Potentiality of Small-Scale Hydro Power Plant Using the Kinetic Energy of Flowing Water of Gumoti & Surma River of Bangladesh: An Energy Odyssey

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Abstract- Bangladesh is progressing through a phase of development where automation is the key to its Economy. At this stage electricity is very important for the advancement of this country. Now-a-days it becomes very challenging to meet the required demand of the country. This is because of increasing price of fuel in the world market and also the unavailability of fuel. Under these circumstances renewable energy can be a great prospect. There are a good number of rivers consisting sufficient flow of water in Bangladesh. These rivers flowing water can be a great source of kinetic energy and utilizing this kinetic energy of flowing water Hydro Electricity can be produced. In this paper the real life practical data of Gumoti & Surma rivers were analysed. The main purpose is to utilize the maximum velocity of flowing water to rotate the turbine shaft. A system is introduced that does not need the Dam or Reservoir to produce Electrical Power and is observed that, 18.834MW-hr & 14.804MW-hr worth of energy can be produced annually from Gumoti & Surma rivers respectively. This amount of power can be very useful for these rivers nearby inhabitants as they are still out of national grid range. This paper has two parts. The first part illustrates the power crisis scenario of Bangladesh and why it is necessary to seek alternate resources and the second part describes about one viable solution to solve this crisis to some extent.

Keywords- Small-scale Hydro, Electricity, Renewable Energy, Gas, Gumoti, Surma, River.

1. Introduction

Energy is the most fundamental sector for the progression of a nation. The production of energy is going on from many years for the need of energy in all around the world but the true scenario is that the whole world is currently facing dreadful energy crisis in spite of numerous energy sources. The current demand for energy exceeds the available resources and this gap is projected to widen significantly in the imminent future and Bangladesh is no exception [1]. The per capita energy consumption in Bangladesh is 252 kWh which is very low compared to other developing countries [2]. Electricity is a key ingredient for the developement of the most economic activities of every country. In recent years, due to power supply shortage the pace of establishment of essential physical infrastructures, building up of new power plants and industrialization in the country has slowed down. The percentage of population under the coverage of electricity supply is only around 49% and in the rural areas, where more than 70% of the

population lives, only 25% have electricity. Bangladesh has the installed range of the power plants of around 8000MW for meeting the demand of around 7000MW. However due to failure in the proper fuel management, increase in energy demand and lack of infrastructures in the last few years the whole country is suffering from 1000-1800MW of electricity. Around 1000 MW of power could not be generated from the public power plants due to shortage of gas as fuel and so on [3]. It is also notable that energy demand is much higher during irrigation period than the other period. The energy production of Bangladesh is mainly dependence on fossil fuel but the resources of fossil fuel are limited and it's using results in global warming [4]. Thereupon, to encounter the growing energy demand, the government of Bangladesh has enhanced focus on renewable energy in the past decade. Bangladesh is endowed with vast renewable energy resources such as biomass and solar energy. Besides, hydro and wind power can be considered as potential renewable energy resources. Harnessing these resources appears to be a promising solution for improving the quality of life of rural villagers [5]. At present, Bangladesh is producing only 300 MW of electricity including hydroelectricity from its renewable energy sources. As potential renewable energy resources, Hydropower will have a significant important role in the approaching future. Hydropower is the largest renewable energy source, and it produces around 16 % of the world's electricity and over four-fifths of the world's renewable electricity. Currently, more than 25 countries in the world depend on hydropower for 90 % of their electricity supply (99.3 % in Norway), and 12 countries are 100 % reliant on hydro. In developing countries, another advantage of hydropower technology is that it can have important multiplier effects by providing both energy and water supply services (e.g. flood control and irrigation), thus bringing social and economic benefits [6]. Bangladesh has one hydro power plant in Kaptai, Chittagong having generation capacity of 230MW. That means this technology is not premature for Bangladesh. On the other hand, International research confirms that the emission of greenhouse gases is substantially lower in the case of hydropower compared to that generated by burning fossil fuels. From the economical point of view, the utilization of half of the feasible potential can reduce the emission of greenhouse gases by about 13%; also it can substantially reduce emissions of sulphur dioxide (main cause of acid rains) and nitrogen oxides [7].

