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# Analyzing Offshore Wind Power Patent Portfolios by Using Data Clustering

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**ABSTRACT**

Offshore wind power has been extremely popular in recent years, and in the energy technology field, relevant research has been increasingly conducted. However, research regarding patent portfolios is still insufficient. The purpose of this research is to study the status of mainstream offshore wind power technology and patent portfolios and to investigate major assignees and countries to obtain a thorough understanding of the developmental trends of offshore wind power technology. The findings may be used by the government and industry for designing additional strategic development proposals. Data mining methods, such as multiple correspondence analyses and k-means clustering, were implemented to explore the competing technological and strategic-group relationships within the offshore wind power industry. The results indicate that the technological positions and patent portfolios of the countries and manufacturers are different. Additional technological development strategy recommendations were proposed for the offshore wind power industry.

Keywords: Offshore Wind Power, Patent Portfolio, Assignee, Patent Analysis, Multiple Correspondence Analysis, k-means Clustering

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## 1. INTRODUCTION

Within the last 20 years, numerous countries have begun to recognize the effects of global warming, climate pattern changes, and air, water, and soil pollution caused by long-term fossil fuel use (i.e., coal, petroleum, and natural gas). In addition, fossil fuels are nonrenewable resources, and availability is gradually diminishing because of constant use. In December 2007, the third session of the Conference of the Parties of the United Nations Framework Convention on Climate Change convened in Kyoto, Japan to address these problems. The Kyoto Protocol, which was drafted at this convention, regulates and controls the quantity of anthropogenic greenhouse gas emissions, and it was expected to reduce the influence of the greenhouse effect on the global environment. During the 2012 United Nations Climate Change Conference, representatives from nearly 200 countries agreed to extend the Kyoto Protocol regulations until 2020. In addition, continuing depletion and unsustainable use of nonrenewable energy sources have caused numerous countries to consider renewable energy as a vital focus in national technological development (Klessmann *et al.*, 2011; Muichalena and Hills, 2012; Tseng and Chiu, 2013; Tseng *et al.*, 2008; Valenzuela and Qi, 2012).

Of all the renewable energies, wind power has received the most global attention, especially regarding the development of offshore wind power (Jacobsson and Karltorp, 2012; Kaldellis and Kapsali, 2013; Li *et al.*, 2011). Interest in marine wind-power development is immense because resources for building on-land wind farms in Europe are becoming scant. Breakthroughs in offshore wind power technology are another reason for the gradually increasing funding. Wind power is the one renewable energy that approaches the same level of cost-effectiveness of fossil fuel-generated energy. Because of increasingly saturated land resources, offshore wind power is expected to become the primary driving force of global renewable energy development (Chen, 2012). Various nations have established wind power research departments or promoted relevant research projects to conduct national-level research and surveys of local wind power potential. These studies are expected to identify the distribution of potential wind power quality, rapidly locate sites suitable for wind power development, and serve as a reference for additional wind power development (Taiwan Ministry of Economic Affairs, Bureau of Energy, 2007).

In this study, a patent analysis was conducted, which primarily involved using statistics, analysis, and comparisons of relevant patent document information for understanding the developmental trends in offshore wind power technology. These data were used to exhibit relevant technical information regarding offshore wind power and explore current technological developments. Patent analysis was used to understand the patent rights, including the patent strategies of various countries, future developmental trends, and development and production, which can be used to understand industry trends, competitor status, and strategic planning. In industries, the effective analysis of patent information substantially reduces development time, provides an understanding of competitors, and facilitates rapid entry into markets. Understanding patent information is critical in offshore wind power, in which technology is being rapidly developed.

A patent model involving multiple correspondence analyses (MCAs) was used in this study for the following purposes: 1) to analyze mainstream offshore wind power technology and understand the current technological development status; 2) to analyze the primary assignees and assignee countries and identify different strategic groups; and 3) to conduct trend analyses on the technological development focus of primary assignees, explore the direction of corporate technology, and forecast future technology development trends. This study used patent portfolios and multiple correspondences to understand the corresponding relationships between assignees, the assignee countries, and technology. The visual effects of this geometric space can effectively exhibit and reveal the technological distribution of corporations and competitors, highlight the gaps in current technology, and provide information to serve as a reference for firms when deciding on technology exchanges, cooperation, or the people or organization to be licensed with patent rights.

