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Experimental results on power absorption from a wave energy converter at the Lysekil wave energy research site

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ABSTRACT

Power generation from wave power has a large potential to contribute to our electric energy production, and today, many wave power projects are close to be commercialized. However, one key issue to solve for many projects is to decrease the cost per installed kW. One way to do this is to investigate which parameters that have a significant impact on the wave energy converters (WEC) performance.

In this paper, experimental results on power absorption from a directly driven point absorbing WEC are presented. The experiments have been carried out at the Lysekil research site in Sweden. To investigate the performance of the WEC, the absorbed power and the speed of the translator are compared. The result confirms that the buoy size and the translator weight have a large impact on the power absorption from the generator. By optimizing the buoy size and translator weight, the WEC is believed to produce power more evenly over the upward and downward cycle.

Moreover, to predict the maximum power limit during normal operation, a simulation model has been derived. The results correlates well with experimental data during normal operation.

1. Introduction

The energy demand is continuously increasing worldwide and conventional methods for power generation are causing many environmental issues such as global warming, acid rain and air pollution. Harnessing natural resources and converting them into electric power can be an effective solution to ease the conflicts between large energy demand and environment pollution. Among all sources of renewable energy, wave energy has the highest energy density [1], and is considered as a promising alternative energy resource for the future. In 2012, the worldwide installed ocean power capacity was approximately 6 MW and in the next coming years this number is believed to increase to 35 MW [2]. The research within this area has come far and two review articles of different types of WEC technologies and their progress are given in Refs. [2,3].

Uppsala University has developed a wave energy converter (WEC) that uses a point absorber directly driving a linear generator for power production, see Fig. 1a. Various efforts have been made to optimize the system in order to decrease the cost per installed kW and to increase the reliability. In general the use of directly driven generators, or generators moving with a variable speed, have increased in renewable energy applications, particularly in the wind industry. Most of the developers have switched from using a fixed speed technology to a variable speed technology [4]. The main reason for the change is the increased power absorption (power capture ratio) which can be achieved with a variable speed control. The rotation speed can be controlled with power electronics according to wind speed to maximise the power production. A direct drive approach also has other benefits such as less maintenance work since mechanical parts that are otherwise needed between a conventional generator and the low speed motion of the waves, like turbines, gear boxes etc., are not needed. However, a direct drive approach tends to have a somewhat more complicated electrical system since a conversion system is required before the connection to the grid. Furthermore, a generator moving with low speed is larger compared to a 50 Hz generator with the same power rating. In the wave power area there exists a number of different projects developing linear and directly driven generators, some examples are given in Refs. [5–10].

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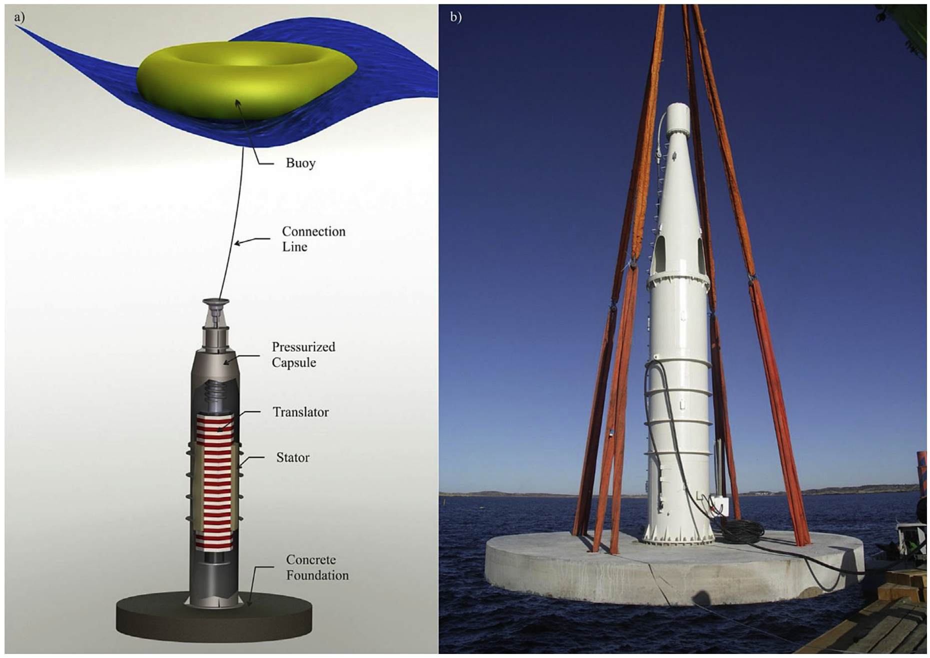