2. Location, Topography and Economy of Bangladesh

The People's Republic of Bangladesh, is located between 200 34' and 260 38' north latitude and between 880 01' and 920 41' east longitude [8]. Bangladesh has an area of 147,570 square kilometers and extends 820 kilometers north to south and 600 kilometers east to west. On the south is a highly irregular deltaic coastline of about 580 kilometers, fissured by many rivers and streams flowing into the Bay of Bengal. The country is divided into 7 divisions (regions): Dhaka, Chittagong, Rajshahi, Rangpur, Barisal, Sylhet and Khulna. The population of Bangladesh is reached at 152.51 million which made the country most densely populated [9]. There are almost 310 rivers and their tributaries crisscross the country of which the major rivers of the country are Padma (Ganges), Jamuna, Meghna, Bramhaputra, Surma and Karnafuli. More than 90% of Bangladesh's rivers are originates outside the country. Three major types of landscapes are found in Bangladesh: floodplains (80%), terraces (8%), and hills (12%). Excepting the eastern hilly region, almost all of the country lies in the active delta of three of the world's major rivers: the Ganges, the Brahmaputra, and the Meghna (GBM Out of these, 57 rivers is Tran boundary, which originates from India and Myanmar. Apart from the south-eastern region, other parts of the country are mostly flat in nature [10]. During the annual monsoon period, the rivers of Bangladesh flow at about 140,000 cubic meters per second, but during the dry period they diminish to 7,000 cubic meters per second. The north western section of the country, drained by the Teesta River, is somewhat higher and less flat, but the only really hilly regions are in the east, notably in the Chittagong Hill Tracts to the southeast and the Sylhet District to the northeast. Near the Myanmar border in the extreme southeast is the Keokradong, which, at 1,230 m (4,034 ft), is the highest peak in Bangladesh [11]. The climate in the country maintain a major three-season cycle: Summer (March-May), rainy season (June-September) and winter (December-February).The standard maximum and minimum temperatures are 26.5 and 13.9°C respectively in winter. On the other hand, the corresponding respective values in summer are 32.60C and 22.4°C. The annual highest and lowest temperature is 30.40C and 21.20C respectively and while rainfall is 203 mm [12].

Bangladesh is a developing economy; since 1996 the economy has developed at a pace of 5-6% per year. More than half of the country's GDP is generated from the service sector. However, more than 40% of Bangladesh's population is engaged in agriculture. Presently, production and export of garment makes a significant contribution to the economy of the country [13]. At present, Bangladesh has a GDP of total $105.00 billion (at the rate of 2010-11), whereas GDP per capita is $775 and GDP growth rate is 6.32% [13-14]. GDP grew 6.7% in fiscal year 2011 compared to 6.1% in the previous year.

A pie chart showing the contribution of different sectors in the country economy is given below. Figure 2, is a pictorial representation of the Bangladesh map showing different rivers throughout the country is illustrated for a better comprehension about the potentiality of hydro energy in Bangladesh.

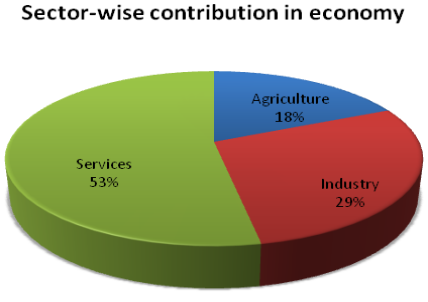


Fig. 1. Contribution of different sectors in GDP of Bangladesh [15]

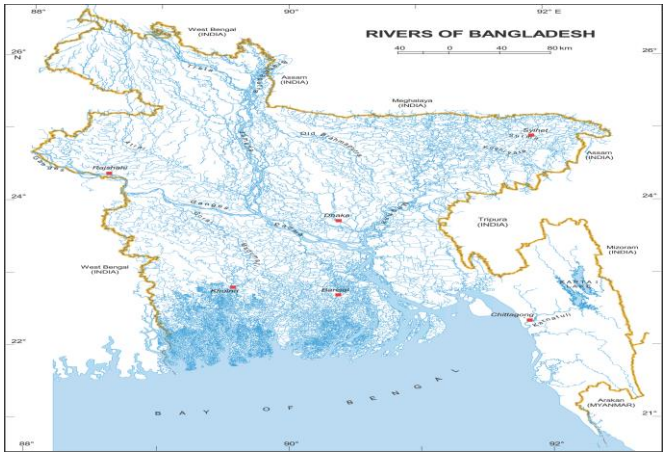


Fig. 2. Rivers of Bangladesh [16]

