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News & Highlights

Airborne Wind Energy Prepares for Take Off

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During a test flight off Norway's coast, a team of wind-energy pioneers watched as what looked like a very big toy plane took off from the bobbing, jumbo-sized buoy to which it remained tethered (Fig. 1). To safely land the nearly 2-ton [1], experimental drone back onto its floating base-station, the vehicle's automatic flight control system would have to guide it through maneuvers that a wind-energy leader compared to "trying to parallel park a car with the curb shifting forward, backward, up and down" [2]. With the automatic flight control system taking cues from the team's simulations of the possible motions at sea of both the aircraft and buoy, the landing proved flawless, reported the drone's makers, suggesting that a similar drone might sometime soon harvest wind power off coasts around the world.

The fledgling offshore wind industry is entering a phase of rapid growth according to a recent report from the International Energy Agency (IEA) in Paris [3]. Although offshore wind technology "today supplies just 0.3% of global power generation," IEA executive director Fatih Birol wrote in the October 2019 report, "its potential is near limitless." Between now and 2040, offshore wind power is expected to increase its capacity 15-fold or more, and to give birth to a $1 trillion USD business [3].

For Makani Technologies, the California firm that designed and built the drone, the August 2019 flight test was "a big milestone," said Paula Echeverri, the company's chief engineer. Offshore wind is "the target operating environment and the target market where we see really huge value for our technology," she said. To tap floating-systems expertise of the oil and gas business, Makani had started a partnership with that industry's Royal Dutch Shell months before the test [4,5].

The test also confirmed that sophisticated, high-tech "airborne wind energy" (AWE) technology like the Makani drone, remains young, complex, and associated with a high risk of failure. After successful flight testing at altitude that same day, a second landing did not go so well. The drone became damaged and unusable as it missed its mark due to a "subtle and unexpected aerodynamic effect," a Makani spokesperson said, and plunged into the water.

Currently the biggest and most powerful AWE technology demonstrator, the Makani "M600" has become the poster child for this small but prolific technical community that believes that "kites" offer a better way to harvest wind energy than the towering wind turbines that dot many landscapes. Because, by definition, kites are tethered flying devices, AWE experts refer to a drone with a tether, like Makani's, also as a kite. Images of the Makani kite, which has a 26 m wingspan and eight motor-turbines designed to produce 600 kW of power [6], grace the program covers of the two most recent AWE conferences, in Glasgow, United Kingdom, in October 2019 [7], and in Freiburg, Germany, in 2017 [8].

Fig. 1. The prototype, 600 kW energy kite made by Makani to autonomously harvest power from offshore winds hovers during flight tests near the coast of Norway in August 2019. The kite connects to its floating base-station by a tether attached to its 26 m wing that spools from the drum near the top of the structure. The kite lands and takes off from the tilted plate to the right of the drum which fits into a groove beneath its wing's bank of motor-generators. Credit: Makani Technologies, with permission.

Kites do not need towers—a substantial cost savings. Because kites can reach the stronger, steadier winds routinely found above the approximately 100 m elevations of most wind-turbine hubs [9] and can also quickly relocate to a better spot if the wind dies down, these agile fliers can outperform fixed turbines in multiple ways, said AWE researcher Roland Schmehl, an associate professor of aerospace engineering at the Delft University of Technology (TU Delft) in the Netherlands. Dispensing with towers in the offshore environment is a particularly attractive proposition because water depths exceeding 50–60 m render the conventional ways of erecting turbine towers impractical. However, developers of some wind-turbine projects in deep water have begun experimenting with floating foundations adapted from the offshore oil and gas industry [3].

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Fig. 2. A ground-gen AWE system flies its kite above an agricultural field in June 2018 at the former naval airbase Valkenburg in the Netherlands, now a European testing and training center for unmanned aerial technologies including AWE and drones [15]. To efficiently collect wind energy as it moves away from its base station (lower right), this autonomous, 25 m^2 kite maneuvers in cross-wind loops or figure 8s that transfer maximum force from the wind to pulling the kite's tether. As it unreels, the tether spins a generator that converts this wind-powered pull into electricity. Credit: Kitepower BV, with permission.

