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Feasibility Study of Pico Hydro Power Plant in Shongrampunji Waterfall for Clean Environment

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ABSTRACT
Electricity from the energy of combustion of fossil fuel is increasing day by day in Bangladesh. In this case, increasing carbon compounds in environment is a great threat. Besides, in many hilly remoted regions there is no access of electricity. Another energy resources cannot meet the demand of electricity due to lack of transportation, lack of management and high cost of energy. To solve the problem, pico-hydro powerplant can be an alternative energy source for such kind of hilly remoted regions.Shongrampunji waterfall can be a resource of hydroelectricity for remoted hilly regions around Jaflong of Sylhet. The paper represents the overall important data of Pico-hydro powerplant and evaluates the feasibility of Shongrampunji water fall as a resource of pico-hydropower plant. To justify the feasibility, flow rate, water head of Shongrampunji waterfall is recorded and approximate power generation, COE are calculated using HOMER software.

Keywords: Pico-Hydro, Shongrampunji, Electricity, Environment, Waterfall

1. Introduction

The value of electricity is enormously growing worldwide for its versatile and widely used form of energy. The expanding new technologies and industries cannot be thought for a little moment without electricity. In simple sentence, accessibility of useable energy in the form of electricity has gradually assumed as an indispensable part of our everyday life. The demand for electrical energy in developing country like Bangladesh in particular generally get raised at a rate faster than the rate at which number of peoples are increased. The distance between demand and availability of electricity therefore retain a challenge in technologically developing and advanced countries. Bangladesh will need an average 34,000 MW of power by 2030 to sustain its economic and industrial improvement of over 7 percent. [1] As 2015, 92% urban population and 67% rural population have the access to the electricity for their source of light. [2] That means 33% of rural people are still away from electricity. Bangladesh has 15 MW solar energy capacity through rural households and 1.9 MW wind power in Kutubdia and Feni. Bangladesh has planned to produce 5% of total power generation by 2015 & 10% by 2020 from renewable energy sources like wind, waste & solar energy. [3][4]

The objective of this research is to show that the waterfall has enough feasibility to set up pico-hydro power plant .Jaflong is a hilly station and popular tourist destination in the Division of Sylhet, Bangladesh. It is about 60 km from Sylhet town and maximum populations are Khasi tribe [5]. Their living vicinity named 'Khasi Polli' is very near to the Shongrampunji waterfall.

For small and remote areas like Jaflong that require only a small amount of electricity in the range of 1 kW to 5 kW. Pico-Hydro-Power plant with smaller turbines of 200 to 300 watts may power a single home a head of 1 meter. [6] Total height of Shongrampunji waterfall is about 40 meters on average. It has a wide water falling surface with divided streamline at bottom side. Total power from four streamline is about 1.73kW which is enough for one house. If all streamlines are used for this purpose, then total Khasi Polli would be under electric supply only from Pico-Hydro-Power-Plant of Shongrampunji waterfall.

Fig.1 Shongrampunji waterfall

2. Methodology

The methodology for establishing a pico-hydro power plant is very necessary as it is the only stage where feasibility of pico-hydro power plant is determined. The methodology comprises of

- Power estimation
- Selection of turbine

2.1 Power estimation

For feasibility of electricity production, it is necessary to check how much power can be achieved to have a feasible output for consumers. Here is a defined formula

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to calculate the output power theoretically. The formula is given below [7-9]:

Input Power, $P_{in}=H*Q*g$

Output Power, $P=\eta*H*Q*g$……………….(1)

Here,
η= overall efficiency of hydropower plant.
as a rule of thumb, it is determined 50% considering all losses.On that point overall efficiency includes turbine efficiency ,electrical efficiency, mechanical efficiency etc.. [8-9][12]
H =available water head(m)
Q=water flow rate(liters/s)
From the equation (1), it is realized that available water head and water flow rate are main parameters to determine the output power.

