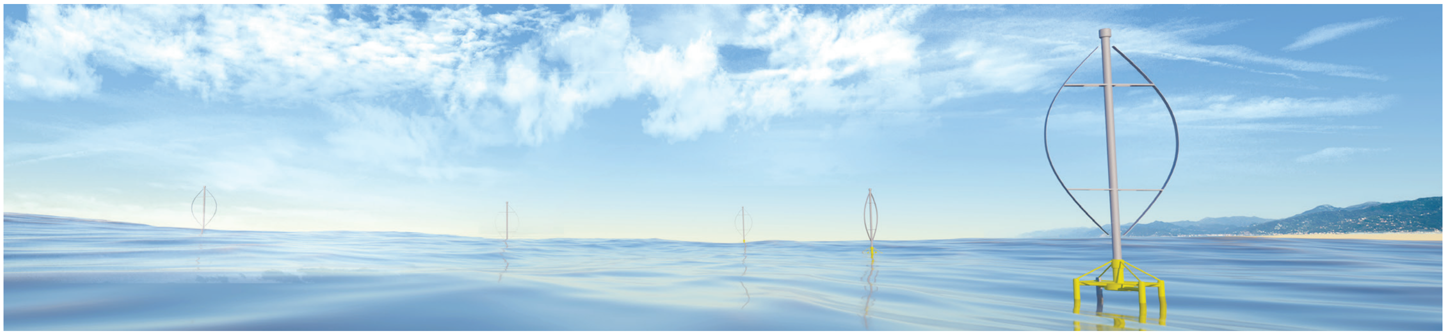
VERTICAL-AXIS WIND TURBINES FOR OFFSHORE WIND ENERGY



Technical advancements in vertical-axis wind turbines (VAWTs) could help realize the potential of offshore wind as a reliable, domestic renewable source of energy for advancing climate security. Sandia National Laboratories develops tools for the design and analysis of VAWTs, along with studying the technical and economic feasibility of prototype systems. Current research is focused on optimizing VAWTs to reduce the costs of floating offshore wind energy. In addition to VAWTs having a lower center of gravity from the drivetrain placement, Sandia has developed a towerless VAWT concept that significantly reduces turbine mass and associated costs.

THE CLIMATE CHALLENGE

Wind power is a seminal part of the U.S. Department of Energy's efforts to address climate security by developing domestic, sustainable, and zero-carbon sources of electricity. Offshore wind alone could generate approximately 2 times the combined capacity of all U.S. electric power plants. Offshore wind resources are stronger and more consistent than land-based resources. They are also optimally located near high-density coastal regions with large power needs.

The U.S. aims to deploy 30 gigawatts of new offshore wind energy by 2030, which would power 10 million homes and avoid 78 million metric tons of CO_2 emissions. This level of deployment will require installation in deep-water sites using floating systems. However, floating offshore wind is currently 3–4 times more expensive than land-based wind and will require significant technological advances to reach a competitive levelized cost of energy compared to other alternatives

THE SANDIA APPROACH

Sandia National Laboratories is developing and evaluating VAWT technology to access deep-water offshore wind resources where floating systems are required.

Sandia has studied VAWT technologies since the 1970s, demonstrating multiple scales of the technology from 2- to 34-meter diameter systems. Licensed to the FloWind company, the 17-meter VAWT design was the most commercially successful wind turbine at the time and most successful VAWT to date.

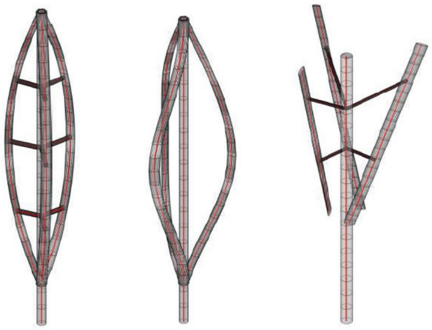
VAWT research at Sandia started with land-based systems and now focuses on floating offshore designs.

