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Analysis of Axial Turbine Pico-Hydro Electrical Power Plant in North Sulawesi Indonesia

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Abstract. This study presents analysis of pico-hydro electrical power plant in North Sulawesi, Indonesia. The objective of this study is to get a design of axial turbine pico-hydro electrical power plant. The method used the study of literature, survey the construction site of the power plant and the characteristics of the location being a place of study, analysis of hydropower ability and analyzing costs of power plant. The result showed that the design of axial turbine pico-hydro installation is connected to a generator to produce electrical energy maximum can be used for household needs in villages. This analyze will be propose to local government of Minahasa, North Sulawesi, Indonesia.

1. Introduction

North Sulawesi region more specifically in the villages of Minahasa district has a mountainous topography and has many rivers which is a potential source of enormous energy for power plants which, when carefully planned can overcome the problem of electric energy crisis. Problems that have long and at this time every day power outage for about 2-3 hours a day. However, the electricity crisis was not so much solved using the integral energy source potential flow of river water in the area of North Sulawesi. There are still many villages far from urban areas still do not have adequate power supply. In anticipation of that, it is necessary to build small-scale power plants (1 kW - 5 kW). **Figure 1** shows that the electrical energy production by 2013 in the province of North Sulawesi using water power is still very little 9.02% [1]. It shows that the construction of the hydroelectric power plant is still very much needed in the area of North Sulawesi. Shortage of electricity in rural areas is very likely to occur because it is far from the urban and the power grid, but did not rule urban areas are also experiencing the same thing. In fact, many cities and districts that rely on diesel and hard to come by when the oil, resulting in a power outage in rotation may even are expanded. One solution is emerging development in Indonesia at this time is to find a way out through the construction of power plants micro scale with the power source stream flow and more dependable again when rural communities require the construction of power plants as small as possible, namely less than 5 kW and that can be realized through pico hydro power plant (PLTPH).

   Based on the analysis of the energy force of the waterfalls and design turbines, all of which were made through experiments in the laboratory and in the field (in the village where the installation location) to the mounting PLTPH and generate electrical energy production is less than 5 kW is an invention/innovation targeted in research this. For the creation of the PLTPH development, it previously had to be done: first, about the theoretical studies as the

basis for analysis through literature; second, conduct survey research sites (including survey the village is selected villages that have the potential to obtain characteristics of the villages and communities for the purpose of character education for these communities through socialization to shape the character of the community so that there is a sense of belonging and accept, help build and maintain the power plant in village) in the form of: discharge of river water, river water dam layout, long conductive flow of water to the location of the water falls, the water level fell, and location of turbines; Third, experiments in laboratory experiments in the form of high variation of water falling; Last, economic analysis and supply to the local government Minahasa district for expansion into other villages potentially built PLTPH. The objectives of this research is to get the design of efficient and effective from axial turbine models for installation in PLTPH which generates electrical energy production of less than 5 kW for a household in the village Tinoor Minahasa North Sulawesi, Indonesia.
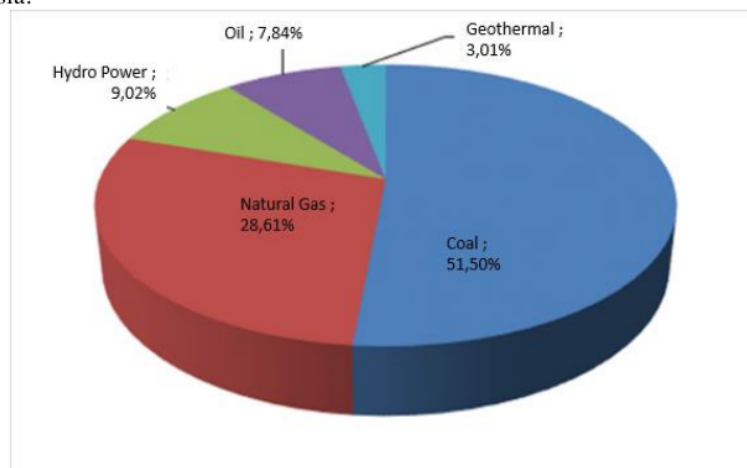

Figure 1. Production of electric energy in North Sulawesi.

Pico hydro is hydro power with a maximum electrical output of 5 kW [2][3][4]. The system is beneficial in terms of cost and simplicity from a different approach in the design, planning and installation from the power applied to the water is greater. The latest innovations in pico hydro technology have made an economic powerhouse even in some of the poorest places in the world and can be accessed. It is also a versatile resource. Alternating current electricity possible can be produced from a standard electrical equipment to be used. Common examples of devices that can be powered by pico hydro are light bulbs, radio and television. Typically, pico-hydro power systems are found in rural areas or hilly [5][4]. This system will operate using a container of water on which a few meters from the ground. From the reservoir the water flows downhill through the piping system and it allows the water to turn turbines. Thus, the turbine will rotate the alternator to produce electricity. However, this study was conducted to demonstrate the potential of consuming water that is distributed to homes in rural areas as an alternative renewable energy source. The flow of water in the pipe has the potential and kinetic energy will be converted into the potential energy of motion of the turbine which then into electrical energy in generators. Technically, pico hydro has three main components: water (as a source of energy), turbine and generator [6][7]. Pico hydro get energy from the flow of water that has a certain altitude difference. Basically, pico hydro utilized the potential energy of water falling (head). The higher the water falls, the greater the potential energy of water that can be converted into electrical energy. In addition to geographical factors (layout of the river), the height of falling water can also be obtained by stemming the flow of water so that the water level is high. Air flowed through a pipe plant rapidly into the house in general was built on the banks of the

river to drive turbines or waterwheels pico hydro. Mechanical energy derived from rotation of the turbine shaft is converted into electrical energy by a generator [8].

