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A Comparative Study and analysis of Sea Snake Wave Generator

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Abstract

There is a huge amount of energy in the wind and the sea and it's renewable. The objective of this report is to harness the kinetic power of the ocean waves and the flowing current of a sea using the sea snake wave power generators. It's totally sustainable and it doesn't produce any harmful gas emission. This report is introducing the renewable sources of energy in general. The mechanisms that are used to convert ocean wave into a clean energy are going to be introduced as well. Also the mechanism of the sea snake wave generators would-be explained. Furthermore, calculations of energy production and all related methods to the sea snake wave generators would-be pointed out in this report.

Keywords: electricity, kinetic energy, sea snake, wave power, renewable energy, generator

Introduction

Renewable energy is generating electrical power using sustainable sources of energy. The power generated by natural sources of energy does not produce any greenhouse gases, which can contribute to stop climate change and pollution damage. The first law of thermodynamics states that energy can be neither created nor destroyed; it can only change forms described by Anon (2006). In general the energy can be conserved in many different forms. The energy in its natural forms such as wind, solar, wave, biomass &tidal power can be harnessed to produce electrical power. The energy can change its form from solid to liquid to plasma and vice versa. Using modern technology people can change the form of energy conserved in a sustainable sources and produce clean electrical power using renewable energy sources.

The scope of this report is "wave energy" as the renewable power source of energy. The blowing air along the surface of the ocean produces waves. According to Kashem et al., (2018), Touti et al., (2020) and Ahmed et al., (2019) each wave conserves a lot of energy within the movement. In reality, water fulfills almost 75% of the Earth's total volume described by Cruz and Sarmento (2007). So in most cases locating the electrical wave power generators is easy and available for most parts of the world. There are many different wave power plants available and getting tested around the world with many different designs. Sea snake wave generators (SSWG) will be the main objective of this report.

The SSWG contains many cylindrical tubes connected to each other using hinged joints. The SSWG will be floating as a giant snake offshore. Khandakar et al., (2019), Kashem et al., (2017) and Kho et al., (2017) stated that the SSWG mission is to convert the wave's kinetic energy to electricity. In simple words, the SSWG will generate power using the hinged joints that connect its cylindrical tube sections. As waves move the joints up and down and side to side, hydraulic rams drive an electrical generator. After that, the electricity generated is carried to shore via sub - sea cable. Chowdhury et al., (2019), Hong et al., (2018) and Kashem et al., (2016) stated that this report will describe the mechanical stages of the SSWG in more details. The type of material& design structure for the cylindrical tubes will be observed from many different points of view. Also, the internal design of the SSWG including the machinery and the mechanical structure will be observed in this report.

Wave energy convection

Introducing new technology for generating renewable power energy is developing in many different areas. By using renewable energy people can reduce the use of our limited energy resources such as oil, gas etc. According to Siddique et al., (2017) and Mubarak et al., (2016), to protect the environment for future generations it's essential that people should rapidly move to a more sustainable lifestyle.

New mechanisms to produce free energy from sustainable sources of energy have been developed in the past few years. The solar power can be converted to electricity using photovoltaic, it's a direct transfer of the sun energy to electricity and it's widely used because of the accessibility to the source of this energy "The Sun" (Chowdhury et al., (2019), Tabassum et al., (2016) and Shabrin et al., (2017)). The hydro-power is also renewable sauce of energy, by building dams and turbines attached to power generators in the mid-stream of the rivers, the water current flowing in rivers from up to down-streams is going to rotate those turbines and the generators will produce clean energy (O'Connor, Lewis & Dalton 2013).