3. Present Power Generation Scenario in Bangladesh

This segment of the paper demonstrates a concise overview of the status of power generation in Bangladesh. With the rapid growing energy demand it is being difficult for Bangladesh to meet required power generation. It is also observed that the demand for electricity has been increased with a rate of 5.43 percent per year whereas, the generation of electricity with a rate of 5.37 percent per year between 2007 and 2011. The lower increasing rate of generation (5.37 percent) than that of the demand (5.43 percent) has accelerated the rate of load shedding which has been increased at a rate of 6.72 percent per annum during the same period [17]. Though in the mean time a large number of different types of power plants synchronized them with the national grid along with public and private sector, Bangladesh still facing scarcity to conform with the energy demand. In FY 2012, Generation capacity (both public and private) has increased to about 8300 MW.

Table 1. Power Generation capacity (MW) as on July, 2012.

Public Sector	
	Generation Capacity (MW)
BPDB	3600
APSCL	682
EGCB	210
RPCL	52
Subtotal	4544(55%)
Private Sector	
IPPs	1297
SIPPs(BPDB)	99
SIPPs(REB)	226
15 YEAR Rental	169
3/5 YEAR Rental	598
Quick Rental	1382
Subtotal	3771(45%)
TOTAL	8315

According to new plan of the Government, targets for additional 12473 MW by 2015 and 15273 MW by 2016 have been set up. Under this plan, 500 MW imported electricity will be added to the national grid by 2013. Based upon a preliminary study by Bangladesh Power Development Board (BPDB) the anticipated peak demand would be about 10,283 MW in FY2015, 17,304 MW in FY2020 and 25,199 MW in 2025. According to PSMP- 2010 Study year-wise peak demand forecast is given below:

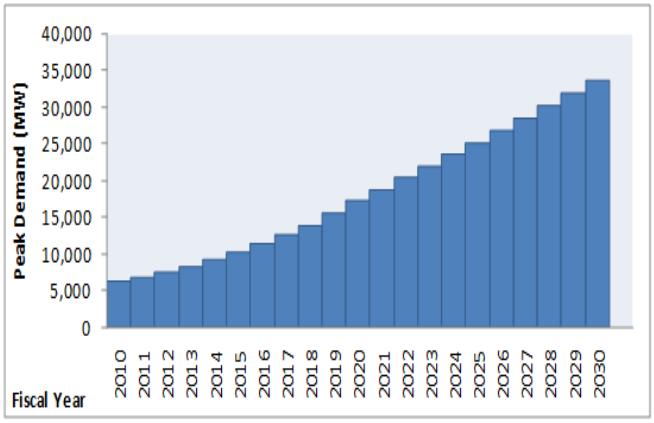


Fig. 3. Study year-wise peak demand forecast [18]

While the demand for electricity is increasing, the production capacity of existing power stations is falling. The potential deficit/surplus of electricity during 2011 to 2016 is shown below:

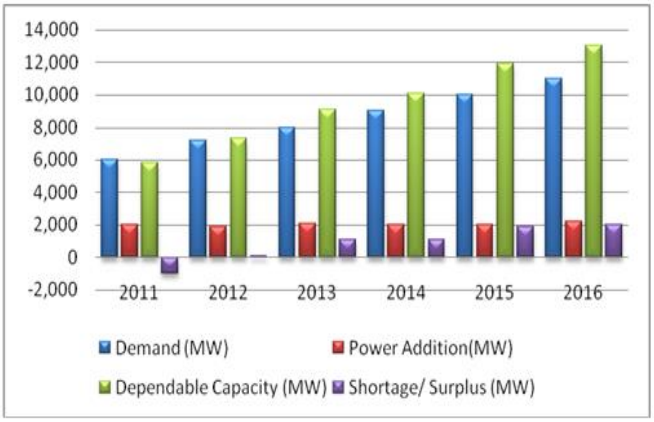


Fig. 4. Probable power shortage/surplus (2011-2016) [19]

But the literal scenario of progressing power generation is different than the projected generation by the BPDB due to crisis of fuel, ill management and corruption.

