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Potentiality Assessment of Tidal Power in Bangladesh

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Abstract- *Extensive energy crisis in Bangladesh in terms of electricity supply has become a common word of the recent years that is characterized as the biggest obstacle of the countries socio-economic growth. Most of the developing endeavor called a halt due to fierce energy demand. Most of the power plants are limited natural gas and export based fuel. Dernier solution is to emerged in renewable energy i.e. solar, wind, hydro, biomass, tidal and wave power. Albeit solar and wind power alleviating energy exigency but expanding at sedate rate and we have only one aged hydro power plant. Supreme solution is to explore naturally available high potential tidal power exploiting large coastal area latch on the Bay of Bengal. As a riverine country Bangladesh has a dazzling destiny in tidal power harvesting. In this research work we have tried to demonstrate the tidal asset of two big rivers named Karnaphuli and Halda in Chittagong division of Bangladesh that possesses maximal tidal energy availability and opportunity for establishing such economically admissible plant. More than 80% of the local power crisis can be restrained; in the meantime 8.5% of the national demand could be supplied using enforceable potentiality of the twin river. Consummate location of the plant considering local ecological and environmental conditions is also studied.*

Keywords: Energy crisis, Renewable energy, Tidal power.

1. INTRODUCTION

Energy is the most important sector for the progression of a nation. With economic development and industrialization in developing countries, the demands for energy resources are increasing rapidly nowadays. Acknowledging the increasing energy crisis and global climate warming, many countries around the world is starting to invest much time and money on the clean and renewable energy [1, 2].

The energy needs of communities increases as the technology develops. This energy need is provided from different traditional energy sources like coal, fuel, oils, geothermal energy, hydraulic energy, nuclear energy etc. These energy sources have limited life time resembling run out nature. The current demand for energy exceeds the available resources and this gap is expected to widen significantly in the near future and Bangladesh is no exception. Bangladesh is a developing country with lots of possibilities. Most of the generated power in Bangladesh comes from coal, diesel and other conventional energy sources [3]. The main source of energy in Bangladesh is Natural gas (24%) [8]. As these conventional energy sources are projected to run out in the imminent future, Bangladesh has a mammoth task in hand due to the dependency on unsustainable energy sources. Renewable or sustainable energy sources are the best alternative to solve this issue. There is a great amount of renewable energy sources in Bangladesh.

Solar power and wind power are the common renewable energy sources which prove their Potentiality. Besides, tidal energy can play a significant role as the country is blessed with numerous rivers meeting ocean in its southern part. Tidal power is one of the renewable energy sources and has huge potential to produce power from tides potential and kinetic energy. Tidal power is much denser form of renewable energy than wind power since water is about eight hundred times denser than air [4, 5].

Demand for electricity in Bangladesh is around 10,000 MW with around 15,000 MW installed capacity leaves a shortage of 1,600 MW daily [13]. The demand will reach 34,000 MW by 2030 [14]. Moreover the government has planned to cover 10% of its energy need from renewable energy by 2020. Thus tidal energy can become a great initiative for driving all odds in way of prosperity of the country. Tidal power can also supply required energy for local development. Chittagong and Cox's bazar district experiences greater tidal variation and have potentiality of power generation. Chittagong district of Bangladesh experiences a power demand of about 900 MW with a shortage of around 140 MW [13] slower its faster industrial and economic growth. Numerous rivers with potential tidal variation can be utilized remembering present energy crisis and future alerting demand.

2. TIDES AND TIDAL ENERGY

Gravitational attraction of sun, moon and earth gives rise of sea water level and rotating nature of earth results water movement as tide. Strong and weaker tide named spring tide and neap tide occurs daily in a repeating manner. When tide goes to coast area is known as flood tide and returning tide from estuaries to sea known as ebb tide. Tidal variations become regular fact at the sea areas and variations can be observed from sea shore to back rivers point. Power can be generated as kinetic energy from tidal current or from potential energy difference of flood tide and ebb tide using different water turbines and generator arrangement.

3. THEORETICAL ANALYSIS

Variation of water levels at estuaries and sea nearer rivers due to tidal movement can be utilized as potential energy difference that is established between high and low tides. There are two potential tidal energy harnessing technology naming tidal barrage and tidal stream system.

