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Design of a bidirectional, dual-channel, dual-rotor ocean wave impulse power generation device

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Abstract

As a kind of renewable energy with huge reserves, ocean wave energy is becoming a new research hotspot in addition to wind energy and solar energy. This article firstly introduces the power generation principle and working process of ocean wave energy, and summarizes the current status of domestic and foreign related research and commercial wave energy projects at this stage. On the basis of the traditional wave energy power generation device, through the use of a double-layer flow channel structure and the characteristics of the reverse rotation of the inner and outer rotors of the dual-rotor motor, the structure of the general power generation device is optimized and improved, and the wave energy contained in the back and forth and reciprocating motion is fully utilized. The huge kinetic energy realizes high-efficiency power generation. Compared with traditional wave energy motors, the energy utilization rate has been increased from about 20% to more than 30%, thereby realizing the efficient use of clean energy.

Keywords

Wave energy; power generation device; double-rotor motor; double-layer flow channel; improve energy utilization.

1. Introduction

With the rapid development of science, technology and economy, the demand for energy of mankind is increasing day by day. On the one hand, traditional fossil energy is gradually facing exhaustion, and on the other hand, environmental pollution and destruction are becoming increasingly prominent. Therefore, looking for alternative renewable and clean new energy sources has become a new energy direction. The sudden emergence of new energy sources such as solar energy, wind energy, and ocean energy has gradually made energy use more efficient and clean, and has become a new engine for energy sustainability and continued economic growth.

The earth has abundant marine resources, and the ocean contains large-scale sustainable energy [1]. Ocean energy mainly includes natural resources such as wave energy, tidal energy, ocean current energy, temperature difference energy, salinity difference energy, marine biomass energy, and seabed geothermal energy [2]. Due to the influence of atmospheric circulation, considerable ocean wave energy is widely distributed on the ocean surface. Due to the conversion of ocean wave energy from solar energy, it is also a renewable energy source [3]. It is not only rich in resources [4], has a high energy flow density [5], and does not produce waste pollutants during the energy conversion process. , The impact on the environment is small, and its energy is proportional to the square of the wave height, the wave motion period and the width of the front wave surface. Data shows that the current global wave energy equivalent power generation is as high as 10 TW, and the average annual wave energy is estimated to be close to 93,000 TWh [6], which far exceeds the power generation capacity of solar and wind energy. This makes the research on wave energy a country to carry out. New

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research hotspots in the layout of new energy. For coastal cities and countries, the development of wave energy can be used as a good compensation for traditional energy sources and ease the power supply pressure at peak power consumption.

2. Current research status at home and abroad

Regarding the origin of wave energy, it can be traced back 300 years ago, but the real scale was in the middle of the last century. European coastal countries, Japan and other maritime countries used their geographical advantages to carry out a lot of ocean wave energy research. According to incomplete statistics, the current total installed capacity related to wave energy has exceeded 100w kw, and there are more than thousands of wave energy power stations, and the number of stations built and the power generation are increasing at a rate of 2.5% and 10% per year respectively [7].The earliest commercialization of wave energy was Japan's Yoshio Masada, who first successfully developed a miniature wave power generation device for navigation lights in the 1960s. Since then, Japan has built a number of shore-based fixed and breakwater wave power stations since the mid-1980s, with a single unit capacity ranging from 40kW to 125 kW [8].

The United Kingdom is the country with the most extensive and in-depth research on wave energy, and its technology is in a leading position in the world. In 1990 and 1994, 75 kW and 20 MW oscillating water column and fixed water columns were built on Isle of Isle and Osprey, Scotland, respectively. Type shore-based wave power station [9]. In 1995, Britain built the world's first commercial wave generator and put it into use. It is located at the mouth of the Clyde Bay and has an installed capacity of 2,000 kW.