As this report is introducing the sea snake wave power generators, the free source of energy is going to be the ocean waves. There are many different devices developed to produce electricity from the ocean waves. Heatwole et al., (2012) pointed to the following exciting designs:

- Three sea snake wave generators (Pelamis) located off the coast of Portugal, can generates a 2.25MW capacity of wave energy
- The Limpet located at Islay has been operating over two years, can generate 500kW trail installation

According to Kashem et al., (2020), and Nabipour-Afrouzi et al., (2018), the sea snake wave generators not only produce a free energy from the wave movements but also the energy it produces is a clean source of energy. There are many different designs that can be obtained to produce power from the sea waves; however, this project will describe, and analyze the sea snake wave generators or Pelamis (He et al., (2012)).

Hardware Used to Convert Wave energy

There are different types of hardware to convert the wave energy. These are described below.

Slow Linear Pump

The conventional linear hydraulic ram is the primary moving element; therefore, it is the input for taking power mechanism. There are many different consideration and designs are out there, the rams used for the Pelamis were a group of twelve rams arranged in a truss shape like the edges of coronet, therefore, it gave the large springs at any force level all six degrees of controlled freedom. However, one of the most common problems in this task is high temperature which races due to shear loss and friction by moving parts at the interface, therefore, cheap hydraulic rams can suffer from friction force which can conserve several present of its useful thrust (Safe et al., (2014), and Shaila et al., (2018)). One way to improve it is by using hydrostatic seals for the piston and the rod gland, and by cutting a fine screw tread with a flat top on one face of the seal can give them a leakage rate that can be carefully chosen. By using this technic, instantaneous change can be avoided in pressure or velocity where it can complex the full mechanism.

Connections

One of the best connections to use is the flexible hydraulic hoses used in the car brakes. They are a great attraction in low power hydraulics. Designer can have a freedom in choosing where to place the equipment as these connections are fixable and allows all the parts to have movement freely. The disadvantage of this hoses is they are, where there is no source of a fixable hose that has a bigger diameter than the size of 50mm. Study was performed by McConnell (2004) on the flexible cable test performance, therefore, this study shows that the major fail can cause less damage by using several parallel small hoses rather than using one big fixable hose in moving hydraulic fluids. Other solution can use rigid steel piping where it can take the oil from the hydraulic cylinder to other parts of the system.

Design consideration for the hydraulic machine

The hydraulic machine should run at synchronous speeds of 1500 r/min or 1800 r/min for 60 Hz networks. Energy generators for powerful designs can generate as high as 10MW; therefore, hydraulic machine should be suitable for this type of generators. It should also be able to collect power from number of different energy generators, in particular energy stores. It should be as efficient as possible particularly at the load parts. As for geometric distribution, the hydraulic machine have a high tolerance, therefore, it should have self-set clearances and spherical bearings (Sheikh et al., (2017), and Kashem et al., (2018)). It shouldn't be heavily loaded, or moving, or solid to solid interfaces. For each of the separation flows it should have very rapid changes from pumping to motoring to idling, independently. Finally, it should allow the user to control the displacement directly using computer at the digital database level.

The initial cost of the SSWG from the manufacturer is equivalent to 2,600,000$ according to EPRI report in California (2004). This number is including the steel section and all the internal components. There are other maintenance costs and installation cost are not in the aim of this project (O'Connor, Lewis & Dalton 2013).

Working Principals

SSWG contains a series of large semi-submerged cylindrical sections, which are linked to each other's end by articulating joints. However, these joints allow the cylindrical sections to move freely around both vertical and horizontal axes. The train of cylinders is connected from one end to the sea bed, and arranged inline to the wave's motion. This joints allow the cylinders pitch and yaw to be displaced in a relative to each other, in response to passing waves, hence, the longitudinal direction of SSWG is perpendicular to the wave direction of motion, so it can allow it to move up and down the waves. Angular movement is created by this action between adjacent ends. This movement is acting force on the hydraulic rams, where the hydraulic pistons pump oil through hydraulic motors. The hydraulic motors produce electricity by driving electrical generators. In addition the SSWG will dive in the water when high intensity of waves is running.

