The Study on Self-powered Systems for Underwater Sensors Based on Tidal Current Energy

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Abstract. This paper proposes a vertical axis power generation device based on tidal energy for sensor used for information collection, the energy supply bottlenecks solving, and the sensor working efficiency improvement. The underwater operation test of the prototype system is carried out for finding the relation between the output power and the blade deflection angle and the blade speed ratio. This paper discusses how to improve the efficiency of energy conversion by modifying the parameters of prototype, which can provide a reliable guidance method for the next practical application. Experimental results show that the device can meet the energy demand of sensor networks.

1. Introduction

The ocean which area accounts for about 71% of the surface of the earth has rich natural resources and high economic values. The ocean is a basic component of the global life support system and is a kind of precious wealth helps to realize the sustainable development. How to make better use the marine resources has become the focus of research focus nowadays [1]. Digital ocean is an important means to promote scientific and modern marine management in China, and the important guarantee to promote the implementation of Chinese national marine strategy and the "One Belt One rode" strategy. Marine information acquisition, information transmission and data fusion are the prerequisite and basis of Digital Ocean [2].

Underwater sensors play an important role in marine data acquisition, pollution prediction, ocean mining, marine monitoring and so on [3]. However, energy supply is the bottleneck of applications underwater sensors. Statistics show that the vast majority of underwater sensor using battery power, and limited energy battery can only provide a period of electric energy for underwater sensor, when the battery is exhausted, i.e. with sensor failure. Therefore, it is an important research direction for underwater sensors to solve the energy supply problem effectively.

The tidal current energy is generated by the periodic flow of water caused by celestial gravitational. The energy is more abundant at the place of seaboard., straits, the mouth of bay and so on, because of tidal speed. According to statistics, the average power of tidal current energy in China exceeds 14GW [4]. The energy density of tidal current is about 30 times that of solar energy, and 4 times that of wind energy. Besides, there is no need to develop tidal dams for tidal current, which is less destructive to the marine environment and less expensive to develop. Tidal current energy has a very broad prospect

to be developed. Great attention has been paid to it and great achievements have been made by present [5, 6].

2. Vertical-axis tidal current turbine structure optimization

Vertical-axis tidal current turbine refers to the axis of rotation of blade perpendicular to the flow direction, compared with the rim generator, has great advantages. The main performance is: the simple design and installation, light weight, low manufacturing cost, the generator can be placed above the water reducing sealing cost. Besides, the generator can be used alone or as a whole integrated platform to solve the problem of power supply of sensor network. A schematic structure of power system is showed in Fig.1. This system will be integrated with the impeller generator as a whole. The impellers are installed outside of the generator, so that it can drive generator rotor and generate power. The vertical axis of the impeller makes it possible that the system can capture any flow direction of the fluid kinetic energy. The submersible buoy system will be suspended in the water turbine generator set. Two sets of axial rigidity rotating in the opposite direction will be arranged in series unit, so that their rotational torque will be effectively counteracted, which will make the operation of the system stable. Showing in Fig. 2, the prototype drawing is designed combined with the IEECAS (institute of electrical engineering of the Chinese academy of sciences).

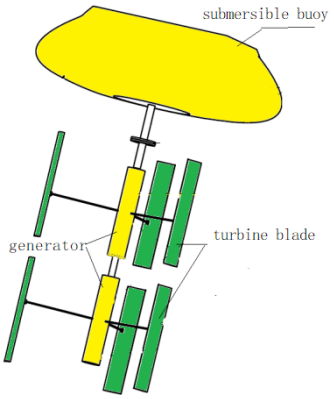

Figure 1. 2 sets of generator installation demonstration

Figure 2. generator design drawing

3. Turbine structure optimization

The traditional tidal generator structure drives the blade through the water, the blade to drive the rotor of the generator through a transmission device generates current through the method of cutting magnetic lines works in the ocean structure is too complex, in the eastern coastal salinity corrosion in China is high, the attachment of marine organisms, high sediment environment, must do extra protection to the generator, especially the transmission device and the generator equipment problems caused by the increase of the cost and the equipment structure more complex, low efficiency power

generation. In order to solve the above problems, combined with the IEECAS developed vertical axis tidal current turbine, the generator will blade and generator design together, and remove the transmission device in current driven directly by the impeller drives the generator to generate electricity. The utility model has the advantages of better structure compactness and higher safety reliability, and the installation, operation and overhaul are convenient, and the power generation efficiency is higher.

