Research on Key Technologies of Wave Energy Power Generation System

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Abstract. Most of the surface of the earth is occupied by oceans, and huge energy is stored in the oceans. Among marine energy sources, wave energy, tidal energy, tidal current energy, etc. are included. As a widely distributed, high energy density, pollution-free and environmentally friendly renewable energy source, ocean wave energy attaches great importance to ocean energy in most countries in the world. Compared with wind power and photovoltaic, the utilization of ocean energy with wider distribution and greater energy density is still lagging behind. Ocean wave energy power generation mainly refers to the use of corresponding technical equipment to convert the powerful kinetic energy of ocean waves into electrical energy. In view of the current tight supply of traditional energy, it can effectively relieve the problem, promote the development of marine resources and improve the environment. Therefore, this paper studies the wave power generation technology. First, the article analyzes the system principle of using wave energy to generate electricity, introduces several commonly used wave energy conversion devices, and then studies its power generation technology from the aspect of control strategy, so as to maximize the energy conversion power in the wave energy generation process. It will maximize the conversion of wave energy to electrical energy.

1. Introduction

As we all know, the treasures in the ocean are inexhaustible and inexhaustible. In the ocean, it not only contains a lot of clean and renewable energy, but also contains many other types of resources, such as various types of marine life, many chemical elements dissolved in seawater, various mineral resources deposited on the bottom of the ocean, and huge reserves [1]. Natural gas and oil resources, etc., these resources cannot be developed without humans and equipment. Strengthen the full utilization of ocean wave energy and convert the wave energy into electrical energy, which can play a good role in protecting the ecological environment of the ocean. The demand for electrical energy resources has effectively alleviated the progress of electrical energy resources [2]. The obtained electrical energy is provided to relevant equipment, so as to efficiently develop other resources in the ocean, and realize the purpose of utilizing ocean energy to develop ocean resources for the benefit of mankind.

Comprehensive consideration of wave resources, ocean engineering, operation and maintenance and other factors, the power supply capacity of a single wave energy device is limited. In order to meet the increasing demand for electricity from isolated users at sea, it is one of the effective ways to deploy wave energy device groups and establish wave energy power plants. The wave motion has reciprocating characteristics, and the output power of the wave energy device fluctuates greatly [3]. The isolated users' microgrids, such as islands, are very small in size, and their ability to resist power supply shocks is very limited. Therefore, the grid-connected access mode of wave energy plant group, the stable power supply
The mode of wave energy plant, the characteristics of the power generation system of wave energy plant, the feed-network converter and its control strategy, and the monitoring of wave energy plant are all the key technologies to be solved urgently in the establishment of wave energy plant [4]. In this paper, the principle of wave power generation and the control strategy for maximum wave energy capture are studied, and some results have been achieved.

2. Working Principle of Wave Energy Power Generation System

Taking the most common type of hydraulic energy storage as an example, its components include hydraulic cylinders, accumulators, hydraulic motors, oil tanks, generators, power converters and loads [5]. Its working principle is shown in Figure 1.

![Fig. 1 Structure of wave energy power generation system](image)

From the perspective of the basic composition of the wave energy power generation system, it is mainly composed of a hydraulic energy storage subsystem and a hydraulic power generation subsystem [6]. The main work of the former is to continuously collect the mechanical energy contained in the undulating waves; the main work of the latter is to convert these collected mechanical energy into electrical energy and output it to the grid.

Due to the existence of the accumulator, the hydraulic energy storage system can still maintain a relatively stable and regular energy storage characteristic under the condition of continuous wave changes, so that the wave conditions and the power generation process are decoupled from each other, which is conducive to simulation modeling [7].

The principle of wave energy conversion generator is consistent with the law of conservation of energy, that is, the continuous wave of the wave is used to drive the power generation device to move the captured wave energy to move the internal devices of the device, and the wave kinetic energy is converted into the mechanical energy of the moving parts in the device, which is then The electric energy is transmitted to the load. As shown in Figure 2, at present, wave energy generators can be divided into three categories, hydraulic power generation, turbine power generation (water turbine / air turbine) and direct drive linear power generation.
3. Design of the controller of the wave energy generation system

3.1. Controller Structure Design

In the system, the controller can perform power conversion. The controller is the most important part of the system. In the actual project, the three-phase AC permanent magnet synchronous generator is selected. Due to the instability of wave energy, the voltage output by the generator also fluctuates greatly at different times [8]. Therefore, it cannot be directly used for the load, and needs to go through the process of rectification, DC conversion and inverter. In order to improve the utilization efficiency of power generation, the rectifier circuit uses a three-phase fully controlled bridge rectifier circuit.