Reaction turbines operate under pressure inside the stator (casing). When water passing through the stator in the direction of the turbine shaft helical, causing a whirlpool. The flow was then directed by the blades of the turbine wheel. The angular momentum of the forces in the water rotates the turbine wheel. In contrast to the impulse turbine, the water pressure drops in the stator and the turbine wheel. Examples of a reaction turbine is Propeller (propeller), Kaplan, and Francis, Screw and kinetic turbines water (used to lower head is less than 5 m). Reaction turbines often have houses and geometry turbine blades of a complex which makes it more difficult to process large-scale production of the smallest in the settings in developing countries [9]. However, the reaction turbine can perform well even in low head distance of less than 10 m, thus making it more desirable since the low head of water resources are more accessible and closer location.

Turbine power (Pt) generated:[6][7]

$$Pt = \rho \, g \, H \, Q \eta \ (W) \tag{1}$$

Calculation of Electric Power and Energy:

Power turbine shaft

$$Pt = 9.81 \times Q \times H \times \eta turbin \tag{2}$$

Power is transmitted to the generator

$$Ptrans = 9.81 \times Q \times H \times \eta turbin \times \eta belt \tag{3}$$

Power generated generator

$$P' = 9.81 \times Q \times H \times \eta turbin \times \eta belt \times \eta gen \tag{4}$$

2. Methods

The method used literature study, site survey research (including survey the village in order to obtain the characteristics of villages and rural communities Tinoor for the purpose of character education for these communities in receiving, helped build and maintain the power plant), analysis beginning on the ability of electric power, and discussions with local authorities. Conducting preparatory activities before carrying out such research; reflecting the result of socialization, preparation of materials and experimental tools, setting work schedules. Data collection in the village Tinoor form: discharge of river water, water velocity, channel length conductor, high waterfalls, and location of the turbines.

Methods of direct observation in the field through measures such as speed streams and cross-sectional area perpendicular to the water flow of the river to get water discharge flowing river as initial data in the analysis of the ability of river water, and then to analyze the electrical energy taken preliminary data height measurements falling water (planned 1.63 m) including measuring the distance from the dam to the water fall. Technique of direct measurement with the following procedure: first measure the water velocity and the second measuring cross-sectional area perpendicular to the flow of river water in order to get water discharge (cross-sectional area multiplied by the speed of the water, m^3/s), and the last measure the height of falling water to get the length of the aqueduct of dam water to the water fall.

3. Results and discussion

This generator power electric generated will be distributed to users. In planning the required amount of power at the load center should be under the power capacity is raised, so that the power supply voltage is stable and the system becomes more reliable (long). The water flowing with capacity and a certain height distributed to the house installation (casing). At

home the turbine, the water plant will 12 and turbine, turbine ascertained in this case will receive the water energy and convert it into mechanical energy in the form of turbine shaft rotation. The rotating shaft is then connected to the generator by using the tire/belt. Of the generator will produce electricity that will go into the control system before the electrical current supplied to homes or other purposes (load). That briefly the process of pico-hydro, alter energy flow and water level into electrical energy [7].

The results of the analysis of water and high power capabilities of falling water according to calculation on a gross basis before further analysis can be seen in **Table 1** as follows:

Table 1. Results of the analysis of water and high power capability falling water.

Q (m³/dt)	H_{bruto}(m)	H_{losses}(m)	H_{eff}(m)	P(kW)	P'(kW)
0.236	1.63	0.23	1.4	2.69	1.85

Water discharge (Q) in **Table 1** is a water discharge pipe is planned to enter the rapidly with height of 1.63 m water fall and if we calculate minimum water flow of 20% of the water flow was then obtained 91.6 l / sec. Generates power without taking into account the total efficiency of 2.69 kW and if we take into account the total efficiency of 0.643, the installed power of 1.85 kW.

Table 2. Results of the analysis of electric energy.

$\sum\eta$	H_{eff}(m)	Q_{80} (m³/dt)	Q_{90} (m³/dt)	Q_{100} (m³/dt)	$\sum$E(MWh)
0.643	1.4	0.236	0.207	0.133	19.295

Table 2 shows the results of the analysis of electrical energy which is calculated based on the total efficiency, the force of gravity, high falls and the actual effective water obtained from the difference between the height of fall slop and total loss of height of falling water (0.1 m previously planned 0.23 m). The total energy obtained during a year high real effective water fall of 1.4 m was 19.295 MWh with installed power of 1.85 kW.

Total electrical energy obtained within a year of 19,295 kWh (Table 2). If we calculate the value of selling electricity to PLN by calculating the total cost of expenditure per year of IDR 25 million, the value of the electricity sold at IDR 1295/kWh.

4. Conclusion

The ability of hydroelectric power of 2.69 kW is installed or the electrical power produced by the force of the water. The head of effective of 1.4 m with the generated power of about 1.85 kW with water flow of 0.236 m³/s. The total energy is obtained within a year was 19.295 MWh.

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