American Journal of Engineering Research (AJER)
e-ISSN : 2320-0847 p-ISSN : 2320-0936
Volume-03, Issue-11, pp-167-197
www.ajer.org

Research Paper Open Access

Conceptual Design of Solar-micro Hydro Power Plant to Increase Conversion Efficiency for Supporting Remote Tribal Community of Bangladesh

[1.]Anmona Shabnam Pranti , [2.]A M Shahed Iqubal , [3.]A. Z. A. Saifullah

[1] *Faculty, Department of Electrical and Electronics Engineering, IUBAT—International University of Business Agriculture and Technology, Dhaka, Bangladesh*

[2] *Faculty, Department of Mechanical Engineering, IUBAT—International University of Business Agriculture and Technology, Dhaka, Bangladesh*

[3*] *Professor & Chair, Department of Mechanical Engineering, IUBAT—International University of Business Agriculture and Technology, Dhaka, Bangladesh*

ABSTRACT: *Bangladesh is endowed with people along with limited primary energy sources and low electrification rate. Most of the hilly areas are out of the coverage of national grid where tribal people, a significant part of the country, are dwelling. The economic development of the whole country depends upon their advancement which is related to the electrification rate. Available micro hydro potential in hilly region could be a solution for this crisis if modified design is used. This paper deals with a new design of water power potential conversion efficiency increment of a micro hydro power plant to 95% from about 50% by using solar power for heating the water. In this proposed hybrid design, a parabolic reflector is considered to be used after comparative solar intensity analysis on different micro hydro power sites in Bangladesh to increase the velocity as well as the flow rate through penstock by heating the water to increase power production and efficiency. The main purpose of this concept is to supply electricity to more people, especially, remote tribal community by available renewable energy sources for economic development.*

KEYWORDS: *Bangladesh, Tribal Community, Energy Crisis, Renewable Energy, Solar Hybrid Micro Hydro Power Plant*

I. INTRODUCTION

The national security of a country depends on energy reserve and economic growth is determined by the amount of use of electricity which increases the GDP rate. In this era of modernization and globalization, everyday electricity is needed to run necessary and luxurious commodities like refrigerator, air-conditioner, television, and computer for social, educational and technological growth as well as to be connected to the outer world through internet. Energy security has become a burning question for Bangladesh, a South Asian developing country with limited energy resources compared to recent population and industrialization growth. The average electrification rate is very low. Most of the people using electricity live in urban areas and facing massive load shading. The energy policy must facilitate energy access to all Bangladesh citizens with necessary improvements [1]. The government has to encourage the Rural Electrification Board (REB) and its network of rural cooperatives (Palli Biddyut Samitee – PBS) to create small-scale generating capacity whose power would be distributed on a priority basis independently of the national grid to customers in the local participating PBS [1, 2]. To fight with the current situation electricity generation from renewable sources is inevitable to support remote areas. Thus another recommendation for the REB is to explore the potential of getting financing for renewable energy projects from firms investing carbon emission offsets [2]. Small scale hydroelectric power plant has eliminated electricity scarcity problem in developing countries like Nepal, Sri Lanka and Brazil. However, Bangladesh has some suitable sites for micro range hydro electricity production but the proven potential is not significant to support vast community. On the other hand huge amount solar energy can be tracked because of suitable geographical location. The main objective of this study is to focus on the possible increase of electricity production from the available limited hydro potential by a fusion of hydro and solar potential for social and economic development of the deprived tribal community of Bangladesh.

II. GEOGRAPHIC AND SOCIOECONOMIC ARCHITECTURE OF REMOTE TRIBAL AREAS OF BANGLADESH

Bangladesh is on the tropic of cancer with warm weather [3]. It has been blessed by vast population of about 160 million [106] with a growth rate of 1.19% [107] in a limited land of 147,570 km^2 [3]. More than half (80%) of the people reside in a limited modern facility rural areas[94, 4, 5] and a significant part of minority and tribal community lives in hilly regions, an inevitable part for determining national economic prosperity which depends on daily electricity use[4]. In Bangladesh, per capita electricity consumption is 136 kwh/year which is one among the countries having lowest energy consumption in the world [6]. Different tribal people live in Mymensingh, Sylhet, Rajshahi , Bandorban, Khagrachori, Rangamati and Chittagong district [7] like 50,000 Manipuri, Khasia and Tripura in Moulvi Bazar [8], 2, 88,077 ethnic minorities (Chakma, Marma, Tanchangya, Tripura, Pankua, Lushai & Khiang) in Rangamati [9], 524,961 mostly Chakma and Tripura in Mong Circle Khagrachori [10, 11] and 12 ethnic groups 125,000 Chakma, 66,000 Marma, 37,000 Tippera, 16,000 Mru, 8,000 Tanchangya, 2,000 Chaks, 2,000 Kumis, 2,000 Kuki/Lushais, 2,000 Khyang, 2,000 Pankho, 2,000 Bangoji and 2,000 Mrung in Chitrtagong[12]. Most of the tribal people, 778,425 among 897828, live in rural areas with limited facilities and electricity supply [7].Table 1 show the respective literacy rate of that district where mostly the tribal people live. From Table 1, it is clear that the literacy rate of each district is below that of the national and capital (Dhaka) 57.91% [19] and 96.9% [18] respectively. The difference of urban and rural literacy rate is 14.02% (65.83% and 51.81% respectively) [20]. Education is the most important key of economic development and electrification is one of the preconditions of educational enhancement in remote areas.

93% power of Bangladesh is produced by Coal, oil and gas [21], where the reserve are 3.3 Billion tons [23], 5,724 bbl/day [24] and 20 TCF [22] respectively and is used in industry like cement, fertilizer or for running vehicles [25]. Only 7% is hydro power in the electrical power mix [99] to support electrification to 52% people [26], 6066MW electricity is necessary, and current generation capacity, 4162 MW [21], is not enough for all people getting supply of electricity. Primary energy purchase from abroad for conventional power generation in near future after finishing the reserve will not be economical while we are already importing 90% of our oil [31, 28]. So it is quite unrealistic to think about new electrification unless introducing renewable power production.

III. METHODOLOGY AND ESTIMATION

3.1. Different power production procedures respective to Bangladesh: Total installed capacity (according to BPDB) is 6693 MW of which 250 MW coal based, 1127 MW oil and 5086 MW gas based and 230 MW Hydro power plant [29]. Though conventional power generation will stop before 2020 for gas reserve deduction, the prime source of thermal power [31], renewable power production is not convenient yet where technologically improved renewable energy plant is important for sustainability [31]. Bangladesh is very close to the equatorial line (24 North). Solar energy falls almost perpendicularly and day lengths difference of winter and summer is less. Therefore, it is a suitable place for tracking solar energy [30]. However, roof top solar cell is not admirable because of the low conversion efficiency, 30% theoretically and 10-15% practically [32]. Diesel engine plant has low installation cost but its operational (fuel) cost is high [33]. In Bangladesh wind power production is not possible because of low wind profile [31], approximately 6.5m/s [32]. Nuclear power needs high technological support [32]. Hilly region micro hydro site in Bangladesh can be the best option for decentralized power supply as low cost scheme, which has been shown in Peru through experiment [33, 31]. But it is not considered because of low available potential and efficiency.

3.2. Fusion of solar and hydro power for electrifying rural off grid Bangladesh: Electricity is produced by using stored potential and kinetic energy in micro hydro power plant [34] and the Greeks learned the procedure first [34]. Hydro power is the dominating factor in the national energy mix in many developing countries. Now-a-days small hydro power is used for removing power deficiency problem in Nepal, India, China, Peru and a country like USA [34]. This plant, capacity =<100 KW [28, 34, 95, 35], uses run off river system suitable for hilly areas where small rivers run with high current [34, 28]. The total installation capacity of small range hydro power in our neighbor country India is 12,841.81 MW [37], in Nepal is 14.6 MW [38] and in Sri Lanka is 181 MW [39]. However the total estimated small scale hydro power potential by BPDB and BWDB in Bangladesh is only 1.129 MW [31] which is the lowest in South Asian countries. The amount of power production from a micro hydro power plant depends on the stream power [95]. Though 1 m/s current velocity has an energy density of 500 W/m^2, very little amount of this can be converted into electricity [40, 41]. Generally the efficiency of this type of power plant is considered as much as 55% [109]. The conversion efficiency depends upon various factors among which velocity of the falling water is the most important. Hydro power production process is the oldest process of harnessing energy which can be improved by the development of technology and its contribution can be significant to supply electricity to people of remote off grid area. Full utilization of water power through micro hydro power plant by using improved technologies can be a smart solution to provide electrical power to the remote hilly region. The geographical location of our county is suitable for tracking solar energy. We can utilize the huge amount of incident sun power to increase the conversion efficiency of a micro hydro power plant situated in our country. A hybrid system can be made with the water potential available in the hilly region of our country along with solar power to support more people who are still in dark. As we cannot increase the total available potential of our country, so it is the only way to construct more efficient micro hydro power plant than the existing one so that the impact of low available potential can be relaxed by generating more power by the same stream available in our country.

