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Evaluation of technologies for harvesting wave energy in Caspian Sea

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ABSTRACT

Ocean is one of the renewable sources of energy that can supply part of the world's energy needs and thus reduce the rate of consumption of fossil fuels and other non-renewable resources. The wave energy can be converted to electricity or other forms of usable energy. Water waves have a relatively high power density with a total global power of approximately 1–10 TW, equivalent to a large fraction of the world's current total energy consumption. This study is aimed at evaluating the existing systems for converting the wave energy into electricity with the idea in mind that they could be used in the Caspian Sea, with average wave energy of 5–14 kW/m. To achieve this, major devices in this field along with the most important design parameters are identified and analyzed. Each existing system's main features are presented in a benchmark table, where each feature is assigned a weighting factor. The total score for each energy extraction system is then obtained. The most suitable device is chosen based on the conditions of the Caspian Sea including amplitude, wavelength and frequency of the waves, the depth of the sea as well as the seabed and shore conditions. The performance and maintenance costs of the device have also contributed to the final selection. Based on the current study, point absorber wave energy converters are the most appropriate devices for harvesting wave energy in Caspian Sea.
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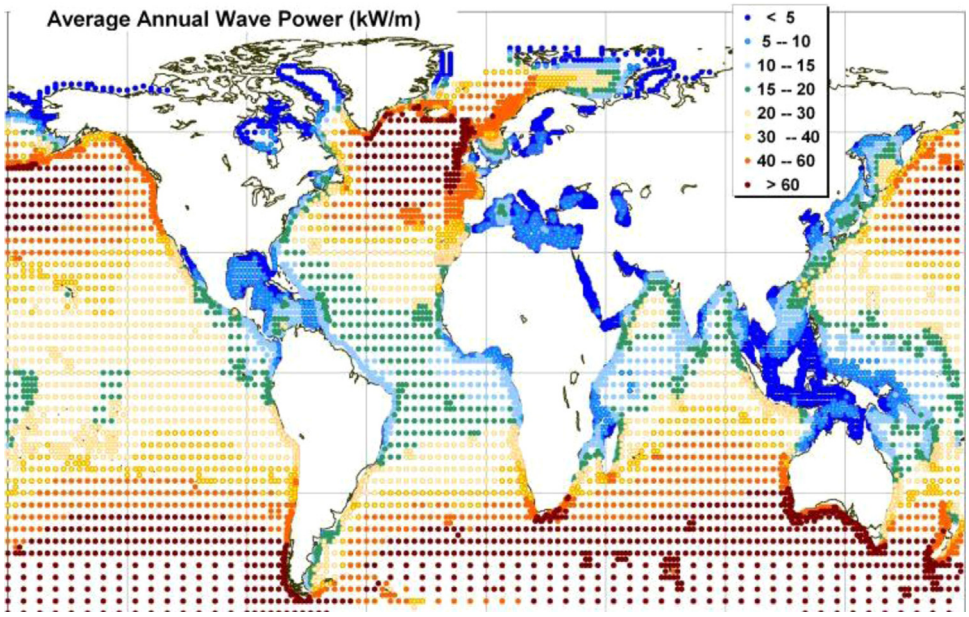

Fig. 1. Worldwide average wave power potential (kW/m) [33].

1. Introduction

The growing need for energy, scarcity of fossil resources, and environmental pollution due to fossil fuels along with the impacts of global warming on human life have drawn attention towards renewable energy resources. Ocean wave energy is one of the cleanest form of renewable energy. Salter's article [1] in Nature was perhaps the turning point in attracting the international scientific community to the wave energy. Many efforts have since been made to extract this potential energy. Fig. 1 shows the distribution of potential wave energy in the world. Wave energy technology is still in its infancy, the situation that wind energy technology had more than 20 years ago. A number of obstacles are yet to be overcome to make full use of this energy source. Over past few decades, extensive research has been made in the field of wave energy conversion [2,3]. Wave energy has been reviewed by a number of investigators including McCormick [4], Charlier and Justus [5], Ross [6], Brooke [7] and Cruz [8].

Caspian Sea has great wave energy potential, yet it has not received attention by researchers and investors. Mediterranean Sea with a mild wave energy climate [9] has been studied by many researchers to extract its wave energy. Likewise, the region between Balearic Islands and Sardinia with a maximum wave energy potential of ~15 kW/m [10] has been a favorable site for many years. Caspian Sea is situated where the south eastern Europe meets the Asian continent, between the latitudes of 47.13°N and 36.34°N and the longitudes of 46.43°E and 54.51°E [11]. This Sea is bounded by Iran in south, Turkmenistan and Kazakhstan in east and north east, Russia in north west and west, and Azerbaijan in west. It has a coastline length of about 7000 km. The Caspian Sea is relatively wild most times of the year, due, in part, to the direction of the winds. This raging sea has extremely large potential for wave energy. Although the Caspian Sea is a closed water basin, due to its large surface area and depth as well as its diversified weather systems, it is exposed to storms and elevated winds most of the time. Caspian Sea has an average and maximum wave power of 14 kW/m and 30 kW/m, respectively [12].

The objective of this study is to identify the most suitable system for extracting wave energy in the Caspian Sea. Wave energy system for a site is usually selected based on several important criteria including the status of the sea/ocean, manufacturing technology, installation and maintenance of the mechanical and electrical equipment as well as the efficiency of the device. The Caspian Sea has relatively soft seashore and its bed is made of soft silica, making it inappropriate for oscillating water columns or overtopping systems. Given that this sea is salty, an appropriate system should be one with a high corrosion resistance. In addition, the moving mechanical parts are preferred to be sealed to keep the maintenance costs low. Having all these in mind, among the most efficient wave energy conversion systems, a point absorber-type converter is most suitable for the Caspian Sea.

2. Existing wave energy extraction technologies

Major research and development of wave energy converters began through a number of programs in Great Britain in 1975 [13]. These programs were then followed by the Norwegian government. In 1985, major efforts were made towards the construction of two real size converters with the rated power of 350 kW and 500 kW on a coast near Bergen, Norway. Until the early 1990s, activities in this field remained at the academic level in Europe mainly. The most notable achievement of this period is a small scale 75-kW oscillating water column (OWC) based in Islay, Scotland, in 1991 [14]. Around the same time, two OWCs were built in Asia, including a 60-kW converter integrated with a breakwater in the port of Sakata, Japan [15], and a 125-kW bottom-standing power plant in Trivandrum, India [16]. The 2-MW converter in Scotland, destroyed by the waves, is among the unsuccessful systems of the time.

In 1999, a 400-kW OWC was deployed in Portugal followed by a 300-kW Limpet in Scotland in 2000 [17]. The floating point absorber SEAREV was first introduced in France in 2003 [18]. Two years later, a newer version of this absorber was launched in Port Kembla, Australia [19] and a semi-industrial 1:5 scale prototype, called Wave Dragon, was thrown into the water in Denmark [20]. In 2006 and 2007, a number of OWCs were installed in Sweden, Spain, and in the state of Oregon in USA. Later in 2008, other converters were launched including a Pelamis in northern Portugal [21], 16 OWC systems in Mutriku, Spain [22], and a floating system at the Oregon State University [23].

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