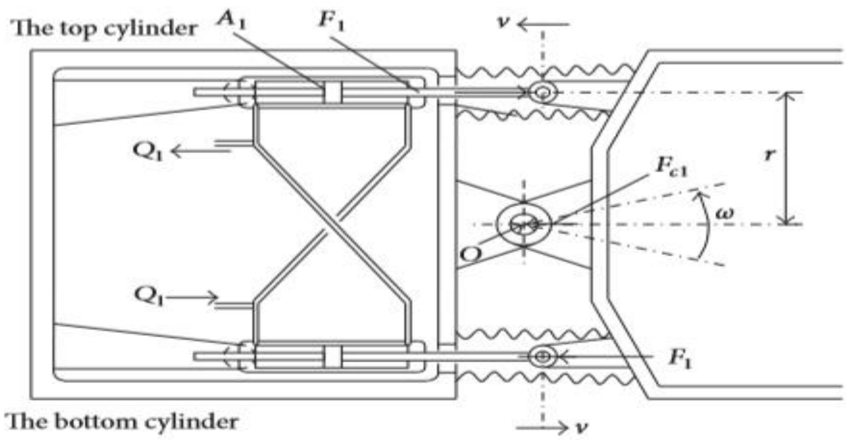

Figure 1- Schematic of the energy transfer process

The figure 1 shows a free body diagram of the energy principles of the SSWG at the joints where the hydraulic rams are located (Marsh (2005) If a double hydraulic cylinder for the mechanism has been chosen, therefore, it will have a double rod cylinder that will pass the oil regardless the motion direction. Whereas a force was pushed the top cylinder, it will pull the bottom cylinder moving it in the opposite direction simultaneously. The equation 1 is for the energy transfer:

$$E_1 = 2F_1v = 2A_1pr\omega = \frac{Q_1P}{\eta_1} \qquad (1)$$

Where, E_1 −The input mechanical energy of two double rod cylinders, F_1 −Recation Force, v −Velocity of the double rod cylinder, A_1 −Piston Area, p −Output Pressure, r −Radius. ω −Angular Frequency of the wave, Q_1 − Total hydraulic flow of two double rod cylinders, and η_1 −Efficincy of the double rod cylinder.

The two reaction forces at the top and bottom cylinder have the same magnitude but opposite in direction. So the reaction force applied on O axis is:

$$F_{c1} = F_1 - F_2 = 0 \qquad (2)$$

NAVITS, which is one of Microsoft Excel tool primarily developed by the author for the Hydraulics and Maritime Research Centre under the Charles Parsons research award. The software calculates the wave energy output of any wave energy device, providing it has a power matrix. (He, Qu & Li 2013). Sea snake wave generator "Pelamis" was chosen for analysis in this report. Since the power matrix was first published in 2003 the reliability of it has never been fully proved, and unfortunately, there no update for the matrix since. Therefore, the Pelamis device is the only used in the context of a case study and provide a platform methodology to examine the paper's research aims.

By multiplying each cell point of the scatter plot of hours with the corresponding cell of the wave energy convertor, the NAVITAS calculated the total annual output power. Wave Energy

Input (WEI) can be obtained using the following equation:

$$WEI = 0.55Hs^2.T_s \qquad (3)$$

Where, H_s −Wave height, T_s − Mean zero crossing period.

To calculate (T_e) the energy in the particular period of time the following equation can be used

$$T_e = 1.2 \times T_z \qquad (4)$$

Wave Energy Output (WEO) can be obtained using the following equation:

$$WEO = WEI \times 3.5 \qquad (5)$$

Results & Calculation

This section will contain a load of graphs plotted biased on methodology's formulas and equations; therefore, it will show the amount of power can collect using one sea wave converter at different positions of the offshore. The output power will be related to the frequency and height of the waves. After the calculation, Figure 2, 3, 4 and 5 have been obtained which shows the wave energy output of the sea snake wave generators at different wave height and time period.

