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WAVE ENERGY CONVERTER USING BOTH HORIZONTAL AND VERTICAL MOTION

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Abstract- *Ocean wave energy plays a significant role in the growing demand of electric power. Economic, environmental, and technical advantages of wave energy set it apart from other renewable energy resources. The aim of the project is to generate electricity from waves. In order to generate electricity, the wave energy converter (WEC) captures the energy contained in the ocean waves. The power generation relies on the wave intensity. Traditionally, only the vertical movement of the float is transformed into electricity in wave energy converters. But this technique will convert both the vertical and horizontal movements of the float into electricity. The mechanism will be used here is the rack and pinion mechanism. The setup consists of frame, float, rack and pinion, DC generator and a bridge rectifier circuit. The float will be fixed with the rack and pinion setup which in turn will be coupled with the gear assembly and it will be coupled with the generator. The gear assembly will be used to increase the input speed of the generator shaft. The rectifier circuit will be used to change the polarity of the current produced. In this project both the vertical and horizontal motions of the float is converted into electricity.*

Keywords: Wave, Float, Wave Energy Converter (WEC), Rack and Pinion, Wave Height

1. INTRODUCTION

Renewable energy is the energy generated from natural resources which are replenished such as wind, solar, biomass, and tidal power. Approximately 71 percent of the surface of the Earth is covered with water, and the oceans retain about 96.5 percent of all Earth's water [1]. These wave energy of the ocean water will be transformed into electricity. It has many benefits over other renewable sources of energy. For example, the most obvious advantage of wave energy over solar energy is that it is available at night, not just in the daytime.

The waves are generated by the energy passing through the water, which causes them to move in a circular motion. Waves transmit energy, not water, through the sea and have the potential to travel across a whole ocean basin if they are not obstructed. Waves are most often wind-driven. The friction between wind and surface water is causing waves or surface waves. As the wind blows across the surface of the sea, river or lake, a continuous disruption produces a crest of waves. These types of waves are found throughout the open ocean and along the coast.

Bangladesh is a developing country. Power plants are basically based on coal fired, oil and gas fired, thermal oil and gas fired, gas turbines, gas engines, hydro-electrics that are so environmentally harmful. But they can't fully meet their electricity demands. Energy from ocean waves can solve this issue well. Bangladesh has the world's longest sea beach Cox's Bazar with 2 to 8m tidal head/height rise and fall [2]. Therefore, the potential for tidal power in the country is significant. However, no study has yet been carried out where coastal engineering infrastructure (such as Bangladesh Coastal Island) already exists. So our government should pay attention as quickly as possible to the wave power generation sector. The main objectives of this study is to generate power from the wave energy converter using both horizontal and vertical motion.

2. PROSPECTS OF WAVE POWER IN BANGLADESH

Bangladesh is a developing country in the world. It is likely to make progress towards growing energy demand. Bangladesh is now facing an energy crisis. In Bangladesh, around 70% of individuals have no access to energy and most of them live in the town. About 40 per cent of them live below the poverty line [3]. On the other side, climate change poses additional threats to growth. In order to tackle these circumstances, renewable energy technology is one of the potential sources to satisfy its immense energy demand and can lead to sustainable development as a nation has a large supply of renewable energy sources.

Renewable energy is accessible in our country such as solar, wind, hydro power generation, but wave power generation is not reached at this level. In the field of tidal power generation, Bangladesh has excellent potential.

Because lately, from two neighboring nations, India and Myanmar, Bangladesh has acquired big ocean region. For Bangladesh it's a great victory. Bangladesh was assured of rights over 118,813 square kilometers or territorial sea from this ocean win. Bangladesh now has an exclusive economic zone of 200 nautical miles and access to the open sea, preventing it from becoming a 'sea-locked nation' [2].

There are so many spots in Bangladesh to build wave power plants. There are so many spots to build a plant after ocean victory, but the primary issue is to pick a ideal place for a power plant to meet all possible requirements and benefits such as the presence of high tide waves, appropriate for embankment, significant stability away from the location, simple conversion systems, large enough to build an power plant. Bangladesh has coastal areas such as Hiron Points, Sundarikota, Mongla, Char Changa, Cox's Bazar, Golachipa, Patuakhali, Sandwip, Barishal and so on. These places, particularly Sandwip, are appropriate for building a big wave power plant as well as generating enough electricity from tidal waves.

