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# TIDAL ENERGY: PERSPECTIVE OF BANGLADESH

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## ABSTRACT

Bangladesh is blessed by the nature with renewable resources that are used all over the world in a wide range but in our country it is limited. The country has vast ocean area with various power resources such as Wave energy, Ocean Thermal Energy Conversion (OTEC) and Tidal energy. In the Bay of Bengal, the tidal range and tidal stream speed indicate the potentiality of tidal power generation in Bangladesh. This paper describes various methods of utilizing tidal power to generate electricity and assess the tidal energy resources of three potential sites of Bangladesh. The tidal data recorded by the Department of Hydrography of The Chittagong Port Authority (CPA) and Bangladesh Inland Water Transport Authority (BIWTA) have been analyzed. This study clearly indicates the bright prospects of tidal power in Bangladesh.

Key words: Gravitational effect, Sustainable energy, Tidal stream, Tide control, survey area

## INTRODUCTION

Energy is a basic human need and building block of a society. The development of any country largely depends on power sector improvement. The power sector will be stable by utilizing sustainable energy sources. Renewable energy can not only help solve energy crisis but also contribute to poverty alleviation and fight environmental degradation such as desertification, bio-diversity depletion and climate change effects in Bangladesh. Bangladesh is in the midst of a major energy crisis. It is trying to overcome the problem with costly rental power plants. Bangladesh is also looking for nuclear power plants to solve the crisis on a long-term basis which is not suitable for the country [Haque *et al.* 2010]. But by this time renewable energy is gaining popularity and contributing to solve energy crisis.

The Bay of Bengal is a blessing for Bangladesh. The country has vast ocean area that contains huge power resources such as wave energy, OTEC and tidal energy. Bangladesh can easily meet its huge power demand by proper utilization of the above mentioned energies. Regarding tidal power, it can play a vital role in integrating as new source of renewable energy to the off-grid power connection in isolated areas, namely Sandwip, Dublar Char, in Bangladesh that can reduce the present energy crisis and improve the social, environmental and economic perspectives of Bangladesh [Haider *et al.* 2014].

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Average tidal range from 2-8 m and tidal stream speed of more than 2 m/sec makes tidal power quite prospective in Bangladesh [Siddiqui 2013; Hossain *et al.* 2015]. Tidal power plant is a reliable energy source to replace the burning of fossil fuels. In addition, it is a renewable source of energy that produces no greenhouse gases or any type of waste. Bangladesh can take tidal power generation as a challenge and can easily overcome at least a part of the power crisis [Haque *et al.* 2010]. The objective of this paper is to concentrate on the basic principle of tidal energy; how it works; current status of the development of tidal power in the world and it focuses on the prospects of tidal power in Bangladesh.

## TIDAL ENERGY IN DETAILS

Tidal power is a form of hydropower that converts the energy of tides into useful forms of power, mainly electricity. Tidal power is classified as a renewable energy source, because tides are caused by the orbital mechanics of the solar system and are considered inexhaustible within the human timeframe. Energy from tidal power is also a form of pollution free energy, which has a lot of potential. Tides are more predictable than wind energy and solar power. Linear Momentum Actuator Disc Theory (LMADT) is applicable to a porous disk in a steady uniform flow of liquid or gas [Draper 2011]. Tidal power is the only technology that draws on energy inherent in the orbital characteristics of the Earth–Moon system. Tidal energy is one of the oldest forms of energy used by human. Indeed, tide mills, in use on the Spanish, French and British coasts, date back to 787 A.D. but it is likely that there were predecessors lost in the anonymity of prehistory [Wikipedia 2016].

## TIDAL CONSTITUENTS AND BASICS OF TIDES

Primary constituents include the Earth's rotation, the position of the moon and the sun relative to the earth. Range variation of tides: springs and neaps are shown in Fig. 1.

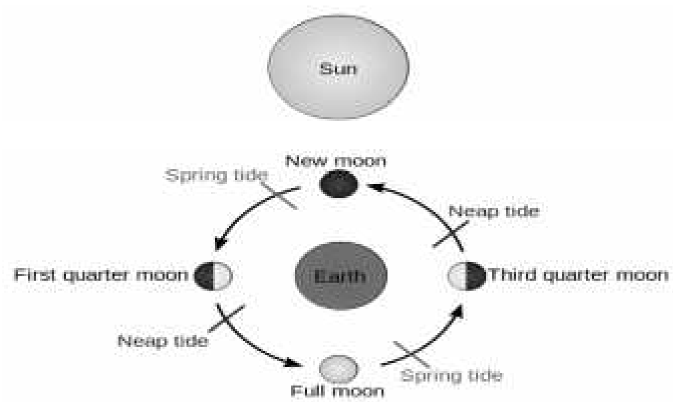


Fig. 1. Gravitational effect of the Sun and the Moon on tidal range [Wikipedia 2016]

It can be concluded that diurnal tides are generated because the maxima and minima in each daily rotation are unequal in amplitude. Fig. 2 demonstrates tidal force and its tendency to create bulging at the water's surface; thus making for the differential sloshing effect.

