Studies on Wave and Tidal Power Converters for Power Production

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Abstract

Wave and Tidal energy is a predictable, environmentally desirable source of power. The use of water to create electricity comprises a number of technologies, primarily wave power. The long-term potential of wave power is estimated to be between 10-15% of global electricity consumption. Wave power captures energy generated by the waves, by using the rise and fall of waves to activate pumps and generators. Wave power is more predictable than wind power, as waves normally continue for six to eight hours after the wind drops. This allows wave power to smooth out some of the volatility of wind-generated power. Wave power installations are not only less visible and less noisy; they also positively influence the living conditions of fish by providing sheltered areas. Hence, as the technology matures further and costs are brought down, wave power can be one of the intelligent energy sources of the future.

Keywords: *Tidal Energy, Wave Energy, Converters, OWC (Oscillating Water Column).*

I. Introduction

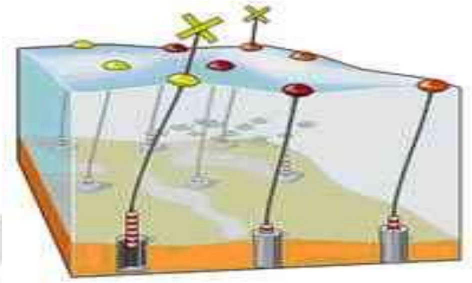
Ocean waves can be characterized through a vast number of wave parameters, but summarized quite accurately by a small number of basic statistics [1-54]. Irregular waves are often described by a spectrum (Sf) that indicates the amount of wave energy at different wave frequencies (f). Several spectral characteristics and wave parameters can be directly calculated from this time series representation by the use of spectral moment, mn. The area under the spectral energy function is the total energy of the wave spectrum and is often defined by the parameter m0. Higher spectral moments are calculated using Eq. (1); n may take any integer value (positive and negative). ∫ (1) The most important wave parameters are The standard deviation of the sea level is given by the significant wave weight (Hs), which corresponds to the average of the highest one-third of through-to-crest wave heights, or the significant wave height estimated from the spectral moments (H_{m0}) [55-60]. Equation (2) The energy period (Te) or mean wave period with respect to the spectral distribution of energy, here denoted by T-10, is defined by (3) Instead of Te, the peak wave period Tp and the zero-up crossing period Tz is most commonly used as characterizing parameters of the wave period. The peak wave period Tp indicates the predominant wave period, without taking the rest of the wave spectrum into account, while Te represents the average energy period of the Typical Atlantic oceanic values of Te and Hs range roughly between 5 and 15 s and 0 and 10 m. Based on these parameters, the omni directional wave power (in kW m-1) can be calculated [60], with the wave number based on the energy period ke and taking the water depth h into account, by [61-70] Oceanic wave conditions can be composed of various wave fronts, e.g. waves from a locally generated wind sea and swell originated from a distant weather system, coming from different directions. In order to adequately describe the wave conditions, other parameters should be included such as the overall spectral shape in both frequency (spectral bandwidth) and direction (directional spreading)[71-79], but it might even be complemented with information regarding the wind, tidal currents or other environmental parameters. The details required of the wave climate go together with the advances of the development of a device. Basic information such as the scatter diagram, representing the joint probability of the significant wave height and period, can be sufficient for basic tank testing. However, specific details of the frequency and directional spectrum and possibly other parameters will be more important for making accurate predictions of the annual energy production (AEP) at a certain location of interest or verification of sea trial results [80-90]. The wave power content in a wave train decreases in shallow water as a result of several mechanisms. In intermediate and shallow waters, the waves are influenced by the sea bed, creating turbulence by breaking waves and friction by the seabed and marine growth while the waves start to align with the shoreline due to refraction, which can possibly extend (or reduce) the length of the wave front. Whole wave spectrum. The main advantage of Te is that it can be used directly to calculate the average wave power level, while Tp requires a coefficient to match it to Te, which requires knowledge of the spectrum. However, as representative wave parameter to which the performance can be presented or assessed, Tp might be more adequate, e.g. for a resonant based WEC. The ratios between different parameters that describe the wave period depend on the spectrum. For a JONSWAP spectrum with a peak enhancement factor $\gamma = 3.3$ the ratios Tp/Tz = 1.286 (and a ratio of Te/Tz =1.15 can be assumed), while for a Pierson-Moskowitz spectrum ($\gamma = 1$) the ratios Tp/Tz = 1.40 [90-100].