This study explored the current development conditions of offshore wind power technologies, including technological classification ranges, key patentees, and the technological development trends in various countries. MCAs and cluster analysis were adopted to classify patentees, countries, and technologies into different strategic groups. The primary contribution of this study is identifying the technological advantages and disadvantages of firms from various countries by using positioning analysis to analyze differences.

Although previous studies have addressed offshore wind power (Jacobsson and Karltorp, 2012; Kaldellis and Kapsali, 2013; Li *et al*., 2011), according to a review of patent documents, studies on the technological positioning of offshore wind power patentees and countries are still insufficient. This study contributes new information to relevant research. In addition, regarding theoretical contributions, this study disclosed a number of traditional statistical distributions and also adopted new analysis models to effectively identify offshore wind power technology strategic groups from an intuitive visual space perspective. For practical contributions, this study explored the current mainstream technology development of offshore wind power and the positioning patent portfolios through the analysis of relevant patents. Accordingly, the study results may serve as strategic references for enterprises regarding patent portfolios, investment opportunity identification, and industrial strategic development.

## 2. LITERATURE REVIEW

### 2.1 Current Offshore Wind Power Development

Currently, global offshore wind power generation is 5,538 MW, of which 90% is generated in Europe. By the end of 2012, China generated 509.5 MW and Japan generated 33.8 MW of offshore wind power, primarily in near-shore and shallow marine areas. Of countries possessing offshore wind power, the power generation of China reached nearly 510 MW, and was ranked third internationally, following Great Britain (2,947.9 MW) and Denmark (921 MW) (European Wind Energy Association [EWEA], 2013)(Figure 1). In the current stage, the wind power generating devices used in mainland China are typically terrestrial. The number of offshore wind power devices is still limited. However, having realized that offshore wind power is the global development trend, mainland China is actively promoting the demonstration and application of offshore wind power as well as developing the offshore wind power industry. Japan (33.8 MW) has recently demonstrated offshore wind power potential, but development remains substantially behind that of the leading countries in offshore wind power (EWEA, 2013).

In the past year, over 10 countries in Europe have added 1,162 offshore wind turbines at 55 offshore wind farms. Overall, these countries have generated 4,995 MW of offshore wind power (Figure 2) and have exhibited considerable increases in their annual growth rates. In 2012, the power generation of these 10 countries reached

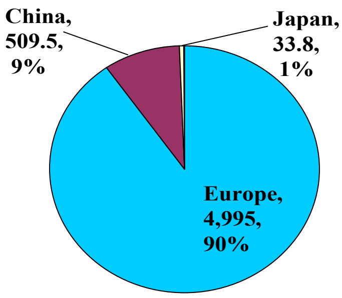



**Figure 1.** Global offshore wind-power generation. Source: The European offshore wind industry: key trends and statistics 2012 (European Wind Energy Association, 2013).