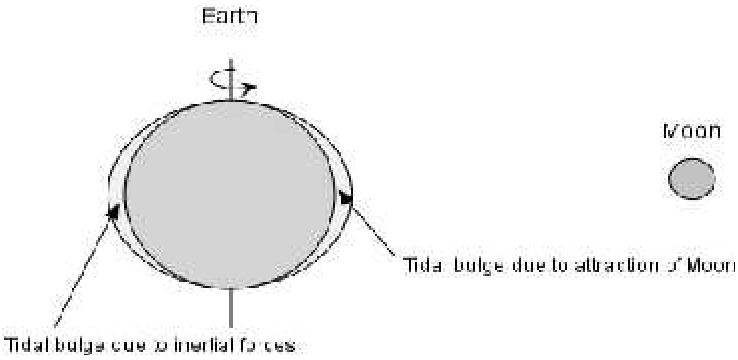


Fig. 2. Tidal force and its tendency to create bulging at the water's surface [Peter 2003]

## CLASSIFICATION OF TIDES

### *Tidal Stream*

Tidal streams are fast flowing volumes of water caused by the motion of the tide and manifest itself as tidal current. Tidal stream devices seek to extract energy from this kinetic movement of water, much as wind turbines extract energy from the movement of air. The technology involved is very similar to wind energy, but there are some differences. Water is 800 times denser than air and has a much slower flow rate; this means that the turbine experiences much larger forces and moments. The turbines must either be able to generate power on both ebbs of the tide. Tidal stream speeds more than 2 m/s are required to generate power efficiently [Wikipedia 2016].

### *Stream Type Tidal Power Calculation*

The power available from these kinetic systems can be expressed as [Cyberaid 2016]:

$$P = \frac{\rho A V^2}{2} C_P \tag{1}$$

Here, $C_P$ = the turbine power coefficient [the factor 16/27 (0.593) is known as Betz's coefficient [Betz 1966], $P$ = the power generated (in watts), $\rho$ = the density of the water (for seawater it is 1027 kg/m$^3$), $A$ = the sweep area of the turbine (in m$^2$), $V$ = the velocity of the flow.

### *Tidal Range*

Tidal Range is the vertical difference in height between the high tide and the succeeding low tide. Artificial tidal barrages or lagoons may be constructed to capture the tide. Barrages are essentially dams across the full width of a tidal estuary. This is where a dam or barrage is built across an estuary or bay that experiences an adequate tidal range. This tidal range has to be in excess of 5 metres for the barrage to be feasible [www.icli 2016].

*Range Type Power Calculation*

The potential energy contained in a volume of water is [Tousif 2011]:

$$P = \frac{1}{2}\mathrm{A}\rho g h^2 \tag{2}$$

where, $h$ is the vertical tidal range, A is the horizontal area of the barrage basin, ρ is the density of water = 1025 kg per cubic meter (seawater varies between 1021 and 1030 kg per cubic meter) and $g$ is the acceleration due to the earth's gravity = 9.81 meters per second squared.

The average potential power for one tidal period becomes [Tiwari 2010]

$$\overline{P} = \frac{\rho A R_2 g}{2T} \tag{3}$$

when the basin has a constant surface area A, ρ is the density of water, R is the tidal range. In this case, energy is averaged over the tidal period *T*.

*Electrical power from tidal flow*

Harnessing the power of the tides can be achieved by placing bi-directional turbines in the path of the tidal water flow in bays and river estuaries. To be viable, it needs a large tidal range and involves creating a barrier across the bay or estuary to funnel the water through the turbines as the tide comes in and goes out. Fig. 3 gives a schematic diagram for electrical power from tidal flow.

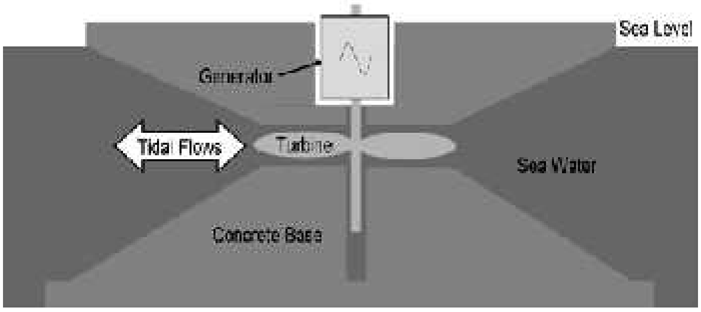


Fig. 3. Electrical Power from Tidal Flow

POWER GENERATION METHODS

Tidal power can be classified into four generating methods:

*Tidal Stream Generator*

Tidal stream generators (TSGs) make use of the kinetic energy of moving water to power turbines, in a similar way to wind turbines that use wind to power turbines. These turbines can be horizontal, vertical, open, or ducted and are typically placed near the bottom of the water column where tidal velocities are the greatest.