3.3. Main Concept for the hybrid plant: Financial, technical, organizational and social intermediation is needed to design a successful plant among which technical intermediation is our prime concern. A study on Nepali power plant has pointed out that 30% of installed power plant remain ineffective due to poor hydrology estimation and inefficient design of channel (penstock) through which water is conveyed to the turbine [33, 34].

The power production from water entirely depends upon the flow rate (Q) of the water and the head of the water (H) and is proportional to the flow rate for constant head and constant conversion efficiency of the turbine [42, 34]. The theoretical power depends upon flow rate and head of water which is the vertical distance between the water entering points from intank to water leaving point of penstock to the turbine which depends upon the characteristics of the pipeline [34, 42, 43, 68].

Theoretical power (P) = Flow rate (Q in m^3/s) × Head (H in m) × Gravity (g in m/s^2)

P= (9.81×Q×H) KW

At the time of energy conversion, some energy is lost due to work done [28]. The flow rate is the product of the cross sectional area (A) of penstock and the velocity of the fluid (V) [34, 44].

$$Q=A\times V$$

So, water velocity is an important factor in order to increase the electrical power production.

Viscosity is a property of a liquid which controls the flow rate by the cohesion between liquid particles [114]. For constant diameter of penstock, the flow rate of water through the pipe depends on the velocity as well as the viscosity of the water [96]. In case of liquids, viscosity and temperature and viscosity and velocity have inverse relationship [45, 46, 54].

Temperature ∞ 1/resistance to flow

Considering laminar flow through penstock, the Hagen-Poiseuille law of viscous flow can be expressed as below [114].

$$P_1-P_2= (32\times\mu\times V\times L)/D^2$$

where,

L= penstock length

D= penstock internal diameter

V= Velocity of water in pipe

μ= water Dynamic viscosity

P_1-P_2= pressure loss through the pipe.

The pressure drop will decrease rather than increase with the decrement of the viscosity of the water which is more advantageous for enhancing the power production as net head H= available head **-** pressure drop. As pressure has no effect on viscosity [46], so dynamic viscosity and velocity has an inverse relationship when pressure drop is considered constant for a specific pipe. With the increment of temperature, the viscosity of water will decrease as well as the velocity and flow rate will increase which will causes more power production from the same available potential.

A parabolic concave mirror has the capability to converge all incident parallel rays to the focal point (F) and very high temperature can be achieved which may cause fire [110]. This high temperature can be utilized in micro hydro power plant to increase the flow rate of the flowing water. Because of geographical location every year we have at least 300 sunny days [101].

POTENTIAL OF MICRO HYDRO POWER IN BANGLADESH: Around 232 rivers flow through Bangladesh [31]. It is quite easy to find out suitable run off river micro hydro power plant site in our country. Moreover, 12% hilly area of Bangladesh [97] has stream flow which can be used for electricity production for supplying to the leg behind tribal community. The first micro hydro power plant installed in Bamerchara, Chittagong (10 MW) [31] was a demo power plant to test the feasibility of micro hydro power in Bangladesh to provide electricity to 140 families in the village and to a Buddhist Temple [98]. One 20 KW micro hydro power plant has been installed at Barkal, Rangamati [98] and two are possible to install at Madhobkundo (10-20 KW) in Moulovi Bazar and Sailipropat (5-10 KW) in Bandarban respectively [31]. Some experts pointed out in 1981 according to IECO Master Plan that 11, 56,320 KWh of energy could be generated in Chittagong-Bandarban area, 63,06,041 KWh in Mymensingh-Sherpur area and18,70752 KWh in the greater Dinajpur-Rangpur area annually. Their identified sites are Foy's Lake at Pahartali, Choto Kumira in Chittagong, Sealock in Bandarban, Nikhari Chara and Madhabchar at Baralekhamin Moulavibazar, Ranga Poni Gung at Jaintiapur in Sylhet, Bhugai Kangsha and Marisi in Sherpur, Punarbhaba and Talma in Thakurgaon and Pathraj in Dinajpur [48]. Through another survey of Bangladesh Water Development Board (BWDB) and Bangladesh Power Development Board (BPDB) in 1981, the potential of micro hydro power was identified in 12 places of our country, 1.1 GWh in Chittagong-Bandarban area, 6.3 GWh in Sylhet-Moulovi Bazar area, 8.6 MWh in Mymensingh-Sherpur area and 1.8 GWh in Dinajpur-Rangpur area [49]. Another study has been done by LGED-Local Government Engineering Department of Bangladesh on three hilly districts [31].Table 2 shows the site from the result of BPDB and BWDB joint survey in 1981[98] and the potential site of LGED survey [31].There are some other micro hydro sites in Chittagong. One is Choto Kumira Canal (power potential 19.19 KW) and another is Mahamaya Chora, (power potential 4.95 KW) [4]. Moreover, micro hydro power can be generated at Sangu and Matamuhuri River identified by BPDB [98].Table 3 shows some potential micro hydro power sites, their flow rate, available head and possible electricity production on which the calculation has been done.

INCIDENT SOLAR ENERGY ON DIFFERENT MICRO HYDRO POWER SITES OF BANGLADESH

The amount of solar electromagnetic flux incident on earth surface per unit area perpendicular to the rays is solar constant [50]. The geographical location of Bangladesh (23.50 North latitude), nearest to equatorial line, has made it a suitable place for tracking huge amount of solar energy falling almost perpendicularly throughout the year as the difference between winter and summer season’s day length is smaller than most other countries of the world. Bangladesh has also appropriate climatic condition as we get almost 300 sunny days in a year [101]. The average incident solar power in our neighbor country India is about 4.5 KWh/m^2 which is equivalent to 5 trillion KWh/yr [100]. The estimated value of solar constant in early January is about 1.412 KW/m^2 and in early July is 1.321 KW/m^2 after absorbing 6.9% by the atmosphere [50]. Average value of solar constant is about 137 MW/cm^2 [51]. Only a small part of this power can be concentrated by a reflector which has the capability to damage our eyes [52]. The intensity of the reflected rays is the highest at the focal point of a curved mirror. It is possible to achieve up to 3,500 °C temperature by concentrating solar energy with special and expensive instrument. And, 700°C can be achieved by low cost ordinary equipment which is being used in India [53]. Solar constant on the earth entirely depends up on the latitude of the specific place. Incident solar energy per square centimeter is calculated by the equation [51]

$$E = (MW/cm^2) \times (\text{Area in } cm^2) \times (\text{Time in sec})\ MJ$$

The total amount of energy incident on the solar collector is $5.9 \times 10^6\ MJ/cm^2$ in 12 hr duration [51]. The sun does not remain constant directly overhead on any particular place throughout the year and the declination can be calculated by the formula [54]

$$\text{Declination } \Theta = 23.5° \sin((T / 365.25) * 360°)$$

where,

T= number of days counted from the vernal equinox (March 21), Θ=0º at equator [51, 55].

The declination varies from 23.5° north latitude on June 21 to 23.5° south latitude on December 21 [54].

The declination on 1st April of the year $\Theta = 23.5 \text{ Sin } \{360(10/365.25)\} = 4.023º$

Table 4 indicates the solar declination on the 1st day of each month of the year in Bangladesh after the calculation. The latitude of a particular place is also a determinant of solar declination and intensity of a particular place. Rangamati is a southeastern Hill District at 23^0 44´ north latitudes [9] and other two districts Khagrachori and Bandarbon of Chittagong hill track are at 23.166667 North [56, 57] and 22 North [58] latitude respectively where most of the micro- hydro power sites are situated. Some other micro- hydro power plant potential is also in Sylhet, Chittagong and Moulvi Bazar district which are at 24° 53' North [59], 22° 20' North [60], 24.35º north [8] latitude respectively.

The solar constant for a particular day for a particular place can be calculated by [51, 61]

$\sigma_D = (137mW/cm^2) \cos(L(\text{site latitude}) - \Theta)$

The solar constant of Bandarban on 1st May is $\sigma_D = (137MW/cm^2) \cos(22 - 14.924)º = 135.957613\ MW/cm^2$.

Though actual day Length (sunset to sunrise) differs from day to day. In Bangladesh we get sun energy almost eight hours a day throughout the year with a little variation [102]. Actual day length is calculated by the equation [51]
$T_D= (24/\pi) \mathrm{Cos}^{-1}\{(-\tan \Theta) (\tan L)\}$ hour
where
Θ= solar declination
L= observer's latitude
Time from sunset to sun rise at Khagrachori on 1st May

$$T_D= (24/\pi) \cos^{-1}\{(-\tan 14.924)(\tan 23.167)\}=12.54893 \text{ hours}$$

The amount of energy collected by collector/unit area is dependent on time duration between sunrise and sunset [62]
$E = \sigma_D (3{,}600\ T_D /\pi)$ MJ
The amount of energy per unit area at Rangamati on 1st April

$$E = \{128.983875 (3{,}600 \times 12.04385 /\pi)\} \text{ MJ}$$

$$= 1781040 \text{ MJ}= 1.7\times10^6 \text{ KJ}$$

The calculated value of solar intensity, day hours and energy captured on earth surface of different districts of micro- hydro power site in Bangladesh and Kramer Junction, California for the first day of each month of the year is given in Table 5.

