Wave Energy in Bangladesh

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Abstract— **For the energy requirements of coastal nations ocean energy can give a significant contribution, especially those with island communities if it converting into useable forms. In the coastal zone of Bangladesh, access of electricity is lower than 3% out of 10 million people and national grid will not come for many years in most of the islands, if at all [1]. Most of the people of remote coastal areas are using kerosene for lighting as well as for cooking along with fire wood. In some of the off-grid locations diesel generators, operated and maintained by private entrepreneurs or cooperatives, are playing he key role for supplying electricity for few hours in the evening. Bangladesh is a country vastly surrounded by water. Bangladesh has a wide coastal area and longest uninterrupted shoreline. It has a 724 km of coastal line along the Bay of Bengal [2]. So Bangladesh harnessing a huge potential of wave energy that may be the vital source of electricity and can face the energy crisis problem of island communities in Bangladesh. In this paper, feasibility study of wave energy based on oscillating water column (OWC) device in three island Sandwip, Kutubdia and Saint Martin of Bangladesh are discussed including the calculations of the number of wave device needed for the available sites and with the analysis of investment, payback period, operation and maintenance cost for those sites. There is also a comparison between the costs of wave energy conversation (WEC) power plant; other renewable energy power plant and conventional power plant are shown.**

Keywords- Wave Energy conversion(WEC), Ocillating Water Colmun(OWC) device, Wave Hieght, Wave Period, Island.

I. INTRODUCTION

Ocean wave arise from the transfer of energy from the sun to wind then water. Solar energy creates wind which then blows over the ocean, converting wind energy to wave energy. Once converted, this wave energy can travel thousands of miles with little energy loss. Energy can be taken from waves almost everywhere but if the waves are too small expenses will be too high. Wave energy is stronger around the poles and around the equator the water contains lesser potential [3]. Although many wave energy conversion techniques have been patented and also new patents are granted each month, there are only nine basic techniques on which these technique are based. The nine basic techniques are heaving and pitching bodies, cavity resonators or oscillating water column, pressure devices, surging wave energy converters particle motion converters, Salter's duck, Cockerell's rafts, Russell's rectifier and wave focusing techniques. Among the various wave energy converters, the OWC is generally considered one of the most promising wave energy conversion devices. The system has been successfully constructed and tested at a number of sites [5-6]. It can be seen that for Bay of Bengal the value is 15 kW per meter of crest width [3]. OWC wave energy converter can run this wave condition easily. Geographically, the islands of Bangladesh are scattered along the Bay of Bengal and the river mouth of the Padma. Islands of Bangladesh divided into three parts are Western Bay of Bengal, Middle Bay of Bengal and Eastern Bay of Bengal [7]. Sandwip island located at Middle Bay of Bengal and its geographic location is $22.490513^0 N 91.421185^0 E$. Kutubdia and Saint Martin both islands located at Eastern Bay of Bengal. Kutubdia geographic location is $21^0.49' N 91^0 51.5' E$ and Saint Martin geographic location is $18^0.04' N 63^0 03' E$. Saint Martin Island has become a popular tourist spot among all the islands and People do not live on this part of the island only for electric power supply, so it is advisable for the tourists to go there early and come back by afternoon. Electrical energy is very important for developing Saint Martin island. If Saint Martin island have electric supply facility 24 hours it become more popular tourist place than other. Among all the islands Sandwip, Kutubdia and Saint Martin are mostly surrounded by Bay of Bengal. It is very difficult and expensive to transmit electrical power from main land to island. It will be better if islands community generate his electrical power from wave than other. This paper present if those islands communities generate his power from ocean wave energy based on OWC device is it feasible or not , cost analysis is also present and finally a comparison among other traditional power generation are present..

II. POWER OUTPUT FROM OWC DEVICE [8]:

OWC device extract power from wave by using the water column rise and fall, which in term compress and depressurized an air column resulting continues power production through a wells turbine. The total energy E in wave is given by:

$$E = E_p + E_K = \frac{\rho g H^2 \lambda b}{8} \text{..........(1)}$$

Where b is the width of the crest which depend on the width of the chamber and we are considering the width of the chamber as 5m which is standard one, g is the acceleration due to gravity (9.8 m/s^2), ρ is the mass density of water

