A Study on Tidal Power Conversion for use in Bangladesh

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Abstract-Electricity from tidal power is a form of pollution free renewable energy which has a lot of potential. This potential has not been realized yet, due to two major problems ◎high capital costs and environmental concerns. This paper discusses how the two problems could be resolved utilizing small-scale technologies, innovative financing, and involving local communities to ensure that all key impacts are manageable. Bangladesh has a long coastal area with 2~8 m tidal head/height rise and fall, most of which is protected against flooding by embankment and sluice gates. Therefore, the potential for tidal power in the country is significant because the barrages necessary for creating controlled flow through turbines (to tap tidal power) are also needed for flood control. It is feasible to generate electricity using the Bay of Bengal. Our research study shows that all twelve months of the whole year are feasible for power production but 8 months of the year (from the late March to October) are most suitable for power production

Index Terms- .Tidal Power, Conversion,

1. INTRODUCTION

Tidal power is not a new concept and has been used in Britain and France since at least the 11th Century for milling grains (ACRE, 1999). Oceans cover over 70% of the earth's surface and the energy contained in waves and tidal movements is enormous. It has been estimated that if less than 0.1% of the renewable energy available within the oceans could be converted into electricity it would satisfy the present world demand for energy more than five times over (Wavegen, 1999). However, tidal power remains well below its potential in terms of application. Presently, tidal plants exist only in France since 1967 (La Rance), Canada since 1984 (Annapolis Royal), and in China (the Bay of Kislaya and Jiangxia Creek). Many tidal projects are being considered today including the seven projects in England, Derby Hydro Power of Western Australia: (48 MW); Corova, south coast of Alaska; Southern portion of Chile; Gujarat, India: (1000 MW); Mexico: (500 MW); the Philippines: (2200 MW) and China: (20,000 MW) (Tidal Electric Inc, 1999; Green Energy, 1999; ACRE, 1999). The usual technique in harnessing the tide is to dam a tidally-affected estuary or inlet, allowing the incoming tide to enter the inlet unimpeded and then using the impounded water to generate power. The main barriers to uptake of the technology are environmental concerns and high capital costs. In recent years, these problems have been mitigated considerably by design, by involvement of experts and local communities in the identification and installation of new plant, and by a growing understanding of how to achieve more sustainable energy development. However there have been very few studies in the academic literature that analyze this process of how a new form of sustainable energy has been changing to become more mainstream and acceptable (Baker, 1991). Generally speaking, it is quite possible to harness energy from the tides; however the technology is not yet practically and commercially available; there are also environmental concerns. Therefore, until now, tidal power generating issues have not been substantively addressed. The attempts to achieve environmental resolution will be the primary focus of this paper. The other major problem of high capital costs will also be addressed. Like hydro schemes, tidal power has high capital costs due to the large scale of engineering involved, but involves low operating costs. Tidal power has the extra problem of having to be located in a coastal environment where engineering is likely to be even more costly due to the changeability of the coast. However, there is no research that has been conducted yet where the coastal engineering infrastructure is already present (like Bangladesh Coastal Islands). This paper also suggests how tidal power can be harnessed in Bangladesh, where the necessary engineering (coastal embankment and sluice gates) infrastructure already exists.

2. OBJECTIVES OF THE STUDY

The main objective of the project is to produce energy from tides and waves which can be used to drive water and air turbines to generate electricity. Tides can cause huge quantities of water to rush back and forth as they ebb and flow. This movement of water can be used to drive generators. A dam or barrage is built across the mouth of a river or across an inlet. Water turbines are installed in the barrage wall and as water rushes in and out it drives the turbines and generates electricity. The amount of electricity produced depends on the range of the tide and the volume of water that passes though the barrage. To make it worthwhile, the tidal range (that is, the height between the high and low tides) should be more than 4m for electricity generation to be economic.

3. EXTENT OF THE STUDY AREA

In this feasibility study three places at Sandwip of Satal Khal, Mongla at Pussur River and Baghkhali River at Cox's Bazar have been chosen for tidal and wave power generation in the coastal area of Bangladesh as the tidal ranges of the above-mentioned three places vary from 4.0 m to 7.75 m (approx.) during spring tides.

