An Analysis of the Potentiality of Tidal Power in Swandwip by Using One Way & Two Way Power Generation Technology: An Ideal Model

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Abstract- Swandip is an island along the south eastern coast of Bangladesh. Swandip is a sub-division of Chittagong district located at 22.490513°N 91.421185°E. It is situated at the estuary of the Meghna River on the Bay of Bengal and separated from the Chittagong coast by the Swandip channel. It has a population of nearly 400,000. There are 15 unions in Swandip. There are also as many as fifteen different wards, 62 mahallas and 34 villages on the Swandip Island. The entire island is 50 kilometres long and 5-15 kilometres wide with an area of 762.42 km2. Swandip has a very large potential for tidal power generation with a tidal variation of 5-6 m. A flood control barrage exists around the entire island and this contains 28 sluice gates. Considering each sluice gate is capable for one turbine and one generator, a very large amount of power can be generated from Swandip. The main objective of this paper is to utilize these sluice gates to find the potentiality of tidal power in Swandip by using one turbine for both one way & two way power generation technology & support the results by proper mathematical model. The mathematical regime proposed in this paper is very simple and effective and only associated with two variables, surface area of the basin and tidal variations. Based on this methodology the outputs are $0.028AR^2$ and $0.056AR^2$ for one way and two way power generation systems respectively. Because of the massive size of the oceans and the prediction accuracy of tidal, it is more preferable than any other renewable sources. While the discussion in this paper focuses mainly on Sandwip, the messages are relevant for other areas that has the potential to engage in Tidal Power.

Keywords- One way power generation, wo way power generation, basin area tidal variation.

1. Introduction

Now a day's tidal power is knocking the future for electricity production. The use of tidal power originated in around 900 AD when early civilizations constructed tide mills. These mills used the force of the tide to turn a waterwheel, which in turn was used to grind grain into flour [1,2]. Britain and France are using the tidal power concept since 11th century for milling grains [3,4]. The first study of large scale tidal power plants was initiated by the US Federal Power Commission in 1924 which would have been located if built in the northern border area of the US state of Maine and the south eastern border area of the Canadian province of New Brunswick, with various dams, powerhouses and ship locks enclosing the Bay of Fundy and Passamaquoddy Bay. Nothing came of the study and it is unknown whether Canada had been approached about the study by the US Federal Power Commission. The world's first large-scale tidal power plant (the Rance Tidal Power Station) became operational in 1966 [5, 6]. The facility is located on the estuary of the Rance River, in Brittany. With a peak rating of 240 Megawatts, generated by its 24 turbines, it supplies 0.012% of the power demand of France [7]. The second tidal barrage was put in service at Annapolis Royale Nova Scotia , Canada in 1982 in order to demonstrate the functioning STRAFLO turbine, invented by Escher-Wyss of Switzerland and manufactured by GE in Canada. This 16 MW turbine has some difficulties with clogging seals necessitating two forced outages, but has been functioning without interruption since its early days. There are approximately 10 small barrages scattered throughout the world, but they are not intended for commercial power generation. For example there is a 200KW tidal barrage on the river Tawe in Swansea Bay. China has several tidal barrages of 400KW and less in size [8]. Bangladesh has a long coastal zone, most of which is covered by embankments and sluice gates [9-11]. In most cases, the coastal area of Bangladesh is remote from population centers and has no electricity [10, 12]. But this coastal environment is very resourceful in terms of agricultural production, shrimp aquaculture and other business and commercial activities [13, 14]. At present this area has expanded shrimp aquaculture haphazardly, which is unsustainable [15]. This expansion has not been integrated with electricity supply [16,17] Some recent studies have suggested that coastal area of Bangladesh is ideal for harnessing tidal electricity from the existing embankments and sluice gates by utilizing small scale tidal energy technology [18, 19]. Lack of electricity is the main barrier to coastal development in Bangladesh [20]. Bangladesh can take tidal power generation opportunity as a challenge and can easily overcome at least some portion of the national power crisis. Sandwip is a self dependent island of Bangladesh, where agricultural products are exported to other parts of the country after local consumption. As the island is not connected to the national grid and also it has no major power plants in service, so majority of the people have no access to electricity. Presently, a 100 kW solar PV powered mini grid system has been installed under IDCOL finance which started operation in September 29, 2010 [21]. However, due to high price of electricity, the number of consumers is small and the plant runs less than 50% of its rated capacity which indirectly increases the per unit energy cost. Because of this high price, Solar Home System (SHS) are getting the popularity but the energy cost of that is also very high for such poor people. Tidal energy sources available in the island may provide electricity to the people at a much cheaper rate compare to this which may change the overall socio-economic condition of the people. This paper focuses on the available tidal energy and the possible power generation with mathematical model. The messages are also relevant for other areas that have potential to engage in Tidal Power.