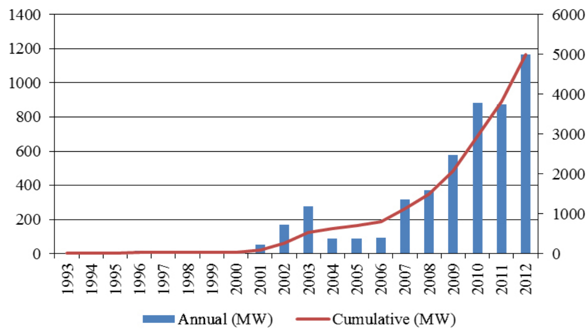


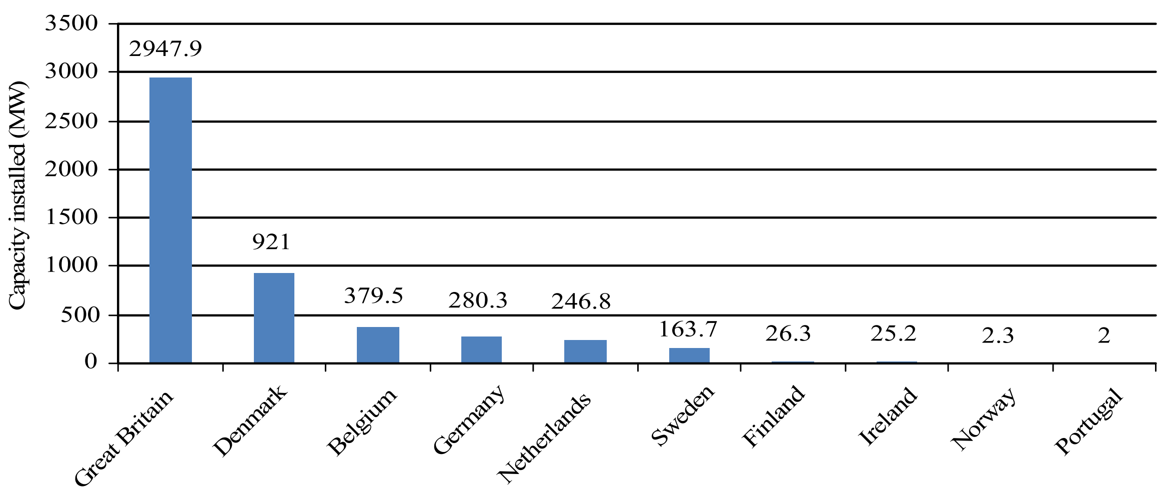

**Figure 2.** Trends in offshore wind-power generation. Source: The European offshore wind industry: key trends and statistics 2012 (European Wind Energy Association, 2013).

1,166 MW, indicating a 25% growth (compared with 874 MW generated in 2011). Figure 3 presents the number of offshore wind farms, wind turbines, and the power generation in these 10 European countries. The figure also shows that Great Britain generated the highest amount of offshore wind power in Europe, accounting for 59%, and that Denmark was in second place, at approximately 18.4%. Accordingly, Great Britain is the country generating the largest amount of offshore wind power in Europe (EWEA, 2013). Great Britain established its first wind power generating plant in 1991. Over 250 wind power generating plants have been built since then. In recent years, Great Britain has been ambitious in offshore wind power promotion policies and market growth with the goal of establishing its own offshore wind power industrial chain.

## 2.2 The Offshore Wind Power Industrial Chain in Taiwan

Wind power is a renewable energy that is being heavily promoted by advanced countries worldwide. To solve the problem of insufficient land space for installation, leading countries in wind power development, such as European nations, the United States, and China, have been actively developing offshore wind farms. The offshore wind power industry constitutes numerous domain categories, including scaffolding, cabins, shafts, blades, site development, and marine engineering. Figure 4 shows the patent situation of the current offshore wind power industry in Taiwan.

Taiwan has advantages in strong domestic forge-welding processing capabilities, which can be directly




| Country | Great Britain | Denmark | Belgium | Germany | Netherlands | Sweden | Finland | Ireland | Norway | Portugal |
|---|---|---|---|---|---|---|---|---|---|---|
| No. of farms | 20 | 12 | 2 | 6 | 4 | 6 | 2 | 1 | 1 | 1 |
| No. of wind turbines | 870 | 416 | 91 | 68 | 124 | 75 | 9 | 7 | 1 | 1 |

**Figure 3.** Offshore wind-power development in various countries. Source: The European offshore wind industry: key trends and statistics 2012 (European Wind Energy Association, 2013).

