Installation of Pico-Hydro System to Augment the Electricity Requirement of a Rural Community in Victoria Oriental Mindoro, Philippines

Jupete N. Diswe, Kent Andrew C. Dudas, Arvin Jan A. Padilla, Reimbert Randall A. Roca and Engr. Igmedio F. Isla, Jr.
School of Mechanical and Manufacturing Engineering
Mapua University
Intramuros, Manila, Philippines
ifisla@mapua.edu.ph

Ma. Janice J. Gumasing
School of Industrial Engineering and Engineering Management
Mapua University
Intramuros, Manila, Philippines
mjjgumasing@mapua.edu.ph

Abstract

This study focuses on the design, fabrication, and installation of a pico-hydro system in a rural community down South of Oriental Mindoro. The researchers were inspired by the fact that there are still many Filipinos that are deprived of having electricity, these were the people from remotes areas. Pico-Hydro system is not new to us anymore, but it can give help and provide free electricity to others if there is an abundant source of water in the area and available head good enough to produce electricity. The Department of Energy (DOE) manual was used as a reference for selecting the place for the study and for the methods in measuring the important parameters in the construction of the system. Major parts of the Pico-hydro were fabricated using the available materials from Calapan and Victoria, Oriental Mindoro. The researchers were able to produce a maximum output power of 211.5W with a water flow rate of 74.39 L/s and an effective head of 2 meters. The produced output was lower than what the researchers had expected but is enough for the consumption of a small community.

Keywords
Pico-hydro system, rural community, electricity

1. Introduction
The hydroelectric power is widely available in the world; it only varies with the design that suits a specific place or location. For this project, the researchers decided to use a crossflow type of turbine due to the low head and the water flow rate available in the community of Sitio Palayang Bayan. The minimum electricity demand in each house was also considered for the design of the Pico hydro system.

The main objective of this study is to design, fabricate, and install a Pico Hydro System as an alternative power source for the small indigenous community living at Sitio Palayang Bayan, Brgy. Villa Cerveza, Victoria, Oriental Mindoro.

The Department of Energy (DOE) utilization management manuals and guidelines for micro-hydropower development in rural electrification were used as a reference in this study because they contain important information that can help the researchers in building the pico-hydro system. There are three main project cycles when developing a mini-hydropower these are planning stage, implementation stage, and operation stage. The first stage is project planning in here the selection of potential sites, site reconnaissance, and planning of potential sites must be done. In order to properly choose a site, the topographical map of the site and local information must be acquired. The most important is that the plant site must be near the load center and water source. The site must have a potential head that can be used for the micro-hydropower plant. The second stage is project implementation where the detailed design of the micro hydropower plant is done as well as the construction of it as well as the design of the turbine and lastly is the operation and maintenance stage. The last stage is important especially in the events of natural disasters or when problems occur while in operation. In order to make the micro-hydropower plant last longer, it must be periodically inspected if there are problems while operation.

2. Methodology

The Figure 1 below shows the process flowchart in the design and development of the Pico-Hydro system.

