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EVALUATION OF TECHNOLOGIES FOR HARVESTING WAVE ENERGY IN MOZAMBIQUE

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ABSTRACT: *This paper describes wave energy technologies for the solution of long term Mozambique`s energy problem with better reliability. A short overview about wave energy devices is explained with a basic energy analysis. This report also includes some evaluations and discussions of wave energy systems in the following pages. This report focuses on some important factors such as location, wave energy density, power absorption, efficiency and maintenance to determine the most convenient wave energy device to generate energy for Mozambique in Africa. The general purpose of the article is to understand how efficiently wave energy systems generates energy, and solve the Mozambique`s increasing energy demand in our century.*

Keywords: *wave energy technologies, Oscillating water column, Energy planning, Mozambique`s energy demand, energy production from wave energy devices, wave energy parameters*

INTRODUCTION

Wave energy is a relatively new trend for supplying energy demand from the ocean. The improvement of the technology leads to obtain more information and better understanding of the characteristic of wave structure. Basically, there are two main factors which cause waves from the ocean that are solar effect and the wind effect. Because of the steadiness of the wind and availability of solar effect, there is an enormous probability of generating energy from the ocean all parts of the world. To capture considerable amount of energy by applying ocean requires having comprehensive infrastructure and doing scalable test at sea to determine or design the most effective devices for related area. Furthermore, due to the development in wave energy converter, it is achieved to make connection between operating devices associated with ocean surface structure and electrical supply infrastructure which contribute to be allowed by politically and financially to access to sea concession (Falcão, 2010). In this regard, (Nielsen et al. 2009) also have consensus with Falcao that he mentioned there is an increasing demand for installing wave energy devices that rise to an industrial level nowadays such as implementations for Pelamis as a wave energy devices and this is maybe due to the availability of use of prototypes of it at sea test.

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Fig.1. Observation of given area from stellate source: Google map

In this report, it will be chosen a convenient wave energy device for Mozambique, (where is 360, 450 longitude and -180,-90 altitude) which is an African country. Mozambique is almost the poorest country in the world and in this country people generally occupy with farming (UNDP, 2008). Mozambique strongly needs more energy where many parts of the country still have not electricity access (Bensch et al., 2011). This report will focus some important factor to determine the most convenient device that:

- → Overview of devices
- → Location (population density nearby, transmission losses etc.)
- → Wave energy density
- → Power absorption of the chosen device, i.e. use the energy data you calculated earlier to relate your choice of device to the sea area.
- → Efficiency
- → Maintenance

1. Environmental conditions and loadings

Better analysis and descriptions are required to implement this kind of devices into real environment in this regard decomposition of the sea state and the useful measurement from the satellites can be considered a useful sources to extend knowledge of the wave sources from several located points to geographical areas (Falnes, 2007). To achieve this aim some technological devices are used such as high frequency radar which assesses the wave fields, acoustic Doppler Current Profilers (ADCP) which measures the current profiles at sea(Nielsen et al., 2009).

1.1. Mooring analysis

Almost all wave energy devices require a reliable mooring structure.

- maintain the devices position
- comply with acceptable tension induced by the tidal level current wind and waves
- ensure efficiently long service
- easy installation and maintenance
- decommissioning for single and multiple devices

2. Methodology

It is needed to calculate the probability (table 1.) from the given data for the given location by using “Bivariate Histograms” which shows the occurrence depending on the maximum wave high(Hs) and the period (Tm). It has a significant importance in theoretical simulation of the wave energy devices to observe the most available time with high wave level for generating more energy.