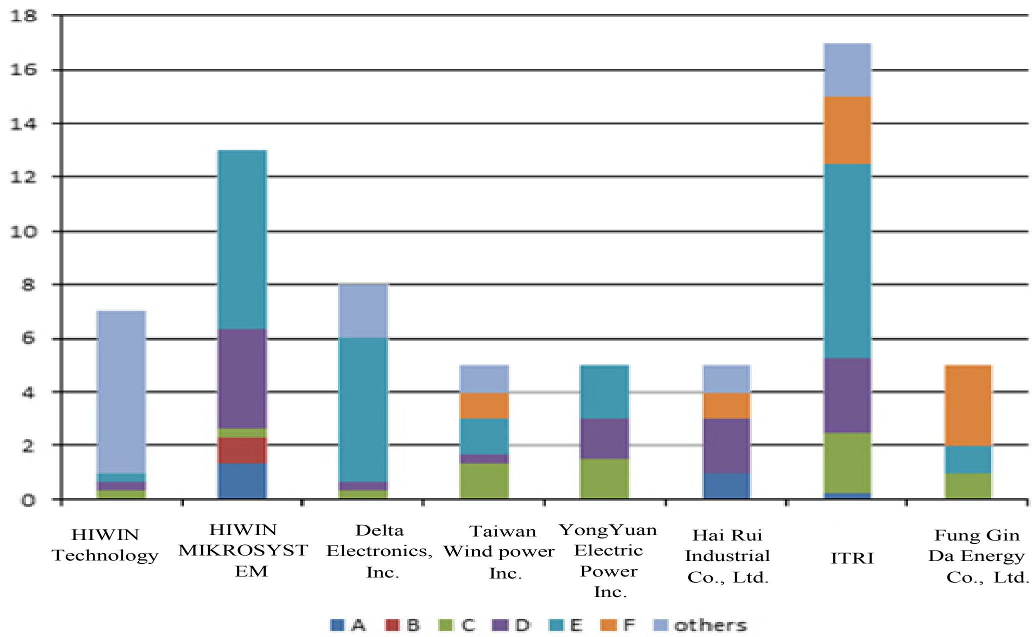



**Figure 4.** Supply-chain plan of the offshore wind-power equipment industry in Taiwan. ABCDEF is following "Offshore wind classification": A means tower part; B, grid network facilities; C, engine room; D, wind power shaft; E, wind power blade; and F, control system.

applied to developments in the wind power industry. In addition, generator manufacturers in Taiwan possess fundamental gearbox technology and practical experience regarding scaffold construction. Therefore, Taiwan requires only minimal additions in R&D fees to convert key components for use in wind power generators and other wind power-related products. Taiwan also has professional wind energy, meteorological, and geographical analysts who can be employed to enhance wind energy estimations and forecasting abilities. This substantially facilitates improvements in simulation precision and the discovery of potential wind farm sites. Technical abilities related to electromechanical, electronic control, information, and steel component industries in Taiwan are highly developed and can be used as the foundation for developing wind power units. In other words, Taiwan possesses superior production factors (Ma, 2012).

## 3. RESEARCH METHODS

In this study, the research topic was determined before establishing the patent search direction and subsequently conducting the research. Analyses conducted to understand mainstream trends and technological developments were based on the data obtained in the patent search. Finally, multiple correspondence and cluster analyses were performed to conduct position analyses of offshore wind power patent portfolios and strategic groups based on information obtained from the patent analysis.

### 3.1 Search Strategies and Data Sources

Because the United States constitutes the largest commercial market, system development and data can be traced to 1975, thereby enabling the exhibition of historical trends. In the analysis of global technology, systems from the United States exhibit universal representation (Bass and Kurgan, 2010). Therefore, this study used the United States patent database for conducting patent analysis and collected patents available to the public from the US Patent and Trademark Office database. Patent data were limited to the US patents publicly available from 1976 to July 23, 2013. The search conditions were as follows: (TTL/offshore and wind) or (TTL/offshore and turbine); or (ABST/offshore and wind) or (ABST/offshore and turbine); or (ACLM/offshore and wind) or (ACLM/offshore and turbine). Initially, 805 patents were obtained. After eliminating old patents containing fields with missing values, 644 offshore wind power-related patents were obtained.

### 3.2 Multiple Correspondence Analyses

Correspondence analysis involves using a low-dimensional perceptual map to process categorical variables, analyze the positions of targets in relationship to each other, and present the relationships between related attributes (Hair *et al.*, 2006); this indicates that MCA is an extension of correspondence analysis (Everitt and Dunn, 2001). MCA is a type of multivariate statistical method that simultaneously analyzes multiple types of variables; it is also known as homogeneity analysis.

During categorical variable processing, MCA adds normalized and orthogonal weights to the rows and columns in a data matrix and derives a multidimensional plane formed by the vectors of each row and column. The targets of conducting an MCA on the patent portfolios were the patent assignee, International Patent Classification (IPC) categories, and the assignee country. Correspondence analysis involves using diagrams to depict the information in cross-tabulation. The perceptual map exhibits the following data: 1) the relationship between assignees, in which close points indicate a high correlation and can be classified into the same category; 2) the relationships among assignee countries; points close to each other in the diagram represent a correlation and that a competitive relationship exists between assignee countries; finally, 3) the relationship between assignees, the assignee countries, and IPC categories. Close distances between an assignee or an assignee country in relation to an IPC category indicates the high performance of the assignee or the assignee country in that IPC category.

