Paper 48

Performance measurement of a newly proposed ocean wave energy conversion system

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Abstract

This paper presents feasibility study of ocean wave energy conversion of the Bay of Bengal and a newly proposed ocean wave energy conversion system. The feasibility study fixates on significant wave height of ocean wave and quantifying the energy in the wave. This experimental investigation is focused on the velocity of wave which will be able to capture energy from wave as a thrust force which will be used to the conversion of electrical energy. The performance of fabricated setup are investigated and found it works successfully for the energy conversion. The amount of force provided in the system is determined by a back calculation manner and this considered as an equivalent force delivered through the ocean wave. A correlation makes with the force provided in fabricated setup and force provided by the ocean wave; hence produce a proportional relationship between the forces. The detail performance parameters are also presented.

INTRODUCTION

The renewable energy is the foremost interest of scientific community in present situation. Ocean is one of the largest reservoir of wave energy. Bangladesh has a few of large costal area which is very suitable to implement this project. The theoretical ocean wave energy is estimated 8000-80000 TWh/year [1]. Considering the recoverable energy and if the efficient conversion systems are utilized, the annual quantity can even reach 2000TWh [2]. Variability in several time-scales is the main disadvantage of the wave energy which includes wave to wave, with sea state, and month to month variability [3]. It is researched [4] that the wave energy contains 15-20 times energy than wind or solar energy per square meter. There are hundreds of Ocean wave energy conversion system have been developed and most of these are based on oscillating wave column [5]. Drew et al. [6] published the most recent review on the wave energy conversion technologies. This research provides an overview of the energy conversion of ocean waves generated in the Bay of Bengal with the wave energy extraction process. So, the specific objective of this project is to develop a model/prototype experimentally to produce electrical energy by using ocean (costal) wave. Then, the areas of further research are identified. Waves are described by height and period, with height measured as the difference between trough and crest, and period as the time between successive crests. The amount of power provided by the wave is determined with the help of some formula as well as determination of force delivered by the wave. The force, frequency, time period and other parameters are considered for the experimental setup hence identifies the performance of the setup. The above project can prove itself to be a very competent one for today's energy crisis and our fight against environment pollution. Spatially in a country like ours this project can save a lot of money and time by saving energy and providing a high production rate. This can always be more suitable for our less skilled man power as this project is to develop a robust system. This research seeks to predict the investigation of results obtained in the ocean wave energy conversion for the generation of electricity for Bangladesh that has not yet been reported.

FEASIBILITY STUDY AND WAVE POWER CALCULATION

The graphs shown below are the significant wave height (m) of Bay of Bengal at different years. The data of wave height is a average value for every day. The data is collected at Longitude 92 East and Latitude at 21 North. The data collection time starts from 717 points which is gradually increases by adding one minute after every point [7].

Fig. 1 and Fig. 2 provides information about the significant wave height of the Bay of Bengal over the year 2010- 2013. There are two basic general trends: downward and upward. As regards the first three month that means January to March the wave heights fluctuated within 0.4 Meter to 1.2 Meter, and the trend was upward. By the way, it is seen that the wave heights fluctuated within 0.8 Meter to 2.8 Meter during the month of April to June but the trend was downward. From July to September the significant wave heights fluctuated abruptly i.e. 0.9 Meter to 3 Meter, but the trend was downward. The last three month of the year 2010, 2011, 2012 and 2013 the wave heights are sudden rose and fell at August and finally fluctuated wildly, but the trend was upward. It is noticeable that the significant wave heights are higher at the month of July.

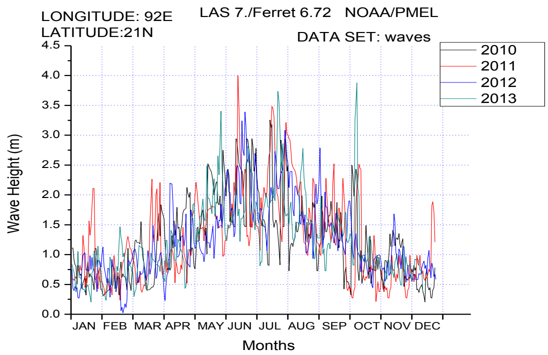

Fig. 1. Combined significant wave height merged (m) in the year 2010- 2013

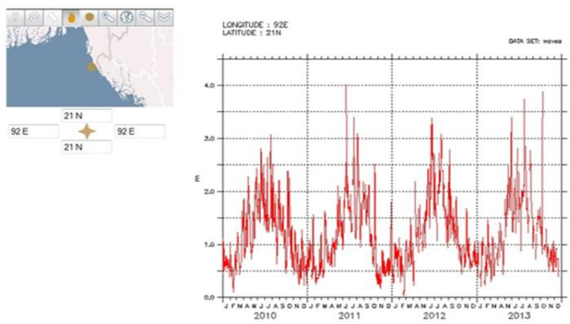

Fig. 2. Significant wave height merged (m)

A. Wave front power

A wave resource is typically described in terms of power of wave front per meter. This can be calculated by multiplying the energy density by the wave celerity (wave front velocity).

$$\text{Where } C = \frac{gT}{8\pi} \quad (1)$$

$$P_{wf} = C \times E_d \quad (2)$$

Equation (2) can be written as,

$$P_{wf} = \frac{gT}{8\pi} \times \frac{\rho_w g H^2}{8} = \frac{\rho_w g^2}{64\pi} H_m^2 T \qquad (3)$$

Here the water depth is larger than half the wave length.

