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The Designing and Constructing the Simplest Pico-hydropower Generator for the Rural Community

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Abstract. . Small-scale hydropower is one of the most cost-effective and reliable energy technologies to be considered for providing clean electricity generation. The development of the simplest pico-hydropower system for the rural community in Yala province, Thailand was carried out in this work. The main criteria of the generator are set to be cost-effective, reliable, and environmentally friendly, which can be manufactured locally and capable of operating a wide range of flow rate. In this study, the AC washing machine motor (TOSHIBA, inverter direct drive, AW-SD) utilized an innovative design for the electrical generator in order to streamline the pico-hydropower applications. The results show that the generator is capable of producing up to 800-1000 W, AC power at the head of 1.2-2.2 m, a speed of 650-850 rpm. The generated power can be used for the TV of 85-100 W, lighting fluorescent lamps of 40-60 W, an electrical fan of 45 W and another appliance of about 100 W. The simplest pico-hydropower could play important role in providing the basic necessity to the off-grid rural folks. Finally, the simplest pico-hydropower power is much more suitable and affordable by the rural community due to its comparatively low investment, disturbs little to local setting and can easily be operated and managed by the local community.

INTRODUCTION

Hydropower is one of the most efficient renewable energy sources. It is one aspect given by the national plan for the renewable technology development with wisely energy utilization from natural resources included wind, water, and solar energies or biogas and farm waste. Low head hydro or pico-hydropower system is almost always “run-of-river”. This effectively means that there is inconsequential storing of water which may result in shut down at some stage of river flow when there is inadequate rainfall. These are therefore the main focus for the rest of this technology summary.

About 1.6 billion people lack access to electricity and many of these are in rural areas with no hope of connection to the electrical grid [1]. Electricity is only one of various energy sources used to the rural poor; other sources such as biomass are also important, and energy in itself cannot reduce poverty unless other enabling factors are present. Electricity also enables communities to improve connections with their neighbors and friends and the world at large. Hydropower provides about 20% of world total power consumption and is utilized in more than 150 countries [2]. Even in developed countries, the average hydropower exploitation has reached up to 60% of the total resources, with about 82% hydropower resources exploited in the US, about 84% in Japan, 73% in Germany, and over 80% in France, Norway and Switzerland [3]. Most hydropower available around the world can be categorized as large hydro. The hydropower plant can be classified according to the size of electrical power it produces (TABLE 1).

The small-scale hydropower scheme is not included despite the availability of potential sites which could benefit the rural community tremendously. Nfah and Ngundam [4] looked at the same thing, the feasibility of hybrid power system. Water turbine of 5 kW capacities with an available flow rate of 92.6 l/s and head of 10 m is used to provide 24 V DC systems. Islam et al. [5] are also looking at the potential sites for small-scale hydro which has a low head (less than 10 m). It is important to choose appropriate turbine for these locations due to seasonal variation. Selection criteria of the turbine were highlighted and Maher et al. [6] discussed the off-grid electrification options in rural Kenya. Moreover, in, lowercase Vietnam, several Chinese manufacturers have sold pico-power plants at prices as low as $20-70 for a power plant of 300-500 W. However, the devices sold are said to be low in quality and could potentially cause damage to any equipment that is coupled if done incorrectly [7].

TABLE 1. Classification of hydropower by size [8].

Class	**Power**
Large	> 100 MW
Medium	10 MW - 100 MW
Small	1 MW - 10 MW
Mini	100 kW - 1 MW
Micro	5 kW - 100 kW
Pico (PHP)	<= 5 kW

Figure 1. Environment and housing of mountain people at Talingchan, Bannangsata district, Yala province.

Comparisons between pico-hydropower and solar powered systems were made to evaluate the feasibility of the renewable energy resources. Pico-hydropower usually refers to schemes of up to 5 kW output [8]. The available power is related to the water flow rate and the available head between intake and powerhouse. Where only low heads are available (less than 10 m) the flow rate must be greater to compensate for the lower water pressure. Yala province has many rivers, big and small, which are capable of producing electricity especially to off-grid settlements living nearby. Even sites with the low head are worth looking at for their potential. This paper is focusing on pico-hydropower, a run-of-river application which does not require dam or reservoir for water storage. It is cost-effective, environmentally friendly and the turbine can be manufactured locally.

MATERIAL AND METHOD

To determine the power potential of the water flowing in a river or stream it is necessary to determine both the flow rate of the water and the head through which the water can be made to fall. The flow rate is the quantity of water flowing past a point in a given time. Typical flow rate units are liters per second or cubic meters per second. The head is the vertical height, in meters, from the turbine up to the point where the water enters the intake pipe or penstock. The potential power can be calculated as follows [9]:

$$P = Q \times H \times g \tag{1}$$

When P is theoretical power (kW), Q is flow rate (m^3s^{-1}), H is head (m) and g is gravity (ms^{-2})

Figure 2. Design and construction of pico-hydropower turbine.

At this site, we utilized natural division in the river to provide a more easily controlled flow of water to the intake. Maize sacks filled with clay soil and rocks were used to reinforce the channel leading to the intake and boulders were positioned to form a pool with sufficient depth to ensure that the penstock is kept full. The edges around the boulders were sealed with more stones and soil sacks. This case study describes a pico-hydropower using an AC washing machine motor as generator which has an electrical output of 800-1000 W. The penstock consists of 3.1 m of 20.3 cm diameter PVC pipe. The net head is 1.6 m (FIGURE 2).

