Tidal Energy: A Solution to Energy Crisis in Coastal Area of Bangladesh

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***Abstract*— Around the globe the most concerning discussions are on environmental situation and energy crisis. High price along with increasing scarcity of fuel is making decision makers to think about renewable energy. It is high time Bangladesh Government gave much attention towards renewable energy. Government has already been working on solar energy and biogas so that they become popular. In this paper, we present tidal energy of Bangladesh as another potent and promising source of renewable energy. Encompassed by the Bay of Bengal to the south, this country has considerable scope to develop tidal power. Here in this paper we show tidal data of 6 different sites of Bangladesh to propose that Bangladesh has real potential of using tidal sources for power generation which should be properly utilized. Installation of tidal power plants can ensure the best use of tidal energy available in Bangladesh to solve the energy crisis of the country.**

Keywords—Tidal energy, renewable energy, tidal barrage, power generation, power consumption.

I. Introduction

Bangladesh is a densely populated and underdeveloped country with population of almost 160 million [1]. Consumer and industrial demand of electricity is increasing with time and it is not possible till now to fulfil the energy demand of the whole country. Government has taken some policies to reach the demand but conventional energy sources are insufficient in this regard. Annual power consumption of Bangladesh in 1984-85 was 3,640,000 kWh [2] whereas in 2012 it has become 39,100,000 kWh [3]. Although Bangladesh is gifted with natural gas, the rising price of gas and the realization of the exhaustible nature of gas reserve have focused interest and effort on harnessing renewable energy. There are number of variety of renewable energies practised around the globe such as – solar energy, hydro power, wind energy, biomass, bio-fuel, geothermal energy etc. In Bangladesh perspective a potent source of renewable energy is still unutilized. Bangladesh has a long coastal region with many rivers passing all over the country (Fig. 1). The Bay of Bengal provides a huge possibility of using tidal energy as renewable energy in the coastal region and it continues from Teknaf region to the Pussur River in Sundarban. There are many coastal rivers with tidal height of approximately 4-5 meters [4]. This vast energy potential has not been harnessed yet significantly. So, tidal power plant is a potential option to solve energy crisis of Bangladesh. Though most of the coastal islands of Bangladesh are isolated from the main land, in some cases like Kutubdia, we can connect the tidal power plant to the main grid which will increase the total amount of electricity in national grid and will improve the power crisis situation of the country. As tidal energy is renewable it is very much cost effective and rising and lowering of tide is completely natural phenomena which we just need to utilize for our purpose. Bangladesh as a developing country is trying to expand industries and energy crisis is one of the main obstacles in this case. Bangladesh's installed electric generation capacity was 10314 MW in 2014 [5, 6]; only three-fourth of which is considered to be available. Only 62% of the population has access to electricity with a per capita availability of 321 kWh per annum [5]. Many of our power stations are closed or short in production because of the gradually diminishing reserve of our natural gas. As a result industries depending on them cannot get required amount of gas for production. This situation is worsening the state of economic development in the country. Renewable energy must be introduced in large scale for the future and as tidal energy is very much promising in our country it must be considered as such. Tidal power plants should be installed so that at least some portion of power demand of the country can be fulfilled and the development of the country smoothly goes on.

II. Tidal Resources of Bangladesh

Bangladesh has a long coast line of 724 km and many small islands in the Bay of Bengal, where strong tide and wave are continuously present [7]. Originating from Indian ocean, tides along Bangladesh coast enter in two submarine canyons, Hiron point and Cox's Bazar, at about the same time after travelling the deep Bay of Bengal [8, 9]. The tides in the bay are semi-diurnal with two high and two low tides occurring every 24 hours and 50 minutes [10]. The tides across

Bangladesh have a large variation in range corresponding to the seasons, the maximum occurring during the south-west monsoon [8]. Tidal energy is generated because of the tidal range (the difference between the high tides and low tides). The tidal change is not noticeable in inland rivers because the frictional forces cause a gradual decay of tides as tidal wave travels along inland rivers. Though Bangladesh has about 24,000 km of rivers, streams and canals that together cover about 7% of the country's surface, [11] because of the lower tidal range these are not preferable as tidal station. Due to partial reflection the tidal range increases in the north-eastern corner of the bay [9]. So the major tidal channels are lower of the Meghna river, Sahbajpur channel, Hatiya channel, Sandwip channel, Pussur river, Kutubdia channel, Moheskhali, Baghkhali on the coastal area of Bangladesh [12]. Coastal area of Bangladesh thus with its huge potential can be utilized by establishing tidal power plant.

