Assessment of Streams in Oras, Eastern Samar: A Basis for the Design of Pico-hydro Projects and Potential Site for Installation

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Abstract: Pico-hydro is a technology that generates small energy usually in the range of 1Kw to 5KW from flowing water like streams. It is known fact that there are communities in Eastern Samar that are rich in water resources where we can install turbines of 200 to 300 Watts at run-of-stream to power a house. This technology of generating small energy from run-of-streams can be used in electrifying small houses in an off-grid rural areas. The focus of the study is the stream characteristics of Lunang, Binowangan, Pisaak and Camanga Streams and the potential power that can be generated at specific streams in so that the researchers can recommend the design of pico-hydro technology suitable for each of the potential streams. Binowangan has large reservoir of water due to the manmade structure, but it cannot guarantee the continuity of water flow over the year. Peak potential energy at Benogawan Falls is five hundred thirty watts (533.67 watts) and zero potential energy during dry season. The minimum potential power that can be generated at Lunang Stream during dry season is 43.95 watts and a peak power potential of 44.34 watts at the month of August or during rainy season. During dry season, a potential electric power of 78.48 watts can be generated at Camanga stream with the average flow rate of 6 liters per second. The power that can be generated at this season is enough to power bulbs at home or within the site. At rainy season, the stream is capable of generating 251.14 watts. Among the streams that were investigated, Pisaak Falls has the highest power potential for pico-hydro. Two kilowatts power potentials during rainy season and 470 watts during dry season.

1. Introduction

Pico-hydro is a technology that generates small energy usually in the range of 1Kw to 5KW from flowing water like streams. It is known fact that there are remote areas that are rich in water resources where we can install turbines of 200 to 300 Watts at run-of-stream to power a house. This technology of generating small energy from run-of-streams can be used in electrifying small houses in an off-grid rural areas.

Some of the off-grid rural areas in Eastern Samar are already a recipient of the expanded rural electrification program of the government like the residential solar power systems in Sta. Monica, Oras but there are still communities in Eastern Samar that have not been reach by ESMALECO and has not been included in the missionary electrification effort of the government. However, there are communities in Oras, Can-avid, Taft and Borongan have nearby streams which are potential source for pico-hydro. There is a need to study the characteristics of these streams and determine the potential power that can be generated at specific streams in so that the researchers can recommend the design of pico-hydro technology suitable for each of the potential streams.

This paper focuses on the assessment of streams in Oras, Eastern Samar in order for the researchers to determine the potential site to install pico-hydro plans. Specifically this aims to determine the characteristics of the stream, analyze volume of streams, flow rate of water, height of each head, and determine the potential power that can be generated from specific streams using a predetermine turbine head size.

2. Review of Related Literature and Studies

This section includes the review of related literature and studies which the researcher has perused to shed light on the development of the project.

In many countries in Asia there is a huge gap between demand and supply of electric power. Every year this gap is widening and to cope up with the increasing demand, load shedding is often resorted to. Installation of new power plants require huge capital and land. Due to these constraints, pace of growth in generation is low. Many developing countries are facing this problem. Development on the renewable energy front is also very slow due to their pertinent issues. Small scale electrical power generation is becoming popular in many countries as it helps in reducing the cost of electricity, the stress.
on the main system and transmission distribution expenses to remote areas. Electric generation with capacity 5 Kw-100 Kw is classified as micro and below 5 Kw is classified as pico generation. Traditionally conventional permanent magnet alternators are in use for pico generation. But due to their obvious operational advantages and owing to availability of modern control techniques, induction generators are assuming significance. Induction generators employing slip ring induction motors are already in use for wind power generation in grid connected mode [3,4]. When an induction generator is not connected to supply grid, it is said to be operating in self excited mode. In this mode, normally small induction motors are used, and capacitors are connected to its terminals for the supply of required reactive power. These generators can be used for wind and picot hydro generation.

