A Review of Wave Energy Extraction Technology

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Abstract. The current research on the utilization of wave energy has not formed a globally recognized technologically optimal wave energy power generation technology. The various types of wave energy power generation devices have different power generation principles and structural forms. Wave energy has the characteristics of wide distribution and high energy density, but it is also the most unstable type of ocean energy. Compared with other energy sources, wave energy has the characteristics of high energy density, and it is technically easy to realize the miniaturization of equipment, which contributes to the development of ocean resources. This article will mainly introduce current mainstream wave energy technologies, and explore their working principles and analyse their development trends.

1. Introduction

There are various types of wave energy absorption and conversion devices in the world, but so far no globally recognized dominant wave energy device has been recognized globally [1]. The principle of power generation of wave energy convertor (WEC) is generally that the wave energy is first converted into reciprocating mechanical energy by a wave energy acquisition system, and then converted into a mechanical energy of a smooth rotational motion through a Power Take-off (PTO) system, eventually converted to electrical energy via a generator set and output. For example, according to the workplace and technology, it can be divided into shore-based, low efficiency offshore and high-efficiency offshore, according to the functional uses can be divided into large-scale grid-connected power generation, special equipment power supply and other forms of direct energy supply [2]. This report will divide the wave energy device according to the working principle, which helps us to have a deeper understanding of the energy harvesting mode and development trend of the wave energy convertors. We will make an overview of the technical characteristics and research status of the wave energy convertors and summarize their development trends.

2. Development Status of Overtopping Technology

Overtopping WEC (OT-WEC) is the introduction of waves into high-level reservoirs through waterways to form a water level difference, and ultimately uses a hydraulic head to directly drive a hydroelectric generating unit to generate electricity. The working characteristics of the Overtopping WEC is to maximize the concentration of waves and raise the water level through various designs, and convert it

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into potential energy to be stored in the reservoir. Overtopping technologies mainly include Tapered Channel, Wave Dragon, and Sea Slot-cone Generator [3].

As shown in Figure. 1, the horn-shaped constriction channel of the Tapered Channel has a wide opening on one side which is in communication with the sea, and then gradually contracts to the high position reservoir. In a channel that is gradually narrowing, the wave height is continuously amplified until the wave peak overflows the contraction channel side wall and enters a high level reservoir, converting the wave energy into potential energy (a first-order conversion). The gap between the headwaters of the high-position reservoirs and the offshore of the fixed-wave overtopping technology can reach 3m-8m, and the hydroelectric generating units can generate electricity (secondary and tertiary conversions).

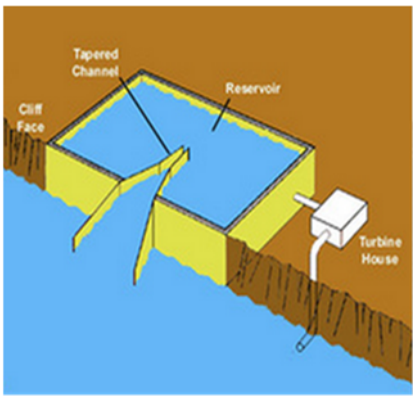

Figure 1. Schematic diagram of the Tapered Channel

Figure 2. Wave Dragon

The advantage of the overtopping energy conversion convertor is that there are no moving parts in the first-class conversion. The reliability is good, the maintenance cost is low, and the output of the device is stable. The disadvantage is that the construction of the power station requires terrain and it is not easy to promote. Compared to this type of fixed wave energy convertor, the floating wave energy convertor has more popularization prospects, and improving the conversion efficiency of the floating wave energy device is currently the focus of research in the field.

3. Development Status of Oscillating Water Column Technology

The basic structure of the Oscillating Water Column WEC (OWC-WEC) wave energy convertor is composed of a gas chamber, an air turbine and a generator. The underwater part of the air chamber communicates with seawater, the water part of the air chamber communicates with the atmosphere, and the air turbine and generator are installed at the outlet of the air chamber. Its working principle is shown in Figure 4. The wave undulation causes the free liquid surface in the air chamber to vibrate. The air in the compression chamber is reciprocally ejected, converts the wave energy into the pressure potential energy and kinetic energy of the air, and drives the air turbine.

