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Analysis of the Current Situation and Development of Tidal Energy Generation

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Abstract: *As a clean, non-polluting and renewable energy source with abundant reserves, tidal current energy is highly sought after by various countries. In this paper, we present a preliminary analysis of domestic and international research on tidal power generation and propose future development proposals to provide impetus for the development of tidal power generation into commercial mode. Although some progress has been made in the demonstration of tidal power generation in various countries and relevant data with high scientific value have been obtained, the research and development of tidal power generation devices is still in the technical development stage, and many problems remain to be solved. If a highly efficient and reliable tidal power generation device can be developed, it will be of great significance for meeting future energy demand and sustainable energy use.*

Keywords: *Tidal power generation; Hydraulic turbines; Current status of development*

1. Introduction

Energy is the material basis for the existence and development of human society, and since the 20th century, the large-scale development and use of fossil fuels such as coal, oil and natural gas have contributed to human development while causing a lack of conventional energy and pollutant emissions. Therefore, the development of renewable and non-polluting energy sources has become a unanimous goal for all countries in the world. The oceans, which occupy 70% of the planet, are rich in energy and could theoretically meet the planet's energy needs without causing pollution. Tidal current energy, as part of ocean energy, has superior characteristics such as stable and concentrated energy and predictability, and has received the attention of many scientific and technical workers at home and abroad[1][2].

In recent years, many countries are actively participating in the research of tidal energy generation, some countries are in the early stage of research, some countries are in the technical research stage, and some countries are in the commercialization stage. However, tidal power generation generally suffers from unstable rotational speed, unstable power output, low energy acquisition efficiency and high operating costs. Therefore, tidal power generation needs further efforts from all over the world to solve these difficult problems. This paper summaries recent research on tidal power generation at China and abroad, and presents proposals for the future development of tidal power generation technology.

2. Composition of Tidal Power Generation Systems and Their Classification

A complete tidal power system consists of five components: energy capture device, support structure, control system, energy transfer system and energy conversion system. Most of the emerging tidal power systems are placed underwater and do not generate excessive noise or damage the diversity of species underwater.

Tidal current energy generation systems are classified according to different classification methods, as shown in Fig. 1.

Horizontal and vertical axis types according to whether the impeller rotation axis is in the same direction as the tidal current flow. Horizontal axis tidal, the impeller rotation axis is parallel to the tidal flow direction, this type is currently a more mature technology. Its load uniformity, smooth rotation, good self-starting performance, the control of the blade is mostly used in the form of variable pitch propeller, can achieve maximum energy gain. The power output is smooth and the impact on the control system is small, but the blade design of the horizontal axis type is difficult; the vertical axis type tidal energy means

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that the impeller rotation axis is perpendicular to the tidal flow direction, its design is simple and the impeller rotation is independent of the incoming current direction, which can be well adapted to the tidal flow direction; however, the starting performance is poor, easy to stall and the power output is unstable, which leads to low energy utilization. According to the way the support structure is installed in the ocean, it can be divided into frame type, Pile foundation type, gravity type and floating type. Gravity means that the turbine stands vertically on the sea surface mainly by its own weight, usually in reinforced concrete caisson construction, and is used in waters of 0~10m. Pile Foundation means consisting of a steel pipe pile between 3 and 5m in diameter, suitable for waters less than 25m, The floating type is a box platform floating on the surface of the sea, the platform is then anchored to the seabed with a mooring system, suitable for waters greater than 50m, and is one of the future trends in the development of wind turbine foundations for deep sea waters. The advantages and disadvantages of the four methods are shown in Table 1.