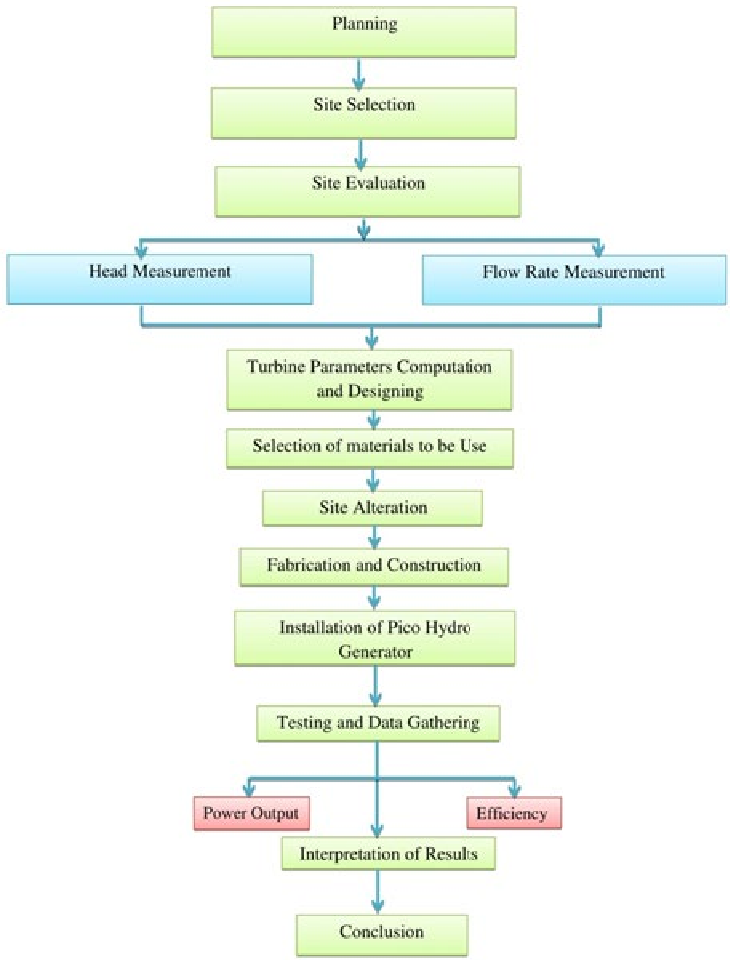

Figure 1. Process Flow Chart

2.1. Planning

One of the important parts of this study is to choose an appropriate location where the pico-hydro system will be built based on the results of the conducted data during the head and water flow testing. A checklist is then formed in order to make the project objectives reached that includes the following: (a) data gathering using single bucket method (abundance of water, heat, water flow rate), (b) total electricity power requirement of the community, (c) budget and cost computation (d) design of the pico-hydro system (e) duration of project (f) accessibility.

2.2. Site Selection

In the site selection, the researchers considered the following: the abundance of water, the water flow rate, the head, and also the people who will benefit from it. Oriental Mindoro has a lot of places wherein the pico-hydro system could be built upon and we have located three possible places. The researchers choose this community of Sitio Palayang Bayan as a project site because in order to fabricate the pico-hydro system the location must have plenty of water. It was also considered if the site was prone to floods which may cause damage to the project considering that it was located near a river. In addition, there was a nearby community and the community needed an alternative electric source which can help the family and their children to study especially at night.

2.3. Site Evaluation

Further evaluation was done during the visit. For the head height measurement, the researchers used a tape measuring device to record the actual height. The volume flow rate of the water was observed using a 210-liter drum and a stopwatch. This water supply from the man-made canal delivers enough water that can create enough water power that will make the turbine working. The Table 1 shows the water flow rate available on the site. By dividing the volume of the drum by the time recorded, we can get the flow rate such as the following:

Table 1. Flow Rate of Water in the Site

Trial	Volume drum (liters)	Time (sec)	Flow rate (L/sec)
1	210	2.88	72.9167
2	210	2.65	79.2453
3	210	2.81	74.7331
4	210	2.91	72.1649
5	210	2.88	72.9167
Average			74.3953

2.4. Turbine Parameter Computations and Designing

The dimension that was computed was all based on the water power gathered on the site at Sitio Palayang Bayan using the water power formula as shown in equation 1 and the measuring head on the location. All the equations used for the computation was based on Department of Energy manuals.

$$\text{Water Power} = Q_y H \qquad (1)$$

After solving for the water, the maximum speed of the rotor can be computed using equation 2 as shown below.

$$N = 513.25He0.745(WP)0.5 \qquad (2)$$

The outer diameter of the rotor can be computed using the head and the maximum speed of the rotor as shown in equation 3.

$$D_o = 40HeN \qquad (3)$$

Note: for the rotor diameter use factor of safety = 2

Using the computed outer diameter of the rotor, the length of the rotor can be computed using equation 4.

$$L = (Do)(N)50(He) \qquad (4)$$

The radius of the curvature of the blades can be computed after getting the outer diameter of the rotor as shown in equation 5.

$$Co = 0.163(Do) \qquad (5)$$

Note: a safety factor of 2 was used

The diameter of the shaft was computed using equation 6 as shown below.

$$Dshaft = 3P\ (80)nt \qquad (6)$$

Note: 1800 is the generator rated RPM
Note: The researchers use a 1-inch diameter shaft due to the availability of pulley shafting diameter.

