Study on Key Design Technology of Energy Capture for Ocean Current Energy Generator Unit

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Abstract. The main problems in energy capture for ocean current energy generator unit are low efficiency and short service life, and it is basic to solve the problems that study on the key design technology of energy capture for ocean current energy generator unit. In this paper, depending on the national marine renewable energy resource special fund project, that is, design and fabrication on a 300kW horizontal axial ocean current energy generator unit, the key design technologies of energy capture for ocean current energy generator unit are studied. The key technologies include design of the efficient blade hydrodynamic profile suitable for running in ocean water, design of the strengthening blade considering alternating stress amplitude due to pressure difference, design of the pitching driver compliance with varies due to current speed or direction, design of accurate algorithm for driving blade rotating conform to current change consisting of consistent pitching and independent pitching as well. Thus, the reliable technology support is provided for high efficient energy capture and long term running of ocean current energy generator unit with the study on the key technologies.

1. Introduction

Ocean energy is a kind of clean renewable energy stored in the sea, it has great significance to relieve energy crisis and environmental pollution to develop and use ocean energy. In many countries, particularly with abundant ocean energy resources, the power generating technology making use of ocean energy is powerfully forward.

Ocean current energy is an important aspect of ocean energy and an important new force of renewable energy source, it is being substantially developed to generate power using it worldwide.

In ocean energy, the power generating technology making use of ocean current energy is relatively mature, and it has been carried out for many years to research the ocean current energy generator unit worldwide. The first horizontal axial ocean current energy generator unit (Seaflow), with rated capacity 300kW, was successfully developed by Marine Current Turbine (MCT) Company cooperated with other organizations in 2003[1]. The AK1000TM unit developed by Atlantis Resources Corporation successfully installed in the sea with 35m water depth in 2010 [2].
China has abundant ocean current resources. The economically exploitable capacity offshore is about $82\times10^4$ kilowatt according to the principle of available area estimated with current speed equal or more than 1.2m/s [3]. In China, the ocean current energy generator units have been researched in recent years with rated capacity less than 300kW and power efficiency no more than 40% [4]. There are many important projects, particularly supported with the national marine renewable energy resource special fund, in progress by universities, research institutes and high-tech enterprises. Among them, there is a 300kW ocean current generator unit being developed by Guodian United Power Technology Company Limited, a 60kW ocean current generator unit has been developed by Zhejiang University with power efficiency 39%, a 200kW ocean current generator unit has been developed by China Ocean University with power efficiency 35.2% as well.

Up to now, the horizontal axial and the vertical axial are the main types of ocean current generator unit to capture ocean energy [5-6]. The main problems are low efficient and short service life in energy capture [7] and which greatly influence the industrially progress for ocean current generator unit. It is basic to solve the problems that study on the key design technology of energy capture for ocean current energy generator unit and apply with it further.

In this paper, depending on the national marine renewable energy resource special fund project, that is, design and fabrication on a 300kW horizontal axial ocean current energy generator unit, the key design technologies of energy capture for ocean current energy generator unit are studied and deeply analysed.

2. Energy Capture

The horizontal axial ocean current energy generator unit generally runs at a specific site below the mean sea level. The central axis of generator unit is parallel with ocean current direction, illustrated in figure 1.

![Figure 1. Horizontal axial ocean current energy generator unit](image)

To achieve that the ocean current energy turned into the electricity power, the first step is to capture ocean current energy by ocean current energy generator unit. Energy capture depends on rotor system consisting of blade and hub, pitching system consisting of pitching driver, pitching bearing and pitching reduction gear, controlling system mainly referring to controlling algorithm as well. As studying in the project of design and fabrication on a 300kW horizontal axial ocean current energy generator unit, energy capture illustrated in figure 2.

The main function of rotor system is to capture ocean current energy. As ocean current flows toward generator unit, blade capture the kinetic energy creating moment to drive rotor rotating, thus the kinetic energy from ocean current is transformed to the rotary energy of rotor. Furthermore, the
electricity power is produced and given out from the rotary energy by energy transmission and conversion system. The main function of pitching system is compliant with variation of current speed and direction to drive blade starting, running, pitching and stopping with certain speed and angle so as to efficient energy capture. The function of control system is to give control order. According to the order signal, the pitching system and the rotor system complete energy capturing. The rotor system, pitching system and controlling system are an integrity to capture energy, only the three links all have high efficient and long term service life, the energy capture of horizontal axial ocean current energy generator unit can be value.

Therefore, to study the key design technologies of energy capture is exactly to study the key design technologies of rotor system, pitching system and control system.

3. Rotor System
The rotor system consists of blade and hub, and the key design consist in complying with operating conditions in the sea.

3.1. Blade Design
The blade of generator unit is a kind of component directly seizing the ocean current energy, which made of carbon fibre, glass fibre, bonder and foam in generally. Because of continuous running in the sea for long time, the key technologies in design blade exist in two aspects: one is hydrodynamic profile design suitable for efficient energy capture and the other is strengthening design considering alternating stress amplitude due to pressure difference.

![Energy capture of ocean current energy generator unit](image)
Design of hydrodynamic profile suitable for efficient energy capture is very complicated and hydrodynamic profile directly influence the efficient of ocean energy capture. Design experience of offshore wind turbine blade should be taken as reference. In design, hydrodynamics and fluid-solid coupling methods are adopted, also cavitation and three dimensional flow field theories are considered, with the purpose of the best power coefficient. As studying in the project of design and fabrication on a 300kW horizontal axial ocean current energy generator unit, the relationship between power coefficient and blade tip speed ratio illustrated in figure 3.