Figure 1 shows comparative solar intensity curve of different districts of micro- hydro power site in Bangladesh and Kramer Junction, California. From figure 1, it is clear that the variation of solar intensity on different sites of micro-hydro power plant in Bangladesh is almost constant throughout the year and in every month it is higher than that of Kramer Junction, California, USA, latitude 34.992 North [63], where a 33 MW Solar Thermal Power Plant is situated and sun energy is used to raise the temperature of liquid flowing through a pipe in order to produce electricity [64]. We should best use of this huge amount of energy, the gift of nature, for electricity production to lessen the current scarcity in Bangladesh.

IV. CONCEPTUAL DESIGN OF PROPOSED POWER PLANT

Large or small amount of electricity can be produced by utilizing the potential energy of water by creating dam or using run off river water. Figure 2 shows classification hydroelectric power plants [42]. According to other conception, large scale hydro power is considered up to 100 MW, small scale is up to 5 MW and micro hydro power is up to 100 KW [65, 66]. The ranges of hydro power plant higher than 30 MW is large, small hydro is 30 MW-2 MW, mini hydro is 2 MW-100 KW, micro hydro is 100 KW-10 KW and Pico hydro is less than 10 KW [67]. According to another information 10 KW-200 KW capacity plant is also called micro hydro power plant [33]. No dam is necessary in micro hydro power scheme (run off river) [68, 69]. Some civil works are needed - like wire and channel for diverting water in to in tank, penstock for conveying water to the turbine, tail race to divert used water from turbine, power house for housing turbine coupled with generator, small control and transmission system, inverters for electrical power control and a battery for storing power for using at pick hours [42, 34, 43]. Figure 3 and 4 shows the conventional micro hydro power plant design and the conventional micro hydro power plant with penstock view respectively. Figure 5 shows penstock and reflector design in proposed system. As found in Table 3, most of the micro hydro power site in Bangladesh have net available head of not more than 10 m.The smooth internal surface pipe is to be used as penstock because when friction loss is only 1/3 (gross head),we can get maximum power output. Maximum 10-15% loss is acceptable for better design [27, 114].
As penstock has to bear weight and pressure of water, for low pressure PVC pipe(range upto160-350 psi) and for higher pressure Galvanized steel, welded steel pipe**,** high density polyethylene pipe are used after considering power loss and economic tradeoff [27, 43**,** 70]. A metal tube (steel) is considered to be used in this system as an inner case because conductivity is higher, and the tube should pass through the focal line of the reflector. The outer periphery of the penstock tube should be built with general glossy glass to reduce the heat loss [71]. Special solar-selective coating will prevent oxidation and heat radiation loss [72, 71]. The average length of penstock has been considered as 50 m which is the practical length of one micro hydro power plant in our country and 300 mm diameter has been considered which is generally used in 4-11 m head micro hydro power plant [27]. For high head plant Pelton wheel, for low head plat Francis turbine, for medium head plant multi-jet Pelton turbine, for small scale low head plant cross flow impulse turbine and for micro hydro power plant cross flow Pelton turbine is used [43, 73, 42]. However, cross flow turbine and synchronous generator is suitable for off grid micro hydro power plant sites in Bangladesh

[49, 31]. Though According to the Fermat's principle, sun rays always travel minimum path, up to 80%, not all rays, can be concentrated to the focal point by large curve mirror (spherical and cylindrical) because of spherical aberration [75, 103, 72, 52] and only 200°C temperature can be earned by burning glasses [72]. A parabolic reflector, used in Newtonian telescopes and to collect energy from distant source, has the capacity to concentrate all parallel sun light closer to the reflector and to achieve high temperature by concentrating as incident and reflection angle of inner surface is same [74, 52, 75, 72]. One axis tracking system of parabolic reflector consisting of curved mirrors, 182.88 m^2 area and 50 m in length has been considered in our design.

V. CALCULATION OF EFFICIENCY INCREMENT

100% theoretical power which depends upon head and volume of water flow cannot be harnessed. Minimum 5 m head and 1 litre/second flow rate are needed to produce electrical power [76]. The low head low speed micro hydro power plant turbines and generators are less efficient and according to different information turbine efficiency is 80% [42] or 95% [43], generator efficiency is 95%[43], turbine generator sets efficiency is 40-80% [77] and transmission efficiency is 98% [43]. The overall efficiency remains almost 55%. For system beyond 10 KW efficiency is 60-70% [28], for mini hydro efficiency is 75-85% [65] and for micro hydro efficiency is 60-80% or 65-75% [65]. The general efficiency of a micro hydro power plant considered according to different information is 79% [43] or 55% [109] or 53% [34] or 50% [42, 77, 28, 65, 49, 78]. Based on all information, overall efficiency of 50% is taken for calculating output power in Bangladesh:

Potential available $P=9.81\times Q(m^3/s)\times H(m)$ KW

Electrical power can be generated $P_e=0.5\times 9.81\times Q(m^3/s)\times H(m)$ KW [78]

Table 6 shows flow rate, available head, potential available and electrical power output in different micro hydro power site in Bangladesh selected for calculation.

Kramer Junction, California, USA, Solar thermal power plant (33 MW) is at 35.019804756678 º North Latitude [64] where average solar intensity is 97.32827505 MW/cm^2[calculated] and uses 836.1236 m^2 (20×450 $feet^2$)[79] parabolic trough reflector to achieve 700° F temperature by synthetic oil flowing through the receiver tube [79].

The respective temperature could be produced by 836.1236 m^2 solar parabolic reflector of that kind for a specific place is

$T_1=\{(\sigma_D\times 700)/97.32827505\}$ºF

$=\{(5/9)[\{(\sigma_D\times 700)/ 97.32827505\}-32]\}$ºC [80]

In this design the area of reflector is considered=182.88 m^2.

Temperature could be raised $T_2= \{T_1*(182.88/836.12736)\}$ºC in Synthetic Oil heat exchanger in a particular place.

Temperature rise in water can be calculated by the formula [11]

$S_o / S_w = (m_w\times\Delta T_w)/(m_o\times\Delta T_o)$--------(1)

Mass of oil and water are m_o and m_w respectively. Temperature difference in oil is ΔT_o and water is ΔT_w.

Specific heat of liquid water is S_w= 4.1796 kJ/kg ºC [83] and that of Synthetic Oil is S_o=2.341 kJ/kg ºC[84].

And, $m_w=(d_w /d_o)\times m_o=1.125\times m_o$ kg [85],

Where, density of water is d_w = 997.0479 kg/m3 [86] and density of synthetic oil is d_o = 886.2 kg/m3 at 0ºC [87].So,

Temperature rise in water= $\Delta T_w = 0.4978\times\Delta To$------------- (2),

Table7 shows dynamic viscosity for different temperature obtained by the solar concentrator for micro hydro power plant.

According to Hagen-Poiseuille law [114],

$P_1-P_2 = 32\times\mu\times V\times L / D$

Where

P_1-P_2 = Pressure drop

μ = Dynamic viscosity

V = Water velocity

L = Pipe length and

D = Pipe diameter

$V=\{(P_1- P_2)\times 0.3\times 10^6\}/(32\times\mu\times 50)$

As steel pipe, welded new, unpickled, with roughness factor of 0.03mm has been chosen for the design, constant pressure loss is considered for the calculation. Cross sectional area of the pipe is $A=\pi r^2$ = 0.070685834 m^2, where D = 300mm [44] and flow rate through penstock

Q =A×V [44]

=0.070685834×V m^3/s

Available water potential is P_1=9.81×Q (Litre/second)/1000)×H(meter) KW

and possible electrical power production is P_2= 0.5×9.81×Q (Litre/second)/1000)×H(meter) KW.

Table 8 shows all the calculated comparative data of velocity, flow rate, power production and conversion efficiency in proposed system and conventional current system. At 25ºC Dynamic viscosity 891×10^-6 µ Ns/m^2 is considered [111]. The respective current velocity of water is calculated in ft/s by software "Pressure Drop Online-Calculator for Mobile and PDA" downloaded from internet and converted in m/s. [88]
X= power output in proposed system and Y=efficiency of water energy conversion.

VI. DISCUSSION

Advantages and social impact of this hybrid power plant in Bangladesh need to be paid attention very carefully. Current available energy service is not sufficient for supporting the need for the poor, found in a study of UN, was the Millennium Development Goals of 'The UN-Energy Paper'[105] and it has become a great challenge for the government and general people of Bangladesh to supply electricity to all people within 2021. Because, reliable and affordable energy supply to the poor population is the precondition of sustainable development. Almost 1.6 billion people of the world is out of electricity [105]. Although lack of electricity supply slows down local economic development, youth opportunities and enhances social crimes and problems, the electrification rate of the rural areas of many developing countries are not more than 10% [112]. The scenario is quite worst in Bangladesh. Overall 52% [26], in Urban Areas 80% [89] and in rural areas only 25%[90] people are connected with national grid but are continuously facing massive load shading.

