Overcoming The Challenges of Implementing Offshore Wind Farm Development In The U.S. Through Education and Research

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Abstract

Higher quality wind resources, less negative impact on aesthetics of the landscape and ease of transportation and installation are some of the advantages of offshore wind farms over wind farm projects on land. Furthermore, wind turbines are designed to take advantage of the steady wind speed prevalent over the ocean thus enabling higher utilization rate for offshore wind energy generation capacity. More than 66 percent of offshore wind in the United States (U.S.) is in high wind power density. The National Renewable Energy Laboratory (NREL) estimates that the U.S. has 4,200 gigawatts of developable offshore wind potential. Despite these attributes, there are no offshore wind farms in the U.S. Offshore wind projects have grown steadily in Europe and Asia, with Europe accounting for 90 percent of the roughly 8.8 gigawatts (GW) global offshore wind turbine capacity. The challenges of offshore wind energy projects include, significantly high support structure cost, high Operating and Maintenance (O&M) costs, high electrical infrastructure costs, high turbine costs, stricter environmental standards, and less developed construction techniques. This paper describes the challenges associated with offshore wind energy projects and how to mitigate them. For instance, through technological advances, the high cost of foundation can be reduced. By employing efficient O&M strategy, associated costs can be reduced. By employing these and other methodologies future offshore wind energy projects can be commercially viable. The challenges for conducting research for the implementation of offshore wind farm in the U.S. has educational component. The product of this research work should have educational value for researchers and students of engineering education.

Introduction

Currently, the U.S. imports about 33 percent of its energy within a global market where demand often exceeds supply and where political situations may be volatile [12]. Therefore, there is a compelling strategic reason to reduce the U.S's dependence on imported energy by exploiting sources of energy from within. Offshore wind energy is one component of the energy mix which can reduce U.S.'s reliance on imported energy. In the U.S., offshore wind energy must become competitive with other sources of energy as done in some European and Asian countries.

For example, proximity to coastal population centers, ease of transportation and installation, abundant high quality winds, implicit abatement for land use, relatively lower aesthetic concerns and efficient transmission are some of the compelling reasons why offshore wind energy development is growing steadily in Europe and Asia. Of the estimated 8.8 GW of installed global offshore wind turbine capacity, Europe accounts for 90 percent of it [3]. In addition, offshore manufacturers are designing 10 to 15 megawatt turbines instead of the traditional 2 to 5 megawatt turbines to take advantage of the abundant and reliable wind blowing from onshore. Classifications for wind resources are based on a scale of zero to seven based on their power density and over 66 percent of offshore wind in the U.S. is in wind power class six or seven or high power density range. The U.S has over 42000 gigawatts of developable wind potential [1]. In spite of these enormous potentials, offshore wind development in the U.S. is still in the early phase of development. However, there is a shift among different levels of government and universities to fully embrace offshore wind. Through engineering education for instance, ungraduate and graduate students are being introduced to state of the art research and trends in offshore wind energy development.

The first offshore wind farm in the U.S. is scheduled to be built soon on the southeast coast of Block Island, Rhode Island by American offshore wind developer, Deepwater Wind. The wind farm is expected to generate 30 megawatts of electricity and two larger offshore projects are scheduled to be built along the Atlantic coast soon [1].

Specific Offshore wind farm challenges

Offshore wind energy development is challenged by the following characteristic issues; significantly high support structure cost, high Operating and Maintenance (O&M) costs, high electrical infrastructure costs, high turbine costs, stricter environmental standards, less developed construction techniques, low natural gas prices and wind subsidy issues and offshore development risks [2]

The costs of offshore wind energy are driven by the following parameters:

- Support structure costs such foundation costs – are significantly higher for offshore due to high water depth and method of construction. The foundation cost for a conventional turbine built onshore costs around 4 to 6 percent while a similar foundation built offshore costs 21 percent of the total costs [2].
- O&M costs are significantly higher than for onshore due to reduced access, wave and weather conditions. It could be as high as 30 percent of the total costs for offshore wind farms [2].
- Electrical infrastructure costs which involve the cost of transmission line to support multiple wind turbines between offshore farm and onshore grid can result in significant costs compared with onshore wind farms. This could be as high as 21 percent of the total costs in deeper waters [2].
- Turbine costs could be as high as 33 percent.
- Environmental issues such as permitting process, siting and impact on marine wildlife are more stringent and expensive for offshore wind farm developments.
- Installations and construction techniques are not as well developed as for onshore. This ultimately drives up the cost.

- Abundant natural gas presents challenges for wind energy. The U.S. is presently experiencing low natural gas prices due to high production of gas from shale deposits. Availability of energy incentive such as the Production Tax Credit (PTC) may affect costs.

- Due to higher risks associated with offshore development, the investor is charged higher interest rates and premiums.

Overcoming the Challenges and Mitigating Risks- The two main approaches for overcoming the challenges of offshore wind energy and mitigating risks are through research and development and through research and educational approach.