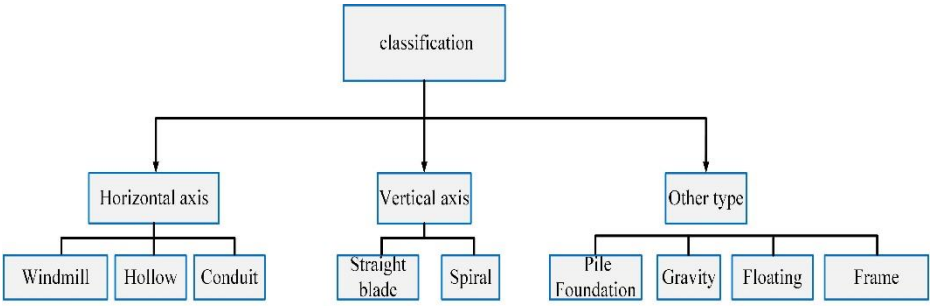

Figure 1: Classification of tidal energy conversion systems

Table 1: Summarising the advantages and disadvantages of support structures

Type of support structure	Advantages	Disadvantages
Frame Pile Foundation	Easy to install and maintain	High requirements for subsea geology
Gravity	No need to consider tidal differences, Waterways avoidance	High construction costs
Floating	Simple structure	Poor wave resistance

3. Current Energy Research Status

3.1. Status of foreign research

According to published literature, tidal energy devices have been developed worldwide by TGL (Tidal Generation Limited) MCT (Marine Current Turbine), Lunar Energy, Ocean Flow Energy, AR (Altantis Resources) in Singapore, OpenHydro in Ireland, Hammerfest Storm in Norway, Verdant Power in the USA, Clean Current Power Systems in Canada and others have developed tidal current energy devices, as shown in the more typical tidal current energy devices (Fig 2).

The main representative horizontal axis tidal power devices available internationally are SeaGens from the UK, the world's first megawatt tidal power generator[3]; the "AK-1000TM" from Singapore, which uses a fixed pitch paddle design and does not require a reversing mechanism [4]; and the Open Centre from Ireland, which uses a direct-drive generator and is characterised by its low speed and simple design [5]. Norway's HS300, with a total installed capacity of 300 KW, uses a sit-on-the-bottom technology with automatic convection [6].

The main vertical axis tidal energy device is the Canadian EnCurrent, which is based on the concept of the Darrieus wind turbine and uses a fixed blade[7]. Kobold in Italy, with an installed capacity of 120KW, is the world's first vertical axis power generator to be connected to the grid[8]. Current Power in Sweden, which uses a direct-drive generator for the turbine, has completed tests on a prototype.

Other forms of tidal energy devices include the UK's Stingray device, which is a sit-on-the-bottom design that can adapt to the flow of the tide to achieve stable energy harvesting, but has a more complex control system [9]. The US VIVACE system, which converts energy at low tidal currents, is already in commercial operation[10]. Bent Hilleke in Denmark invented a new type of impeller with blades that reduce reverse torque during rotation, and later developed a specially shaped base that can increase the incoming flow velocity while improving energy capture efficiency[11].

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Figure 2: Partial prototype of a foreign tidal energy device

3.2. Current status of research in China

Compared with foreign tidal energy development, China's tidal energy research and development started late. On the basis of the introduction of foreign tidal energy technology, the development and utilization of China's marine energy has attracted the government's great attention and reached an unprecedented height. As a result, China has gradually stepped into the fast lane of tidal energy development and utilization. At present, China's tidal current energy development mainly has:

In 2004, the "Wanxiang I" tidal power plant with a total installed capacity of 70KW developed by Harbin Engineering University was put into operation, but due to its floating installation, it was susceptible to wind and waves and its efficiency was low[12]. In 2005, the university also developed the "Wanxiang II" tidal power plant with a total installed capacity of 40KW, which was found to have a low tidal energy utilization rate and low reliability [13]. In 2004, Zhejiang University developed a 5KW tidal power generation device, and in 2009, it developed a semi-direct-drive tidal power generation device with a total installed capacity of 25KW [14]. Northeast Normal University developed 1KW low-flow and 2KW direct-drive power generators, which were tested at sea in 2006 and 2008. The unit uses a horizontal axis turbine with wide blades and low requirements for starting flow rates[15].The 5KW floating tidal energy device developed by China Ocean University has blades made of flexible materials that can adapt to fluid flow, and is low cost and easy to maintain [16].

