# A COMPREHENSIVE STUDY OF POTENTIAL ZONE AND LOW HEAD HYDRO SYSTEM IN BANGLADESH

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***Abstract*—Running down the fossil fuel and the incapability to meet up the increasing demand of electricity is some problem for the economic development of Bangladesh. The country is getting trouble due to carbon emission of developed country. Bangladesh has several rivers and canals providing off- grid network. This paper focuses on the potential of micro-hydropower plant in Bangladesh. This paper also replicates on energy scenario of Bangladesh. To progress the economy of Bangladesh it is need to explore green energy providing good investigation on establishment of extensive micro-hydropower plant. The most likely sites for micro-hydropower have low head(less than 10m) that also has a regular disparity. Thus the selection of suitable turbine has a vital role on the sustainability of the project. The present potential sites are mentioned and means to identify new sites are outlined by performing hydrology studies, topographic studies, head calculations, turbine selection and so onward.**

Keywords: Hydro Power, Micro Hydro, Mini Hydro, Crossflow Turbine, Propeller Turbine

## I. INTRODUCTION

Bangladesh with its rising commerce and industries is facing an overwhelming mission to handle up with the power calamity. The rapid increasing of power demand is not at same rate of power generation. The significant gap between power generation and estimated demand is to be approximately 2500MW [1]. Consequently the uninterruptable power supply is not possible for organization and foreign investors are put off their concern from Bangladesh. Electrical energy consumption in Bangladesh is per capita is only 154KWhr which is much less than the developed country [2]. In order to meet the challenge of energy crisis, Bangladesh needs to opt for the alternative solution in the formation of renewable energy as well as green energy giving concern on less carbon emission. The economic and environmental aspects should be taken into the consideration for achieving the goal of energy security and energy sustainability. Hydro power is the most widely used renewable energy due to the vast contribution around 19% of world's electricity from both large and small power plants [3]-[5]. The Department of Energy (DOE) refers large hydropower power plants having the generation capacity of 30MW [6]. Smaller hydropower plants are entitled as having generation capacity of 100KW to 30MW and micro-hydropower plants defines as from 5KW to 100KW [6]. Due to the hilly northeast and southeast region of Bangladesh, there are some possibilities to install the hydropower plant in hilly region. Kaptai Hydropower plant is only one plant having capacity of 230MW which is located in Chittagong. The Water Development Board and Power Development Board [7] have taken a survey of small Hydropower potential in the country. It acknowledged 12 potential rivers/charas with an estimated annual production of 1.1 GWh in Chittagong-Bandarban area, 6.3 GWh in Sylhet and Moulovibazar area, 8.6 MWh in Mymensingh - Sherpur area and 1.8 GWh in the Dinajpur-Rangpur area. However, only limited study has been made for the micro-hydro potential. Recently, LGED [8] has taken up a project at Bamerchara in Bashkhali of Chittagong District and BCSIR [9] in Sailpropat, Bandarban and in Madhobkundu, Moulovibazar. The BCSIR has estimated that these two sites have the potential for annual energy production of 43.8 MWh and 1.3 GWh respectively. To produce electricity with proper implementation of advance technology efficiently the water head of 2 meters can be appropriate. Due to the uneconomical planning of the grid network the energy problems in remote and hilly zone stay alive [3]-[4]. Micro-hydropower provides low-cost solution for these remote sites. It makes available a good solution for energy problems in remote and hilly areas where the extension of grid system is comparatively uneconomical [10].

This paper reports on the selection of an appropriate turbine suitable for the micro hydro sites and demonstrates the parameters needed to be considered to explore new potential sites for micro-hydropower generation of Bangladesh..

## II. POTENTIALITY OF HYDRO POWER

Micro-hydropower in comparison to other nonconventional energy sources includes the following. Areas with natural water falls on the dam-toe or canal drops are suitable sites for micro-hydropower plants. For such site selection long range studies are not required. Several studies [8]-[10] have reported the micro hydro potentials in different regions of the country. Table 1 shows some of these data. The head varies from 2m to 10m whereas the flow rate varies from 40 to 1000 l/s. Again there is a seasonal variation both in flow rates and available head. The output power is calculated as P = 5 Q Ho (kW), where Q is the flow rate in m3/s and Ho is the available head in meter and assuming a 50% system efficiency.