*Tidal Barrage*

Tidal barrages make use of the potential energy in the difference in height (or hydraulic head) between high and low tides. When using tidal barrages to generate power, the potential energy from a tide is seized through strategic placement of specialized dams. When the sea level rises and the tide begins to come in, the temporary increase in tidal power is channelled into a large basin behind the dam, holding a large amount of potential energy.

*Dynamic Tidal Power*

Dynamic tidal power (DTP) is an untried but promising technology that would exploit an interaction between potential and kinetic energies in tidal flows. Tidal phase differences are introduced across the dam, leading to a significant water-level differential in shallow coastal seas – featuring strong coast-parallel oscillating tidal currents such as found in the UK, China, and Korea.

*Tidal Lagoon*

A newer tidal energy design option is to construct circular retaining walls embedded with turbines that can capture the potential energy of tides. The created reservoirs are similar to those of tidal barrages, except that the location is artificial and does not contain a preexisting ecosystem. The proposed Tidal Lagoon Swansea Bay in the Wales, United Kingdom would be the first tidal power station of this type once built [Bentz 1966]. Images of Various Technologies (Design) Involved in Tidal Power are shown in Fig. 4.

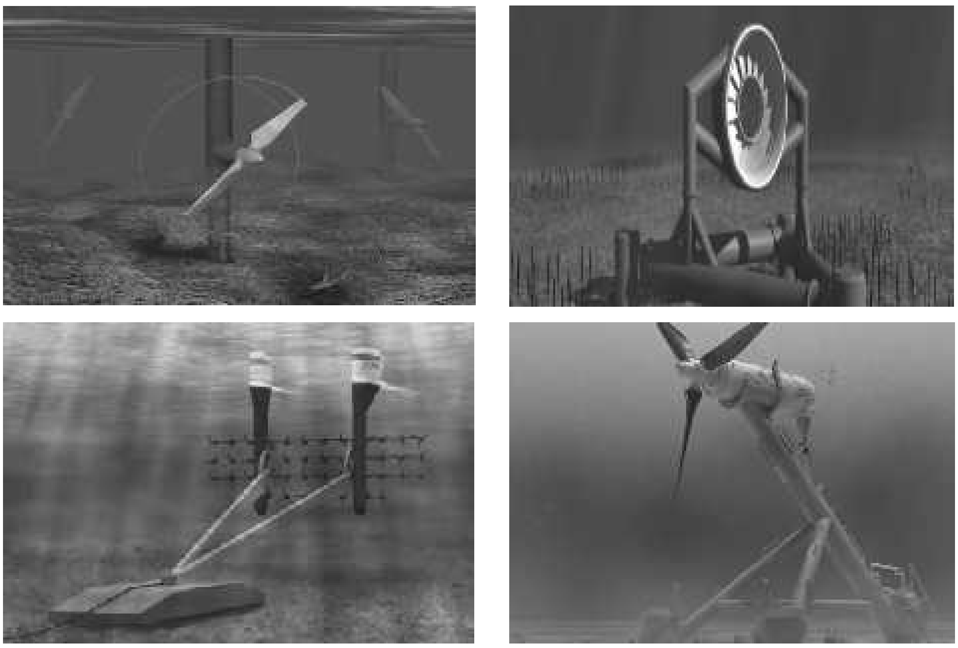

Fig. 4. Several Techniques (Design) Developed for Converting Tidal Energy into Electricity [Wikipedia 2016]

## PRESENT STATUS OF TIDAL POWER IN THE WORLD

Most of the power stations in the world that run on tidal power are barrage systems. Table 1 shows the lists of tidal power stations that are in operation as of August-2011 [Wikipedia 2015, Nova 2012 and Jinangxia 2015]. The Bluemull Sound Tidal Stream Array of United Kingdom of capacity 0.5 MW has been started in 2016 [Guardian 2016].

**Table 1. List of power stations (in operation)**

| Station | Capacity (MW) | Country | Commissioned Year |
|---|---|---|---|
| Annapolis Royal Generating Station | 20 | Canada | 1984 |
| Jiangxia Tidal Power Station | 3.2 | China | 1980 |
| Kislaya Guba Tidal Power Station | 1.7 | Russia | 1968 |
| Rance Tidal Power Station | 240 | France | 1966 |
| Sihwa Lake Tidal Power Station | 254 | South Koriea | 2011 |
| Strangford Lough SeaGen | 1.2 | U.K. | 2008 |
| Uldolmok Tidal Power Station | 1.5 | South Korea | 2009 |

Table 2 shows the list of tidal power stations that are only at a proposal stage. [Wikipedia 2015, Nova 2012 and Jinangxia 2015]. The Department of Trade and Industry has stated that almost 10% of the United Kingdom's electricity needs could be met by tidal power [Wikipedia 2015].