4. PENETRATION OF TIDES IN BANGLADESH WATERS.

There are six major entrances through which tidal waves penetrate into the waterways system in Bangladesh and these are: 1.The Pussur Entrance, 2. The Haringhata Entrance, 3.The Tentulia Entrance, 4. The Shahbazpur Entrance, 5. The Hatiya River Entrance, and 6.The Sandwip Channel Entrance.

5. ORIGIN OF TIDES IN THE BAY OF BENGAL

Originating in the Indian Ocean, tides enter the Bay of Bengal through the two submarine canyons, the 'Swatch of no ground' and the Burma trench and thus arrive very near to the 10 fathom contour line at Hiron Point and Cox's Bazar respectively at about the same time. Of the principal constituents, most dominant are M_2 and S_2 whose natural periods of oscillations are 12 hours 25 minutes and 12 hours respectively. Extensive shallowness of the north eastern Bay gives rise to partial reflections thereby increasing the tidal range.

6. TIDAL BEHAVIOR IN OTHER OCEANS

The Bay of Fundy on the east coast of Canada has the largest tidal range in the world with an annual average of 10.8 meters. In Australia there are many places with a large enough tidal range to use tidal energy. Most wave energy can be found where winds are the strongest. Norway, Japan, and the USA have all developed wave power technology. Norway used a 350kW device successfully for over five years before it was damaged in a storm. Studies have found that the waves off the west coast of Tasmania have three times as much energy as the waves off the coast of Norway.

7. CHART DATUM

The modified chart datum (**CD)** for Bangladesh waters as developed by BIWTA (1980) and as given below will be used for tidal characteristics of coastal belt. $\mathbf{CD = Z_0 - (M_2 + S_2 + K_1 + O_1) - SA * SSF}$, where $\mathbf{Z_0}$ is the arithmetic mean of hourly heights observed over the period of one year and it is also known as MSL datum, $\mathbf{M_2}$ is the principal lunar semidiurnal constituent, $\mathbf{S_2}$ is the principal solar semidiurnal constituent, $\mathbf{K_1}$ is the luni solar diurnal constituent, $\mathbf{O_1}$ is the lunar diurnal constituent, **SA** is the solar annual constituent, also known as meteorological tidal constituent and **SSF** is the station safety factor which varies from 1.0 to 1.4 along the waterways as one proceeds from coast to an upland station.

8. DATUM FORMULA

Based on above-mentioned chart datum the following formula will be used for calculating tidal ranges and wave power.

1. MHWS (Mean High Water Spring)= $Z_0 + (M_2 + S_2) + SA$
2. MLWS (Mean Low Water Spring)= $Z_0 - (M_2 + S_2) - SA$
3. MHWN (Mean High Water Neap) =$Z_0 + (M_2 - S_2) + SA$
4. MLWN (Mean Low Water Neap) = $Z_0 - (M_2 - S_2) - SA$
5. LAT (Lowest Astronomical Tide) = Z_0 - (Sum of principal constituents) and
6. HAT (Highest Astronomical Tide) = Z_0 + (Sum of principal constituents).

For an accurate determination of tidal power, analysis of data of five years of each of the three places of the stations have been done for computing tidal information using given formulas.

9. BENEFITS OF TIDAL POWER

The key benefits of tidal power are:

9.1 ECONOMIC

Tidal power has been used, to a limited extent, over several centuries, but only recently has any significant effort been put forth to realizing its vast potential. Today, sites suitable for the utilization of tidal power exist in many places around the world. Except for the fact that it involves massive capital outlays, tidal power can result in extremely low costs per Kw.hr once it is built.

9.2 RENEWABILITY

Although not entirely solar (as it is mostly lunar power), tidal energy is truly renewable. Long after fossil fuels have gone, the tides will still be there (in an energy-hungry world and its escalating needs).

