The Promise of Wave Power

GUEST OPINION

By Annette von Jouanne

The solutions to today's energy challenges need to be found through increased electricity generation using alternative, renewable and clean energy sources. An extremely abundant and promising source of energy exists in the world's oceans. It is estimated that if 0.2 percent of the ocean's untapped energy could be harnessed, it could provide enough power for the entire world. Ocean energy exists in many forms including wave, tidal, thermal, and salinity. Of these forms, researchers at Oregon State University (OSU) have identified significant opportunities and benefits from wave energy extraction.

Research conducted by OSU (using data from the National Oceanic & Atmospheric Administration ocean monitoring buoys), as well as studies by the Electric Power Research Institute (EPRI), has shown that the Oregon coastline presents some of the richest ocean wave energy potentials in the nation. This has prompted the formation of an engineering team at OSU investigating novel direct-drive ocean wave energy extraction devices. OSU is the prime location to conduct ocean energy research, noting the following strategic facilities:

- OSU is the home of the nation's highest power university-based energy systems laboratory, with a 750kVA dedicated power supply and full capabilities to regenerate back onto the grid.
- OSU is the home of the O. H. Hinsdale Wave Research Lab (WRL) with world-class wave tank facilities, including a 342-foot wave flume.

The combination of key facilities at OSU, ongoing successful wave energy research, and the tremendous wave potentials off the Oregon coast has led researchers at OSU to pursue the formation of a U.S. Ocean Energy Research and Demonstration Center in Oregon. The center would be strategically located at OSU for research and development with a demonstration site off Reedsport, Ore. Reedsport has been identified by EPRI and the Bonneville Power Administration (BPA) as an optimal location for wave energy extraction demonstration — not only from the standpoint of the nature and magnitude of the wave energy source, but also based on other key features such as coastline geometries and access to the electrical transmission grid. A link to the significance of Reedsport is the use of the electrical substations primarily installed to provide power to a now-disused paper mill and an existing effluent pipe to serve as a conduit in the ocean for power take-off cables.

Photo courtesy of: Oregon State University

Testing is performed at Oregon State University's O.H. Hinsdale Wave Research Lab.

Currently, OSU's team is engaged in the nation's only university research program funded from federal resources in ocean wave energy extraction. Several novel wave energy buoy concepts are arising from this research focused on a more direct conversion of processes.

Understanding the processes requires advanced modeling techniques, which are also being developed through this work including advanced fluid structure interaction modeling in both 2D and 3D.

BACKGROUND

The world's first wave energy device patent was registered in 1799 by Girard in Paris. After more than 200 years of development, there are currently more than 1,500 wave energy device patents. Historically, there have been two booms of interest in the research of wave energy, corresponding to the 1970's oil crisis and pollution concerns as well as concerns regarding natural resource reserves since the mid-1990s. Ocean energy extraction technology is currently in a very preliminary state of development — where wind turbines were approximately 15 years ago, with no clearly superior engineering solutions yet established. The OSU team is engaged in research, development and demonstration preparation stages to move toward optimal wave energy topologies (similar to the wind turbine research process which led to the predominant horizontal-axis, three-blade turbine designs). Ocean wave energy has advantages over wind energy in

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KCP&L LINE REBUILT LIVE

Two years ago, Kansas City Power & Light Co. was starring at a serious bottleneck in its transmission system. A major 345-kilovolt line needed to carry more power to serve the regional wholesale electric market.

KCP&L turned to Quanta Services, whose crews replaced the conductors one at a time while power was diverted from the line being worked on to a temporary line. This reduced the needed outage time and did not require the rebuilding of the existing structures.

Work, which began in February 2003, was completed in four months at a cost of less than $7.1 million while boosting the capacity of the line by 40 percent.

that it is more predictable, with forecast times in the range of several hours, less variable, and offers higher available energy densities.

Depending on the distance between the conversion devices and the shoreline, wave energy systems can be classified as shoreline, near-shore and offshore extraction systems.