3. LITERATURE REVIEW

Since the late 18th century, the history of capturing ocean energy has started. Monsieur Girard was granted the first wave energy conversion patent registered in 1799. The patented device was a vessel with waves driving pumps and other equipment connected to the coast. In the UK alone, 340 patents were submitted from 1855 to 1973. The first and second large-scale tidal power plant in the world, however, was located at the Rance River estuary in St. Malo, France, in 1966. This marine power station still works, generating 240 MWh of electricity every year [2].

The possibility of harvesting wave energy to generate electrical power on the Lebanese coast is explored by Joseph Youssef et al. [4]. As such, a compact device was constructed for wave harvesting. It consists of a float-rack-pinion system which transmits the waves ' vertical heaving motion and turns it into a rotating motion. This in turn is used by an alternator to generate electricity. A prototype was constructed and effectively tested to light up a 3-W lamp in shallow water near the coast. On the Lebanese coast, where the water depth is about 1.0 m, the model was tested. The suggested system's effectiveness is estimated to be about 11%, which is deemed to be quite small.

Asif Iqbal Chowdhury et al. [5] study presents the fundamentals of the vertical ocean wave power converter, as well as a summary of the wave power studies being carried out at Cox's Bazar, Bangladesh. They measure a maximum voltage level on multi-meter around 53.7mV in this experiment when the height of the wave was about 27 inches. Annual energy production from each unit is also estimated to be 6.34 KWh.

A.Anish et al. [6] generates energy from movement of horizontal and vertical waves. The buoy's vertical and horizontal movements are transformed into electricity in this technique. The system used here is the system of the rack and the pinion. The configuration consists of buoy, rack and pinion, gear assembly, DC generator and a rectifier circuit. From this setup it is possible to produce a maximum of 12V. This setup coverts the buoy's vertical and horizontal wave power into electrical energy.

Md. Arefin Kowser et al. [7] manufacture a new wave power generation model and evaluate the efficiency of the newly suggested transformation scheme for ocean wave electricity. For ten forces applied in the collector, the information is drawn. The force applied to the collector is a period of constant time. The period deemed five, seven, ten and fifteen seconds. It shows that more thrust force is needed for maximum voltage for a 5-second time period and the voltage has reached more or less than 12.5 volts. This feature also demonstrates that the peak voltage varied slightly within 11.5 volt in 7 second time span.

4. METHODOLOGY

To design and fabricate the wave power generator the following steps are followed-

1. To study about the different types of wave energy converter and components used.
2. Design a suitable model that will convert ocean wave energy to electricity.
3. Select frame material and manufacture it.
4. Select light and hard material for float, rack and pinion because they are the moving parts in the wave power generator.
5. Select two small size waterproof DC generator and two full wave bridge rectifier.
6. Assemble all the parts according to designed model.
7. Add a load like LED light or multi meter with setup to show output.

4.1 Required Components

To fabricate the wave power generator the following components were used-

1. Frame: Length of the frame is 700 mm, width 350 mm and height 800 mm.
2. DC Generator: DC generator voltage 6V which empty-load current under 6V is about 430mA and locked-rotor current is about 2.64A.
3. Float/Buoy: Length of the float 300 mm, width 230 mm and height 200 mm.
4. Rack and Pinion: Length of the rack 600 mm, Number of teeth in pinion 21, Pinion module 0.5.
5. Bridge Rectifier: Bridge rectifier peak reverse voltage (V_{rrm}) is 400V, maximum RMS bridge voltage (V_{rms}) is 280V, maximum DC blocking voltage (V_{dc}) is 400V, average forward rectified current (I_o) is 2.0A, maximum reverse current (I_r) is 10µA and forward volt drop element (V_f) is 1.1V.
6. Multi-meter: DC Voltage measuring range 1 mV to 1000V and current measuring range 1µA to 20A.

4.2 Working Procedure of the Wave Energy Converter

- The experimental arrangement will be installed on the ocean floor or at a certain water level depth.
- The waves strike the float, and the float moves

forward, up and down, depending upon the force of the waves.