II. Methods and Materials

II.A. Different Wave Energy Converters

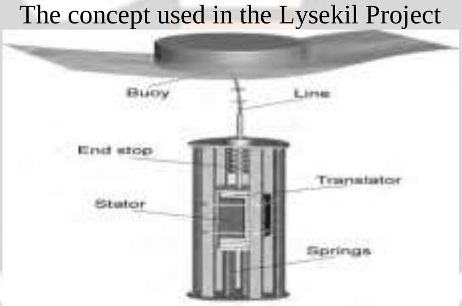
Point Absorber Wave Energy Farm ➔

It is also a point absorber, meaning that the width of the WEC is small in comparison to the wave length.



Potential environmental considerations for the development of wave energy include the following ➔

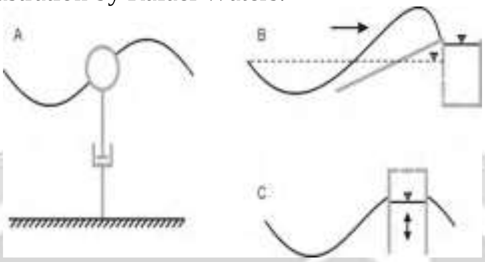
The concept used in the Lysekil Project



The Lysekil research site, as seen from the observation tower(2008)

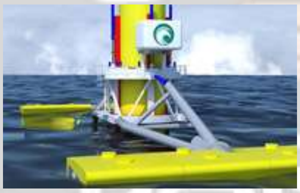
An illustration of some of the work within the Lysekil project.

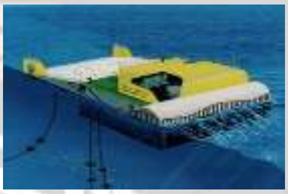
A: Classification of wave energy devices. A: Wave activated bodies. B: Overtoppingdevices C: Oscillating water columns. Illustration by Rafael Waters.



A New Approach to Converting Wave Energy into Electricity.

II.C Wave energy converters





II.D Pelamis / Sea Snake type Wave Energy Converter.

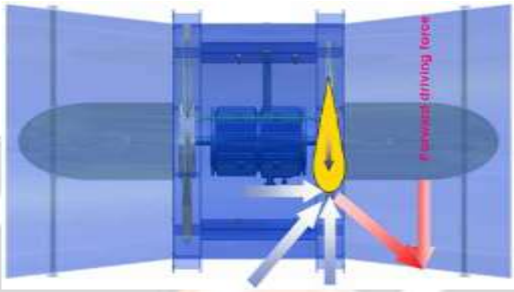
Company called Ocean Power Delivery are developing a method of offshore wave energy collection, using a floating tube called "Pelamis". This long, hinged tube (about the size of 5 railway carriages) bobs up and down in the waves, as the hinges bend they pump hydraulic fluid which drives generators.

II.E Limpet Wave Energy Converter

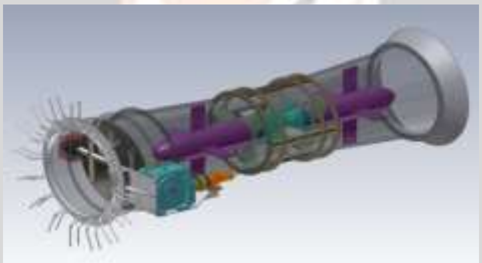
Limpet (Land Installed Marine Powered Energy Transformer) is a shoreline energy converter sited on the island of Islay, off Scotland’s west coast. The current Limpet device – Limpet 500 – was installed in 2000 and produces power for the national grid.
Limpet uses the principle of an oscillating water column. The following diagrams show how this works:

II.J Wells's turbine

Its principle sketch with flow vectors and forces for axial flow from the left to right (for the opposite flow direction vectors symmetric to rotor plane apply).