Generally the demand of an off grid village is very low (5 KW-50 KW) [113], less than the loss in transformer [91]. It is quite uneconomic to construct new transmission line in hilly tribal areas for too small load which needs 0.875 USD for 1KWh energy transmission [91]. Moreover, significant amount of power is lost on the way as transmission loss. Besides, distribution loss of Bangladesh is 26% [26].People are now looking for modern, decentralized and environment friendly renewable energy scheme like Micro hydro power plant [28] which is economical [31], non-polluting, does not emit CO_2 and destroy ecology like large hydro plant [92, 104, 28]. Power production remains almost constant unlike solar cell and wind power [31]. 20% world energy will come from renewable sources by 2020 [36]. European Union is producing 13% electricity from Hydro electric power plant to reduce 67 million tons CO2 emission/year [92] according the target, of a seminar at Kyoto, of reducing green house effect by 8% in Europe and 5% in other industrial countries [92]. Though the installation cost of micro hydro power plant is very high, in Sri Lanka and Nepal it is 2762.5(21.2% civil cost) and 1587.5(43.8% civil cost) USD/KW respectively and in general 3085 USD/KW [33], compared with other plant of same capacity like diesel plant [28]. It is useful for developing countries because of low maintenance or running cost [33, 34, 31] as least investment [91] and no fuel purchasing is needed and power production cost is almost USD 0.018/KWh compared with 0.6/KWh grid power [91]. However economic success depends upon the objective as the scheme is usually used to supply electricity to rural, remote and off grid community. Effect of high installation cost can be neutralized by meeting the demand of more people (tribal community) by setting more efficient proposed design for long term by using only extra parabolic reflector and free fuel (sunlight and water).The efficiency of micro hydro power plant in our country is considered as 50%. But by using this hybrid power plant 95% available hydro potential can be converted to electricity As our main concern is to supply electricity to more people by our existing resource, a trade-off between efficiency and investment cost should considered.

Micro hydro power plants are being used for poverty reduction and economic and social development in rural areas of Nepal by achieving 80% secondary school success [92], Sri Lanka, Pakistan, Peru, Zimbabwe [33], and China where there are more than 85000 small scale micro hydro power plants [42]. In China, one village per capita income and electrification rate changes from 19 to 115 USD and 60% to 99% respectively because of a micro hydro power plant [91]. Academic performances of rural children, who need to compete with technologically advance urban children at tertiary level to maintain development harmony, depend upon the use of electricity as they cannot access services like internet, cable TV and mobile phones which are used to communicate them with the outer world. Without electricity, it is not possible to run evening adult education centre in rural hilly areas for agricultural villagers to change their life style and socio-economic condition which has been done in a village of Nepal to raise the literacy rate from 30% by introducing a micro hydro power plant [92]. CO2 emission can be reduced and village children time spent in collecting fire wood for cooking can be saved for studying by the use electricity [92]. Not only the advanced livelihood but also small enterprise is necessary to develop socio economic condition of a remote community and a micro hydro power plant can be a smart solution. Though Bangladesh has limited potential of micro hydro power, it is possible to accelerate economic growth in remote areas by the best use of it to obtain economic sustainability.

VII. CONCLUSION

Energy plays a vital role in human development and electricity is the most usable form of energy. A great portion of household's expenditure is on energy and per day 1 to 4 hours of a woman, in collection fire woods, is spent for energy [93]. So for reducing dependency on CO_2 creating fossil fuel, increasing electrification rate in remote hilly regions, a significant part of our country and achieving energy security for the county, alternative sources of renewable energy is necessary. We cannot think our national prosperity without social and economic growth of the unprivileged poor community of the remote hilly areas. In 30 years, micro hydro power plant has not got importance and financial assistance from the government [33], though natural water fall of hilly areas could be an added advantage [31] and in some circumstances it can be beneficial for rural people with improved design. To implement a successful plant although the cost is strongly site specific, the cost can be minimized by local advanced design. It is needed to consider many tasks. The tasks include not only the arrangement of sufficient finance but also the intermediation of current technology. But the potential is not significant. On the other hand, the solar power alone cannot be the solution for supplying electricity to these people as the efficiency is very low. That is why it could be the best way to built a hybrid power plant by using solar and micro hydro power potential in rural off grid hilly areas in order to obtain a sustainable development for the country. Micro hydro power plant conversion efficiency can be increased by 90% by using this solar hybrid technology.

Actually the main objective of a micro hydro power plant is to generate electricity for the remote hilly area people who are leg behind from the modern world and to improve their socio economic condition. So the main concern of a micro hydro power plant should be to generate more electricity from the available stream by improving the design to enlighten the leg behind community of our society to increase the economic growth of our country which mostly depends upon the electrification rate of our country. Although a micro hydro power plant can play a vital role to improve the economic condition of developing countries, no definite strategies has been taken to identify the role of this kind of power plant in energy sector development for rural growth [33]. AS ADB provides subsidies for rural electrification program like micro hydro power plant system up to 100 KW [33], the government of Bangladesh can get help, if they will take the strategy of this kind of power plant for electrifying tribal community. Certainly it is not possible to cover all poor rural un-electrified area of our country by micro hydro power plant, but its impact can be significant in reducing the difference between the level of livelihood of on grid people and off grid tribal people who are a significant part of our country.

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Figures and Tables

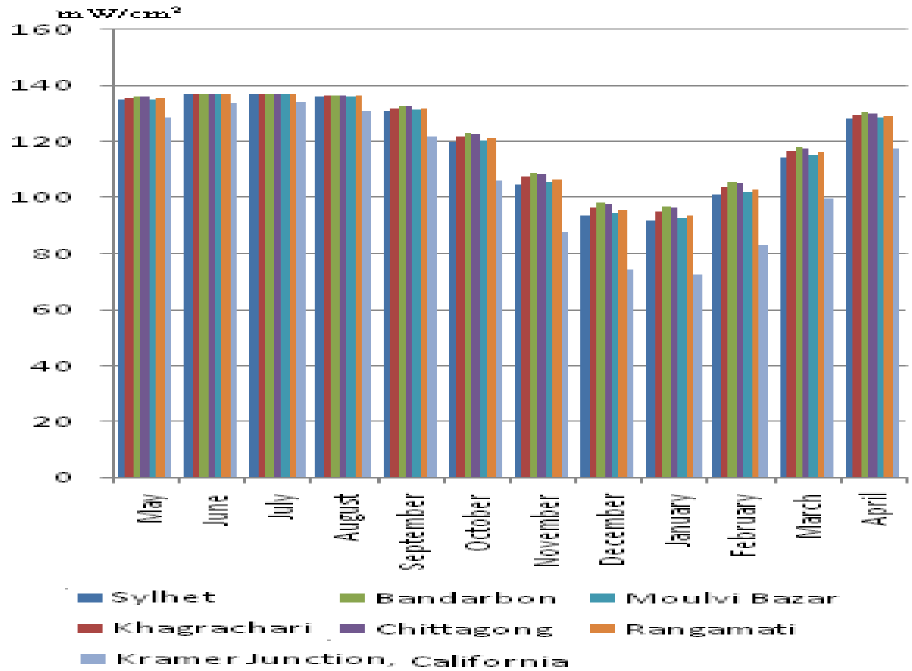

Figure 1: Solar intensity curve of different districts of micro- hydro power sites in Bangladesh and Kramer Junction, California.