Small waterfalls and water flows at many places are found to be running throughout the year. If the height of water fall is more than 10 meters, it is possible to generate electricity by using micro turbines and small induction generators. Where more small water flows with lower head are available, the flow can be aggregated with minor civil construction and, electricity can be generated. For developing a Pico hydro generation unit, it is necessary to measure the head of water, its discharge or flow, suitable location for construction of a dam if necessary, selection of turbine and generator and their location etc. Small water turbines are now available in different sizes and there is a scope to select a proper turbine from available range. A substitute for turbine can be a centrifugal pump, which can be used as turbine with little modifications. The problem however is that the water pressure required for a pump to work as a turbine is high and this technology is not yet fully proven. Dr. Punit Singh et al presented a study conducted in Tanzania for 10 KW generation by using a pump as turbine. D. A. Howey, presented a scheme of pico hydro generation by using a small propeller turbine. Instead of using an induction generator, he developed an axial flux permanent magnet alternator which was capable of developing a power of 200 watts at 230 volts. Edward CG Ando et al, discussed a novel application of Pico hydro generation for telecommunication system. He presented a detailed economic analysis of the complete unit right from small dam up to the alternator. Ahmed M.A. Haidar et al presented a case study of Pico hydro generation for domestic and commercial loads. They used a water pump as turbine and an alternator. MATLAB analysis of the unit is also presented. The output is used for charging storage batteries. H. Zaimuddin et al proposed a new idea of using the consumer water distribution network and installing small generating units in the path of water flow to charge storage batteries. They were able to generate electric power up to 1.2 Watts.

Most of the developing countries are suffering from what many call the energy crisis, characterized by depletion of locally available energy resources and dependence on imported fuel. In addition, the energy crisis is exacerbating the food crisis by increasing the rate of deforestation and thereby causing degradation of farmlands. Furthermore, dependence on imported fuel is weakening the capacity of the concerned countries to buy food whenever the need arises. The fate of our country Ethiopia is not different from this issue. Ethiopia is a country with a population of 80 million and a total area of 1.1 million sq.km. Of these 80 million people 85% is living in rural area where it is hard to get modern energy, electricity. Therefore, these people are forced to use traditional energy sources for their demand. However, still there are people living in urban areas but relying on traditional fuels. This may be because that these people are not able to afford for the modern fuel and/or are unaware of the advantage that the modern fuels have over the traditional ones. With this in mind, Ethiopia is a country that relies extremely on traditional fuel, third from Africa, led by Chad and Eritrea. Moreover, more than 99.9% of the rural energy consumption of the country is mate by traditional fuels.

Water had power by both its motion (kinetic energy) and by its position (potential energy). To make this energy usable, prime movers such as water wheels are required. Earlier in the history of energy development and use, water wheels provide power by direct connection or with pulley and gear systems to drive various machines, such as grist mills and textile mills. Moreover, since ancient times, water wheels have been used for lifting water from a lower to a higher elevation in irrigation systems. In this fast developing world however the way of consumption of water power is changed from its direct way to indirect way, a more efficient and easily usable electrical energy. In the case of hydropower electricity production, the prime movers are water wheels or turbines. These prime movers convert the power available in the water to rotational/mechanical energy of the shaft of the generator. Then the generator acting as an energy converting unit converts the rotational/mechanical energy to electrical energy. This is the principle of hydropower engineering, the technology involved in converting the pressure energy and kinetic energy of water into electrical energy [6].

3. Methodology

The following discussion describes the materials and processes used in the development of the project.

3.1 Research Design
The paper is a descriptive-evaluative research since the researcher will describe the characteristics of the streams and will evaluate whether the stream is a potential site for installation of pico-hydro project.

3.2 Instrument and Data Gathering Procedure

The potential site may be determined by the distance of streams to residential area, this can be done using ocular inspection and also the researchers will take note the volume and flow rate of a stream using a bucket, stopwatch and a meter stick. The bucket method will be used in determining the flow rate. In this method, the amount of water gathered using a bucket will be recorded per minute. In determining volumetric flow, a Styrofoam will be released on surface of the stream and the distance travelled in meter by the Styrofoam will be recorded over time. Multiple readings or multiple trials will be done to reduce errors due to equipment limitations and coordination with the timings.