B. Statistics for wave power

A wave resource is typically described in terms of power per meter of wave front (or wave crest). This can be calculated by multiplying the energy density by the wave celerity (wave front velocity). This graph constructed by average wave energy density per meter of wave front. Average wave power density can be calculated as

For January

$$H_{mj} = \sum_{i=0}^{n} H_{mi} \times T_i \left[i = 1, 2, 3, 4......, 31 \right] \qquad (4)$$

$$P_{aj} = \frac{H_{mj}}{n} \left[n = 31 \right] \qquad (5)$$

For February

$$H_{mf} = \sum_{i=0}^{n} H_{mi} \times T_i \left[i = 1, 2, 3, 4......, 28 \right] \qquad (6)$$

$$P_{af} = \frac{H_{mf}}{n} \left[n = 28 \right] \qquad (7)$$

And so on for the other months.

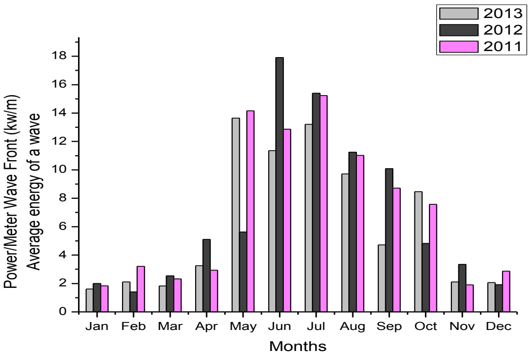

Fig. 3. A comparison of wave power at different months among the year of 2011- 2013.

In Fig. 3 comparative information about the average energy of wave of the Bay of Bengal over the year 2011- 2013 are provided. During the first four months means January to April there is no considerable change of wave energy. From May to August significant change of wave energy is observed, whereas at the month of July of these years showing good average wave energy. The wave energy of September and October of presented years is too much better than November and December. It is also seen that the wave energy level are almost same for every year.

EXPERIMENTAL INVESTIGATION

An experimental setup for ocean wave energy conversion system is shown in Fig. 4. Each component are indicated in the schematic diagram i.e. Wave Collector, Rail with Bearing, Rack and Pinion, Pinion with Shaft and Pillow Block, Ratchet mechanism, Chain, Flywheel, Generator, Generator output measuring circuit. The collector and Rack gear are fixed that can reciprocate to and fro motion. The other parts remain stationary but they can rotate about their axes. At what time equivalent force of an ocean wave is applied to the collector which moves to back results the pinions will start to rotate due to contact of rack and pinion with each other. It is also seen that pinions and a sprocket is attached together in a shaft so sprocket also rotates.

The sprocket is connected with a ratchet mechanism by a chain that's why the power is transmitted in one direction and other is free. The ratchet mechanism and Flywheel are attached in a shaft where the shaft is supported by two pillow blocks. The flywheel starts its rotation with the backward movement of the collector. The flywheel keeps its rotation due to ratchet mechanism if the collector stops its movement. While the force is disappeared in the collector it will reach to its initial position due to spring action at this moment the sprocket and chain will rotates reverse direction but the flywheel rotates its initial direction due to ratchet mechanism. This process will be repeated continuously at varying force and time period. The flywheel stores energy as a rotational energy. Tachometer is used to record the RPM of the flywheel. A pinion is attached with the flywheel that also coupled with the generator results the generator also rotates and generates electrical energy. An external circuit with voltmeter, ammeter and load resistance is connected to measure the efficiency of the system.

Fig. 4. Experimental Setup

RESULTS AND DISCUSSION

A. Wave force

Neglecting friction, a free travelling ocean wave has a constant total power. Averaged over a period or a wavelength, the total power is equally divided between, Potential energy associated with the displacement of water from its equilibrium position, and Kinetic energy associated with particle motion[8].

Wave Velocity $C = \sqrt{\frac{gL}{2\pi} \tanh \frac{2\pi h}{L}}$ (8)

[For shallow water (d=$L/20$ or less); $C = \frac{ghT}{L}$]

Force provided per meter of wave front = F_w

$$F_w = \frac{\text{Power per metre of wave front}}{\text{Celerity or wave front velocity}}$$

$$F_w = \frac{\frac{\rho_w g^2}{64\pi} H_m^2 T}{\sqrt{\frac{gL}{2\pi} \tanh \frac{2\pi h}{L}}} \qquad (9)$$

Where,

L = Wave length (m)

H = Depth below seawater level

ρ_w = Seawater density [1024kg/m^3]

g = Gravitational constant [9.81m/s^2]

H_m= Height of wave (m) [significant wave height]

T = Time period of wave (s)

C = Celerity (m/s) [wave front velocity]

B. Force applied to the wave collector

N_{Ai} = Initial Speed of the flywheel.