3.1 Tidal Barrage

Traditionally a dam like structure across the entire estuaries width is built to create hydraulic head difference between the entering and outgoing tide. Large basin area to store high head water is facilitated with the dam like barrage. Gates and low head water turbines are installed along the barrage.

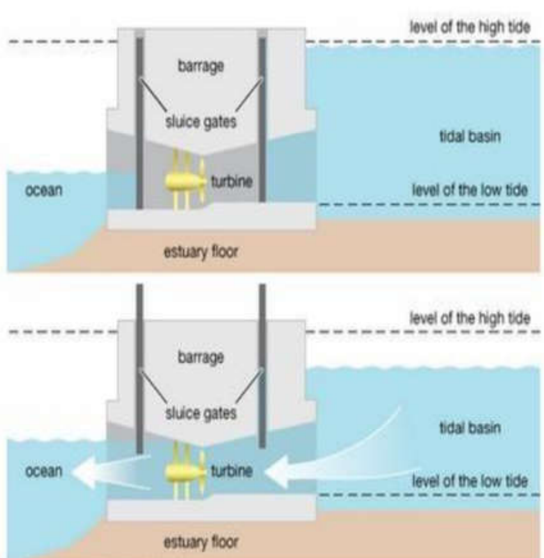
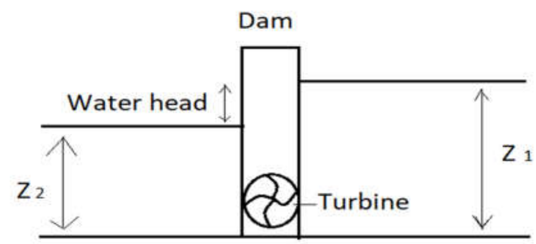


Fig. 1: Tidal energy harnessing system [10].

During flood tide, water is allowed to flow into the basin area through gates. During ebb tide gates are closed and after some time enough water head difference is created between basin and estuaries water that possesses potential energy. Created hydrostatic water head then passes through water turbines running generators to produce electricity.



Available power:

$$P = \rho . g . C_d . A . \sqrt{2.\ g.\ (Z1 - Z2)^3} \quad (1)$$

Where, ρ = Density of water
C_d=Discharge coefficient
A= Basin area
Z1-Z2= Water head difference
g= gravitational force=9.8 ms^{-2}

Power can be generated by one way or two way method. Bidirectional turbine can be used. Power calculation can be done easily from [7]:

$$P = 0.028\ AR^2 \text{ for one way system} \quad (2)$$

$$P = 0.056\ AR^2 \text{ for two way system} \quad (3)$$

Where, A= basin area, R= Tidal range

3.2 Tidal Stream

Tidal stream technology is more likely to wind energy harnessing system where fast flowing mass of water caused by the tidal movement run underwater turbines with their kinetic energy for generating electric power [13]. Turbine speed is as low as 7-11 rotations per minute but produces much energy since water is 800 times denser than air that causes large forces and moments. Energy available from tidal stream plant can be calculated as follow using water density ρ , tidal range R and velocity of water flow v [13].

$$E = ½ \times \rho \times R \times v^3 \quad (4)$$

Energy available at specific site is proportional to the cube of the tidal current value and cross sectional area of the turbine blades. Bidirectional turbines can be used to maximize potential utilization of high water movements of water body near estuaries, rivers and canals mouth. It involves less environmental and ecological issues but complicated installation and maintenance.

4. TIDAL NATURE IN BANGLADESH

Tides are originate in the deep Indian ocean and enter the Bays of Bengal through ‘Swatch of no ground’ and ‘Burma trench’ submarine canyons then arrive at Hiron Point and Cox’s Bazar respectively at the same time and at Chittagong coast after some time [9]. Tidal range is further increased due to the north eastern bays shallowness that gives raise a partial reflection. Tidal variation occurs twice a day and natural periods of oscillation for Bangladesh are 12 hours 25 minutes and 12 hours respectively.

5. DATA COLLECTION

Auto gauge data for Karnaphuli and Halda river of Chittagong division were collected from Bangladesh Water Development Board (BWDB) Chittagong divisional area office located at Chandgaon, Bohoddarhaat, Chittagong. There are two tidal stations for Karnaphuli River and Two tidal stations for Halda River daily tidal data collection.

