E2I EPRI Assessment

Waveberg Wave Energy Conversion Device

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Introduction

E2I EPRI is leading a U.S. nationwide, government/industry, public/private collaborative program to assess and demonstrate the feasibility of offshore wave power to provide efficient, reliable, cost-effective, and environmentally friendly electrical energy. E2I EPRI strives to initiate momentum towards the development of a sustainable commercial market for this technology in the U.S. and thus provide economic benefits and job creation. State energy agencies and utilities from six (6) states (Maine, Massachusetts, San Francisco CA, Oregon, Washington, and Hawaii) and the Department of Energy (DOE) National Renewable Energy Laboratory (NREL) and E2I EPRI are collaborating to accomplish a project definition study in CY 2004. This study will produce system designs for wave energy conversion device power plants, performance estimate and economic assessments for one site – wave energy conversion device per state. This scoping effort is intended to provide the information needed by funding decision makers to decide whether or not to proceed to the next phase of work, detailed design, permitting and financing.

E2I EPRI contacted all known Wave Energy Conversion (WEC) Device manufacturers in December, 2004. Information needed to assess the potential application of WEC devices to offshore sites was requested from those manufacturers. The WEC Device information received was assessed and compared in February and March 2004 in order to establish a decision-making basis for the advisors in this project.

The Waveberg was not assessed at that time because the device development was not far enough along to allow for a proper assessment of its technical and economic viability. At the request of Waveberg, E2I EPRI reviewed and assessed the information that was provided by the company. The following chapters provide a high-level technical assessment with recommendations with respect to the devices technical development.

The Waveberg Device

The Waveberg device consists of 4 floats (1 center and 3 outer) which float on the ocean surface. As a wave passes through, these floats move in response to the wave action. The relative motion between the center float and the outer floats drive water pistons, pumping sea-water to a higher pressure level.

Waveberg units are catenary (slack) moored and the pressurized water is brought to the ocean floor by a flexible hose. The pressurized water is piped to shore using fiber reinforced plastic pipes. Onshore an impulse turbine and generator converts the water pressure into electricity.

Stage of Development

The Waveberg device has been tested at sub scale in a wave tank and in the ocean. Wave tank tests were carried out using regular waves. The model tested was 9 foot long weighing about 50 pounds. An approximate static performance model was developed to estimate the device power output.

The tests carried out were useful from the perspective of observing device behavior and validating the analytical static model. Significant uncertainties in the device performance remain to be addressed.

EPRI/E2I recommends that the company create a theoretical model of the device using tools that are commonly used in the offshore oil and gas industry and that can be used to evaluate device performance and structural stresses on the system. The model should be verified with wave tank tests. Once these model is verified, the design can be evaluated and a proper assessment of its technical and economic viability can be established.

Construction & Materials

The company envisions the use of fiber reinforced plastics for most of the device construction. While fiberglass reinforced constructions have been used in the building of ships, it is typically not used for stationary installations as it is perceived as a costly material (labor intensive).

The basic Waveberg device has been tested at sub scale, but no stress and performance measurements have been obtained. As such it is difficult to assess structural stresses acting on the device and impacts on the device construction itself. If the device is to be insured against potential damage, it will need to be designed to meet standard build-codes developed by the Offshore Oil & Gas industry or the ship-building industry. E2I/EPRI recommends that the company design the system using standard codes and practices. Alternative materials such as concrete and steel and their impact on cost should also be assessed.

Mooring

The devices mooring has not been developed. It is envisioned that the device is moored using a standard catenary 3-point mooring system. This will allow the system to turn into wave direction and allow it to ride out storms. As the Waveberg will have a shallow draft, the effect of drift forces is expected to be minimal. This is especially important in locations with large peak-current velocities.

Power Take Off

The power take off consists of water rams pumping sea-water onto a higher pressure level, suitable to pump to shore. The power take off was designed to operate at a constant pressure level, which can be adjusted slowly by elevating the system pressure level using shore-based pressure tanks, which will discharge onto an impulse turbine.

A critical area of the design is bringing the pressurized water to a common interconnection point on the ocean floor. Offshore tanker terminals typically use such flexible hoses. However they tend to be costly specialist items. Piping the pressurized water to shore will require the laying of appropriately sized fiber-reinforced pipes. It is unclear how this will affect economic viability based on additional frictional losses and increased complexity (as compared to a submarine cable). In addition it might introduce additional environmental and permitting issues.