## 4. RESEARCH RESULTS

### 4.1 Patent Search Results

Two types of multiple correspondence patent distribution analyses were developed in this study. The first type was used to understand the patent distribution of corporations, countries, and competitors, and gaps in current industry technology. This did not require a consideration of the time factor; therefore, the approval date variable was omitted. The second type of analysis was used to explore the direction of corporate technology and forecast technological development trends. The time factor must be considered for this analysis; thus, the approval date variable was included. The analysis process of the first analysis is less complex than that of the second. In the second type, the distribution of patent accumulation presented in Figure 5 shows that the accumulated number of patents up to 1995 was 50%. Based on this information, patent accumulation was divided into a first and second stage. The first stage was from 1976–1995, and the second stage was from 1996–2012. If the patent distribution of assignees bridged both the first and second stages, the movements of the assignee coordinates in the first and second stages were used to understand the direction of corporate patent distribution or trends in technological development.

Table 1 presents the 10 assignees with the most approved wind power patents contained in the United States patent database. Regarding the assignee countries, the leading five countries were the United States, France, Norway, Japan, and the Netherlands, at 458, 38, 36, 15, and 15 patents, respectively. Table 2 shows the distribution of the 10 most numerous IPC categories (namely, the first IPC in each patent). The results shown in Table 2 indicate that offshore wind power technology is mostly concentrated in B63B, E02B, E21B, and E02D. According to the definitions of the IPC, the B63B category represents ships or other ship and water vessel equipment, E02B denotes hydraulic engineering, E21B denotes soil or rock drilling, and E02D represents foundations, excavations, fillings, and underground or underwater structures.

### 4.2 Patent Portfolio Positioning Analysis

This study used patent portfolio positioning to conduct MCA. In general, previous scholars have used MCA in marketing research (Kaciak and Louviere, 1990), the usage of medical care and medicine (Bonnefoy-Mazure *et al.*, 2013; Liu and Liu, 2011), geology and geography applications (Dai and Lee, 2001), psychological analysis (von Humboldt *et al.*, 2012), and tourism behavior-related studies (Richards and van der Ark, 2013). However, the use of MCA in patent analysis is insufficient.

