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An Overview of Tidal Power in China

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Abstract. Tidal energy is a renewable, clean and non-polluting renewable energy source with huge reserves, which is of great significance to alleviate the energy tension in coastal areas. The eastern coast of China is dotted with many economically developed cities such as Shanghai, Shenzhen, Hong Kong, etc. The energy consumption of these cities is very high and growing at a very high rate year by year. Although China has constructed the "West-East Electricity Transmission" project to alleviate the problem of electricity tension in the eastern coastal cities, it cannot fundamentally reduce the dependence on traditional fossil energy. Therefore, on the basis of extensive data collation, this paper further explores the possibility of utilizing tidal energy for power generation in China by studying China's tidal energy reserves, and analyzes the difficulties in developing tidal energy in China as well as puts forward suggestions for the future development of tidal energy.

Keywords: Tidal energy, China, overview, renewable energy, analyzation.

1. Introduction

The earth's oceans cover 70.8% of the earth's surface area, and the theoretical reserves of tidal energy in the world are about 8×10^{10}kW [1]. With the growth of population and the rapid development of the society, the consumption of energy is increasing, and the selection of suitable renewable energy is an inevitable choice in the future due to the non-renewable nature of traditional fossil energy sources and their impact on the environment. Renewable energy mainly includes solar energy, wind energy, geothermal energy, ocean energy, etc. Among them, ocean energy mainly includes salinity difference energy, tidal energy, temperature difference energy, wave energy and current energy, which contain huge energy [2]. Among the many ocean energy, only tidal energy comes from the gravitational force of celestial bodies [3], which means that as long as the earth, the moon and the sun exist, tidal energy will always exist.

Compared to other countries in the world, the research on tidal energy has been very mature and has been utilized to generate electricity from tidal energy since a long time ago, but China's research on tidal energy started later compared to other countries. The world's largest tidal energy power station for France's Lens tidal power station, as early as 1966 was built and put into use, and the use of bulb through-flow turbine generator, the installed capacity of 240,000 kilowatts, the annual power generation of about 550 million kilowatt-hours [4-5]. The UK has world-leading technology for wave and tidal energy development, with the world's first full-size wave and tidal energy installations a British innovation [6]. In 2012, the UK and France signed the 'France-Alderney-Britain' project, in which the UK transmits

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power from tidal energy located in the Alderney Islands in the English Channel to France; in addition, SSE Renewables Scotland and Alstom France have partnered to build the world's largest wave energy power plant in the world [7]. Japan is also very active in the development and utilization of ocean energy, only engaged in wave energy technology research science and have more than ten technology companies. Japan is also very active in the development and utilization of ocean energy, with more than a dozen scientific and technological units engaged in research on wave energy technology alone, and a power generation device called "Mighty Whale" was developed and put into commercial operation in 1988 [8]. In 1984, Canada built Annapolis tidal test power station, with an installed capacity of 19,000 kilowatts, using a new type of full cross-flow turbine-generator set, reducing investment by 20%, and achieved good economic benefits [9]. It also verified the feasibility of building a large-scale tidal power station at the Bay of Fundy Station Camber.

China's tidal energy development started later. In 1980, China Jiangxia tidal test power station was officially put into power generation operation, the total installed capacity of the station up to 3,000 kilowatts, and its average annual power generation amounted to 10.7 million kilowatt-hours [10]. In recent years, there have also been few new tidal energy power plants in China. There is no shortage of tidal energy reserves in China, but the degree of exploitation of tidal energy has been relatively low.

This paper first introduces the principle of tidal energy in general, and on the basis of analyzing the current status of tidal energy research in various countries, combined with the actual situation of tidal energy development in China, analyzes some of the problems that need to be overcome for the development of tidal energy in China, and tries to put forward feasible suggestions for the development of tidal energy in China.