When the impeller rotates perpendicular to the direction of the stream, the energy density P obtained by the motor is [7]:

$$P = \frac{1}{2} C_p \rho A v^3 \tag{1}$$

$$C_p = f(\lambda, \beta) \tag{2}$$

$$\lambda = \frac{\omega D}{2v} \tag{3}$$

Among them, C_p is the impeller energy conversion factor, ρ is flow density, A is impeller area, and v is flow velocity. It can be seen from the expression that the output power of the turbine is mainly affected by the energy conversion coefficient C_p after the design of the motor and the arrangement of the sea area according to the actual conditions .The experimental results show that the capture coefficient C_p showed as expression 2 will change as the blade tip speed ratio λ showed as expression 3 and pitch angle change. Finding the most suitable parameters of the motor and improve the efficiency of the motor by experiments is the main purpose of this paper

3.1. Turbine performance test structure design

Capture power and output power are the two most important parameters of the tidal generator structure system, and they are the most direct parameter indexes to reflect the system's advantages and disadvantages. Fig.3 design scheme to test the performance of the motor under various experimental environment, during the experiment, the output end of the generator is connected with the resistor load box (as Fig.4), measuring instrument measuring the load of electrical parameters can be obtained, speed, voltage and current output electric power system has parameters, and on the basis of effective output parameters, to determine the optimal design of the motor.

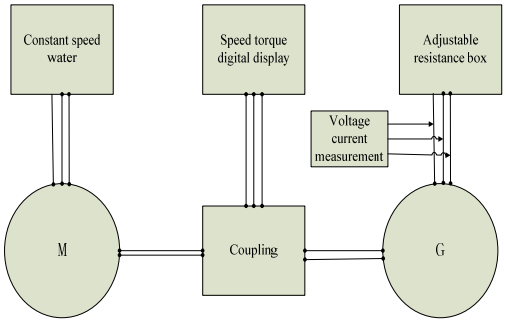

Figure 3. Experiment scheme

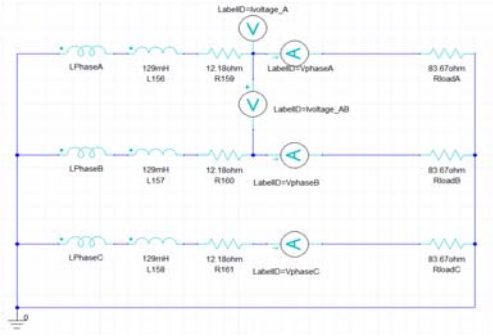

Figure 4. Resistance load box

3.2. Motor energy conversion coefficient optimization

When the flow is stable and continuously through the blades, one side surface streamline is relatively dense, smaller flow control, the flow velocity, the pressure is small, the other side surface streamline relatively sparse flow tube is thick, the flow velocity is slow, pressure, the pressure difference driving rotating blades. The research show that the matched blade deflection angle is an effective method to improve the operation and power characteristics of the vertical shaft impeller, and its hydrodynamic performance is also different, and when the generator load changes, the blade tip ratio of the motor will change accordingly, which will affect the energy conversion efficiency of the motor [8]. Finding the optimal deflection angle has become the key problem of vertical axis impeller performance design and blade control, and some research progress has been made in recent years. In this paper, experimental methods are used to test-6 degrees, -3 degrees, 0 degrees, +3 degrees, +9 degrees, +12 degrees, +15degrees, repeated test under 1m/s flow rate, record experimental data, and find out the equipment configuration with the highest energy conversion efficiency. The result is showed in Fig. 5.

