American Journal
In Quality, We trust
American Journal of Engineering & Natural Sciences (AJENS)
Volume 1, Issue 1, August 2016

Wave and Wind Energy Converter Integration Process Design and Simulation

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***Abstract*— Demand of energy is increasing by leaps and bounds. The great challenge now is to meet this energy demand in a sustainable manner. Integration of wave and wind energy converter could be an emerging resource option. Same basement could use for wind turbine as well as wave energy device. Two point absorber power buoy model has been chosen for wave energy converter. This oscillating buoy model can take load of wind turbine. Though because of hydrodynamics and damper effect, large wind generator cannot be used. So a basic 3 blade horizontal axis wind turbine applied to the system. Saint Martin Island is taken as a reference for all the input parameters for wave and wind energy calculation. This paper also presents a MATLAB simulation of converters individually**.

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***Keywords*— Wave energy converter, Power buoy, Power take off, Wind turbine, Damping force, Saint Martin Island**

I. INTRODUCTION

Sea waves offer the highest energy density among renewable energy sources. Waves are generated by winds, which in turn are generated by solar energy. Solar energy intensity of typically 0.1–0.3 kW/m2 horizontal surface is converted to an average power flow intensity of 2–3 kW/m2 of a vertical plane perpendicular to the direction of wave propagation just below the water surface [1]. An estimate of the global wave power resource accounts for about 2 TW. Due to the general wind pattern, the oceans' eastern shores are where the most energetic wave climates are encountered. The Atlantic coast in Europe is estimated to have an average resource of 290 GW out of which 32 - 48 GW is estimated to be technically achievable [2]. Wind energy plants around the world produced 273 TWh of electricity in 2009, from an estimated installed capacity of 159 GW [3]. The long term wind flow, especially in the islands and the southern coastal belt of Bangladesh indicate that the average wind speed remains between 3 to 4.5 m/s for the months of March to September and 1.7 to 2.3 for remaining period of the year [14]. There is a good opportunity in island and coastal areas for the application of wind mills for pumping and electrification. But during the summer and monsoon seasons (March to October) there can be very low pressure areas and storm wind speeds 200 to 300 kmph can be expected. Wind turbines have to be strong enough to withstand these high wind speeds [5]. Bangladesh has favourable conditions for wave energy especially during the period beginning from late March to early October. Waves generated in Bay of Bengal and a result of the south-western wind is significant. Maximum wave height of over 2 meter with an absolute maximum of 2.4 meter was recorded. The wave periods varied from 3 to 4 seconds for waves of about 0.5 meter and about 6 seconds for waves of about 2 meter[15][16][17]. Above information shows a marginal output from both of the wind and wave energy converter. Integration of these two converters would be the best way to use our vast renewable resource utterly.

II. TYPES OF WAVE & WIND ENERGY CONVERTERS

An There is a wide variety of wave energy technologies, resulting from different ways in which energy can be absorbed from the waves, and also depending on the water depth and on the location (shoreline, near-shore, offshore). These technologies is relatively new and a lot of project replacing the older just before that will finish, or sometimes before they start [6].

Fig. 1 Different types of Wave energy converter

Wind turbines can be separated into two basic types determined by which way the turbine rotates. Wind turbine that rotate around a horizontal axis are more common (like a wind mill), while vertical axis wind turbines are less frequently used. Savonius and Darrius are the most common in the group [7].

III. TWO POINT ABSORBER POWER BUOY MODEL

It's the simplest oscillating-body device; in most cases such systems are conceived as point absorbers (i.e. their horizontal dimensions are much smaller than the wavelength). The first device developed with this technology was the G-1T in Tokyo Bay (1980), the Norwegian Buoy which was tested in Trondheim Fjord in 1983 and an evolution of the Norwegian Buoy which was tested in Denmark (1990)[6].

A line from the top of the generator is connected to a buoy located at the ocean surface, acting as power take-off. Springs attached to the translator of the generator store energy during half a wave cycle and simultaneously act as a restoring force in the wave troughs [6].