Table 1- Probability of the given area

Tm \ Hs	0. - 1.	1. - 2.	2. - 3.	3. - 4.	4. - 5.	sum
0.- 3	0	0	0	0	0	0
3. - 4.	0.0095	0.0033	0	0	0	0.0128
4. - 5.	0.0585	0.1068	0.0005	0	0	0.1659
5. - 6.	0.1163	0.1513	0.0222	0	0	0.2898
6. - 7.	0.1257	0.1502	0.0121	0.0017	0	0.2897
7. - 8.	0.055	0.0951	0.0041	0.0004	0	0.1546
8. - 9.	0.0153	0.0412	0.0017	0	0	0.0582
9. - 10.	0.0032	0.0165	0.0009	0	0	0.0206
10. - 11.	0.0004	0.0056	0.0004	0	0	0.0064
11. - 12.	0	0.0014	0.0003	0	0	0.0017
12. - 13.	0	0.0003	0.0001	0	0	0.0003
13. - 33.	0	0	0	0	0	0.0001
sum	0.384	0.5716	0.0422	0.0021	0	1

Additionally, incident power (kW/m) for given location also has been calculated for each cell and the total available power calculated by applying equation-1 (table 2.).

Table 2- Incident power (kW/m) for given location

Tm \ Hs	0.5	1.5	2.5	3.5	4.5	sum
2.5	0	0	0	0	0	0
3.5	0.003491	0.01091475	0	0	0	0
4.5	0.027641	0.454167	0.00590625	0	0	0.487715
5.5	0.067163	0.78638175	0.3205125	0	0	1.174058
6.5	0.08579	0.9226035	0.20645625	0.05685225	0	1.271702
7.5	0.043313	0.67402125	0.08071875	0.015435	0	0.813488
8.5	0.013655	0.330939	0.03793125	0	0	0.382526
9.5	0.003192	0.14812875	0.02244375	0	0	0.173765
10.5	0.000441	0.055566	0.011025	0	0	0.067032
11.5	0	0.0152145	0.00905625	0	0	0.024271
12.5	0	0.00354375	0.00328125	0	0	0.006825
13.5	0	0	0	0	0	0
sum	0.58464	7.832349	1.6062375	0.15666525	0	10.17989

$P = 0.42 H_s^2 T_m$ Where, Hs: max wave length, Tm: mean wave period (Hagerman and Bedard, 2003) (1).

It clears from the table 2 that the total incident power was around 10 kW/m, which is relatively low. Energy density and the power density are also calculated (where maxes energy density: 165,414.99 and power density: 12,252.96 for this energy density). On the other hand, annual energy output also calculated by using given data for the 20 m with a 20 m width oscillating water column (OWC) wave energy devices (1,783.5 mWh/year)

3. General overview for some important wave energy devices

Even though there is considerable number of wave energy devices, they were classified according to location, operation modes and types in this report.

3.1. Location

3.1.1. Shoreline devices

These kinds of devices are usually constructed on coastline, which have not enough energy capacity, and generate less energy. However, there are some advantages and disadvantages of these kinds of devices(Falcão, 2010).

Advantages

- easy maintenance
- to be close utility network
- low probability of expository to an extreme wave condition

Disadvantages

- low wave power due to the water level
- Geological availability of the shoreline.

(Drew, Plummer, & Sahinkaya, 2009)

3.1.2. Near shore devices

These devices, which are moored on a seabed, are relatively in shallow water compared to offshore devices (Nielsen et al., 2009).

Advantages

- High power
- Connection of electricity at onshore

Disadvantages

- Expensive maintenance
- Cable cost for grid connection

3.1.3. Offshore

These devices are generally located in deep water which is over one-third of the wavelength.

Advantages

- extracting more energy
- high probability of occurrence of wave

Disadvantages

- difficult construction
- difficult maintenance

95% of the energy in wave is located between surface and one-quarter of wavelength below it(Drew et al., 2009).

3.2. Operation modes of devices

The operation mode of the devices is another important factor to make a classification.

3.2.1. Submerged pressure differential

Fixed air-filled chamber and moveable upper cylinders, which are used to create pressure differences, are the two most important parts of these kinds of devices(Drew et al., 2009). These devices generally located near shore (Archimedes wave swing).

Advantages

- slamming safety

Disadvantages

- maintenance

3.2.2. Oscillating water column (OWC)

In this system, air pressure is created by applying to the differentness of sea level in a chamber which opens to the sea below the waterline. A low pressure Wells Turbine is often used in this devices. Limped is the best example for this machine which is constructed in Scotland (Drew et al., 2009).