9.3 PREDICTABILITY

Unlike wind and solar energy, tidal power is entirely predictable. It, therefore, provides the potential to be used as a base-load power supply that is immune from climatic conditions and anthropogenic demands. For example, the amount of power generated is strongly related to the size of the tidal range. The output varies with the square of the tidal range, i.e., if a tidal range of x gives a power output of y, then a tidal range of 10x will give a power output of 100y. The power output is also directly related to the area of the impoundment structure that, in-turn, dictates the volume of water passing through the turbine during each generating phase. Tidal power generating equipment is also very efficient compared to other modes of power generation and, in general, the bigger the power generating equipment, the higher the efficiency. Continuous power generation, that matches electricity demand, is an important characteristic of electricity supply. Generally, this is achieved through the continuous running of base-load generation equipment supplemented with peak-load generation equipment during peak periods. Nuclear power plants cannot be shut down quickly and are operated hours per day and, therefore, nuclear power is a base load type of power. Fossil fuels are somewhat easier to shutdown but typically they vent the steam to the atmosphere when demand for electricity declines at night. On the other hand, tidal power is a power source that can be shut down quickly and restored quickly without major losses in efficiency.

9.4 VERY LONG TERM

The technology is very simple and has a potential life of more than 40 years. At least, that is the experience with tidal energy so far and there seems no reason to doubt the figures. Dams built in the Roman Empire Era still function today. Hoover Dam began power generation in 1936 and continues to function without any indications of potential failure. Thus it is reasonable to assume that tidal generators will last for many years, far beyond the normal 20 to 30 years life expectancy of other forms of power generation. Because the tidal generator uses no fuel and maintenance is minimal, the cost of electricity after the capital costs have been paid off in 15 or 20 years can be assumed to be nearly zero.

9.5 OTHER ADVANTAGES OF WAVE AND TIDAL ENERGY

1. Renewable energy
2. Abundant (estimated that it could produce 16% of worlds energy.)
3. Pollution free (except during construction)
4. Relatively consistent (unlike wind that is in consistent and is highly concentrated in certain areas depending on the topography.)
5. Water is a free resource
6. Presents no difficulty to migrating aquatic animals (avoidable)

10. METHODOLOGY

An Example of Methodology for the Floating Wave Power Vessel to Convert Wave Energy into Electricity is Floating Wave Power Vessel (FWPV) based on ship construction, will be anchored in 50-80 m depth of water. It will be designed to have a maximum power output of 1.5 MW, producing about 5.2 million kWh per year. This design functions by capturing the water from waves that run up its sloping front face. The captured water is returned to the sea via a standard Kaplan hydro-electric turbine. In many respects this is a floating Tapchan.

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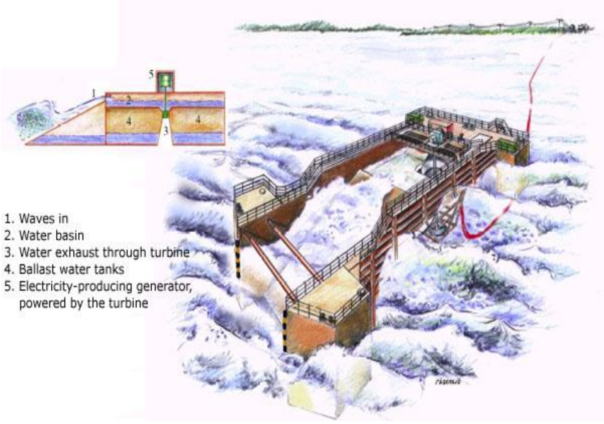

Figure: Floating Wave Power Vessel.

Methodology for the Stingray Tidal Stream Generator to convert Wave Energy into Electricity

Material selections were made using Engineering Business Ltd.'s (EB) in house knowledge of building subsea machines. The timescale of the project and cost limitations also had a large influence on specification. For example a commercial machine designed to be in the water for many years would have a greater number of stainless steel components to resist corrosion and allow for easy maintenance over its lifetime. However a compromise with cost had to make in this project and in many places painted steel parts could be used at a fraction of the equivalent stainless steel cost. Due to the size of the machine the design allowed for the machine to be broken down easily into key parts for transportation by barge and re-assembly on site. Preliminary designs had been for a twin hydroplane machine. During the design process this was simplified to a single hydroplane design to ease manufacture and reduce cost. Parametric modeling of performance and cost had shown that a single hydroplane could be configured such that it had similar overall performance to that of the optimized twin hydroplane machine developed.

