Picohydro Scale Power Plant Pilot Project Utilizing Limited Water Flow as Renewable Energy

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Abstract. Until now, the energy needs of all countries have started to run out and each country is competing to find alternative energy sources as a substitute for energy sources for future needs. In Indonesia, as an archipelagic country with many rivers, it is actually easy to get an environmentally friendly alternative energy source that becomes a pilot project for a pico-hydro power plant that is useful for replacing energy sources from fossils. The pilot project of a pico-hydro Scale Power Plant Utilizing River Water Flows as Renewable Energy needs to be continuously studied and developed by all parties. The purpose of this study was to obtain an overview of the usability of river flows that can be used as a picohydro scale generator application. The research method was carried out by field surveys, making a study of river flow potential for picohydro applications. From the results of this study, information was obtained that in every river flow that flows water with a constant flow, the installation of pico-hydro scale plants can be used, because this condition will affect the operational conditions of the generating equipment, such as turbine rotation, power generated, pico-hydro efficiency up to the application in the form of the resulting load will be a problem if the river flow used in this pico-hydro application changes or is not constant, especially when the water flow becomes smaller so that it cannot turn the turbine during the dry season. The results of the survey and analysis of potential studies at a cross-sectional area of 2.15 cm obtained a river water flow velocity of 2.46 m/sec with an average measurement discharge of 3.26 m^3/second, so that if it is estimated that the potential power that can be generated reaches 4.57 kW .

Keywords: Picohydro, pilot project, Water Discharge, renewable energy, river flow

1 Introduction

Energy needs are increasing from time to time, the use of limited water flow discussed in this paper is intended for various types of water flow models that are not too large, but can flow continuously. This limited water flow can be in the form of river flow, irrigation flow, limited sewer flow or overflowing water fed to the river. This situation results can be enjoyed by people who need electricity both for personal use, household activities, education, office activities and companies. Hydroelectric power plant is one of the most widely developed power plants in Indonesia. Micro hydro power plants are one of the right choices to be developed in the natural conditions of archipelagic countries with certain demographic conditions, including Indonesia. The construction of this power plant model does not have a negative impact on the environment or reduce water for agricultural irrigation purposes. Besides that, the most important thing is that this plant does not require fuel to operate it. As the main source of energy input in the form of water mass flow potential is not reduced, but energy is only used in the form of water potential energy. In addition, the speed of the water used to drive the turbines sourced from the flow of water, both from rivers, irrigation, must be

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determined and measured correctly to support the operation of the hydropower system, especially pico hydro, perfectly without any insignificant obstacles. The potential of Indonesia's Hydro Power Plants is estimated at 76,670 Megawatts (MW) and Mini or Macro Hydro Power Plants of 770 MW are assets that must be utilized for the prosperity of the people [1].

(a). Sewer flow channel (b). Dam pouring channel

Figure 1. Types of limited and fixed channels in picohydro applications

In recent decades much has been done to fulfill a need to adapt and apply other technologies that have proven applicable to a plant similar to the pico model, ie a model in which the plant can operate at low flow velocities. scientists have conducted in-depth studies related to techniques that can provide benefits and scientific contributions related to this pico-hydro technology, for example what has been done is to make and test an axial model generator for micro-hydro power plants. This testing and development model has been widely adopted by several people such as its application and application to electric vehicles and wind turbines which are tested on a certain scale [2].

As we all know that actually to get clean energy a country has to make the latest innovations and breakthroughs in producing renewable energy which is very special, therefore to assist in producing electricity that is environmentally friendly and assisting in increasing the provision of inexpensive turbines, cooperation is needed. from various parties what can be done is to carry out an electricity economic revolution in a village that is reachable or unreachable. the main goal of researchers in producing electrical energy through technology is to standardize the supply of Pico-scale turbines or those that can produce electricity below 5 KW, so that it is possible to do mass production of course with the help of the government or private companies, especially in developing countries. developing country. This implementation results in a cost-effective financing and the deployment of this micro-hydro technology is very easy and not difficult, especially in remote areas, at this time people in remote areas such as in Vietnam and in Nepal can produce or make picohodros easily [3][4]. This generator model is very easy to make and implement by people in rural areas, by the way, the installation method is also not complicated, it can be done alone or with the help of technicians and or with the help of other people who have previously installed this complete device, so that the availability of electrical energy in the community in general both in remote areas in rural areas can be carried out properly and thoroughly [5].