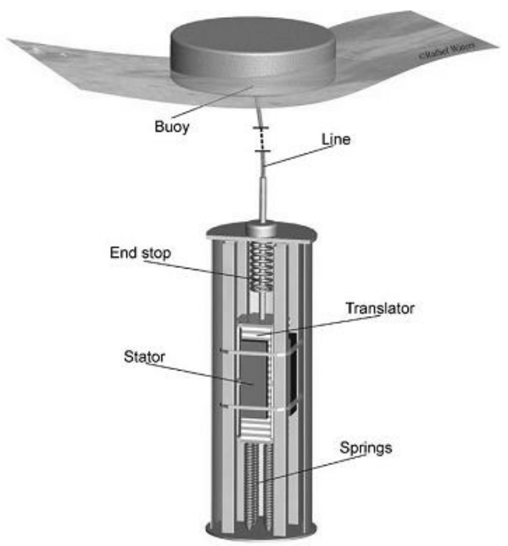


Fig. 2 Heaving buoy with liner electrical generator [6]

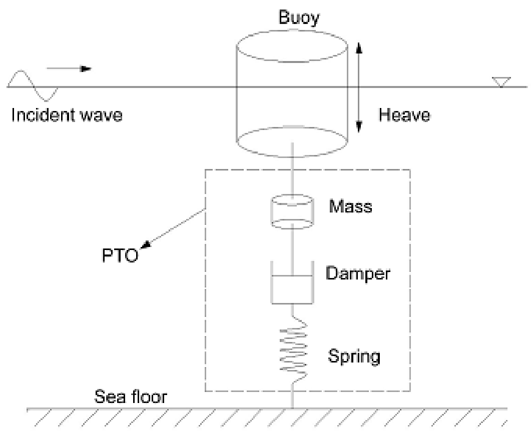


Fig. 3: Schematic display of Heaving point absorber WEC model [8].

IV. PROPOSED ENERGY CONVERTER INTEGRATION MODEL

When selecting a location for an offshore wind farm, the water depth and seafloor characteristics need to be evaluated. The type of wind turbine determines the water depth that is acceptable for its placement. Stationary wind turbines are usually located in water depths of less than 20 meters, whereas floating wind turbines can be placed in depths over 200 meters[9]. In our design we have used 3 blade horizontal offshore wind turbine.

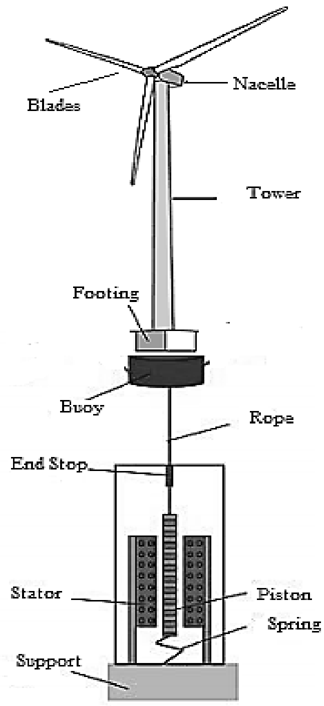
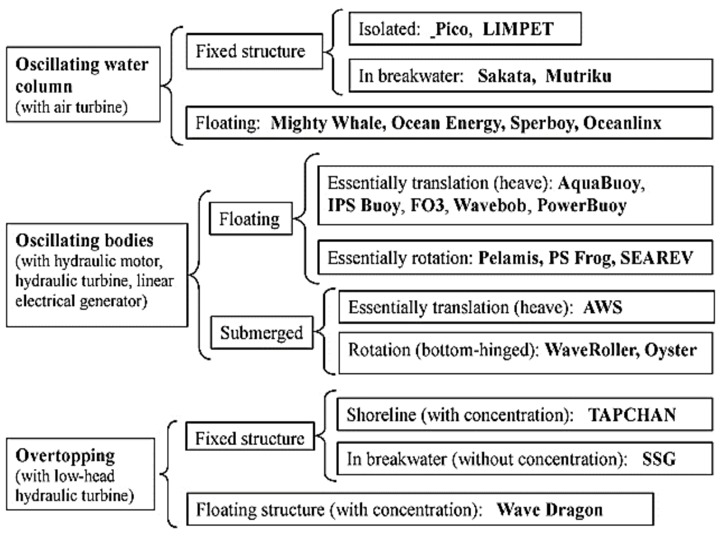


Fig. 4 Integration model

The WEC's ability to extract energy from the ocean wave depends on the geometry of the buoy, the mass of the moving parts together with the damping from the generator and load.