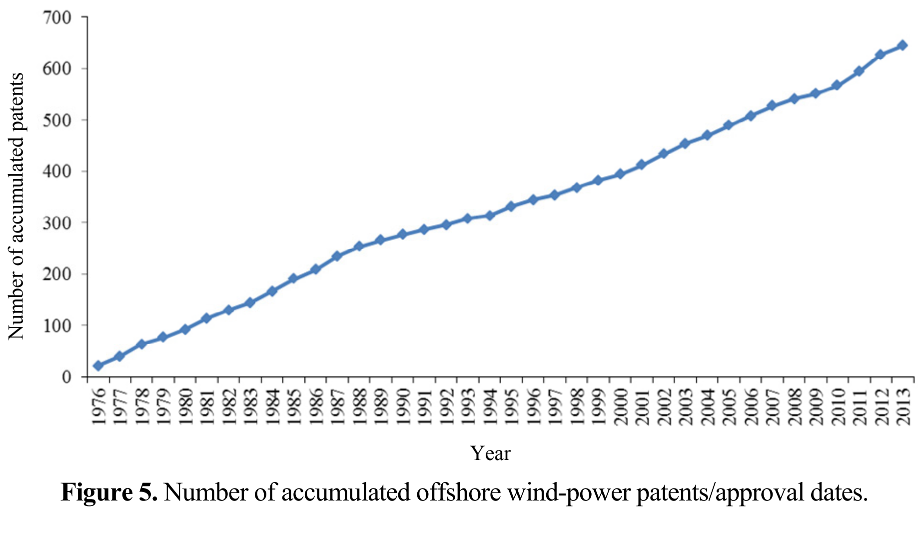



**Figure 5.** Number of accumulated offshore wind-power patents/approval dates.

**Table 1.** Quantity of patents held by the 10 leading assignees

| Rank | Assignee | Quantity | Percentage |
|---|---|---|---|
| 1 | Exxon Production Research Company | 33 | 5.1 |
| 2 | Shell Oil Company | 27 | 4.2 |
| 3 | Chevron Research Company | 20 | 3.1 |
| 4 | Texaco Inc. | 18 | 2.8 |
| 5 | Conoco Inc. | 14 | 2.2 |
| 6 | French Institute of Petroleum | 11 | 1.7 |
| 7 | Technip France | 11 | 1.7 |
| 8 | FMC Technologies, Inc. | 11 | 1.7 |
| 9 | Union Oil Company of California | 10 | 1.6 |
| 10 | Deep Oil Technology, Inc. | 9 | 1.4 |

**Table 2.** Distribution of the leading 10 IPC (International Patent Classification) categories

| Rank | IPC category | Quantity | Percentage |
|---|---|---|---|
| 1 | B63B | 150 | 23.3 |
| 2 | E02B | 147 | 22.8 |
| 3 | E21B | 99 | 15.4 |
| 4 | E02D | 43 | 6.7 |
| 5 | F16L | 19 | 3.0 |
| 6 | F03D | 17 | 2.6 |
| 7 | B01D | 11 | 1.7 |
| 8 | B65B | 11 | 1.7 |
| 9 | F03B | 10 | 1.6 |
| 10 | F25J | 7 | 1.1 |

Occasionally, the positioning map of an MCA cannot adequately explain the relationship between multivariate categories, especially when numerous multivariate categories are present. This causes the categories in a positioning map to overlap, and the subsequent severe blurring causes difficulties in conducting additional determinations and analysis. Therefore, correspondence cluster analyses were applied to clarify the relationship structure and correlations between multivariate and multiple categories. In other words, MCA was first used to quantify the original categorical data prior to conducting cluster analysis (Arimond and Elfessi, 2001; Wen and Chen, 2011).

This study conducted MCA on 644 patent data. The assignees constituted 293 corporations or organizations, and the assignees belonged to 27 countries. These patents included 96 categories in the three levels of the IPC hierarchical patent classification system. This showed that the technical fields involved in offshore wind power patents are broad, and that MCA is suitable for analyzing assignees, assignee countries, and IPC categories. In addition, two-step cluster analysis was conducted on the patent data. First, hierarchical clustering analysis was used to determine the optimal group number, which was four. k-means clustering was then used to divide the IPC categories into four groups. Figure 6 shows the MCA of offshore wind power patent portfolios regarding assignees, assignee countries, and IPC categories. Table 3 presents the primary members of these groups.

Figure 2 and Table 3 show that the majority of assignees and assignee countries were close to Group 4. The technologies in Group 4 were B63B, E02B, E21B, E02D, and F16L, and the countries in this group comprise the United States, France, Norway, Japan, and the Netherlands. These countries were the countries containing the most approved offshore wind power patents. This indicates that in offshore wind power technology, the technological development in these advanced countries is extremely similar. This method can be used to explore the direction of current mainstream technological developments. In addition, the positions of the offshore wind power patent portfolios for Canada, Germany, and Denmark were comparable. The portfolios