VAWT DESIGN & ANALYSIS TOOLS

Sandia has expertise in VAWT design and analysis, with extensive capabilities in the development of design-optimization tools and numerical optimal control of floating systems.

The Offshore Wind ENergy Simulator (OWENS) enables the coupled analysis of aero-hydro-servo-elastic simulations necessary for design and certification of offshore and land-based VAWT systems. With OWENS, designers can model and optimize any type of VAWT and analyze entire systems to reduce the levelized cost of energy. OWENS can model realistic environmental conditions of atmospheric turbulence, waves, and current and simulate the system dynamics and elastic response of the turbine. OWENS combines aerodynamic, hydrodynamic, and finite element modules into a continuous analysis workflow from basic parametric inputs and solves for the system response for steady, transient, and modal analyses.

In addition to OWENS, the Code for Axial and Cross-flow TUrbine Simulation (CACTUS) code calculates the aerodynamic performance and loads of turbine designs. This mid-fidelity model is based on a lifting-line/free wake formulation that calculates rotor power and blade loads in the time domain. Simulation setup is quick, and time-to-run varies from just seconds to minutes.

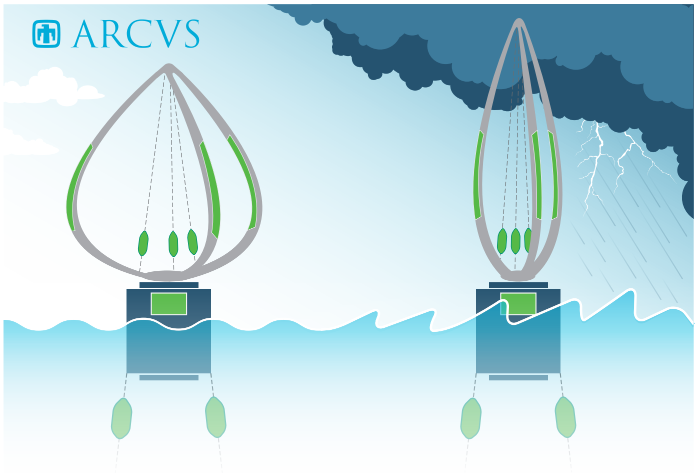


Sandia's OWENS toolset can analyze the structural finite element mesh of user-specified, free-form VAWT designs.

FLOATING VAWT DESIGN STUDIES

VAWTs have been proposed as a possible solution for improving the efficiency and lowering the cost of floating offshore wind. In the 2010s, Sandia designed a series of 5 MW floating VAWT rotors to investigate optimal rotor configuration, number of blades, material choice, and blade design. Floating platform design and analysis was also performed to determine the optimal floating platform architecture.

Leveraging those study results, Sandia is now developing the ARCUS design concept for floating offshore wind. ARCUS is a Darrieus VAWT that replaces the traditional rigid tower with pre-stressed blades and tensioned center supports, like a bow, which enables efficient material utilization and rotor-area control for load reduction that can reduce rotor mass by up to 50%.



The patented "towerless" ARCUS VAWT (U.S. 11,421,650 B2) has been designed by Sandia to address the high costs of floating offshore wind.

SUMMARY

VAWTs offer some unique design advantages for floating sites that cannot be replicated by more standard horizontal-axis wind turbines (HAWTs). For example, placement of the drivetrain at the base of the VAWT lowers the vertical center of gravity, reducing platform costs and improving accessibility of the drive components, which can also decrease maintenance costs.

The towerless ARCUS VAWT concept and design could result in further reductions in turbine mass properties that enable floating offshore wind to be cost competitive with alternative generation sources. The next steps in the commercial development of floating VAWTs are to demonstrate these technologies at appropriate scales and produce and validate commercially ready simulation tools.

CLIMATE SECURITY AT SANDIA

Sandia is integrating capabilities from across the Labs to support our missions and address the national and global security threats associated with the rapidly evolving climate crisis. Our vision is to advance climate security through science, technology, and action.

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