Table 1: Location of Tidal data collection center

Name of the river	Geographical location	Tidal station
Karnaphuli	Originating from Lushai hill tracks 22º12'60.00'' N, 91º47'59.99''E and ends in the bay of Bengal at 22º13'7.55''N, 91º48'27.32''E	152/2 Kalurghat gauge station Latt:22º23'43.6'' N Long: 91º53'7.8'' E
		147/1 Sadarghat tidal station Latt:22º18'20.95'' N Long:91º49'7.64'' E
Halda	Originate from Chittagong hill tracks 22º38'00'' N, 92º10'00''E then ends in the Karnaphuli river near Kalurghat at 22º25'13''N, 91º52'33''E.	117/2 Madunaghat auto gauge station Latt:22º25'48.19'' N Long:91º52'33.19'' E
		121/1 Enayetghat gauge station Latt:22º37'32.16'' N Long:91º48'5.15'' E

At the time of collecting data, Mrs. Arifa, officials of Chittagong BWDB office provide us tidal data. Some data are also collected from Bangladesh Inland Water Transport Authority (BIWTA) online portal. 2 tide watchers and data logger of Madunaghat auto gauge station supplied us tidal data of Halda river of Chittagong district. All collected data are then analysed orderly catalogued for needful use.

6. PROSPECTS OF TIDAL POWER IN BANGLADESH

Tidal energy being associated with sea sticked coastal estuaries, rivers and canals that are highly available at the southern part of Bangladesh gives potential opportunity for harnessing useful energy with existing and proven technology. Potentiality of tidal power at different places of Bangladesh is studied by several researchers [1, 2, 3, 4]. Tidal power for minimizing country's energy shortage with local priority needs study of local rivers potential. Karnaphuli and Halda River can aid power shortage of the country remarking Chittagong division. Karnaphuli is the largest and important river of Chittagong originating from the Lushai hills of Asam, India and then flows into the Bay of Bengal after running a distance of 270 kilometre and Bangladesh got 163 Km of the river in its part. A hydroelectric power plant constructed across the river at Kaptai impedes its natural flow and reduces effective length at about 143 kilometre where about 16 kilometre used for water vessel way. However, daily tidal variation occurs and experienced along entire effective length. Average width of the river is 130m and average depth is about 15m [10]. Halda River originating from Halda chora in Ramgamati Upazila under Khagrachari district runs through Fatikchari, Hathazari and Raozan Upazila then meets Karnaphuli River near Kalurghat of Chandgaon Thana. 98 kilometer Long River is the only tidal river where natural sanctuaries of shrimp are located. About 29 kilometer of the river can be exploited using big boat navigation and around 24 kilometer more can be wandering by small boats.

7. DATA ANALYSIS

Estimation of available energy and feasibility of new facility construction should be examined before plant implementation. Analysis of particular sites characteristic can give a clear idea about proposed plants acceptability and future sustainability based on proper and necessary data. It also helps for future policy making and master plan development. Collected tidal data of the Karnaphuli and Halda rivers are analysed, transformed and then recorded below.

Table 2: Tidal range data of Karnaphuli river for different years.

Year / Month	2012	2013	2014	2015	2016
January	4.33	4.70	4.27	4.62	4.80
February	4.66	4.12	4.21	4.52	4.84
March	3.93	4.26	4.26	4.28	4.72
April	4.67	5.33	5.24	4.66	4.63
May	5.12	5.22	5.18	4.67	5.06
June	5.45	5.72	5.34	4.77	5.28
July	4.50	5.34	5.28	5.23	5.30
August	5.50	5.28	5.32	5.29	5.07
September	5.28	5.08	5.14	5.44	4.82
October	5.53	5.04	5.25	5.19	4.48
November	5.06	4.83	4.87	4.90	5.05
December	4.60	4.98	4.71	4.83	4.85

Table 3: Water discharge rate of Karnaphuli River for several years.