2. Overview of tidal energy

Tidal energy is mainly formed by the combined gravitational force of the sun and the moon on the earth, which is mainly affected by the moon's gravitational force more. According to the definition of gravity formula: $F = \frac{Gm_1m_2}{r^2}$, through the calculation, the sun and the moon on the earth's gravitational force ratio of 5:11, even if the sun's mass is much larger than the earth, due to the distance between the sun and the earth is much larger than the earth and the moon distance, so that the sun's gravitational force on the earth is smaller than the moon's gravitational force on the earth. Normally, two tides are formed in a day when the Sun-Earth action is received; in a month, two astronomical tides also occur.

Celestial bodies receive not only gravitational force but also centripetal force when they move. Since the radius of the celestial body's motion is much larger than its own radius, the motion of the celestial body can be regarded as uniform circular motion. According to the formula of centrifugal force $F = m\omega^2 r$ the direction is outward along the radius, and the vector sum of gravitational force and centripetal force on the celestial body is 0, so it is in uniform circular motion [11].

The moon orbits the earth in one week for one month, in one month, there will be two times the moon, the earth, the sun in the same straight line, the direction of gravitational force and centripetal force direction overlap and superposition, at this time the tide is the largest, the astronomical tide. In addition to the big tide, there is also the phenomenon of small tide, when the gravitational force of the earth by the moon and the gravitational force of the sun are perpendicular to each other. In a day, because the earth is mainly affected by the moon's gravitational force, to the same point on the earth, there will be two times a day from the moon closest or farthest, this time the gravitational tidal force for a day in the largest, the formation of "tide".

Seawater in the process of high tide and low tide, will produce great energy, which comes mainly from the potential energy of seawater [12-13]. According to the national standard "Marine Renewable Energy Resources Survey and Assessment Guidelines"[14], tidal energy can be developed if the annual average tidal range is >3.0m. In China, the urban development around the tidal energy available area is more developed, if the tidal energy can be reasonably utilized to generate electricity, it can greatly improve the level of clean energy utilization in the area.

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3. Characteristics of tidal energy

Tidal energy has three characteristics, which are inexhaustible, minimal environmental impact, and stable. Tidal energy is a green and clean renewable energy and inexhaustible, the earth's high tide and low tide is related to the movement of celestial bodies, as long as celestial bodies exist, tidal energy exists. And, the utilization of tidal energy has less impact on the environment. Tidal energy power stations are generally built in less densely populated areas, do not require immigration, and will not flood the original land like hydroelectric power plants. Tidal power stations do not require high dams, and the magnitude of change in water level after the completion of a tidal power station is comparable to the degree of change in local tide levels. Even if an earthquake damages the dam, it will not cause serious disasters to local residents. Additionally, tidal energy is a stable renewable energy source. Tidal energy is not affected by weather changes, the sea water rises and falls periodically, there is no dry or abundant water period, and the energy supply is stable.

4. Features of tidal energy distribution in China

China has abundant tidal energy reserves, but the geographical distribution of tidal energy is uneven and the development environment is complex.

According to the data provided by UNESCO, the global available marine energy is as high as 8×10^{10} kW, while the theoretical reserves of China's coastal tidal energy resources are about 1.1×10^{8}kW, and the available amount is about 0.2179×10^{8}.

However, China's tidal energy is distributed in the eastern coastal area, and mainly concentrated in the southeast coast. The exploitable amount of tidal energy in the southeastern coastal area accounts for about 88% of China's tidal energy, which is mainly distributed in Shanghai Municipality, Zhejiang Province and Fujian Province. As can be seen in Figure 1, most of the East China Sea is poor in tidal energy; the available area is concentrated in Jiangsu Province, Shanghai Municipality, Zhejiang Province and Fujian Province. The resource-rich area is less distributed, and only a small amount exists in Hangzhou Bay.

In addition, the main terrain in China where tidal energy can be utilized are plains and mountains. Plain terrain has small tidal range, the land is mainly composed of mud and silt, the coastline is straight, not suitable for the construction of tidal energy power plants. In the region of Fujian and Zhejiang province, the steep terrain, large tidal range, and large water depth make it, suitable for the construction of tidal power plants, but the problem of sediment deposition is very serious. China built many tidal power plants in the 20th century but was forced to shut them down due to severe sedimentation problems.