The power generation system on shore does not raise any significant concerns as they are standard items. Alternative configurations could entail locating impulse generator and associated equipment on an offshore platform in close proximity to the devices to minimize losses in the system and bring power back to shore using sub-sea electrical cables.

Operation & Maintenance

The Waveberg device will require minimal intervention because of the shore-based power take off failures. However, significant intervention for preventative and reactive maintenance will be required for the mooring system, structural and to minimize the effect of marine growth on the device surface. Being a freely floating attenuator, the device can be designed for ease of deployment and recovery.

Performance

The device performance was provided by the manufacturer. Based on the limited amount of data available, E2I/EPRI was unable to confirm any of the performance data presented and simply applied capture width ratio tables provided by Waveberg. Mechanical to electrical efficiency was estimated at 60% with a breakdown as follows; Generator: 95%, Pelton Impulse Turbine/Generator, 80%, Water Transmission: 80%. Significant uncertainties in the performance model remain to be addressed by Waveberg.

State	Rated Capacity	Capacity Factor	PAve (kW)	Annual MWh
Hawaii	134	40.0%	54	469
California	97	40.0%	39	338
Oregon	107	40.0%	43	376
Washington	113	40.0%	45	397
Massachusetts	146	40.0%	59	513
Maine	152	40.0%	61	532

Table: 45m Waveberg Performance

State	Rated Capacity	Capacity Factor	PAve (kW)	Annual MWh
Hawaii	19	40.0%	8	66
California	11	40.0%	4	38
Oregon	12	40.0%	5	43
Washington	14	40.0%	5	48
Massachusetts	23	40.1%	9	80
Maine	24	40.0%	10	86

Table: 26m Waveberg Performance

EPRI/E2I recommends a modeling of the device using design tools common in the offshore Oil & Gs industry and a verification of this model with wave tank tests that are properly instrumented. The Waveberg performance data demonstrates that the device performance can be optimized using rapid tune ability and changing float-sizes and proportions.

EPRI/E2I recommends carrying out a careful parametric optimization of the device concept to determine optimal physical sizing and optimal configuration of the floats.

Cost

Cost outlines were created for the Waveberg by Infrastructure Composites International. The data showed that a single 26m Waveberg unit would cost $199,477 and that for volume production of the unit, this cost could potentially be reduced to $61,000 per unit. This cost includes only structural components and excludes the Power Take Off, Moorings and Water Pipes to shore.

Concept Promises/Issues

The device concept presented by the Waveberg team is a surface based attenuator. This type of a device has the advantage that it can be designed in such a way that all portions of the power take off are located above the sea surface. As such, it is easily accessible for operation and maintenance crews. In addition, the device can be designed for simple and quick deployment and recovery operation. Having a shallow draught, design loads on the system based on high currents can likely be minimized. Current peak velocities (100 year return) are often driving parameters for the mooring design.

Much of the optimization work can be carried out using a combination of computer modeling and wave tank validation by a qualified engineering team.

Recommendations

The device presented by the Waveberg team is in an early development stage. At this stage, it is too early for E2I EPRI to draw conclusions upon the competitiveness of the device. The uncertainties come from the limited amount of data obtained in previous work and performance and cost data presented. In addition, the device concept has to be properly understood and performance optimization has to be carried out. In order to achieve initial validation objectives, E2I/EPRI recommends the following work be accomplished:

1. Create a device simulation using industry standard hydrodynamic software codes. The device simulation should allow for parametric optimization of pod sizes, number of pods, water ballast etc. This will require writing additional software code for the proper analysis of the system.

2. Parametrically optimize the device using the created custom software

3. Carry out tank tests in irregular waves at appropriate scales. This will likely require a series of wave tank tests at various scales for efficiency verification, survivability etc. It will be important to test in irregular waves using a standard wave spectrum (such as Jonswap or Pierson Moskowitz).

4. Resolve design engineering issues such as mooring design, pressurized water interconnection, material choice etc.

5. Design the system using standard codes and practices from the Offshore Oil & Gas industry and/or the shipping industry. EPRI/E2I recommends consulting with a company that has experience with insuring such projects.

The engineering specifications obtained from the above program can then be used to make a statement whether or not the device can become a competitive resource option in this emerging industry and next steps for building a full-scale demonstration device initiated.