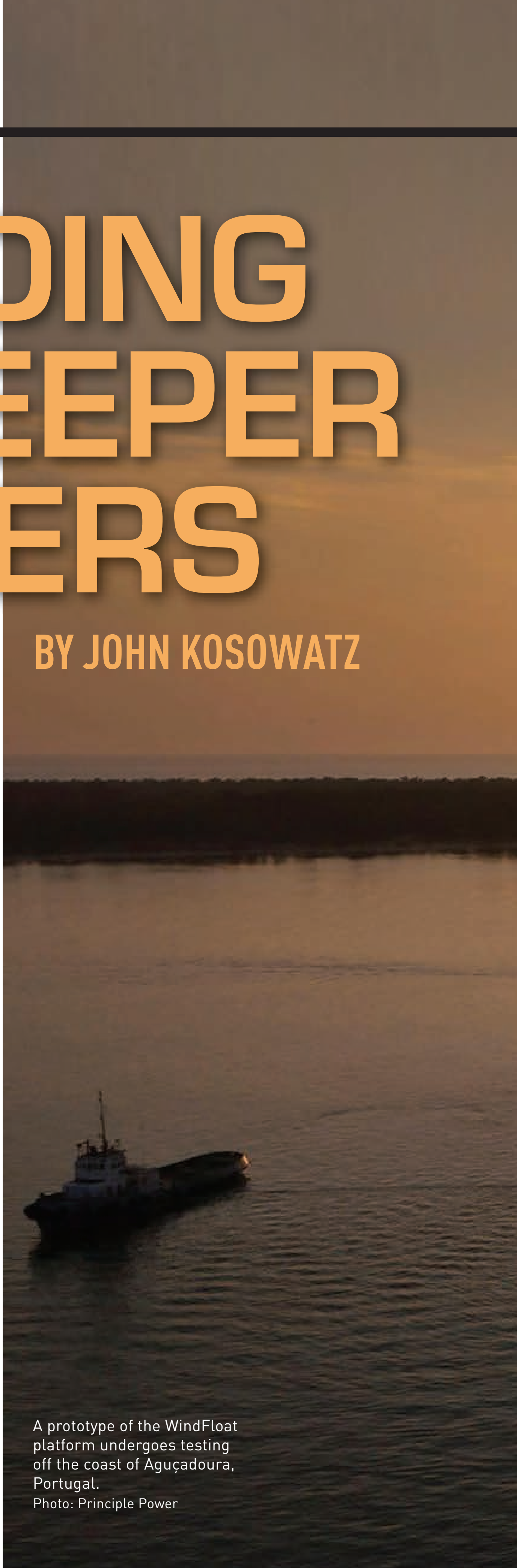
HEADING FOR DEEPER WATERS

FLOATING PLATFORMS CAN TAKE OFFSHORE TURBINES BEYOND THE HORIZON—FAR FROM THE SIGHT OF LAND, AND ALSO INTO A REGION OF MORE FAVORABLE WINDS.

BY JOHN KOSOWATZ



A prototype of the WindFloat platform undergoes testing off the coast of Aguçadoura, Portugal.
Photo: Principle Power

Wind power is one of the fastest growing electricity sources in the United States. According to the U.S. Energy Information Administration, wind turbines accounted for 30 percent of all new generating capacity over the past five years.

But to remember just how unpopular wind farms can be, all you say is two words: "Cape Wind."

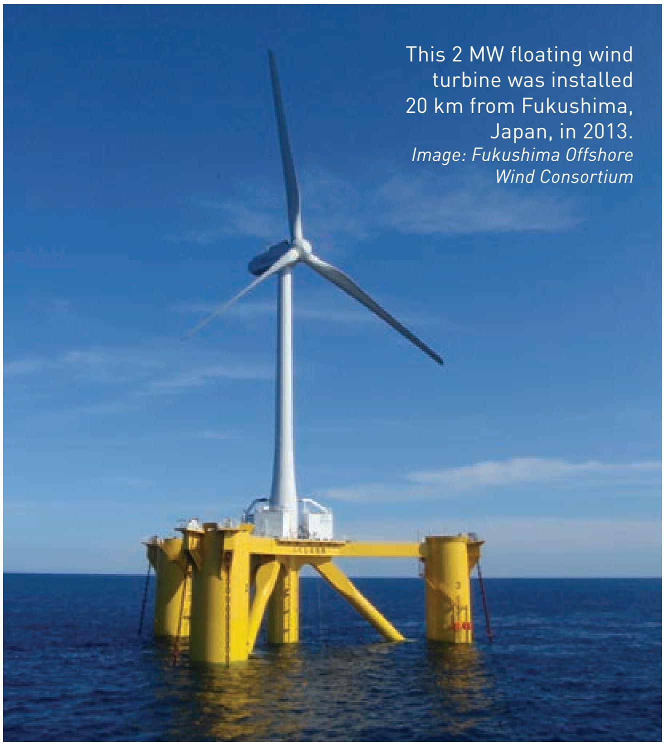
That was a project, now apparently dead, to install 130 wind turbines in Nantucket Sound. The local population, backed by some heavy spenders, said no. Arguments about risk to the environment and wildlife, and the intrusion on the sea view carried the day.