(1000 kg/m^3 for fresh water or 1030 kg/m^3 for salt water). H is the wave height (m). The total energy in deep water of a wave can be described by linear theory and is a equally composed of potential energy E_p and kinetic energy E_K where

$$E_p = E_K = \frac{\rho g H^2 \lambda b}{16} \text{..........(2)}$$

The potential energy is a progressive wave of height H, whereas the kinetic energy is dependent on the motion of the particles. For a variable sea state, the transfer of wave energy from point to point in the direction of wave travel is characterized by the energy flux or more commonly, wave power:

$$P = \frac{\rho g H^2 C_g b}{8} \text{..........(3)}$$

Where C_g is called the group velocity and is represented by:

$$C_g = \frac{C}{2}\{1 + \frac{2kh}{\sinh(2kh)}\} = nC$$

Where C is called the phase velocity. In deep water $C_g = \frac{C}{2}$ and shallow water $C_g = C$.

Now for OWC the output power for deep water is given from equation (3) that:

$$P = \frac{\rho g H^2 C\, b}{16} \text{ [for deep water } C = \frac{gT}{2\pi} \text{]}$$

$$P = \frac{\rho g^2 H^2 T b}{32\pi} \text{..........(4)}$$

T is the period of wave (s). As it is tested that the efficiency of OWC system is 70% [9] so the eq. (4) become

$$P = \frac{\rho g^2 H^2 T b}{32\pi} * 0.7 \text{..........(5)}$$

From above equation it could be clear that square of the wave height is directly proportional to the wave period because other parameter of the equation are constant.

III. DATA ANALYSIS:

Sea waves are a very promising energy carrier among other renewable power source, since they are able to manifest an enormous amount of energy resources in all geographical regions. Energy can be taken from wave almost everywhere but if the waves are too small expenses will be too high. Any site in the world within an average wave power level of over 15KW/m has the potential to generate wave energy at competitive prices [3]. Wave power could be a significant alternative source of energy in Bangladesh with favorable wave conditions, especially during the period beginning from late March to early October. The peak wave height occurs during the months of June and July. Wave height data of 2011 collected from Bangladesh Navy and wave period is predicted from the scatter diagram , hindcast estimation technique are also used in this data analysis [3,10-11]. And also by using eq. (5) the mean output power from an OWC device for this three islands respectively are shown in this part.

A. Saint Martin Island:

Figure.1 shows that the average wave height and period data at Saint Martin island for a year. At this site, the maximum average wave height have been measured on the month of July which is 6.965m and the corresponding wave period is 4.485s.On other hand the minimum average wave height have been measured on the month of February which is 6.31m and the corresponding wave period is 3.235s. Mean output power for this site shown in Figure.2. Maximum mean power output from this site is 213.7KW/m and average mean power output from this site is 167.9872KW/m which is assumed to be per KWh of the generator. So annual output from each OWC device for this site is (167.9872KW*8760) =1.47GWh.

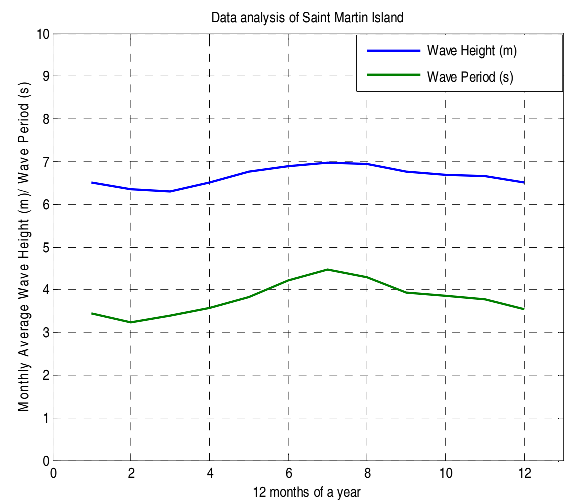

Figure 1: Wave Height/ Wave period data of a year for Saint Martin Island.

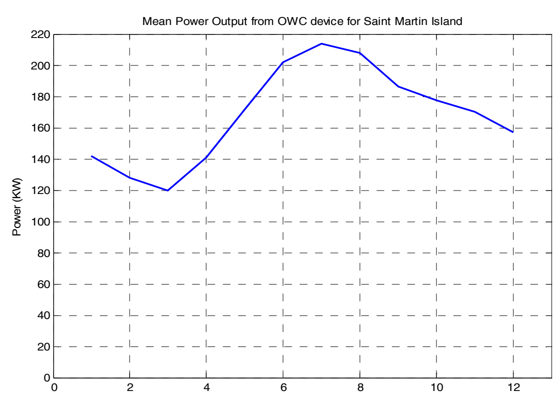

Figure 2: Mean power output from an OWC device of a year for Saint Martin Island.