2. Tidal Energy

Tidal energy is produced through the use of tidal energy generators. The large underwater turbines are placed in areas with high tidal movements and designed to capture the kinetic motion of the ebbing and surging of ocean tides in order to produce electricity. Tidal power has great potential for future power generation because of the massive size of the oceans and if there is one thing we can safely predict and be sure of on this planet, it is the coming and going of the tide. This is the distinct advantage over other sources that are not as predictable and reliable, such as wind and solar. Tides come and go for the gravitational force of the Moon and Sun and also the rotation of the Earth. The rotational period of the moon is about 4weeks, while the earth takes 24hours for one rotation which occurs a tidal cycle of around 12.5hours. Moreover, once the construction of the barrage is complete, the maintenance & running costs are very small and the life time of the turbines are generally very high for instance, around 30years. The above discussion suggests that tidal energy will be a preferred option over the other choices to meet the sky rocketing demand of electricity. There are two types of generation methodologies that ate available to use in Sandwip. They are (1) one way generation & (2) two way generation system.

2.1. One Way Tidal Power Generation System

This section of the paper provides a brief overview of the one way tidal power generation system with the view of graphical representation. In one way tidal power generation system one way turbine is used. In order to generate tidal power both sea water level and the river basin water level is considerable. From Figure-1 it is seen that sea water level is varying approximately sinusoidal. During high tide basin water level will follow sea water level very closely because sluice gates are open. When the sea and basin water levels are equal at point P1, both sluice gates and turbines are closed. It will be closed until a sufficient head H1 built up. When the heads built up sluice gates at point Q will be open and the basin water level will fall with duration of T. At point P1' there is not sufficient head H1' is present to produce electricity. As a result both turbine and sluice gates will be closed until the two levels are equal. The moment these two levels are equal again then next cycle will start. Hence total power generation duration will be T. The advantage of this kind of plant is only one turbine is required for the plant and the cost of the turbine, operation and maintenance are low. Turbine model required for this kind of plant is also industrially available. However, the disadvantage of this plant is the amount of power produced is less. Apart from its demerits this kind of power plant is widely used.

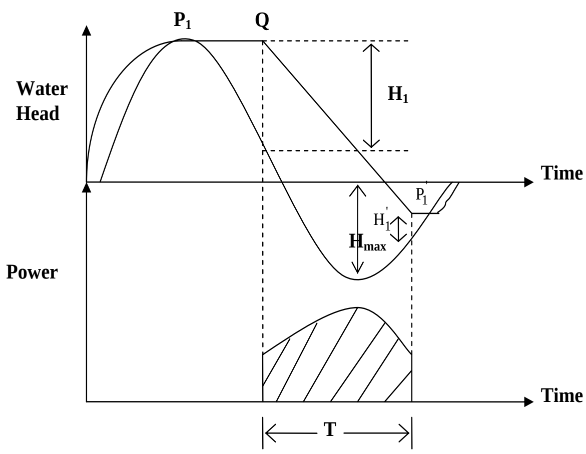

Fig. 1. One way tidal power generation system.

