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INSTALLATION OF MICRO-HYDRO POWER PLANTS IN THREE SELECTED LOCATIONS IN CHITTAGONG-A FEASIBILITY STUDY

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Abstract- *Harnessing micro-hydro and mini-hydro resources and setting up decentralized small-scale waterpower or micro-hydro schemes are particularly attractive option in terrain areas without hampering ecosystem. Although several scattered studies were carried out on the potential sites in Chittagong region by different researcher, concrete works to explore site-wise potential on installation of mini/micro hydro power plant is needed. We have identified three potential sites for installation of micro-hydro power plants. These sites are Sitakunda, Richang and Toibang of greater Chittagong, Bangladesh and are different from those found by other researchers in Bangladesh as far as we know. A detail study on the potential of micro-hydro power plants for these sites have been studied and presented in the paper. It is found that with the available head and flow rate a cross flow turbine or a waterwheel will be the best for the electricity production and the generator should be flexible enough to cover the range 500-3500-W in these sites. It is also found that effect on the ecosystem of the area is very less and the ecotourism will increases hopefully. Both the way of living and the living standard of this vicinity will be ameliorated after such installation. Design issues of micro-hydro power plant have also been discussed in the paper.*

Keywords: Micro-hydro power plant, Hydro-electric power plant, Renewable Energy, Micro Grid, Global Temperature Rise, Climate Change.

1. INTRODUCTION

Hydro power plants have obtained extensive interests to the researchers, planners and the govt. due to their ecological irreproachability and acceptable prices for generating electrical power without producing harmful pollution and green-house gases. Hydro power plant can be categorized based on their power producing capacity. Table 1 shows different category of hydro power plants.

Table 1: Classification of Hydro Power Plants

Large- hydro More than 100 MW and usually feeding into a large electricity grid
Medium-hydro 15 - 100 MW - usually feeding a grid
Small-hydro 1 - 15 MW - usually feeding into a grid
Mini-hydro Above 100 kW, but below 1 MW; either stand-alone schemes or more often feeding into the grid
Micro-hydro ranging from a few hundred watts for battery charging or food processing applications up to 100 kW; usually provided power for a small community or rural industry in remote areas away from the grid.

There is an increasing need in many countries for power supplies to rural areas, partly to support industries, and partly to provide illumination at night. Government authorities are faced with the very high cost of extending electricity grids. Often Micro-Hydro Power (MHP) plant provides an economic alternative to the grid. This is because independent micro-hydro power plants save on the cost of grid transmission lines, and because grid extension schemes often have very expensive equipment and shaft cost. Micro Hydro Power (MHP) plants can also be considered as environmentally friendly renewable energy sources since they can be sized and designed to limit the interference with river flow, canal flow or natural water falls in hilly regions or even on waste water flow in city corporations. Moreover, micro-hydro power plant can be designed and built by local staff and smaller organization following less strict regulation and using ‘off the shelf’ components or locally made machinery. Due to such advantages, researchers throughout the world have shown extensive interest on feasibility study as well as installation of MHP plants [1-16]. Some governments have already adopted formal policies which encourage localization, and it may be that many more will do so in the near future.

In Bangladesh mainly three govt. agencies i.e. Bangladesh Power Development Board, Bangladesh Water Development Board and Local Government Engineering Department have studied hydro potentials in the country. Researchers of other research organizations and universities have also conducted research projects on feasibility study of installing micro and mini hydro power plants in the country. These studies are not exhaustive, still more work needs to be done on this area. The authors of this paper have found out three potential sites in Chittagong for MHP plants. These are as follows.

1. Eco-Park (Sahasra Dhara) – Sitakunda
2. Alutila (Richang Jharna) – Khagrachori
3. Alutila (Toibang Jharna) – Khagrachori

Studies conducted on these sites for possibility of installation of MHP power has been presented in the paper. Some design issues of MHP plants have also been presented.

2. MEASUREMENTS AT THE SITES

Measurements conducted on finding out water flow rate and water head to get micro-hydro potentials are discussed below.

