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Hydrodynamic modelling of a direct drive wave energy converter

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Abstract

In this article we present numerical studies of waves interacting with a cylindrical point absorber that is directly driving a seabed based linear generator. For waves useful for power conversion, the wave/point absorber interaction can be modelled, using potential theory assuming an inviscid irrotational incompressible fluid. The generator is modelled as a viscous damper. This paper pays special attention to the case when the converter is in resonance with the wave. The power capture capability of the system has been studied both for a harmonic wave and for real ocean waves.

Keywords: Wave energy; Resonance; Linear generator; Ocean waves; Potential wave theory; Point absorber

1. Introduction

Wave power devices are traditionally using conventional high speed rotating generators for energy conversion. This requires a system that converts the slow linear/rotation motion of the wave energy absorber to a high speed rotating motion. Hydraulic systems or turbines are used for this purpose. Such a solution gives a complex system with many moving parts. An alternative to the hydraulic systems are direct drive energy converters [1] with a linear generator. Although linear generators are fairly new for wave energy applications [2], the first electric linear motor was patented more than 100 years ago in the USA [3]. The advantage with these generators is the reduction in complexity and fewer movable parts, which in turn leads to less maintenance [4]. The drawback is a more complicated transmission to grid, since the voltage will vary in both frequency and amplitude.

In this paper we consider a concept for electric energy extraction from water waves based on a linear generator located at the sea floor [5,6]. The alternator of the generator is connected by a rope to a buoy, located on the sea surface. The alternator is also connected by a spring to the mooring system (see Fig. 1). The hydrodynamical action of water waves force the buoy and thereby the alternator to move with a vertical motion.

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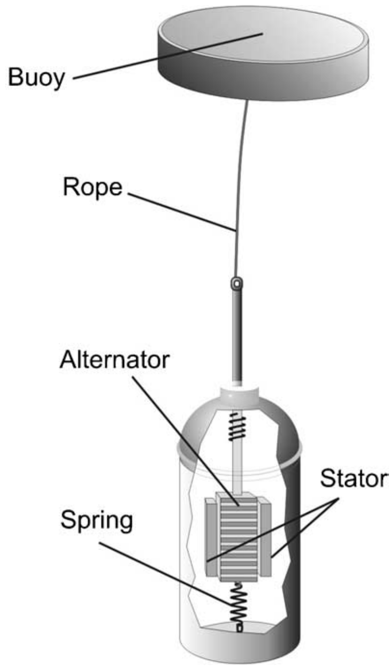

Fig. 1. Schematic figure of the converter.

The moving alternator, which is equipped with permanent magnets, induces currents in the stator windings according to Faraday's law of induction. In this way a substantial part of the energy in the waves can be converted into electric energy. In this article we present a study of the hydrodynamical interaction of harmonic and realistic waves with the buoy-generator system, using linear potential theory.

In order to calculate the excitation force and hydrodynamic parameters for the partially submerged buoy we assume, for simplicity, the buoy to be a cylinder moving in heave. For this purpose we make use of analytical expressions derived by Bhatta and Rahman [7]. These expressions are derived using variable separation and eigenfunction expansion of the velocity potential in cylindrical coordinates. Similar methodology has been used before in various ways by Miles and Gilbert [8], Garret [9], Yeung [10], Sabuncu and Calisal [11] and others.

This paper is intended to give an estimate of different parameters, such as buoy radius spring constant and generator damping coefficient in order to obtain high power capture ratio. In particular we are interested to investigate the influence of resonance on the power extraction capacity of the whole system. The converter has been simulated in a harmonic wave and in two wave climates: one measured and one with a JONSWAP spectrum [12,13].

2. Modelling

2.1. Equation of motion

As the point absorber we consider a circular cylinder with radius a, with the axis oriented in the vertical (z) direction. The cylinder is partially submerged, with draft d, in water of finite depth h. A surface wave is incident on the cylinder and the wave–buoy interaction gives rise to forces acting on the cylinder and to a scattered wave. The incident wave can be of arbitrary shape but is assumed to be plane parallel.

A rigid floating body has six degrees of freedom. We will restrict the discussion to vertical (heave) motion only. This is reasonable since our interest lies in modelling wave power converters with a point absorber tethered directly above a generator located at the seafloor. By assuming that the length of the tether is much larger than the buoy motion (in any direction) only the heave motion will appreciably affect the alternator motion