TABLE 1
HYDRO POWER POTENTIAL

| Sites | Estimated Average Discharge (l/s) | Available Head, Ho (m) | Output Power, P(kW) |
|---|---|---|---|
| Sailopropat Banderban[5] | 100 | 6 | 3 |
| Madhabkundu, Maulovibazar[5] | 150 | 10 | 7.5 |
| Faizlake[11] | 42.5 | 12 | 2.5 |
| Chota Karina Chara[11] | 311 | 6 | 9.3 |
| Ringuli chara[11] | 340 | 4.6 | 7.8 |
| Sealock [11] | 1132 | 9 | 51 |
| Longi chara[11] | 425 | 3 | 6.4 |
| Budia chara [11] | 170 | 7.6 | 6.5 |
| Nikhari chara 11] | 480 | 6.8 | 16.3 |
| Madhabchara[11] | 996 | 9.9 | 49 |

Micro-hydropower is easy to operate and there is no need for painstaking maintenance, whereas wind power plant causes severe noise pollution, teething troubles, and poor performance due to operation and maintenance problems. Major challenge relies on designing signal conditioner, computer interfacing, and software for system operation. The pulsating input power pattern for the wind power station is another major problem. Moreover, there are various problems while handling biogas: pollutants such as effluent slurry, accumulation of volatile fatty acids, gas forming methane organic bacteria, and leakage of gas from gas holder. Other problems include drop in Ph level and failure of digester [12]. Micro-hydropower plants are clean and pollution free. It maintains the ecological balance and stream flow of the rivers. The impacts on the environment of each energy sources have been studied thoroughly and the enhancement of these technologies has been considered [12]. The estimated power output is governed by the following equation: P = Q × H × 7.83, where P is the theoretical amount of power in KW, Q is the discharge flow rate in m3/s and H is the water head in meters. The equation is an approximation relied on theoretical studies. The actual power output varies depending upon pressure losses through the inlet and penstock also upon the turbine and generator efficiency. Another factor is the reduction of stream flow leading to the penstock due to environmental and fisheries constraints. The factors mentioned reduce the amount of energy produced. Micro-hydropower projects have been successfully implemented to provide standardized technologies for off-grid decentralized power to these remote hilly areas and small villages. Power to some mountainous villages has brought about major socioeconomic development. Micro- hydro powers have replaced diesel generators and implemented in a hybrid system in line with solar power [12]. These power plants have been used for direct mechanical energy for small industries and agriculture. Small-scale projects include battery charging, welding workshop, crop processing, grain milling, home, farm, ranch, and village. Another small-scale implementation may be to power homes in remote areas without a dam. The most major use of micro hydropower is the off-grid decentralization of its surrounding areas. Micro-hydropower meets smooth and stable power supply. Thus, the surrounding areas of individual generating stations can be easily powered and it is very economical. This will reduce consumer demand on the national grid network. Moreover, micro-hydropower stations can always be fed to the national grid. Micro-hydropower projects are generally well thought-out to be more environmental friendly than both large hydro and fossil fuel-powered plants. With all these advantages, micro-hydro-power can be implemented as principle renewable sources for sustainable development especially in developing countries like Bangladesh.

## III. PARAMETERS FOR CONSIDERATION NEW HYDRO POWER

Choosing a site is one of the most important steps in development, as it will largely determine the amount of energy that can be developed and the complexity of site development. Some factors to be considered are outlined as follows [13].

### A. *Topographic Maps*

Mapping of an area is one of the prime tools for site selection. Information such as the length of pipelines, transmission lines, and possible water head can be obtained from such maps. Other relevant information is the source of the stream and its direction of flow, roads to access the site, and also the size of the drainage area. Some of the sources for mapping include the 1:50,000 scale national topographic system (NTS) maps, 1:20,000 scale TRIM maps, local forestry maps, and custom maps based on recent photos.

### B. *Site Hydrology*

Hydrology study includes exploration of the origin of the stream flow and its destination. It also includes measurement of stream flow direction and flow rate. Although this study is time consuming, but it facilitates proper planning. The available tools to determine the hydrology of a potential site include maps, stream flow data, and water quality studies.

### C. *Water Quality Studies*

Studies should be performed to obtain relevant data regarding the level and variety of sediments like silt, fine sand, gravel, rocks, floating debris, and dissolved chemicals. Basically the data are used to determine the material for the equipment that comes in contact with water and also to take necessary precautions for the sediments that flow along the stream. There are other hydrological matters related to water quality studies that need to be considered.

### D. *High Head*

The water should be allowed the maximum vertical displacement and the shortest path to travel. The maximum vertical displacement accounts for the high water head. Large water head accounts for higher power produced. For high head, the turbine speed will be large; thus a small turbine can be opted for a given power output. However, at high heads the pipe pressure ratings and the strength of the pipe materials should be considered for design. Water must be allowed in the shortest route to travel; otherwise it will require long penstock which is quite costly. Longer pathway for the water to travel will reduce its flow rate due to fluid and other forms of friction.