**Table 2. List of power stations proposed**

| Station | Capacity (MW) | Country | Year of commencement of construction |
|---|---|---|---|
| Garorim Bay Tidal Power Station | 520 | South Korea | |
| Incheon Tidal Power Station | 818 or 1,320 | South Korea | 2017 |
| Severn Barrage | 8,640 | United Kingdom | |
| Tugurskaya Tidal Power Plant | 3,640 | Russia | |
| Mezenskaya Tidal Power Plant | 12,000-8,000 | Russia | |
| Penzhinskaya Tidal Power Plant | 87,100 | Russia | |
| Skerries Tidal Stream Array | 10.5 | United Kingdom | |
| Tidal Lagoon Swansea Bay | 320 | United Kingdom | 2015–2017 |
| Dalupiri Blue Energy Project | 2,200 | Philippines | |
| Gulf of Kutch Project | 50 | India | 2012 |
| Alderney tidal plant | 300 | Alderney (UK) | 2020 |

Images of the MeyGen, Scotland, the world's five biggest stream type tidal power plants - 86MW [google/meygen 2015], are shown in Fig. 5. MeyGen Tidal Energy Project

Fig. 5. Image of the MeyGen Tidal Energy Project, Scotland - 86MW [google/meygen 2015]

located in the Inner Sound of the Pentland Firth off the north coast of Caithness, Scotland, is currently the world's biggest underwater tidal turbine power project under development. The tidal array project received offshore planning consent for its 86MW first phase development from the Scottish Government towards the end of 2013 [google/meygen 2015]. The second phase development of the project is expected to raise the total installed capacity to 398MW by 2020 [google/meygen 2015].

## PRESENT SCENARIO OF TIDAL POWER IN BANGLADESH

Bangladesh covers an area of 147,570 sq km which extends from $20^0\ 34'$ N to $26^0\ 38'$ N latitude and from $88^0\ 01'$ E to $92^0\ 41'$ E longitude; maximum extension is about 440 km in the E-W direction and 760 km in the NNW-SSE direction [http.Banglapedia 2015]. Recently Bangladesh has been assured rights over 118,813 square kilometers of territorial sea [http/prothomalo 2016 and Mahbubuzzaman 2010]. Bangladesh has a 200 nautical miles exclusive economic zone and access to open sea, thus preventing it from turning into a 'sea-locked country'. The southernmost part of Bangladesh is bordered by about 710 km long coast line of the Bay of Bengal, which has the continental shelf of up to 50 m depth with an area of about 37,000 $km^2$ with tidal height 2~8 m rise and fall [Quader 2010 and Mahbubuzzaman 2010].

According to Bangladesh Power Development Board, through 18 power stations with 50 units where 30 units are run by gas, only 2 units by coal, 5 units by hydro and the rest of them by oil in public sector and 27 power stations of 38 units under Public Private Partnership (PPP)) have the installed generation capacity of 12,780 MW [www.bpdb 2016]. But it is not enough to meet up our power demand. In our country most of the power stations are run by natural gas and the rate is very high in which the resource is being used. If this alarming rate continues it is a matter of time when the gas reserve will drastically fall [Haque 2010].

Natural gas lies at the heart of the country's energy usage, accounting for around 72% of the total commercial energy consumption and 81.72% of the total electricity generated [www.bpdb 2016]. In order to come out from this problem a quick solution envisaged by the government has started to use rental power plants which were temporary and quick and also thought out to be advantageous for the government.

Bangladesh has many available spots that are suitable for constructing a large tidal power plant at such coastal areas like Hiron Points, Sundarikota, Mongla, Char Changa, Cox’s Bazar, Golachipa, Patuakhali, Sandwip, Barisal etc. Table 3 shows the Probability of Power Generation from Tide in Bangladesh [Roy 2015].

**Table 3. Probable power generation stations and estimated output**

| Name of the Station | Tidal Range (m) | Output Power (MW) |
|---|---|---|
| Sandwip | 5.53 | 28.83 |
| Cox’s Bazar | 3.54 | 11.82 |
| Hiron Points | 2.90 | 7.93 |
| Golachipa | 3.55 | 11.88 |
| Patuakhali | 3.54 | 11.82 |
| Barisal | 3.9 | 14.34 |
| Sundorikota | 4.78 | 21.54 |
| Mongla | 4.8 | 21.72 |
| Char Changa | 5.6 | 29.57 |
| Total | | 176.64 |

But among all of them Sandwip is the best spot for barrage type tidal power generation. There is a geographical reason behind this: Sandwip is an island along the south-eastern coast of Bangladesh. Sandwip is a sub-division of Chittagong district located at $22^0$ $4905130^{'}$ N and $91^0$ $421185^{'}$ E which is situated at the estuary of the Meghna river on the Bay of Bengal and separated from the Chittagong coast by the Sandwip Channel [Roy 2015]. The entire island is 50 kilometres long and 5-15 kilometres wide with an area of 762.42 square kilometres [Roy 2015].

