Pico-hydro as A Renewable Energy: Local Natural Resources and Equipment Availability in Efforts to Generate Electricity

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Abstract. Pico hydropower (PHP) is a small power plant system to generate electricity that is suitable for implementation in the rural area. The potential of local natural resources such as bamboo and the existing of many induction motors with small capacity, both of them respectively can be used as turbine material and as an induction generator. Bamboo as a natural and bio-composite material there are many in Indonesia and Southeast Asia. The main objective of the present research is how local natural resources bamboo can be used as turbine material and induction motor using as an induction generator, with the aim to finding cheap and ease equipment for pico hydro implementing. Moreover, through this research, for the first time, pico hydropower (PHP) was applied with a using bamboo turbine and Induction Motor As Generator (IMAG). The results obtained are a cross-flow turbine with dimension diameter of 125 mm, turbine width of 50 mm and with 20 blades. From laboratory test result at water pressure, 0.55 kilogram per square centimetre and flow rate 4 litres per second, power system capable of load 114 Watt LED lamps, maximum voltage and current respectively 100 Volts and 0.38 Amperes. Pico-hydro with cross-flow turbines made from bamboo material and generator IMAG has been implemented on demonstration site in Jembul village, local natural resources material and equipment availability which is cheap and ease of implementing. The pico hydro exhibits a good electrical output result that can be improved for a good performance for the next.

1. Introduction

The Quran is an ancient text which is the word of God and is a guide for Muslims, which there is knowledge about the environment in it. That knowledge needs to be explored and published because in the future will provide benefits for environmental sustainability. Nature will be balanced if all forms of human behaviour or activities do not cause damage to the natural environment, because basically, environmental damage will cause a natural imbalance. Quran is science and science from an Islamic outlook corner must show the interrelatedness of all parts of the universe [1]. *"He sends down from the sky, rain, and valleys flow according to their capacity, and the torrent carries a rising foam. And from that [ore] which they heat in the fire, desiring adornments and utensils, is a foam like it. Thus Allah presents [the example of] truth and falsehood. As for the foam, it vanishes, [being] cast off; but as for that which benefits the people, it remains on the earth. Thus does Allah present examples."* (Quran 13:17), the Quran surah talks about the cycle of water which expresses about renewable

energy. With so many mountains in Indonesia it is an advantage because according to the Quran, the mountain is a stake. Moreover, as a place where water is stored which then flows on the valley naturally according to their capacity, the term *'...flows on valley naturally according to their capacity'* express the kinetic energy of water. In the Quran, it is stated that the mount firmly stands because it functions as a stake of the earth which consists of large sturdy rocks and basically, rock is the mountain building material. *"Have we not made the earth a resting place? And the mountains as stakes?"* (Quran 78: 6-7). Moreover, in the mountain that is the place where the rain falls from the sky and the place where springs come from, that can be used as water potential energy. Based on the contents of the verse in the Quran, it is necessary to utilise the potential of water energy by developing and implementing turbines and generators of the potential that exists in the surrounding environment.

As an archipelagic nation and mountainous region, Indonesia has abundant resources which can be exploited as the sources of energy to sustain life. However, over time, the natural availability is continuously depleting and need to anticipate it, New and Renewable Energy (NRE) becomes the best alternative solution, because environmentally friendly. What is Renewable Energy? Renewable energy is a source of energy from nature that is continually produced and recharge by nature —the sun, the wind, water, the earth's heat, and plants [2]. Renewable energy sources are those resources which can be used to produce energy, again and again, e.g. solar energy, wind energy, biomass energy, geothermal energy, or others are also often called alternative sources of energy. Renewable energy technologies turn these fuels into usable forms of energy—most often electricity, but also heat, chemicals, or mechanical power. The main topic of this paper concern about water energy because it is still available for use in Indonesia, especially about pico hydro (the power under 5 kW), especially in the mountainous region in the rural communities. Until now, need to know that the Indonesian government in its regulation only includes micro-hydro, while the pico hydro has not been mentioned up to adopt. Indonesia country has a huge amount of hydropower resources. The potential of hydropower is estimated about 75,000 MW which makes Indonesia ranking fourth in Asia after China, the former Russian Federation and India. However, only 34,000 MW of 75,000 MW is exploitable [3].