3.2.3. Oscillating wave surge converter

These devices which consist of a hinged deflector located perpendicular wave direction. These are also near shore devices, where the deflector is above surface and is hinged to sea bed. Additionally, oscillating water column analysis is carried out to understand the efficiency of the turbine by applying to the Pico plant which makes possible to evaluate and improve power(Nielsen et al., 2009). Oyster can be a good example.

3.3. Type

Because of the large number of devices it is considerable them into three predominant types.

3.3.1. Attenuator

In this type of devices, attenuators have parallel position to the wave direction. Pelamis is one of the more important development in this types of devices which developed by ocean power deliver ltd (Pelamis wave power) (Drew et al., 2009).

3.3.2. Point absorber

These are relatively small devices, which do not need to steady wave direction, and they can be floating surface or submerged below the surface. It is applied to create pressure differences to extract energy in these devices. Power buoy is one of the most common example for this devices which designed by Ocean Power Technology(Drew et al., 2009).

3.3.3. Terminator

Apart from the attenuator devices terminator devices are located as perpendicular to the predominant wave direction(Drew et al., 2009). Salter ducks which developed by the University Edinburgh is a well-known example which is shown

RESULTS

Even Mozambique relatively has large land surface (799,380 km^2), there is significantly low density nearby the wave energy installation location due to the low population density (23 people per km^2) of the country (Bensch et al., 2011). It is expressively vital to have available place for the construction of OWC devices. In this area OWC is determined the most effective and suitable wave energy devices because of the high reliability, costly effective and very convenient for low energy potential area.

In terms of technical and theoretical situation, which has a crucial importance for designing wave energy devices, basically the air, which is in the isolated water column, is pressured by the incident waves to flow through turbines that drive the electric generator (Paixão Conde & Gato, 2008).Transmission of the captured energy is another significant factor that the OWC devices provide perfect benefits in terms of transmission of the captured energy since it does not need any cables or another hydraulic equipment to transport energy to onshore.

Maintenance and efficiency are also other important advantages for OWC which Thorpe (1993) mentioned that OWC is the most cost effective wave energy devices with an efficiency of around 60%. In terms of efficiency this devices are considered really preferable because of the harbor walls the efficiency of the device increased significantly (Thorpe, 1993).

DISCUSSION

As it can be clearly seen from the methodology part above, the given location (Mozambique) obviously have average wave energy power potential with power of 10.13 kW/m. in this regard, this area can be considered s grade of 3/5 however it is almost impossible to determine about the level of a region just considering incident power. The calculation method of power has been mentioned in the same part. These are the crucial step to determine the most effective wave energy device in given location. When it is taken into account of the location data and the technological advantages, the OWC is considered the most suitable wave energy devices, with the around 30 kW/m average rated power level, for this location. There are two most important reasons for choosing OWC which are economic situation of the given location and feasibility of the devices in terms of cost and reliability.

Mozambique is an African country and almost the poorest country in the world therefor is can be difficult to find foundation from government and other investors. Due to this reason, economic situation has vital importance to construct a wave energy device that area. In this regard, according to ocean energy council (2012) OWC provides long term reliability and really cost effective method in terms of maintenance and structure such as there is an OWC device in India and it has been demonstrating a perfect performance for 10 years.

CONCLUSION

In this report, it is aimed to calculate the annual power availability at the given site, where is 36^0, 45^0 longitude and -18^0,-9^0 altitude, by applying to given data from wave scatter table for designated sea area. It has been considered to be a significant parameter to choose the most efficient devices for given area. As a result of calculation of power annual energy capacity of the region is also calculated (kWh/year) by multiplying the power with total hours in a year (8760) and all the result will be given in resulting section. By taking into account of these calculations, it is considered to choose the most convenient wave energy devices for proposed area. In this context, OWC has chosen as convenient devices for the area mainly due to the economic situation of the Mozambique and the availability the country in terms of location and population density. Efficiency and the life cycle of the devices were considered another important factor to be chosen.

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