2.2 Water flow rate measurement

To determine water flow rate, there are different methods that can be used to measure. From different methods, bucket method is the simplest method to be applied [10]. It is feasible in pico-hydro power plant in that sense, as the water flow rate is small and the location of consumers is far from waterfall. By this method, first of all it is necessary to take a bucket of known volume. Then, the bucket is kept at the water flow of waterfall and measure the time to fill up the bucket from stopwatch. Then if the volume is divided by the time to fill up, the flow rate is calculated simply. By using the method, 5-6 trials should be repeated to measure exact water flow rate, Q.

2.3 Water head measurement

There are many methods of head measurement. As the houses are far from water reservoir, the simplest and most practical method for head measurement is water-filled tube and calibrated pressure gauge [10]. Through this method, the pressure gauge reading in psi can be converted to head in meters using the following equation of pressure to head conversion [10]:

$H = 0.704 \times P$ ………………………… (2)

Where,
H = Head (meter)
P = Pressure (psi)

the mentioned equation (2) is simply a pressure head (psi) to (meter) conversion equation. As pressure gauge measures pressure as psi unit, but for calculation purpose it is needed to convert to meter unit for pressure head[11].

2.4 Selection of turbine

As a small amount of power generation is possible in Pico hydro power(<1kw). So, low head turbine is much suitable for this. There are two types of turbine based on action of flow. They are:

1) Impulse turbine
2)Reaction turbine.

For low head hydro power, reaction turbine is suitable and also cost-effective. Types of reaction turbine is given below[13-14]:

1)Francis turbine
2) Kaplan turbine
3)Kinetic turbine.

Besides them, many latest turbine with less power loss can be applicable for low water head. It is best suit to select type of low head turbine duringpractical implementation for better efficiency .

3. Theoretical calculation

For calculating flow rate, we have used bucket method for different four sites by the help of a 25 litre bucket and a stopwatch for time calculation. From Table 1-Table 4, the data of time calculation is recorded and given below.

Table 1 Time for filling up bucket(Site 01)

No. of Trials	Time(s)
01	2
02	2.09
03	2.5
04	2.4
05	2.1
06	1.9

Average Time, $t_{avg.}$ =2.12s
Flow rate, Q=11.81 L/s
Head, H=15m; η=50%
Output Power, P=$\eta*H*Q*9.8$
=868W

Table 2 Time for filling up bucket(Site 02)

No. of Trials	Time(s)
01	6.4
02	6.2
03	5.8
04	6.6
05	6.4

Average Time, $t_{avg.}$ = 6.28s
Flow rate, Q=3.98 L/s
Head, H=11.8m; η=50%
Output Power, P=$\eta*H*Q*9.8$
=230.12W

Table 3 Time for filling up bucket(Site 03)

No. of Trials	Time(s)
01	3.3
02	4.2
03	3.2
04	3.4
05	4

Average Time, $t_{avg.}$=3.62s
Flow rate, Q=6.9L/s
Head, H=10m; η=50%
Output Power, P =*η*H*Q*9.8*=338W

Table 4 Time for filling up bucket(Site 04)

No. of Trials	Time(s)
01	4.7
02	4.8
03	5.4
04	5
05	5.2

Average Time, $t_{avg.}$=5s
Flow rate, Q=4.98L/s
Head, H=12m; η=50%
Output Power, P=η*H*Q*9.8 =292.8W

Total power can be achieved from four sites
=(868+230.12+338+292.8)W
=**1.73kW**

4. Simulation of integratedenergy model

4.1 Component selection

First, we have to design our model. For this simulation modeling we have use "HOMER Micro-grid pro" software which is reliable and perfect for off-grid renewable energy modeling [15]. From 'Add/Remove' button we've selected 'primary load, PV, Hydro, Converter and a Battery storage. Though the simulation is for Pico hydro power plant, for reasonable cost of energy (COE) and having a good monthly solar radiation in Jaflong, we have integrated this solar energy. At night, to get power supply from solar energy, we have also used a battery storage. As the wind speed in Jaflong is not well enough (1.9 m/s recorded from NASA), it is not designed in integrated off-grid model. Now our off grid integrated renewable model is ready.

