WHITE PAPER

Floating Foundations: The Next Frontier in Offshore Wind Power

Most offshore wind power generation projects to date have been developed in shallow ocean waters where foundation structures could be affixed to the ocean floor. However, the more powerful wind resources found above deeper coastal waters and farther out at sea have largely gone untapped. The development of new floating foundations may soon change that.

In 2018, California announced its goal to rely solely on zero-emission energy sources for electricity by 2045. By that same year, Hawaii expects to use 100% renewable energy sources. Maine committed in 2019 to 100% renewable energy by 2050. Along with other coastal U.S. states, all are eager to add offshore wind power to their power portfolios in their pursuit of these ambitious goals.

Until recently, their efforts were largely stymied by a simple reality: The deep ocean waters along the California, Maine and Hawaii coastlines were ill-suited for offshore wind development. The fixed-bottom structures used on offshore wind farms located in shallow ocean water cannot be easily adapted for installation on deep ocean floors.

The tide is turning, thanks to the development of new technology that makes it possible to mount offshore wind turbines on floating foundations and harness the steady, powerful winds that flow over these deep waters.

Floating Technology is a Potential Game-Changer

Floating foundations currently being deployed in the offshore wind market offer solutions to many challenges at once. First, they make development projects possible at deep-water sites that produce higher energy yields than shallow water projects. Fixed-bottom solutions cannot be used for installations on deeper ocean floors, usually not deeper than 225 to 250 feet.

In addition to being suitable for deep-water coastal areas, floating foundations make it possible to build wind farms in even deeper waters farther from the shore. These projects are less invasive to the seabed, making them more environmentally friendly than fixed-bottom foundation wind farms. Some states pursuing early-stage offshore projects in shallow waters are also considering expansion opportunities further offshore. In other words, floating foundation technology may be leveraged by any state that sets its sights on deeper water installations.

Every floating offshore wind development opportunity faces unique design challenges, driven by project site weather conditions, water depth, seabed conditions, local port and harbor infrastructure and the available supply chain. Four types of floating foundations have been developed to address these varying conditions.

The most widely used to date are semi-submersible platforms, which are designed primarily for use in shallower deep waters. Currently, these are the four primary types of floating foundations.

- Spar foundations are simple cylindrical structures that maintain stability by keeping the center of gravity below the center of buoyancy. Constructed from concrete and steel, they are kept in position by catenary or taut spread mooring lines with drag or suction anchors.
- Semi-submersible foundations consist of a number of buoyancy tanks connected with bracings or submerged pontoons. They can be made of concrete or steel, with some using active ballasting. They are kept in position similarly to spar foundations.
- Tension leg platforms are highly buoyant semi-submerged structures that are connected to tensioned tendons that secure the foundation to piled anchors in the seabed. Their shallow draft and tension stability allow for a smaller and lighter structure but increases stresses on the tendon and anchor system.
- Barge foundations are designed to balance the hydrodynamic and wind turbine generator (WTG) loads against the buoyancy of the barge. Able to float in shallower waters, these concrete or steel structures rely on damping pool technology that help stabilize the floating wind turbine, even in extreme conditions.

Global Market Potential

Offshore wind is one of the fastest-growing renewable energy markets, and floating foundations are the market's next frontier, opening new offshore wind markets throughout the world. The promise of offshore wind has drawn the attention of governments and energy companies globally.

Recent industry estimates, according to a June 2019 article by Power Technology, suggest the potential for floating wind power is around 7,000 gigawatts (GW) for Europe, the U.S. and Japan combined. By comparison, the world's entire population currently consumes a little more than twice that much energy — about 15,000 GW — from coal, natural gas and renewable sources. So, floating offshore wind holds enormous, long-term potential as the world rethinks its energy resources.

But realizing that potential is still decades away. During a recent global floating wind conference, panelists estimated that 10 GW of floating offshore wind would be developed globally by 2030.

The only commercial floating wind farm in operation today is Hywind Scotland, located off the coast of Peterhead, Scotland. Developed by the Norwegian energy company Equinor and commissioned in 2017, the farm has five floating foundations with a total capacity of 30 megawatts. It has been operating at 65% of its maximum capacity.

A single-turbine floating offshore wind demonstration project became operational in France a year later. Globally, there are now more than a dozen floating offshore wind projects in various stages of development, including one in the U.S. off the coast of Maine. That 12-MW project — the first in the U.S. — is expected to consist of two turbines built on a floating structure. With financing now being negotiated, the project is expected to be under construction in 2021 and come online a year later.