III. SITE SELECTION FOR TIDAL POWER PLANT

Coastal area of Bangladesh is suitable for establishing tidal power plant. There are some large tidal sites and many channels of low tidal range in a large number of deltaic islands, where barrages and sluice gates already exist. These barrages were created for flood control and they are also needed for creating controlled flow through turbines in tidal power plant. As a result the higher construction cost can be minimized as there already some required infrastructure exists. According to researchers it can be said that Bangladesh may harness energy from Low head tidal movements (2-5 m head) and Medium head tidal movements (5m or over) [10]. Coastal regions, particularly Khulna, Barisal, Bagerhat, Satkhira and Cox’s Bazar regions are geographically suitable for low head tidal movements. Islands in coastal region like Sandwip and Kutubdia have medium head tidal movements. Moreover, the infrastructure needed for barrages and sluice gates is already present in some of these regions as they are protected by embankments [10]. Considering the feasibility of power generation, we have selected six places of the coastal region of Bangladesh for our study. These are - Satal Khal of Sandwip Island, Naf river at Teknaf, Baghkhali river at Cox’s Bazar, Kutubdia Channel of Kutubdia Island, Pussur river at Hiron point and Khapravanga river at Kuakata. We have selected these sites as the tidal ranges of these areas are between 2-8 m which is suitable for power generation. The tidal data of Sandwip, Kuakata, Teknaf, Cox’s Bazar and Hiron point has been collected from BIWTA [13] and tidal data of Kutubdia has been collected from LGED [14].

IV. TIDAL ENERGY GENERATION TECHNOLOGY

Utilization of tidal energy can be classified into two main types: potential energy harvesting and kinetic energy harvesting. [15] By constructing barrage to make a basin, potential energy of vertical rise and fall of water can be exploited and kinetic energy can be exploited from tidal currents or horizontal movement of tides. So, the tidal energy generation technology can be categorized into two types-

1. Tidal Barrages
2. Tidal Current Turbines

There are two main operation patterns in which power can be generated from a barrage [15, 16]-

1. One Way Tidal Power Generation System
2. Two Way Tidal Power Generation System

For our study we have calculated energy using the one way power generation process. The average power from the one way system= η x $0.056\ AR^2$. [16]

Let,
Surface area of basin = A
Tidal Range (The difference between high tide & low tide) = R
Density of water = ρ
Gravitation Acceleration = g

We know,
Power from tidal source = $\frac{1}{2} A\rho g R^2$
If, $A = 4\text{x}10^6\ m^2$ (assumption)
$\rho = 1025.18\ kgm^{-3}$
$g = 9.81ms^{-2}$

Therefore, $P = \frac{1}{2}$ x 9.81x 1025.18 AR^2
$= 5028.5079\ AR^2$
Again, we know, 1 lunar day = 24 hr 48min
$=8.92\text{x}10^4$ sec
Average Power = $(5028.5079/8.92\text{x}10^4)\ AR^2$
$= 0.056\ AR^2$
So, Total average power for one way generation system= η x $0.056\ AR^2$.

