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Catch the Next Wave

Hydrodynamic simulation helps to deliver two- to three-times wave power efficiency improvement.

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If all the ocean's energy could be harnessed, it would produce more than 500 times the global energy consumption. The practical potential for wave energy worldwide is projected to be between 2 trillion and 4 trillion kilowatt hours per year. The World Energy Council estimates that about 10 percent of worldwide energy demand could realistically be met by harvesting ocean energy.

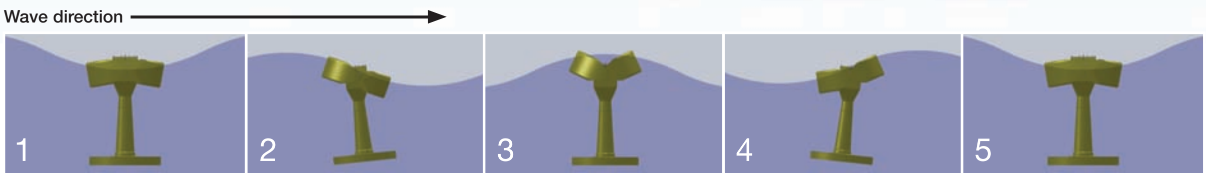
But wave power is a much less mature technology than solar or wind power or, especially, fossil fuel. A tremendous amount of work lies ahead in optimizing the design of wave power systems. Researchers must improve efficiency and reduce costs to the point that these systems can make a major contribution to meeting global energy requirements.

Columbia Power Technologies (COLUMBIA POWER), LLC, is attempting to harness this potential by developing commercially viable and scalable wave power generation systems. In conjunction with Oregon State University, the company is working to develop and commercialize innovative wave energy harvesting devices.

There are several key advantages of wave power:

- **Power density**: Wave power is much denser than other renewable energy systems, enabling wave parks to produce large amounts of power from a relatively small footprint.
- **Predictability**: The supply of energy from wave power can be accurately forecast several days in advance, enabling utilities to make precise sourcing plans.
- **Constancy**: Unlike solar power, which produces energy only when the sun is shining, ocean swells are available 24 hours per day.
- **Proximity to load centers**: Wave energy will not require substantial buildout of transmission capacity, since 37 percent of the world's population live within 60 miles of a shoreline, and 70 percent reside within 200 miles.

Preparing to test the wave power device



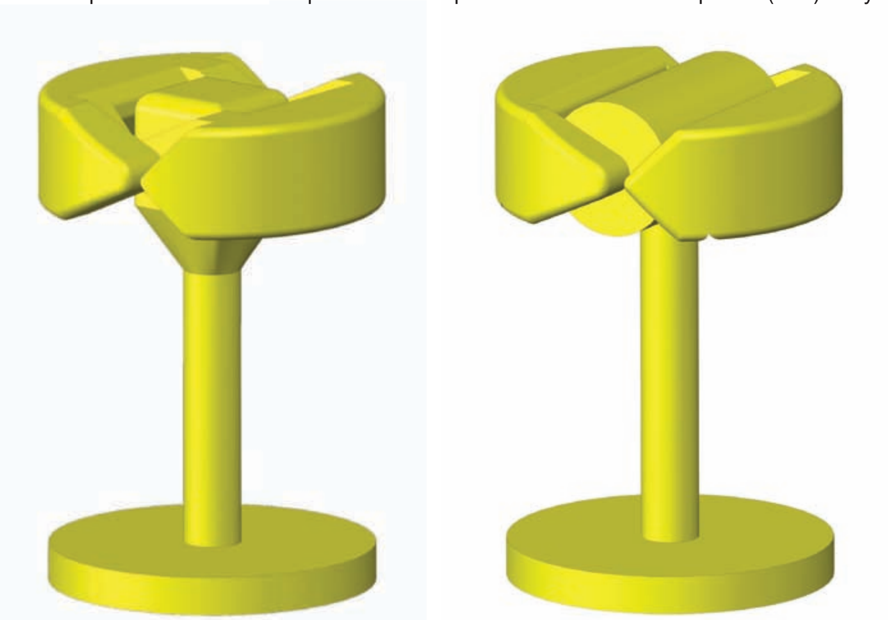
COLUMBIA POWER's wave power system: The wings and vertical spar react to the shape of the passing ocean swell. Each wing is coupled by a drive shaft to turn its own rotary generator.

The wave power industry, however, faces a major challenge since product developers have much less experience in the design of wave power devices relative to other renewable energy systems. Wave power companies need to rapidly advance efficiency and reduce costs of their designs to demonstrate viability to potential investors and customers. Other industries have taken decades or longer to develop technology to the point of commercial viability. But the wave power industry does not have that kind of time. To achieve its goals, it needs to rapidly improve designs while conserving limited capital.

COLUMBIA POWER is focusing on development of direct-drive systems, which avoid the use of pneumatic and hydraulic conversion steps and their associated losses. The company believes that direct-drive systems are the future of wave power because they are more efficient and reliable as well as easier to maintain. The number-one design challenge was to optimize the design of the buoy to maximize the proportion of wave power transferred to the buoy. Relative capture width is a dimensionless measure of the efficiency of the device in capturing the available energy of the wave. A relative capture width of 1 means that the buoy has captured 100 percent of available wave energy.

