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Representative technology development of marine renewable energy in China

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Representative technology development of marine renewable energy in China

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Abstract. The increasing energy demand and the global climate change problem make Chinese government consider renewable energy as a solution for the sustainable development. Under the support of the special fund program for Marine Renewable Energy (SFPMRE) established since 2010, about 1 billion Yuan (130 million dollars) has been funded for the R&D and demonstration of MRE technologies in China. Some wave and tidal current energy technologies have suffered rigorous sea test and continuous demonstration. The Plan of Marine Renewable Energy Development (2016-2020) released in Dec 2016 presents that the accumulative installed capacity for wave energy converters reaches 1 MW and 10 MW for tidal turbines till 2020, and more than 5 islands would be supplied by the complementary power generation of MRE and other REs. The representative MRE technologies have been confronted with opportunities to improve the technology readiness levels towards commercialization.

1. Introduction

Chinese government has paid great attention to the development of Renewable Energy (RE). In Dec 2016, the Plan of Renewable Energy Development to 2020 was released, which presents that the proportion of non-fossil energy consumption would increase to 15% and the share of RE power generation in the gross generation increase to 27% till 2020. The Strategy on Energy Revolution of Production and Consumption released in Dec 2016, envisions that the proportion of non-fossil energy consumption would increase to 20% till 2030 and 50% to 2050. Renewable Energy (RE) has been emphasized to realize the targets. As a kind of prospective RE, the development of Marine Renewable Energy (MRE) has been implemented since 1980s in China. China has abundant MRE resources, with more than 1580 GW of offshore potentials, including waves, tidal currents, tidal range, ocean currents, thermal gradients, changes in salinity, and offshore wind.

In 2008, the State Oceanic Administration (SOA) was entitled to perform the new functions of administration, utilization and development of ocean energy from the States of Council of China. In 2010, the Renewable Energy Law of the People's Republic of China (Amendment) enforced outlines a policy to accelerate and promote the development of renewable energy projects. According to the "Law of renewable energy", Ministry of Finance (MOF) and SOA released the "Interim measurements of marine renewable energy special funds" (SFPMRE) to support MRE research, including pilot demonstration projects used in isolated islands, pilot demonstration grid-connected projects, technologies industrialization, R&D. SOA established the Administrative Centre for Marine Renewable Energy to coordinate and manage the SFPMRE. Under the support of SFPMRE, more and more MRE technologies have entered the large scale prototype sea test and demonstration. Now, the



SFPMRE has entered the ninth round and has supported more than 110 projects with a total funding of \$ 190 million.

Especially, the Plan of Marine Renewable Energy Development to 2020 released in Dec 2016 set the goal of 50MW installed capacity of MRE and the application in remote islands and marine instruments in China. More and more public and private sectors have been engaged in the RD&D of MRE.

2. Wave energy technology development

2.1. History of wave energy converter development

Research and development of wave energy converters (WEC) have been conducted for more than 30 years in China. The wave energy technology is relatively mature and the versatility of the WEC technology is increasing. About 26 institutions have been engaged in the R&D of WEC technologies, resulting in 37 WECs have been deployed till the end of 2017, such as the 8 kW and 30 kW pendulum-type converter developed by National Ocean Technology Center (NOTC), the 100 kW and 260 kW eagle-type device developed by Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences (GIEC CAS) [1].

2.2. Representative WEC technologies in China

GIEC has been engaged in the development of WEC technologies for more than 30 years. A series of OWC modules with 10W, 60W, 100W capacity used in navigation buoy have been manufactured [2]. From 2009 to 2013, GIEC developed and deployed four duck-type devices, including three 10 kW devices and one 100 kW devices. For the sea test of the 100 kW Duck III, the device could generate electricity continuously in high wave conditions with 25 kW maximum output power, whereas the stability is relatively poor [3]. Based on the advantages and experiences of the duck-type WEC, GIEC developed the eagle-type WECs, with the features of a semi-submerged boat, a wave-absorbing floating body, a gate-shape support arm, wherein the floating body is fixed connected to the upper end of the gate-shaped support arm, the lower end of the support arm is connected with a hinge connecting to the boat-shaped body via a base, the support arm can rotate around the hinge, together with the floating body.

Since Nov 2015, the “Wanshan” eagle-type converter (100 kW) has been deployed near Wanshan Island and has generated more than 30 MWh till May 2017. The gross weight of “Wanshan” converter is about 450 tonnes. There are four hawk-nose type energy-capturing structures integrated in one semi-submerged boat. The total efficiency is more than 20% with 4s-6.5s wave period and 0.6m-2.5m weigh height. The maximum output power is 128 kW.



Figure 1. Xiandao 260 kW WEC in demonstration.

Since Dec 2017, “Xiandao” eagle-type converter (260 kW, with 60 kW solar panel) has been deployed in South China Sea (Figure 1). There are eight hawk-nose type energy-capturing structures integrated in one semi-submerged boat. The maximum daily power generation is nearly 1000 kWh.

2.3. Development trends of WEC technologies in China

The series of eagle-type converters are of a kind of oscillating buoy (OB), which is more suitable for use in coastal areas in China. Whereas, some converters of Oscillating water column (OWC), attenuator, and inverted pendulum have been proven to be low conversion efficiency and reliability.