Research and Development Approach

Foundations- By introducing new technologies and through optimization of the existing technologies and design methods, costs of foundations can be reduced. The foundations currently employed commercially for offshore windfarms are shown in Figure 1[10]. As shown, the monopile is the most common foundation concept due to its robust design, mass fabrication and ease of installation. However, its application is mostly suited for shallow waters. Since many new offshore farms will be in deep waters, application of monopile foundation will be quite expensive. The current design can only support 6 megawatts (MW) wind turbine for water depth of 35m. Research and development efforts have shown that jacket type structures supported on piles are better suited for deep water applications and may be more economically viable. In addition, since the monopile has a high degree of standardization and productivity in the supply chain, the current design can be optimized and made cheaper and technically efficient by varying its geometric parameters such as length, diameter and thickness hence its weight. The diameter is governed by the fundamental frequency of the turbine and thickness is governed by fatigue loads and shell buckling. Research work should also consider optimization under fatigue load especially in welded attachments of the shell [3].

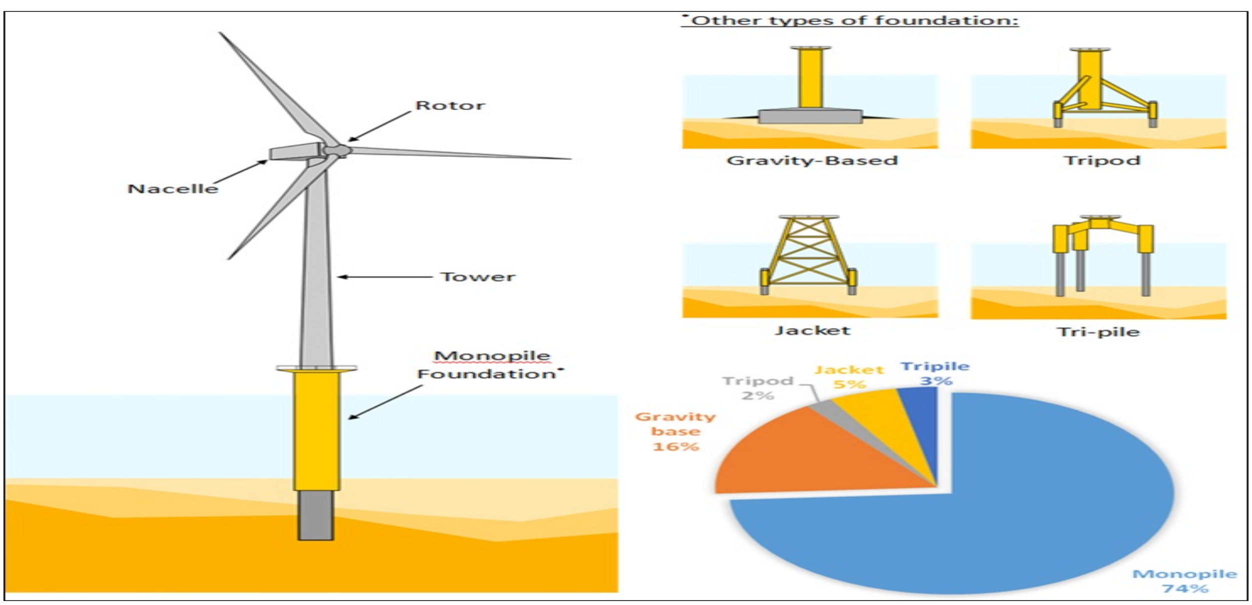

Figure 1: Offshore Wind Turbine Foundation types

Installation and Construction Techniques – Traditional approach for installation of offshore projects is pile driving. A new approach that can reduce installation time and cost is the Mono Bucket foundation concept by [5]. It can be installed in a variety of site conditions such as sand, silt, clay and mixed strata for water depths of up to 55m and does not require seabed preparation. It consists of a large monopile welded to the top of a single giant suction bucket. It is installed by using a jet suction system as a driving force. This lowers the pressure in the cavity between the foundation and the seabed generating water flow and lowering the resistance around the edge of the foundation skirt for ease of penetration as shown in Figure 2a and 2b [4]. A jetting system controls the vertical alignment ensuring the foundation is installed with tolerances. State of the art equipment for offshore foundation construction is the Suction jacket by Geotherm [4]. It has three legs welded together forming a jacket structure attached to three giant suction buckets that is anchored to the foundation. It reduces foundation time and installation thus lowering costs [6].

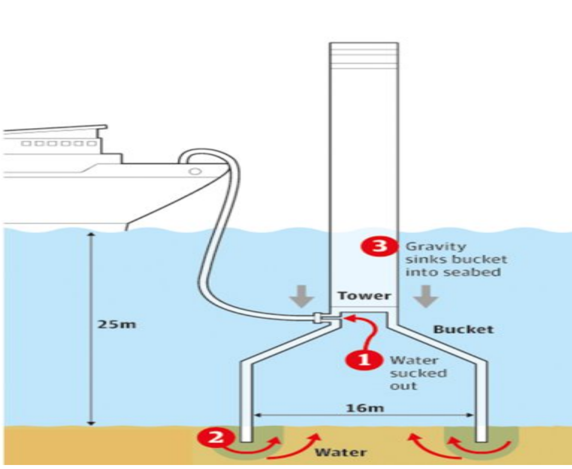

Figure 2a: Schematic Diagram of the Mono Bucket

Figure 2b: Picture of the Mono Bucket

O&M Costs – A case study suggested that the following strategies can significantly reduce O&M costs [7]:

- Turbine installation procedure – the rotor and the tower would be pre-assembled in port before shipment for offshore installation so that only one single offshore lift will be necessary for installation.