As COLUMBIA POWER set out to determine the optimal shape for the buoy, engineers looked at five different hydrodynamic simulation software packages. The company selected ANSYS AQWA software because of its ease of use, and tests showed that it provided a better match with physical experiments than did competitive software. COLUMBIA POWER also valued that ANSYS AQWA offers both frequency and time domain solutions. Frequency domain solutions are faster, which makes them ideal for quickly evaluating a large number of shapes, while time domain solutions provide the high level of accuracy needed to refine to the best shapes in the later stages of the design process.

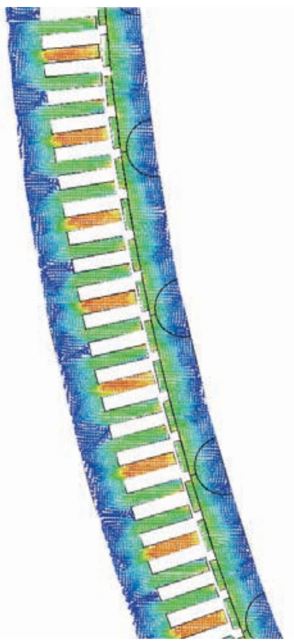
COLUMBIA POWER engineers developed an initial concept design in SolidWorks®, built a prototype and tested it at 1/33 scale in the Tsunami Wave Basin at the Hinsdale Wave Laboratory at Oregon State University. The team used high-resolution cameras to track light-emitting diodes on the buoy, measuring its motion in the waves. Engineers exported the concept design to ANSYS AQWA software and performed a time domain simulation while using a wave climate with the same amplitude and frequency as that measured in the wave tank. There was a very good match between the measurements and predictions from ANSYS AQWA. Since then, engineers have used ANSYS AQWA as their primary design tool to optimize the shape of the fiber-reinforced plastic (FRP) buoy.



COLUMBIA POWER engineers doubled efficiency of the buoy by using ANSYS AQWA to optimize its geometry.

COLUMBIA POWER has since evaluated over 350 different geometries with ANSYS AQWA in an effort to maximize the relative capture width of the buoy. At the same time, the company worked closely with Ershigs Inc., its structural partner that produces the FRP floats, to explore the manufacturability of various shapes and to ensure that the final design can be produced at a low cost. The company also looked at the survivability and environmental impact of proposed buoy designs. COLUMBIA POWER engineers used a sinusoidal wave shape and a suite of wave frequencies ranging from 2 seconds to 20 seconds for frequency domain simulations. The response amplitude operators calculated by ANSYS AQWA software were used in a post-processing routine written by COLUMBIA POWER engineers that calculates the relative torque and speed of the buoy as well as the relative capture width.

Once they felt that they were close to an optimal shape for the buoy, COLUMBIA POWER engineers moved to time domain modeling, which makes it possible to evaluate the nonlinear effects of the waves. The team evaluated the shapes that had proven best in frequency domain modeling against a variety of wave climates, including those found at seven different coastal locations around the world. At the same time, engineers began optimizing the power takeoff system that converts mechanical energy into electrical energy. ANSYS AQWA model results from frequency domain models were post-processed in Matlab® Simulink® to incorporate the power takeoff reaction torque and to compute power output. The ANSYS AQWA time domain models were coupled to a DLL that simulated both linear and nonlinear power takeoff operation. The DLL for the power takeoff model was developed in Matlab Real Time®. Engineers used the output from ANSYS AQWA to drive a numerical model developed in Simulink that simulates the power takeoff system and control strategy. The control strategy tunes the power takeoff to the wave climate by changing the amount of current produced by the generator, which, in turn, changes the mechanical load placed on the system. This makes it possible to consider in a single model the effects of different buoy shapes, power takeoff system designs and control strategies; it also helps to determine the power that would be generated by each approach in a variety of different wave climates.



Maxwell software from ANSYS was used to optimize the generator design.

COLUMBIA POWER recently began using Maxwell electromagnetic simulation software from ANSYS to optimize the design of the generator. Engineers evaluated three different electromagnetic simulation software packages and concluded that Maxwell was the easiest to use and the most stable. Maxwell is being used to analyze the electromagnetic performance of the generator while varying the air gaps between the rotor and stator, different magnet geometries, different magnet types, and different types of steel. The overall goal is to maximize the generator's energy output while minimizing its cost.

As a technology startup with far-from-unlimited funding, COLUMBIA POWER must be capital efficient. By focusing its development efforts on simulation and using physical testing judiciously as a verification tool, COLUMBIA POWER is moving forward in the development process much faster than would be possible using traditional development methods. ANSYS AQWA and Maxwell simulation software enable the company to make its mistakes in the computer, where they are far less expensive than in the ocean. ANSYS AQWA technology, in particular, helped to more than double the efficiency of COLUMBIA POWER's wave power system. COLUMBIA POWER has benefitted from the excellent technical support and productive training sessions provided by ANSYS. As a result, the company is on track to soon deploy the first ocean demonstration of its technology in Puget Sound.