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Design & Analysis of Vertical Movement Ocean Wave Generator

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***Abstract*—The solutions to today's energy challenges need to be explored through alternative, renewable and clean energy sources to enable a diverse national energy resource plan. An extremely abundant and promising source of energy exists in the world's oceans. Ocean energy exists in the forms of wave, tidal, marine currents, thermal (temperature gradient) and salinity. Among these forms, significant opportunities and benefits have been identified in the area of ocean wave energy extraction, i.e., harnessing the motion of the ocean waves, and converting that motion into electrical energy. This paper presents the fundamentals of vertical movement ocean wave energy converter, and also a summary of the wave energy research being conducted at Cox's Bazar, Bangladesh. This paper is intended to serve as an introduction to wave energy converter for scientists and engineers, particularly those with an ocean wave energy background.**

***Keywords*—Vertical Movement Ocean Wave Generator (VMOWG) , Wave conversion, Ocean Wave Height, Ocean Wave period, Cox's bazar.**

I. Introduction

Ocean waves are both clean and renewable sources of energy with a tremendous worldwide potential of generating electricity. An ocean wave is initiated where wind and water interact. It then travels across the sea until it collapses on the shore. This is known as the cycle of the wave. If fully exploited, about 40% of the world's power demand could be supplied by this resource – equivalent to as much as 800 nuclear power plants. In 2001, more than 1000 different methods of utilization of wave energy had been patented by many different wave energy companies, most of which never even made it past the first few stages. Only a few of these projects have been shown to work in reality [1]. Like a developing country Bangladesh, power plants are basically based on coal fired, oil and gas fired, oil and gas fired thermal, gas turbines, gas engines, hydroelectric which are so harmful for environment. But they can't manage to full fill their demands of electricity. Ocean wave energy can be a good solution for this problem. In our project named "Vertical movement ocean wave generator design and analysis", we basically focus on our demands of electricity, generation of electricity, environment safety and most importantly focus on our huge sea area and its proper utilization. Our ocean wave generator converts wave energy to electrical energy. This generator basically works on ocean and also some rivers where we get strong waves

II. Wave Energy

Wave energy or wave power is essentially power drawn from waves. When wind blows across the sea surface, it transfers the energy to the waves. They are powerful source of energy. The energy output is measured by wave speed, wave height, and wavelength and water density. The more strong the waves, the more capable it is to produce power. The captured energy can then be used for electricity generation, powering plants or pumping of water. It is not easy to harness power from wave generator plants and this is the reason that they are very few wave generator plants around the world.

Bangladesh harnessing a huge potential of Ocean wave energy. Bangladesh has a wide coastal area 724 km of coastal line along the Bay of Bengal. There are lots of Available sites in Bangladesh-

- Cox's Bazar
- Saint Martin Island
- Sandwip Island
- Kutubdia Island

TABLE I. SEA AREA OF BANGLADESH [2]

Area	Measurement
Territorial Sea	12 nmi (22.2km; 13.8 mi)
Contiguous Zone	18 nmi (33.3km; 20.7 mi)
Exclusive Economic Zone	200 nmi (370.4km; 230.2 mi)

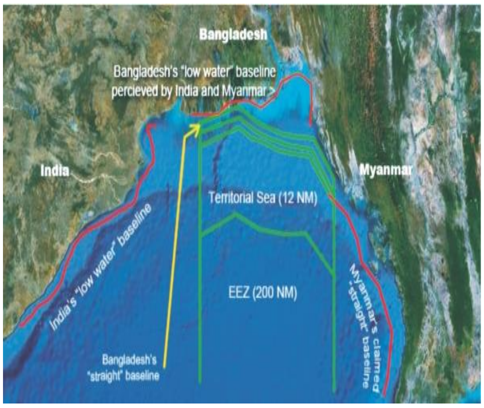

Fig. 1. Available Sea Areas of Bangladesh [2]

III. Wave Energy Converter

A. Pressure Differential Principle

The Archimedes effect converters (ex. Archimedes Wave Swing) are air-filled chambers in the form of point absorbers with movable upper cylinders that are moored to the sea bed. The variations in pressure exerted on the upper cylinder during the crests and troughs move the cylinder down and up, and this mechanical movement is turned into electricity by a linear electric generator. As the water level inside the chamber rises and falls due to the oscillatory movement of waves, the air inside is compressed and pushed out of the chamber or expanded and sucked into the chamber through a turbine [3].

B. Mechanical Flexing

In mechanical flexing two cases work here. One is attenuator and another is point absorber. The wave energy can be harnessed by turning these wave-induced mechanical movements into electricity. In attenuators, hydraulic pumps at the joints between the cylindrical components are designed to resist mechanical flexing [3].

C. Overtopping Principle

The wave energy can also be captured in the form of potential energy. The WECs under this category are designed to capture sea water that enters a tapered channel into a reservoir raised above the sea level. The accumulated sea water in the reservoir is then controllably released back to the ocean through a hydraulic turbine to generate electricity [3].