Of the two main types of AWE systems, the Makani demonstrator is a "fly-gen" system, meaning its electricity is generated aboard the kite [10]. Electrical current produced as the wind spins the kite's turbine rotors during unpowered flight flows through its conductive tether down into the grid. The kite uses its turbines as motors only for brief activities, such as launching or landing, that consume relatively little energy. In the other main type of AWE system, called "ground-gen," wind sweeps aloft the kite, which can have rigid or flexible wings, so that its tether unreels and spins a generator to produce electricity at the ground station (Fig. 2). When the tether has fully unwound, control cables temporarily pitch the kite wing downward, which reduces how much it catches the wind and allows the ground station's winch to reel it back at little energy expense [10]. During energy harvesting, the kite spools out and back repeatedly "like a yo-yo, only on a large scale," Schmehl said.

For nearly the past two centuries, visionaries have attempted various practical uses for kites. A few have realized their dreams to a limited degree, including kite-drawn carriages, ships, and lifting devices [11]. Today's pursuit of kites as wind-energy sources, which has conceptual roots in the 1930s [12], began in earnest 10–15 years ago, when the larger, conventional wind energy field suddenly surged, said Schmehl. But industrial kites have so far not attained major commercial success, he said.

In a September 2018 report commissioned by the European Union, which has funded energy-kite development for a decade, AWE was described as "an emerging energy technology" that "has a long way to go before it can reach commercialisation" [13]. Still, the industry warrants further support, the report concluded, because of its potential future importance and strong European leadership. The report also stated that achieving and proving "device reliability through continuous automated operation" is the most urgently needed next step. AWE's flying systems make reliability a significant hurdle to overcome, Schmehl said. When something goes wrong, developers cannot simply troubleshoot the disabled system. "We have to actually land it and relaunch," he said.

As a Silicon Valley startup, Makani stands out from most of the 60-plus university programs, research labs, and smaller startups that made up the AWE ecosystem as of 2018 [12]. Almost all the AWE companies have survived funded by small private investments and modest government support, particularly from the European Union. Makani, however, has received much more generous funding, Schmehl said, first from the US government's Advanced Research Projects Agency-Energy, then from Alphabet, the parent company of Google, when the kite was a project of its Moonshot Factory [14], and now as an Alphabet-owned business [4].

Although the Makani kite is still in development, the recent tests showed "there are no more miracles to solve," said Echeverri, referring to such challenges as devising an adequately smart flight controller for a floating system. Ahead, the problems have "known solutions or more traditional engineering development solutions," she said.

As the kite moves towards commercialization, the company is seeking additional partners and anticipates two more development stages before going to market, the first being a "pilot" in 2020 summer focused on longer-duration autonomous operation, she said.

Countering the reservations of the 2018 EU report, some energy-kite specialists think simpler, lower-power, ground-gen AWE systems could pay off soon. Stephan Wrage said he became smitten with the idea of using kites to pull ships as a 14-year-old kite enthusiast. After graduating in 2001 with an industrial engineering degree from the Technical University of Dresden, Wrage launched the Hamburg, Germany-based company SkySails to develop kite-based propulsion systems that can reduce fuel costs and emissions of ocean-going cargo ships. Based on its expertise in building simple and reliable industrial kite systems, the company recently added an AWE division, said Wrage, SkySails chief executive officer. By the end of 2020, SkySails Power expects to install its first commercial AWE system, with a power of up to 200 kW, in Mauritius for the Ireland Blyth Limited business group, he said. That size, which fits inside a shipping container, could power a remote village, military or scientific outpost, or disaster scene. Also anticipating its first sales soon, in the same power range, is Kitepower, an AWE spinoff from TU Delft, said Schmehl, who co-founded the Delft-based company and sits on its advisory board.

The level of interest from potential customers, is "growing dramatically," Wrage said. "I think the time for power production with kites is now here."

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