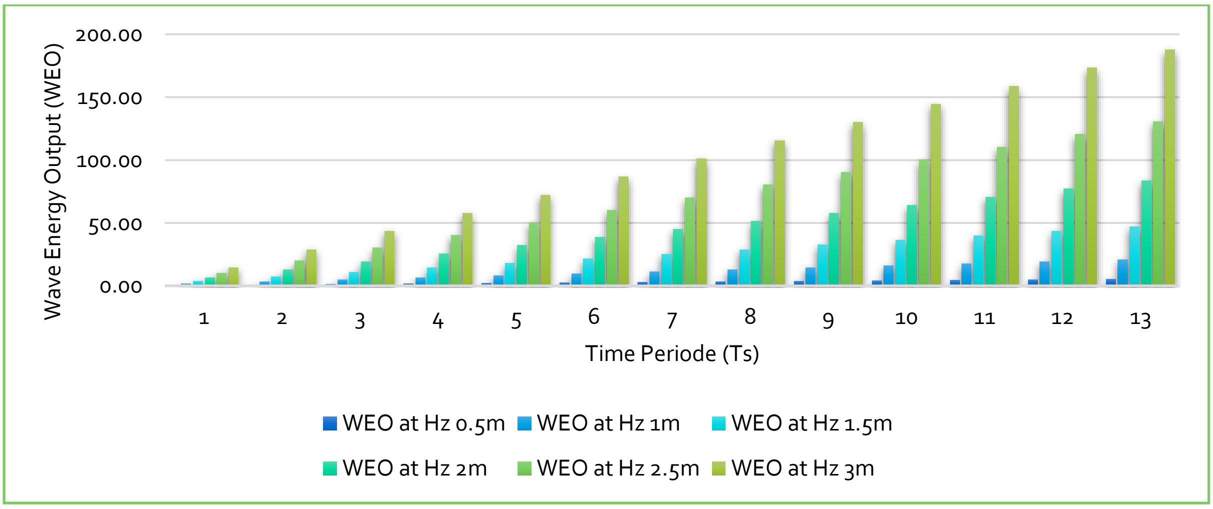

Figure 2- Wave Energy Output at Wave Height between (0.5m to 3m)