4. Fuel crisis and Renewable Energy Resources in Bangladesh

This part of the paper explains ongoing fuel crisis in Bangladesh and its renewable energy sources situation. Electricity is produced from domestic gas and a little percentage through hydro power in the Eastern part of Bangladesh. Whereas in the Western part of the country, Coal and imported liquid fuel is used for generation of electricity. A pie chart presenting the contribution of different fuels in the Total Generation Capacity of 8351 MW is shown below:

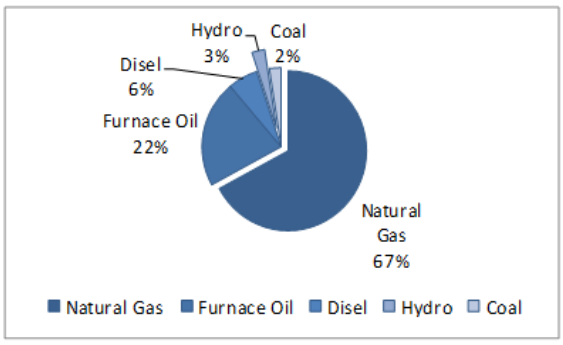


Fig. 5. Installed Capacity by different resources as on July, 2012 [20]

A good number of generation units have become very old and have been operating at a much-reduced capacity. As a result, their reliability and productivity are also poor. The major fuel source for power production is the natural gas in Bangladesh. Therefore, due to the shortage of gas supply, it is being difficult to run some power plants of the country as per their usual generation capacity and thus some are went out of order [21]. Also in the country, gas is not only being used in electricity generation but also used in different purposes. As an alternative fuel to natural gas, coal can be extensively used. But Bangladesh is densely populated country it is very troublesome to rehabilitate the people in the mine areas. Moreover, coal burning is the main point of CO_2 emission which now-a-days is a burning discussion. In addition, Furnace oil is accounted for slightly less than 22% energy generation. Although there is no Oil field in Bangladesh, the only way to fulfill the existing demand is to import from International market. As a result the Government needs to share a huge subsidy each year. The consistent rise of oil price in International market and to reduce the subsidy Government has impelled to increase the price of all types of oil including diesels for four times in the year 2011 [22]. Furthermore, Government is trying to build a Nuclear power station with the help of the Russians; however it is still a question about the massive financial cost for this sort of power plant.

As an alternative of mainstream energy, the government of Bangladesh is now looking to explore the potential of low cost renewable energy sources. Out of various renewable sources solar, biomass, wind energy and hydro-power can be effectively used in Bangladesh. However, the growth of renewable energy in the country is very low. Compared to the other countries worldwide, Bangladesh ranks at 109 for total installed renewable energy capacity with 0.02% of an estimated total world renewable energy capacity of 1,322,347 megawatts [23]. To lessen the energy crisis and develope people's quality of life, therfore, the government should immediately take initiatives to extend its renewable energy sectors and implent more policy to the development of the power sector considering its importance in the overall development of the country.

5. Hydro Energy Scenario & Prospect of Small- Scale Hydro in Bangladesh

Hydropower is an eco-friendly clean power generation method based on the natural water cycle. The concept of generating electricity from water has been around for a long time and there are many large hydro-electric facilities around the world [24]. Hydropower is usually classified by size (generating capacity) and the type of scheme (run-of-river, reservoir, pumped storage) [25]. Figure 6 is showing different types of hydro power genration system around the globe.