In view of the non-linearity of wave energy generation and the wide range of output voltage, if you want to stabilize the output voltage within a certain range, it is required that the conversion circuit must also have the function of buck and boost. Buck and Boost circuits only have a single step-down and step-up function, obviously cannot meet the stable output requirements. The traditional Buck-Boost circuit, which is a single-switch converter, has the function of buck-boost at the same time. However, because there is only one switch, the switching of the working mode fluctuates greatly, and the input and output polarities are reversed [9]. The double inductance structure of the Cuk circuit complicates the calculation of circuit parameters and increases the difficulty of circuit design. Some other isolated conversion circuits need to add coupling devices such as transformers to increase the complexity of the circuit.

Therefore, how to have both the buck-boost function and reduce the requirements on the device, as well as the design difficulty and cost of the main circuit, is the key idea of the DC-DC converter circuit design.

In this paper, a dual-tube H-bridge Buck-Boost circuit is adopted. This circuit has the advantages of the same output polarity and wide voltage range. The circuit topology is shown in Figure 3, including two switch tubes Q1, Q2, two fast recovery diodes D1, D2, input capacitor C1, output capacitor C2, and an inductor L. Q1 and D1 form the step-down part, and Q2 and D2 form the step-up part. While meeting the design needs, it also simplifies the circuit structure and parameter calculation process.
3.2. Maximum power tracking control based on Buck-Boost circuit

The block diagram of the maximum power tracking control based on the Buck-Boost circuit is shown in Figure 4. The electric energy emitted by the linear motor is supplied to the buck circuit after being rectified by an uncontrolled three-phase bridge, and the size of the output resistance of the motor is regulated by controlling the switch of the buck circuit. The control parameter is the average power at the load end, and its value is calculated by collecting the single-phase voltage and current of the motor. After analyzing the change of average power by the hill climbing method, the required duty ratio of the switch tube is obtained. This method can be used in the control system of the off-grid wave power generation device [10].

Fig. 3 H-bridge Buck-Boost circuit topology

Fig. 4 Block diagram of power tracking control based on Buck circuit
4. Wave Energy Controller Buck-Boost Circuit Simulation

4.1. Work point selection

The parameters of the three-phase permanent magnet synchronous generator are 690V, 1000rpm and 18kW. The working curve of the generator is shown in Figure 5.

![Figure 5 Generator operating characteristic curve](image)

(a) Full load voltage curve (b) Power curve

4.2. Control strategy

In order to enable the H-bridge Buck-Boost main circuit to achieve the required performance indicators of the system, it can achieve the effect of voltage stabilization under different working modes. And in order to improve the stability and accuracy of the system, it is usually designed as negative feedback closed-loop control. The design takes the dynamic model of the conversion circuit as the research object, so it is necessary to analyze the characteristics of the conversion circuit when there is small AC disturbance and establish a mathematical model.

In the conversion circuit, the switch tube, freewheeling diode, filter capacitor, inductance, etc. are all non-linear devices. These devices make the conversion circuit also have strong nonlinearity. To establish a mathematical model for it, first of all, it must be linearized.

1. In the switching cycle of the conversion circuit, the device variables in the circuit are averaged to avoid ripples during switching affecting circuit analysis.

2. The DC and AC components are used to represent each average variable, and after simplification, the DC component is eliminated to obtain a small signal model containing only AC disturbances.

3. Linearize the small signal model and replace the nonlinear system near the stable operating point with a linear expression.

Figure 6 is the single-phase average generated power waveform based on the maximum power tracking control algorithm of the Buck-Boost circuit. The average power is stable at about 70w. Without the Buck circuit, the load of the linear generator is kept at 30Ω when the load resistance is 30. The average power of the phase is shown in Figure 7. From the comparison of the two figures, it can be seen that the maximum power tracking algorithm based on the Buck-Boost circuit achieves a more ideal effect.
The simulation results show that under different wave conditions, there is a unique load resistance value to maximize the output power. Finally, the maximum power tracking control method based on the buck-boost circuit is proposed. The buck-boost circuit is simply analyzed, and it is concluded that the output resistance of the motor can be changed by changing the duty ratio of the switch tube. Using the hill climbing method to verify the maximum power tracking simulation of the system, the simulation results show that the MPPT algorithm based on the buck-boost circuit is feasible.

5. Conclusion
The technology of using wave energy to generate electricity has a history of hundreds of years, and it has developed particularly rapidly in recent decades. From the perspective of development history, it mainly includes theoretical research, device manufacturing, internal testing, external sea trials and other stages. Compared with related research abroad, my country’s research on this technology started relatively late and the technology is not mature enough. However, in recent years, more attention has been paid to the development and utilization of wave energy at the national level, making the development in this field very rapid. There are many types of wave energy conversion devices. Each device has advantages and disadvantages. First, in the target sea area, you should fully understand the wave characteristics, and then select the appropriate type according to the wave characteristics of the target sea area. In this paper, the generation power of the wave energy power generation system is studied. Under the sea conditions where the wave frequency is large, it has a higher power generation. It is hoped that the research in this paper will be helpful to the research of wave energy power generation technology.
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