Where, η is the turbine efficiency, A is the surface area of basin and R is the tidal range.
Tidal energy projects are characterized by low values of power conversion efficiency of η, usually ranging from 20 to 40%, with an average of 33% often being used [17]. So, to calculate average power we assume that the turbine efficiency is 33% and basin area is $4\text{x}10^6\ m^2$**.**

TABLE I. TIDAL RANGE IN SELECTED STATIONS OVER 2012 IN METERS

Month	Sandwip	Teknaf	Cox's Bazar	Kutubdia	Hiron point	Kuakata
January	5.31	3.40	3.39	4.80	2.60	2.50
February	5.21	2.92	3.29	4.70	2.86	2.35
March	6.59	3.02	3.45	5.00	3.11	2.78
April	6.45	3.00	3.76	4.80	3.29	3.02
May	6.25	3.25	3.42	5.20	3.01	2.72
June	6.85	3.45	3.36	5.10	2.76	2.80
July	6.79	3.70	3.14	5.60	2.81	2.87
August	7.03	4.00	3.38	5.50	2.88	2.78
September	6.99	3.53	3.30	5.96	2.93	2.68
October	7.07	3.26	3.05	4.78	2.90	2.85
November	6.14	3.19	3.42	4.58	3.16	2.77
December	5.46	3.01	3.34	4.10	3.07	2.72

TABLE II. FULL ENERGY PROFILE OF SANDWIP AND KUTUBDIA ISLANDS IN 2012

Month	Sandwip				Kutubdia			
	High Tide(m)	*Low Tide(m)*	*Tidal Range(m)*	*Monthly Average Power(MW)*	*High Tide(m)*	*Low Tide(m)*	*Tidal Range(m)*	*Monthly Average Power(MW)*
January	5.71	0.40	5.31	4.1685	5.40	0.60	4.80	3.4062
February	5.57	0.36	5.21	4.0130	5.27	0.57	4.70	3.2658
March	6.82	0.23	6.59	6.4204	5.52	0.52	5.00	3.6960
April	6.99	0.54	6.45	6.1505	5.60	0.80	4.80	3.4062
May	6.82	0.57	6.25	5.7750	5.77	0.57	5.20	3.9976
June	7.62	0.77	6.85	6.9370	5.82	0.72	5.10	3.8453
July	7.61	0.82	6.79	6.8160	6.20	0.60	5.60	4.6363
August	7.83	0.80	7.03	7.3064	6.33	0.83	5.50	4.4722
September	7.64	0.65	6.99	7.2235	6.52	0.56	5.96	5.2515
October	7.34	0.27	7.07	7.3898	5.54	0.76	4.78	3.3779
November	6.50	0.36	6.14	5.5735	5.43	0.85	4.58	3.1012
December	5.95	0.49	5.46	4.4073	5.06	0.96	4.10	2.4852

V. DATA ANALYSIS

From the data provided in TABLE I we have calculated the average power of our selected sites- Sandwip, Teknaf, Kuakata, Hiron point, Kutubdia and Cox's Bazar and the annual energy output in selected tidal stations are given in the table below-

TABLE III. ANNUAL ENERGY OUTPUT IN DIFFERENT STATIONS

Station	Average Annual Energy (in GWh per year)
Sandwip	65.12
Teknaf	20.85
Cox's Bazar	18.42
Kutubdia	46.28
Hiron point	14.10
Kuakata	11.88