Shoreline devices are devices fixed to or embedded in the shoreline. Examples include the Oscillating Water Column (OWC), which is the most developed of the shoreline devices. An OWC system has a partially submerged hollow air chamber, which opens to the sea under the water line. A wave enters the air chamber and forces the air in the column to pass through a turbine. When the wave retreats, the air will be drawn back and pass through the turbine again.

Near-shore devices are in between the shoreline devices and offshore devices. Near-shore devices are characterized by being used to extract the power directly from the breaker zone and the waters immediately beyond the breaker zone.

Offshore devices are the farthest out to sea; they extend beyond the breaker lines and utilize the high-energy densities and higher power wave profiles available in the deep-water waves and surges. For utility grid support applications, submersible electrical cables are needed to transmit the generated power onto land where they can be interconnected to the grid. The devices (e.g. buoys) can be placed in such a way that they have little visible impact and would be connected in arrays of several buoys depending on the desired overall generating capacity.

DEVELOPING WAVE ENERGY GENERATOR BUOYS

OSU researchers are currently developing three novel prototype wave energy generator buoys to directly convert the linear motion of the waves to electrical energy. The research and development goals are driven by the important issues of survivability, reliability and maintainability — in addition to efficient and high-quality power take-off systems. The OSU wave energy team is focusing on “direct drive” approaches that allow generators to respond directly to the movement of the ocean, with coupling by magnetic fields for contact-less mechanical energy transmission. Note: This is in contrast to using intermediate hydraulic or pneumatic systems. The extracted energy is then processed through advanced power electronics for efficient transmission through sub-sea cable along the sea floor to land, and interconnection to the grid.

OSU’s three direct-drive prototypes include a Permanent Magnet Linear Generator Buoy, a Permanent Magnet Rack and Pinion Generator Buoy, and a Contact-less Direct Drive Generator Buoy. These buoys are designed to be anchored one to two miles offshore in typical water depths of greater than 100 feet — where the buoys will experience gradual, repetitive ocean swells. Inside the Permanent Magnet Linear Generator Buoy, the wave motion causes electrical coils to move through a magnetic field, inducing voltages and generating electricity. In the Permanent Magnet Rack and Pinion Generator Buoy, linear to rotary conversion is being developed as an extension of the concept of permanent magnet gears. In this device the rotary speed of the magnet gears are greater than the linear speed of the rack (which moves up and down with the ocean swells) making the output more effective for rotary generators. The Contact-less Direct Drive Generator Buoy exhibits linear force transmission using large, high-strength permanent magnets configured in a “piston.” The motion of the piston is then transformed to rotation using a ball screw to drive a permanent magnet rotary generator.

LOOKING TO THE FUTURE

Pioneering developments in ocean wave energy extraction devices are taking place at OSU to best take advantage of wave power in ways that are reliable, maintainable and able to survive a hostile ocean environment. The developing prototype generator buoys are being designed so that they can be “winched down,” or pulled beneath the ocean surface during severe storm or tsunami conditions. Just like wind energy, wave energy systems will be more expensive at first, and then the cost will come down — becoming very competitive due to the advantages of increased energy densities, availability and predictability. While wave energy is about 15 years behind wind, several factors promise that the “catch-up” time can be much less, including advanced technologies and materials as well as the lessons learned from offshore wind installations. Initial wave generator rating estimates are that buoys of approximately 12 foot diameters and heights could produce power on the order of 250kW per unit. Thus, a network of 200 such buoys could power the business district of downtown Portland, Ore. Fortunately for the Pacific Northwest, the winter period of highest wave energy potentials coincides with peak electricity demands. OSU researchers are also investigating small-scale wave energy generators, which could be integrated into water craft anchor systems to power a variety of electronic devices and enable ocean data collection/monitoring buoys to become self powered.

There is reason to hope that advancements being made in ocean wave power may enable a major new, reliable and flexible source of affordable renewable energy.

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