Using the computed parameters, the researchers were able to design the cross-flow turbine needed for the area as shown in Figure 2.

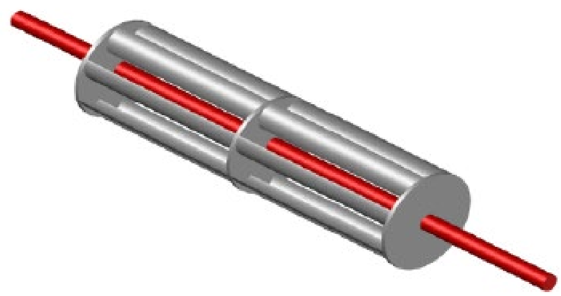

Figure 2. 3D Design of the Cross-Flow Turbine

2.5. Selection of Materials to be Used

The waterway and nozzle of the system were made from a galvanized iron sheet which is cheaper than stainless steel, the galvanized iron can also be used in a long term. The turbine was made from galvanized pipes which will be cut according to the computed curvature. The researchers also used a 1.5-inch size of angle bar as based on the base of the generator as well as support to the tank to prevent bloating that was caused by the volume of water.

3. Results and Discussion

The generator used for the system was bought in the area to prevent a large cost for its transportation. The specification of the generator is shown in Table 2.

Table 2. Generator Specifications

Brand	Mindong China
Type	A.C. Synchronous
Power Capacity	3 KW
Voltage	115/230 V
Ampere	26/13 A
Frequency Rating	60 Hz
Rated RPM	1800 rpm
Phase	Single-phase

For the selection of the right bearing to be used, a consideration includes the quality and durability as well as the size of the shaft to be used, and the service life of the bearing. It is to make sure that the bearing is good enough to withstand 24 hours of work. So the researchers used two pillow block bearings with a 1-inch diameter for each side of the turbine.

For power transmission, belt drives are used and the considerations in choosing a belt include the availability of the type of belt, quality, durability, and service life of the belt as well as the pulley diameter and the center distance between the two pulleys. The specifications of belt drive and pulley is shown in Table 3.

Table 3. Belt Drive and Pulley Specifications

Belt Type	V-belt
Belt Length	A85
Diameter of the Turbine Pulley	5 inches
Diameter of the Generator Pulley	14 inches

3.1. Data Gathered Without Dummy Load

These trials were done without using a dummy load. This is to monitor the rpm and the voltage that the system produces as we increase the load or the power usage during the testing. The power output is shown in Table 4.

Table 4. Power Output Without Dummy Load

Trial	Load (watts)	Generator (rpm)	Current (amp)	Output Voltage (V)	Power Output (watts)
1	38W + continuous power bank	1650	1	182	182 watts
2	78W + continuous power bank	1620	1	175	175 watts
3	278W + continuous power bank	1560	1.1	170	187 watts

These trials were done with the use of a 2SM type of battery as a dummy load. Its main function in the set-up is to store energy when the consumption is minimal and to avoid excessive rpm in the generator.

4. Conclusion

The pico-hydroelectric system was built in order to serve as a source of electricity for a small community in Sitio Palayang Bayan, Barangay Villa Cerveza Victoria, Oriental Mindoro. The design and fabrication of the system followed the parameters attained in the site which were 2.2-meter head and 74.3954 L/s water flow rate. Material that was needed to build the system was bought from the city not in Manila in order to lessen the expenses and avoid damages while transporting. The system was designed to generate power using a 3kVA generator. The maximum output that the system could generate is 211.5 watts while having a load of 23 watts and the generator is at 1930 rpm.

In order to distribute the generated power, 10 makeshift electrical post and 300-meter-long electrical wires with a diameter of 1.25 sq.mm, and having a 12A rating was used. There is a circuit breaker to serve as a safety device in case of an emergency.

A 2SM type of battery was used as a continuous power bank and energy reservoir in order to store the excess power generated when the electrical consumption was at a minimum. This is also to prevent the generator to have excessive rpm. The power bank is composed of a used battery charger, battery, and 300W inverter. The test result shows that the circuit containing the battery and the connected load was able to regulate the rpm but causing the power output to drop to 187 watts. The said output was observed to be enough for all the connected households since all they need was a light source during the night.

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