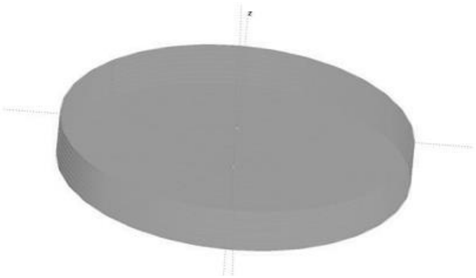


Fig. 5 Cylindrical buoy by CAD tool design [2]

In figure 6, we have designed a conceptual model of our integrated energy converter. The total height of the system is 24 meter. This height is mainly depending into the buoy. The larger diameter buoy can take larger wave and tall wind turbine.

As in the introduction part we have discussed that the average wave height in Bay of Bengal is not more than 2-2.4 meter. The height of the buoy in our design is 3m. This 3m height can easily take a wave range between 2-2.5 meter. Larger diameter and height buoy will be needed in large wave height area like Atlantic Ocean.

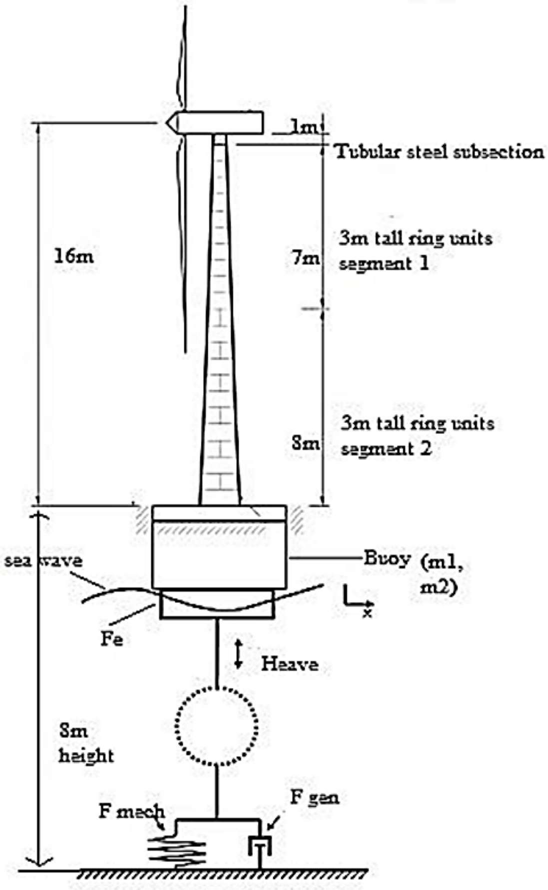


Fig. 6 Conceptual sketch of our integration model

Blade height is also a very important factor in designing of a wind turbine. Our whole wind model is 16m. The length of each blade is taken 1m.

V. DATA ANALYSIS & SIMULATION

Bangladesh is situated in the latitude between 20°34' - 26°38'N and longitude between 88°01-92°4E. The country has a 724 km long coastal line along the Bay of Bengal. There are many islands in the Bay, which belongs to Bangladesh. The strong south /south-westerly monsoon wind coming from the Indian Ocean, after traveling a long distance over the water surface, enter into Asia over the coastal area of Bangladesh. This wind blows over Bangladesh from March to September with a monthly average speed 3 m/s to 6 m/s. The wind speed is enhanced when it enters the V- shaped coastal region of the country. According to preliminary studies, (from meteorological department, BCAS, LGED, and BUET) winds are available in Bangladesh mainly during the monsoon and around one to two months before and after the monsoon (7 months, March to September). During the months starring from late October to February wind speed remains either calm or too low. The peak wind speed occurs during the months of June and July [10].

Month	V_{av} (m/s)	V_{max} (m/s)
January	5.08	23.32
February	4.71	19.78
March	4.29	18.94
April	3.58	20.03
May	5.75	26.30
June	5.96	29.80
July	5.33	24.20
August	5.96	20.40
September	4.79	17.70
October	4.17	15.90
November	3.79	14.50
December	4.08	15.20

Fig. 7 Monthly average wind speeds in Saint Martin Island [11].

Saint Martin’s island shows the high wind average compare to other coastal parts at Bangladesh like Potenga, Coxsbazar, Teknaf, Chorfashon, Kuakata and kutubdia [11]. A MATLAB Simulink model has designed for wind turbine calculation.