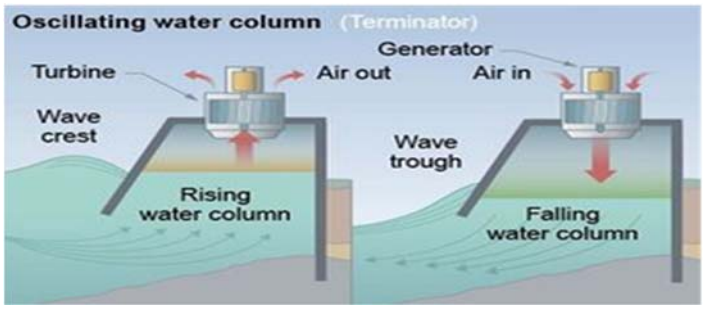

Figure 3. Schematic diagram of OWC-WEC

The advantage of the oscillating water column type wave energy convertor is that the PTO is not in contact with seawater and has high reliability [4]. It works on the water surface and is convenient for research and implementation. Disadvantages are limited conversion efficiency of the air turbine, and limited by the location, need to be built on the coastline or shallow water offshore areas.

Oscillating water column wave energy convertor is currently the most mature wave energy conversion device. The typical OWC wave energy devices are LIMPET (fixed 500 kW, as shown in Figure 4) of UK and floating device (floating 500kw, as shown in Figure 5) of Australia.

Figure 4. LIMPET

Figure 5. Floating Device of Australia

4. Development Status of Oscillating Body Technology

The working principle of Oscillating Body WEC (OB-WEC) is to use the oscillating motion of the floating body under the action of waves to realize the collection and absorption of wave energy. In OB-WEC devices, the available oscillatory motions mainly include heaving and rolling [5, 6]. Since the specific energy conversion structure of the oscillating-buoyant device has a variety of forms, only the typical structure type in the oscillating-buoy technology, the point absorber-type wave energy device, will be selected as an introduction.

The scale of point absorber-type wave energy device is smaller than the wave scale, and the wave energy is absorbed by the heave motion of wave. The point absorber consist of relatively moving buoys, anchor chains, hydraulic or power generating devices, and the like. These floating bodies have a floating body and a relatively stable static floating body, and rely on the relative motion between the moving float and the static floating body to absorb wave energy.

The currently built point absorber-type wave energy device include the Aqua Buoy device, the Archimedean wave pendulum (shown in Figure 6), and the Power Buoy (shown in Figure 7) and other wave energy conversion devices.

Figure 6. Archimedes Wave Pendulum

Figure 7. Power Buoy

5. Conclusion

Compared with other energy sources, wave energy has the characteristics of high energy density, and it is technically easy to achieve miniaturization, which contributes to the development of marine and coastal defense. Due to the need for the exploitation of ocean resources, there are many facilities at sea (including sea surface, underwater and islands), such as various monitoring instruments, underwater mining systems, underwater robots, and offshore platforms. These facilities require electricity and are currently powered by batteries or diesel power. The power supply of offshore facilities is extremely difficult and costly. Solving the problem of power supply in offshore facilities is of great significance. The development of special wave energy converter using the ocean energy around offshore facilities to power offshore facilities is far better than battery-powered, cheaper and more secure solutions.

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References

[1] Antonio F O. Wave energy utilization: A review of the technologies [J]. Renewable and sustainable energy reviews, 2010, 14 (3): 899 - 918.
[2] Falnes J. A review of wave-energy extraction [J]. Marine structures, 2007, 20 (4): 185 - 201.
[3] Muetze A, Vining J G. Ocean wave energy conversion-a survey [C]//Industry Applications Conference, 2006. 41st IAS Annual Meeting. Conference Record of the 2006 IEEE. IEEE, 2006, 3: 1410 - 1417.
[4] Evans D V. The oscillating water column wave-energy device [J]. IMA Journal of Applied Mathematics, 1978, 22 (4): 423 - 433.
[5] Falnes J. Wave-energy conversion through relative motion between two single-mode oscillating bodies [J]. Journal of Offshore Mechanics and Arctic Engineering, 1999, 121 (1): 32 - 38.
[6] Budar K, Falnes J. A resonant point absorber of ocean-wave power [J]. Nature, 1975, 256 (5517): 478.