References related to the next picohidro or subsequent discussion are related to the financing required in making it independently or in groups. 3 hydro installations can generally be implemented if the main and supporting components can be provided and procured according to existing standards, for example the main components are penstock pipes, electric generators, electrical control systems, electrical cables, energy saving lamps, protective transportation or complete equipment covers. pokohydro, labor to make operational training tools for its use [6] [7]. These references can be used as a reference in making hydro-scale power plants besides that deviations that occur may be considered for several things that can be detrimental to the initial project which has been designed systematically and structurally, so that implementation in the field and the final results of the project only then can the implementation go well and the errors that occur from the start of the planning are not too far apart from the errors.

Energy needs are increasing from time to time. People really need electricity both for personal use, household activities, education, office activities and companies. Because both smart devices, infrastructure, and means of transportation have used electrical energy to operate them. Electrical energy derived from non-renewable energy such as oil, natural gas, coal is almost exhausted because it requires a very long formation process. Electrical energy derived from renewable energy such as solar heat, geothermal, wind and water is a source that can produce energy without depleting natural resources and can be restored continuously [8]. The Ministry of Energy and Mineral Resources itself has issued the Minister of Energy and Mineral Resources Number 13 of 2020 concerning the Grand National Energy Strategy with one of its programs for providing Electricity Charging Infrastructure for KBLBB as an effort to encourage the KBLBB ecosystem (Battery-Based Electric Motorized Vehicles). Indonesia uses around 1.2 million barrels of oil per day (BOPD), of which most of its fuel needs are imported. With the increasing use of electric vehicles and reducing the use of oil-fueled vehicles in Indonesia, it is hoped that the potential for a reduction in fuel consumption of 6.03 million kL can be achieved by 2030. Therefore, it is necessary to utilize local energy sources, especially renewable energy sources and gas, to improve air quality and support the achievement of national targets for reducing greenhouse gases [9][10]. Therefore, renewable energy is urgently needed as a deterrent to the depletion of energy sources. Hydroelectric power is a model of power generation that has been widely developed in various regions of the world, including Indonesia as a country with many sources of water energy. Based on this background, to get cheap and environmentally friendly electrical energy, hydropower is used. A micro-hydro power plant is a power plant that can produce power from 5 kW to 100 kW. Bonded is presented in Figure 2 Power (kW) presents a model of the relationship between certain heads with different flow rates according to the needs in the field [11].

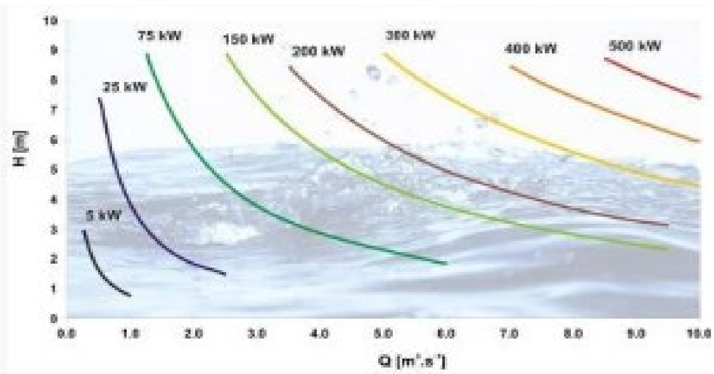

Figure 2. Power developed at different head and flow rate.

