power-offtake; multidirectional seas.

INTRODUCTION

There is a significant interest in ocean renewable energy. Offshore wind turbines and wave energy converters (WEC) are two major types of the offshore renewable energy devices. The focus in this paper is on the second category. Up to now there have been numerous efforts on the study of wave energy converters in waves. Most of them have been concerned with single body motions. Only a few have focused on multi-body dynamics and considering hydrodynamic interactions.

In this study, the wave energy converter consists of a semisubmersible and several buoys sliding along some guides attached to the semisubmersible platform. This concept is known as the FO^3 platform (See Fig. 1). It was first proposed by Fred Olsen Co. Dynamic analysis of such a concept is challenging even in the frequency domain due to its multi-kinematics and hydrodynamic interactions.

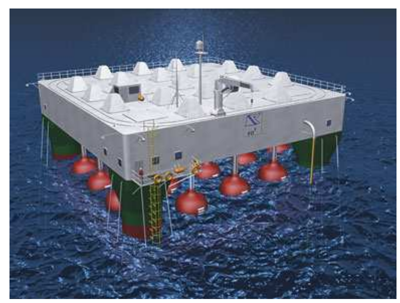

Fig. 1 FO^3 the Wave Energy Converter. Courtesy of Fred Olsen and ABB.

This device has been studied by Rogne (2007)who considered the motions of the WEC in the vertical plane using the multi-body analysis approach in WAMIT (2006). He assumed a unidirectional wave and showed that the dynamic problem is symmetric about the x axis. He then solved the hydrodynamics subproblem by considering the platform and each buoy to move freely in surge, sway and pitch, resulting to a total number of 42 dofs. In this way, he obtained the hydrodynamic coefficients like added mass and potential damping for each floating body. To solve the entire dynamic problem, he performed a post processing and reduced the degrees of freedom from 42 to 16 implying 2 dofs for surge and pitch of the platform and the buoys accounting for the buoy-sliding, and 14 dofs for heave of the platform and 13 buoys.

Taghipour (2008) solved the problem in another way. He considered the entire WEC as a single floating body whose dynamic motions were obtained by a mode expansion method, using the 16 modes directly. Such an approach has been frequently used to study the dynamic response of flexible marine structures in waves, referred to as hydroelasticity (see e.g. Newman (1994)). The alternative method, while maintaining the same accuracy, was found to be more efficient by a factor of 10-15. Yet, the