### E. *Proximity of Lines or Loads*

For on-grid generation, the site should be closer to the distribution and transmission line. Also for off-grid generation, the loads should be at a close proximity. This ease in distributing the power will result in low transmission costs. It is to be noted that for on-grid micro-hydro plant it is cost effective to connect to the 11 to 33 KV lines. Voltage levels greater than that increase the connection the cost.

### F. *Turbine*

The selection of type of turbine is one of the problems in design of hydro plant. The characteristics, parameters, and classification involved facilitate the choice of turbine. There are two methods of selection [6].

1) ***Graphical Selection:*** It is the various types of turbine, graphs relating discharges, head work, model test result, and test report. Turbine is selected according to the head and discharge values [6].

2) ***Analytical Selection:*** According to the head and discharge values, the turbine parameters are calculated using the formula

$$P_t = \frac{P}{\eta} \quad (1)$$

Where P is power in KW, and η is the system efficiency including turbine, generator, and gear box efficiency. Then specific speed can be calculated as

$$N_s = \frac{(N \times P_t)5}{H}(\frac{5}{4}) \quad (2)$$

Where Pt is turbine output in KW, and N is the rated speed in rpm.

Runner Diameter: After performing model test and selecting design of turbine, the actual runner diameter is determined by the manufacturer. The following formula can be used [6].

$$D_r = (0.0242N_t)^{(2/3)} \quad (3)$$

Where Dr is runner diameter and Ns is specific speed in rpm

$$D_2 = \frac{84.6 \times D_r \times H^{0.5}}{N} \quad (4)$$

Where D2 is Discharge diameter and N is speed of turbine. Turbines can be classified according to their specific speed:

- High head turbine and low specific speed (Pelton),
- Medium head turbine and medium specific speed (Francis),
- Low head turbine and high specific speed (Kaplan and Propeller).

Turbines are designed as Dam Base, Canal fall, Run-off River, and Hilly region depending upon specific site conditions [12].

Kaplan Turbine: Large quantity of water at low head is suit-able for such turbines. These turbines range from head of30 meter and specific speed from 255KW to 860KW 10].

Francis Turbine: Moderate quantity of water at medium head is suitable for such turbines. These turbines range from head of 55 meter to 240 meter and then specific speed from 51KW to 255KW [14].

Pelton Turbine: These turbines range from 8.5KW to 30KW for single jet Pelton Wheel and from 30kW to 51kW for Pelton Wheel with double jet. The head value ranges above 240 meter [14].

Bulb Turbine: Large Rivers with high flow are suitable for such turbines. These are more economic than Kaplan turbine. These turbines range from head of 3 to 23 meters and specific speed from 200KW to 40KW [14].

PIT Turbine: These are modified version of the Kaplan turbine that works on head value below 15 meter [14].

S-Type Turbine: These turbines are smaller version of Kaplan turbine with horizontal inlet. These turbines have water head as low as 1 meter to15 meter. Specific speed ranges from 50KW to 500KW [14].

Cross-Flow Turbine: These turbines are subset of impulse turbine. The hand ranges lower than Pelton turbine with values up to 180 meter and specific speed up to 2MW[13].

Penstock Diameter: The diameter is calculated using design discharge, head, and plant capacity using this formula [6]:

$$\frac{\Pi \times D_2}{4} = \frac{Q_d}{V} \qquad (5)$$

This formula gives the diameter of penstock [14].

Synchronous Generator: Generally for commercial purpose synchronous machine is widely used. Generators driven at low speeds by prime-movers like water turbines will have salient pole construction having large number of projected poles [14].

Low Environmental Impact: When choosing the site, care must be taken to avoid unacceptably high environmental impacts such as damage to fish populations, endangered species, or air quality [14].

Power Reliability: The Power output is directly dependent upon head and discharge. Head and discharge depend upon rainfall and also stream flow in rivers and canals. The estimation of river flow and rainfall determines the reliability of Power output from the micro hydro-power plant [14].

## IV. MICRO-HYDRO SITES IN BANGLADESH

In February 1981, the Water Development Board and Power Development jointly carried out a study on the assessment of Small/Mini-Hydropower Potential in the country [12]. The committee explored 19 prospective sites for possible installation of small hydropower plants. Later in the month of April 1984, Six Chinese experts visited Bangladesh and they identified 12 potential sites for development of mini- hydropower plant. Out of these sites, only Mahamaya Chara, near Mirersharai, close to Dhaka-Chittagong highway was identified as the best site for development of small hydro. Following are the sites that were identified (Table 2) [10], [12]. In 2004 sustainable Rural Energy, Local government Engineering Department has explored some potential micro-hydro sites in Chittagong which is listed in Table 3. Most of the potential sites are situated in the Chittagong hill tracts (CHTs). It requires potential utilization of hydropower and indigenous technical knowledge to utilize the existing opportunities in the CHT areas. Decentralization of micro-hydropower units with local implementation and management through self-reliance and the use of local natural resources will have significant impact on the remote tribal rural development.