Theoretically the power generated can be represented in the following equation,

$$P = \eta\rho gHQ \text{ (kW)} \quad \ldots\ldots (1)$$

In this case, η can be written as the hydraulic efficiency of the turbine, for P is the mechanical power on the shaft, then the symbol g can be written as the acceleration due to gravity, ρ is the density of air, H is the effectiveness, and Q defines the mass flow rate [12]. The explanation above shows that the greater the head produced, the greater the flow rate, so this will have an impact on the power and energy produced, where the power output will increase along with changes in the amount of head and the flow rate of water rotating the blade. - turbine blades. This condition is actually difficult to achieve because to get a high head a dam is needed which can hold a lot of water so that the water flow rate is also higher. Therefore an innovation is needed that can make the flow high but does not require a larger or complicated implementation in the field, what can be done is in a way without a reservoir, namely directly flowing the water flow in the penstock pipe to go to or rotate the turbine blades at picohydro, so that with this condition it will make it easier for users in the field, especially rural communities who need electrical energy as a necessity in carrying out their daily lives with different need.

1.1 Potential water flow for picohydro in various countries

In other countries, such as India, rural areas still need a lot of electrical energy that can reach and meet their needs in carrying out work or the need to earn additional income, as described in the 2020 data, there are 3,17,56,227 restaurants that have not been served. perfectly electrified. Some of these electricity-related problems also occur in power supply models where this often occurs when power outages are interrupted by blackouts or short circuits caused by several abnormal conditions. One way that can be done to overcome these problems is to carry out activities to find new and renewable energy that can be directly applied by rural communities, namely for example micro-hydro scale power plants, Pico hydro, can distribute electricity to community members and so can be done in other needs such as for example for information via television, radio, YouTube, internet that can be used by the community. The following presented in table 1 is a condition where the PL model is applied in several countries.

The development of pico-hydro technology is currently in increasing demand by countries seeking and innovating renewable technologies to meet the needs of electrical energy in their respective countries, many countries in the world are utilizing the use of hydroelectric power both from the Asian continent to the European continent. as well as the American continent, however, technology models for pico-hydro power plants are still dominated by Asian countries where their use has been widely applied but shows that it is being carried out optimally, [2,10,11,12]. in this case the use of this micro-hydro generator model is carried out by countries that have tried renewable energy innovations such as from the United States, Canada, or better known as the Americas, always from the European continent such as the Netherlands, Spain, the Swiss River Aceh is known as the Blue Continent and then from Asia such as Indonesia, Nepal, India, Thailand and other ASEAN countries [13].

Table 1. The Picohydro Scale Generators in Several Countries

Latin America		Africa		South and SE Asia	
Argentina	12,400	Benin	4500	China	93,000
Bolivia	47,400	Cameroon	27,600	India	978,400
Brazil	524,300	CAR	7200	Indonesia	558,300
Chile	5200	Cote d'Ivoire	18,700	Lao PDR	10,000
Colombia	58,400	Ethiopia	97,800	Malaysia	30,600
Ecuador	35,700	Gabon	1700	Myanmar	48,600
Guatemala	8000	Guinea	9200	Nepal	292,500
Nicaragua	29,600	Ghana	33,700	Philippines	118,700
Peru	20,300	Kenya	80,200	Sri Lanka	170,600
		Lesotho	2000	Thailand	272,300
		Madagascar	46,100	Vietnam	153,900
		Malawi	1800		
		Mozambique	9200		
		Nigeria	32,600		
		Rwanda	4900		
		Senegal	5500		
		Sierra Leone	32,100		
		Tanzania	37,900		
		Uganda	17,500		
		Zambia	3500		
		Zimbabwe	6000		
LA total (18.8%) Analyzed 64.1% of total pop.	741,300	Africa total (12.2%) Analyzed 65.2% of total pop.	479,700	Asia total (69%) Analyzed 90.1% of total pop.	2,726,900

Source: Mariyappan [9].