The research on wave power generation in China is relatively late compared to Western countries, but it has developed rapidly since the 1980s. In 1990, a 3kw shore-based wave energy power generation experimental station was successfully developed by the Pearl River of the Guangzhou Energy Institute of the Chinese Academy of Sciences [10]. In 1996, a 20kw experimental station and a 5kw wave power generation ship were successfully developed. In 2005, the Chinese Academy of Sciences completed the world's first independent and stable wave energy power station in Shanwei, Guangdong. In 2018, the second-generation 260 kW (200 kW wave energy and 60 kW solar energy) wave-light complementary offshore mobile energy platform "Pioneer One" carried out an open sea trial in Hainan, and was successfully connected to the remote island power grid through a submarine cable.

3. The principle of wave power generation

Wave energy uses the reciprocating force and potential energy difference generated by the repetitive motion of shock waves to drive equipment to generate electricity. At present, the mainstream ocean wave energy power generation methods can be roughly divided into three types: The wave motion produces water or air flow, the fluid drives the water turbine to rotate, and the water turbine drives the generator to achieve power generation. ②Using the front and back rotation or swing of the wave device to generate water or airflow, turning the water (gas) turbine, thereby driving the generator to generate electricity; ③The low-pressure wave is converted into low-pressure water by using the water level gravity difference generated by pumped storage, similar to hydroelectric power generation , Generate electricity by impacting the turbine [7].

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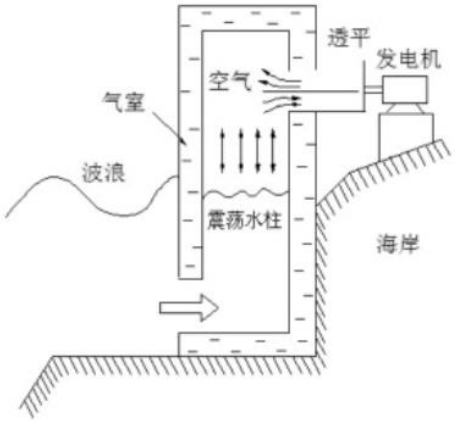

Figure 1. Oscillating water column wave energy power generation device

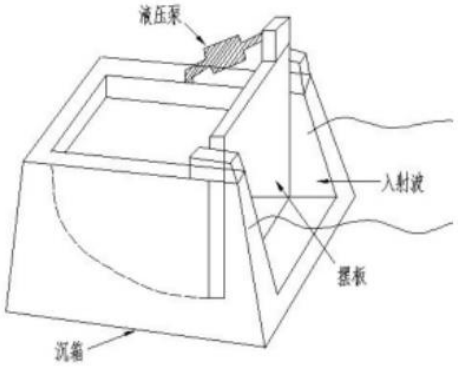

Figure 2. Swinging wave energy generating device

4. Design of new wave energy power generation device

Based on the traditional wave energy power generation device, this article developed a two-way dual-channel dual-rotor ocean wave impact power generation device through improvement. This device makes full use of the variability and reciprocity of wave motion to improve the energy conversion efficiency of the wave energy device. As well as reliability, the device has a simple structure and stable operation. It is a breakthrough in the development of wave energy utilization technology. At the same time, it also realizes green power, which is fully in line with the concept of energy saving and emission reduction.

4.1. Design scheme

The principle of dual-rotor design: The traditional DC generator adopts the form of power generation in which the stator is fixed and the rotor rotates. The rotor rotates under the action of external force. The two sides of the coil cut off the lines of magnetic force under the magnetic poles of different polarities, and induce electromotive force in them through the commutator. Used in conjunction with the commutation function of the brush, when the brush is pulled out from the brush end, it becomes a DC electromotive force.

On this basis, according to the characteristics of sea waves, a counter-rotating double-rotor permanent magnet motor is proposed. The stator of the traditional motor is used as the outer rotor, and the original rotor is used as the inner rotor, and the two move in opposite directions. The outer rotor has armature windings, and the inner rotor is also called a permanent magnet rotor because it is equipped with permanent magnets. The magnetic field of the permanent magnet interacts with the magnetic field generated by the armature winding to produce electromagnetic torque.