TABLE 2
POTENTIAL SMALL HYDRO SITES IDENTIFIED BY BPDB AND BWDB.

| District | River/chara/ stream Name | Potential of electrical energy in KW |
|---|---|---|
| Chittagong | Foy's Lake | 4 |
| | Hoto Jumira | 15 |
| | Hinguli Chara | 12 |
| Chittagong Hill Tracts | Sealock | 81 |
| Chittagong | Lungi Chara | 10 |
| | Budia Chara | 10 |
| Sylhet | Nikhari Chara | 26 |
| | Ranga Pani Gung | 626 |

| | | |
|---|---|---|
| Jamalpur | Bhgai-Kongsa | 69KW for 10 months and 48 KW for 2 months |
| | Marisi | 35KW for 10 months and 20KW for 2 months |
| Dinajpur | Dahuk | 24 |
| | Chawai | 32 |
| | Talam | 24 |
| | Pathraj | 32 |
| | Tangn | 48 |
| | Punarbhaba | 11 |
| Rangpur | Bhuri Khora Chikli | 32 |
| | Fulkumar | 48 |

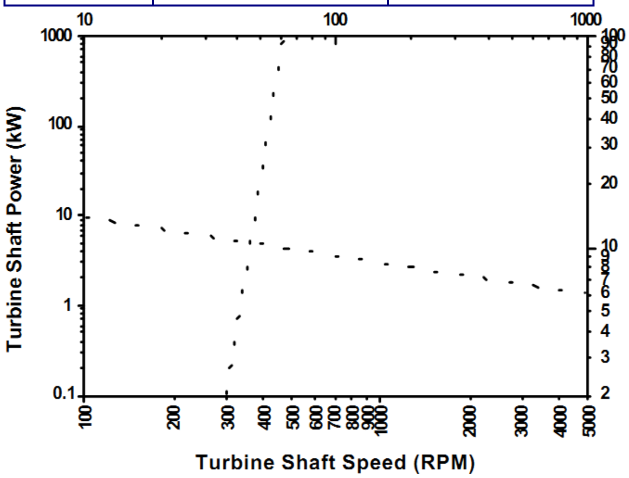


Fig. 3. Nomogram for the selection of turbine speed [7].

Considering the generator speed of 1000 rpm, the turbine speed, n (rpm) can be selected from the nomogram shown in Fig. 3 such that the specific speed should remain within the range. Then the approximate runner diameter can be calculated from the following equation: $D = 40\frac{\sqrt{H}}{n}$ (7)

Where D is in meter. The jet thickness $t_j$ usually between one fifth to one tenth of the diameter. The approximate runner length in meter is:

$$L = \frac{0.23Q}{t_j\sqrt{H}} \quad (8)$$

## V. RESULTS AND SIMULATION

Salient Feature of Bamercharа Micro-Hydropower Unit: Estimated capacity of the system was 10 kW. Salient feature of the unit has been illustrated as follows:

- turbine type: crossflow,
- penstock: 52m,
- design flow: 150 liter/sec,
- net head available: 6m–10m,
- preferred governor: flow control (manual),
- electrical output: 4–6 KW, 50Hz, 3 phase voltage, 220V/440V.

Considering water head of 11 meters and flow rate of 150 L/s, it was estimated that maximum 10 kW hydropower could be generated from “Bamerchara” site shows Fig. 4. But when irrigation starts, water head falls rapidly.

Consequently full power generation was not possible. Furthermore, about 41 percent potential energy was lost by the penstock, turbine, and generator and transmission line. Fig. 5 illustrates relationship between water head and extractable hydropower from a stream.

Fig. 4. Bamerchara micro-hydropower unit.

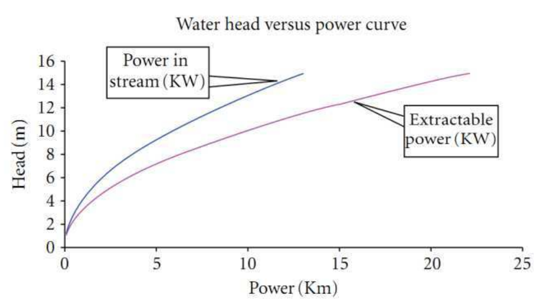


Fig. 5. Relationship between water head and power.