- Let's first consider the float's vertical movement. When a wave hits the float, it pushes the float up and down.
- The pinion passes over the rack in the vertical mounting. The pinion and DC generator are connected.
- When the pinion rotates in the opposite direction, the polarity of the generated current will be altered.
- Therefore the generator's current is transported via a bridge rectifier that reverses the polarity. Therefore, during both the upwards and downward movement, electricity is produced.
- The horizontal movement of the float is similar. When the float hits the wave, it pushes the float forward and backward and produces electricity as well as vertical movement.

4.3 Design of the Model

The design of the model was prepared by using Solid works software. In my design to produce power from both motion of float two rack and pinion is used. Figure 1 shows the line diagram and figure 2 shows CAD model of the wave energy converter.

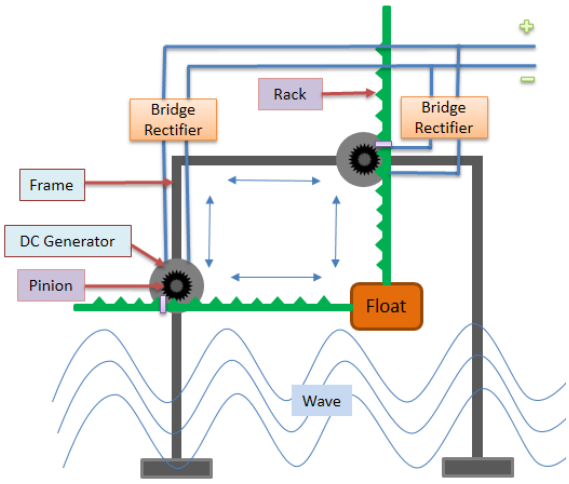

Fig. 1: Wave Energy Convertor Line Diagram

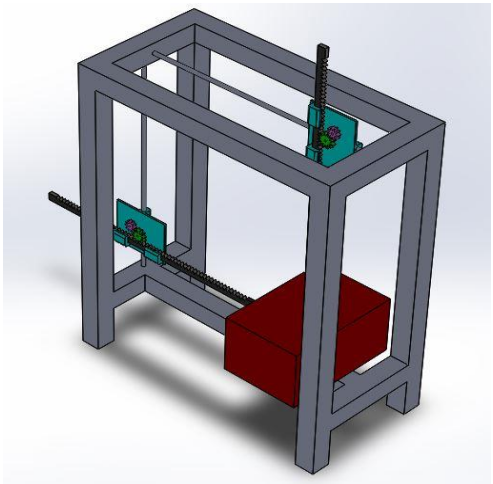

Fig. 2: CAD model of the wave energy converter.

4.4 Fabrication

The frame was fabricated by using rectangle shape bars. At first rectangle shape bar were cut into appropriate size. Then they were welded together to form the frame structure. Two stainless steel round shape bar is also cut according to the size which connection was given with the frame by nut and bolt. Then two connector (frame and rack) is made from plastic material. Four bushes and a plastic plate are used to make a connector. Two bushes are used to connect with frame and other two is for rack connection. Then 600 mm long round shape rack which module is 0.5M was made from plastic. In this study two rack and pinion is used. Then pinion is connection is given with rack and motor shaft. Two rack was given with the float by making two holes in the rectangular float. Float is made from plastic board. Figure 3 shows the fabricated wave energy converter.

Fig. 3: Fabricated Wave Energy Converter

5. DATA COLLECTION AND ANALYSIS

During testing following method is used to collect data-

- At first the setup is placed into the water and placed it into the water in such a way that the buoy can float.
- When wave strikes the float it started to give horizontal and vertical motion together.
- Then the rack and pinion run the generator and electricity is produced.
- During data collection period bridge rectifier is not used because it has some forward voltage drop.
- Then two multi meter is used to measure voltage and current and wave height was also measured.
- Then collected data is analysed.

5.1 Data Collection

Data was taken at fluid mechanics lab at a certain water height. Table 1 shows the data which was taken during wave energy converter testing. It was very tough to take the exact value of the wave height during testing.

So the value of height which is shown in table is the approximate value of wave height.