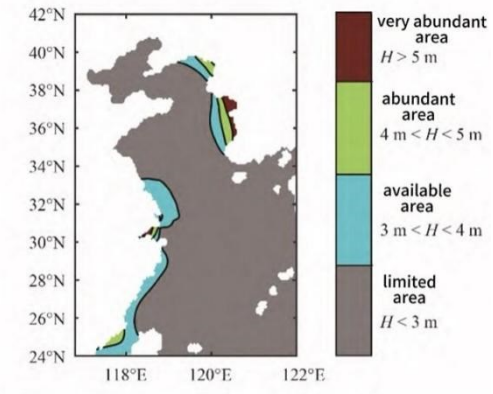

Figure 1. The distribution of the tidal energy resource[15]

5. The operating principle of a tidal energy power plants

There are two main forms of utilizing tidal energy[16-17]. The first is to utilize the kinetic energy of the tide, seawater has a high flow rate during high tide and low tide, and the water current is used to push

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the hydroelectric unit to generate electricity, similar to the principle of wind turbines. This type of tidal energy power station tends to generate less power, and in the process of high tide and low tide, there is pressure energy and other potential energy, resulting in low utilization of tidal energy, so this type of tidal energy power generation form has not been widely used. The second is the construction of dams, through the isolation of water to play the role of "water storage", the use of the difference between high tide and low tide to generate electricity. The advantage of this method of power generation is that it utilizes the potential energy of the tides, such as potential energy and pressure energy, and can generate power in both directions. When the tide of the tidal power station is high, the water level of seawater is higher than that of the reservoir, a large amount of seawater enters the reservoir through the generator set, and the seawater pushes the turbine to convert the kinetic and potential energy contained in seawater into the mechanical energy of the turbine, which drives the generator to generate electricity, and finally produces electric energy. When the tide is low, the seawater level is lower than the water level in the reservoir, at this time the water in the reservoir flows to the ocean through the turbine, driving the generator to generate electricity. Through the continuous rise and fall of the tide, the generator can produce a constant flow of electricity.

According to the different ways of power generation, there are four types of tidal power stations: one-reservoir tidal power station, two-reservoir tidal power station, one-way power generation and two-way power generation. Table 1 gives examples of the most representative tidal power stations in different countries around the world.

Table 1. The most representative tidal power stations in the world

Name of Power Plant	location	Installed capacity (kW)	Number of generators	Mean range of tidal (m)	Run mode
Jiangxia Tidal Power Station	Wenling, Zhejiang, China	4 100	6	5.08	two-way power generation
Sihwa Lake Tidal Station	Sihwa Lake, Gyeonggi	254 000	10	5.60	one-way power generation
Rance Tidal Power Station	Brittany	240 000	24	10.85	two-way power generation
Annapolis Tidal Station	Bay of Fundy and Annapolis River	17 800	1	6.40	one-way power generation
Kislovodsk Tidal Station	White Sea	800	2	2.30	two-way power generation

6. Current Situation and Prospect of Tidal Energy Development in China

6.1. Current Situation

China's tidal energy power generation started late, the first small-scale tidal power station was built in 1956, and 70 tidal power stations such as Shashan, Jiangxia, etc. were built in the following 30 years, although the number of them is the first in the world, many of them were forced to shut down because of improper siting, conflict with shipping routes, siltation, etc. In 1991, China conducted the second screening of tidal energy in the whole country and screened out several sites with better conditions and carried out preliminary scientific research, but none of them was able to start construction [18]. At present, there are only eight tidal energy power stations in normal operation in China, the largest of which is the Jiangxia tidal power station in Zhejiang Province, which adopts bidirectional power

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generation, has installed six generating units, with an installed capacity of up to 4100kW, and an annual power generation close to 800×10^4kW-h, which is basically ready for commercialization.