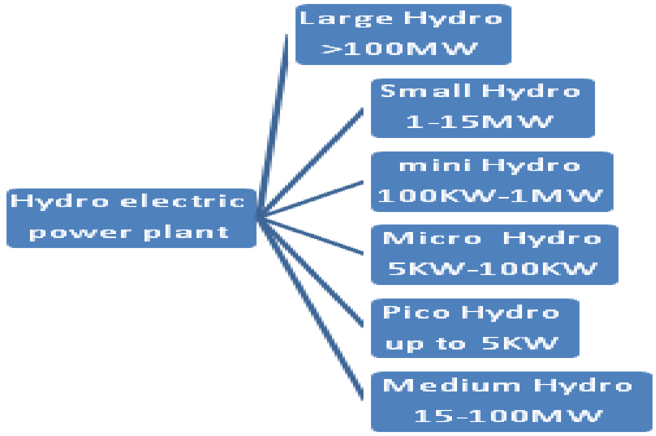

Figure 2: Classification of hydroelectric power plant

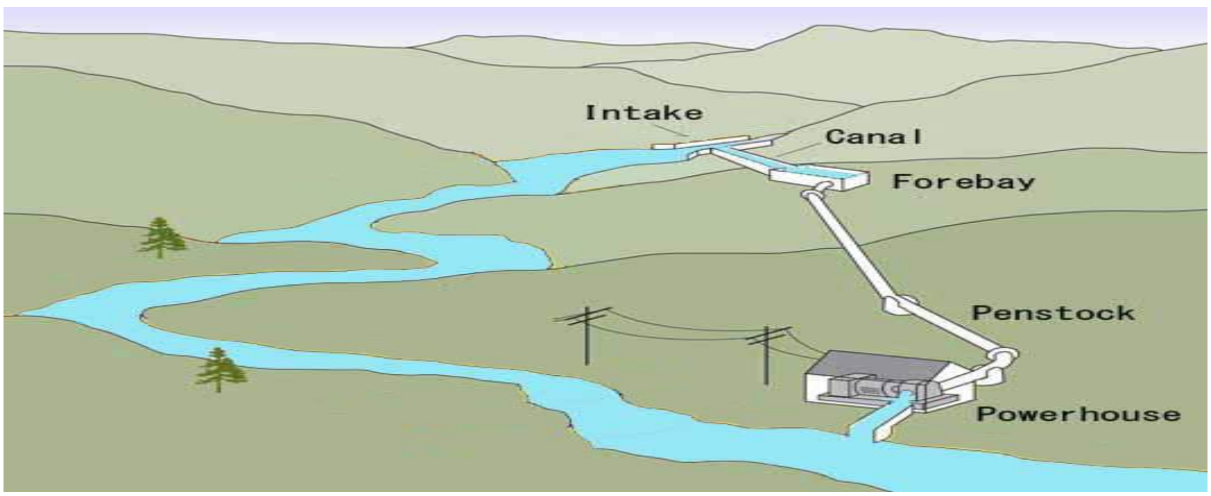

Figure 3: Conventional micro hydro power plant

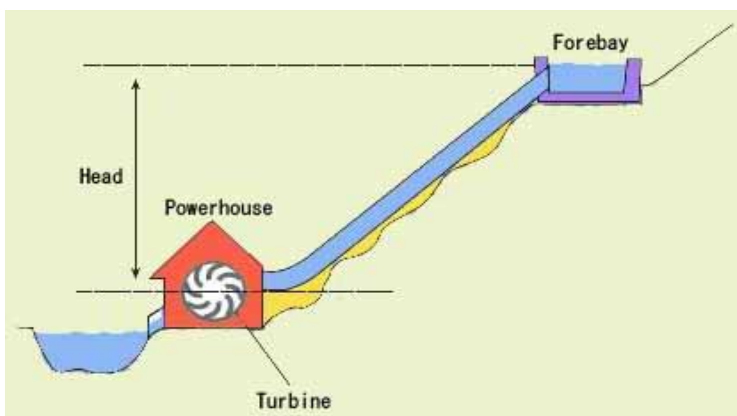

Figure 4: Conventional micro hydro power plant with penstock view

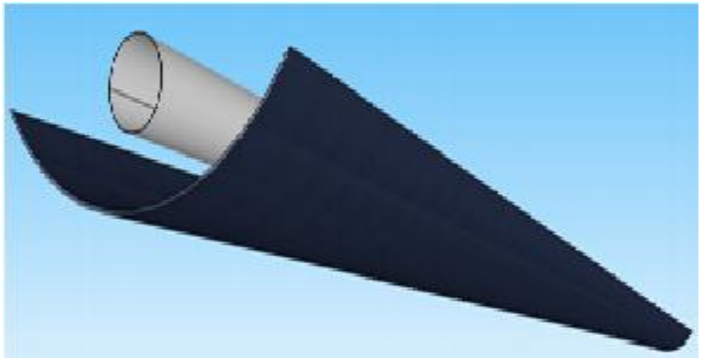

Figure 5: Penstock and reflector view in proposed design

Table 1: Literacy rate of different tribal districts of Bangladesh

District	Rangamati	Bandorban	Khagracori	Sylhet	Chittagong	Mymensingh	Moulvi Bazar	Dhaka	National
Literacy Rate	36.5% [13]	43% [14]	26.3% [10]	46% [15]	43.2% [16]	25.42% [17]	30.8% [108]	96.9% [18]	57.91% [19]

Table 2: Micro-hydro site pointed out in BPDB and BWDP joint survey and LGED survey

Site Name	***Sectional Area***	***Power Potential (kW)***
Nunchari Tholi Khal	11	5
Choto kumira	128.2	15
Hinguli chara	-	12
Lungi chara	545	10
Budia chara	660	10
Madhub chara	83.7	78
Bhugai kongsa	704	65.5
marisi	692.3	32.5
Sealock Khal	25	30
Taracha Khal	35	20
Rowangchari Khal	30	10
Hnara Khal	20	10
Hanara Khsl	25	30
Monjaipara	15	10
Bamar chara	-	10

Table 3: List of micro hydro power site with their flow rate, available head and possible electricity production

Site Name	***District***	***Flow Rate (liter/second)***	***Head (meter)***	***Power Potential Available (KW)***
Sailopropat	Bandarban	100	6	2.94
Madhabkundu	Moulovibazar	150	10	7.36
Faizlake	Chittagong	42.5	12	2.50
Sealck	Bandarban	1132	4	22.21
Madhunaghat bridge	Chittagong	7870	3.28	126.61
Sapchari waterfall	Khagrachori	38	10	1.86
Nikhari chara	Sylhet	480	6.8	16.01
Madhab chara	Sylhet	996	9.9	48.37
Lungichara	Chittagong	425	3	6.25
Budia chara	Chittagong	170	7.6	6.34
Chota karina chara	Chittagong	311	6	9.15
Bamar chara	Chittagong	150	10	7.36
Mahamaya Chara	chittagong	552	.9144	2.48
Ruanchori canal	Bandarban	771	5	18.91

Table 4: Solar declination on the 1st day of each month of the year in Bangladesh

Day (1st day of each month)	***Declination Θ in degree***
May	14.924
June	22.079
July	23.17
August	17.97
September	7.78
October	-4.172
November	-15.35
December	-22.13
January	-23.075
February	-17.612
March	-8.4
April	4.023

Table 5: Solar intensity, day hours and energy falls on earth surface of different districts of micro- hydro power site in Bangladesh and Kramer Junction, California for the first day of each month of the year.

District	*Latitude*	σ_D	*Day*	*Td* *hours*	*E* *MJ*
Sylhet	24.88	134.9389777	May	12.54893	1941408
Sylhet	24.88	136.8364899	June	13.26801	2081519
Sylhet	24.88	136.9390512	July	13.41243	2105754
Sylhet	24.88	136.0058887	August	12.81075	1997585
Sylhet	24.88	130.9497365	September	12.14863	1823915
Sylhet	24.88	119.7796679	October	12.04671	1654339
Sylhet	24.88	104.6252304	November	12.58197	1509239
Sylhet	24.88	93.4579613	December	13.27452	1422355
Sylhet	24.88	91.79398732	January	13.39943	1410177
Sylhet	24.88	101.0547034	February	12.77681	1480307
Sylhet	24.88	114.5539886	March	12.1726	1598697
Sylhet	24.88	128.0316551	April	12.04385	1767892
Khagrachari	23.167	135.5860729	May	12.54893	1950718
Khagrachari	23.167	136.9753254	June	13.26801	2083631
Khagrachari	23.167	136.9999998	July	13.41243	2106691
Khagrachari	23.167	136.437383	August	12.81075	2003923
Khagrachari	23.167	132.0942694	September	12.14863	1839857
Khagrachari	23.167	121.7129784	October	12.04671	1681041
Khagrachari	23.167	107.221078	November	12.58197	1546685
Khagrachari	23.167	96.40919203	December	13.27452	1467271
Khagrachari	23.167	94.79158367	January	13.39943	1456227
Khagrachari	23.167	103.7734052	February	12.77681	1520132
Khagrachari	23.167	116.7479435	March	12.1726	1629316
Khagrachari	23.167	129.4311451	April	12.04385	1787216
Bandarbon	22	135.957613	May	12.54893	1956063
Bandarbon	22	136.9998699	June	13.26801	2084004
Bandarbon	22	136.9714661	July	13.41243	2106252
Bandarbon	22	136.6615955	August	12.81075	2007216
Bandarbon	22	132.806507	September	12.14863	1849777

Bandarbon	22	122.9679309	October	12.04671	1698374
Bandarbon	22	108.9348381	November	12.58197	1571406
Bandarbon	22	98.37060899	December	13.27452	1497122
Bandarbon	22	96.78541744	January	13.39943	1486857
Bandarbon	22	105.5726307	February	12.77681	1546488
Bandarbon	22	118.183016	March	12.1726	1649343
Bandarbon	22	130.3184507	April	12.04385	1799469
Chittagong	22.33	135.8582576	May	12.54893	1954634
Chittagong	22.33	136.9986867	June	13.26801	2083986
Chittagong	22.33	136.9852919	July	13.41243	2106465
Chittagong	22.33	136.6039332	August	12.81075	2006369
Chittagong	22.33	132.6106719	September	12.14863	1847049
Chittagong	22.33	122.6182056	October	12.04671	1693544
Chittagong	22.33	108.4547748	November	12.58197	1564481
Chittagong	22.33	97.82006577	December	13.27452	1488743
Chittagong	22.33	96.2256403	January	13.39943	1478257
Chittagong	22.33	105.068257	February	12.77681	1539100
Chittagong	22.33	117.7821527	March	12.1726	1643749
Chittagong	22.33	130.0730028	April	12.04385	1796079
Moulvi Bazar	24.35	135.1520893	May	12.54893	1944474
Moulvi Bazar	24.35	136.8925065	June	13.26801	2082371
Moulvi Bazar	24.35	136.9709762	July	13.41243	2106245
Moulvi Bazar	24.35	136.1523865	August	12.81075	1999737
Moulvi Bazar	24.35	131.3163948	September	12.14863	1829022
Moulvi Bazar	24.35	120.3893401	October	12.04671	1662760
Moulvi Bazar	24.35	105.4384725	November	12.58197	1520970
Moulvi Bazar	24.35	94.38010782	December	13.27452	1436390
Moulvi Bazar	24.35	92.73032247	January	13.39943	1424561
Moulvi Bazar	24.35	101.9056209	February	12.77681	1492771
Moulvi Bazar	24.35	115.2438161	March	12.1726	1608324
Moulvi Bazar	24.35	128.476929	April	12.04385	1774040
Rangamati	23.73	135.3867264	May	12.54893	12.54893
Rangamati	23.73	136.9431842	June	13.26801	13.26801