In recent years, with the introduction and digestion of foreign technology, China has begun to achieve a gradual leap from tens of kilowatts to hundreds of kilowatts. Harbin Engineering University developed the "Sea Energy I" floating vertical shaft power generation device, which is a floating vertical shaft impeller and direct-drive generator, fixed by four sets of mooring system, successfully sea trial in 2012, the system efficiency was measured to be more than 30%. In 2013, the "Sea Energy II" with a total installed capacity of 200 KW was successfully installed at Zhaitang Island, Qingdao[17]; In the same year, the "Sea Energy III" with a total installed capacity of 600 KW was also successfully launched. In the same year, the 600KW "Haineng III" was also successfully launched. The 650KW horizontal axis power generator developed by Zhejiang University was tested in 2017. The 300KW horizontal axis semi-direct drive power generator with variable pitch propeller blade control was jointly developed by State Grid and Zhejiang University and launched for water trials in 2018. Northeast Normal University and Hangzhou Jianghe Hydropower Co., Ltd. have developed a 300KW horizontal axis power generation unit. The design flow velocity is 2m/s and the blade control is in the form of self-pitching, and the sea trial study was carried out in 2019.The 400KW vertical shaft power generation unit and the 300KW horizontal shaft power generation unit developed by Hangzhou Lindong New Energy Technology Co., Ltd. both operated in a grid-connected manner and entered sea trial studies in 2016 and 2018 [18].

With the development of tidal energy technology in China, several hundred kilowatts of tidal energy generation has been achieved in China, but there is still a lot of room for research and development if we want to develop efficient and reliable megawatt-scale tidal energy generation devices.

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4. China's Current Special Challenges

Although China's tidal energy research has made great progress, from the current situation, tidal energy generation is still in the technology demonstration stage, there are still many problems to be solved, mainly in the following aspects.

1) Resources are limited. Although China's coastline is long, there are few comprehensive resources of tidal energy, only Zhoushan sea and Taiwan Strait exist as a class of resources, and this area has low flow speed, complex flow direction, large tidal difference, complex topography, extreme weather from time to time, which will need to seek answers in a large number of practice for the safety and convenient maintenance of the entire tidal energy generation system.

2) Low conversion efficiency. The current form of tidal energy use is through the hydrodynamic action of the fluid medium, the fluid kinetic energy into the mechanical energy of the system, and then the mechanical energy into electrical energy. Due to the randomness of the tidal flow direction, tide level and flow speed, the process of obtaining the maximum tidal energy and improving the conversion efficiency needs to be constantly practiced and summarised. The process of continuous experimentation and improvement is necessary, resulting in long research and development cycles. This results in long development cycles and high operating and testing costs.

3) System design. In the case of the relatively mature horizontal axis tidal power generation units, there are problems with large scale units such as jamming, designing support structures suitable for the water depth, typhoons and channel avoidance conditions in the waters where they are located, and how to improve the reliability of the support structures also await a technical breakthrough.

5. Recommendations for the Development of Trend Energy in China

5.1. Increasing support

The state should increase incentives for the development and utilization of tidal energy, establish a special fund for tidal energy development and make it clear that local governments with tidal energy resources should provide support for the development of tidal energy. Both national and local governments should set up tidal wave energy research and development teams to pool their ideas and explore continuous improvements. In addition, policies should be given to favour grid-connectable tidal energy generation units to connect to the national grid system, establish a taxation system to promote the development of tidal energy, and clarify preferential feed-in tariffs for tidal energy to maximise the economic benefits generated by tidal energy generation

5.2. Strengthen cooperation between industry, Academia and research

A system of state investment, joint development by universities, research institutes and enterprises, in which universities and research institutes provide theoretical support and analysis and evaluation for enterprises, utilise their respective strengths, complement each other's strengths, divide and collaborate, overcome the stagnation caused by insufficient funding for research and development and technical bottlenecks, and jointly realise technological innovation, and finally hand it over to enterprises for market and industrialisation.

