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Offshore wave energy generation devices: Impacts on ocean bio-environment

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ABSTRACT

As the crisis of petroleum-based energy is aggravating and the carbon emission is elevating, the search and exploitation of renewable energy sources such as solar, wind and oceanic powers, are of global interest and underway in some developed countries. In western countries pioneering the oceanic energy utilization, wave is currently an attractive energy source due to the predictability and the ease to be absorbed into power grid. As wave-energy generators (WEGs) and the associated devices interact with the surrounding environment, they would have impacts on the biological components within the ecosystem in the vicinity of WEGs. However, the environmental effects of offshore WEGs on local fauna and flora have yet to be evaluated in a comprehensive way. This article discusses several aspects, including influence of offshore WEGs on marine macrofaunal communities, interactions between offshore WEGs and biofouling organisms, impacts of offshore WEGs on marine birds and of electromagnetic fields (EMFs) on marine animals as well as "artificial reef" effects. If precaution is taken with the planning and construction of offshore WEGs, and environmental monitoring is performed with operation of these devices, marine wave energy can become a desirable alternative to fossil fuels.

Contents

1. Introduction

Currently fossil fuels and nuclear sources constitute the majority of the global energy supply. However, in addition to resource limitation, the combustion of fossil fuels may cause serious environmental burden predominantly known as greenhouse effects, and the ratification of the Kyoto protocol appeals the reduction in emission of greenhouse gases (i.e. carbon dioxide, nitrogen oxides, etc.). Lately, the environmental impacts and safety issues of nuclear power plants are of serious concern due to the susceptibility to unpredictable natural disasters, for instance, the recently reported Japanese earthquake and tsunami brought about radiation leakage from Fukushima Daiichi Nuclear Power Plant. Accordingly, clean and sustainable energy sources are in urgent need and actually under exploitation to meet the increasing energy demand and to allow for the alleviation of environmental pollution.

Nowadays, in the search of clean energy sources in replacement of petroleum-based energy, research and exploitation of marine resources is growing at an exciting rate worldwide. In contrast to

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Fig. 1. The Pelamis machine, designed and developed by Ocean Power Delivery Ltd, UK, operating at the Agučadoura Wave Park, Portugal.

wind and solar energy, marine wave energy is potentially more readily assimilated into electric power grid system because of the fact that it can be predicated more accurately a couple of days (2–3 days) in advance, be output and sold as civilian power. The well-know Pelamis converter designed by Ocean Power Delivery Ltd, UK, represents one of the most widely-used offshore technology for wave energy conversion with high power capture/unit weight (Fig. 1). Pelamis converters have been deployed to establish the first wave power plant in commercial practice with the capacity of 2.25 MW in Europe [1]. Another example for the leading offshore wave technology is PowerBuoy® device designed by Ocean Power Technologies (OPT), USA, which was being operated off the Hawaii coast with a capacity of 0.04 megawatts (MW) in 2007 (Fig. 2), and has successfully completed 5.6 million cycles in operation according to the bulletin of OPT Inc. [2]. Provided that proper measures are taken in the deployment, operations and maintenance, marine wave power would be a promising renewable electricity resource with great sustainable potential.

Given its carbon emission-free benefit, high power density, high utilization factor, and no occupying of land resources, marine wave energy is considered to be a desirable alternative of fossil fuels [3]. However, the exact bio-environmental assessment of wave energy generators (WEGs) and associated devices are yet to be performed. The lack of relevant environmental knowledge would not only lead to uncertainy and suspicion that affect the decision-making of government agencies, the commitment of WEGs investors, but also evoke the concerns of the public. The above-mentioned biological environment includes the macrofaunal community dwelling on the sea-bottom, the biofouling organisms (like mussels, barnacles and algae) on buoys and buoy lines, marine birds roosting on the protruding devices, and the artificial reefs recruiting a variety of sessile and motile organisms.

China has a long coastline of 18,000 km, ranking the top fourth in the world. Moreover, China possesses an amplitude of continental shelf, the area of which ranks the top fifth in the world. The

Fig. 3. Floating wave energy generation with a permanent-magnet linear generator, in Jiangsu Province, China (in trial phase).

tremendous wave energy reserves on the coastal areas of our country can be exploited and converted into electricity sources for the residents in offshore islands and for the sentry boxes in the oceanic frontier. In spite of the deployment of several onshore wave power stations along the eastern and southern coast of China, the research and development of offshore wave energy conversion are sparse and the environmental impacts of the WEGs and associated devices (i.e. the underwater infrastructure, transmitting cables) are lacking. The main purpose of this paper is to provide the international advances in the field of offshore WEGs and their accessorial devices interacting with the oceanic environment, which would be of referential value to the relevant research and engineering, in addition to stimulating smooth and effectual development of the oceanic energy generation in our country. Actually the offshore wave energy technologies in China have emerged, with the endeavors of Chinese researchers and under the supporting of National Ocean Bureau and National Natural Science Foundation of China (NSFC). As shown in Fig. 3, the floating WEG device integrated with a permanent-magnet linear generator [4] is anticipated to have high energy yield under the sea circumstance of the annual average wave density off the Chinese eastern and southern coast, which is approximately one-tenth to one-twentieth of that of American western coast and European coast (3–5 KW/m vs 40–100 KW/m).

Even in the western countries that pioneer the development of wave energy conversion technology, environmental impacts are not properly realized and are underestimated or neglected in most

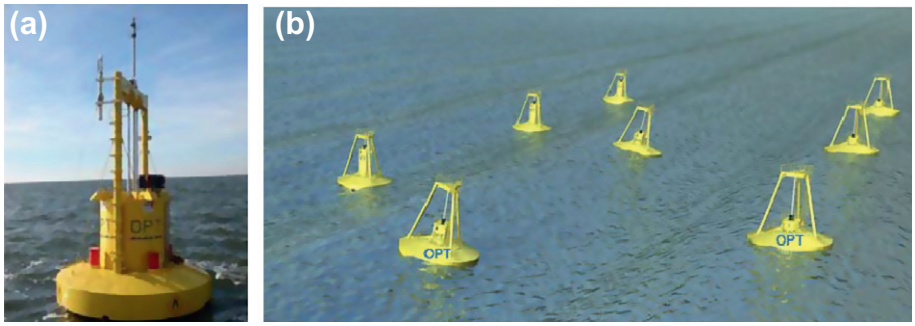

Fig. 2. (a) The PowerBuoy® machine by Ocean Power Technologies Inc. (OPT) operating off the Hawaii coast, USA; and (b) Illustration of an array of PowerBuyo® devices.