The tides at Chittagong Division are predominantly semidiurnal with a large variation in range corresponding to the seasons, the maximum occurring during the south-west monsoon. In 1984, an attempt was made by the Electronics and Electrical Engineering Department of Bangladesh University of Engineering and Technology to assess the feasibility of tidal energy in the coastal regions of Bangladesh, especially at Cox's Bazar and at the islands of Maheshkhali and Kutubdia. The average tidal range was found within 4-5 metres and the amplitude of the spring tide exceeds even 6 metres [Ullah 2012]. From different calculations, it is anticipated that there are a number of suitable sites at Cox's Bazar, Maheshkhali, Kutubdia and other places where permanent basins with pumping arrangements might be constructed which would be a double operation scheme [Rahman 2015; Paulson 2001].

## RESULTS AND DISCUSSION

### *Scope of Tidal Power in Bangladesh*

Bangladesh has a long coastal area which can be used for different purposes. Some recent researches have suggested that the coastal area is ideal for harnessing tidal power. Scope of tidal power in Bangladesh has been assessed on the basis of capacity of power production in the ocean area and two river basin areas of the state. The rivers of Bangladesh carry silt and water level is not the same throughout the year which is more clear from the tide table made by Bangladesh Inland Water Transport authority (BIWTA). According to them only two rivers [Karnaphuli of Chittagong and Possur of Khulna] shows scope of power production through tide. For that reason only the above mentioned two rivers tidal speeds have been considered in this study.

The tidal data of the Bay of Bengal and two rivers [Karnaphuli of Chittagong and Possur of Khulna] basin area is always recorded through several tide machines in different locations of the Bay of Bengal by the Department of Hydrography of Chittagong Port Authority (CPA) and BIWTA in Bangladesh for the purpose of ship transportation, fishing and territorial sovereignty. CPA has stated that the tidal speed or range is almost the same throughout the year in the Bay of Bengal in normal day condition. For this reason only two spots in the Bay of Bengal and another one in Possur Rriver of Khulna are considered:

i) Station-one: Basin of Possur River of Khulna [From BIWTA tide tables-2016]
ii) Station-two: Basin of Karnaphuli River [According to CPA, it is station 10 ]
iii) Station-three: Bay of Bengal [According to CPA, it is station 18]

as shown in Fig. 6 (map of Bangladesh) from where the primary tidal data that has been collected by CPA and BIWTA.