But suppose there was no heavy construction on the ocean floor. And if the turbines were over the horizon, out of sight from shore, they wouldn't disturb the view. Those are some of the reasons that wind power is moving into deeper waters.

And that move involves challenges for marine engineering.

"The goal is to stay behind the horizon," said Habib Dagher, director of the University of Maine's Advanced Structures & Composites Center, and leader of a commercial venture to place a wind turbine founded to a floating hull in the Gulf of Maine. "Plus, the wind regime farther offshore is better."

But getting there has been a challenge. Building in shallow water—50 meters or less—allows developers to economically fix a platform to the seabed using a variety of foundations. Going deeper requires some type of floating platform loosely tethered to the ocean bottom on which to attach the turbine and its tower. While floating platforms aren't new—oil and gas producers have built very large tension-leg platforms and others for drilling and processing—wind turbines present different problems. Platforms must be smaller but able to support a single tower reaching 80 meters for a 6 MW machine with a 154-meter rotor diameter, and



This 2 MW floating wind turbine was installed 20 km from Fukushima, Japan, in 2013. *Image: Fukushima Offshore Wind Consortium*

maintain stability in high seas and winds.

Six MW turbines are the holy grail of the industry, but the big machines are yet to be installed in deep water. Developers are working their way up, initially with a handful of smaller, mostly experimental floating turbines.

Norwegian energy giant Statoil has been a leader. In 2009, the company installed a 2.3 MW floating turbine with a 100-meter spar in the North Sea. A spar is a cylindrical buoy-type platform filled with ballast and extending deep beneath the waves to provide stability. After recently withdrawing from a planned wind farm in the Gulf of Maine, the firm now plans to build a 30 MW installation off Scotland using 6 MW turbines.

In the U.S., Seattle-based Principle Power and DeepWater Wind have teamed to bring Principle Power's semisubmersible technology to the West Coast. Principle Power has successfully operated a pilot 2 MW project off the coast of Portugal since 2011. Now the team is poised to build an eventual 30 MW array of 6 MW wind turbines 18 miles off Coos Bay, Ore. The project has received $47 million from the Department of Energy.

Called WindFloat, the triangular semi-submersible platform will be larger than the prototype, using three 27.5-meter tall, 10.5-meter-diameter columns tied together with steel members. A 6 MW wind turbine is to be attached to the top of one column, and each column fitted with a large water entrapment heave plate at its base.

Ballast is pumped into the columns to attain a 20-meter draft. The plates act as dampers to provide stability, which is further enhanced by a hull trim optimization system utilizing an array of instruments that measure ocean currents, and wind speed and direction. Data is fed into a control system that pumps ballast water among the columns as needed to provide stability and keep the tower close to vertical.

In Maine, the university and its DeepCwind consortium have built a 1:8 prototype of a 6 MW turbine and operated it successfully in the Gulf of Maine. Dubbed VolturnUS, its triangular-shaped semi-submersible platform is made of concrete and steel and supports a 65-foot-tall fiberglass tower with a 20 kW turbine. After a year-long test off the coast of Castine, Maine, the venture plans to put a full-scale turbine in place in 2018 with financial backing from the state.