Rangamati	23.73	136.993463	July	13.41243	13.41243
Rangamati	23.73	136.3089899	August	12.81075	12.81075
Rangamati	23.73	131.7310678	September	12.14863	12.14863
Rangamati	23.73	121.0894774	October	12.04671	12.04671
Rangamati	23.73	106.3783688	November	12.58197	12.58197
Rangamati	23.73	95.44860079	December	13.27452	13.27452
Rangamati	23.73	93.81559236	January	13.39943	13.39943
Rangamati	23.73	102.8899733	February	12.77681	12.77681
Rangamati	23.73	116.0382777	March	12.1726	12.1726
Rangamati	23.73	128.983875	April	12.04385	12.04385
Kramer Junction, California [151]	35.0198	128.6677273	May	12.54893	1851181.684
Kramer Junction, California [151]	35.0198	133.5239797	June	13.26801	2031130.198
Kramer Junction, California [151]	35.0198	134.0833774	July	13.41243	2061841.366
Kramer Junction, California [151]	35.0198	130.9849423	August	12.81075	1923839.992
Kramer Junction, California [151]	35.0198	121.8216185	September	12.14863	1696775.539
Kramer Junction, California [151]	35.0198	106.2097935	October	12.04671	1466918.637
Kramer Junction, California [151]	35.0198	87.42972191	November	12.58197	1261190.671
Kramer Junction, California [151]	35.0198	74.37307159	December	13.27452	1131898.678
Kramer Junction, California [151]	35.0198	72.4663709	January	13.39943	1113257.82
Kramer Junction, California [151]	35.0198	83.20075906	February	12.77681	1218772.024
Kramer Junction, California [151]	35.0198	99.5443561	March	12.1726	1389225.277
Kramer Junction, California [151]	35.0198	117.4552008	April	12.04385	1621849.724

Table 6: Flow rate, available head, potential available and Electrical power output in different micro hydro power site in Bangladesh.

Site	*District*	*Q* (*litter/second*)	*H* (*meter*)	*Potential Available in Water P (KW)*	*Electrical Power Output* P_e *(KW)*
Sailopropat	Bandarban	100	6	5.8	2.943
Madhabkundu	Moulovibazar	150	10	15	7.3575
Faizlake	Chittagong	42.5	12	5	2.50155
Sealck	Bandarban	1132	4	44.42	22.20984
Madhunaghat bridge	Chittagong	7870	3.28	253.23	126.61
Sapchari waterfall	Khagrachori	38	10	3.7278	1.8639
Nikhari chara	Sylhet	480	6.8	32.01984	16.00992
Madhab chara	Sylhet	996	9.9	95.753448	48.365262
Lungichara	Chittagong	425	3	12.50775	6.253875
Budia chara	Chittagong	170	7.6	12.67452	6.33726
Chota karina chara	Chittagong	311	6	18.30546	9.15273
Bamar chara	Chittagong	150	10	14.715	7.3575
Mahamaya Chara	Chittagong	552	.9144	4.952	2.475792864
Ruanchori canal	Bandarban	771	5	37.81755	18.908775

Table 7: Dynamic viscosity of water for different temperature obtained by the solar concentrator for micro hydro power plant

District	*Temperature rise in synthetic oil for 182.4 m^2 reflector in ℃*	*Temperature rise in water in ℃*	*1st day of the month*	*Dynamic viscosity* $\times 10^{-6}$ *N-s/m^2*
Sylhet	114.039806	56.56374377	May	504
Sylhet	115.6981127	57.38626391	June	504
Sylhet	115.7877449	57.43072149	July	504
Sylhet	114.9722193	57.02622079	August	504
Sylhet	110.5534593	54.83451579	September	504
Sylhet	100.7915194	49.99259362	October	547
Sylhet	87.54749085	43.42355546	November	595
Sylhet	77.78799762	38.58284682	December	652
Sylhet	76.33378865	37.86155917	January	652

Sylhet	84.42707407	41.87582874	February	652
Sylhet	96.22460324	47.72740321	March	547
Sylhet	108.003239	53.56960656	April	504
Khagrachari	114.6053267	56.84424204	May	504
Khagrachari	115.8194463	57.44644537	June	504
Khagrachari	115.8410102	57.45714104	July	504
Khagrachari	115.3493184	57.21326192	August	504
Khagrachari	111.5537093	55.33063981	September	504
Khagrachari	102.4811116	50.83063134	October	547
Khagrachari	89.81609901	44.54878511	November	595
Khagrachari	80.36718831	39.8621254	December	652
Khagrachari	78.95349998	39.16093599	January	652
Khagrachari	86.80304904	43.05431232	February	595
Khagrachari	98.14198227	48.67842321	March	547
Khagrachari	109.2263056	54.17624757	April	504
Bandarbon	114.9300294	57.00529458	May	504
Bandarbon	115.8408966	57.45708473	June	504
Bandarbon	115.8160735	57.44477244	July	504
Bandarbon	115.545266	57.31045196	August	504
Bandarbon	112.1761603	55.63937549	September	504
Bandarbon	103.5778614	51.37461926	October	547
Bandarbon	91.31381789	45.29165368	November	595
Bandarbon	82.08134379	40.71234652	December	652
Bandarbon	80.69598573	40.02520892	January	652
Bandarbon	88.37545939	43.83422786	February	595
Bandarbon	99.39614571	49.30048827	March	547
Bandarbon	110.001755	54.56087049	April	504
Chittagong	114.8431991	56.96222673	May	504
Chittagong	115.8398626	57.45657186	June	504
Chittagong	115.8281564	57.45076558	July	504
Chittagong	115.4948728	57.28545688	August	504

Chittagong	112.0050127	55.55448628	September	504
Chittagong	103.2722234	51.22302281	October	547
Chittagong	90.89427269	45.08355925	November	595
Chittagong	81.60020352	40.47370094	December	652
Chittagong	80.2067756	39.7825607	January	652
Chittagong	87.93466836	43.61559551	February	595
Chittagong	99.04581628	49.12672488	March	547
Chittagong	109.7872489	54.45447547	April	504
Moulvi Bazar	114.2260522	56.65612189	May	504
Moulvi Bazar	115.7470677	57.41054559	June	504
Moulvi Bazar	115.8156454	57.44456012	July	504
Moulvi Bazar	115.1002492	57.08972362	August	504
Moulvi Bazar	110.8738956	54.99345224	September	504
Moulvi Bazar	101.3243347	50.25687001	October	547
Moulvi Bazar	88.25821347	43.77607388	November	595
Moulvi Bazar	78.59389588	38.98257236	December	652
Moulvi Bazar	77.15208689	38.2674351	January	652
Moulvi Bazar	85.17072261	42.24467841	February	652
Moulvi Bazar	96.82746926	48.02642475	March	547
Moulvi Bazar	108.3923805	53.76262074	April	504
Rangamati	114.4311103	56.75783073	May	504
Rangamati	115.7913569	57.43251302	June	504
Rangamati	115.8352974	57.45430752	July	504
Rangamati	115.2371108	57.15760696	August	504
Rangamati	111.2362938	55.17320173	September	504
Rangamati	101.9362108	50.56036056	October	547
Rangamati	89.07962397	44.18349349	November	595
Rangamati	79.52769176	39.44573511	December	652
Rangamati	78.10054475	38.73787019	January	652
Rangamati	86.03098495	42.67136854	February	595
Rangamati	97.52177891	48.37080234	March	547

Rangamati	108.8354195	53.98236807	April	504

Table 8: velocity, flow rate, output and efficiency of power conversion in conventional design for selected micro hydro power site in Bangladesh

Micro hydro power site	*Velocity at 25^0C ft/s*	*Velocity in m/s*	*Pressure drop P_1-P_2 N/m2*	*Previous output power in KW*	*Water energy can be harnessed in previous system*
Sailopropat	4.64	1.41427	6.705535	2.943	50.74137931
Madhabkundu	6.96	2.12141	10.0583	7.3575	49.05
Faiz Lake	1.97	0.60046	2.846962	2.50155	50.031
Sealock	52.54	16.0142	75.92862	22.20984	49.9996398
Madhunaghat bridge	365.28	111.337	527.8875	126.61	49.99802551
Sapchari water fall	1.76	0.53645	2.543479	1.8639	50
Nikharichara	22.28	6.79094	32.19813	16.00992	50
Madhab Chara	46.23	14.0909	66.80967	48.365262	50.51020408
Lungi Chara	19.73	6.0137	28.51298	6.253875	50
Budia Chara	7.89	2.40487	11.4023	6.33726	50
Chota Karina Chara	14.43	4.39826	20.85364	9.15273	50
Bamar Chara	6.96	2.12141	10.0583	7.3575	50
Mahamaya Chara	25.62	7.80898	37.02496	2.475792864	49.99581712
Ruangchori Chanal	35.79	10.9088	51.72222	18.908775	50