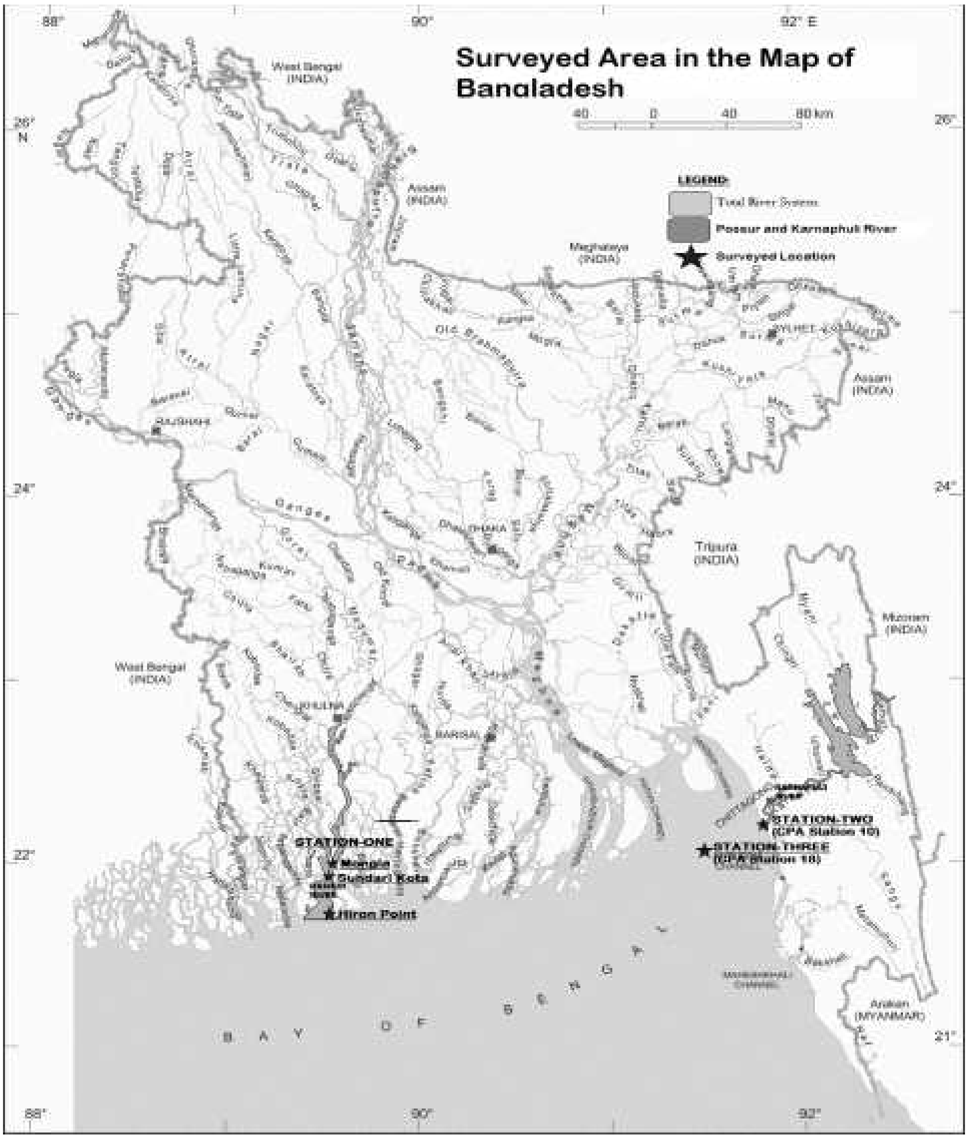


Fig. 6. Survey Area shown in Bangladesh [Banglapedia 2015].

In this research, the collected tidal stream data has been analyzed for power production and presented through several graphs. The possibilities of power production per square metre area with different times [hour, day and month] are shown in the following sections.

*Station-One [Possur River Basin at Khulna]*

The possibility of power production per hour per square metre area from January to December-2015 in the three different locations of Possur River is shown in Fig. 7:

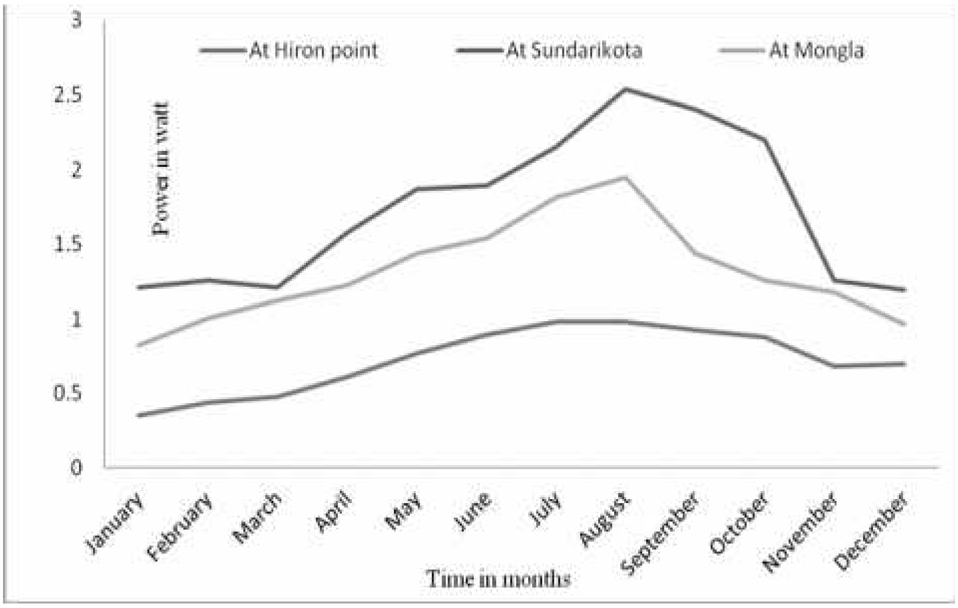


Fig. 7. Possible Power Production per Month at the Three Places (Hiron point, Sundarikota and Mongla) of Possur River Basin at Khulna from January to December-2015.

*Station-Two [According to CPA, it is Station 10]*

The possibility of power production per hour per square meter area during a day of January-2016 is shown in Fig. 8.

