技術開発レポート

Generation Systems Using Wave Energy

1. Introduction

Marine energy is a new and exciting technology but it is yet to reach a level of development comparable to either wind or solar power. Marine energy can be split up into wave energy and tidal energy. Tidal energy can be harvested in near-shore or river estuaries using either low-head hydro technology or even underwater turbines which look similar to wind turbines.

The main focus here is wave energy capture and there are now a many devices under investigation. These can be shoreline, near-shore or off-shore. A recent review was published in (1). In the UK the main two devices that reached a reasonable level of development are the oscillating water column (commercially generating on the Isle of Islay–250 kW) and the Palamis (a multiple-section snake device which generates using hydraulic pumps at the inter-section joints to power a turbine).

2. Wave Energy

Deep sea wave energy is generated by winds blowing across the surface and exciting the water. This produces large waves of long time period and large amplitude. The water molecules rotate in a circular orbit, with the radius decreasing with depth. Therefore kinetic energy needs to be stored in the sea water to establish wave motion. The phase shift in the orbits produces progressive waves on the water surface which are essentially waves of potential energy. It is the potential energy waves that are harvested and converted into electrical power. Sea wave behavior is very complex and prediction difficult. When waves come into a shoreline the shallowing sea bed produces drag and the circular orbits become more elliptical and the wave energy is damped (breaking waves). Hence shoreline wave energy is much lower than deep-sea wave energy. Countries on eastern borders of major oceans tend to have good wave energy; hence in Europe, the UK, Ireland, Portugal and Spain all have good wave energy. Japan has more modest resources. A basic equation for the power per meter of wave front, which illustrates that large, long-period waves are high energy waves, is (2):

$$P_{\text{wave front}} = \frac{981.2 \times \text{Wave Height}^2}{\text{Wave frequency}} \quad \text{W/m}$$

The north-east Atlantic Ocean borders will have wave fronts above 50 kW/m, while Japan is in the region of 15 kW/m.

3. Oscillating Water Column (OWC)

The OWC is a simple and probably the most tried and tested device. An example is illustrated in Fig. 1 and it consists of two basic components: the chamber and the turbine. Waves flow into the front of the chamber so that the water level inside oscillates with a height and phase difference with respect to the wave fronts. This pressurizes and depressurizes the column so that air moves in and out of the chamber via bidirectional turbine (2).

In most OWCs the turbine is a Wells type; these have pear-shaped blades that have the same rotation whatever the airflow direction. They can have reasonable conversion rates provided the flow coefficient (inlet air velocity/turbine blade tip-speed) is low − less than 0.1. This gives a high Reynolds number and means that they must be of a reasonably large radius. Torque from the turbine pulsates at twice wave frequency due to the oscillating nature of the device; the power delivery can be smoothed by allowing the turbine speed to vary over a cycle so that kinetic energy is stored in the turbine/generator inertia as the speed increases and then converted to electrical energy as it slows. The Isle of Islay plant uses a cage induction generator via a controlled rectifier (to magnetize the generator), DC link and inverter, and this is a common arrangement for this device.

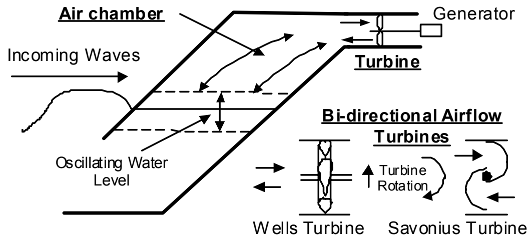

Fig. 1. Oscillating water column arrangement

For a small experimental wave-tank-scale set-up something simple like a Savonius rotor can be used (2) as shown in Fig. 1. It is easy to manufacture and a permanent magnet generator can be used to develop a few watts of energy. It requires a flow coefficient of around one so that it rotates at a low speed. But will have a conversion rate under 10 % for an oscillating airflow (2). It was used in this application to illustrate the operation of a multi-chambered column since they can be connected in series.

4. Conclusions

A simple description of wave energy is put forward together with an explanation of an OWC arrangement. This is a simple device which is straightforward to construct and test.

References

(1) J. R. Halliday and D. G. Dorrell : "Review of Wave Energy Resource and Wave generator Developments in the UK and the Rest of the World", IASTED EuroPES conference, Rhodes, Greece, pp.28-30 (2004-6)

(2) D. G. Dorrell, M.-F. Hsieh, and W. Fillet : "Segmented small oscillating water columns using in-line Savonius rotors", ISOPE Conference, Lisbon, Portugal, pp.1-6 (2007-7)

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