Renewable energy resources and intensive explorations of different alternatives energy are currently being conducted worldwide. Pico-hydro power (PHP) is at the forefront of these options because it is considered the most cost-effective renewable energy option to provide electricity for rural areas. Energy can enable to be derived from extremely low head and flow streams of 1 m and 1 L/s, respectively. The future of the pico-hydro market looks prosperous because there is a substantial availability of low head and flow hydroelectric sites in less developed countries. In the future, technology can play a crucial role in the lighting of houses in remote communities, with the energy source derived from a domestic water supply [4]. The wasted energy of daily used water and rainwater also can be converted into the electrical energy by the hydroelectric mechanism through several energy conversion processes [5]. Pico hydro project is implemented with low cost using irrigation water and generated power and can be utilized to household appliances in rural areas [6].

The baseline concept for multi-year system development of a pico-hydroelectric power system in Nepal. How green energy solutions for rural applications should be highly contextualised to ensure maximum impact and long-term sustainment. Another result is a viable baseline concept for a green electric power solution in remote rural locations [7]. Stand-alone power systems can be a solution to the problem of the lack of electricity, which highlights challenges such as modules installation costs as well as the sufficient knowledge required for installing, maintaining and operating such systems. With this fact in mind, a 250 W Low Head turbine (propeller) system was developed and optimised to have the advantage of the simplicity of installation and construction from readily available materials [8]. Pico hydropower (PHP) offers an efficient, reliable and cost effective of alternative power sources in developing nations, especially in Malaysia. By and large, the objective is to provide essential strategic implications for Malaysia and other Southeast Asian countries [9].

Independence of villagers must be encouraged about the use of water energy to generate electricity, namely by introducing easy and simple technology. Bamboo which grows a lot in Indonesia and the ease of access to getting induction motors with small capacity, which both of them respectively can be

used as turbine materials and made induction generators. The objective of this paper is how to make a turbine with material from local natural wealth and make a generator from an existing electrical motor. Turbine, generator, and auxiliary arrangement as a pico hydro equipment system. The cheap and easy manufacturing of turbines and the ease of getting generators by utilising electrical motors is the aim. The hope that the pico hydropower plant easy to make and inexpensive. So it can spur villagers to be able to implement it, in a rural area, in mountainous. An experiment about Induction motor as the generator was done by [10] to found cheaper and easy generator.

2. Material and Method

2.1. Turbine

Bamboo is a fast-growing, renewable, widespread, low cost, environmental enhancing resource with great potential to improve poverty alleviation and economic development [11]. Bamboos occur and grow well in tropical forests in Indonesia [12], and bamboo is an important plant that is needed to be used for various purposes. More than 90 per cent of bamboos are in village lands and homesteads, mostly cultivated by people and is local natural wealth. Indonesia is a tropical country; there is much variety of bamboo and Indonesia becoming the biggest exporter of bamboo in the world after China. Indonesia has around 154 types from 1,250 to 1,500 type of world bamboo diversity. Bamboo is found in many places, either grow naturally or cultivated deliberately [13].

(a) (b)

Figure 1. Bamboo turbine: (a) Runner with shaft; (b) Parts of turbine.

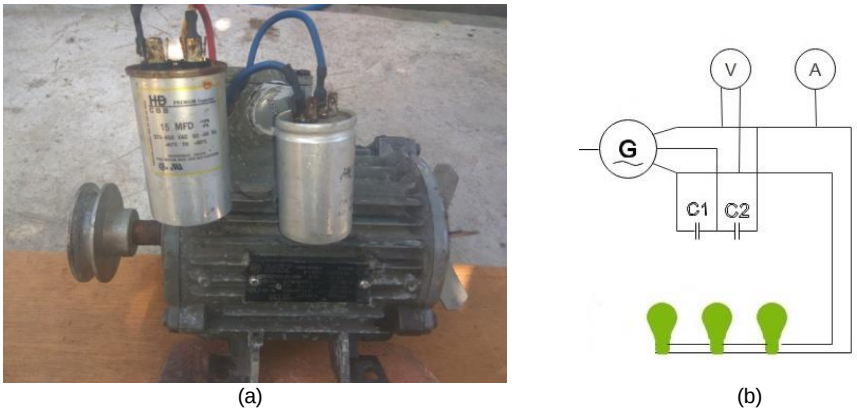
Turbines are the main equipment for the Pico hydro power plant, turbine innovation needs to be carried out technically and economically, with cheap orientation and ease to implementation. Some proper turbines are expensive so in the Xiagnabouli province, Lao People's Democratic Republic for cost-effective solution for rural electrification, choice pump as turbine to implementation [14]. In this research, crossflow turbine is used by using the type of ori bamboo (*Bambusa arundinacea*), petung bamboo (*Dendrocalamus asper*) and bamboo of Japan (*Pseudosasa japonica*) which are used as material. The dimensions include diameter, turbine width and number of base blade calculations, referring to Mockmore article, with reference to water flow capacity of 5 liters per second and a nominal turbine rotation of 750 rpm.