2.1 Flow Measurement

Two methods are commonly suggested for measuring the flow in small or medium sized streams. Large discharges are best determined by a hydraulic engineer. The float method of testing stream flow is the easiest test to conduct and will yield satisfactory data, except in case where a stream is shallow or rocky and thus impends the movement of a weighted float. Basically the cross section of an unobstructed area of the stream is measured and a weighted float such as bottle weighted with pebbles is timed as it floats down a 100 ft course.

To measure the velocity of water current in different time the floating system was used, because it is simple and easier way of measuring the velocity of flow by means of floats. The surface velocity at any section may be easily obtained with the help of single float. Observing the time taken by the float to travel a known distance, the current velocity is calculated by dividing the distance traveled by the float by the time taken to travel that distance.

2.2 Water Head Measurement

After the height of the water behind the proposed dam or diversion has been decided, it is necessary to measure the head of water that will result. To determine the difference in level between two points, surveyor's level was set at about midway between the points. An assistant hold of a surveyor's rod at one point, sight through the level and recorded the height, then the height of the other end is recorded. The difference of the reading is the difference in elevation of the two points. Often it is impossible to see the two points from a single setting of the level so rods must be read at intermediate or turning points. The difference in readings between each pair of points can be added together to calculate the total elevation drop from the dam or diversion. Proposed penstock length was also measured.

3. ECO-PARK SITE AT SITAKUNDU

Fig.1 shows the site of micro-hydro potential at Eco-park, Sitakundu, Chittagong and subsequently data collection and calculations are also presented.

Fig.1 Photograph of the proposed site at Eco-park

Length, **L** = 1.2192 m
Width, **W** = 0.286 m
Area, **A** = 0.2787 m²

Table 2 shows the duration of the observations at different times at the site.

Table 2: Duration of observations

No of obs.	Time
01	0.82
02	0.99
03	0.93
04	0.91
05	0.86
06	1.06
07	0.99
08	0.87
09	0.84
10	0.86

Average time **t** = 0.913 s

$$\text{Velocity } \mathbf{V} = \frac{1.2192\text{ m}}{0.913\text{ s}}$$
$= 1.33$ m/s

Flow, **Q** = **VA**
$= 1.33 \times 0.2787$
$= 0.3706$ m³/s

Head, **H** = 52 feet
$= 15.8496$ m

Gravitational acceleration, **g** = 9.81 m/s²
Density of water, **ρ** = 1000 kg/m³

Turbine efficiency tends between 0.4 and 0.6 of gross power.

Let, turbine efficiency = 50%

Then Power, **P** = efficiency (%) ×flow (m³/s) ×head (m) × Gravitational acceleration (m/s²)×Density of water (kg/m) $= 0.5\times0.37067\times15.8496\times9.81\times1000$
$= 28.82$ kW

Following data were found out for the reservoir
Length, L = 9.144 m
Width, W = 3.048 m

Depth (average) = 2 m
Volume of the reservoir = 55.75 m³

4. RICHANG JARNA SITE AT KHAGRACHORI

Fig.2 shows the site of micro-hydro potential at Richang Jarna, Khagrachori, Chittagong and subsequently data collection and calculations are also presented.

Fig.2 Photograph of the proposed site at Richang Jarna

Length, **L** = 1.651 m
Width, **W** = 0.127 m
Area, **A** = 0.2097 m²

Table 3 shows the duration of the observations at different times at the site.

Table 3: Duration of observations

No of obs.	Time
01	1.10
02	0.76
03	0.82
04	0.98
05	1.06
06	0.86
07	0.80
08	0.95
09	1.01
10	0.93

Average time **t** = 0.927 s

$$\text{Velocity } \mathbf{V} = \frac{1.651 \text{ m}}{0.927 \text{ s}}$$
= 1.78 m/s

Flow, **Q** = **VA**
= 1.78 × 0.2097
=0.3734 m³/s

Head, **H** = 40 feet
=12.192 m

Power, **P** = efficiency (%) ×flow (m³/s) ×head (m) × Gravitational acceleration (m/s²)×Density of water (kg/m) = 0.5×0.3734×12.192×9.81×1000
= 22.33 kW

Following data were found out for the reservoir
Length, L = 7.62 m
Width, W = 6.4 m
Depth (average) = 0.762 m
Volume of the reservoir = 37.16 m³

5. TOIBANG JHARNA SITE AT KHAGRACHORI

Fig.3 shows the site of micro-hydro potential at Richang Jarna, Khagrachori, Chittagong and subsequently data collection and calculations are also presented.