B. Kutubdia Island:

Figure.3 shows that the average wave height and period data at Kutubdia island for a year. At this site, the maximum average wave height have been measured on the month of June and July which are 7.16m and the corresponding wave period are 4.61s and 4.75s respectively. On other hand the minimum average wave height have been measured on the month of February which is 6.55m and the corresponding wave period is 3.16s. Mean output power for this site shown in Figure.4. Maximum mean power output from this site is 258.42KW/m and average mean power output from this site is 198.065KW/m which is assumed to be per KWh of the generator. So annual output from each OWC device for this site is (198.065KW*8760) =1.73GWh.

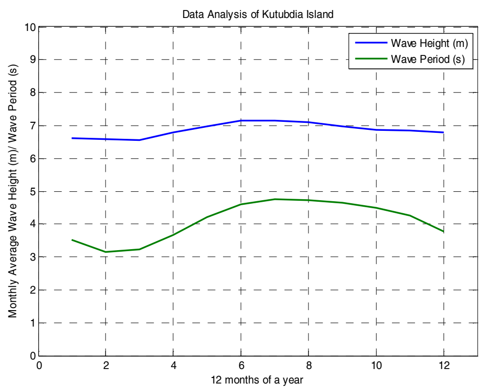

Figure 3: Wave Height/ Wave period data of a year for Kutubdia Island.

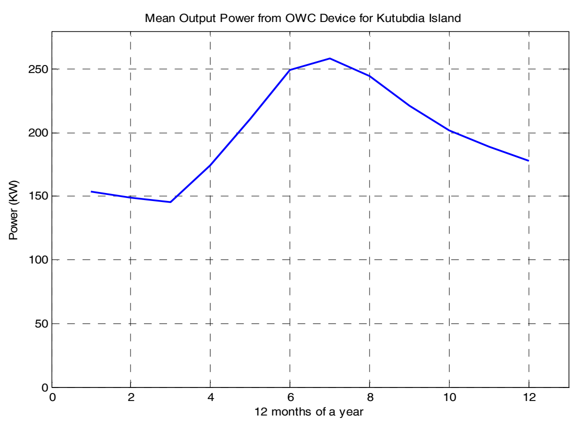

Figure 4: Mean power output from an OWC device of a year for Kutubdia Island.

C. Sandwip Island:

Figure.5 shows that the average wave height and period data at Sandwip island for a year. At this site, the maximum average wave height have been measured on the month of June and July which are 8.4m and the corresponding wave period are 4.6s and 4.78s respectively. On other hand, the minimum average wave heights have been measured on the month of February that is 7.58m and the corresponding wave period is 3.55s. Mean output power for this site shown in Figure.5. Maximum mean power output from this site is 502.565KW/m and average mean power output from this site is 397.9367KW/m which is assumed to be per KWh of the generator. So annual output from each OWC device for this site is (397.9367KW*8760) =3.48GWh.

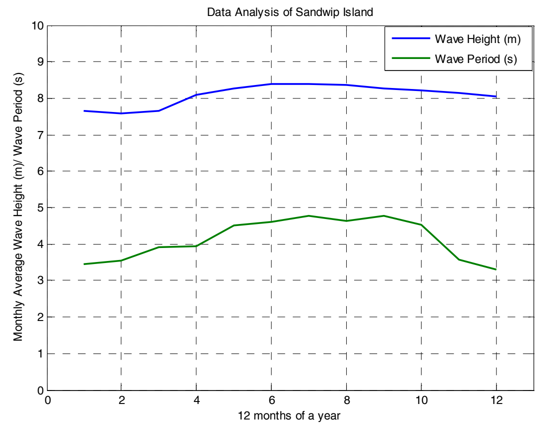

Figure 5: Wave Height/ Wave period data of a year for Sandwip Island.

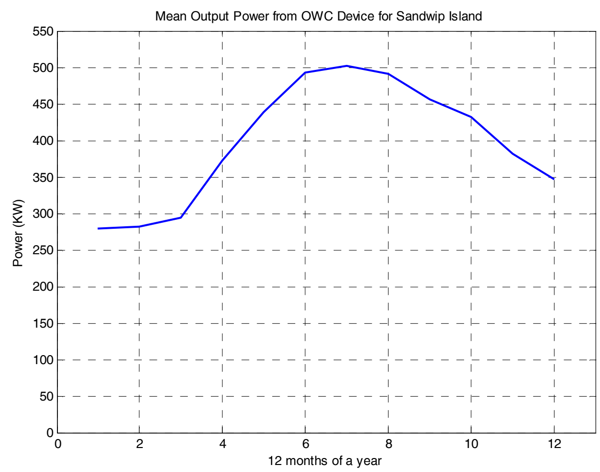

Figure 6: Mean power output from an OWC device of a year for Sandwip Island.