Year	Yearly highest velocity (m/s)	Yearly lowest velocity (m/s)	Yearly average velocity (m/s)
2009	0.68	0.053	0.57
2010	0.62	0.183	0.51
2011	0.51	0.167	0.39
2012	0.57	0.143	0.42
2013	0.49	0.136	0.35
2014	0.59	0.184	0.43
2015	0.52	0.121	0.41

Table 4: Width variation of Karnaphuli River for several years.

Year	Yearly highest rivers width during flood monsoon (m)	Yearly lowest rivers width during dry season (m)	Yearly average rivers width (m)
2009	115.5	67.8	83.2
2010	107.8	56.6	86.4
2011	111.6	61.4	91.3
2012	104.5	73.5	82.4
2013	96.9	57.8	79.4
2014	113.7	63.7	94.8
2015	116.9	62.6	85.3

Table 5: Tidal range data of Halda River for different years.

Year / Month	2012	2013	2014	2015	2016
January	4.01	3.88	4.12	4.16	3.96
February	4.13	4.13	3.98	4.46	3.91
March	4.47	4.14	5.01	4.64	4.48
April	4.76	5.07	5.16	4.74	4.91
May	4.48	5.42	4.56	4.57	5.56
June	4.71	5.62	4.97	4.71	5.26
July	4.76	5.11	4.98	4.89	5.28
August	4.76	5.16	4.77	4.96	4.34
September	4.51	4.90	4.48	4.89	4.82
October	4.44	4.73	4.37	4.54	4.48
November	4.31	4.61	4.44	5.81	4.56
December	3.87	4.91	4.52	4.03	3.87

Table 6. Water discharge rate of Halda River for several years.

Year	Yearly highest velocity (m/s)	Yearly lowest velocity (m/s)	Yearly average velocity (m/s)
2009	0.62	0.045	0.52
2010	0.58	0.176	0.49
2011	0.43	0.158	0.32
2012	0.51	0.137	0.39
2013	0.45	0.128	0.33
2014	0.51	0.174	0.43
2015	0.45	0.113	0.35

Table 7: Width variation of Halda River during several years.

Year	Yearly highest rivers width during flood monsoon (m)	Yearly lowest rivers width during dry season (m)	Yearly average rivers width (m)
2009	64.5	29.5	62.2
2010	58.2	25.5	49.3
2011	50.5	18.5	42.1
2012	86.2	13.9	63.4
2013	54.4	17.9	47.6
2014	89.5	30.8	67.9
2015	60.2	19.8	51.4

8. RESULTS AND DISCUSSION

Tidal variation is regular and predictable event at the sea coast area that occurs twice a day and independent of environmental issues. This tidal variation creates water head difference naming tidal range can vary over months of the year even from year to year.

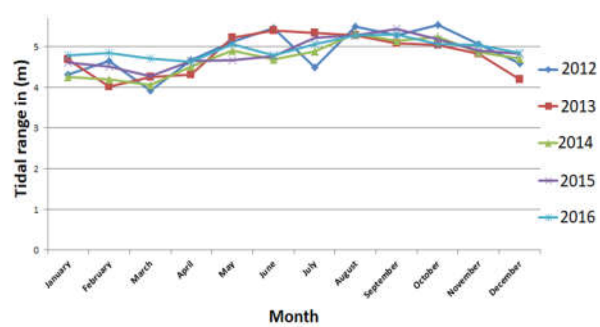


Fig. 2: Tidal range variation of karnaphuli river over years.

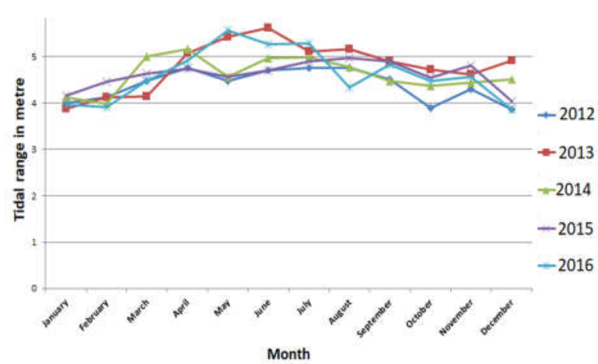


Fig. 3: Tidal range variation of Halda river over years.

