Analysis of Wave Energy and Energy Storage Characteristics of Wave Energy Converters

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Abstract. With the development of wave energy extraction technology, the performance requirements of wave energy converters have also become higher in order to maximize operating efficiency and the use of wave energy. In this paper, the wave energy characteristics and energy storage characteristics of current common wave energy converters are studied for this demand. Because small-scale wave energy converters are characterized by their strong mobility and relatively lower power generation, it is not easy to integrate the generated energy directly into the power grid. Therefore, a small, highly efficient and environmentally friendly storage method is needed. Through investigation, the lithium battery pack is used to store the energy output from the converters by means of a filtered regulated charging circuit.

1. Introduction

The wave energy in the ocean is widespread and environmentally friendly. Wave energy can be collected and generated on a large scale for human beings. At the same time, they can also be used to generate power for navigation buoys, underwater vehicles and so on. The small wave energy converter is one of the wave energy power generation devices. Its main feature is its strong mobility and it can be directly assembled in various devices to supply power. It has a good application development prospects. Studying its wave characteristics and energy storage characteristics will help improve the performance characteristics of wave energy converters and maximize the use of wave energy.

The actual waves are randomly and irregularly affected by many factors, such as geographical conditions and wind speed. Its displacement, frequency, and wave height all change with time, so it is hard to accurately model and analyze real sea waves according to the theoretical calculation of the rated waves [1]. Therefore, it is necessary to analyze and study the wave characteristics.

Proper storage of energy generated by wave energy converters is critical for efficient use of wave energy. Lithium-ion batteries have a high specific energy, a wide operating temperature range, and a long working life. They have great potential both in military and civil use [2, 3]. It has large electric energy capacity, good cycle performance, superior to other types of batteries, good cost performance; it has no memory effect and can be used repeatedly for charge and discharge; it has small size, light
weight, high specific energy. Compared with NiMH batteries with the same capacity, the volume can be reduced by 30% and the quality can be reduced by 50% [4-6].

2. Wave characteristics analysis

After a large number of observations and statistics of the waves, the random waves actually have a certain degree of regularity, especially certain characteristic parameters, such as the number of waves appearing in a certain size of wave height and wavelength is basically certain. A large number of simple waves with different amplitudes, frequencies, phases, and directions are superimposed to form a real sea wave. Here, parameters such as amplitude and phase are random numbers, so the summation is still a random function. This research method can reflect the randomness of waves and is an effective method. With above method, the wave height of the waves can be expressed as:

$$h(t) = \sum_{n=1}^{N} (X_n \cos \omega_n t + Y_n \sin \omega_n t)$$

Where $$X_n$$ and $$Y_n$$ are sequence of real random variables that are not related to each other. The mean values $$E(X_n) = 0$$ and $$E(Y_n) = 0$$ can prove that wave height is a stationary random process.

So for the sake of research convenience, the wave transmitted to the device is considered to be identifiable and has the following components:

$$\eta_n = a_n \sin(k_n x - \omega_n t)$$

Where $$\eta_n$$ the vertical surface displacement of the nth wave is, $$a_n$$ is the amplitude of the nth wave, $$k_n$$ is the displacement coefficient of the nth wave, $$\omega_n$$ is the angular frequency of the nth wave, $$x$$ is the traveling wave in the x direction The displacement. Here, the relationship between the displacement coefficient $$k_n$$ and the angular frequency $$\omega_n$$ of the nth wave is

$$\omega_n^2 = g k_n \tanh(k_n h)$$

Where g is the acceleration of gravity, and h is the depth of water. It can be seen from the formula that the wavelength of the traveling wave can be expressed as

$$\lambda_n = \frac{2\pi}{k_n}$$

The ocean wave is composed of all the waves from $$n = 0$$ to $$n = \infty$$, so the sum of the vertical surface displacements of the waves is

$$\eta = \sum_{n=0}^{\infty} a_n \sin(k_n x - \omega_n t)$$

Where $$\eta$$ is the sum of the vertical surface displacements of the ocean waves.

It can be seen that each wave can be approximated by a sine function, but each wave corresponds to a different random sine function, and the wave height corresponds to the amplitude of the sine function. Due to the small size of the small wave energy converter, it is commonly used in the micro wave to light wave level. In order to verify the power performance of wave energy converters under
small waves, the research team will study the power generation characteristics of the convertor under small wave conditions.

3. Energy storage characteristics analysis
Nominal voltage values of Lithium-ion batteries are very different, and the corresponding rated voltages are also different. Therefore, when charging a lithium-ion battery, the nominal voltage and rated voltage are two important indicators, otherwise the battery may not be fully charged or overcharged. The normal charging current of a lithium-ion battery is between 0.1C and 0.5C, charging current is too small will make charging time longer, charging current is too large to make the battery damaged.

Lithium-ion battery charging needs to add a current limiting circuit to prevent over-current. During charging and discharging, the battery capacity decreases monotonously with decreasing voltage. When the capacity is high, the battery voltage and capacity are basically linear, so you can estimate the amount of charge through the battery voltage. Figure 1 is the change curve of battery voltage with capacity under the different discharge currents of STL18650 lithium iron phosphate battery.

![Figure 1. Voltage variation curves of STL18650 lithium iron phosphate battery under different discharge currents](image)

When the battery current is the same, the relative charge state can be compared by the voltage value. The change of the voltage across the lithium ion battery with time is also one of the important characteristics at different discharge currents. Sectional constant voltage charging method is to change the constant current of the segment into the constant voltage of the segment. This kind of charging method makes the oxygen produced by the chemical reaction in the lithium-ion battery have time to be recombined and absorbed, the internal pressure of the battery is reduced, and the battery can absorb more electricity. The constant current and periodic pulse charging method is to continuously increase the acceptable charging current of the lithium ion battery during the charging process, so that the entire battery charging process can be completed faster. According to the characteristics of different charging modes and the characteristics of the output energy of the wave energy convertors, it is determined that the sectional constant voltage charging method is more practical, but the voltage fluctuation range cannot be too large, otherwise the battery is easily damaged.

4. Conclusion
The article mainly analyzes the wave characteristics and battery charge and discharge characteristics of the wave energy convertors. The wave is composed of simple fluctuations of multiple amplitudes,
frequencies, phases and directions, and the wave height expression of the wave is obtained. This article also describes and analyzes the characteristics of the charge and discharge of lithium batteries and their charging modes. Selecting the sectional constant voltage charging method to charge lithium-ion batteries provides reference value for the design of the charging circuit and power matching in future studies.

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