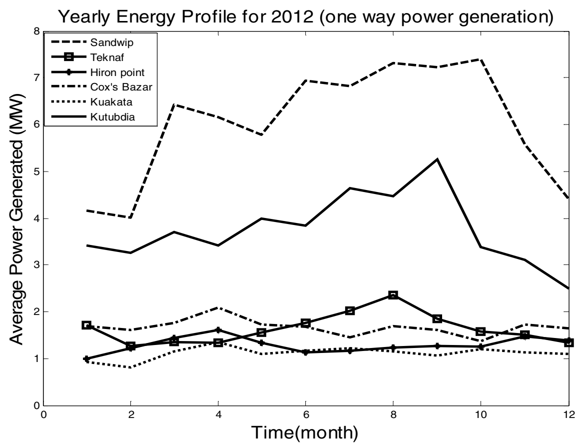

Fig. 2: Yearly Energy Profile for Selected Stations Over 2012

Yearly Energy profile of Kutubdia and Sandwip are given below-

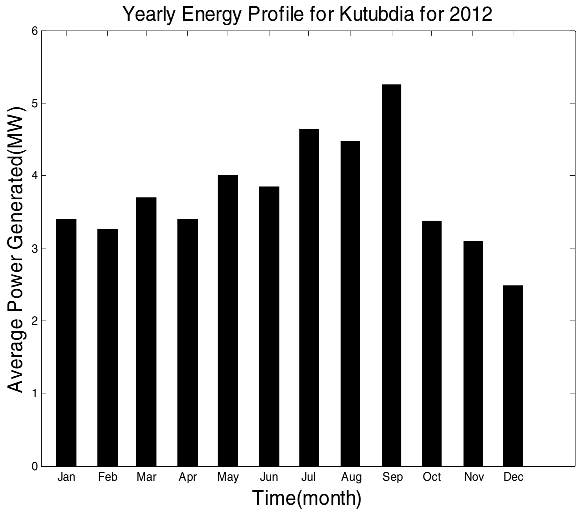

Fig. 3: Yearly Energy Profile for Kutubdia Island over 2012

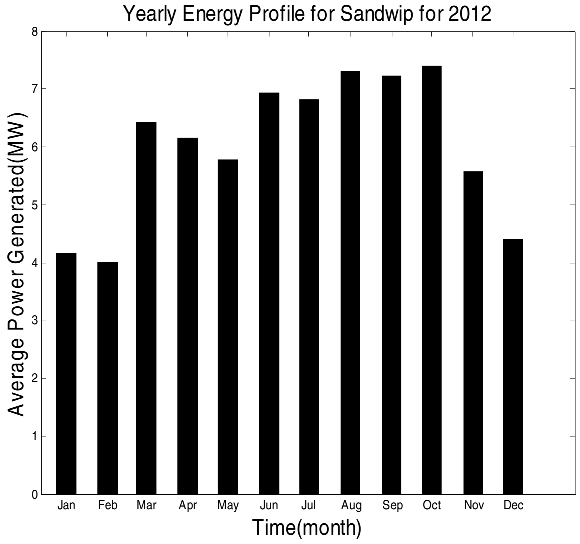

Fig. 4: Yearly Energy Profile for Sandwip Island Over 2012

Analysis of the above tables and figures indicate that Bangladesh has a good prospect of tidal energy in Sandwip and Kutubdia island because the generated average power in Sandwip is about 7 MW and in Kutubdia generated average power is about 5 MW which is very high than other stations.

VI. TURBINE SELECTION

For tidal barrage system generally 3 types of turbines are used. They are Bulb turbine, Rim turbine and Tubular turbine. Among them Bulb turbines are considered as the most popular and efficient ones for low heads up to 3m. These turbines are reversible and can generate power on the flood tide and act as a rotor to pump sea water into the basin. [18, 19]

Rim turbine has greater theoretical efficiency and greater inertia but is not feasible for low head tide. However it can only operate on the ebb generation and cannot be used to pump storage to basin. [18, 19]

Tubular turbine cannot operate on low tide. Although, it has greater efficiency but cannot operate on flood tide or cannot be used to pump storage like Rim turbine. [18, 19]

Since in Bangladesh we only have low head tide (2m-5m) and medium head tide (≥5m) [20]. So, only Bulb turbine can be used here. Moreover, it can also operate both on flood tide and ebb tide generation and can storage by pumping. Therefore, Bulb turbine is the most suitable for power generation in Bangladesh.

VII. CONCLUSION

Renewable energy is the future of power generation. On the other hand conventional energy sources (i.e. fossil fuels) are being used up and dependency on them is going to cause huge energy crisis in near future. So, many countries are doing researches to implement renewable energy as source of generating power. In this matter, tidal energy can be one of the main sources of renewable energy for Bangladesh. Tide is an important element for ecosystem as well as a potent source of energy. As a riverine country, Bangladesh has potential to harness this energy. More detailed studies are needed to implement tidal power plant. The analysis of data in this paper definitely indicates very promising scope of power generation from tidal energy in Bangladesh. Coastal regions of Bangladesh, particularly Sandwip and Kutubdia are highly promising for installation of tidal power plant.