6.2. Limitation

As of now, there are still a lot of limitations for China to develop tidal energy. China's research on tidal energy, in addition to the degree of utilization, construction scale need to be improved, but also need to carry out more research in technology. China's research on tidal energy is still only in its infancy and faces many limitations, mainly in the following areas:

(1) Serious sediment deposition in coastal tidal energy-rich areas. The tidal energy-rich areas shown in Figure 1 have high sediment content. Excessive sediment deposition will block the access of tidal energy power stations, which will lead to tidal energy power stations having to shut down to clean up the silt, resulting in a waste of tidal energy resources.

(2) China's tidal energy power stations have high power generation costs. Some scholars [16]have pointed out that the power generation cost of China's Jiangxia tidal energy power station is RMB 2.58/(kW-h), which is much higher than the power generation cost of other energy sources. The high cost of tidal energy power generation is mainly due to the immaturity of the current technology, which makes tidal power generation volatile and unsustainable. In addition, the tidal power station is constructed in seawater waters, and the high salt environment in the water will produce electrochemical corrosion on the equipment, which requires a large amount of money to maintain the equipment, increasing the cost.

(3) There are limitations in the level of material development. In the high humidity and high salt environment, the life of existing materials is greatly shortened, especially metal materials, will be subject to a variety of chemical corrosion and galvanic corrosion. In addition, marine organisms can attach themselves to the surface of the equipment, causing serious damage.

6.3. Prospect

The bottlenecks faced by China in tidal energy development need to be addressed in these areas:

(1) For the problem of sediment deposition, waters with low sand content need to be selected for tidal energy utilization. Reducing the sediment content of rivers is an impractical measure, so in the short term this type of water needs to be avoided for tidal energy development. In the long term, the upstream of estuarine areas with high sediment content can be managed to improve the environment of the waters so that tidal energy can be fully utilized.

(2) The cost of power generation will be reduced as the level of technology improves. Currently, experts around the world have proposed some solutions, such as using pumped storage, two-way power generation, or multi-reservoir measures to solve the problem of unstable power supply; Chinese engineers and technicians are committed to designing turbines adapted to seawater environments and adopting new construction techniques, which can reduce the construction cost by 20% to 38% [19]. And the turbine blade can be designed to improve turbine The power generation efficiency of the unit can also be improved by designing new turbine blades.

(3) The research and development of new materials is also the focus of tidal energy development in China. It is necessary to study the corrosion resistance of turbine materials and dam surface materials, such as the use of vinyl coatings and cathodic protection to reduce electrochemical corrosion and the adhesion of marine organisms, in order to extend the service life of the components and improve the efficiency of tidal energy generation.

7. Conclusion

With the development of the economy, the demand for electricity is expanding, and the unsustainable supply of electricity has become a constraint to China's development. Especially in the coastal areas, the economy is developed, the demand for electricity is huge and can not get rid of the situation of tense electricity in the short term. The development of tidal energy power generation can reduce the dependence on fossil energy and also effectively solve the problem of environmental pollution. It is a

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stable and feasible renewable energy source. By combining the characteristics of tidal energy itself and the distribution of tidal energy in China, it is proved that China's tidal energy resources can be utilized and have great potential for future development. However, there are still many technical bottlenecks in China's tidal energy power generation: sediment deposition problems in coastal areas, high power generation costs, and limitations in the level of material development. To address these issues, China needs to select places with low sediment content to develop tidal energy in the short term, research new and efficient turbines, and focus on corrosion-resistant materials. It is believed that in the future, with the advancement of science and technology, the cost of power generation from tidal power plants will be further reduced, and tidal energy can become an integral part of the world's renewable energy.

Nevertheless, this article still has some limitations. For example, the article is based on a large amount of relevant information, the reference information has certain limitations; the data in the article come from the literature, and have not been empirically investigated, there may be some errors; the suggestions given in the article for the development of tidal energy are only a direction, and do not provide more specific and detailed suggestions. In the subsequent research, it is necessary to study the problems of tidal energy development and the degree of influence from more aspects, for example, in the study of sediment deposition, it is necessary to study the specific influence of sediment deposition on the life of the turbine blades; the study of the cost of power generation needs to be compared with the cost of other related tidal power stations to get more detailed data and so on.

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