Strengthening design considering alternating stress amplitude due to pressure difference is very necessary. Because of long time rotating in the sea, the fatigue life of blade is significant influenced by varying pressure due to different location. On the basis of normal analysis, strengthening design should reinforce weak points superposing influence on fatigue life of alternating stress amplitude when blade running. As studying in the project of design and fabrication on a 300kW horizontal axial ocean current energy generator unit, blade structure is designed as a type of three webs. The blade profile and structure illustrated in figure 4.

**Figure 3.** Relationship between power coefficient and blade tip speed ratio

![Figure 3](image3.png)

**Figure 4.** Blade profile and structure

3.2. **Hub Design**

The hub is the first component impacted by ocean current flowing which supports blades and protect pitching system set in it. So it should be very solid to bear the impact force. The key design of hub consists in that incident stream cover should be designed as streamline. Thus, the resistance of hub to stream is greatly lowed and the current energy consumption is also much reduced. As result, the ocean current capture efficient should be improved. In addition to this, the streamline type can give sense of beauty.
4. Pitching System
The key design of pitching system consists in complying with varies due to current speed or direction. The pitching system mainly consist of pitching driver, pitching components, etc.

4.1. Pitching Driver
The pitching drive is critical in ocean current energy capture of generator unit. When ocean current varies in speed and direction induced from ocean tidal rising and falling, it can fulfill function as follows:

(1) When ocean current energy generator unit starts up, it can drive blade angle to achieve current energy generator unit self-starting relying on ocean current energy.

(2) When ocean current energy generator unit runs, it can drive blade angle to achieve current energy generator unit stable operating at full capacity after reaching rated capacity.

(3) When ocean current energy generator unit stops, it can drive blade angle to achieve given safe location and braking safely, so as to guarantee the unit safely shut off.

(4) Pithing driver must satisfy the function of changing pitch angle forward and reverse because ocean current can flow in positive and negative direction one day due to natural character.

As studying in the project of design and fabrication on a 300kW horizontal axial ocean current energy generator unit, the pitching driver illustrated in figure 5.

![Pitching driver of ocean current energy generator unit](image)

**Figure 5.** Pitching driver of ocean current energy generator unit

4.2. Pitching Component
Pitching components include pitching bearing and pitching reduction gear. Pitching bearing supports blade to vary pitching angle so as that the load on it is very complicate and enormous. In design pitching bearing, the key factors exist in not only enormous axial and radial load but also overturning moment must be born. Hereby, multi-row cylindrical roller bearing is the best choice. As studying in the project of design and fabrication on a 300kW horizontal axial ocean current energy generator unit, a kind of three-row cylindrical roller bearing consisting of two-row axial and one-row radial cylindrical roller bearing adopted.

Pitching reduction gear plays an important role in pitching system. In design pitching bearing, the key factors exist in not only high efficient, compact structure but also running smooth and steady, long operation and maintenance period.
5. Controlling System
The key design of controlling system consists in accurate algorithm tracking ocean current change to drive blade rotation consistent with ocean current varying in speed and direction. If ocean current flow from one direction to reverse, from high speed to low speed or reverse, the controlling system must give off order to control pitching system and drive blade consistent with ocean current varying in speed and direction in the case of starting, running, stopping and from one direction to reverse with the purpose of obtaining the best pitching angle to maximum energy capture.

As studying in the project of design and fabrication on a 300kW horizontal axial ocean current energy generator unit, the relationship between best pitching angle and ocean current speed is illustrated in figure 6, and some control order signals are set to keep best relationship between pitching angle and ocean current speed, illustrated in table 1.

The highest sufficient ocean current energy should be captured following the relationship curve and the given data. There are two kinds of methods to control pitching angle, that is, consistent pitching and independent pitching. Consistent pitching means the all blades of ocean current energy generator unit keeping same speed and angle. While independent pitching refers to that each blade of ocean current energy generator unit holds respective speed and angle and there is difference between different blades. In the case, ocean current condition located at different blades is even more precise tracked.

![Figure 6. Relationship between best pitching angle and ocean current speed](image)

**Table 1.** Controlling order signals

| Signal                        | Value   |
|-------------------------------|---------|
| cut in current speed          | 0.7 m/s |
| cut out current speed         | 4.0 m/s |
| rated current speed           | 2.0 m/s |
| rated rotor rotation speed    | 14rpm   |
| pitching speed (running)      | 4 deg./s|
| pitching speed (turning direction) | 2 deg./s|
| pitching speed (stopping)     | 8 deg./s|
| pitching speed (safety)       | 8 deg./s|
| pitching speed (rapid)        | 8 deg./s|
| pitching speed (emergency)    | 8 deg./s|
| pitching speed (default)      | 8 deg./s|
6. Conclusion
In the paper, depending on the national marine renewable energy resource special fund project, that is, design and fabrication on a 300kW horizontal axial ocean current energy generator unit, the key design technologies of energy capture for ocean current energy generator unit are studied and deeply analysed. To sum up, the key design technologies of energy capture consists in that of rotor system, pitching system and control system.

To design rotor system, the key technology exists in complying with operating conditions in the sea, including hydrodynamic blade profile design suitable for efficient energy capture, strengthening blade structure design considering alternating stress amplitude due to pressure difference and streamline incident stream hub cover design. To design pitching system, the key technology exists in complying with varies due to current speed or direction, including pitching driver design auto-adjusting pitching angle and speed, multi-row cylindrical roller bearing design and efficient and reliable pitching reduction gear design. To design control system, the key technology exists in accurate algorithm tracking ocean current change to drive blade rotation consistent with ocean current varying in speed and direction, including two kinds of methods, that is consistent pitching and independent pitching. The reliable technology support is provided for high efficient energy capture and long term running of ocean current energy generator unit with the study on the key technologies.

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