5.3. Exploring multi-Energy complementary research

The development of an integrated energy system centred on multiple complementary energy sources, making full use of offshore wind, solar and wave energy, combined with tidal energy, can prevent a single energy source from being insufficient to provide a stable and continuous supply of electricity. It can also be combined with deep-sea farming, which will make offshore multi-energy complementary power generation a catalyst for solving energy supply and commercial operation models.

6. Conclusion

The 21st century is the century of the sea and it has become inevitable that mankind will obtain energy from the sea. It is urgent to solve the energy supply problems of many offshore islands and ocean platforms. This paper reviews the current situation and future outlook of tidal energy generation from

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three perspectives: the current status of research on tidal energy at home and abroad, the unsolved problems of tidal energy development and utilization in China, and the feasible suggestions. If an efficient and feasible tidal current energy generation system can be developed, it will effectively alleviate the problem of energy supply and demand in the world.

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References

[1] China Economic Information Network, China New Energy Industry Analysis Report. 2003.
[2] Zhang L, Shang JH, Zhang ZY, et al. Current status of tidal energy research 2015 - hydrodynamics[J]. Journal of Hydropower, 2016, 35(02):1-15.
[3] Marine Current Turbines Led 2013.technology development [EB/OL].http://www.marinebines.com.
[4] Atlantis Resources Corporation [EB/OL]. [2009-11-11].http//www.atlantis resources corporation. com/ the-atlantis-advantage/atlantis-technologies /ak-series.html.
[5] Openhydro Ltd.[EB/OL].[2009-11-11].http://www.openhydro.com/home.html.
[6] Hammerfest Storm AS [EB/OL] http://www.hammerfeststrom.com/index.php?lang=en.
[7] New Energy Corporation Inc.http//www.newenergycorp.ca.
[8] Ponte di Archimede International 2013.Projects [EB/OL] http: // www. pontediarchimede. com/ language us/.
[9] Baker N.j.M AMMDirect drive power take off for the stingray tidal current generator.International Conference on Marine Renewable Energy.2002:39-48.
[10] Vortex Hydro Energy.http://www.vortexhydroenergy.com/html/about.html.
[11] http://www.hps.as/advantages.html.
[12] Zhu D, Li F, Zhang L,et al. 70kW tidal current experimental power plant. Technical Report of Harbin Engineering University.96-A17-06-03, 2002.
[13] Sheng Qihu, Luo Qingjie, Zhang Liang. 40kW tidal power plant carrier design, Proceedings of the First Symposium of the Marine Energy Professional Committee of China Renewable Energy Society, 27-28 March 2008, Hangzhou: 159-168.
[14] Liu H W, Ma S, Li W, et al. A review on the development of tidal current energy in China [J]. Renewable & Sustainable Energy Reviews, 2011, 15(2):1141-1146.
[15] You Y , Li W , Liu W, et al. Development status and perspective of marine energy conversion systems[J]. Dianli Xitong Zidonghua/Automation of Electric Power Systems, 2010, 34(14):1-12.
[16] Li B, Li L, Yang L, et al. Utilization of tidal energy and the status of research [J]. Solar Energy. 2010(09):39-42.
[17] Sheng Qihu, Tang Fuding, Wang Haifeng, et al. Design of 2x150kW floating vertical axis tidal power independent power generation system[C]. Dalian, Liaoning, China: 2013.
[18] Wang X, Zhang Y, Xia H, et al. Field test and evaluation of self-developed tidal power generation device [J]. Chinese Journal of Scientific Instrument, 2018.