3. Tidal current energy technology development

3.1. History of tidal current energy technology development

Research and development of tidal current energy technologies have been conducted for more than 20 years in China. The tidal current energy technology is relatively mature and the technology is converging. About 24 institutions have been engaged in the R&D of tidal current energy technology, resulting in 23 tidal turbines have been deployed till the end of 2017, such as the 1 MW vertical axis turbine developed by LHD Corp., the 300 kW and 650 kW horizontal axis turbines developed by Zhe Jiang University (ZJU), and the Haineng series turbines developed by Harbin Engineering University (HEU) [4].

3.2. Representative tidal turbines in China

3.2.1. LHD turbines. LHD Corp. has been developing the modular vertical axis turbines since 2009. In Mar 2016, the first platform to host 3.4 MW turbines was towed and fixed in Xiushan channel. In July 2016, two 300kW and two 200kW vertical axis turbines were deployed for demonstration (Figure 2). The 1 MW project was gridded in Aug 2016. The accumulative power generation reached 600 MWh till Dec 2017.



Figure 2. LHD 1MW turbines in demonstration.

3.2.2. ZJU turbines. ZJU has been engaged in the development of tidal current energy technology for more than 10 years. In 2005, ZJU designed and tested a 5 kW stationary horizontal axis turbine with a fixed base. Then, a 25 kW prototype was developed to solve the sealing and lubricating problem.

Now, ZJU turbines are a series of semi-direct-drive horizontal-axis turbine (Figure 3), which were co-sponsored by the SFPMRE and National High-tech R&D Program (863 Program). The ZJU turbines ranged from 120kW to 650kW have been deployed near Zhairuoshan Island for sea trial since May 2014. During the sea trial, the maximum conversion efficiency is 0.371. Until Apr 2018, the turbines have generated over 40 MWh of electricity.



Figure 3. ZJU turbines in demonstration.

In Mar 2018, Guodian United Power Technology Co. deployed a new 300 kW turbine based on ZJU technologies, and realized 270° blade-changing.

3.2.3. HEU turbines. Based on Wanxiang-I 70 kW floating vertical-axis device and 40 kW Wanxiang-II bottom fixed vertical-axis device developed in 1996 and 2002 respectively, HEU subsequently developed the Haineng series tidal turbines. In the support of the National Key Technology R&D Program, Haineng I vertical-axis tidal turbine (2×150 kW) was developed and tested from 2012 (Figure 4). The carrier is a catamaran-type with $24 \times 13.9 \times 2$ m, the diameter of the turbine is 4 meter. The sea test lasted for more than 1 year and halted for mechanical fault in Nov 2013. The efficiency of two turbines was about 30% respectively.



Figure 4. Haineng I 300 kW tidal turbine in test.

The Haineng II horizontal-axis tidal turbine (2×100 kW) was supported by SFPMPRE. The floating device was deployed in 2014. The diameter of the turbine is 12 meter. The Haineng III vertical-axis tidal turbine (2×300 kW) was supported by SFPMPRE, the floating device was deployed in 2014. The diameter of the turbine is 6 meter. Unfortunately, the test for Haineng II and Haineng III encountered some problem and lasted for less than 3 months.

3.3. Development trends of tidal turbines in China

The bottom-fixed tidal turbines are more reliable, such as the LHD turbines. Meanwhile, the horizontal axis turbines are more efficient, such as the ZJU series turbines.

4. Marine renewable energy test site

SFPMRE has sponsored more than 60 RD&D projects for tidal current energy and wave energy technologies since 2010. Among which, more than 30 projects has been experienced the sea trial. Some technologies have been validated, such as Eagle converter and ZJU turbines. However, more technologies only experienced short-term trial, for reasons such as lack of trained personnel, increasing uncertainties and costs. Thus, professional test sites for MRE in pre-consented areas are necessary.

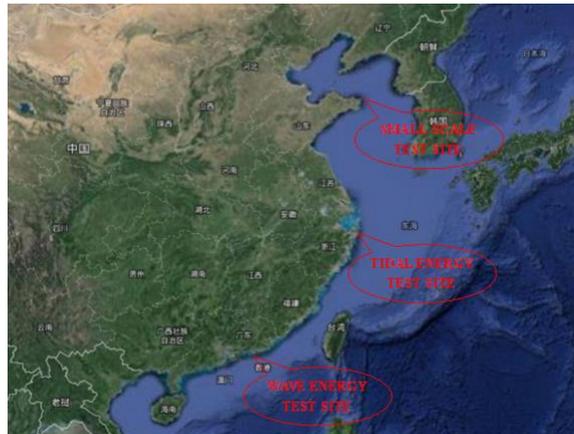


Figure 5. Planning of three test sites for MRE in China.

In the support of the SFPMRE, three MRE test sites has been planned in China (Figure 5), one test site in Weihai, Shandong Province for small-scale device testing, one test site in Zhoushan, Zhejiang Province for full-scale tidal current turbine testing, another test site in Wanshan, Guangdong Province for full-scale wave energy converter testing.

Now, the test site in Weihai has obtained the lease for sea area of 5 km². The test site in Zhoushan and Wanshan are waiting for the license of local government.

5. Conclusions

Due to the limit of coastal wave resources in China, wave energy converters no more than 100 kW would be suitable to improve the stability and survivability, then to decrease the cost of the devices. Wave energy converters more than 100 kW would be deployed for remote islands in the next five years [5]. For the tidal current technology, the modular 300 kW turbines are suitable for installed in shallow waters and increase the engineering experience. With more and more MRE technologies entering the large scale prototype sea trial, a competitive MRE industry would be formed.

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