3.2 Data Analysis

In general the feasibility of the proposed pico-hydro system is based on the following potential input and output power equation:

\[
\begin{align*}
\text{(1) } \ P_{\text{in}} &= H \times Q \times g \\
\text{(2) } \ P_{\text{out}} &= H \times Q \times g \times n \\
\end{align*}
\]

where:

- \( P_{\text{in}} \) = Input power (Hydro power)
- \( P_{\text{out}} \) = Output power (Generator output)
- \( H \) = head (meter)
- \( Q \) = water flow rate (liter/second)
- \( g \) = gravity (9.81 m/s²)
- \( n \) = efficiency (0.8)

Based on equation (1) and (2), both head and water flow rate are very important parameters in hydropower system. Head is a measure of falling water at turbine, i.e. vertical distance from the top of the penstock to the turbine at the bottom. Water flow is the amount of water flows within one second. Normally, water flow available is more than needed since the flows for pico-hydro are small. Thus, it is important to measure head carefully because the greater head, the greater power and the higher speed of turbine rotation.

4. Results and Discussions

Electricity generation in pico-hydro depends on the simple concept of hydropower. The moving water will spin the turbine which will cause the drives of the generator and hence, the electricity will be produced. Unlike with the other hydro power generation like in Micro hydro or larger ones, pico-hydro solely dependent on running water. As long as there is flowing water, a small electrical energy can be generated. However, before embarking on pico-hydro power generation project, it is essential to survey the water source characteristics to ensure availability of water all throughout the year. In site where there is no natural water flowing specially during dry season, water source does not provide enough water available over the year. Flowing water can be improved by constructing a weir because it is important to note that the potential power is directly proportional on the head and the water flow rate. This means that doubling the size of the head will also double the potential power. The minimum head for pico hydro is .90 meter and a minimum water flow rate of 6 liters/sec is needed to generate an approximate 300 watts of electricity.

Flow rate is the quantity of water available in a stream or river and may vary widely over the course of a day, week, month and year. When a site has been identified as topographically suitable for hydropower, the first task is to investigate the availability of an adequate water supply. In order to adequately assess the minimum continuous power output to be expected from the micro-hydropower system, the minimum quantity of water available throughout the year must be determined.

Streams characteristics such as the width, water depth and water flow rate were recorded by the researchers every month to observe the viability of the site for pico hydro project. Figure 1 shows the depth of water in different streams in Oras, Eastern Samar. There is less rain fall during the month of May so it can be seen in Figure 1 the water reservoir of different streams under study. The manmade structure three (3) meters below road level in Lunang stream impounds larger amount of water even during summer and same in the case of Binowangan Falls. The water level in Binowangan is eighty (80) centimeters and among the four streams investigated, Lunang has the greatest reservoir of water during summer. Contrary to the case of Binowangan Falls, there is no water coming from the head of Binowangan Falls and this is the main reason that even there is a man made structure in Binowangan Falls only thirty four (34cm) centimeters water level has been recorded. Camanga stream and Pisak Falls have abundant natural water flowing even during summer. Unlike in Camanga stream, the Pisak Falls also has a manmade structure that holds the water. There is a significant increase in the water level for all streams under study from the month of July and August due to rainfall. Water impounded at Pisak Falls at small dam reaches at its peak level of ninety centimeters (90cm) from July to August. Water reservoir of the four streams depend on the size of the manmade structure present at the site. Lunang and Binowangan holds greater amount of water during summer because of the bigger dam present at both site as compared to the water impounding structure at Pisak Falls.

In the run-of-the streams schemes, on which most of small and pico hydropower systems are based, a low diversion structure is built on the streambed prior to the intake to divert/channel the
required amount of flow to the intake for power generation whilst the rest of the excess water continues to overflow it. This structure, commonly known by the name weir, is not constructed to store water rather to increase the level of water so that the water can inter to the intake structure in a reliable and controllable way. Weirs can be constructed permanently or temporarily using traditional water management techniques. If the terrain in the vicinity of the site is relatively flat, to get the required head for power generation, the water may be conveyed by using pressure pipes or penstocks from a long distance. But this may be costly and constructing weirs to get the required head may be an economical option. The intake of a hydro scheme is a structure designed to permit and control the required amount of water flow to a water way without producing a negative impact on the local environmental and with minimum head loss.