1.2 Various turbine models for pico hydro power plants

ractice in the field related to this efficiency which is the determining factor is the electric generator and various kinds of hydraulic loss models. One of the losses that occur is for example losses due to friction from fluid viscosity, looseness and leakage. therefore the losses incurred must be minimized as small as possible so that efficiency will be high, if written in buying and selling, then:

$\eta = P_{mec} / P_{hyd}$ ………..……………. (2)

$P_{mec} = T\omega$ …………...………..…… (3)

can be written down, T is torque (Nm)
and ω = rotational speed (rad/s).

Phyd = ρgQH (in KW) ……….. (4)

Can be symbolized Phyd represents the power of water, ρ as the density of water (kg/m),
Q is the water flow rate m/s, g = 9.81 (m/s) = gravitational force,
H head(m)

Several research innovations have been carried out by several researchers related to how to increase the efficiency of this pico-hydro scale generation, one of which is by innovating the blades, namely by combining or making a damel number model. By making this model, the implementation of economies of scale has been carried out to obtain an efficiency of 81%, this indicates that there is still a need for a new travel plan to improve efficiency in hydroelectric power generation, especially on the pico-hydro scale, which can be applied to actual conditions so that later it becomes a certain point and highest for a better efficiency and further improve a product on this picohydro [14], On the other hand, the explanation related to this review is that a smaller slope or angle of inclination results in better efficiency, of course this must be aligned with the operational conditions that occur in the design if the previous design has been carried out, now this slope is of course the one of the points that must be done is testing and more in-depth testing so that the results are better and further increase the efficiency of the tool [15] [16].

$$C\ (a,b,c) = a \times P\ b\ c \times H \quad (5)$$

An explanation of the start-up costs in small or small-scale generator applications is given to the seller 5, for letters a, b and c are a predetermined coefficient, then for C, which is the cost represented by the currency value of the country of India (Rs.), P = Installed capacity (kW), H = head (m). This observation has been carried out carefully and involves recognized standards [17], for this to facilitate understanding, it is written in the financing agreement, namely:

$$C = 6.882 \times P\ 0.6369 - 0.0782 \times H \quad (6)$$

Again the explanation is, C = Cost incurred per kW in Indian Rupees, P = Capacity in kW, H = Head in m. The maximum allowable deviation of ±10% has been studied at the initial planning stage. Low head requirements for ASG so as to save or minimize initial investment costs.

2 Research Method

This study uses the method of literature study and measurements at the actual location. The data collection method is carried out by reviewing various related literature to obtain various information related to the research object that has been previously planned, including the working principle and the use of new and renewable energy in the use of meeting electricity needs, especially water energy as an environmentally friendly electricity source. This study uses secondary data collected from various journals, proceedings, reports, and news articles related to the potential and utilization of water energy in various sources from water flow with sufficient head to drive a pico-hydro or hydropower generating system. The data collected is then compiled and analyzed so that conclusions are obtained to answer the research problems that have been focused previously.

3 Results and Discussion

This research is carried out directly, in principle there is no difference between mini-hydro and micro-hydro power plants. Power generation systems can also be built with or without heads according to the potential of the local area. Headless means that the power generation system uses the natural flow of river water or irrigation to drive a turbine (waterwheel). Generally, this model generator system uses an impulse turbine which is not completely submerged in water. The blades (blades) of the impulse turbine are designed in such a way as to increase the contact area with the water [18].

Mini-hydro and micro-hydro power generation systems that use heads utilize the potential energy of falling water to drive turbines. Figure 1 shows the energy conversion process in a mini/micro hydro power plant. The potential energy of water can be modified by making a dam to enlarge the head or directly using a waterfall. Enlarging the head means increasing the potential energy of water and thereby increasing the potential power that can be generated. Furthermore, the water will be flowed through the carrier channel (head race) to the head tank. This tranquilizer serves to precipitate and filter impurities that are carried by the water as well as to control the flow of water entering the pentstock pipe. In the pipe the potential energy of the water is converted into kinetic energy. The fast pipe plays a role in optimizing the energy of falling water to turn the turbine. In the turbine, water energy will be converted into mechanical energy in the form of turbine shaft rotation [18]. In the final stage, the generator connected to the turbine shaft will rotate and produce induced electricity. Generally, turbines and generators and other electrical distribution controls are housed in a powerhouse.