- Use of improved crew transfer system – This will reduce waiting time caused by weather conditions.

- Mother vessel accommodation – A mother vessel is located close to the wind plant from which workboats can be launched with average travel time of 30 minutes for repair work and transfer of personnel for the turbine. This system provides the benefit of reduced travel time to the wind plant for minor repairs and inspection,

The study showed that the turbine installation procedure and use of improved crew transfer resulted in a significant reduction levelized cost of energy (LCOE) hence O & M costs.

Research and Educational Approach

Environmental Issues- Permitting for offshore wind farm takes between 6 to 8 years. It is difficult for investors to get financing for a project that takes such a long time. However, comprehensive research study conducted by [8] will provide valuable educational tool to regulators, researchers, developers, resource managers and developers to adjust requirements for offshore wind siting and permitting processes and provide a better understanding of natural resource management and conservation efforts. Studies conducted on the Outer Continental Shelf waters of the Mid Atlantic coast involved using various technologies and methods to monitor and analyze wildlife distribution patterns. Boat-based surveys are used to monitor behavioral data of dolphins and seabirds. State-of-the-art video aerial surveys flown at high altitudes are used to monitor and collect data on marine animals. Tracking techniques which involve attaching satellite transmitters to various birds also provided valuable information in this study. Offshore wildlife migration timing and pathways are monitored and recorded using weather surveillance radar. This study provides a comprehensive data on wildlife distribution across the Mid-Atlantic coast. Thus, through engineering education and increased public awareness, barriers to offshore wind power deployment can be removed and permitting and siting procedures minimized. Environmental management decisions can be easily made by stakeholders such as government agencies, developers and environmental consultants [8].

High risks of offshore wind investments - Risk areas that may affect investing in offshore wind projects include the complexities of constructing in the deep sea, uncertainty surrounding wind resource availability, and high capital costs, contractor's track record. To mitigate these risks, adequate considerations should be given to various foundation technologies currently available such as tripods, jackets and extra-large monopiles. Detailed analysis of site specific weather data can be done by constructing meteorological towers to measure wind and wave speed at the planning stage. Since higher wind speed can present challenges during installations, detailed analysis based site specific weather data should be conducted to establish appropriate working schedule. The costs of foundation, grid connection and construction take the lion share of offshore wind projects. However, potential for cost mitigation include utilization of experienced contractors, economics of scale and larger wind turbines for higher energy production [9].

Advancing Offshore Windfarm Development Through Engineering Education

The U.S. Department of Energy's Wind Program has allocated $200 million for competitively selected offshore wind research, development and demonstration projects since 2011. As enumerated previously, barriers to offshore wind development include technical challenges of project installation, mitigation of environmental impacts, grid interconnection, and high energy cost. However, engineering education can bridge this gap. A transition strategy for engineering education curriculum can be developed to meet the needs of engineering graduates who are competent and literate in addressing offshore wind energy development. Such curriculum will include developing and incorporating courses relating to wind engineering. Through engineering education, courses, workshops, assignments and laboratory courses relating to wind engineering can be incorporated from first year to the final year in universities. A framework for such curriculum could be as discussed in [11] and further developed below:

- Introductory Level –Develop courses relating to renewable energy fundamentals in the first year. This will require some level of commitments from staff to develop materials for lectures, tutorials, homework and possibly site visits. Calculus and physics background may be a requirement for this course. The main objective of this course will be to develop students understanding of available sources of carbon-free energy systems, how much energy can be harvested, and to expose students to technological basics of main items such as wind turbine fundamentals, and wind turbine systems and safety, and how wind turbine generates power.

- Intermediate Level - Develop courses relating to wind energy systems in the second year. The objective will be to deepen students understanding of the engineering, political and economic aspects of renewable energy and wind energy in particular. Students will be introduced to wind turbine fundamentals, fundamentals of electricity and power generation and transmission. The course will also address challenges facing wind energy.

- Advanced Level- Implement courses leading to wind turbine design, installation, and construction, power generation, conversion of wind energy to electricity, wind farm modeling, site placement, economics, political and environmental issues of wind energy systems.

Conclusion

Challenges and risks to offshore wind projects can be mitigated through research on improved wind turbine concepts, design and fabrication of substructures and new offshore to grid connection techniques. In order for engineers graduating from higher institutions to have a good understanding of sustainable engineering, a curriculum transformation through engineering education is imperative. This will help the society to focus on sustainable development and policy makers can draw investors' awareness to the benefits of wind energy investments.

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