U.S. Market Potential

The Maine project is just the tip of the U.S. floating offshore wind iceberg. The country is currently projected to install approximately 2 GW of floating wind power by 2030. Most of these installations are expected to be located along the West Coast, where the water is much deeper and winds more powerful than off the East Coast, which — except for Maine — is better suited to fixed-bottom approaches to foundation design.

Along with California, Hawaii and Maine, Oregon is also among the U.S. states with deep water near their shores. Interest in these regions is high as a coalition of offshore wind industry members has launched Offshore Wind California (OWC) to serve as a unified, dedicated voice aimed at adding offshore wind to the state's energy mix.

Elsewhere, groups are seeking to collaborate as well. In Maine specifically, the University of Maine is contributing to the design and holds several patents on the floating concrete semi-submersible hull concept that will be used on the project planned there. Legislation has already been signed by the state's governor that requires the state's Public Utilities Commission to purchase the power generated by the turbines. Under the proposed power purchase agreement, the average electricity bill in Maine will increase just under $1 a month as a result. But proponents say it will be money well spent, given that the planned project could establish the state as an early market leader, and that the university could have the potential to license its floating technology for future projects.

The Advantages of Floating Offshore Wind Technology

Floating foundation technologies, no matter the depth of water installed in, offer advantages over fixed-bottom designs.

First, they require less foundation material than other offshore options. As best practices are developed, they are expected to take less time to install and commission as well. That is because, unlike fixed-bottom systems, floating foundations can be constructed onshore and floated to the site, minimizing the significant costs associated with at-sea installations. The vessels now used for fixed-bottom installations can cost up to $500,000 a day to operate.

Floating offshore projects also largely address the complexities associated with the Jones Act, which forbids ships built, owned or operated by non-U.S. citizens from transporting goods between U.S. ports. Currently, the highly specialized vessels needed for offshore wind installations are only available from foreign-owned companies.

The construction, operation and maintenance of fixed-bottom designs also requires as many as four different ports: a manufacturing port for steelwork; a construction port for project offices and construction; an assembly port where towers, cells, blades and other components are assembled and loaded onto barges and installation vessels; and a port devoted to operations and maintenance. For floating structures, the number of ports and harbors needed can be cut in half. Most floating foundation structures can be fabricated and assembled at a single construction port. A second port could then provide the maintenance facility where turbines can be floated in the event of a turbine failure or for other major repairs.

While the floating technologies currently favor returning the platforms to harbor for repairs, research is also underway on whether and how repairs performed at sea might reduce maintenance costs.

The Challenges Ahead

The results so far from the floating wind demonstration projects around the world are encouraging and have drawn the attention of governments and industries interested in offering investment and operating aid. To keep progress moving forward, however, multiple challenges will need to be overcome.

First and foremost, floating offshore wind will need to move from expensive demonstration projects to a commercially viable model. For that to occur, floating foundation offshore wind designs must become cost-competitive with other forms of electricity generation, and especially fixed-bottom designs. Operational costs also must be considered. Because the cables that tether the floating structure to the seabed must be continuously monitored for corrosion and wear, operational expenses for floating structures may be higher than those for fixed structures.

Attention to cost reduction strategies, including ways to achieve economies of scale, are needed to drive down costs. Research and development efforts that focus on cost and risk reduction, along with supply chain optimization, should take priority.

The good news is, progress is being made. Based on the pace of current efforts, there might be little or no cost difference between floating and fixed-bottom foundations by 2026. At a recent industry conference, panelists suggested a 50/50 split globally between fixed-bottom and floating foundations by 2050.

Beyond achieving cost parity, it will take the combined efforts of policymakers, investors, researchers and energy industry members to develop strategies and policies to overcome barriers to market entry, improve the technology outlook, and garner more public and private investment. It remains unclear who will take the lead in driving the market forward. Will investment come from existing private developers or new original equipment manufacturers behind the technologies? What role will governments play in incentivizing and supporting new floating offshore wind projects? If projects are delayed and commercialization stalls, who — if anyone — will step in?

These are all questions that must be asked and answered to fuel floating technology's deployment, cost competitiveness and long-term success.

Because the market is still young, public and private U.S. groups have the potential to take a global leadership role in market development. Floating technology offers great potential as a U.S. export opportunity. Given the nation's resources and rising interest, it is well within reach.

About Burns & McDonnell

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