Table 9 : velocity, flow rate, output and efficiency of power conversion in proposed design for selected micro hydro power site in Bangladesh

Site	*Month*	*Dynamic Viscosity $\times 10^{-6}$ N-m/s^2*	*Velocity increase m/s*	*Flow rate m^3/s*	*Q litter/s*	*Current power output KW*	*Water energy can be harnessed in current system*
Sailopropat	May	467	2.692265113	0.190305005	190.3050049	5.600676294	96.56338438

Sailopropat	June	467	2.692265113	0.190305005	190.3050049	5.600676294	96.56338438
Sailopropat	July	467	2.692265113	0.190305005	190.3050049	5.600676294	96.56338438
Sailopropat	August	467	2.692265113	0.190305005	190.3050049	5.600676294	96.56338438
Sailopropat	September	504	2.494618667	0.176334201	176.334201	5.189515534	89.47440577
Sailopropat	October	547	2.298515188	0.162472463	162.472463	4.781564587	82.44076875
Sailopropat	November	595	2.113088753	0.149365441	149.3654408	4.395824923	75.79008488
Sailopropat	December	652	1.928355534	0.136307419	136.3074192	4.011527346	69.16426458
Sailopropat	January	652	1.928355534	0.136307419	136.3074192	4.011527346	69.16426458
Sailopropat	February	595	2.113088753	0.149365441	149.3654408	4.395824923	75.79008488
Sailopropat	March	547	2.298515188	0.162472463	162.472463	4.781564587	82.44076875
Sailopropat	April	504	2.494618667	0.176334201	176.334201	5.189515534	89.47440577
Madhabkundu	May	504	3.741927999	0.264501301	264.5013013	12.97378883	86.49192554
Madhabkundu	June	467	4.038397669	0.285457507	285.4575072	14.00169073	93.34460486
Madhabkundu	July	467	4.038397669	0.285457507	285.4575072	14.00169073	93.34460486
Madhabkundu	August	467	4.038397669	0.285457507	285.4575072	14.00169073	93.34460486
Madhabkundu	September	504	3.741927999	0.264501301	264.5013013	12.97378883	86.49192554
Madhabkundu	October	547	3.447772781	0.243708694	243.7086945	11.95391146	79.69274309
Madhabkundu	November	595	3.169633128	0.224048161	224.0481611	10.9895623	73.26374869
Madhabkundu	December	652	2.892533299	0.204461129	204.4611286	10.02881836	66.85878907

Madhabkundu	January	652	2.892533299	0.204461129	204.4611286	10.02881836	66.85878907
Madhabkundu	February	652	2.892533299	0.204461129	204.4611286	10.02881836	66.85878907
Madhabkundu	March	547	3.447772781	0.243708694	243.7086945	11.95391146	79.69274309
Madhabkundu	April	504	3.741927999	0.264501301	264.5013013	12.97378883	86.49192554
Faiz Lake	May	467	1.143052214	0.080797599	80.79759906	4.755746681	95.11493362
Faiz Lake	June	467	1.143052214	0.080797599	80.79759906	4.755746681	95.11493362
Faiz Lake	July	467	1.143052214	0.080797599	80.79759906	4.755746681	95.11493362
Faiz Lake	August	467	1.143052214	0.080797599	80.79759906	4.755746681	95.11493362
Faiz Lake	September	504	1.059137667	0.074866029	74.86602929	4.406614484	88.13228968
Faiz Lake	October	547	0.975878216	0.068980766	68.98076556	4.060207861	81.20415722
Faiz Lake	November	595	0.897151906	0.063415931	63.41593069	3.732661681	74.65323361
Faiz Lake	December	652	0.818719914	0.0578719	57.87189994	3.406340031	68.12680061
Faiz Lake	January	652	0.818719914	0.0578719	57.87189994	3.406340031	68.12680061
Faiz Lake	February	595	0.897151906	0.063415931	63.41593069	3.732661681	74.65323361
Faiz Lake	March	547	0.975878216	0.068980766	68.98076556	4.060207861	81.20415722
Faiz Lake	April	504	1.059137667	0.074866029	74.86602929	4.406614484	88.13228968
Sealock	May	467	30.48526058	2.154876068	2154.876068	42.27866846	95.17935269
Sealock	June	467	30.48526058	2.154876068	2154.876068	42.27866846	95.17935269
Sealock	July	467	30.48526058	2.154876068	2154.876068	42.27866846	95.17935269

Sealock	August	467	30.48526058	2.154876068	2154.876068	42.27866846	95.17935269
Sealock	September	504	28.24725533	1.996680802	1996.680802	39.17487733	88.19197957
Sealock	October	547	26.02672155	1.839720519	1839.720519	36.09531659	81.25915485
Sealock	November	595	23.92708687	1.691306091	1691.306091	33.1834255	74.70379446
Sealock	December	652	21.83530167	1.543446509	1543.446509	30.28242051	68.17294127
Sealock	January	652	21.83530167	1.543446509	1543.446509	30.28242051	68.17294127
Sealock	February	595	23.92708687	1.691306091	1691.306091	33.1834255	74.70379446
Sealock	March	547	26.02672155	1.839720519	1839.720519	36.09531659	81.25915485
Sealock	April	504	28.24725533	1.996680802	1996.680802	39.17487733	88.19197957
Madhunaghat bridge	May	467	211.9462502	14.98159746	14981.59746	241.0299325	95.18221874
Madhunaghat bridge	June	467	211.9462502	14.98159746	14981.59746	241.0299325	95.18221874
Madhunaghat bridge	July	467	211.9462502	14.98159746	14981.59746	241.0299325	95.18221874
Madhunaghat bridge	August	467	211.9462502	14.98159746	14981.59746	241.0299325	95.18221874
Madhunaghat bridge	September	504	196.386704	13.88175796	13881.75796	223.3352748	88.19463522
Madhunaghat bridge	October	547	180.9486267	12.79050459	12790.50459	205.7787541	81.26160174
Madhunaghat bridge	November	595	166.3510905	11.75866557	11758.66557	189.1781151	74.70604395
Madhunaghat bridge	December	652	151.808127	10.73068407	10730.68407	172.6395375	68.1749941
Madhunaghat bridge	January	652	151.808127	10.73068407	10730.68407	172.6395375	68.1749941
Madhunaghat bridge	February	595	166.3510905	11.75866557	11758.66557	189.1781151	74.70604395

Madhunaghat bridge	March	547	180.9486267	12.79050459	12790.50459	205.7787541	81.26160174
Madhunaghat bridge	April	504	196.386704	13.88175796	13881.75796	223.3352748	88.19463522
Sapchari water fall	May	467	1.021204009	0.072184657	72.18465703	3.540657427	94.97981188
Sapchari water fall	June	467	1.021204009	0.072184657	72.18465703	3.540657427	94.97981188
Sapchari water fall	July	467	1.021204009	0.072184657	72.18465703	3.540657427	94.97981188
Sapchari water fall	August	467	1.021204009	0.072184657	72.18465703	3.540657427	94.97981188
Sapchari water fall	September	504	0.946234667	0.066885387	66.88538657	3.280728211	88.0070876
Sapchari water fall	October	547	0.871850589	0.061627486	61.62748598	3.022828187	81.08879735
Sapchari water fall	November	595	0.801516424	0.056655857	56.65585686	2.778969779	74.54718008
Sapchari water fall	December	652	0.731445202	0.051702814	51.70281416	2.536023035	68.03001863
Sapchari water fall	January	652	0.731445202	0.051702814	51.70281416	2.536023035	68.03001863
Sapchari water fall	February	595	0.801516424	0.056655857	56.65585686	2.778969779	74.54718008
Sapchari water fall	March	547	0.871850589	0.061627486	61.62748598	3.022828187	81.08879735
Sapchari water fall	April	504	0.946234667	0.066885387	66.88538657	3.280728211	88.0070876
Nikharichara	May	467	12.92751438	0.913792136	913.7921355	30.47862289	95.18668078
Nikharichara	June	467	12.92751438	0.913792136	913.7921355	30.47862289	95.18668078
Nikharichara	July	467	12.92751438	0.913792136	913.7921355	30.47862289	95.18668078
Nikharichara	August	467	12.92751438	0.913792136	913.7921355	30.47862289	95.18668078
Nikharichara	September	504	11.97847067	0.846708189	846.7081891	28.24110494	88.19876969