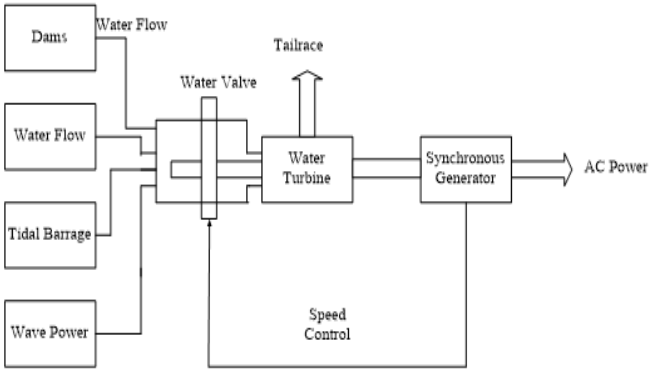


Fig. 6. Hydro electricity power generation system

To true extent the scope of hydropower generation is very limited in Bangladesh because of its plain terrains except in some hilly region in the northeast and southeast parts of the country. However there are lot of canals, tributaries of main river like Karnafuli, Shangu, Matamuhuri as well as tiny waterfalls having good potentials for setting up mini/micro hydropower unit in Chittagong Hill Tracts(CHT) region [26]. The scientific community agrees on the great potential presented by small-scale and tidal stream hydro power plants (plants that utilize natural water flows but have no dams or regulation capabilities). Like large-scale hydro power, electricity generation in small-scale plants is renewable and inexpensive [25]. Karnafuly Hydro Power Station with a generating capacity of 230 MW is the only hydropower station in the country. The power station has 5 units. The first unit was build in 1962 and the last in 1988. It is operated by Bangladesh Power Development Board (BPDB). Now, BPDB is considering, attaining an additional 100W power during the rainy season by the extension of Karnafuly Hydro Power Station. Apart from Karnafuly Hydro Power Station, Kaptai, two other prospective sites, for hydropower generation at Sangu (140MW) and Matamuhuri River (75MW), are identified by BPDB. The first micro hydropower unit of 10 kW has been installed in a village of Bandarban through private initiatives. The project is providing electricity to 140 families in the village and to a Buddhist Temple [27]. Other than these, several reconnaissance surveys and studies have been conducted in the past for installing small hydro power plants in the country, but so far only one hydro power plant has been installed. SRE under LGED has successfully demonstrated first micro-hydro power unit at Bamerchara, Chittagong. Its installed capacity was 10KW but due to inadequate water head about 4KW power was generated

[24]. The Water Development Board (BWDB) and Power Development Board (BPDB) carried out a joint study on Micro-Hydro power potential in the country. In Table- 5 it is given in detail.

Table 3. Potential small hydro sites identified from the study

District	River/Chara/Stream	Potential of Electrical energy in kW
Chittagong	Foy's Lake	4
	Choto Kumira	15
	Hinguli Chara	12
	Sealock	81
	Nikhari Chara	26
	Budiachara	10
Chittagong Hill Tracts	LungiChara	10
Sylhet	Madhab Chara 1500ft. from fall	78
	Ranga pani gung	616
	Bhugai-Kongsa at 2 miles U/S. of Nalitabari P.S.	69kw for 10 months & 48 kw for 2 months
Jamalpur	Marisi at Duka-bad near Jhinaigati Thana Head Quarter	35Kw for 10 months & 20kw for 2 months
Dinajpur	Dahuk at Burabari	24
Rangpur	Buri Khora Chikli at Nizbari	32
	Fulkumar at Raiganj Bazar.	48

Therefore as an alternative, the low head of water fall and current of river water may be used for harnessing hydro-power as a good numbers of rivers of Bangladesh are flowing with consistent water velocity throughout the year. Current of these river water could be used as a promising renewable energy source. The run-of -river schemes have little or no storage, although even run-of-river schemes without storage will sometimes have a dam. The operation regime of run of-river plants, with and without pondage, depends heavily on hydro inflows [25]. In Bangladesh about 1.4 trillion cubic meters of water flows through the country in an average water year. Major rivers of the country have a high rate of water flow of about 5 to 6 months during monsoon season. Currently, the three main rivers that flow through the flat plains of India and Bangladesh (the Ganges, Brahmaputra and Meghna) discharge an average of $2.5\times10^4 m^3 s^{-1}$ to the Bay of Bengal. These rivers flow rate or moving water are source of kinetic energy. By utilizing this kinetic energy we can produce the Hydroelectricity. Therefore, run of rivers of the country could use as an effective renewable energy source. This amount of power can be very useful for these rivers nearby inhabitants as they are still out of national grid range. In this paper, as a potential source of Hydro power using the kinetic energy of flowing water various data of the Gumoti and Surma rivers has been analyst and then calculated the attainable power.