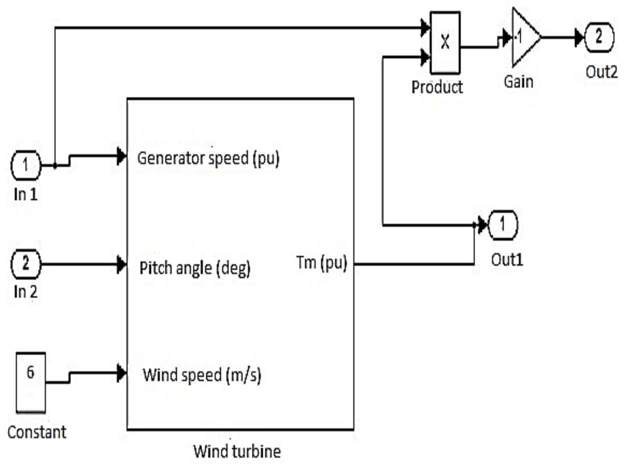


Fig. 8 Simulink model of wind turbine

In this simulation wind speed is taken as 6 m/s. For simplicity, we took zero blade pitch angle value.

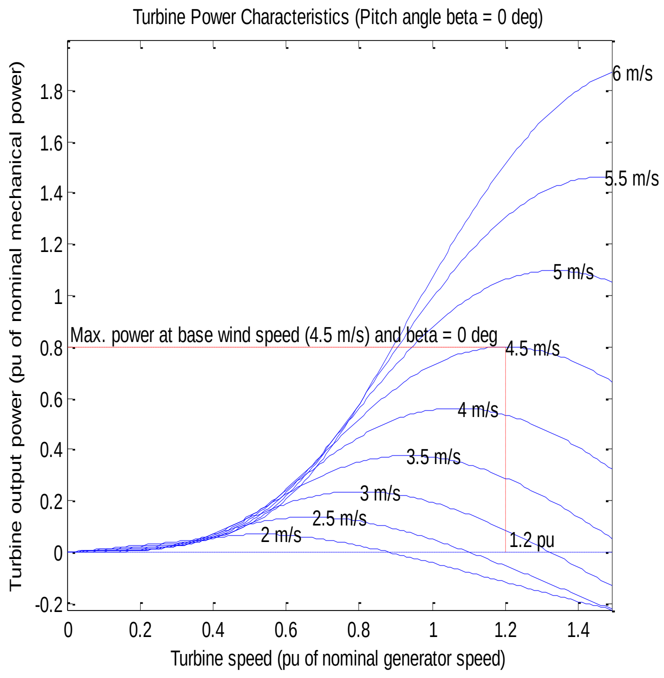


Fig. 9 Wind turbine mechanical output power

Fig 9 is showing a graph in between turbine speed versus turbine output power. So when the turbine speed is increasing because of high wind speed, the turbine output power is also increasing. It's very hard to find the actual statistical data for wave energy in Bangladesh. Different research paper show different types of data. So from those we choose one data table for Saint Martin Island.

TABLE I
WAVE HEIGHT DATA FOR SAINT MARTIN ISLAND [12]

Local date	Jan 06,2014							
Local time(h)	02	05	08	11	14	17	20	23
Wave height (m)	1.5	1.5	1.6	1.6	1.6	1.6	1.6	1.7
Wave period (s)	5	5	5	5	6	6	6	6
Local date	Jan 07, 2014							
Local time (h)	02	05	08	11	14	17	20	23
Wave height (m)	1.8	1.9	1.9	2.0	2.0	2.0	2.0	2.0
Wave period (m)	6	6	6	6	7	7	7	7

One of the most challenging problems in the development of wave energy converters (WECs) relates to their optimisation and control in order to maximise energy conversion. This may be achieved by adjusting the resonant frequency of a WEC to match the dominant frequency of the wave spectrum as it changes with variations in sea state. This is accomplished by changing the damping force in the power take-off (PTO) mechanism [13].