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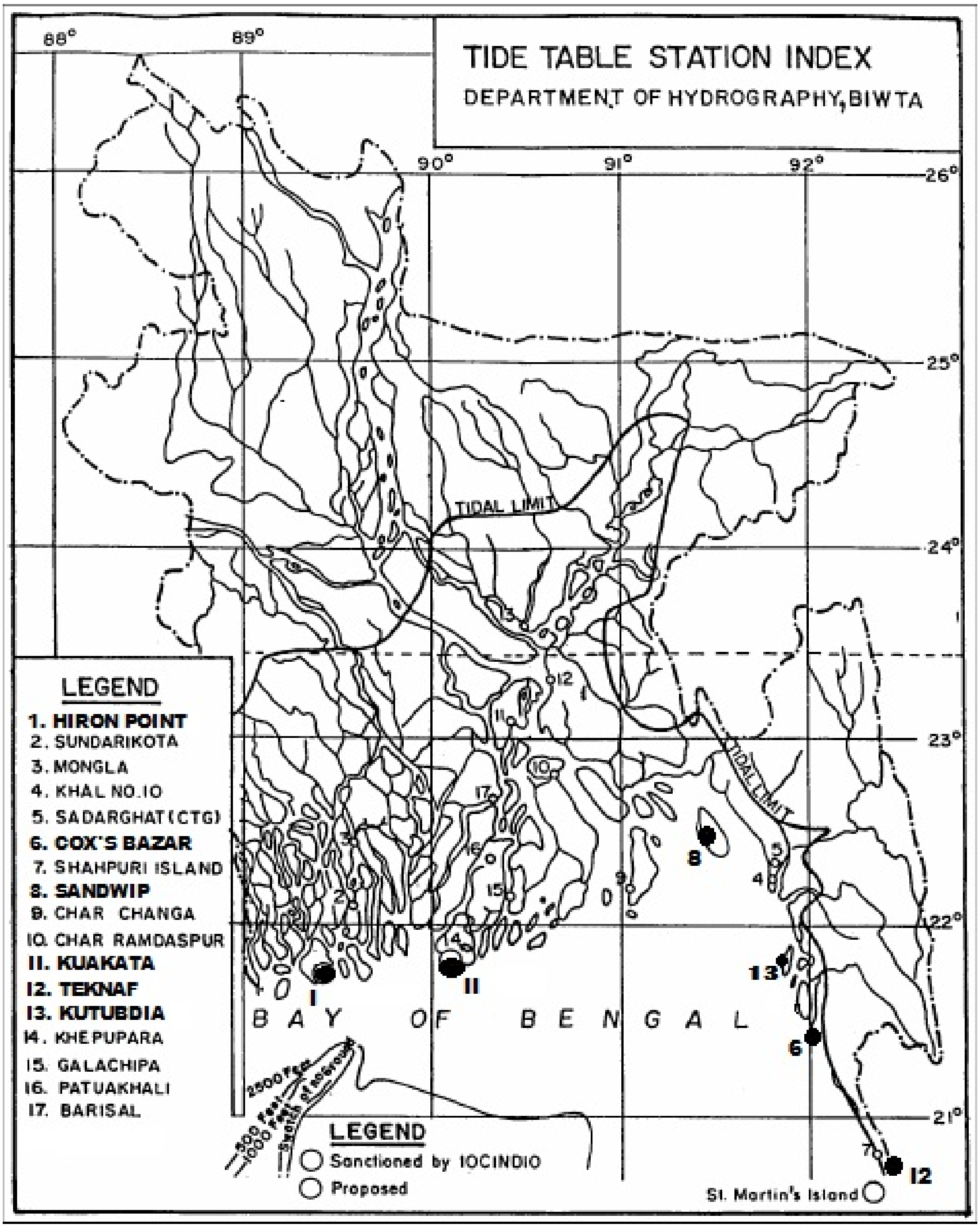

Fig. 1: Tidal Stations in Coastal Region of Bangladesh