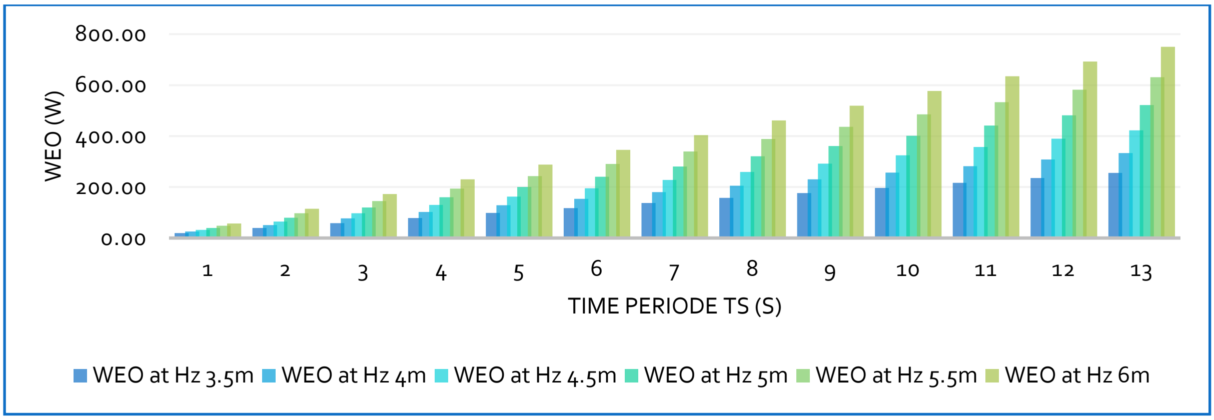

Figure 3- ***Wave Energy Output at Wave Height between*** **(3.5m to 6m)**

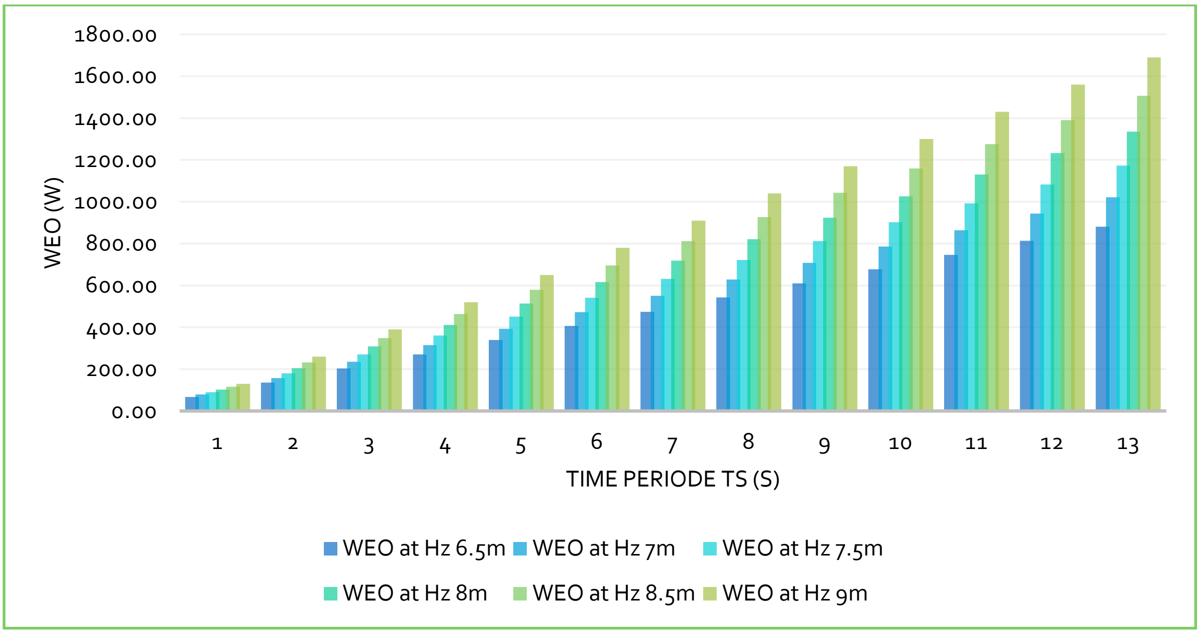

Figure 4-*Wave Energy Output at Wave Height between 6.5m to 9m*

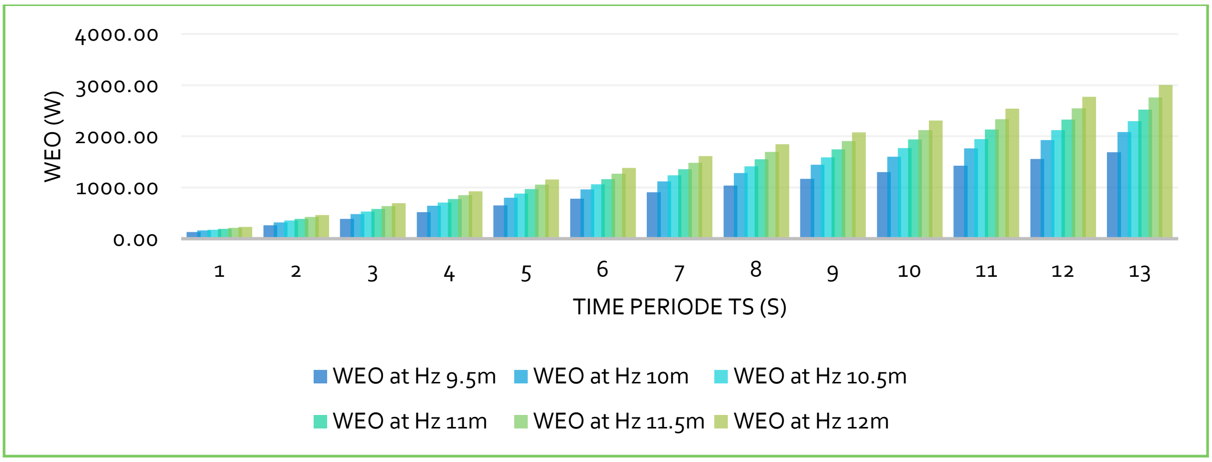

Figure 5-*Wave Energy Output at Wave Height between* (*9.5m to 12m*)

Analysis & Discussion

The following graphs would show the annual power rate that can be captured using sea snake wave generator at different wave heights and frequencies, therefore it can be said that this data can provide an initial picture that could analyze the amount of power could be converted at any given location in relation to its wave heights and frequency, therefore, it can be decided whether the location is going to be a good candidate. Figure 6 was derived from the equations (Retzler (2006) and Rusu and Guedes (2013)).

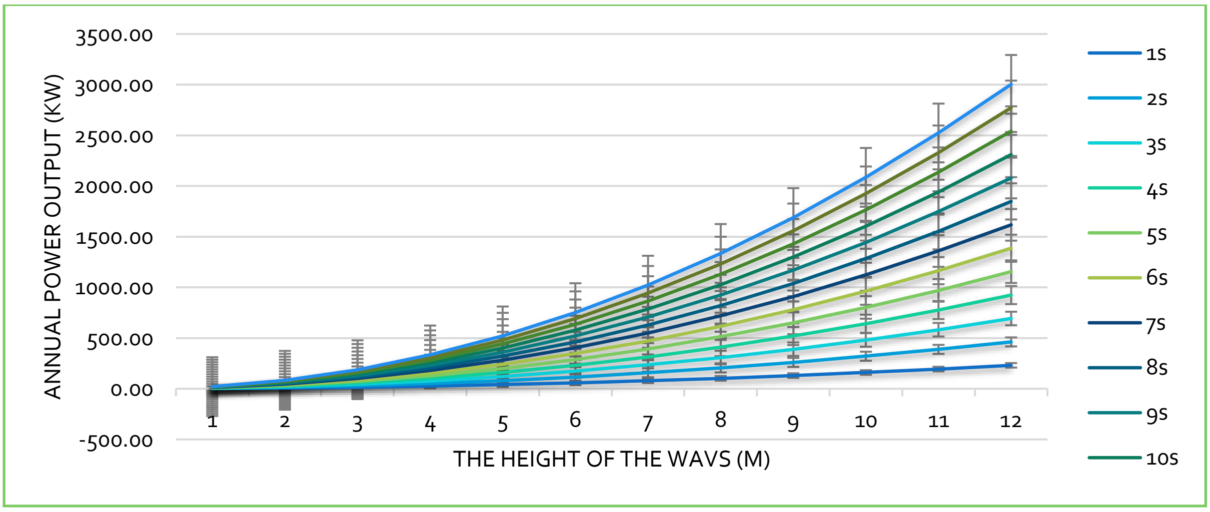

Figure 6- The annual power output in relation to the wave height and frequency

From figure 6 it can be seen that at location such as Europe for example, where the wave's height and period is 8m and 9s respectively if plot the information given in the graph above can find that our SSWG can collect 1.0MW. Another example, in China the average wave height and period are 5.5m and 4s respectively 250kW.

Conclusion

This paper includes an introduction about the basic mechanism of wave power converter and explains simple concepts of the energy conservation. It has also defined the wave energy converter system hardware parts. Explained the working principles of the SSWG and obtained the mechanism of collecting the power, from the point where the wave is propagating the energy. Furthermore explanation has been provided on how power matrix simulation works and simulates the power output of SSWG. Finally a graphical solution of the output power has been given for the Sea Snake Wave Generator at any given location depending on the wave height and frequency.

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