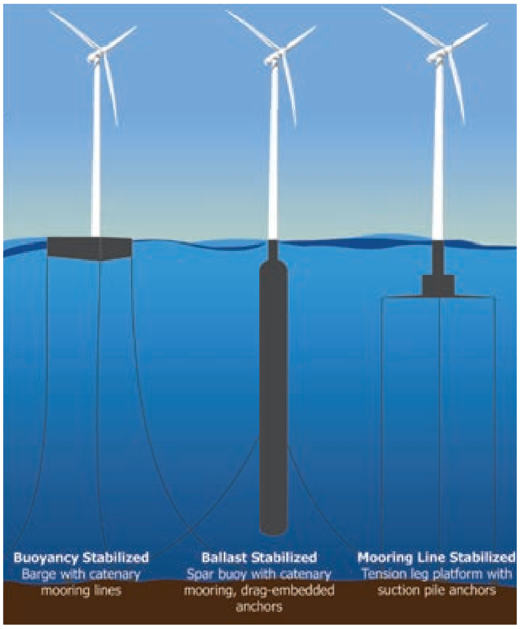
Perhaps the most ambitious effort is a $232 million project being installed off the coast of Fukushima, Japan, by a consortium of Japanese universities, and manufacturing and construction firms. The Japanese government funded the project in the aftermath of the Fukushima nuclear accident that caused the government to shut all the country's reactors and begin thinking of alternative power sources. Offshore wind was attractive, and floating platforms a necessity because the seabed drops sharply off Japan's shoreline.

In 2013 a pilot 2 MW turbine mounted on a V-shaped semi-submersible platform was installed 20 kilometers off the coastline. It was accompanied by a floating 66 kV substation fitted to an advanced spar for a platform. For the next phase, the group has been testing a 7 MW wind turbine that uses Mitsubishi Heavy Industries' digital displacement transmission hydraulics system. It was scheduled for installation in late 2014 but that has been postponed. A spokesman for the consortium's leader, Marubeni Corp., said testing is not complete. A second 7 MW turbine also is rescheduled for placement next year.

Engineers and developers just two years ago were highlighting developmental needs of deepwater turbines. In 2013, the European Wind Energy Association called for developing and validating modeling tools and numerical codes that simulate behavior of the entire structure. Among other items, EWEA recommended optimizing turbine design and size for floating structures, better techniques to assess wind and wave conditions at site locations, better mooring systems, and research into wake and turbulence effects.

"Certainly after three years the industry is improving," said Dominique Roddier, chief technology officer of Principle Power. "For one thing, the American Bureau of Shipping came out with rules for offshore wind turbines. Now there is a guide."

Modeling tools have evolved to predict the response of a fully coupled wind turbine and its substructure. DOE's National Renewable Energy Laboratory in Golden, Colo., has been working to verify offshore wind turbine modeling tools. Its OC3 project (Offshore Code Comparison Collaboration), completed in 2010, was the first international project to address the need to verify modeling tools, using a Statoil-



Companies have pursued various strategies for stabilizing floating platforms (see chart at left). In 2009 Norwegian energy company Statoil tested turbine mounted on a spar platform (shown in an artist's rendering, below).

designed spar as the subject.

That was followed by OC4, which analyzed a 5 MW turbine attached to a floating semisubmersible platform, using the DeepCwind design as the subject. OC4 (The OC3 Continuation) took analysis one step further, focusing on the semisubmersible's increased hydrodynamic complexity, compared to a spar.

"We started by building on land-based tools. We had simulation tools to predict turbine performance as long as the base wasn't moving," said Walter Musial, NREL principal engineer. "With floating platforms, it became much more complex, adding a hydrodynamic set of loads coupled with aerodynamic ones."

The laboratory uses a CAE tool that it calls FAST. According to NREL, "FAST joins aerodynamics models, hydrodynamics models for offshore structures, control and electrical system (servo) dynamics models, and structural (elastic) dynamics models to enable coupled nonlinear aero-hydro-servo-elastic simulation in the time domain."

Now, NREL researchers are moving to the next step—OC5, Offshore Code Comparison Collaboration Continuation, with Correlation—to validate offshore wind modeling tools through comparison of simulated responses with actual physical response data from existing structures. It will examine three structures using data from floating and fixed systems as well as from scaled tank testing and full-scale open-ocean testing.

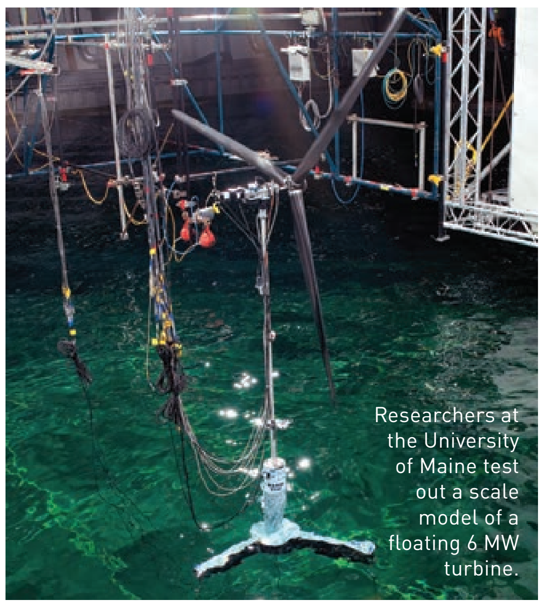
"Our ability to model is no longer an issue," said Dagher. "And our ability to predict is no longer an issue of concern. It took a lot of work to verify."