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Based on the research of the counter-rotating double-rotor permanent magnet motor, the hand-cranked generator is converted into a double-rotor motor, and the hand-cranked generator is equipped with a coaxial shaft, conductive slip ring and stator strut. The coaxial shaft is divided into an inner shaft and an outer sleeve. The outer shaft sleeve is connected with the outer rotor of the double-rotor motor, and the inner shaft is connected with the inner rotor of the double-rotor motor. The inner shaft and the outer sleeve are used to connect with sea water respectively. The two impellers in the drainage groove are connected. Compared with traditional motors, since the stator of the dual-rotor motor rotates, considering the stability of the device during operation, a stator brace is added to stabilize the stator. Based on this feature, the current extraction device-conductive slip ring is redesigned. The current drawn by the conductive slip ring is connected to the battery.

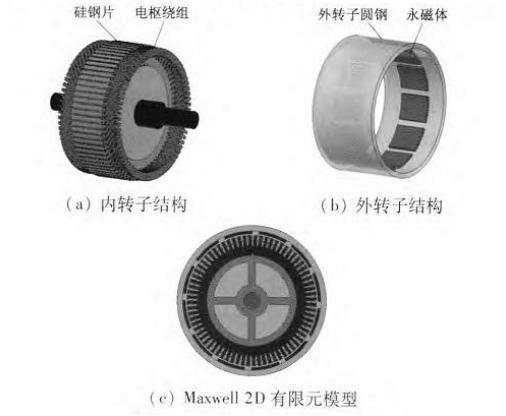

Figure 3. Schematic diagram of stator and rotor structure

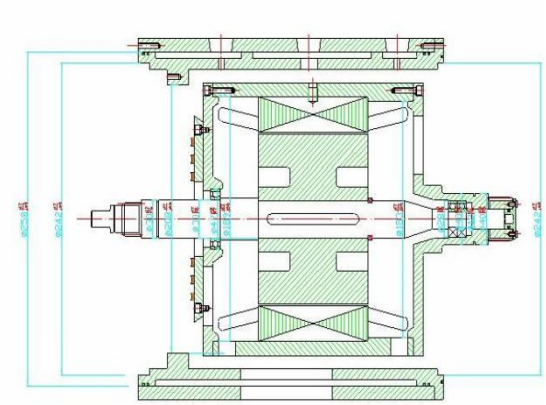

Figure 4. Cross-section of a dual-rotor permanent magnet motor

Wave energy capture design principle: The impact of sea waves on the device is a process of reciprocating motion. When the waves come, the impeller will be impacted through the upper and lower flow channels, and the wave energy is directly converted into mechanical energy of the rotating machine. Under the action of the limit device, due to the different impact positions, the upper and lower impellers rotate in opposite directions. When the wave retreats, it will flow through the upper and lower flow channels in the opposite direction. Under the action of the limit device, the impeller's rotation direction will not change due to the impact position conversion. The device can still capture wave energy and maintain a stable power generation state.

4.2. Device structure

The two-way dual-channel dual-rotor ocean wave impact power generation device includes a double-layer seawater drainage tank, two impellers, a coaxial shaft, a flap valve, a flap valve limit block, a spring return hinged shaft, a dual-rotor motor, a battery, a partition, Floor.

ISSN: 2664-9640

Double-layer seawater drainage trough: Both ends of the upper and lower seawater drainage troughs are gradually flared. The two drainage troughs are separated by a middle partition, placed horizontally and parallel to the impact direction of the waves.

Coaxial shaft: The coaxial shaft is placed vertically, divided into the inner shaft and the outer shaft sleeve, and is fixed on the middle partition plate through the bearing seat.

Impeller: Place an impeller on each seawater drainage trough. The impeller in the upper seawater drainage trough is connected to the outer rotor of the dual-rotor motor through an outer sleeve. The impeller in the lower seawater drainage trough is connected to the dual-rotor motor through the inner shaft. The inner rotor is connected.

Flap valve limit block: In the upper seawater drainage groove, there is a flip valve limit block between the two flap valves of the same group. The flip valve limit block is fixed on the middle partition plate and hinged by spring reset The shaft is connected with the inner wall of the tank, and the layout of the lower seawater drainage groove is similar to that of the upper layer.

