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A Nearshore Heaving-Buoy Sea Wave Energy Converter for Power Production

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Abstract

There exists nowadays an ever-increasing demand for clean and renewable energy, due to the high level of pollution conventional energy production plants produce. Extracting energy from sea waves in Lebanon is a technology that has not yet been developed. In this paper, the potential of harvesting wave energy to produce electrical power on the Lebanese shore is investigated. As such, a compact wave-harvesting device was built. It consists of a float-rack-pinion system that transmits the vertical heaving motion of the waves and converts it into a rotating motion. This in turn is used to produce electricity through an alternator. A prototype was built and successfully tested in shallow water near shore to light up a 3-W lamp. The mechanical design of the manufactured device along with the operation process will be presented in details. In addition, the test results will be summarized along with the potential improvements that can be applied to the system.

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Keywords: Green Energy; Wave Energy Converter; Heaving Buoy; Rack-and-Pinion

1. Introduction

Renewable energy is the energy generated from natural resources which are replenished such as wind, solar, biomass, and tidal power. Researchers are investing heavily nowadays (time and money) in designing and improving renewable energy devices, some of which are wave energy harvesters ([1],[2],[3]). Wave energy is one of the most

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available and consistent energy all year round. It has many advantages over other types of renewable energy. The most obvious advantage of wave energy over solar energy for example, is that it is available at night and not only during the day.

Several authors have studied different types of wave energy converters ([4],[5],[6]). It is important to note however that many of these devices are still in the research and development phase and has not yet been used at production level. Falnes in [7] proposed different types of wave-energy converters. Kofoed et al. [8] also proposed three different projects of wave energy converters. These converters are Wave Dragon, Wave Star and Seawave Slot-cone Generator. The concept of the Wave Dragon works by waves overtopping a ramp, filling a floating reservoir with water a higher level than the mean sea level. The Wave Star is equipped with a number of floats which are moved by the waves to activate pumps. The Seawave Slot-cone Generator is an overtopping based wave energy converter utilizing a total of three reservoirs placed on top of each other. Hybrid systems have also been considered in different other studies ([9], [10], [11]), where one system works in parallel with other systems at the same time to enhance the power production.

To generate an improved amount of power, Wave Energy Converters can be arranged in several rows or in a "farm" [12]. Hong et al. [13] presented a review of strategies for electrical control of wave energy converters as well as energy storage techniques. In this review, different types of wave energy converters are classified by their mechanical structure and how they absorb energy from ocean waves. Several authors analyzed the wave energy resource theoretically and practically available in a sea of moderate depth ([14], [15]). This part of wave energy is quite important; however in this work it will not be tackled.

In this work, a wave energy harvester is presented. First, the system design is explained. The different components of the system as well as the operation process are then detailed. Finally, the manufactured system is presented as well as the testing results.

Nomenclature

S_{ut}	Ultimate Strength (MPa)
S_y	Yield Strength (MPa)
WEC	Wave Energy Converter

2. Wave Energy Converter Design

The proposed wave energy converter (WEC) is based on a previous successful design investigated by Bou-Mosleh et al. in [16]. The device is mainly designed to function in the weak wave energy conditions near the Lebanese shore. In fact it was designed to work in shallow water ($1\,m - 5\,m$). Lebanon is located on the Mediterranean Sea where the minimum average monthly significant wave height at Beirut coasts is about $0.5\,m$ in June as shown in Fig. 1 (expecting even lower values for the actual wave height).

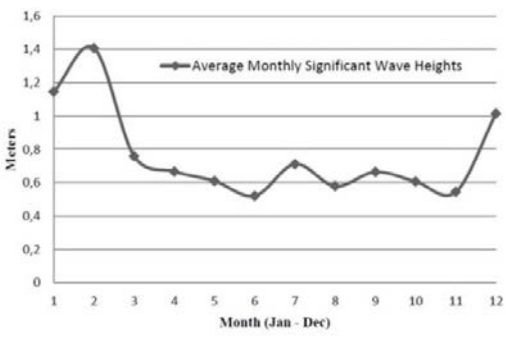

Fig. 1. Average monthly significant wave heights [17]