11. FIELD TRIP

Before started field visit by the 4 member Team of Experts to the proposed sites, hydrographic survey charts were procured from BIWTA for the three places. On the survey chart spots are mark after visiting Bagkhali river of Cox's Bazar and Pussur river of Mongla Port area. All these survey charts showing proposed site of electricity generation from tidal and wave power are kept in Appendix – A, B,C. At the time of collecting tidal data from Cox's Bazar Auto gauge station Mr. Maksud, AGO of Cox's Bazar supplied us tidal data. Sr. Hydrographer and in-charge Chief Hydrographer of Mongla Port Authority and 2 Tide Watchers also provided us tidal data from Mongla Auto gauge station at the time of selecting sites along the Pussur River. Geographical positions of the proposed selected sites are given bellow:

Geogration Positions of Proposed Site

Place	River	Area
A. Cox's Bazar	Bagkhali	Nania sara, Near BIWTA landing station & Autoguage station Lat : 20° 59' – 30" N Long : 91° 59' 29" E
		Maiskhali Channel Lat : 21° 28' – 32" N Long : 51° 58' 30" E
		Laboni point (Sea beach) Lat : 20° 25' 00 N Long : 91° 58' 00" E
B. Mongla	Possur	North of Gulf Foods Ltd Lat : 22° 29' – 00" N Long : 89° 35' 30" E
		Koromjol Junoid khal (Forest office) Lat : 21° 59' – 30" N Long : 88° 30' 00" E
C. Sandip	Satal khal	Sandwip to Char Pia Lat : 22° 28' – 00" N Long : 91° 26' 00" E

12. Collection of Auto Gauge Data

During field visit we collected gauge data from Cox's Bazar and Mongla gauge stations for the period of spring and neap tides. Using those data we calculate tidal ranges. Tidal ranges at Pussur river of Mongla and Bagkhali river of Cox's Bazar will serve the purpose of proposed electricity production as per our requirement. Collected data and their tidal ranges are shown below:

1 A. Cox's Bazar (Bagkhali river)					
Spring Tide - Tidal range			Jun-09		
Date	Time	High Tide (meter)	Time	Height (meter)	Range
6-Jul-09	10:00	4.05	17:00	1.2	2.85
7-Jul-09	10:30	4.02	17:15	1.43	2.59
8-Jul-09	12:00	3.99	18:30	1.19	2.8
9-Jul-09	17:00	0.87	4:15	0.73	0.14
10-Jul-09	11:45	4.23	18:00	0.91	3.32
11-Jul-09	12:15	4.23	6:00	0.85	3.38
12-Jul-09	13:00	4.06	6:30	0.9	3.16

2 B. Mongla Auto Gauge Station (Pussur river)						
Gauge Data : Data collection (RL in Meter)						
Date	Time	HW	Date	Time	LW	Tidal Range
5/8/2009	0:30	3.95	5/8/2009	7:30	0.93	3.02
5/8/2009	12:10	4.24	5/8/2009	20:00	0.9	3.34
6/8/2009	0:50	4.1	6/8/2009	8:00	0.76	3.34
6/8/2009	12:30	4.28	6/8/2009	20:30	0.79	3.49
7/8/2009	1:10	4.21	7/8/2009	8.35	0.66	3.55
7/8/2009	13:10	4.34	7/8/2009	21:10	0.64	3.7
13/8/2009	4:15	4.11	13/8/2009	11:45	1.37	2.74
14/8/2009	0:00	1.25	14/8/2009	5:15	4.02	2.77
15/8/2009	0:35	1.45	15/8/2009	16:00	4.05	2.6

