Design and research of self-propelled wave energy collecting device based on hydrogen storage by seawater electrolysis

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Abstract. In view of the unstable power conversion of the existing wave power generation plant, the high cost of grid-connected power generation and the difficulty of maintenance, a self-sailing wave energy collection device based on the hydrogen storage of sea hydropower is designed. The device can sail to the wave energy-rich area by self-sailing unmanned carrier and can temporarily return to the coast in bad weather. In order to reduce the resistance of the device and improve the efficiency of wave energy collection, a folding integrated wave energy capture device is designed, and when it is captured by wave energy, the wave kinetic energy capture module and the wave potential energy capture module on the device will simultaneously collect the kinetic and potential energy generated by the wave, and when the unmanned carrier sails, the wave energy capture device will automatically be recovered on both sides of the hull. Because the power stability of wave energy conversion is weak, such as direct input into the power grid, will affect the stability of the power grid, the device through the sea hydropower de-hydrogen system, the collected wave energy into hydrogen energy and storage, improve the wave energy storage capacity, and effectively solve the problem of weak power stability of wave energy conversion.

1. Introduction
Waves can be ubiquitous in the ocean, ocean waves contain great energy, wave energy flow density is very large, can be obtained from smaller devices considerable low-cost energy [1]. The current wave energy conversion device in the power generation process has the following problems: (1) The device cannot be moved autonomously after release, so vulnerable to severe weather damage, maintenance difficulties; (2) The existing wave energy collection device difficult to capture the wave kinetic energy and wave potential energy for power generation is less efficient; (3) Existing wave energy collection devices need to be equipped with costly cables for the transmission of electricity at sea, and because wave energy itself is unstable. Therefore, the direct integration of the electrical energy converted into the power grid will interfere with the stability of the power grid.

In response to the above problems, it is necessary to propose a solution to the existing wave energy collection plant power generation instability interference with the power grid, and to make the device with autonomous navigation capability, thereby reducing its impact on the ocean severe weather, reduce maintenance costs. Therefore, the design of self-sailing wave energy collection device based on the solution hydrogen storage of sea hydropower is proposed. This device combined with self-sailing unmanned ship carrier, folding integrated wave energy capture device, sea hydropower de-hydrogen system, alleviates the existing wave energy collection device mobility is poor, power generation
instability interferes with the power grid, in clementine and other problems, its thinking in the field of marine energy utilization is of great significance. The overall design idea is shown in Figure 1.

Figure 1. General design idea diagram

2. Design of self-propelled unmanned carrier

2.1. Function of self-propelled unmanned vessel carrier
The main function of the self-sailing unmanned carrier is to carry a hydrogen energy conversion system and a wave power generation system, so that the entire wave energy conversion device has the ability to sail autonomously and return to the shore when hydrogen energy conversion is completed or in bad weather.

2.2. Structure of self-propelled unmanned vessel carrier
Self-propelled unmanned ship carrier structure mainly includes catamaran hull, deck, inner hull equipment compartment, deck equipment cabin, full swing pod-type thruster, photovoltaic panel, removable damping plate, wave direction judgment sensor. The structure of the unmanned ship carrier is shown in Figure 2.

Figure 2. Schematic diagram of unmanned carrier structure

The hull is designed as a catamaran structure with high stability. The inner hull equipment compartment is two, which is installed in two catamarans. The inner hull equipment compartment is equipped with lithium-ion batteries and control modules that provide electricity to unmanned vessels.

The deck equipment compartment is equipped with a hydrogen conversion system and an integrated hydraulic power generation module. Photovoltaic panels are mounted on top of the deck equipment compartment to replenish the power of an unmanned ship and increase its battery life.

The full-swing pod-type thruster is mounted at the rear of the two hulls, and the full-swing pod enables fast avoidance and flexible navigation of unmanned vessels [2].
The retractable damping plate is mounted on the bottom of the hull with a telescopic bracket. During navigation, the telescopic bracket is in a shrinking state and the damping plate does not touch the water surface. When the unmanned vessel sails into the intended target waters, the telescopic bracket lengths and releases the damping plate so that it is completely submerged in water. When the waves pass over the hull, the damping plate provides downward resistance to the hull, thus reducing the floating of the hull with the waves, improving the relative motion of the power-generating float and the hull, and improving the efficiency of power generation. The wave direction judgment sensor is installed on the middle side of the removable damping plate, when the power generation operation is carried out, the sensor will record the corresponding angle after the wave skimmed the drainboard in the sensor, the unmanned ship control system will control the full swing pod-type thruster to change the direction of the unmanned boat to meet the wave direction, so that its bow coincides with the direction of the incoming wave. It can improve the efficiency and stability of wave power generation.

2.3. Control system of self-propelled unmanned vessel carrier

The control system of the unmanned carrier mainly includes the autonomous navigation control system and the remote-control system.

- The autonomous navigation control system is mainly carried by the Unmanned carrier under the role of GPS module, according to the predetermined direction and speed of autonomous navigation to the target position.