5.1. Mathematical Model

The maximum power output from a turbine used in a run of river application is equal to the kinetic energy of the water impinging on the blades. Taking the efficiency η of the turbine and its installation into account, the maximum output power P_{max} is given by,

$$P_{max} = ½ \eta\rho QV_2$$

Here v is the velocity of the water flow (m/s) and Q is the volume of water flowing through the turbine per second (m^3/s) and ρ is the Water density $=10^3$ Kg/m^3.

Q is given by, Q = Av

Here, A is the swept area of the turbine blades (m^2)=πr^2.

Thus, The maximum available power in the water flowing at mean velocity V through a water rotor blade with sweep area A at any given site [28] can be estimated as follows-

$$P_{max} = ½ \eta\rho AV^3 \quad \text{.....(1)}$$

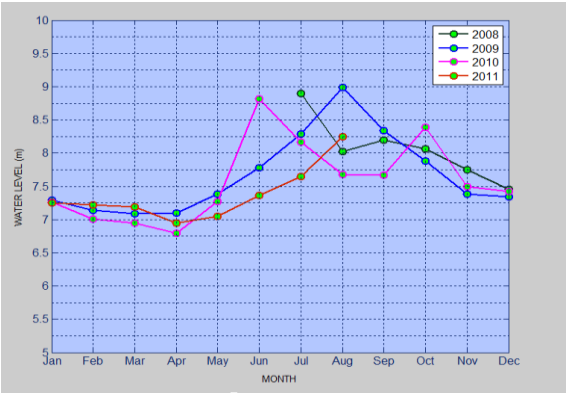
Taking into account the other factors of water turbine only 10-30% of the power of the water is ever actually converted into usable electricity efficiency of this type plant found high as much as 95%.

Hence, the power coefficient needs to be factored in equation (1) and the extractable power from the run of river is given by:

$$P_{max} = ½ \eta\rho AV^3 * C_p$$

Here, C_p is the power coefficient and generalized value for C_p is in a range of 0.35 to 0.45. However, it depends on the radius of the blade of turbine and water velocity. For the simplicity of the calculation, in our study, the value of C_p has taken as 0.4.

5.2. Results & Discussion



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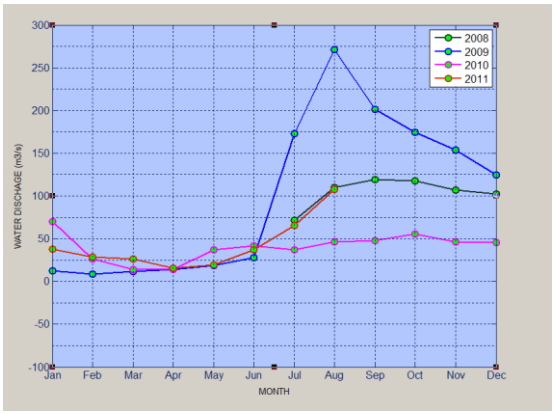

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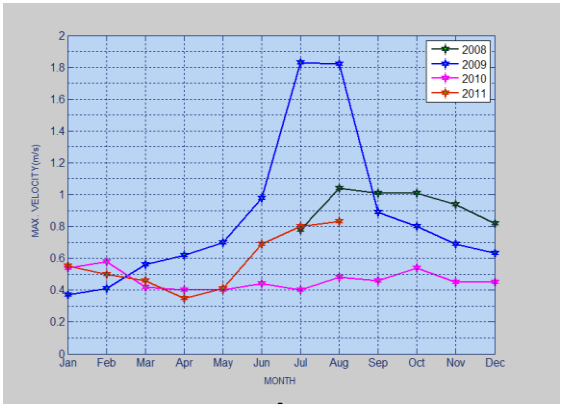


(c)

Fig. 7. a) Average Water Level of the river Gumoti at different months of the years. b) AberageWater discharge of the river Gumoti at different months of the years. c) Average Maximum water velocity of the river Gumoti at different months of the years.