2.2. Two Way Tidal Power Generation System

This part of the paper provides a summary of the two way tidal power generation system with the help of graph, indicating the water flow and position of the turbines, basin water level & sluice gates. This section has also enlightened the benefits and hazards of this system and further modification idea for a better output. During high tide water will go through the turbine and therefore there should be a difference between the points L_1 and L_2. Water is passing into the basin from sea eventually basin water level will up. It will be rising until it reaches at point P_2 and a sufficient head build up. At point P_2 sluice gates will be open but turbines are closed until the basin and sea water levels are equal at point M_1. At point M_2 a sufficient head will build up for power generation and then at point M_2, turbines will open in opposite direction and basin water level will fall. The dive will last until it reaches at point P_2'. While there is not enough sufficient head to produce electricity (up to H_2'), turbines will be closed but sluice gates are open still at point Q_1. The moment they are equal and will be equal at point Q_1' sluice gates will be closed. After building the next head H_2' sluice gate opens and new cycle begins. From the power output curve it is seen that power duration will be T_1, T_2 and T_3. This obviously illustrates power generation will be higher compared to previous power generation regime. However, the problem is associated with the no load period (NLP). During the no load period the system does not produce any power. This is the foremost problem of two way tidal power Generation system. When no load period occurs there is load shedding for some time. This creates a problem in large tidal power plants. In case for the massive generation using two way tidal power generation system the no load period gets higher. Because of this problem two way tidal power generation system is normally not preferred and most preferable is one way tidal power generation system. However, two way tidal power generation system has the capability to produce larger amount of electricity which actually attracted the researcher to invent a regime to curtail the portion of no load period and eventually treat this method as a viable option to ensure the energy security.

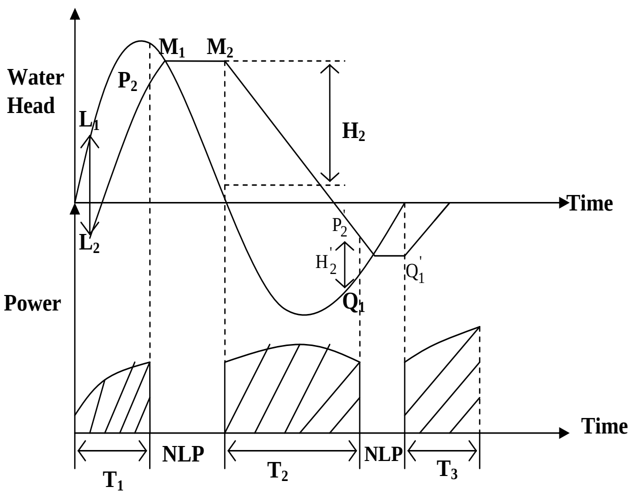

Fig. 2. Two way tidal power generation system.

3. Mathematical Model for One Way & Two Way Power Generation System

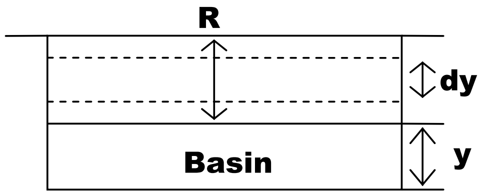

Fig. 3. Assumed Schematic for tidal power model for calculation

Let us consider,

Tidal variation $= R$

Surface area of basin $= A$

$dE = ygdm$; $dm =$ mass of water

$= yg.Ady\rho$

Where, $Ady =$ Volume of the water, $\rho =$ Density in dy.

$= \rho Ag.ydy$

Total Potential energy,

$$E = \int_0^R \rho Ag.ydy$$

$$\rangle\rangle E_{max} = \rho Ag \int_0^R ydy$$

$$\rangle\rangle E_{max} = ½ \ \rho Ag[y^2]_0^R$$

$$\rangle\rangle E_{max} = ½ \ \rho Ag R^2$$

$$\therefore E_{max} = ½ \times \text{mass of water} \times \text{tidal head}$$

$$1 \text{ Lunar day} = 24\text{hr} \ \ 48\text{min}$$

$$= 8.92 \times 10^4 \text{ sec}$$

For One Way Tidal Power Generation,

$$\therefore \text{Average power} = \frac{2 \times ½ \ \rho Ag R^2}{8.92 \times 10^4}$$