- The remote-control system consists of data transmission module, high-definition camera, remote control terminal and other devices, land control center staff can be combined with the remote-control terminal remote control of the unmanned ship carrier navigation.

3. Design of wave energy power generation system

Wave power generation system mainly includes a folding integrated wave energy capture device for wave energy collection and an integrated hydraulic power generation system for producing the electrical energy required for electrolytic water.

3.1. Design of a folding integrated wave energy capture device

The folding integrated wave energy capture device mainly includes floats that float up and down with the waves, wave kinetic energy on both sides of the float to capture propellers, and foldable robotic arms connected to the float. The structure of the folding integrated wave energy capture device is shown in Figure 3.

The potential energy generated by the wave floating up and down by a floating float ingress by a collapsible robot arm captures the potential energy generated by the float, while the wave kinetic energy on both sides of the float captures the kinetic energy generated by the wave motion.

Due to the blocking effect of the unmanned carrier itself on the wave, the two folding integrated wave energy capture devices behind the unmanned carrier are only installed as floats for collecting wave potential energy. When the unmanned carrier sails, the robotic arm folds and recycles the wave energy capture device, preventing the wave energy capture device from generating resistance in the sea water and affecting the navigation to reduce the speed. The folding integrated wave energy capture device recovery status is shown in Figure 4.

Figure 3. Structure diagram of wave energy capture device  

Figure 4. Recovery state diagram
3.2. Design of integrated hydraulic power generation system

Integrated hydraulic power generation systems include hydraulic linkage, hydraulic base, check valve, circulating hydraulic oil pipe, hydraulic oil pressure monitoring sensor, hydraulic oil release valve, hydraulic oil generator [3]. The structure of the integrated hydraulic power generation system is shown in Figure 5.

![Figure 5. Schematic diagram of integrated hydraulic power generation system](image)

Through the float floating up and down with the waves to drive the robot arm up and down swing, thus driving the hydraulic linkage on the hydraulic base to do reciprocating piston movement, through the check valve the mechanical energy of the mechanical arm reciprocating movement into the hydraulic energy of hydraulic oil. High-pressure hydraulic oil can be concentrated through the circulating hydraulic oil pipeline into the power generation main channel, the hydraulic oil pressure monitoring sensor in the power generation channel will monitor the hydraulic oil pressure in the power generation channel, when the oil pressure reaches the pre-set oil pressure to meet the hydraulic oil generator work pressure threshold, will be controlled by the control system hydraulic oil release valve open, thereby releasing high-pressure hydraulic oil to drive the hydraulic oil generator work power generation. The electrical energy generated by the hydraulic oil generator will be incorporated into the microgrid of the unmanned vessel for the operation of the unmanned navigation and wave energy hydrogen systems.

4. Hydrogen energy conversion system

Because the battery life is limited, the charge and discharge speed are slow, and the energy density is less than hydrogen energy, energy storage can be carried out by using the electric electrolytic seawater hydrogen generated by wave energy conversion, which is more energy than conventional batteries. The structure of the hydrogen energy conversion system is shown in Figure 6.

4.1. Hydrogen production system based on infield catalyst seawater electrolysis

When the device is electrocuted, the water is pumped into the electrolytic chamber by pump, using the boost module to increase the voltage of the electrical energy generated by the wave energy conversion, and converting the electrical energy into hydrogen energy under the action of the NiFe-LDH catalyst. The use of NiFe-LDH catalyst hydrolyzed seawater hydrogen can reduce seawater erosion electrode anode, and the method allows the electrode to operate at a larger current, resulting in a higher hydrogen-making speed [4].

4.2. Organic liquid hydrogen storage system

Hydrogen is gaseous at room temperature and normal pressure, with a density of only 7.14% of the air, so the storage and transportation of hydrogen on the device is very important. Since the storage and transportation of offshore hydrogen energy should meet the requirements of high efficiency, safety and low cost, the hydrogen storage and transportation in this device shall be carried out by the hydrogen storage method of liquid organic matter [5]. Hydrogen generated by the device enters the hydrogenation reactor tank through a catheter and reacts with liquid organic matter under the action of the catalyst, and the resulting product is stored in the storage tank. When the device returns to the port, hydrogen is released by dehydrogenation reaction under certain conditions, and a liquid organic compound with
hydrogen storage capacity can be recycled. The hydrogen storage system workflow is shown in Figure 7.

Figure 6. Hydrogen energy conversion system

Figure 7. Flow chart of hydrogen storage system

5. Conclusion
This device has certain advantages in practicality, environmental protection, economy, safety and operational autonomy, it transforms wave energy into another clean energy - hydrogen energy through a series of automated processes, enabling the effective collection and transformation of wave energy, avoiding the unstable power generated by wave energy conversion to the power grid. At the same time, the device to a certain extent overcomes the existing wave power generation plant mobility, limited application of sea areas, vulnerable to bad weather damage, maintenance difficulties, saving the cost of laying the offshore power grid, reducing the cost of the operation and maintenance of wave power generation equipment, can independently and efficiently realize the collection of wave energy and the conversion of hydrogen energy production, has a broad prospect of development and application.

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