2.2. Generator

For a small-scale generation, the induction generator converts potential energy to kinetic energy then electric energy. The rotor spins above synchronous speed and develops a counter-torque that opposes this over-speed, same effect as a brake.

The generators rotor returns the power as electrical energy instead of dissipating it as heat, commonly referred to as asynchronous generation. Then kinetic energy is converted into electrical energy and the generator delivers active power to the electrical grid. However to operate successfully the electrical utility grid must also provide reactive power to create the stator's rotating magnetic field.

That is an induction generator receives its excitation or magnetizing current directly from the utility grid. Motors can usually function as generators, and vice versa, and since the induction generator is actually an induction motor being driven by a turbine called the prime mover. An experiment has been done for 200-watt lamps load by [15] with water wheel turbine as prime over and induction motor as induction generator with specification1.5 kW. three phase, 230 volts, 4.5 A, 1440 rpm. Experiments carried out by Katre did not clearly exhibit how much total efficiency was produced.



(a) (b)

Figure 2. (a) Motor as generator; (b) Circuit generator 3 phase output 1 phase.

When an induction machine is driven by an external prime mover at a speed greater than the synchronous speed (negative slip) the direction of induced torque is reversed and it starts working as an induction generator. Induction motor can be operated as a motor or as a generator, in this research, three-phase induction motor (motor specification as a nameplate) was functioned as a one-phase induction generator, generator set up and circuit as seen on Figure 2 (a) and (b). As a reactive load, in generator dipasang 2 buah capacitor seharga 15 µF dan 12 µF.

2.3. Laboratorium Experiment and Field Implementation

Experimental set up for laboratory test show on Figure 4, water pumping for flow simulation to force and rotating the turbine, and the turbine drive induction generator, besides that's the light emitting diode (LED) lamp as an electrical load. On this experiment measuring water flow, pressure, voltage, and electrical current to determine pico-hydro performance.

Figure 3. Laboratorium experiment set up.

(a) (b)

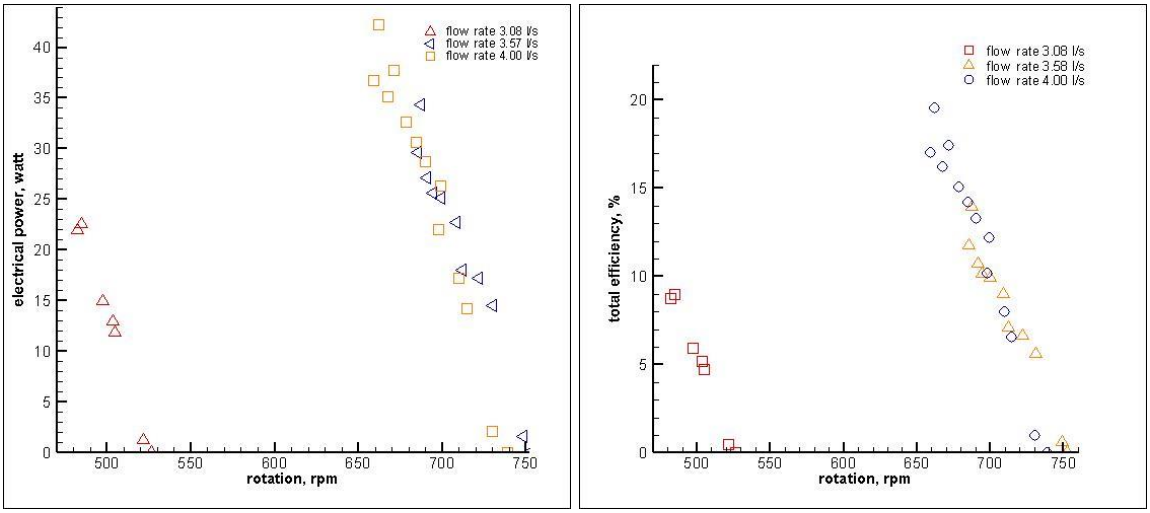
Figure 4. (a) Under construction; (b) Trial.

