Analysis of Tidal Current Energy Technology and Industry in China

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Abstract. The tidal resource is abundant and the research, development and demonstration of tidal current energy technology have made great progress in China. The accumulated installed capacity of tidal turbines is more than 3MW, which is leading internationlly. The carbon emissions peak and carbon neutrality strategy put forward in China requires the transition of energy structure, brings an important opportunity for the development of tidal current energy. The representative tidal current energy technologies are analyzed according to the research focus based on CNKI database. And the patents on tidal current energy technologies are also analyzed. Then, the current and forcast of the levelized cost of energy (LCOE) for tidal current energy in China are given. Finally, the pathway and incentive policies needed are suggested.

1 INTRODUCTION

Tidal current energy, as a kind of prospective Ocean Energy, has been recognized as a potential energy for the transition of energy structure internationally. Tidal currents are generated by horizontal movement of seawater, modified by seabed bathymetry, particularly near coasts or other constrictions, such as islands [1]. The principle of tidal current energy technology is very similar to wind energy technology, while the power density of tidal current energy is several times more than that of wind energy. Meanwhile, the tidal current turbines could be designed to generate in both directions.

According to the International Energy Agency's Energy Technology Perspectives forecasts, more than 100 GW of tidal current energy could be deployed across the world. Countries with high tidal resource include island communities and those with remote and populated areas. The cost of generation in isolated areas could be up to $ 0.43 per kWh, so there is a clear logic to utilising ocean energy [2].

2 ABUNDANT TIDAL ENERGY RESOURCE IN CHINA

A number of methods for the assessment of the tidal current energy resource potential have been discussed. In the widely used energy flux method, the power density (in W/m2) of tidal current energy increases substantially with small increases in velocity [3]. For near-shore currents such as those occurring in channels between mainland and islands, current velocity varies systematically and predictably in relation to the tide. In the specific case of tidal channels, however, there is a further limitation on the calculation of the overall resource.

There are many attractive sites identified for tidal current energy. The potential installed capacity is around 2GW in coastal area (≤20km) in China [4]. The tidal current energy resource in Zhejiang Province is most abundant in China with more than 1 GW of potential installed capacity. The kea utilization area locates in the channels in Zhousan City, where the current velocity varies between 1.5-2.5 m/s generally and the bottom sediments is mainly bedrock. Thus, the bottom-mounted turbines are very suitable for deployed here.

3 TIDAL CURRENT ENERGY TECHNOLOGY STATUS

More than 30 institutions have been engaged in the R&D and industrialization of tidal current energy technology, and about 40 tidal turbines have been deployed with 13 turbines still in the sea till the end of 2020, among which, the maximum capacity is 650 kW. The overall Technology Readiness Levels (TRL) for tidal current energy technology is between 6 and 7 in China.

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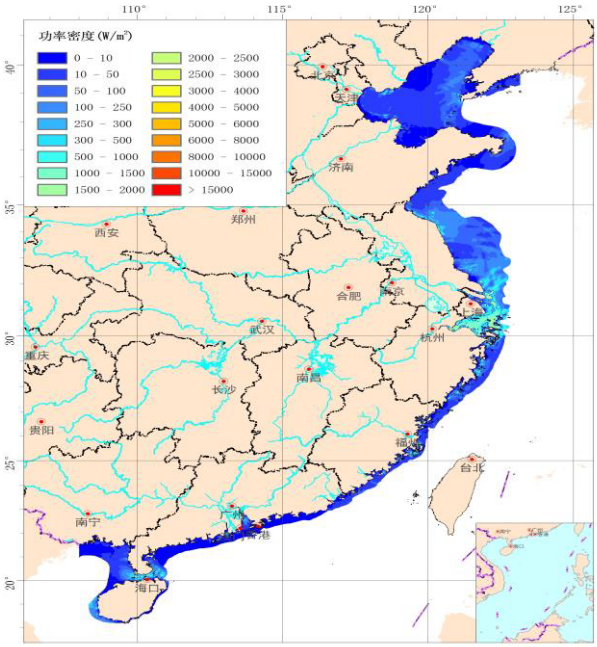

Fig. 1 Coastal tidal current energy distribution in China (Source: *Progress of ocean energy technology in 2014*)

The research focus for tidal current energy reserch between 2011 and 2021 in China are analyzed based on CNKI database. The numerical simulation, water turbine and cfd rank high in the research focus.