D. Hydraulic Flapping Principle

When moored terminator structures oriented perpendicular to the wave propagation direction are hit by waves, the wave energy is absorbed upon impact and deflects the structure. As waves come in and out, this deflection generates a flapping motion to the mechanical and bobbling principles; the flapping movement pumps a high-pressure fluid to generate electricity via hydraulic power take off [3].

IV. Vertical Movement Ocean Wave Generator Design

The whole procedure has been divided into two steps- Moveable part and DC generator part .This idea of electricity generation between kinetic energy of ocean wave which helps to create an optimized model for Vertical movement ocean wave generator, which will reduce the dependency on non-renewable energy.

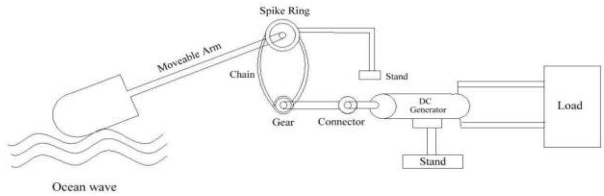

Fig. 2. Design of Vertical Movement Ocean Wave Generator

A. Moveable part

Moveable arm connected with DC generator freely moves up and down with the movement of ocean wave. Moveable part consists of –

- Moveable Arm
- Spur Gear
- Connector (Axle)

Fig. 3. Structure of Vertical Movement Ocean Wave Generator

Fig. 4. Spur Gear

Fig. 5. Connector (Axle)

B. DC Generator

A low rpm DC motor has been used to generate electricity. Here the kinetic energy of the ocean wave is converted by the mechanical process into electrical energy by using DC generator. Connector forces the rotor of DC generator to rotate, so kinetic energy converts into electricity. Amount of the electricity depends on the significant wave height.

Fig. 6. DC Generator

V. DATA ANALYSIS

A. Practical Data Analysis

Basically in this project wave energy is used to generate electricity which is coming from nature. Some value of voltage was measured by using wave energy. A maximum voltage level around 53.7mV on multi-meter was measured when the wave height was approximately 27 inches. Also estimated that annual energy output from each unit is 6.34 KWh. From this implementation it is established that Voltage was depended on wave height which means Voltage is proportional to significant wave height. When wave height is Maximum then voltage rating would be Maximum in this system. Since voltage is not constant so then efficiency is varied time to time.

B. Equations

In ideal cases,

Wave power energy is given by the formula:

$$P = \frac{\rho g^2}{64\pi} H^2 T_e \qquad [4]$$

Wave energy is given by the formula:

$$E = \frac{1}{8} \rho g H^2 \qquad [4]$$

Fig. 7. Measuring Voltage of VMWOG System

TABLE II. VOLTAGE ANALYSIS WITH RESPECT TO TIME

TIME	VOLTAGE
19	12
22	8.6
39	16.5
43	19.3
46	26
67	21.8
69	39.2
78	25.1
83	23.3
93	53.7
97	49
101	32.7
107	15.7

110	14
113	11.2
119	8.2

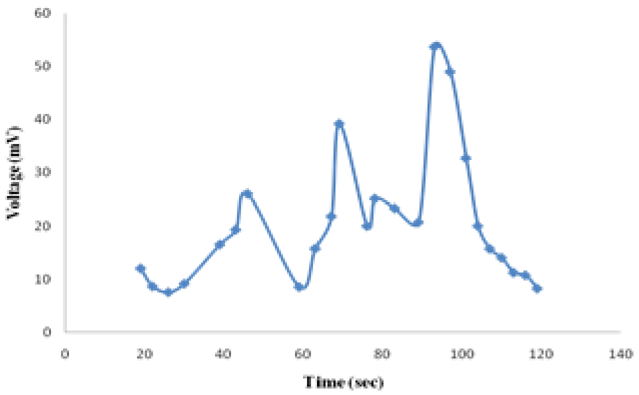

Fig. 8. Time vs. Voltage characteristics

TABLE III. VOLTAGE ANALYSIS WITH RESPECT TO WAVE HEIGHT

WAVE HEIGHT (Inch)	VOLTAGE (mV)
27	53.7
19.5	26
11	8.2
22	39.2
12	12
20	32.7
10	6
5	3
18	22.8
11.75	8.5
17	21
8	9.5
13.5	14
11	12