In Table 2, a zero (0) flow rate in Binowangan can be noticed. In spite of the ten meters elevation drop in Binowangan Falls, there is zero water discharge. Although Binowangan has large reservoir of water due to the manmade structure, it cannot guarantee the continuity of water flow over the year.

Table 2: Monthly Average Flow Rate of Streams Under Investigation

<table>
<thead>
<tr>
<th>Site</th>
<th>Average Flow Rate (liters/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>May</td>
</tr>
<tr>
<td>Camanga</td>
<td>6</td>
</tr>
<tr>
<td>Binowangan</td>
<td>0</td>
</tr>
<tr>
<td>Lunang</td>
<td>2</td>
</tr>
<tr>
<td>Pisak</td>
<td>11.2</td>
</tr>
</tbody>
</table>

There is a small potential electric power that can be generated from Camanga stream from May to June. A weir can be constructed to improve the water flow of the stream. The potential electric power is directly proportional to the flow rate and the elevation drop. In Table 2, Camanga stream has an increasing average water flow rate from May to August and it satisfy the minimum six (6) liters of water per second in order for the site to be viable for pico hydro power generation. So therefore, in order to increase the potential power, a weir can be constructed to improve the water flow all throughout the year. A maximum of two hundred fifty one watts of electric power can be generated at Lunang on the month of August as shown in Table 3. But this will not be enough considering the power transmission loss and the demand of supply in Lunang. There is a tradeoff between head and the flow rate. When the stream is small, meaning the flow rate is low, high head will ensure the turbine to provide enough power as required, and vice-versa.

Table 3: Monthly Potential Electrical Power of Streams Under Study

<table>
<thead>
<tr>
<th>Site</th>
<th>Potential Electric Power (in watts)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>May</td>
</tr>
<tr>
<td>Camanga</td>
<td>78.48</td>
</tr>
<tr>
<td>Binowangan</td>
<td>0</td>
</tr>
<tr>
<td>Lunang</td>
<td>43.95</td>
</tr>
<tr>
<td>Pisak</td>
<td>470.88</td>
</tr>
</tbody>
</table>

5. Summary of Results

5.1 Summary of Results of Binogawan Falls

Clearly in Figure 2, the water in Binogawan falls cannot sustain the amount of water needed to spin the turbine. As mentioned in the previous discussion, hydro electric power depends on the water flowing. There should be a mean to ensure the
availability of water all throughout the years. In spite of the ten meters (10) elevation drop in Binowangan Falls, there is zero water discharge. Although Binowangan has large reservoir of water due to the manmade structure, it cannot guarantee the continuity of water flow over the year. Peak potential energy at Benogawan Falls is five hundred thirty watts (533.67 watts) and zero potential energy during dry season.

In this situation, a small dam nor water impounding would not be feasible too because there is no input water during dry season. Therefore, the researcher cannot consider the site as potential source of hydro power.

5.2 Summary of Result of Lunang

The minimum potential power that can be generated at Lunang Stream during dry season is 43.95 watts and a peak power potential of 44.34 watts at the month of August or during rainy season. The minimal flow rate of Lunang Stream has greatest impact on the potential energy that can be generated at this site. Flow rate in Lunang Stream is very minimal that even if a weir will be constructed in the site will not improve the flow rate and it will not guarantee an increase of potential hydro power. The two (2) meters head of Lunang Stream will not boost the hydro power potential of this site even during rainy season. Thus, Lunang Stream can not be considered as potential site for pico-hydro generation project.

5.3 Summary of Results of Camanga Stream

During dry season, a potential electric power of 78.48 watts can be generated at Camanga stream with the average flow rate of 6 liters per second. The power that can be generated at this season is enough to power bulbs at home or within the site. At rainy season, the stream is capable of generating 251.14 watts. The water flow rate at Camanga Stream can be further improved by constructing a weir. Thus, Camanga Stream can be considered as potential site for pico-hydro generation project.

5.4 Summary Result of Pisak Falls

Among all the streams investigated, Pisak Falls has the greatest power potential for pico-hydro. It can generate a monthly average power of 2,268.07 watts during rainy season and a minimum of 470.88 watts during dry season. The water reservoir and water flow rate are enough to sustain generation of power even during dry season at the elevation drop of ten meters as shown in Figure 4.

6 References