Fig.3 Photograph of the proposed site at Toibang Jarna

Length, **L** = 1.8288 m
Width, **W** = 0.2280 m
Area, **A** = 0.418 m²

Table 4 shows the duration of the observations at different times at the site.

Table 4: Duration of observations

No of obs.	Time
01	0.96
02	0.87
03	0.81
04	1.01
05	0.88
06	0.93
07	0.98
08	0.90
09	0.79
10	0.80

Average time **t** = 0.883 s

$$\text{Velocity } \mathbf{V} = \frac{1.8288 \text{ m}}{0.883 \text{ s}}$$
= 2.07 m/s

Flow, **Q** = **VA**
= 2.07× 0.418
=0.865 m³/s

Head, **H** = 65 feet
=19.812 m

Power, **P** = efficiency (%) ×flow (m³/s) ×head (m) × Gravitational acceleration (m/s²)×Density of water (kg/m) = 0.5×0.865×19.812×9.81×1000
= 84 kW

Following data were found out for the reservoir
Length, L = 6.7056 m
Width, W = 2.7432 m
Depth (average) = 0.9144 m
Volume of the reservoir = 16.82 m^3
$\approx$ 17 m^3

6. ELECTRICAL SYSTEMS FOR MHP PLANTS

Electrical generators in MHP plants are mainly induction generators, synchronous generators with field excitation, or permanent-magnet generators (PMGs). With the rapid development of power semiconductor devices, the generated power from MHP plants can be easily converted to quality power sources using suitable power converters.

Three-phase as well as single-phase squirrel case induction motor operated as Self-Excited Induction Generator (SEIG) is gaining popularity over synchronous generator [17-18]. These motors are available easily and no prior purchase order is required. These generators appears to be most promising and can be operated with variety of prime movers such as micro-hydro turbine, wind turbine etc. The advantages of SEIG are reduced unit cost, brushless rotor construction, absence of DC source for excitation, raggedness, ease of maintenance etc.

Induction machine will operate as a generator if proper supply of inductive (lag) VAR (volt ampere reactive) is available to provide the machine's excitation at a particular operating speed. Self-excitation can be achieved by the connection of suitable capacitors (inductive or lag VAR source) for the induction generator. Once the machine is excited, the magnitude of the steady-state voltage generated is determined by the nonlinearity of the magnetizing characteristics, the value of capacitance, speed and terminal load. As the load and speed of SEIG around any operating point changes, the demand of lag VAR to the machine to maintain constant AC voltage across its terminals also changes, which can be achieved through suitable reactive power compensator. Fig. 4 shows the proposed schematic diagram for a cost-effective and simple micro-hydro power plant. Electronic load controller can control the output frequency whereas variable excitation capacitor can regulate the output terminal voltage.

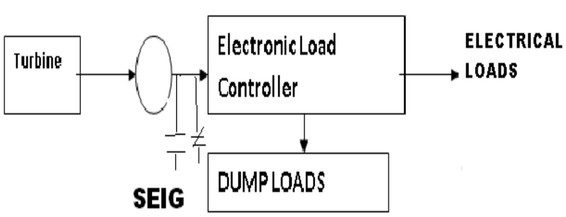

Fig.4 Generation scheme for micro-hydro power plant

To regulate the output voltage variable capacitor is needed which can be obtained through electronically controlled often binary weighted switched capacitor banks. For induction generator application, a fixed capacitor bank, sufficient to excite the induction machine at rated speed and no load, is connected across the machine terminals. Variable lagging VAR are generated by switching in or out appropriately dimensioned of capacitor bank. The switches normally consist of two anti-parallel thyristors in series with a small current limiting inductor [19-21]. As the load and speed changes, the generator demand of lagging VAR also changes, which is met by switching in or out the capacitor banks as per the requirement.