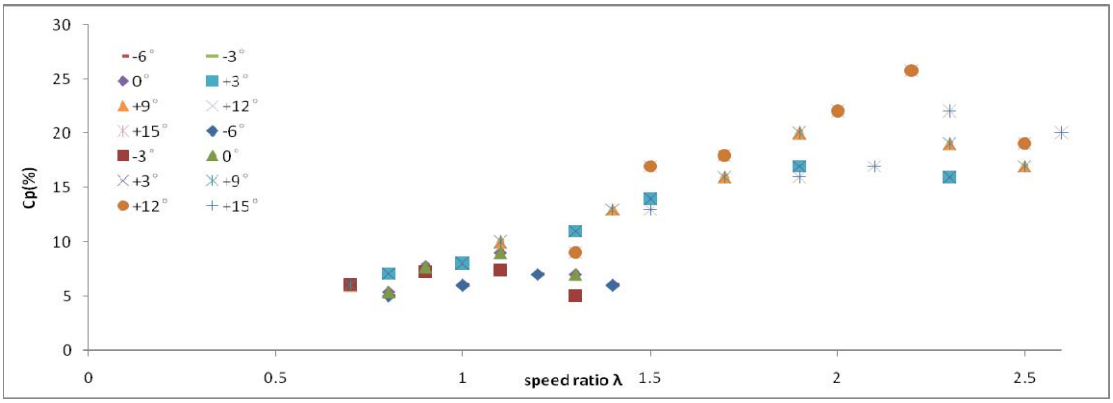

Figure 5. Scatter diagram of C_p at different blade deflection angles and tip speeds radio

3.3. Turbine generator performance test

When the vertical-axis tidal current turbine works, the stator and rotor are directly immersed in sea water, and the sealing and corrosion resistance of the motor are very important. The turbine is sealed with epoxy resin to seal the rotor and prevent corrosion. The epoxy resin directly integrates the generator stator core and the winding wire package to prevent the sea water from entering the stator silicon steel sheet and to destroy the electrical insulation, and the rotor permanent magnet is sealed and antiseptic treated with epoxy resin.

The electric energy conversion efficiency of turbine is an important basis for judging the performance of the turbine and is also the main content of the test. Experimental prototype diameter D=800mm, height H=500mm, blade number B=3, rated speed n=54.9rpm.Under the test flow rate of 1m/s, the experimental results show the optimal tip speed ratio λ=2.2, the impeller capture efficiency

of C_p=0.25, electromechanical conversion efficiency (including leaf support loss, turbine loss) =0.5, motor output voltage 7.2V, current 2A, power 16W. Under the same experimental conditions, when the speed of seawater is 2m/s, the power of the impeller is almost 8 times as high as 1m/s, the capture power is 240W, and the speed of the system is 109.8rpm. The turbine works stably. Under the condition of the highest conversion rate, the output power and motor speed are shown in Fig. 6.

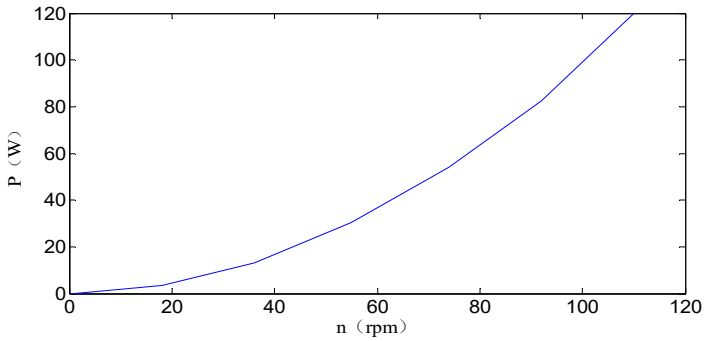

Figure 6. Speed power curve

4. Conclusion

Sensor information acquisition is an important data source of marine information construction in China. It is a strong guarantee for digital ocean, and energy problem is a bottleneck of Marine Sensor continuous work. In this paper, the vertical-axis tidal current turbine is used to convert tidal currents into electrical energy for solving the energy supply problem for marine information acquisition sensors effectively. The has the advantages of good tightness, simple structure, compact structure, low manufacturing cost and simple installation. The experimental results show that the machine can meet the demand of sensor power supply in the running environment and the conversion efficiency of tidal current energy.

Acknowledgments

This work was financially supported by Zhejiang Province Innovation Team fund 2013TD14 and Zhoushan Science and Technology Project 2017C41007, China.

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