Fig. 1. a) Illustration of the WEC developed at Uppsala University. b) Picture of L9 during deployment.

In 2006, Uppsala University deployed their first WEC, the L1 [11]. Since then more than 10 WECs have been deployed at the research site located on the Swedish west coast, outside the town Lysekil. The research site is equipped with a 3 km long subsea cable that connects the WECs to a measuring station on a close by island, Hermanö. In the measuring station, voltage and current data from the WECs are stored. More information about the research site is given in Refs. [12,13].

The WEC consists of a buoy at the surface, which is connected through a connection line (steel wire) to a linear generator placed in a capsule on the seabed, Fig. 1a. To keep the WEC on the seabed, a concrete foundation with a weight of 35 tonnes is attached at the bottom of the capsule. When the buoy moves with the motion of the waves, the translator inside the linear generator will follow the motion in heave, thus inducing a varying magnetic flux in the stationary stator windings.

The power output from the WEC is influenced by a number of different parameters like the buoy size, translator weight, damping etc. To be able to increase the generated power from the WEC it is important to know how it behaves during a full cycle i.e. both when the buoy and translator moves upwards and downwards, the purpose with this work is to study this further. In this paper, the power absorption of a second generation WEC known as the L9 is studied both experimentally and analytically. The L9 was deployed at the Lysekil research site in 2009. A picture taken during deployment is presented in Fig. 1b.

To predict the impact of buoy volume and translator weight, a static model has been derived to find the power limits at different speeds during the upward and downward cycle. The results from the simulations could be used as a design tool early in the design process of a WEC. To verify the model, it has been compared with experimental results for different load conditions.

1.1. Experiments

The experiments were carried out at the offshore research site on the Swedish west coast. Details about the WEC, L9, used in the offshore experiments and details about the measurements done are presented in this section.

1.2. Linear generator

The generator is a linear generator shaped as an octagon, i.e. it has eight sides, see Fig. 2. The stator-sides are made up of thin electric steel sheets and are wound with a three phase winding. The stator-sides are then attached to the capsule walls. The translator has eight sides of surface mounted Ne-Fe-B magnets. To keep a low friction for the motion of the translator and to maintain a 3 mm air-gap between the stator-sides and the magnets, four rails mounted on the translator and 84 wheels divided into four rails are mounted on the capsule. The stator-sides and the translator have the same vertical length. This equal length makes the active area of the generator to change when the translator deviates from its center position. To keep the generator sealed from seawater a piston rod is attached to the translator. When the translator moves up and down, the piston rod will move through a seal housing placed on the top of the capsule. Some of the main parameters of the generator are presented in Table 1.

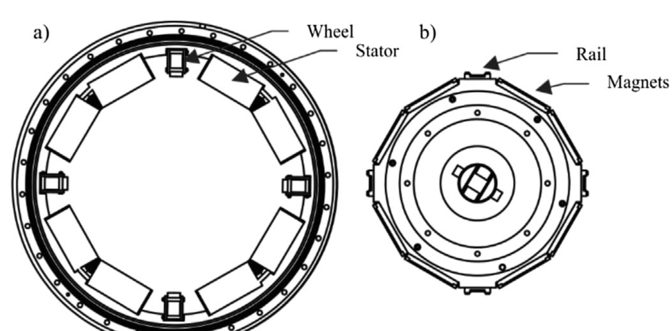

Fig. 2. a) Design of the stator inside the capsule. b) The translator with mounted permanent magnets.