From above data analysis, it could be clear that power output from Sandwip Island is very higher than other two islands and average maximum power output of a year from this site almost twice than other two sites. It does not mean that other two sites are not feasible, both are feasible but they produced less power than Sandwip Island. Because any site in the world within an average wave power level of over 15KW/m has the potential to generate wave energy at competitive prices (without hindcast estimation technique analysis).

IV. Cost Analysis

Cost estimates of energy produced by wave energy conversation are dependent on many physical and economic factors. Theses cost will vary region by region and wave energy topology. The following is an enumeration of a few cost factors associated with a wave farm [12-13]:

a) Sitting and Permitting.
b) Components: initial and ongoing costs.
c) Installation.
d) Taxes.
e) Operation and Maintenance.
f) Project lifetime.
g) Average annual energy production.

The first four factors are included into the initial investment cost. So there are two main component: initial investment cost (IC) and operation & maintenance cost (OMC) which are needed for cost calculation.

It could be clear from data analysis section that 250KW each unit is suitable for both Saint Martin and Kutubdia islands and 500KW is suitable for Sandwip island. The initial invest cost for a grid connected residential system of each unit of 250KW is 1.3 million dollar and operation & maintenance cost is about 3000$/year. In addition, the initial invest cost for a grid connected residential system of each unit of 500KW is 2.4 million dollar and operation & maintenance cost is about 3366$/year. The total cost will be reducing by 30% if we installed 100 or more than 100 units [9, 12-13]. It mentions earlier that the internal width of chamber is 5m, so the total width of each unit is approximately about 6m. If 100 units of OWC established at Saint Martin island, then the total area needed about (6m*100) =600m. So only using one square kilometer a cost effective wave farm can be develop. The total cost of the Saint Martin Island has been calculated and shown in following:

Initial investment cost for 100 units as well as whole wave farm= 1.3*100=130 million dollar.

Operation & maintenance cost per year 100 units=3000*100=300000$

As the average life time of an OWC device is more than 20 years. Let us assume a 20 years estimate of useful life.

So the annual cost of the whole wave farm for this site =

$$(\frac{\text{Annual cost}}{\text{Expected lifetime}} + \text{Annual operating \& maintenance cost})$$

$$= (\frac{130,000,000}{20} + 3,00,000)$$
$$= 68,00,000\$$$

In this site, if 100 units of OWC established, so the total cost is reduced by 30%. Now the total cost becomes for this site (68, 00,000*0.3) =2,040,000$.

It has been calculated in data analysis section that annual energy output from each unit is 1.47GWh. So the annual output from 100 units is (100*1.47)=147GWh.

$$\text{The cost per KWh} = \frac{\text{Annual cost}}{\text{Annual energy output}}$$

$$\therefore \text{The cost per KWh} = \frac{2040000}{147*1000*1000} = 0.01388 USD/KWh$$

Similarly calculation procedure used for other two sites. So total cost per KWh for Kutubdia Island is 0.01179USD/KWh and Sandwip island 0.01064USD/KWh. It could clear that energy production cost in Sandwip Island per KWh is lower than other two sites.

V. Comparison:

There is lot of possibility to produce electricity from these three islands using OWC system and it will seems the cheapest source of grid quality renewable energy in our country. Table 1 shows the comparison between wind power system and other traditional power generation system and this table it has been seen that the cost per KWh of WEC are less than the other traditional power system.

TABLE I. Cost comparison between the WECs system and other traditional power generation system.

Energy System	Fuel Cost in the each KWh (taka)	IC & OMC (taka)	Total cost for each KWh (taka)
Coal	7.00	2.50	8.50
Oil	17.89	2.75	20.64
Gas	1.11	1.95	3.06
Solar PV	0.00	80.86	80.68
Wind Energy	0.00	7.66	7.66
Biogas	0.50	3.50	4.00 (according to IDCOL analysis)
Wave Energy	0.00	1.179	1.79 (according to our analysis)

VI. 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 Saint Martin Island. 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 islands communities as well as Bangladesh.

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