Variation of tidal head differences are periodic over months and more dynamic over years because of change in earths rotational speed, distance between sun and moon, astronomical factors etc.

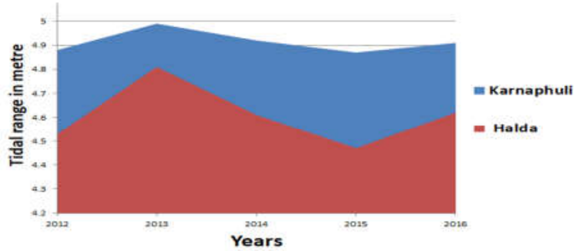


Fig. 4: Variation of tidal head difference over years in Karnaphuli and Halda River.

Halda River experienced lesser tidal range than Karnaphuli River because of its deferred water entry and variable river bed. Moreover Karnaphuli River have higher discharge rate.

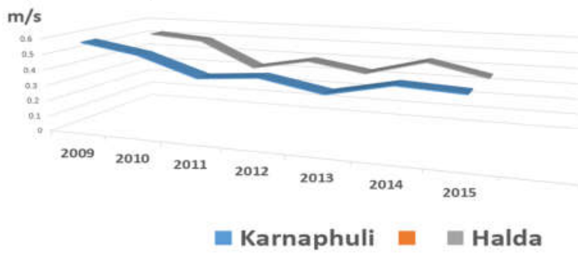


Fig. 5: Average discharge rate variation of two rivers over time.

Potentiality of tidal barrage and tidal stream technology of the Karnaphuli and Halda River can be estimated using equation (1) and (4) respectively. Assumption of mean effective area required for basin construction depends on local ecological impact, water ways, economical importance, Fisheries resources, rivers fringe, sediment structure etc. Two way system is considered for tidal barrage energy harnessing technology. Following calculation are done with assumption and estimating of effective basin area based on visual reconnoitre and geographical analysis.

Table 8: Potentiality of tidal power in Karnaphuli and Halda River.

Topics	Karnaphuli river	Halda river
Effective length	90 Km	52 Km
Average width	86.4 m	54.84 m
Effective area	62.28 Km^2	28.52 Km^2
Tidal range	4.91 m	4.56 m
Potentiality of tidal barrage system	100.36 MW	43.21 MW
Average Discharge rate	0.44 m/s	0.41 m/s
Potentiality of tidal stream system	475.2 KW	383.27 KW
Conversion efficiency of tidal barrage and stream technology	80% and 40%	80% and 40%
Extractable total energy potential	80.28 MW and 190 KW	34.56 MW and 154 KW

Tidal energy potential available at Karnaphuli River can contribute about 6.27% of the countries existing energy gap and Halda River can contribute about 2.7% and unanimously can compensate about 9% of the total void. Chittagong being the port city need adequate and incessant power supply for its large industrial area and growing economic zone. Tidal energy technology can become more significant for local development since it can contribute 88% energy lacking of Chittagong division where Karnaphuli and Halda plant can contribute 62% and 26% respectively.

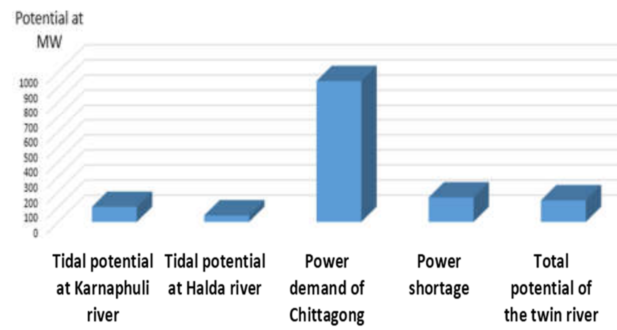


Fig. 6: Contribution of the potential available on local energy situation.

9. CONCLUSION

Tidal power has many advantages as compared to other forms of renewable energy such as predictability, regularity, climate independency and location selective. Another advantage is that global climate change should only increase its generating capacity due to higher ocean levels. Government of Bangladesh should take proximate approach for utilizing its ocean connected rivers and canals providing potential tidal range suitable for economic admissible tidal power plant establishment. Tidal power could be a subsidiary means to mitigate future energy demand of the country.

10. ACKNOWLEDGEMENT

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