A protoype of a WindFloat platform tested offshore was built in drydock at the Lisnave facility (inset) near Setubal, Portugal.

Dagher said testing, validation, and verification of DeepCwind's prototype were accomplished using all of the consortium's 30 members, independent of NREL, and included four in-house and commercial modeling tools, lab and basin-scale tests using a 1:50 model and, finally, instrumenting and collecting data from the 1:8 model.

"We were able to measure how it performed and that gives us a unique data set," he said. "We were able to collect a lot of data in a short period of time. We took that data and compared it to our models."

The consortium installed over 50 instruments on the VolturnUS model, measuring waves, current, temperature, accelerations, strains, turbine performance, and mooring line loads. Dagher is pleased with its performance, noting, for instance, that measurements confirmed the heel angle and maximum acceleration of the nacelle were within 16 percent and 14 percent of what a 6 MW machine would experience 10 miles offshore.



Researchers at the University of Maine test out a scale model of a floating 6 MW turbine.

DeepCwind's semisubmersible platform is constructed of prestressed concrete and steel, the result of vigorous testing of a variety of potential designs. "Each solution has its pros and cons, and all are viable," Dagher said. "For us, the concrete option makes a lot more sense. The bottom line is what is most cost-effective at the end of the day."

DeepCwind relies on consortium member and contractor Cianbro Corp. to build the hull and attach the turbine in its coastal yard. From there, it can be towed to its production site.

Roddier, meanwhile, said Principle Power is satisfied with WindFloat's steel design.

"We set up our objectives with a prototype," Roddier said. "We've proven we can operate in high waves in the ocean" He added that the WindFloat turbine off Portugal has generated 12 gigawatt-hours of electricity since 2011. "Now we are in the precommercial phase, and try to prove that the technology is financially viable," he said. "But the experience of the project prototype is key."

Keeping costs down is critical for offshore developers. In shallow water, contractors can economically build a fixed platform and install the turbine and its tower. In deep water, floaters make more sense, although they are not small structures. Besides the tower, they must support at least 350 metric tons, the weight of the nacelle and rotor blades of a 6 MW Siemens direct-drive turbine, which the company claims is the lightest in class.

At sea, the nacelle will reach 100 meters above the water level, with 75-meter-long rotor blades going higher. So floating platforms together with the wind turbine and tower are fabricated onshore in controlled conditions and towed to their production site. There, more ballast is added—a 6 MW machine will require 20 meters to 25 meters of draft—and the platform is tethered to its moorings. The strategy allows project officials to avoid more costly marine transportation and construction costs; an offshore crane costs about $122,000 per day by itself, Roddier said.

DeepCwind uses a composite tower to reduce corrosion—critical for long-term operations and maintenance—and to reduce costs as well. The lighter tower allows the use of a smaller platform. "We wanted to reduce topside weight," Dagher said. "For every ton you take out of the tower, you can take two to three tons out of the hull."

In the U.S., developers are turning to semisubmersible floating platforms that can be constructed in onshore yards and towed to site. Spars, which reach lengths of 300 feet with a diameter of 20 feet to support a large wind machine, cost more to transport and install at sites that can be 20 kilometers offshore.

The turbine must be installed at sea later. "You have to come back with a crane and a barge," Dagher said. "It is difficult and expensive."

He said a spar can work economically in certain conditions. Statoil has the advantage of building a spar next to deepwater fjords, where it can be floated and fitted out close to shore in controlled conditions, and then towed vertically to its production site. In Japan, the Fukushima spar and its substation were fitted out at a shipyard but a spokesperson said its deep 32-foot-draft was difficult in towing through shallower waters close to shore.

Over the long term, Roddier said, a floating design offers easier repair. For major repairs or repowering, the entire structure can be towed back to shore, rather than hiring ocean-going barges and cranes for a lengthy outage.

"We are designing for a 60-year life," Dagher said. "Most [platforms] now have a 20- to 25-year design life. But after 20 years if you tow back to shore and repower, you can get three 20-year cycles out of the hull."

"Our goal is to compete with other forms of electricity in the 2020s," Dagher said.

According to Roddier: "When you remove the money from grants, the balance of the project must be financeable. We're looking at a lot of things to make the project work better economically. But in offshore wind, if you don't get the costs down, you won't get the project done." ME

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