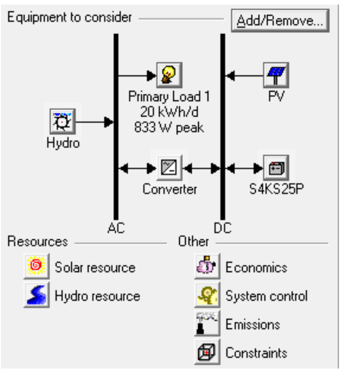

Fig. 2 Off-grid integrated model by HOMER

4.2 Solar Resource Data

We have collected the 12 months(mentioned in Table - 05)solar radiation data for 'Jaflong' using 'Homer' Software via internet.

Table 5 Monthly solar radiation data

Months	Clearance Index	Solar radiation (kWh/m^2 /day)
January	0.624	4.176
February	0.589	4.604
March	0.542	4.996
April	0.490	5.097
May	0.470	5.187
June	0.379	4.261
July	0.347	3.860
August	0.384	4.071
September	0.381	3.650
October	0.571	4.688
November	0.638	4.423
December	0.648	4.100
Average	0.486	4.425

4.3 Hydro resource data input:

We have visited 'Shongrampunji water fall-Jaflong, Sylhet' at June, 2018. In Bangladesh, rainy season starts from the middle of June and ends to the middle of August. We've inputted the hydro resource in Table 6 based on the summer and rainy seasons of our country. Table 7 and Table 8 includes accordingly capital cost of different components and operation and maintenance cost of them [16-17].

Table 6 Hydro source data of Shongrampunji waterfall

Month	**Flow rate (L/s)**
January	300
February	350
March	250
April	250
May	300
June	500
July	650
August	650
September	500
October	450
November	380
December	300

Table 7 Capital cost and size of different components

Components	Capital Cost ($)
1.73 kW Pico hydro power plant	1500
1kW Solar Panel	1800
Converter	200
Battery Storage	200

Table 8O& M and replacement cost of components

Components	Cost
O & M cost for solar panel	$5/year
O & M cost for hydro power plant	$100/year
Replacement cost of solar panel	$5000
Replacement cost of hydro power	$750

First of all, we have simulated the model considering capital cost and the simulation result is given below in Table 09.

Table.9 Simulation result of integrated model with capital cost

Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.
$ 1,900	124	$ 3,491	0.037	1.00
$ 11,900	183	$ 14,240	0.153	1.00

With capital cost, the COE is feasible if power supply is occurred only by hydro power and battery storage . As the COE when considering solar panel, it is **12.85 taka/kWh ($0.153)** and without solar panel COE will be **3.11 taka/kWh ($0.037).**
If we consider the system model without capital cost, then the simulation result is given below mentioned in table 10.

Table.10 Simulation of integrated model without capital cost

Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.
$ 0	124	$ 1,591	0.017	1.00
$ 0	183	$ 2,340	0.025	1.00

The result says that, without capital cost except operation and maintenance cost, the COE will be **1.42 taka/kWh(without solar panel)** and **with solar panel** it will be **2.10 taka/kWh**.

5. Result and Discussion

- Water is available almost at all time. We have visited it twice at the end of rainy season and water flow rate was almost same as first visit.
- The initial capital cost is high enough if PV solar cell is considered. If capital cost of PV solar panel is managed somehow, then it can be a good energy resource for consumers of Jaflong.
- As the output power for different sites are variable, total power output can be changed. Having big stones in water flow, the regular water flow is hampered and hence the water head is also low. If these stones are removed, then regular water flow and a better water head can be obtained that causes increase in power output.
- As the power output is small, it can be used for small electric load like battery charging, or one energy saving bulb etc. It is applicable mostly for remote areas around Shongrampunji waterfall where there is no access of electricity.

6. Conclusion

Pico-hydro power plant is an attractive and environment-friendly energy resource that can be the best future source of energy for remote hilly regions where access of electricity is impossible.
In this regard we have selected Songrampunji water fall that is the best location for small-scale pico-hydro power plant.
We have collected and evaluated data of Songrampunji Water fall mathematically and via HOMER. The result says that this site is enough feasible and can be more feasible using solar panel with energy storage which ensures power supply 24/7.
So, in future if Govt. can co-operate financially and technically, then people will get electricity who are deprived of it that is mentioned earlier.

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