Pico-hydropower is becoming one of the most important renewable energy sources in the world for remote or rural locations day by day. It does not encounter the problem of population displacement and is not as expensive as solar or wind energy. However, PHP units are usually off grid and isolated from the grid network; thus, they require user friendly self control to maintain a constant frequency [16].

Figure 5. Electrification to villager house.

3. Result and Conclussion

The paper presents the potential of pico-hydro plant. The envisaged scheme is well suited in remote rural areas where transmission of power proves uneconomical. Pico-hydro plants can be installed at such places to power one or few homes. The power requirement at such location is minimal during off periods which can be utilized for charging batteries and other electronic gadgets. The pico hydro plants can be installed at much lower financial requirements compared with solar plants and wind mills. The prominent impacts include changes in flow regimes and water quality, barriers to fish migration, loss of biological diversity and population displacement but can also provide multiple benefits beyond energy supply. Technological innovation and material research can further improve environmental performance and reduce operational cost. With a changing climate, the resource potential could change due to changes in river flow particularly in precipitation and temperature in catchment area. This may lead to changes in runoff volume, variability of flow and seasonality of the flow (e.g. by changing from spring/summer high flow to more winter flow), directly affecting the resource potential for pico- hydropower generation. Changes in extreme events (floods and droughts) may increase the cost and risk for the such hydropower projects. Increased sediment load could also fill up reservoirs faster and decrease the live storage, reducing the degree of regulation and decreasing storage services [17].



(a) (b)

Figure 6. (a) rpm vs electrical power; (b) rpm vs total efficiency.

The result of experiment plotting on the graphic, it is seen in Figure 6, the greater the flow rate is, the greater the power produced (Figure 6a) and also the greater the flow rates increase the total efficiency (Figure 6b), the largest total efficiency of 19.57% occurs at flow rate 4 liters per second at a pressure of 0.55 kgf / cm2 (head 5.5 meters), the total efficiency including turbine efficiency, transmission efficiency and generator efficiency. Another experiment that has been done before by the author has achieved a total efficiency of around 30%, with a water flow rate of 7 liters per second. Whereas from the research information by [18] using a pump as a turbine at an 18-meter head and a flow rate of 28 liters per second carried out in Kenya at 45% efficiency. The total efficiency obtained in bamboo turbines with IMAG generators is around 30%, which is smaller than the total efficiency of the pico hydro generator in Kenya, by 45%. This is because the smaller the turbine capacity, the smaller the efficiency, according to what [19] stated.

Combination of bamboo ori, bamboo petung and teak wood which is a natural material that many found in Indonesia, can be used to manufacture cross-flow turbine. The cross-flow turbine utilized to drive an IMAG generator that produces electric power (small-scale hydropower, pico hydro), and the result of laboratory tests shows the electric power output which is significant enough to be utilized as electric power generating that is with the load of 114 watt of LED lights at 100 Volt voltages, as well as the result of field implementation tests capable for lighting the LED lamps at a voltage of 167 Volt. The pico hydro exhibits a good electrical output result that can be improved for a good performance for the next. Pico hydro has still needed although rural areas have been received electrification because in the rainy season the light often extinguished or the existing of pico-hydro can help to reduce high electricity cost, so the author hopes that PHP with bamboo turbine and IMAG generator especially can be widely implemented in Indonesia as an alternative choice. It is proven that the materials that are around us in the form of bamboo from several types and induction motors, can be used and used to make pico hydro power generation equipment.

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