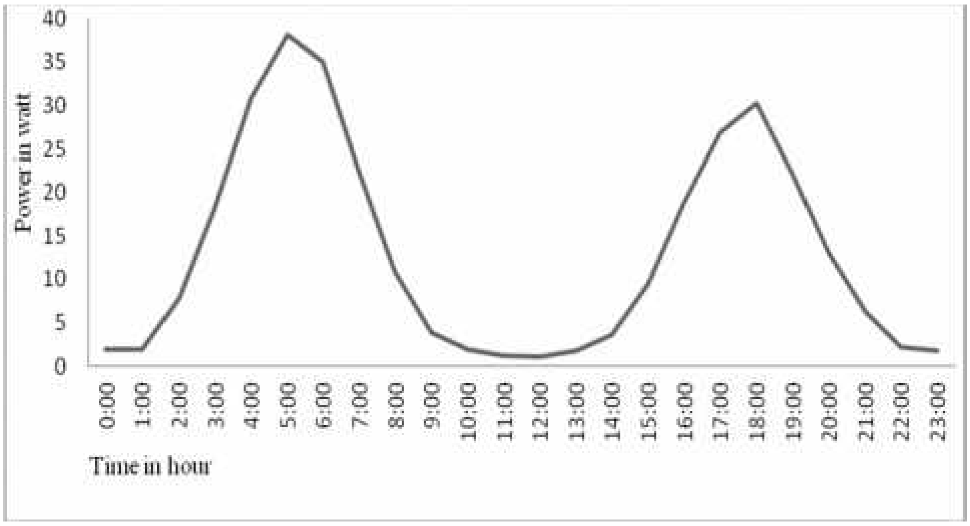


Fig. 8. Possible Power Production per hour at Station Two in January-2016.

The possibility of power production per hour per square metre area from January-2015 to June 2016 is shown in the Fig. 9.

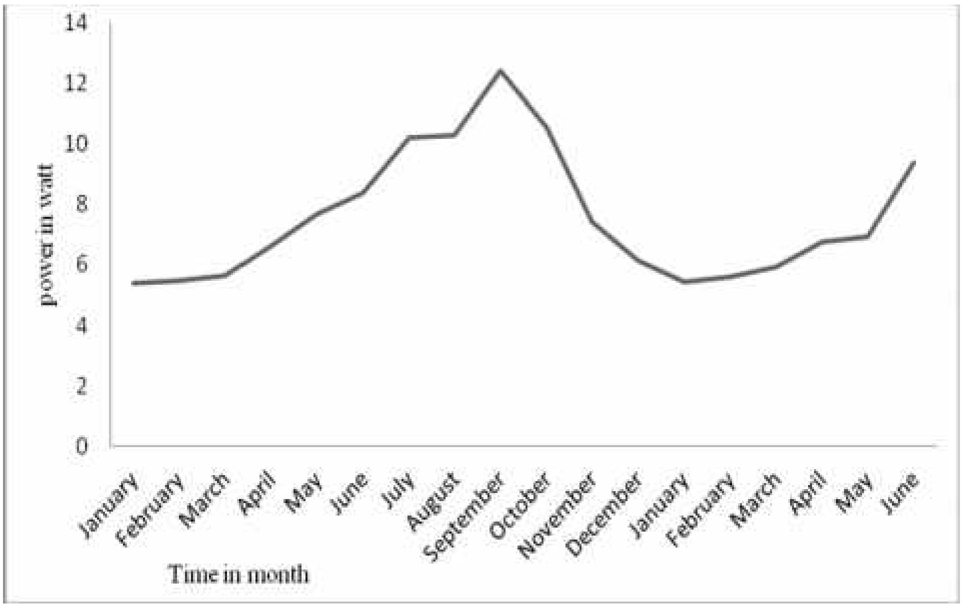


Fig. 9. Possible Power Production per month per square metre Area at Station Two from January-2015 to June 2016.

*Station-Three [According To CPA, It is Station 18]*

Possibility of power production per hour per square metre area during a day of January-2015 is shown in Fig. 10:

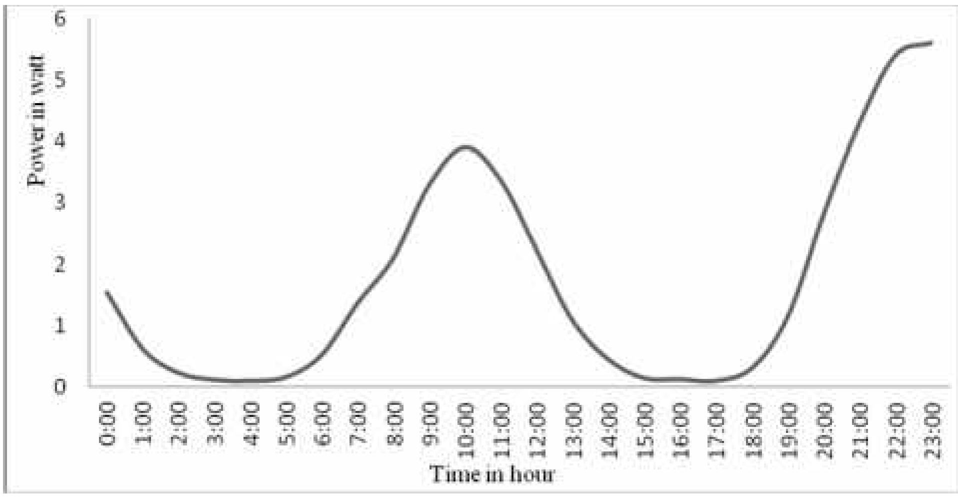


Fig. 10. Possible Power Production per hour in a day at Station Three in January-2015.