Normally, pico-hydro power system is found at rural or hilly area [19] [20]. Figure 1 shows an example of typical pico-hydro system applications at hilly area. This system will operate using upper water reservoir which is a few meter high from ground. From the reservoir, water flows downhill through the piping system. This downhill distance is called “head” and it allows the water to accelerate for prime moving system. Thus, the turbine will rotate the alternator to produce electricity. However, this research is conducted to show the potential of consuming water distributed to houses at town area as an alternative of renewable energy source. The water flow inside the pipelines has potential of kinetic energy to spin small scale generator turbine for electricity generation. Therefore, this project has been done to show the additional use of consuming water distributed to houses for electrical power generation instead of routine activities such as bathe, laundry and dish wash. The electricity can be generated at the same time those usual activities are done without extra charge on the water bill consumption. The main function of the system is to store the generated power by means of battery charging for future use particularly during electricity blackouts. The proposed system is expected has a maximum capacity of 10W which is very much less compared to other pico-hydro power systems.

Usually, it is common knowledge that generator models with low water flow can be found anywhere, urban, rural, hilly, but mostly in rural areas [19][20]. In Figure 1 the applied model of picohydro with a head in the hills, where this system uses a dam or reservoir with a certain height above the land surface. The working system is that water from the hills flows through a pipe that has been installed in place, where the height is called the head as one of the determinants of the energy of the water that can rotate the turbine so that the generator attached or coupled to the turbine shaft also moves freely.

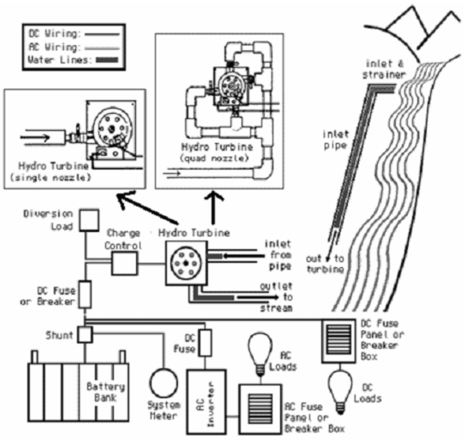

Figure 3. Example of application of picohydro in various conditions

The determination of the type of turbine to be used can be seen from the flow of water produced by pico-hydro sources, such as rivers, waterfalls, ditches and so on. Figure 4 shows the conditions where the Pelton turbine model is a turbine model that can be said to be universal, where this condition is not limited to the head that is at the flow source [20] [21].

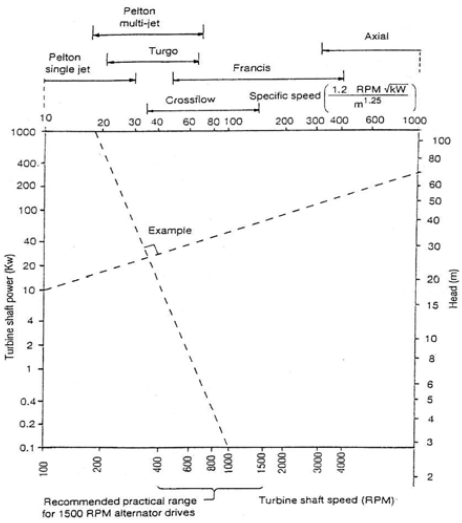

Figure 4. Nomogram for selection of a turbine for a hydro site

Based on the working principle, water turbines are divided into impulse turbines and reaction turbines (Židonis et al., 2015) [22]. The simple concept of an impulse turbine is the change in momentum before and after the water hits the turbine blades. The water energy from the spray jet is directed to hit the turbine blades and cause the turbine to spin. The types of turbines that use this concept include Pelton, Crossflow, and Turgo which are more optimally applied to conditions of medium to high head and low flowrate. The reaction turbine works based on the concept of a pressure difference on both sides of the blades (blades) causing the turbine to rotate [23] [18] . Francis and Kaplan/Propeller turbines are types of reaction turbines that are optimal for working at low heads with large water discharges.

