Development and management of ocean energy in China

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Abstract. Renewable energy is one important countermeasure for global climate change problems. Chinese government has paid more attentions to renewable energy in the context of increasing energy demand. The national strategy, such as the Renewable Energy Law and special fund program for ocean energy, have advanced the big progress of the technology research, development and demonstration for ocean energy in recent years, especially for tidal current energy technologies and wave energy technologies in China. Nevertheless, there are some problems in the development of ocean energy, such as technology readiness levels, incentive policies, test sites, industrialization and so on. Some suggestions are given to improve the applications in remote islands and foster the ocean energy industries in China.

1. Introduction

To solve the increasing energy demand and greenhouse gas emission problems, renewable energy (RE) is emphasized in many countries as an emerging energy. Ocean Energy (OE) is defined as a kind of RE deriving from the gravitational force between the earth and the moon and the sun for tidal energy, and the solar radiation for the wave, ocean thermal and salinity gradient energy. China has abundant OE resources [1], with more than 1580 GW of offshore potentials in the distance of 20 km nearshore, including waves, tidal currents, tidal range, ocean currents, ocean thermal energy, salinity gradient energy, and offshore wind. The development of OE has been implemented since 1980s in China. Chinese government has committed that the carbon emission per unit of GDP in 2020 would decrease by 40-45% relative to 2005 levels, providing a big opportunity for the development of OE in China [2].

According to the Renewable Energy Law of China (amendment) released in 2009, the Ministry of Finance (MOF) and the State Oceanic Administration (SOA) set the “special funding program for marine renewable energy” (SFPMRE) to support the OE technologies research, development and demonstration (R, D &em), including pilot demonstration projects used in isolated islands, pilot demonstration grid-connected projects, technologies industrialization, R&D. Under the support of SFPMRE, more and more OE technologies have entered the large scale prototype sea test and demonstration, especially for the tidal energy technologies and the wave energy technologies. The SFPMRE has entered the tenth round and has supported more than 110 projects with a total funding of $200 million till the end of 2018.

2. Technology development for ocean energy in China

The research of tidal range technologies, tidal current energy technologies and wave energy technologies have been conducted since 1980s in China.
2.1. Tidal range technology development
Jiangxia tidal range plant (4.1MW) has been operating since 1980 and owned by China Longyuan Power Group Co. since 2003 (Figure 1). Sponsored by the SFPMRE, the upgrading project (#1 turbine from 500 kW to 700 kW) was concluded in July 2016. The efficiency of the turbine reaches 88.7%. The accumulated power generation reached 214.43GWh till the end of 2017.

Figure 1. Jiangxia tidal range plant in Wenling.

2.2. Tidal current energy technology development
In recent years, tidal current energy technology has made great progress. The vertical axis turbines developed by LHD Corp. and the horizontal axis turbines developed by Zhejiang University (ZJU) and Guodian United Power Technology Co.(GUPC) have been demonstrated in sea and gridded for more than two years in China.

2.2.1. LHD turbines. In July 2016, two 300kW and two 200kW vertical axis turbines were deployed and gridded in Aug 2016. Two new 200kW vertical axis turbine developed by LHD and a new 300kW horizontal axis turbine co-developed by Blue Shark (France) and LHD were deployed in 2018. The efficiency of these vertical axis turbines is about 30%. The accumulative power generation for the 1.7MW demonstration project reached 1GWh till Dec 2018 (Figure 2).

Figure 2. LHD demon project in Xiushan Island.
2.2.2. ZJU turbines. The semi-direct-driven vertical axis turbines developed by ZJU have more conversion efficiency. The 60kW, 120kW and the 650kW ZJU turbines have been deployed near Zhairuoshan Island for sea trial since May 2014. The 300kW turbine developed by GUPC based on ZJU technology has been deployed since Mar 2018 (Figure 3). Until July 2018, the four turbines have generated over 1GWh of electricity. The efficiency of these horizontal axis turbines is about 40%.

![Figure 3. ZJU demon project in Zhairuoshan Island.](image)

2.3. Wave energy technology development

The innovative eagle-type floating device developed by Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences (GIEC CAS) has been demonstrated near Dawanshan Island for more than two years.

Based on sea trial of the small scaled prototype, the revised 100 kW “Wanshan” converter has been deployed near Wanshan Island since Nov 2015[3], and become the first gridded wave energy converter in China. In Dec 2017, “Xiandao” converter (260 kW, with 200 kW wave energy converter and 60 kW solar panel) was deployed in South China Sea[4] (Figure 4), and gridded for the Yongxing Island. The GIEC eagle-type converters have generated more than 135MWh till July 2018. The efficiency of the eagle-type converters is more than 20%.

![Figure 4. GIEC converter in demon in South China Sea.](image)
3. Present policy system in Chinese OE sector

3.1. National strategy
In August 2012, 12thFive-Year Plan for Renewable Energy was issued in China, in which the development goal of OE technology was involved, meaning the OE is regarded as a national strategy. In December 2016, 13thFive-Year Plan for Renewable Energy was issued, and the OE development strategy was listed as “fostering the demonstration of OE technologies”. In December 2016, the Marine Renewable Energy Development Plan of “13thNational Five-Year Plan” was introduced and delivers the new general development target and prior projects of Chinese OE sector by 2020.

3.2. Public funding program
Chinese government set the SFPMRE in 2010 supporting domestic OE projects, focusing on the research, development and demonstration of OE technologies innovation and demonstration projects. Under the support of SFPMRE, more and more tidal energy technologies and the wave energy technologies entered the large scale prototype sea test and demonstration. Till the end of 2018, more than 110 projects with a total funding of $ 200 million were funded by SFPMRe [5].

3.3. Fixed feed-in tariffs
The feed-in tariff rate of Jiangxia and Haishan tidal power stations, the only two operational tidal range power stations in China, is presently $ 228/MW·h, a selling price higher than that of any other RE energy, with the Jiangxia station of $ 228/MW·h, far higher than that of Haishan station (Table 1). The reason for the different feed-in tariff rate is mainly the subsidies from different organizations. Additionally, the power grid enterprises and operators still need to be further clarified.

| Name   | FIT($/kW·h) | Be profitable by power selling price | Other sources of revenue                     |
|--------|-------------|-------------------------------------|---------------------------------------------|
| Jiangxia | 0.387       | Yes                                 | Aquaculture and tourism                     |
| Haishan  | 0.069       | No                                  | Aquaculture, agricultural and tourism       |

3.4. EIA system
The impacts of OE engineering to water quality, sediment, ecology environment, and topography are mandatorily covered in the assessment, whereas atmospheric and radioactive environment is optional and collision risk between the marine mammals and OE devices is not included.

4. Conclusions
OE industry is still in the beginning in China. OE device innovation activities typically take more than ten years to form a full scale prototype or a product, and require splendid funding at each stage. Meanwhile, OE technological researches have certain research and sea trial risks, bring investors and innovators more financial risks.

A long-term OE industry development plan is urgently needed in China. The roadmap should be based on OE industry status in China, academic researches concerned, stakeholders’ opinions and rational experiences learned from the national OE development strategy in other countries so that the targets designed are more reasonable and reachable[6]. Additionally, the application of tidal current energy and wave energy technologies would be the power supply in remote islands in the next several years in China.
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