II.G Design of the two stage 3 bladed rotor breakwater turbine, shown with the connectors to theconcrete collector on the left hand side.



II.L Wells turbine fitted inline into a harbour wall to create an active breakwater

II.M LIMPET (Land Installed Marine Power Energy Transformer)

The Limpet unit on Islay has an inclined oscillating water column (OWC) that couples with the surge-dominated wave field adjacent to the shore. The water depth at the entrance to the OWC is typically seven meters. The design of the air chamber is important to maximize the capture of wave energy and conversion to pneumatic power.

The turbines are carefully matched to the air chamber to maximize power output. The performance has been optimized for annual average wave intensities of between 15 and 25kW/m. The water column feeds a pair of counter-rotating turbines, each of which drives a 250kW generator, giving a nameplate rating of 500kW.The Limpet's design makes it easy to build and install. Its low profile gives low visibility, so it doesn't intrude on coastal landscapes or views.

II.N The Fuel

The energy contained in ocean waves can potentially provide an unlimited source of renewable energy. Wave energy is a concentrated form of solar energy[101-120]. Ocean waves are created by the interaction of wind with the surface of the sea and the UK has wave power levels that are amongst the highest in the world.
The initial solar power level of about 100W/m2 is concentrated to an average wave power level of 70kW/metre of crest length. This figure rises to an average of 170kW/metre of crest length during the winter, and to more than 1,000 kW/metre during storms.

II.O: The Technology
There are three(3) main types of wave power machines, some of which sit on the shoreline while others are free-floating:
(a) Oscillating water column
(b) Buoyant moored device and
(c) Hinged contour device

II.P Cost
As a consequence of the competing designs and lack of long term commercial operating experience, actual cost data is virtually non-existent and developers have had to make estimates of costs. The estimates always show projected cost per kWh, falling over time due to better designs and increasing unit size.

II.Q Current Uses
There are two wave power devices in the UK. Total installed capacity currently stands at 1.25 megawatts. The first type of device is the LIMPET (Land Installed Marine Powered Energy Transformer), a 500-kilowatt shoreline oscillating water column on the Scottish island of Islay. The second, the 750-kilowatt Pelamis/Sea Snake, is an example of a hinged contour device. It is the first deep-water grid-connected trial and is currently installed at the European Marine Energy Centre in Scotland, where it is undergoing testing.

II.R Potential
Marine energy could provide around 20 per cent of the UK's electricity needs but only if there is sufficient investment in the appropriate technology. A report by the Carbon Trust concludes that wave and tidal power could eventually provide a cost effective way of generating energy and offers a real alternative to other renewable sources such as wind and solar power. However, in the short-term the initial set-up costs of marine energy are high as it requires extensive research and development. Yet the Carbon Trust believes that sufficient investment now could lead to a strong UK marine energy sector.
John Callaghan, programme engineer at the Carbon Trust, said: "The UK leads the world in marine renewable technology development."
He added: "Given our superb natural resources and long-standing experience in offshore oil and gas,

shipbuilding and power generation, the UK is in prime position to accelerate commercial progress in the marine energy sector and secure economic value by selling marine energy devices, developing wave and tidal stream farms and creating new revenues from electricity generation.

III. Conclusion

Wind-generated waves on the ocean surface have a total estimated power of 90 million giga watts worldwide. Due to the direction of the prevailing winds and the size of the Atlantic Ocean, the UK has wave power levels that are among the highest in the world. Wave energy has the potential to provide as much renewable energy as the wind industry, but the development of wave technology is currently at the same stage that the wind industry was in 10 years ago.

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