4.3. Working process

The seawater drainage tank is divided into two layers, and the upper and lower layers are separated by partitions and are relatively independent. This design makes the impellers that drive the rotation of the inner and outer rotors independent of each other. There are flap valve, flap valve limit block, spring return hinge shaft and impeller in each layer. Four flap valves are placed symmetrically on each layer of seawater drainage grooves, and the four flap valves on each layer of drainage grooves are divided into two groups. Each group occupies one inner wall of the seawater drainage groove; it is located on the same side wall of the seawater drainage groove The opening directions of the two flap valves (that is, the two in the same group) are the same, the opening directions of the two groups are opposite, and the two sets share two flap valve limit blocks.

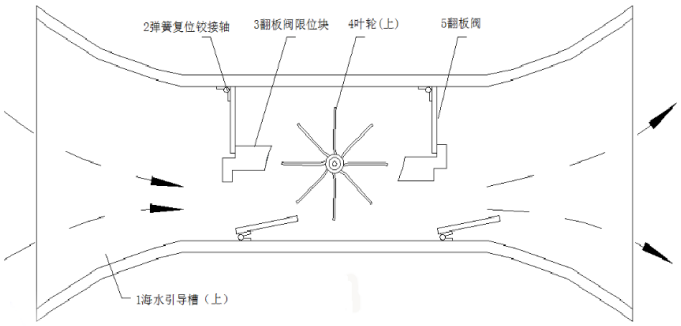

Figure 5. Working state of the upper device, the impeller rotates counterclockwise

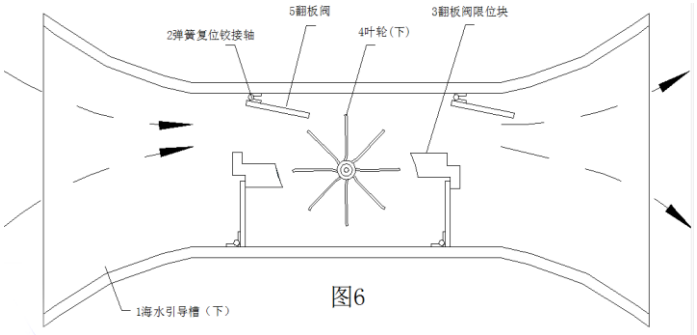

Figure 6. Working state of the lower device, the impeller rotates clockwise

When the waves come, the working status of each component in the upper and lower layers is shown in the figure. At this time, due to the different opening directions of the flap valve, the rotation directions of the upper and lower impellers are opposite, and the inner and outer rotors of the dual-rotor motor are driven to rotate in opposite directions to generate electricity.

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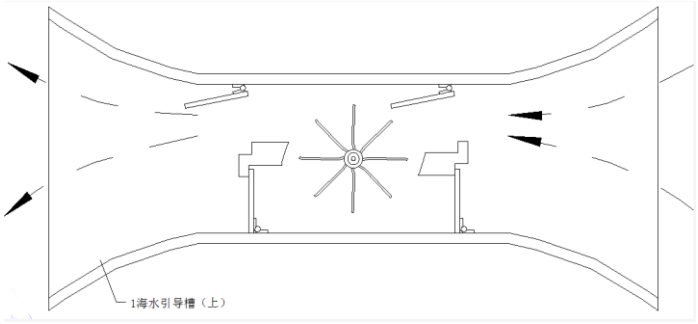

Figure 7: Working state of the upper device, the impeller rotates counterclockwise

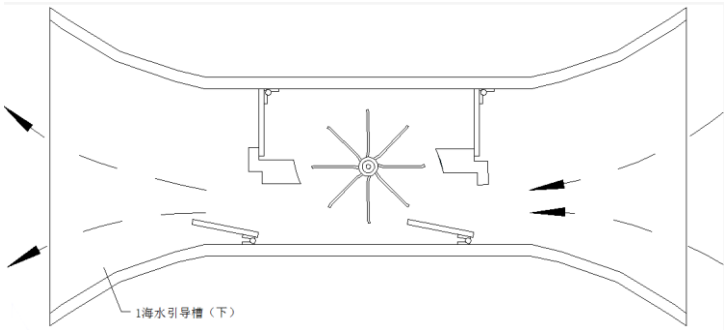

Figure 8. The working state of the lower device, the impeller rotates clockwise

When the waves return to the sea, the single-layer power generation device will open the flap valve on the opposite side, as shown in Figure 5. This design keeps the impeller's rotation direction unchanged and makes full use of the reciprocation of the waves to achieve the purpose of making full use of energy, saving energy and reducing emissions.