7. TURBINE DESIGN FOR MHP PLANTS

Two major attractions have led to a consideration interest in the cross flow turbine for MHP plants. Firstly, it is a design suitable for a wide range of heads power ratings. Secondly, it lends itself easily to simple fabrication techniques, a feature which is of interest in developing countries. The runner blades, for instance can be fabricated by cutting pipe lengthwise in strips.

7.1 Design Calculations

For sizing calculation the dimension we need are runner length (**L**), diameter (**D**) and jet thickness (**t**) The width of the rectangular jet orifice is always equal to runner length.
If **Q** is flow in m^3/s, **H** is net head in meters, and then an approximate dimension can be obtained using the method described here:

First, decide on the preferred running speed and calculate the approximate runner diameter:

$$\mathbf{D} = 41\text{x} \frac{\sqrt{\mathbf{H}}}{\text{rpm cross flow}}$$

The jet thickness is around one tenth to one fifth of the runner diameter.

$$\mathbf{t} = 0.1 \times \mathbf{D} \rightarrow 0.2 \times \mathbf{D}$$

Having estimate **t**, the approximate runner length (**L**) can be found.

$$\mathbf{L} = \frac{\mathbf{Q}}{\mathbf{t} \times \sqrt{(2 \times g \times \mathbf{H})}}$$

$$= \frac{0.23 \times \mathbf{Q}}{\mathbf{t} \times \sqrt{\mathbf{H}}}$$

Let us consider the Toibang Jharna site at Khagrachori and also consider running speed of the turbine = 600 rpm.
Net head **H** = 19.812 m
Flow of water **Q** = 0.865m^3/s
Therefore diameter is

$$\mathbf{D} = 41 \text{ x } \frac{\sqrt{19.812}}{600}$$

= 0.304 m
<u>Thickness of jet</u>
t = 0.2 × 0.304
=0.0608 m
The length of the runner is
0.865

$$\mathbf{L} = \frac{\qquad}{0.0608 \times \sqrt{(2\times 9.81\times 19.812)}}$$
$$= 0.721\text{m}$$

Let the diameter of steel rod (rotor) = 4.5 cm = 0.045 m
Volume of runner = $3.1416 \times (0.152)^2 \times 0.721$
$= 0.0523\ m^3$
Volume of steel rod = $3.1416\times (0.0225)^2 \times 0.721$
$= 0.001146 m^3$
Net volume = $0.0511\ m^3$
Periphery of runner = $2 \times 3.1416 \times 0.152$
$=0.955$ m
No of buckets = 20
Distance between two adjacent buckets = 0.955/20
= 0.047 m
Volume between two adjacent buckets = $0.0511/20\ m^3$
$= 0.00255\ m^3$

7.2 Materials

* Steel plate 6.5mm X 50cm X 100cm
* Steel plate 6.5mm thick (quantity of material depends on nozzle width)
* 7cm ID water pipe for turbine buckets
* 4 hub flanges for attaching end pieces to steel shaft (found on most car axles)
* 4.5cm diameter solid steel rod
* two 4.5cm diameter pillow or bush bearings for high speed use. (It is possible to fabricate wooden bearings. Because of the high speed, such bearings would not last and are not recommended.)
* Eight nuts and bolts, appropriate size for hub flanges

7.3 Tools

* Welding equipment with cutting attachments
* Metal file
* Electric or manual grinder
* Drill and metal bits
* Compass and Protractor
* T-square (template included in the back of this manual)
* Hammer
* C-clamps
* Work bench

8. CONCLUSIONS

To limit change in global climate and meet the increasing demand of electricity, one of the promising solutions is to install more hydro power plants. In Bangladesh large hydro plants may not be feasible due to political regions in hilly Chittagong regions, but there is good potential for mini and micro hydro plants. This paper discusses the strategic importance and potential of such plants. A detailed field survey in three selected locations, i.e. Eco-Park (Sahasra Dhara) at Sitakunda, Alutila (Richang Jharna) at Khagrachori and Alutila (Toibang Jharna) at Khagrachori has been presented to support this claim. Electrical power generation in these sites would be in the range 500-3500 W. Technical issues on installation of a micro-hydro plant such as electrical systems and turbine design have also been presented. It is hoped that this study will also encourage exploring more potential sites and constructing micro hydro power plants in greater Chittagong regions.

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