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Selection of key technology policies for Chinese offshore wind power: A perspective on patent maps

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ABSTRACT

China is rich in offshore wind energy resources and the development of its offshore wind power is considered a practical solution to today's energy requirements. In the field of offshore wind power and, in contrast to more developed countries, China still has a problem with both a weak technical support system and underdeveloped technologies. To shed some light on present day technological advancements in this area, this paper uses the Beijing IncoShare Patent Database as well as patent maps to conduct statistical analyses on the evolution, regional distribution, variation in type and International Patent Classification of patent applications for offshore wind power in China. The research indicates that policies aimed at bolstering technologies were the cause of the observed rapid growth in offshore wind power patents from 2006 to 2013. Regional distribution of these patents is concentrated in Eastern China, with little activity in either Central or Western China. At present, a significant percentage of patents on Chinese offshore wind power have expired, so it is recommended that China both increase its capacity for technical industrialization and reinforce its protection of intellectual property rights. Furthermore, insufficient research on motors, hydraulic engineering and ship propulsion plants is a constraint to technological progress and future policy which aims at improving China's prospects for offshore wind power should focus on these areas.

1. Introduction

Developing offshore wind power is an effective approach to both achieving sustainable energy security and simultaneously combatting climate change. Developed countries with abundant coastline, including the United Kingdom, Sweden, Denmark, and the United States, have designated offshore wind power as an important future energy source by supporting its development with tax incentives, production and consumption subsidies, and many other policies.

China has the capacity to exploit its offshore wind power. In terms of resource endowment, the annual wind speed is greater than or equal to 3 m/s for approximately 7000–8000 h, and is greater than or equal to 6 m/s for 4000 h in the eastern coastal areas. This means that the wind power resources which are available with an offshore height of 10 m are 750 GW [1]. As for the policy support, the government has successively promulgated the following policies: *Interim Measures for the Management of the Development and Construction of Offshore Wind Power (2010), Framework of Wind Power Standard System (2010), Development Plans of Marine Engineering Equipment Manufacturing (2012), Notice on Offshore Wind Power On-grid Power Tariff Policy (2014), Notice on the Wind Power Value-Added Tax Policy (2015), Management Measures for the Offshore Wind Power Development and Construction (2016) and Development Plan for the City Group of Beibu Gulf (2017)*. These policies aid the wind power industry with products, R&D subsidies and tax preferences. Since China started developing its market for wind power in 2003, coastal provinces including Guangdong, Shanghai, Zhejiang, Hainan, Hebei, and Shandong have successively formulated development plans and prepared for the construction of offshore wind plants. Such wind power sites include Daishan, Huanghua, Shanghai, Rudong, and Dongtai.

However, in contrast to developed countries, China still faces numerous difficulties, most notably, a frail technical support system and a lack of the sophisticated technologies necessary for the storage and transmission of offshore wind power. Similar to non-traditional manufacturing easily affected by meteorological disasters [2,3], offshore wind power equipment is vulnerable to gales, seawater corrosion, and wave impacts. Furthermore, in China today, levels of knowledge in the construction, transportation, installation, maintenance and provision of technology for offshore wind power generation sets, such things as

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blades, cooling systems and offshore wind plants, are unable to support increases in offshore wind power generation. Therefore, both creating a system of technology policies and promoting technical innovation should be given priority in the drawing up of policy initiatives.

Analyzing the geographic distribution of patent activity in China can indicate where research into offshore wind energy has been successful and where it has been ignored. This paper draws a patent map to analyze the growth of offshore wind power technology within China using offshore wind power patent data from the Beijing IncoShare Patent Database.

2. Literature review

Policies related to offshore wind power technology have recently gained the attention of academia, with some scholars focusing on European offshore wind power policies. For example, Smit and Söderholm studied the effects of British and Swedish subsidies on technical learning. Smit argued that only the British policies had provided the stable conditions necessary for learning; such policies can be characterized as active [4]. Söderholm, on the other hand, pointed out that Swedish subsidies to pilot projects may not be particularly efficient [5]. Wieczorek et al. compared and analyzed policies pertaining to innovation in the generation of offshore wind power in Denmark, the UK, Netherlands, and Germany. They identified fragmented policies, large overhead costs and limited power-grid infrastructure as the main challenges facing European offshore wind power development [6]. Kaldellis and Kapsali summarized offshore wind power development in northwestern European countries, as well as the future impact of their technical application. They concluded that the most important drawback of offshore wind power was the high cost. In the long run, deep water multi-MW turbines will probably dominate the offshore sector [7]. Satir et al. employed WindPro software to conduct a technical analysis of offshore wind power in the Aegean Sea. They both calculated the potential annual energy production of the proposed project and identified issues relating to the current supporting mechanisms of offshore wind farms [8]. By using two commercial turbines, Li and Yu estimated the capacity factor and the potential energy output of offshore wind power in the U.S. Results revealed that offshore wind turbines could offer advantages over onshore wind turbines in Lake Erie [9]. Guerra, with the emphasis on the EU, investigated energy transition using the emerging offshore renewable energy (ORE) industries in the context of global governance [10]. By contrast, fewer scholars were concerned about the policies of offshore wind power in China.