Here, all the calculations have been done based on the real life data taken from the Water Development Board of Bangladesh.

From the data we find total Maximum velocity, V = 26.37 m/s

Average velocity, V = 26.37/34 = 0.78 m/s [The maximum velocity is divided y 34 because we dealt with 34 set of data]

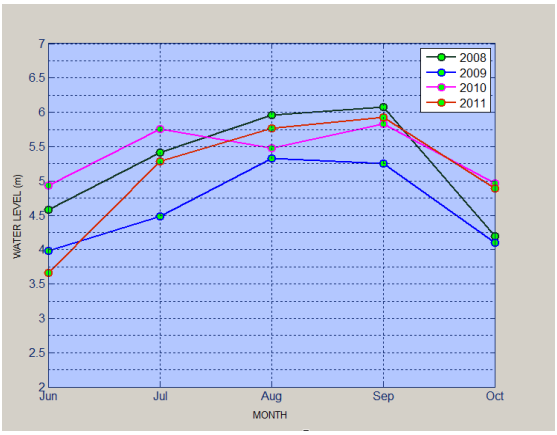
Assume that, the radius of the water turbine r = 3 m

Input Power : P = ½* ρAV^3 » 6.71 KW

Operational Calculation: P_m = ½* ρAV^3*Cp » 2.684KW

Output or Electrical Power: P_e = ½* ρAV^3*C_p * η » 2.15KW [η=80%]

Energy : E = 2.15 *24*365 KWhr = 18.834 MWhr (per Annum)



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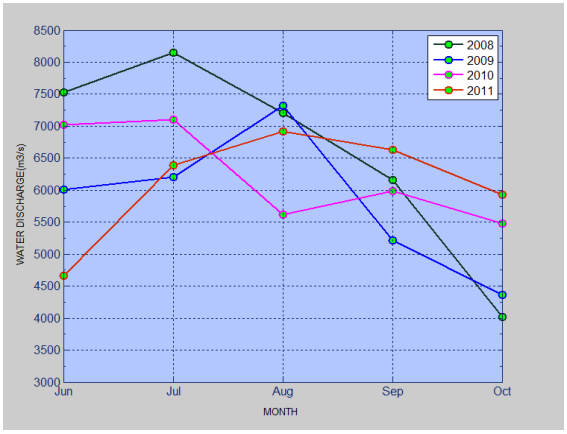

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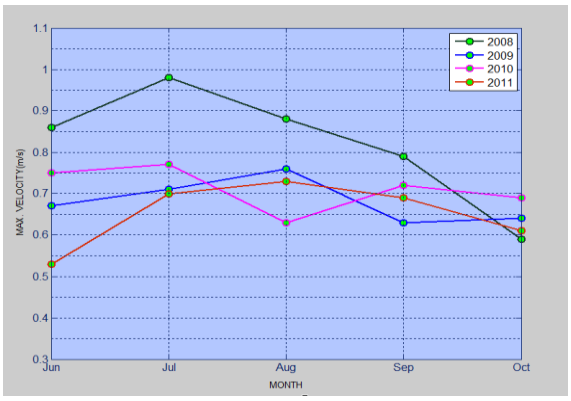

(c)

Fig. 8. a) Average Water Level of the river Surma from June to October. b) Average Water Discharge of the river Surma from June to October. c) Average Maximum Water velocity of the river Surma from June to October.

Here, all the calculations have been done based on the real life data taken from the Water Development Board of Bangladesh.