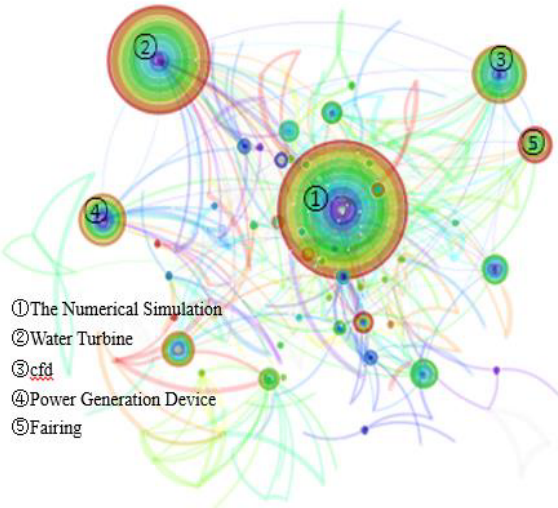

Fig. 2 Research focus for tidal current energy reserch between 2011 and 2021. (Source: Owner-drawing)

The accumulated installed capacity of tidal turbines in China is more than 3MW, accounting for about 30% of the world. The Xiushan Island and Zhairuoshan Island tidal current energy demonstration stations have been in operation since 2016.

For vertical axis tidal current technology, the main player is the LHD Corp. Four vertical axis turbines with two 300kW turbines and two 200kW turbines have been deployed for demonstration near the Xiushan Island since 2016, and gridded continuously since May 2017. The accumulative power generation reached 190 MWh till the end of 2020. However, the total conversion efficiency for vertical axis turbines is less than 25%.

For horizontal axis technology, the Zhe Jiang University (ZJU), the Harbin Engineering University (HEU), the United Power Corp. and the Harbin Electric Machinery Corp. have developed several turbines ranged from 60 kW to 650 kW. Take ZJU turbines for example, the first 60 kW turbine were deployed near Zhairuoshan Island in 2014, then the 120 kW turbine, the 300 kW turbine and the 650 kW turbine were deployed successively. The conversion efficiency for these turbines is between 35% and 40%.

Fig. 3 ZJU 650 kW tidal turbine in demonstration (Source: https://www.zju.edu.cn/)

4 Analysis of Patents on Tidal Current Energy Technologies

The patents on tidal current energy between 2012 and 2021 in China are analyzed based on CNKI database. The number of patents on tidal current energy is increasing. The volume of patenting activities increased with an average of 16 applications per year but declined in 2017 (72). The largest increase was observed in the three-year period from 2017 to 2019, with an average of 36 applications per year.

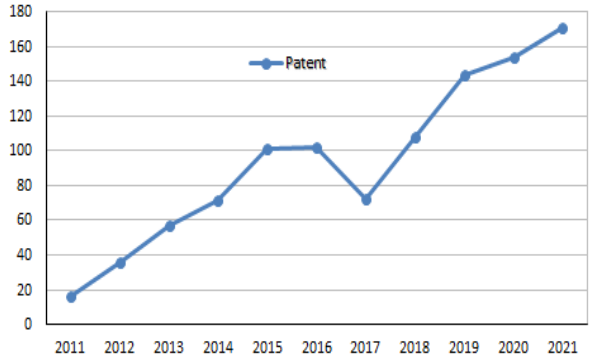

Fig. 4 Tidal current energy patent applications between 2011 and 2021 (Source: Owner-drawing)

Meanwhile, most of the applicants are universities. To a certain extent, the information shows that the intensity of knowledge transfer for tidal current energy technologies is still in early stage in China. Top 5 applicants include Zhejiang Ocean University, United Power Corp., Hohai University, Harbin Engineering University and Shanghai Ocean University. Top 10 applicants have 53.6% of all applications.

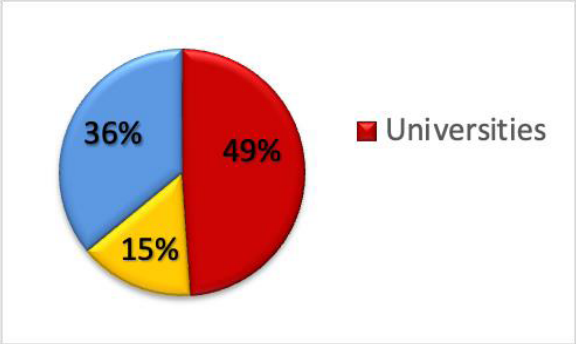

Fig. 5 Distribution of tidal current energy patent applicants (Source: Owner-drawing)

5 LCOE FOR TIDAL CURRENT ENERGY IN CHINA

The important aspect in assessing the progression of tidal current energy technologies is the reduction of the levelised cost of energy (LCOE), which is as important as the improvements in performance and electricity generation for the commercialization of tidal current energy technology. The LCOE for tidal current energy in China is calculated using the NOTC Ocean Energy Model.

For the baseline for the LCOE of tidal energy, two tidal current energy projects are investigated for the capital expenditure (CAPEX), the operational expenditure (OPEX), the annual utilization hours and so on. The CAPEX is about 11100 $ /kW for project A and about 10300 $ /kW. The annual utilization hours is just between 600 and 650. Our model shows that the LCOE of tidal energy is estimated to range between 1.22 and 1.31 $ /kWh for project A and range between 0.82 and 0.88 $ /kWh fort project B. Overall, the reference value for the baseline is about 1.06 $ /kWh.