Nikharichara	October	547	11.03683586	0.780147948	780.1479475	26.02105464	81.2654112
Nikharichara	November	595	10.14646927	0.717211643	717.2116425	23.92187712	74.70954609
Nikharichara	December	652	9.259431312	0.654510625	654.5106247	21.83054738	68.17819007
Nikharichara	January	652	9.259431312	0.654510625	654.5106247	21.83054738	68.17819007
Nikharichara	February	652	9.259431312	0.654510625	654.5106247	21.83054738	68.17819007
Nikharichara	March	595	10.14646927	0.717211643	717.2116425	23.92187712	74.70954609
Nikharichara	April	504	11.97847067	0.846708189	846.7081891	28.24110494	88.19876969
Madhab Chara	May	467	26.82401211	1.896077667	1896.077667	92.07258348	96.1558935
Madhab Chara	June	467	26.82401211	1.896077667	1896.077667	92.07258348	96.1558935
Madhab Chara	July	467	26.82401211	1.896077667	1896.077667	92.07258348	96.1558935
Madhab Chara	August	467	26.82401211	1.896077667	1896.077667	92.07258348	96.1558935
Madhab Chara	September	504	24.854789	1.756881489	1756.881489	85.31328668	89.09682989
Madhab Chara	October	547	22.90093904	1.618771976	1618.771976	78.60675775	82.09287434
Madhab Chara	November	595	21.05346833	1.488181967	1488.181967	72.26537225	75.47025591
Madhab Chara	December	652	19.21290438	1.35808017	1358.08017	65.947694	68.87239611
Madhab Chara	January	652	19.21290438	1.35808017	1358.08017	65.947694	68.87239611
Madhab Chara	February	652	19.21290438	1.35808017	1358.08017	65.947694	68.87239611
Madhab Chara	March	595	21.05346833	1.488181967	1488.181967	72.26537225	75.47025591
Madhab Chara	April	504	24.854789	1.756881489	1756.881489	85.31328668	89.09682989

Lungi Chara	May	467	11.44792903	0.809206411	809.2064108	11.90747234	95.20075422
Lungi Chara	June	467	11.44792903	0.809206411	809.2064108	11.90747234	95.20075422
Lungi Chara	July	467	11.44792903	0.809206411	809.2064108	11.90747234	95.20075422
Lungi Chara	August	467	11.44792903	0.809206411	809.2064108	11.90747234	95.20075422
Lungi Chara	September	504	10.60750567	0.749800385	749.8003847	11.03331266	88.21180996
Lungi Chara	October	547	9.773643246	0.690858124	690.8581241	10.1659773	81.27742636
Lungi Chara	November	595	8.98518127	0.635125032	635.1250317	9.345864842	74.72059197
Lungi Chara	December	652	8.199666956	0.579600297	579.6002973	8.528818375	68.18827028
Lungi Chara	January	652	8.199666956	0.579600297	579.6002973	8.528818375	68.18827028
Lungi Chara	February	595	8.98518127	0.635125032	635.1250317	9.345864842	74.72059197
Lungi Chara	March	547	9.773643246	0.690858124	690.8581241	10.1659773	81.27742636
Lungi Chara	April	504	10.60750567	0.749800385	749.8003847	11.03331266	88.21180996
Budia Chara	May	467	4.578011154	0.323600536	323.6005365	12.0631808	95.17662837
Budia Chara	June	467	4.578011154	0.323600536	323.6005365	12.0631808	95.17662837
Budia Chara	July	467	4.578011154	0.323600536	323.6005365	12.0631808	95.17662837
Budia Chara	August	467	4.578011154	0.323600536	323.6005365	12.0631808	95.17662837
Budia Chara	September	504	4.241927001	0.299844148	299.8441479	11.17759014	88.18945526
Budia Chara	October	547	3.908466561	0.276273219	276.2732185	10.29891304	81.25682897
Budia Chara	November	595	3.593161695	0.253985631	253.9856311	9.468076357	74.70165622

Budia Chara	December	652	3.279035596	0.231781366	231.7813658	8.640345756	68.17098995
Budia Chara	January	652	3.279035596	0.231781366	231.7813658	8.640345756	68.17098995
Budia Chara	February	595	3.593161695	0.253985631	253.9856311	9.468076357	74.70165622
Budia Chara	March	547	3.908466561	0.276273219	276.2732185	10.29891304	81.25682897
Budia Chara	April	504	4.241927001	0.299844148	299.8441479	11.17759014	88.18945526
Chota Karina Chara	May	467	8.37271241	0.59183216	591.8321596	17.41762046	95.14986488
Chota Karina Chara	June	467	8.37271241	0.59183216	591.8321596	17.41762046	95.14986488
Chota Karina Chara	July	467	8.37271241	0.59183216	591.8321596	17.41762046	95.14986488
Chota Karina Chara	August	467	8.37271241	0.59183216	591.8321596	17.41762046	95.14986488
Chota Karina Chara	September	504	7.758048999	0.548384164	548.3841637	16.13894594	88.16465655
Chota Karina Chara	October	547	7.148184087	0.505275354	505.2753538	14.87025366	81.23397971
Chota Karina Chara	November	595	6.571523858	0.464513645	464.5136446	13.67063656	74.68065025
Chota Karina Chara	December	652	5.997019472	0.423904323	423.9043229	12.47550422	68.1518204
Chota Karina Chara	January	652	5.997019472	0.423904323	423.9043229	12.47550422	68.1518204
Chota Karina Chara	February	595	6.571523858	0.464513645	464.5136446	13.67063656	74.68065025
Chota Karina Chara	March	547	7.148184087	0.505275354	505.2753538	14.87025366	81.23397971
Chota Karina Chara	April	504	7.758048999	0.548384164	548.3841637	16.13894594	88.16465655
Bamar Chara	May	467	4.038397669	0.285457507	285.4575072	14.00169073	95.15250241
Bamar Chara	June	467	4.038397669	0.285457507	285.4575072	14.00169073	95.15250241

Bamar Chara	July	467	4.038397669	0.285457507	285.4575072	14.00169073	95.15250241
Bamar Chara	August	467	4.038397669	0.285457507	285.4575072	14.00169073	95.15250241
Bamar Chara	September	504	3.741927999	0.264501301	264.5013013	12.97378883	88.16710045
Bamar Chara	October	547	3.447772781	0.243708694	243.7086945	11.95391146	81.23623149
Bamar Chara	November	595	3.169633128	0.224048161	224.0481611	10.9895623	74.68272038
Bamar Chara	December	652	2.892533299	0.204461129	204.4611286	10.02881836	68.15370955
Bamar Chara	January	652	2.892533299	0.204461129	204.4611286	10.02881836	68.15370955
Bamar Chara	February	595	3.169633128	0.224048161	224.0481611	10.9895623	74.68272038
Bamar Chara	March	547	3.447772781	0.243708694	243.7086945	11.95391146	81.23623149
Bamar Chara	April	504	3.741927999	0.264501301	264.5013013	12.97378883	88.16710045
Mahamaya Chara	May	467	14.86548108	1.050778928	1050.778928	4.712882195	95.17128826
Mahamaya Chara	June	467	14.86548108	1.050778928	1050.778928	4.712882195	95.17128826
Mahamaya Chara	July	467	14.86548108	1.050778928	1050.778928	4.712882195	95.17128826
Mahamaya Chara	August	467	14.86548108	1.050778928	1050.778928	4.712882195	95.17128826
Mahamaya Chara	September	504	13.774166	0.973638411	973.6384114	4.366896795	88.18450718
Mahamaya Chara	October	547	12.6913705	0.897100109	897.1001085	4.023612404	81.25226987
Mahamaya Chara	November	595	11.66752885	0.824729007	824.7290073	3.699018462	74.6974649
Mahamaya Chara	December	652	10.64751482	0.752628465	752.6284653	3.375638014	68.16716506
Mahamaya Chara	January	652	10.64751482	0.752628465	752.6284653	3.375638014	68.16716506

Mahamaya Chara	February	595	11.66752885	0.824729007	824.7290073	3.699018462	74.6974649
Mahamaya Chara	March	547	12.6913705	0.897100109	897.1001085	4.023612404	81.25226987
Mahamaya Chara	April	504	13.774166	0.973638411	973.6384114	4.366896795	88.18450718
Ruangchori Chanal	May	467	20.76641561	1.467891406	1467.891406	36.00003674	95.19399523
Ruangchori Chanal	June	467	20.76641561	1.467891406	1467.891406	36.00003674	95.19399523
Ruangchori Chanal	July	467	20.76641561	1.467891406	1467.891406	36.00003674	95.19399523
Ruangchori Chanal	August	467	20.76641561	1.467891406	1467.891406	36.00003674	95.19399523
Ruangchori Chanal	September	504	19.241897	1.360129537	1360.129537	33.3571769	88.20554717
Ruangchori Chanal	October	547	17.72927987	1.253208934	1253.208934	30.7349491	81.27165589
Ruangchori Chanal	November	595	16.29901864	1.152109726	1152.109726	28.25549102	74.71528701
Ruangchori Chanal	December	652	14.87410443	1.051388477	1051.388477	25.78530239	68.1834291
Ruangchori Chanal	January	652	14.87410443	1.051388477	1051.388477	25.78530239	68.1834291
Ruangchori Chanal	February	595	16.29901864	1.152109726	1152.109726	28.25549102	74.71528701
Ruangchori Chanal	March	547	17.72927987	1.253208934	1253.208934	30.7349491	81.27165589
Ruangchori Chanal	April	504	19.241897	1.360129537	1360.129537	33.3571769	88.20554717