Where, $\rho = 1.025 \times 10^3 \text{kg/m}^3$ and $g = 9.81 m/s^2$

$$\therefore P_{max} = 0.113AR^2$$

$$P_{actual} = ¼ \ P_{max}$$

$$» \ P_{actual} = ¼ \times 0.113AR^2$$

$$\therefore P_{actual(One\,Way)} = 0.028AR^2 \quad ....(1)$$

For Two Way Power Generation,

$$\therefore \text{Average power} = \frac{4 \times \frac{1}{2}\, \rho A g R^2}{8.92 \times 10^4}$$

Where, $\rho = 1.025 \times 10^3\ \text{kg/m}^3$ and $g = 9.81\, m/s^2$

$$\therefore P_{max} = 0.225AR^2$$

$$P_{actual} = \tfrac{1}{4}\ P_{max}$$

$$\text{»}\ P_{actual} = \tfrac{1}{4} \times 0.225AR^2$$

$$\therefore P_{actual(TwoWay)} = 0.056AR^2 \quad \text{....(2)}$$

The significance of the output of equation- (1) & (2) are very effective and simple. After doing the mathematical part with the values of mass of water, tidal variation, surface are of basin and volume of the water; the outputs are $0.028AR^2$ and $0.056AR^2$ for one way and two way power generation systems respectively. It is indicating, if the surface area of the basin and the tidal variation is known then the actual power can easily be calculated. Previously we have discussed that, the prediction of tidal variations are quite accurate which eventually makes the equation more robust in case of the energy generation. In the following section using these equations and the data, the tidal power generaiton for Sandwip is illustrated, which actually explains the significance of these mathematical model.

4. Average Power Output Over the Year 2010 & 2011 using One way & Two way Tidal Power Generation system

To get the tidal variation, data are collected from BIWTA [22]. Basin area of the specific location is 4 Square KM [23]. An analytical analysis of power generation over the year 2010 & 2011 of Swandip area is given below:

Table 1. Average power output over the year 2010 & 2011

Year	2010				2011			
Month	Tidal Variation (m)	Basin Area (Square KM)	Power output P_{actual} (One Way) $= 0.028AR^2$ (MW)	Power output P_{actual} (Two Way) $= 0.056AR^2$ (MW)	Tidal Variation (m)	Basin Area (Square KM)	Power output P_{actual} (One Way) $= 0.028AR^2$ (MW)	Power output P_{actual} (Two Way) $= 0.056AR^2$ (MW)
January	3.86		1.67	3.34	3.77		1.60	3.18
February	4.01		1.80	3.60	3.76		1.58	3.17
March	4.58		2.35	4.70	4.52		2.29	4.58
April	5.01		2.81	5.62	5.11		2.92	5.85
May	5.09		2.90	5.80	4.78		2.56	5.12
June	5.22		3.05	6.10	4.73		2.50	4.48
July	5.48	4	3.36	6.73	4.9	4	2.69	4.80
August	5.4		3.27	6.53	5.1		2.91	5.20
September	5.4		3.27	6.53	5.27		3.11	5.5
October	4.78		2.56	5.12	4.99		2.79	5.58
November	4.98		2.78	5.56	3.76		2.58	3.17
December	3.45		1.33	2.67	4.24		2.01	4.03
Total (Average)	4.77		2.5	5	4.58		2.4	5

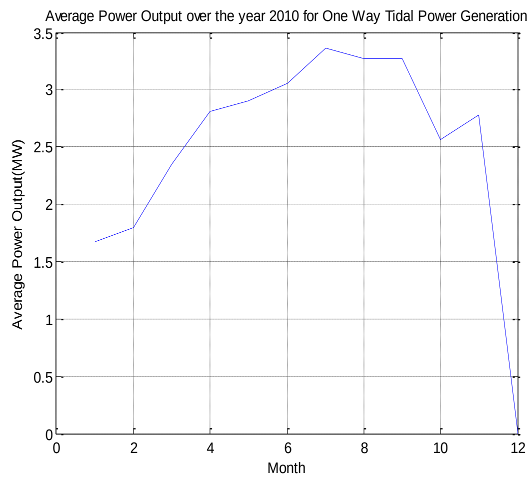

Fig. 4. Average power output over the year 2010 for One Way Tidal Power Generation.