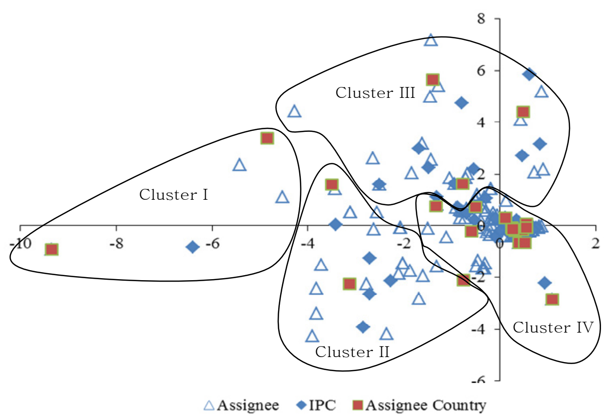



**Figure 6.** Offshore wind-power patent portfolios with multiple correspondences.

**Table 3.** Primary members of the groups

| Group | Primary group member |
|---|---|
| 1 | Polestar Ltd.; Gamesa Innovation and Technology, S.L.; LM Glasfiber A/S; H02P; Spain; Bermuda Islands |
| 2 | Aerodyn Engineering GmbH; Vestas Wind Systems A/S; Aquaculture Engineering Group Ltd.; Dyckerhoff and Widmann AG; Mitsubishi Heavy Industries Ltd.; F03D; H01F; Canada; Germany; Denmark |
| 3 | Single Buoy Moorings Inc.; IHC Engineering Business Limited; BHP Petroleum PTY Ltd.; F03B; F03G; F25J; G01S; Australia; China; Great Britain |
| 4 | Exxon Production Research Company; Shell Oil Company; Chevron Research Company; Texaco Inc.; Conoco Inc.; B63B; E02B; E21B; E02D; F16L; United States; France; Norway; Japan; and the Netherlands |

mainly involved F03D and H01F; that is, the development of wind power units, which emphasized the development of magnets, inductors, and transformers. Australia, China, and Great Britain were mainly involved with F03B, F03G, F25J, and G01S. These categories emphasize hydraulic machinery, hydraulic engines, engines that employ elasticity, gravitational force, and inertia, and technologies that use radio waves to measure distance or speed.

### 4.3 Flow of Assignee Technology and Developmental Trends

The increase or decrease of patents revealed by the approval date analysis showed changes in the development focus over time, described the trend of technological development, and predicted the growth and decline of technologies. This section identified the members of the 10 leading assignees who possessed approved patents both in the first and second stage (using 1995 as the division) to effectively mine information regarding the flow of assignee technology and technological development trends. The results are shown in Table 4.

Table 4 shows that recently, Shell Oil Company not only focused on hydraulic engineering (E02B) and soil or rock drilling research (E21B), but also focused on ships or other ship and water vessel equipment research (B63B; as did Texaco Inc. and Deep Oil Technology Inc.). The French Institute of Petroleum and the Union Oil Company of California recently focused on soil and rock drilling (E21B) patent applications. FMC Technologies Inc. focused on water vessel equipment (B63B) and foundations, excavations, filling, and underground or underwater structure patent applications (E02D).

## 5. CONCLUSION AND RECOMMENDATIONS

The objective of this study was to use relevant patent analysis, MCA, and cluster analysis to identify the current mainstream and technological development trends, and the strategy and positioning of patent portfolios. The results can provide a reference for relevant industries in Taiwan when applying for offshore wind power patents or when devising patent portfolio strategies. This enables firms to choose effective strategies and minimize technology investment risks during strategy development. The results showed that offshore wind power patents are concentrated in the United States, France, Norway, Japan, and the Netherlands. Offshore wind power technology is concentrated in B63 on the table (i.e., ships or other ship and water vessel equipment), E02 (i.e., hydraulic engineering), and E21 (i.e., soil or rock drilling). This indicates that the technological direction in current offshore wind power technology is partially moving toward wind farm development and marine engineering.

The patent portfolio positioning analysis shows that the portfolios of the United States, France, Norway, Japan, and the Netherlands are primarily focused on ship and water vessel equipment, hydraulic engineering, and soil or rock drilling. Among these nations, offshore wind power is the main future direction of development in the Netherlands. The Netherlands began building offshore wind power turbines in 2006, which was considered to be the beginning of green energy at the time (Global Taiwanese Business Service Network, 2012). The installation of offshore wind turbines is complex and involves laying ocean floor cables, building power grids, setting underwater pilings, and constructing work engineering ships, which are all vital components in developing offshore wind power. Australia, China, and Great Britain have an advantage in hydraulic machines and hydraulic engines. In general, the development of offshore wind power installations combines marine engineering, fluid mechanics, mechanical design, and electrical science into technology, integrating multiple sciences and fields. Canada, Germany, and Denmark own numerous patents and technological developments related to the development of wind power units. Denmark had already developed the first wind power unit at the end of the 19th