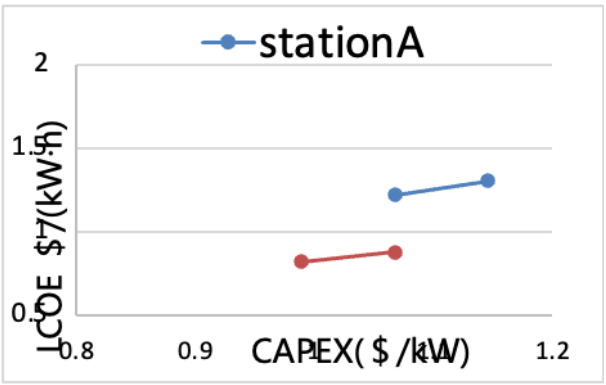

Fig.6 LCOE calculated for tidal current energy in China (Source: Owner-drawing)

The development of tidal current energy sector requires that significant cost reductions are achieved in order for the technology to become competitive with other renewable energy sources.

For the first 10MW tidal demonstration station, the CAPEX would be reduced to about 7000 $ /kW and the annual utilization hours would be increased to be between 1200 and 1500. Thus, the LCOE would range between 0.40 and 0.49 $ /kWh without any public subsidy. When the installed capacity for tidal current energy comes to 100MW, the CAPEX would be reduced to less than 5000 $ /kW and the annual utilization hours would be increased to be between 1800 and 2000. The LCOE would range between 0.20 and 0.22 $ /kWh, which would become competitive with offshore wind energy. Assuming the learning rate is 12%, following the cost reduction curve, the LCOE would be reduced to less than 0.15 $ /kWh when the installed capacity comes to 1GW.

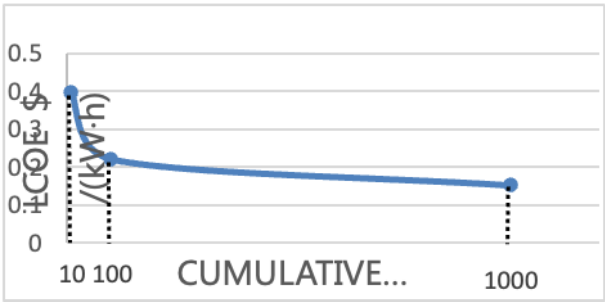

Fig.7 Cost reduction curves prediction for tidal current energy (Source: Owner-drawing)

6 PATHWAY AND INCENTIVE POLICIES SUGGESTED

6.1 Main pathway to industrialization for tidal current energy technology in China

Sustainable innovation for tidal current energy technology. The research and development should focus on the efficient and low-cost technologies, such as the innovative PTO, high conversion efficiency, variable pitch system, lower cost technology for operation and maintenance.

Improvement of TRL for tidal current energy technology. Continued research and development is crucial to maintain the technology's progression. And the demonstration of tidal turbines in real sea conditions for long periods of time could provide invaluable learnings, which is the only way to improve the TRL and an essential step to commercialisation. The risk can be mitigated by subsystems testing and onshore testing. Then, the annual utilization hours for tidal current energy station would improve to more than 1500h per year.

Application of new materials from other offshore sectors. Materials such as reinforced concrete, polymers, composites, and concrete-steel/composite-steel hybrids systems have demonstrated the advantages in other offshore sectors. Demonstrating the potential benefits of the new materials in tidal turbines, moorings and foundations is required to reduce the LCOE for tidal current energy technology [5].

6.2 Incentive policies to boost the progress

Set a national longterm strategy for Ocean Energy which is ambitious for tidal current energy. Establishing clear targets for tidal current energy will attract the public and private investors to deliver larger projects. The deployment targets for tidal current energy are at least 10 MW by 2025, 100 MW by 2030, and 1 GW by 2035. Meeting these deployment targets will support the carbon emissions peak and carbon neutrality strategy and increase economic growth, create thousands of high value jobs, and promote exports in manufacturing and related services.

Increase the public funds and set up an insurance fund for tidal current energy. For the launch of the 10MW tidal curren energy demonstration station, one quarter of public funds matching three quarters social funds would decrease about 9% of the LCOE, which would attract new players to enter the sector. Meanwhile, to slash the costs of the first commercial projects and accelerate the roll-out of tidal current energy industry, a national insurance fund for the ocean energy sector is very necessary.

High Feed-in Tariff for tidal current energy stations. The interim feed-in tariff for LHD first tidal current energy demonstration station is about ＄0.4 per kWh, which is suitable for 10MW demonstration station. Thus, the total amount of the electricity price subsidy for 10MW demonstration station is ＄5-6 million per year. As the increasement of annual utilization hours and the decreasement of the Capex, the feed-in tariff for tidal current energy demonstration station could be decreased to about ＄0.2 per kWh for 100MW station.

7 Conclusion

Despite decades of development, there is about 3MW of tidal current energy installations in China. The figure is about 10MW across the world as of the end of 2020. The tidal current energy would provide a large part of annual electricity demand, only if the LCOE of the tidal technology comes down. The essential phase is to build a 10MW tidal current energy demonstration station for learning purpose, then to bring the first commercial arrays forward and to reduce the LCOE.

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