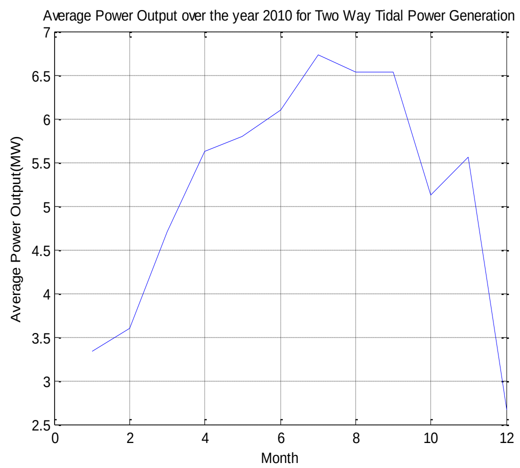

Fig. 5. Average power output over the year 2010 for Two Way Tidal Power Generation.

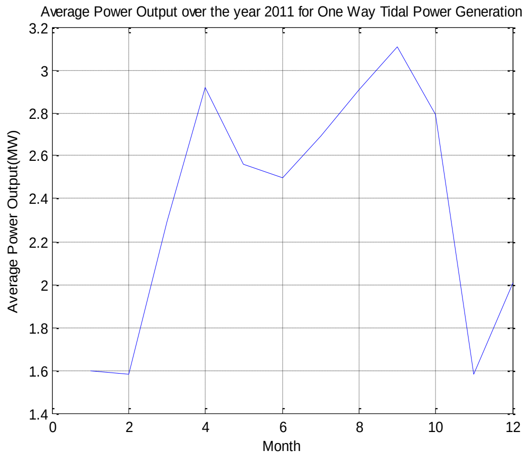

Fig. 6. Average power output over the year 2011 for One Way Tidal Power Generation.

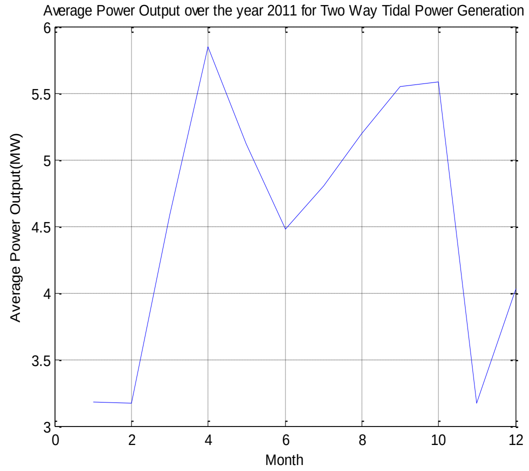

Fig. 7. Average power output over the year 2011 for Two Way Tidal Power Generation.

5. Conclusion

Tides play a very important role in the formation of global climate as well as the ecosystems for ocean habitants. At the same time, tides are a potential source of clean renewable energy for future human generations. Tidal Energy has the potential and prospect to find a place in the power industry. But with the conventional power plant technology being well established and continued to be in the main stream, tidal power plants are yet to gain commercial acceptance. In the near future with its attractive and lucrative features it may pose a competition with the conventional technologies. The conventional energy sources for many countries are almost at their peaks. Depletion of primary power sources will inevitably force people to replace most of the traditional energy sources with renewable energy in the future. Tidal energy is one of the best candidates for this approaching revolution. For Bangladesh, more detailed studies are needed to be carried out. Development of new, efficient, low-cost and environmentally friendly hydraulic energy converters suited to free-Sow waters, such as triple helix turbines, can make tidal energy available worldwide. Moreover, this type of machine can be used not only for multi-megawatt tidal power farms but also for mini-power stations with turbines generating a few kilowatts. Such power stations can provide clean energy to small communities or even individual households located near continental shorelines, straits or on remote islands with strong tidal currents.

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