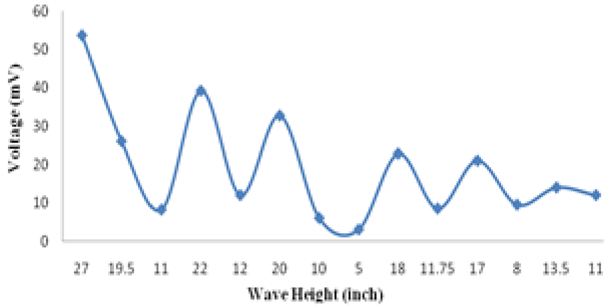

Fig. 9. Wave Heights vs. Voltage characteristics

TABLE IV. POWER ANALYSIS WITH RESPECT TO WAVE HEIGHT

WAVE HEIGHT (m)	MECHANICAL POWER (KW/m)
0.6868	17.088
0.4953	8.913
0.2794	2.836
0.5588	11.346
0.3048	3.376
0.508	9.376
0.254	2.344
0.4572	7.595
0.4318	6.775
0.3429	4.272

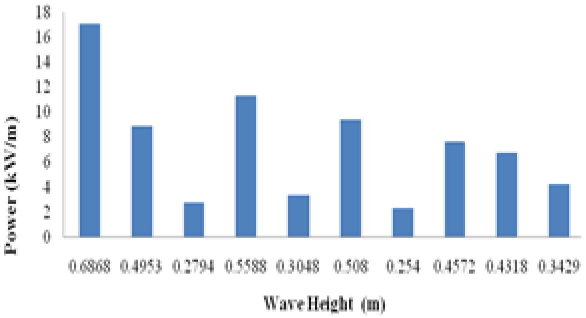

Fig. 10. Wave Heights vs. Mechanical Power characteristics

C. Cost Analysis

The total cost of implementing the project at Cox's Bazar, Bangladesh has been calculated and shown in following:

Initial investment cost for 1 unit VMWOG is 100$
Initial investment cost for 100 units as well as whole wave farm
= 100×100=10000 $.
Operation & maintenance cost per year 100 units
=5×100=500 $.
As the average life time of the VMOWG device is more than 50 years. Let us assume a 50 years estimate of useful life.
So the annual cost of the whole wave farm for this size
= (Annual Cost)/(Expected Lifetime) + Annual Operating & Maintenance Cost
= 10000/50+ 500
= 700 $.
In this site, if 100 units of VMOWG established, so the total cost is reduced by 30%. Now the total cost becomes for this site= (700×0.3)= 210 $.
It has been calculated in data analysis section that annual energy output from each unit is 6.34 KWh. So the annual output from 100 units is = (6.34×100) = 634 KWh.
The cost per KWh = "Annual Cost" /"Annual Energy Output"
= 210/(634×100)
= 0.0033123 $/KWh.

D. Compare

TABLE V. COMPARISON BETWEEN VMOWG SYSTEM & OTHER TRADITIONAL POWER GENERATION SYSTEM IN BANGLADESH

Energy System	Fuel Cost in per KWh ($)	Installation Cost ($)	Operation & Maintenance Cost ($)	Total Cost for Per KWh ($)
Coal	0.0875	0.01875	0.0125	0.11875
Oil	0.2236	0.01875	0.0156	0.25795
Gas	0.0138	0.0125	0.01187	0.03817
Solar PV	0.00	0.9857	0.025	1.0107
Wind Energy	0.00	0.07075	0.025	0.09575
Biomass	0.00625	0.04375	0.00625	0.05625
Wave Energy	0.00	0.01	0.003313	0.013313

VI. FUTURE ANALYSIS

Since there are currently no ocean wave energy plants in Bangladesh, the feasibility of setting up an ocean wave energy plant of high capacity in coastal area or seashore area may be studied. Demand data is not readily available for Bangladesh. The model may be made stronger by using accurate hourly demand data for a specific year. If sufficient data is available different surface may be designed for demand, ocean wave energy for the future. The model may also be enhanced by considering other renewable sources such as solar energy. Future researchers can be enhanced the project by using different types of gear to get better output from the project. They may be created prototype project based on ocean wave power plant to present a optimal view to the society to make an ocean wave power plant & Governments and organizations should be given more financial incentives in this sector.

At this moment, the costs of ocean wave power are generally very high. That power plant cannot be developed without sufficient funding from the governments. On the other hand, renewable energy is the future, and the costs are expected to drop when larger facilities are up and running. Many of the parts that are involved in wave power generation require regular maintenance. The fact that some of these parts are under the water does not make it any easier – or cheaper for that matter. The bottom line is that wave power has an enormous global potential. However, we need more funding and research to polish the technology involved, pushing prices down to a competitive level [6].

VII. CONCLUSION

Power is one of the most important factors of developing socio-economic conditions of a country or community. In most of the islands in Bangladesh, national grid will not come for many years especially in coastal areas. That's why economic and educational growth rate of these islands communities are very poor. This study has shown that the most economically feasible solution for supplying power to the remote Island community of Bangladesh. Though wave power is very much effective for reducing pollution and the cost of per kW wave power is less than any conventional power plant (diesel, coal etc). Thus, wave power can play an important role for the overall socio-economic development of coastal areas communities as well as Bangladesh. [7]

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