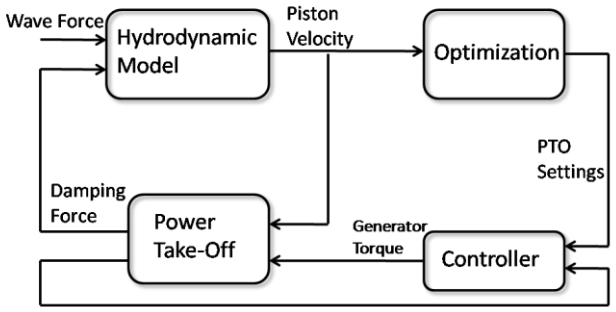


Fig. 10: Representative model of a wave energy converter [13]

Our simulation is related to a point absorber WEC with direct drive PTO; the PTO damping is modelled to be linear. Two methods are given to model the WEC device: FD method and TD method. The TD method approximates the convolution term in the time-domain equation of motion by a state space model. A Simulink model has established to find out the power and energy output in time domain method.

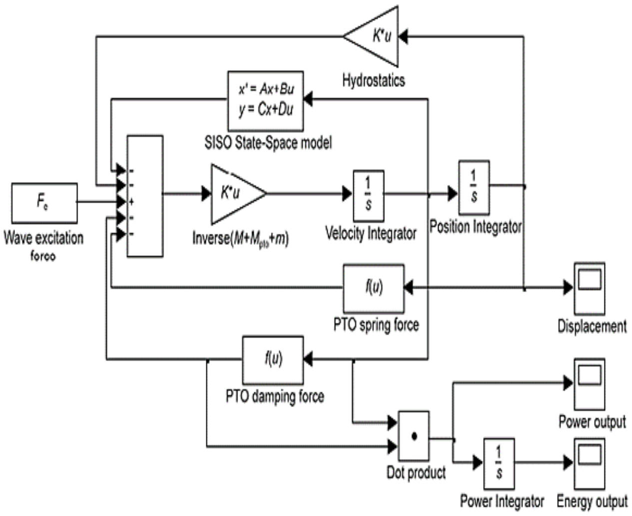


Fig. 11 Simulink model of wave energy converter in time domain (TD) method

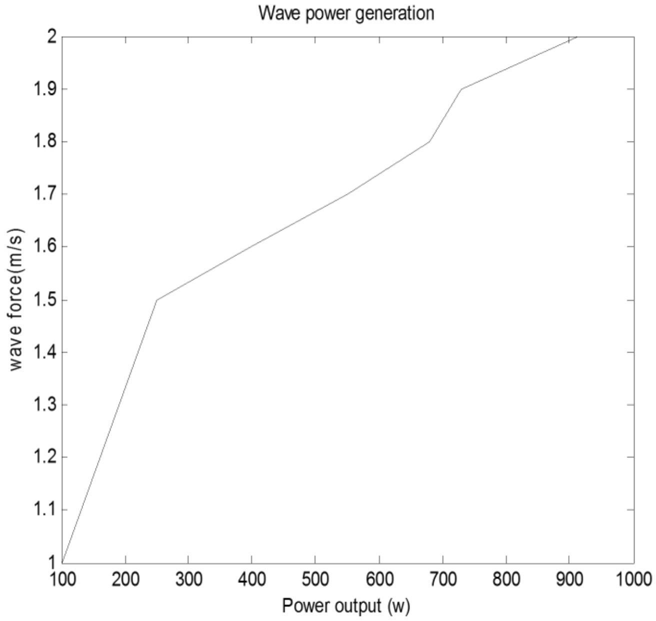


Fig. 12 Wave force excitation versus power output

From fig.12 it is seen that larger wave force creates larger power output. This power output also depends with the damping force and the turbine mass. If we use larger turbine model, power output can vary.

VI. Conclusion

In 2014, Bangladesh wins maritime boundary dispute with India and gained 19,467 Km2 areas in Bay of Bengal. It is surely a vast area and the commercial and economic interest together with environmental stakes. This huge area is also a good resource to generate large amount of electricity. This integration energy converter model doesn't need a large area to implement but could produce almost 2KW power from single device roughly. In Saint Martin Island there is also a huge power shortage. The only power source for this small village peoples are solar panel whose efficiency is not more than 10-11%. Government or private company can implement some pilot project to this island. The model we calculate in this paper is linear. There are few other parameters (like: pressure differential) needs to be addressed to find out the actual value. So these types of pilot project not only will give electricity but also will be helpful for further research about this energy converter model.

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