**Table 4.** Development trends regarding the technological focus of assignees

| Assignee | First-stage coordinate | Second-stage coordinate | First-stage technical field | Second-stage technical field |
|---|---|---|---|---|
| Shell Oil Company | (0.309, -0.226) | (0.385, -0.197) | E02B | B63B |
| | | | E02D | E02B |
| | | | E21B | E21B |
| Texaco Inc. | (0.237, -0.037) | (0.511, -0.291) | B63B | B63B |
| | | | E02B | |
| | | | E02D | |
| French Institute of Petroleum | (0.595, 0.049) | (0.429, 0.067) | B65D | E21B |
| | | | E21B | G06F |
| FMC Technologies Inc. | (0.177, 0.038) | (0.371, -0.167) | B63B | B63B |
| | | | E21B | E02D |
| Union Oil Company of California | (0.424, -0.123) | (-0.313, -1.689) | E02B | E21B |
| Deep Oil Technology Inc. | (0.349, -0.074) | (0.352, -0.181) | B65B | B63B |
| | | | B67D | |

century. However, because the economic benefits were too low, wind-powered machines did not receive considerable attention. The recent energy crisis and increased environmental awareness has driven the development of wind power. In 2012, the Denmark government passed a plan to increase the ratio of wind power production, which is expected to reach 50% by 2020 (The Guardian, 2012).

The development directions of Shell Oil Company, Texaco Inc., French Institute of Petroleum, FMC Technologies Inc., Union Oil Company of California, and Deep Oil Technology Inc. indicate that current patent technology development is moving toward ship equipment-related research, hydraulic engineering, and soil or rock drilling. This is similar to the development direction of the United States, France, Norway, Japan, and the Netherlands. Compared with developing wind power generation on land, offshore development requires solutions for both wind power equipment and marine engineering. Sufficient marine engineering equipment, wind power machinery products possessing low failure rates, and evaluations of wind farms, oceanic conditions, climate, and topography are key technologies and components in building offshore wind farms.

The 21st century is facing rapid global increases in energy prices. Various countries continue to discuss energy policy, and the development of renewable energy has become a critical issue in energy policies. Wind power generation is a rapidly growing field of renewable energy. According to the statistics of the World Wind Energy Association, wind power generation has increased annually. Globally, the accumulated wind generation capacity reached 282 GW in 2012. Taiwan is ranked 28th, possessing a capacity of 563 MW. Recently, land suitable for developing wind farms has become scant. In Europe, offshore wind power is rapidly growing. Analyzing the development of offshore wind power patents and portfolios of various countries and corporations is necessary. Various countries and corporations are strengthening technologies related to ship equipment and marine engineering. Improvements in related technologies and the use of these technologies for increasing offshore wind farm development is a development direction for various countries and corporations.

Although offshore wind farm development in Taiwan is in the beginning stages, Taiwan has a competitive advantage in the production of electromechanical components and possesses a high technological level regarding the production of blades, generators, control systems, and other parts for wind power units. In addition, Taiwan has a strong forge-welding capability, which can be directly applied to wind power equipment. Thus, Taiwan is able to progress in the global offshore wind power market. In addition, although daily operation of wind power machinery causes components to deteriorate, Taiwan can develop an advantage in providing maintenance and can use sea transportation to supply the needs of the wind power market in nearby China. Benefiting from the business opportunities in the offshore wind power industry is a key consideration for Taiwan in the sustainable management of the energy industry. Therefore, this topic is worthy of exploration and consideration by the Taiwanese energy industry. The energy industry in Taiwan must proceed with strategic patent portfolios to avoid losing development opportunities in this industry. The development of wind power technology is rapidly increasing and on-land wind power technology development in Europe is gradually maturing. By contrast, Taiwan has had a late start in wind power development. Nevertheless, Taiwan can enter the wind power industry by selling components such as blades, generators, control systems, and power converters, and by promoting quality testing of key components to obtain international certification. The Taiwanese energy industry can use existing business models and service foundations to integrate offshore wind power components and services, thereby creating a niche in the long-term offshore wind power industry.

The contribution of this study is the exploration of mainstream offshore wind power technologies and patent portfolios. This study provides the government and industry with strategic development suggestions by investigating the in-depth offshore wind power technology development trends among the main patentees and countries. Among the 644 patents analyzed in this study, 27 countries were included; however, some countries were not involved in the analysis. Possible causes for this phenomenon are the characteristics of databases and the narrow search criteria adopted in this study. The reason for adopting narrow search criteria was that the focus of this study was on obtaining precise search results. However, further analyses focusing on all the countries' performance regarding relevant technologies and IPC fields were not conducted. Future studies can use expanded search criteria and conduct in-depth explorations based on the databases from the European Patent Office.

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