Table 1: Voltage and Current Analysis with Respect to Wave Height

Observation No.	Wave Height (cm)	Voltage (mV)	Current (mA)
1	3	36	3.49
2	4	61	4.2
3	4.5	82.6	5.63
4	5	79.2	5.31
5	7	149	9.74
6	9	206	11.76
7	9.5	247	12.14
8	10.5	296	14.33
9	11.5	319	16.85
10	13	414	19.95

5.2 Data Analysis

Basically in this project wave energy is used to generate electricity which is coming from nature. From voltage versus wave height graph (figure 4) a maximum voltage level around 414 mV was measured when the wave height was approximately 13 mm. From the graph it is also noticed that if wave height increase voltage rating is also increase which means voltage is proportional to wave height. When wave height is maximum then voltage rating is maximum in this system.

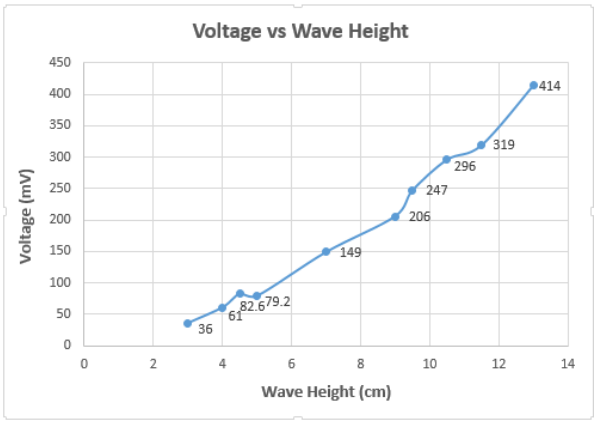

Fig. 4: Voltage Profile over Wave Height Obtained from WEC

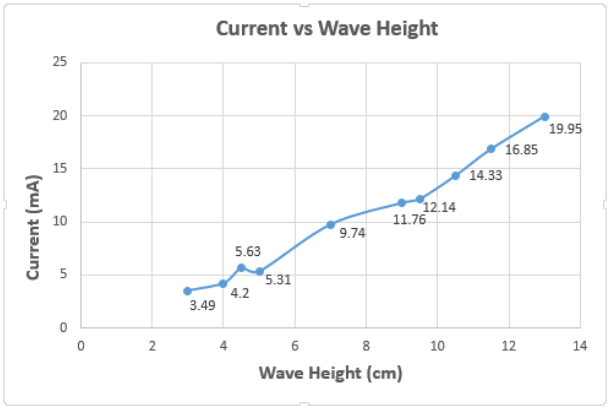

Fig. 5: Current Profile over Wave Height Obtained from WEC

Figure 5 shows current verses wave height graph where current producing rate is increasing with respect to wave height. At 13 mm wave height maximum current is obtained which is 19.95 mA. So power generation rate is proportional to wave height. Since voltage and current is not constant so then efficiency is varied time to time.

6. CONCLUSIONS

In wave power generation produced voltage is not constant. It mainly depends on wave height and time period. In this study at a constant time period data was taken and that was 2 seconds.

Maximum voltage = 414 mV (at 13 mm wave height)
Maximum current = 19.95 mA (at 13 mm wave height)
Time period = 2 seconds

To allow a varied domestic power resource plan, alternatives to today's power problems must be studied through alternative, renewable and clean power sources. In the oceans of the world there is an incredibly abundant and promising source of energy. This instrument uses the surface wave forces in this research to generate electrical power from the wave's horizontal and vertical movement. In this study, rack and pinion, connector and buoy was made from normal plastic. So this setup was not hard enough. So it is proposed that the equipment may be constructed using high-strength, low- weight materials for better power production. In future, further modification can be done so that the wave energy converter can produce more power. Some modification suggestions are given below-

1. We can add another rack horizontally with vertical post of the frame at the opposite side (right side) of the previous one. In this case, float must be heavier than this study.
2. We can also use more than one rack vertically with a single float. In this case horizontally connected rack should be eliminated.
3. We can also use more than one float in a line and each float will be connected with frame through a vertically positioned rack.
4. It is also proposed that the equipment may be constructed using high-strength, low- weight materials for better power production. In this case, aluminum or bakelite can be used as rack and pinion material. To decrease friction between rack

and bushings better lubricants like white lithium grease or silicon based lubricants can be used.

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9. NOMENCLATURE

Symbol	Meaning	Unit
V_{rrm}	Peak reverse voltage	(V)
V_{rms}	Max. RMS bridge voltage	(V)
V_{dc}	Max. DC blocking voltage	(V)
I_o	Average forward rectified current	(A)