Although not many studies have used patent data to study wind power technology, the ones that have, have achieved significant results [11–13]. The studies investigated the key technologies driving the wind power industry with a focus on patents, were mainly concerned with the following:

(1) Patent intelligence or information analysis. By looking at patent data, Noailly and Ryfisch measured the internationalization of green R&D in multinational firms (MNCs) [14]. This gives us the idea of using patents data to analyze China's patents. Dubari et al. used the database of the Swedish Patent and Registration Office to explore patent applications relating to wind power. The authors found patent information can be used to analyze both the evolution and the level of maturity of this type of technology [15]. Daim et al. examined the effects of different wind energy technologies using heterogeneous changes in the patent pre-warning system [16]. Benson and Magee collected patent data to analyze the differences in annual improvement rates in cost and investment in three technical areas: wind turbines, solar photovoltaic, and capacitors [17]. Also touching on wind turbines, Huenteler et al., employing patent citation network analysis, demonstrated the significant effects of a hierarchy of product designs on the evolution of technical knowledge [18]. Kapoor et al. examined the quotation types of the distribution of patent producing firms, and focused on the patent activity within top wind-power generation companies [19]. Urban et al. noted that innovation (e.g., patent) in wind energy has historically been focused in the north, and China and India are the main acceptors of technical transfers of wind energy [20]. Taking datasets covering the time period 1991–2008 for eight core wind power countries in Western Europe, Grafström and Lindman found evidence of national and international knowledge spillover in their invention model [21]. Again focusing on Western European countries, Lindman and Söderholm analyzed the impact of public R&D policies on innovation by looking at patent application data [22]. Evidently, a number of studies have focused on Western Europe, a region of the world with strong development in wind power. Most research, however, has not targeted offshore wind power and indeed, has neglected the differences between offshore and onshore wind power.

(2) Use of patent maps. Tsai et al. explored the development of offshore wind technology and found that, rather than stressing on the wind turbine itself, technologies related to engineering vessels, floating foundations, turbine installations, and integration of multiple technologies, towers and mooring systems had all been identified as top priorities for development. They also proposed some specialized development strategies for far-east countries [23]. This study provides the following enlightenment: the analysis of offshore wind power should be based on the international comparison of patent application between China and other developed countries (or regions, such as the U.S. and Europe).

Although scholars have presented a generally positive picture of Chinese offshore wind power technology, two gaps remain. First, with regards to the geographic concentration and distribution of patent activities in China, only a few studies have looked the relevant technology policies for offshore wind power. At present, limited literature has focused on onshore wind power patents, not offshore wind power patents, even though there are important differences between onshore and offshore wind power technologies. The latter requires more complex transportation and maintenance equipment, for example. Second, most studies have analyzed patent activity as a static, rather than a dynamic process, often failing to see the development of technology as an evolutionary process. The main contribution of the present study is to set up a framework of not only evolution over time but also regional distribution and patent structure, in order to analyze the features of the Chinese offshore wind power industry. As for the dynamic process, this study looks at patent applicants as of January 1, 1985.

3. Method

Patents encompass more than 90% of the latest technical information in the world [24]. Using patent maps is a method of analysis that screens, classifies, and summarizes the technological, economic, and legal environment of patent activity and reflects it in the form of various visual diagrams.

The source of patent data is The Beijing IncoShare Patent Database with data encompassing technologies patented from January 1, 1985 to December 30, 2016. The starting year was taken as 1985 because the *Patent Law of The People's Republic of China* was set out in 1984. Beijing IncoShare Information Technology Co. Ltd. developed the first information platform for technological innovation in China; this platform carefully integrates global patent data and incorporates both a Chinese and English retrieval system. It is the only information platform in China that covers more than 104 million unique patents over the past 230 years from 102 countries. From this database, the patents relating to the ocean and/or energy were searched.

A combination of both keywords and International Patent Classification (IPC) are used for patent retrieval. The keywords include wind force, wind power generator, wind driven generator, wind