One of the power plants that utilize the slope of this river is the hydropower plant in Ndungga. The Wolowona River was deliberately dammed and moved the river flow by optimizing the local topography to increase the head (difference in water level in the reservoir to the turbine). The aqueduct route is made into a 598-meter tunnel through the mountain due to the steepness of the alternative route which also coincides with the state road leading to Ende-Maumere, [24]. The Ndungga PLTM uses two Francis Horizontal turbine units (Figure 3) with an average discharge of 1.95 m/sec and an average head of 63.52 m. This turbine has a specific speed of up to 750 rpm (rotations per minute) and is capable of producing a specific power of 1,100 kW. At the end of the rapid pipe before entering the power house, the rapid pipe is made for two branches to supply water to the two turbines used. The Ndungga hydropower plant also uses two horizontal synchronous generator units with a specific voltage of 6,500 Volts and a frequency of 50 Hz with a power factor of 0.8. Each generator is coupled directly (direct connection) to the turbine so that it has the same specific rotation as the turbine. Furthermore, in the main transformer, the electricity voltage of the Ndungga PLTM will be increased to 20 kV before entering the Ende electricity network.

Figure 5. Ndungga Ende PLTM Turbine and Generator (Sindonews.com, 2019)

The components of mini-hydro, pico-hydro and micro-hydro generators are generally adapted to the characteristics of potential areas. The design and design of the plant including the type of turbine and the construction of the generating equipment used is based on the use of a minimum flow rate [25]. This is also a consideration for several generating systems including the Ndungga PLTM using two or more identical turbines instead of placing a single turbine even with the same capacity. According to Havianto, the minimum flow rate of the Wolowona river is able to drive each turbine (1 MW) of the Ndungga PLTM to produce 600 kW of power. So that at the peak of the dry season this PLTM is still able to supply 1.2 MW of power from the two installed water turbines [24]. In operation, the micro-hydro and mini-hydro models do not pollute the environment and even demand forest conservation as a water catchment area to maintain the supply of fuel for power plants. In addition, the service life is relatively long with lower operating costs [26].

Figure 6. Measurement application and potential installation of pico-hydro irrigation flow

The problem of cost in making a power plant project that utilizes water flow is the key that must be considered before carrying out its manufacturing application. Pico-hydro generators can be applied to agricultural irrigation or other waterways with low water discharge, so that their use can be beneficial for low-income households and these pico-hydro generators can especially be applied in rural areas for the need for electrical energy for use, for example refrigerator, television, radio, fan and so on [26], and can also help rural communities in the process of agricultural work in processing their agricultural products, besides that it can also be used to charge car batteries, cellphones which of course provide benefits for rural residents [27] [28][29].

4 Conclussions

The potential of hydro energy in Indonesia reaches 94,449 MW which consists of the potential for large-scale, medium-scale, and mini-scale hydropower plants or the so-called mini hydropower plants. However, until now the potential that has been utilized has only reached 6.4%. The government targets the new and renewable energy mix in 2025 to be at least 23% and 31% in 2050. With great potential, the development of large-scale hydroelectric power plants is the government's priority in increasing the new and renewable energy mix. The National Energy General Plan targets the utilization of installed water energy to reach 17,896.7 MW. To support this plan, the government, represented by the Director General of EBTKE, makes policies and strategic plans. Water energy utilization technology can be adjusted to the topography of the potential area. In addition to large-scale hydroelectric power generation for a power of more than 5,000 kW, hydro energy can also be utilized as a micro hydro generator for a power between 100 kW to 5,000 kW and a mini hydro generator for a power of less than 100 kW. Besides being able to become electrical energy, water energy is also an alternative energy storage technology with large capacity, namely pumped storage technology.

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