3 A. HIGH AND LOW WATER FROM (BIWTA Format)											
Station :		Cox's Bazar		River:	Bagkhali			Month	June		
		HIGH WATER		LOW WATER				HIGH WATER		LOW WATER	
DATES	T and H	HHW	LHW	HLW	LLW	DATES	T and H	HHW	LHW	HLW	LLW
1	T	500	1715	1100	2345	16	T	1615	330	1015	2200
	H	321	321	160	125		H	308	308	159	133
2	T	615	1745	1230		17	T	500	1700	1115	1345
	H	341	335	155			H	313	297	157	133
3	T	800	1900	1400	15	18	T	600	1800	1300	
	H	351	321	151	129		H	325	307	149	
4	T	815	2000	1445	115	19	T	715	1900	1400	15
	H	363	325	135	125		H	351	307	119	115
5	T	900	2115	1530	200	20	T	800	2000	1430	130
	H	383	341	137	121		H	377	326	119	105
6	T	930	2145	1600	300	21	T	930	2130	107	215
	H	390	351	127	115		H	397	353	1600	94
7	T	1000	2215	1700	345	22	T	1000	2200	101	1700
	H	405	366	120	115		H	405	359	330	89
8	T	1030	2230	430	1715	23	T	1030	2230	85	415
	H	402	357	151	143		H	413	367	1700	73
9	T	1200	2330	1830	530	24	T	1145	2345	87	500
	H	399	345	119	113		H	423	375	1800	75
10	T	1200		1900	600	25	T	1215		91	600
	H	393		101	101		H	423		1900	85
11	T	1230	0	1900	630	26	T	1300	30	89	2000
	H	383	338	113	99		H	406	366	630	83
12	T	1300	30	1930	700	27	T	1400		90	2100
	H	374	334	123	103		H	390		745	90
13	T	1345	130	700	2015	28	T	1445	215	103	2115
	H	367	328	133	125		H	367	353	121	101
14	T	1430	200	800	2100	29	T				
	H	353	326	149	132		H				
15	T	1530	230	900	2130	30	T				
	H	330	317	157	124		H				

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4 A. Cox's Bazar (Bagkhali river)					
Spring Tide - Tidal range			Jun-09		
Date	Time	High Tide (meter)	Time	Height (meter)	Range
6-Jul-09	10:00	4.05	17:00	1.2	2.85
7-Jul-09	10:30	4.02	17:15	1.43	2.59
8-Jul-09	12:00	3.99	18:30	1.19	2.8
9-Jul-09	17:00	0.87	4:15	0.73	0.14
10-Jul-09	11:45	4.23	18:00	0.91	3.32
11-Jul-09	12:15	4.23	6:00	0.85	3.38
12-Jul-09	13:00	4.06	6:30	0.9	3.16

13. VISIT TO SANDWIP AREA

Team of Experts did not feel necessity to visit the Sandwip area because the tidal range at Sandwip – Hatiya channel is maximum in Bangladesh coast and it is about 7.00 meters during spring tide and which also ideal case of maximum economic is for electricity generation from tide and wave power. Moreover the Chief Investigator has enough experience in hydrographic survey and tidal behavior along the Sandwip – Hatiya channel during his services in BIWTA.