Possibility of power production per hour per square meter area January-2015 to June 2016 is shown in the Fig. 11:

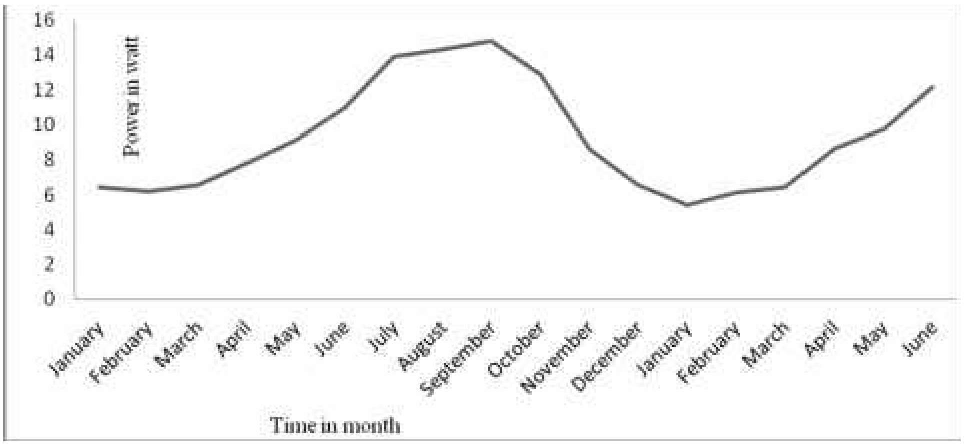


Fig. 11. Possible Power Production per hour at Station Three in January-2015 to June -2016.

Total average possible power production per square metre area from the above mentioned three stations for the year (January to December) 2015 is shown in the Fig. 12:

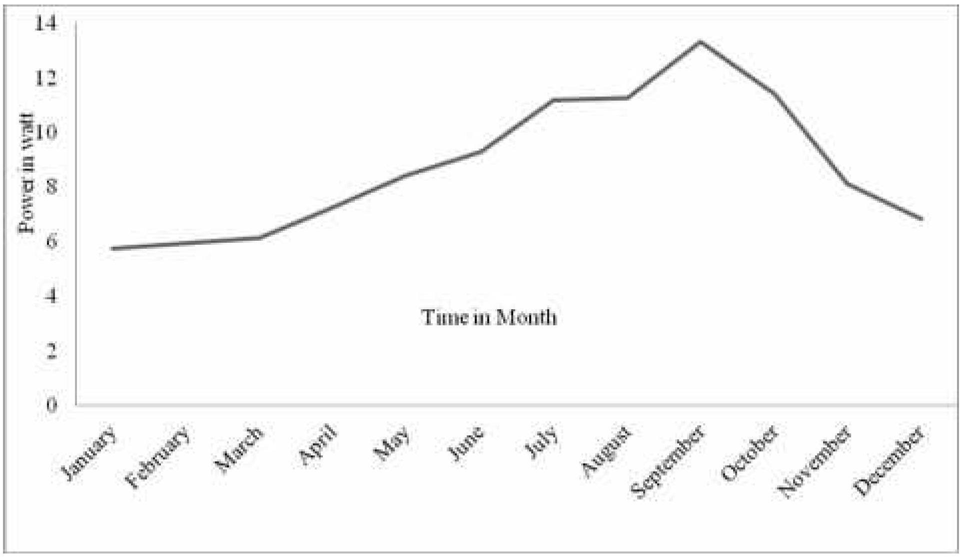


Fig. 12. Possible Average Power Production per month from Three Stations from January to December 2015.

The above given figures indicate that the power production is continuously increasing and decreasing with the variation of tides. For every six hours it is maximum and then goes to a minimum. The maximum and minimum power productions are directly related to the rising and falling of tides; i.e., this is a tide controlled power system.

The possibility of power production per square metre area shows that tidal power in Bangladesh has bright prospects. Since space is not a factor for Bangladesh in the Bay of

Bengal it could easily setup several stream type machines and by series connection the produced power would be considerable. It demands more study on assessments and economic feasibility. Finally, it could be concluded that tidal power can play a vital role in integrating as a new source of renewable energy to the national-grid power connection in Bangladesh.

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