Total Maximum velocity, V = 14.33 m/s

Average velocity, V = 14.33/20 = 0.72 m/s [The maximum velocity is divided by 20 because we dealt with 20 set of data]

Input Power: P = ½* ρAV^3 » 5.28 KW

Operational Calculation: $P_m = ½* \rho AV^3 *» 2.112$ KW

Output or Electrical Power: $P_e = ½* \rho AV^3 *Cp * \eta » 1.69$ KW [η=80%]

Energy, E = 1.69*24*365 KWhr = 14.804 MWhr (per Annum)

It is observed from the calculation that 18.834MW-hr & 14.804MW-hr worth of energy can be produced annually from Gumoti & Surma rivers respectively. The attainable energy is based on assumption of steady water flow with averaged water flow velocity, however it will not impact the actual energy production as, the real data illustrates identical steady water flow through these rivers. There are a good number of rivers with sound water flow in the country could be considered for electricity production to install small-scale hydro power plant. The basic components and technologies in case of run-of-river are likely large hydro power plants. The main plus in this type of power plants is less expense as this sort of power station does not need a series of reservoir to construct. Moreover, this type of power plant could be used as distributed systems installed over a large river basin area with compared to large hydro power plants. Consequently, environmental effects for run-of-river power generation system are minimal. However, a detailed analysis on the type of turbine, its impact on natural water flow of the river, ecosystem and nearby inhabitants would only disclose the true drawbacks of this type of power plant.

There are more than 87,319 villages in Bangladesh, and most of them are unconnected to the national grid thus they do not have access to electricity. All the crops of the country are produced from these villages. Due to rise in fuel price and having not excess to electricity, farmers are experiencing difficulties to irrigate. Consequently, the production of crops in the country are limiting day by day. It is only 10% of our rural householders are connected on the national grid. Therefore the amount of power generated from small-scale hydro plant will be beneficial for the irrigation.

However, with the generated power, electrification by grid connection or sub-station can only reach a small community in the rural areas. As a result, though generation cost is low in hydro power, transmission and distribution cost would be highly expensive. Also, there are a lot of factors need to take into account to set up a hydro power plant. Availability of sufficient water flow is top on them. It is observed that more than 90% rivers of the country are originated from neighboring countries. Therefore it is also suggested that water sharing with the neighboring country is the crucial fact to maintain constant generation of hydroelectricity throughout the year. Without the cooperation of neighboring country with the sharing of downstream water the hydro power generation would be interrupted.

6. Conclusion

The paper presents contemporary energy and fuel crisis scenario in the country with an analysis of small-scale hydro power potentiality using the kinetic energy of water in the country. The demand for power will substantially rise in future if the rest of the population is brought under the electricity coverage and the agenda for high growth through industrialization and investment to realize the Vision is pursued in the country. Bangladesh is progressing through a phase of development where automation is the key to its economy and business. As the country continues to industrialize the importance of power generation and electricity supply has become a key Government priority. Consequently, a range of efforts need to be carried out in order to produce electricity from renewable energy by reducing the dependency on natural gas for power generation and to ensure diversification of the energy resources as well. Though Bangladesh is beatified with ample amount of gas and coal but due to lack of appropriate vision and political commitment and measures to extract these, the country failed to mitigate energy crisis.

The preceding estimation suggests that, the calculated power from the run of river water can be used as a pressing renewable energy source of electricity generation as it promises sustainable energy, which may solve power crisis throughout the country to some extent. Also analysis of the given rivers indicates that Gumoti and Surma has a good prospect of small-scale hydro energy along the other rivers of Bangladesh. Moreover, run of river projects are much less costly than dams because of the simpler civil works requirements. In addition, they have high predictability, water flow predicted years in advance, unlike wind. Apart from these it is highly efficient as much as 90% in extremely low costs per kilowatt-hour whereas coal/oil efficiency is 30% and the technology has a potential life of more than 40 years. Other than these facts units of hydroelectric power are able to start up quickly even while it is used for 1 or 2 hours unlikely thermal power plants where several hours or more start up time take. They are, however, susceptible to variations in the rainfall or water flow which reduce or even cut off potential power output during periods of drought. Energy and economic growth are affiliated with each other and the uttermost way to sustain the economic progression is to insure sufficient generation of power. A country born through sacrifice of so many freedom loving patriots does not deserve to be treated like that. Therefore, the Government should more facilitate the development of the renewable energy sector so that private entrepreneurs come forward to take the initiatives to invest in renewable energy technologies. This paper is one such odyssey towards securing the national energy demand.

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