14. TIDAL POWER PROSPECTS IN COASTAL BANGLADESH

Bangladesh is a country with low use of electricity (per capita consumption of 95 Kw.hr) and considerable need for development along its coastal area. Current electrification is estimated at only 16% of the population, with rural access of less than 5% (BCAS, 1998). This places Bangladesh's electrification rates amongst the lowest in the world. Bangladesh has a long coastal area (710 km) with 2~8 m tidal height/head rise and fall (table-1, BIWTA, 1999). Therefore, the potential for tidal power to be harnessed is significant, because the barrages necessary for creating controlled flow through turbines (to tap tidal power) are also needed for flood control. This avoids the problem of high capital cost as the engineering is either already there or is needed for cyclone protection. Analysis of the following two tables indicates that Bangladesh has very good prospects for tidal energy, particularly in Sandwip. The island of Sandwip is located in the Bay of Bengal, adjacent to Chittagong and is a mere 15 km from the mainland. The population is around 330,000 on an area of 240 km2. The entire island is a mudflat created from the Ganges delta. A scoping visit to Sandwip was made in late November, 1999 by the Executive Agencies (Institute for Sustainability and Technology Policy (ISTP), International Centre for Application of Solar Energy (ICASE) and Tidal Energy Australia (TEA) assisted by the Rural Electrification Board and Grameen Shakti of Bangladesh. This island is not a tourist haven and is also rarely visited by Bangladeshi's. The 5 m tides experienced at Sandwip results in poor accessibility, with the island constantly surrounded by mud flats, except during high tides. The island is subject to flooding from cyclones and in 1991 over one thousand people were drowned. A flood control barrage exists around the entire island and contains 28 sluice gates. A short electricity grid is also available linking the main commercial areas on the island. Two diesel generators of 200 KW run for a few hours late afternoon/early evening supplying electricity, mainly for commercial use. Some households have batteries and some diesel generators are used for powering rice threshers. A photo voltaic (PV) system is used to maintain a fridge for vaccines in the health centre. The mud flats are composed of extremely rich soil; hence it is easy to grow a variety of food crops. The island is an exporter of rice and is largely self sufficient in vegetables and fruits. No aquaculture is conducted on the island, though shrimps are collected from the mud flats. None of the island's schools or colleges has electricity and opportunities for employment growth on the island are limited. According to the scoping visit and expert analysis of different tidal range, Bangladesh may harness energy from coastal tidal resources by applying two technologies:

1. Low head tidal movements (2~5 m head); and
2. Medium head tidal movements (> 5 m head).

	List of Harmonic Constituents (Analyzed for 5 Years)						
1	A. Cox's Bazar : Baghkhali River						
			Year of Analysis				
	Principal Constituents		2004	2005	2006	2007	2008
	Z_o		1.991	2.0411	2.0224	2.0174	2.0174
	S_A		0.4571	-	-	-	0.4140
	M_2		0.9849	0.9842	0.9789	0.9791	0.9793
	S_2		0.3858	0.3942	0.3983	0.3979	0.3977
	K_1		0.0991	0.0988	0.0787	0.0786	0.0786
	O_1		0.7350	0.0729	0.0668	0.0668	0.0668

	Year of Analysis				
Principal Constituents	2004	2005	2006	2007	2008
Z_o	2.3050	2.3059	2.3059	2.3059	2.3050
S_A	0.3893	-	-	-	0.3899
M_2	0.9334	0.9319	0.9314	0.9315	0.9327
S_2	0.3411	0.3407	0.3401	0.3417	0.3415
K_1	0.1429	0.1428	0.1430	0.1430	0.1430
O_1	0.0629	0.0635	0.0625	0.0625	0.0629

	Year of Analysis				
Principal Constituents	2004	2005	2006	2007	2008
Z_o	3.2383	3.2396	3.2396	3.2396	3.2382
S_A	0.4536	-	-	-	0.4536
M_2	1.8567	1.8554	1.8544	1.8551	1.8563
S_2	0.6960	0.6954	0.6978	0.6972	0.6973
K_1	0.1578	0.1581	0.1580	0.1579	0.1578
O_1	0.0801	0.0803	0.0801	0.0800	0.0801

RESULTS AND DISCUSSION

Hydro, Micro hydro and Monohydric have limited potential in Bangladesh, with the exception of Chittagong and the Chittagong hill Tracts. Hydropower assessments have identified some possible sites from 10 KW to 5 MW but no appreciable capacity has yet been installed. There is one hydro power plant at Kaptai established in the 1960s with present installed capacity of 230 MW. So that wave and tidal power may be the important source of electricity near future along the coastal belt in Bangladesh.

RESULTS OF ANALYSIS OF TIDAL DATA

For an accurate determination of tidal power, analysis of data of five years of each of the three places of stations have been done for computing tidal constituents. Results of tidal analysis for five years of each of the selected stations are shown in the tables.

LIST OF HARMONIC CONSTITUENTS

During field visit we collected gauge data from Cox's Bazar and Mongla gauge stations for the period of spring and neap tides. Using those data we calculate tidal ranges and those results are show in appendices.

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