N_{Af} = Final Speed of the flywheel.

m_A = Mass of the flywheel.

r_A = Radius of the flywheel.

I_A =Moment of inertia of flywheel.

α_A =Angular acceleration of flywheel.

ω_i = Initial Angular velocity of flywheel

ω_f = Final Angular velocity of flywheel

T_A = Torque required to accelerate the flywheel
$F_{flywheel}$ =Force required to accelerate the flywheel

$$I_A = m_A r_A^2 \qquad (10)$$

$$T_A = I_A \alpha_A \qquad (11)$$

$$\omega_f = \omega_i + \alpha_A t \qquad (12)$$

$$T_A = \left(m_A r_A^2\right) \left(\frac{2\pi N_f}{t60}\right) \qquad (13)$$

$$F_{flywheel} = m_A r_A \frac{2\pi N_f}{t60} \qquad (14)$$

Force provided in the wave collector = Spring Force + Force Required to Accelerate the Flywheel [Neglecting Friction Loss]

$$= F_s + F_{flywheel}$$

Table 1: Correlation of Force Applied to the collector and force provided by the ocean wave per meter of wave front (Based on data obtained 2nd July, 2012)

Correlation (Based on Experimental Setup)	
Input Force applied (N)	Output Power (W)
72.08	5
10010.53	693.25

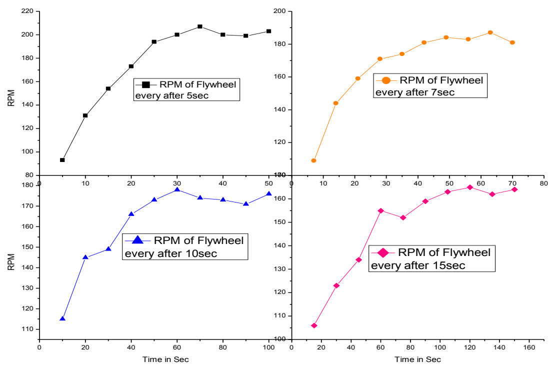

Fig. 5. Merged experimentally obtained rpm w.r.t. time of flywheel

Fig. 5 shows the merged experimental graph of RPM of Flywheel. The data are taken for ten forces that applied in the collector. Force applied to the collector is a constant time period. The time period considered as 5second, 7 second, 10 second and 15 second. This time period considered according to the frequency of ocean wave appeared. This graph also shows the trend of the rpm fluctuation during the force applied. It is observed that the rpm increases rapidly within 5 to 6 force applied than it tends to shows a linear characteristics and it remain constant.

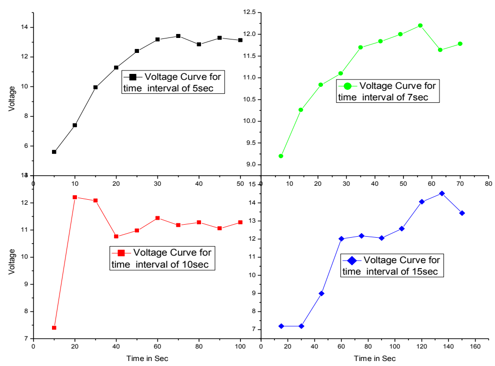

Fig. 6. Merged experimentally obtained voltage w.r.t. time of generator

Merged experimental graph of Voltage obtained from Generator is shown in Fig. 6. The data are taken for ten forces that applied in the collector. Force applied to the collector is a constant time period. The time period considered as 5second, 7 second, 10 second and 15 second. This time period considered according to the frequency of ocean wave appeared. This graph also shows the trend of the rpm fluctuation during the force applied. It is observed that the voltage increases rapidly within 5 to 6 force applied than it tends to shows a linear characteristics and it remain constant. It is also shows that for 5 second time period there needs more thrust force for maximum voltage and the voltage reached more or less than 12.5 volt. This characteristic also shows in 7second time period but the maximum voltage varied slightly within 11.5 volt. The maximum voltages obtain rapidly for higher time period i.e. 10second but the voltage is low that is varied slightly within 11 volt. For time period 15 second shows a different trend that is shows a higher voltage.

CONCLUSION

Ocean wave is one of the largest sources of renewable energy. There is limited resource of ocean wave power in the Bay of Bengal at Cox's bazar, Chittagong. The energy is wave dominated, which can be utilized by a recommended technology with a commercial consideration. In the feasibility study it can be concluded that, it is possible to generate Power with full pace from April to October and considerable amount can be generated at the rest of the months. Moreover, a new experimental design methodology of ocean wave energy conversion system is described in this research. An option has been adopted for hybridization from various renewable sources of that device which can reduces the cost of device as well as power production and increase the power generation as energy conservation and efficiency. The proposed experimental method could be applicable to the conversion of ocean wave all over the world. In this circumstance the research to find out the renewable energy source of Bangladesh is important to mitigate the increasing power demand and a contribution to reduce global warming.

ACKNOWLEDGMENTS

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