4.4. Data analysis

Experimental principle: The DC motor realizes the conversion of mechanical energy and DC electric energy according to the law of electromagnetic induction and the law of electromagnetic force. Driven by the inner and outer double rotors, the armature of the DC generator rotates clockwise at a certain speed, and each conductor generates induced electromotive force with the same direction. The formula for the induced electromotive force of the armature winding of the DC generator is:

$$E_a = C_e n \Phi$$

Among them, n is the relative speed between the stator, the rotor or the double rotor, Φ is the magnetic flux per pole, and C_e is the electromotive force constant of the DC motor. If load resistors are connected to both ends of the armature, current will flow through the armature circuit, I_a and E_a will run in the same direction. According to the circuit law, the electromotive force balance equation of the armature circuit can be obtained:

$$E_a = U + I_a R_a$$

Assuming that the resistance voltage drop of the armature loop is not much change and can be ignored, the power generation capacity can be measured by the terminal current when the impedance of the external circuit is constant.

Experiment content: Simulate the impact of ocean waves through water flow, and detect the power generation effect of the two-way dual-channel vertical axis dual-rotor power generation device. In this experiment, the speed of the impeller is used to reflect the seawater flow rate, and the magnitude of the current is used to reflect the power generation effect.

Analysis of the experimental results: Use an ammeter to measure the current generated by the generator under the same load and different impeller speeds, and compare it with the

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experimental data of the generator (single-rotor motor) before the transformation. The results are shown in Table 1.

Table 1: The relationship between the power generation effect of the device and the water flow rate

Rotating speed(r/min)	30	35	39	46	50	55	59	62	66	70
Double rotor motor current (mA)	18	50	102	146	203	256	282	323	366	407
Single rotor motor current (mA)	0	20	47	81	110	137	157	179	199	226

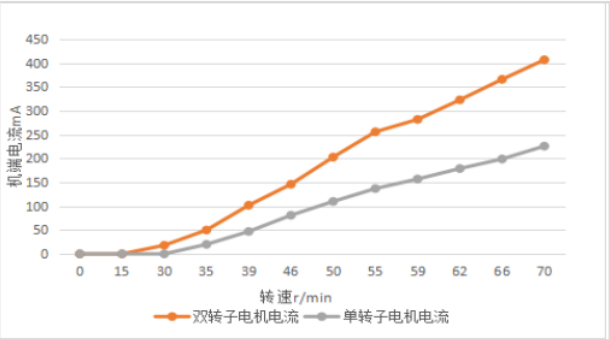

Figure 9 Comparison of power generation effects of two generators

Experimental error analysis: In fact, the rotor speed of the two experiments cannot be adjusted to be completely consistent, and there will be certain errors. At the same time, limited by the experimental conditions, the impact force of the water flow is not large, and the range of change is small, resulting in a small range of change of the speed.

Experimental results: It can be seen that within a certain range, the change of the external terminal current is positively correlated with the change of the water flow. And the performance of the dual-rotor motor is significantly better than that of the ordinary motor.

5. Summary and Outlook

This article introduces the principle of wave energy power generation, and summarizes the research status and progress at home and abroad. On the basis of traditional wave energy power generation devices, the introduction of two-way dual-channel and double-rotor realizes repeated and full use of wave energy. However, like solar energy and wind energy, ocean wave energy also has the problems of intermittency and instability, and its energy is relatively scattered and not concentrated, which greatly increases the development cost. At the same time, it is obviously restricted by geographic area and can only be used in coastal cities. . How to improve the efficiency of power generation, the stability and reliability of device operation, and increase the installed capacity are issues that need to be resolved.

In the future, realizing the centralized utilization of wave energy, realizing the improvement of power generation efficiency, and the issue of new energy grid connection will become the hotspot and key of research in the field of wave energy power generation.

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