RESULTS AND DISCUSSION

Small-scale hydropower electrical generator plays an important role in providing the basic necessity to the off-grid rural area community. It is particularly suited to small-scale applications typically being far cheaper per unit (kWh) of electricity produced than wind power and solar power; this research is to novel pico-hydropower system design and constructs at the Talingchan, Bannangsata district, Yala province (FIGURE 3). The results showed that the generator was capable of producing up to 800-1000 W of AC power at the water differential height of 1.25-2.0 m and motor rotational rate of 650-850 rpm. For household electrical needs comprising lighting with fluorescent lamps using between 40 and 60 W, a television using between 85 and 100 W, an electrical fan using 45 W and other devices using roughly 100 W, the power produced was adequate.

The advantages of this type of generator include cost-effective, reliability, ease of operation and environmentally friendly. Most of the pico-hydropower generator (generally below 5 kW) can be manufactured locally and operated at a wide range of water flow rate. In this study, the AC washing machine motors were modified to be utilized as the electrical generator. The pico-hydropowers system from washing machine motor (FIGURE 2), as a generator is base improved technology systems that have a potential for improvement with scope for local innovations that have been gaining momentum in the country. Pico-hydropower is much more suitable and affordable for the rural community due to its comparatively low investment, disturbs little to local setting and can easily be operated and managed by the local community.

However, energy is always lost when it is converted from one form to another. Small water turbines rarely have efficiencies better than 80%. Power will also be lost in the pipe carrying the water to the turbine, due to frictional losses. By careful design, this loss can be reduced to only a small percentage. A rough guide used for small systems of a few kW rating is to take the overall efficiency as approximately 50% [10]. Since each site for small-scale hydropower implementation is unique depending on the availability of the head and flow rate, care needs to be taken to select the correct turbine for implementation. The cross flow turbine proves to be a suitable turbine for low flow and low head implementation and when a significant variation of flow rate occurs seasonally. Small stream with the small drop of elevation would be big enough to provide green sustainable energy using pico-hydropower technology.

TABLE 2. Energy expenditure per household before pico-hydropower installation (per year).

Expense item	Cost (Bath)
1. Kerosene oil for lantern : 100 Bath/week $\times$ 52 weeks	5,200
2. Diesel oil for electrical dynamo : 4 h/day (1 L $\times$ 30 Bath $\times$ 365 day)	10,950
3. Cooking gas : 15 kg/piece (330 Bath $\times$ 4 pieces)	1,320
4. Charcoal fire : 250 Bath/week $\times$ 52 weeks	13,000
Total	30,470

TABLE 3. Energy expenditure per household for pico-hydropower installation.

Expense item	Cost (Bath)
1. Pico-hydropower from commercial market : 600-1000 W	9,000-15,000
2. Pico-hydropower from washing machine motor : 800-1000 W	6,000-9,000
3. PVC pipe of 20.3 m diameter (8 inch) : 750 Bath $\times$ 3 pieces	2,250
4. Container for water with capacity is 200 L : 1 pieces	600-750
5. Cable (2.0 $\times$ 1.5 mm) : 15 Bath $\times$ 300 m	4,500
6. Coarse sand and rock	1,600
7. Cement : 175 Bath $\times$ 20 pieces	3,500
Pico-hydropower from commercial market setup	19,200-25,350
Pico-hydropower from washing machine motor setup	16,200-19,350

FIGURE 3. Pico-hydropower system setup at the Talingchan, Bannangsata district, Yala province.

Energy costs per unit for households, before and after application, were compared when utilizing pico-hydropower, as presented in TABLES 2 and 3. The results show that energy expenditure per household before pico-hydropower installation is approximated at 30,470 Bath. On the other hand, when installing the pico-hydropower system. The villagers do not have to pay for kerosene oil for lantern, diesel oil for electrical dynamo and cooking gas. As resulted, the villagers can reduce the cost of the household about 16,200 - 19,350 Bath for year. It will be seen that the pico-hydropower generator is developed have lower cost than that available in the market approximately 3,000-6,000 Bath. Including when designed by using simple local devices, it can reduce costs due to PVC pipes, sand, stone and cement about 50-60%. Finally, the system was based on low cost of construction, local materials, easy construction and maintenance systems. The construction cost of this project was most expense of 30% for pipe systems, 20% for control and electricity systems and 50% for generator and turbine systems.

CONCLUSION

Pico hydro is a term used for hydroelectric power generation of under 5 kW. These generators have proven to be useful in small and remote communities that require only a small amount of electricity – for example, to power one or two fluorescent light bulbs and a TV or radio in homes. Pico-hydro setups typically are run-of-stream, meaning that a reservoir of water is not created, only a small weir is common, pipes divert some of the flow, drop this down a gradient, and through the turbine before being exhausted back to the stream. This can be used for the light, some house-ware appliances and some construction, easy construction and maintenance systems. The construction cost of this project was 16,000-20,000 Bath. The system improvement needed to be installed with the diversion load-control charger (battery) and inverter sets for fully workloads. Consequently, the hydropower is one of the most efficient renewable energy sources. As compared to other renewable energy sources, hydropower is reliable, economical, high efficient, low maintenance cost and large storage capacity. Like other hydroelectric and renewable source power generation, pollution and consumption of fossil fuels are reduced, though there is still typically an environmental cost to the manufacture of the generator and distribution methods.

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