Community Service Akseprin Journal
Website : https://jurnal.akseprin.org/index.php/CSAJ/about
e-mail : sac@akseprin.org or akseprin@gmail.com
PUBLISHER: Akademi Sertifikasi Profesi Internasional (AKSEPRIN)

ISSN 3025-0110 (Online)
Pages 25-31, Vol. 01, No. 3, 2023

Received: 2023-07-09 Revised: 2023-08-21 Accepted: 2023-10-02 Published: 2023-12-31

Electrical Power Potential and Installation of Picohydro Turbine-Generator

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ABSTRACT

The 2014 National Energy Policy and the 2017 National Energy General Plan represent the government's dedication to advancing new and renewable energy capabilities. The policy aims to optimize the utilization of clean and renewable energy sources, particularly hydropower. This community service initiative aims to harness hydropower by assessing its electrical potential and developing mechanical electrical components to convert water's energy into electricity. The activity will take place in the village, utilizing one of the various altitudes of the river flow. The measurements conducted yielded an elevation of 1 meter and a discharge of 0.1 m^3/s, resulting in a potential electrical power of around 600 watts. The generating facility selects generators and manufactures turbines based on the assessment of power potential. The employed methods are (1) quantifying the river's flow, (2) assessing the height of the fall (head) at the powerhouse site, (3) determining the potential for electric power, (4) fabricating turbines, and (5) placing turbine-generators within the powerhouse. The outcomes of this endeavor include the establishment of a power plant, the fabrication of turbines, and the installation of turbine-generators utilizing hydropower potential. The installation of turbine generators in this power plant represents the initial phase, which will be followed by the subsequent phase involving the building of water channel dams, penstocks, and electricity distribution for street lighting.

Keywords: Generator; Pico Hydro; Turbine

INTRODUCTION

The 2014 National Energy Policy and the 2017 National Energy General Plan represent governmental pledges to the advancement of new and renewable energy resources. The

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national energy policy is an energy management framework grounded in principles of equity, sustainability, and environmental considerations aimed at achieving energy independence and national energy security (Powell et al., 2018). The government aims to attain a new and renewable energy composition of 23% in the national energy mix by 2025 and 31% by 2050. The objective of advancing new and renewable energy is to mitigate the escalation of global warming caused by fossil fuel consumption. The Government of Indonesia has ratified the Paris Agreement under the United Nations Framework Convention on Climate Change, as enacted in Law No. 16 of 2016.

The National Energy General Plan is a governmental policy concerning the administration of national energy, serving as a detailed implementation strategy for the National Energy Policy, which is interdisciplinary in nature to fulfill the objectives of the National Energy Policy (Meier & Fischer, 2011). The advancement of new and renewable energy because of its ecological benefits, has emerged as a crucial global initiative in addressing the pressing issue of global warming. The attainment of the NRE energy mix objective is actively monitored and diligently pursued, notably through Presidential Regulation Number 112 of 2022 on the Acceleration of Renewable Energy Development for Electricity Provision. The National Energy General Plan has laid out the goals and projections for the development of new and renewable energy (NRE) power plants through 2050. The potential for electrical energy derived from hydropower plants (75 gigawatts) and mini- and micro-hydropower plants (19 gigawatts) totals 94 gigawatts, making it the second largest potential after solar energy within the renewable energy sector, thereby indicating its significant role in the national energy mix.

Table 1. Prospects and forecasts for non-renewable energy development in 2050

No	Energy	Potential (Gigawatts)	Generation (GW)
1	Geothermal energy	29,5	16
2	water	75	37
3	Mini Hydro and Microhydro	19	94
4	Bio energy	32,8	28
5	Sun	200	49
6	Air	61	34

Source: data processing

The proliferation of small-scale hydroelectric power projects persists. Three categories of hydropower plants are recognized based on electricity generation capacity: mini-hydro (100 to 5 MW), microhydro (5 to 100 kW), and picohydro (below 5 kW) [5]. The majority of potential hydropower along river flows, particularly on the island, possesses limited capacity due to its relatively low head height and water discharge. The potential of this water energy can be harnessed as a picohydro power plant with a modest investment, eliminating the need to await

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investors seeking economic viability. Pikohydro comprises three primary components: water (the energy source), turbines, and generators. The implementation of pico hydropower plants necessitates indirect environmental and watershed management to maintain equilibrium and avert ecological harm.

Conserving river ecosystems and watershed areas will more effectively aid in mitigating global warming. This page pertains to the community service initiatives conducted in the village, harnessing the river's flow (Williamson et al., 2019). The river flow in the Plawetan bush, depicted in figure 1, is one of the upstreams of the Pond River, characterized by a well-preserved watershed due to its location inside the Perum Perhutani jurisdiction of the South Kedu Forest Management Unit (KPH). In a certain place along the river, there exists an elevation of approximately 1 meter, which has the potential to serve as a source of electrical energy for a pico hydropower plant. Measurements at the conclusion of the 2022 dry spell indicated a discharge of 0.1 m^3/s. The potential energy of water, harnessed through these heads and discharges, can serve as a power source for power plants using pico-hydro technology, yielding an output of approximately 800 watts

RESEARCH ELABORATIONS

Discharge measurement is conducted in two phases, specifically: 1. Measurement of river flow velocity using the buoy method at two locations, with three measurements conducted at each site. We conducted an assessment of the river cross-section at two different locations. We measured the flow velocity by observing the speed of a ping pong ball traveling 8 meters in the river current. Measurements were conducted at two locations, with each place assessed three times. We measured an 8-meter distance with a measuring tape and recorded the time with a stopwatch. The river's cross-section is measured at four distinct sites inside it. The river measures around 2.5 m in width, with measurements taken at distances of 0.5 m, 1 m, 1.5 m, and 2 m from one riverbank.

We conduct the head measurement using the water pass method, as illustrated in figure 3. The apparatus employed consists of a water level and measurement markers. The height of the drop is the difference between the upper reading (h1) and the lower reading (h2).

The potential calculation is performed using equation:

$P = \rho g h Q$

Accompanied by

P: Actual power output (kW) Q: Water flow rate (m^3/s) h: Effective height (m) g: Gravitational acceleration (9.81 m/s^2) ρ: Density of water (kg/m^3)

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The power potential pertains to the equivalence of hydraulic energy and electrical energy generated by water discharge and elevation height. This indicates that when turned into electrical power, the generator's output remains influenced by the efficiency of the turbine-generator. Turbine manufacturers and power plants produce turbines designed as water wheels with an external diameter of 90 cm. The runner component measures 26 cm in length and 24 cm in width (depth), which is welded to the inner diameter of the turbine, measuring 48 cm in diameter. A steel plate, measuring 2.5 centimeters in thickness, composes the turbine. Water will descend upon the turbine blades, facilitating the conversion of the water's potential energy into the mechanical energy of turbine rotation . The power plant is a facility for the installation of iron-framed turbine generators supported by pine wood stands to utilize local resources effectively.

The generator house safeguards the generator from environmental factors, particularly moisture, to avert short circuits. The generating house has successfully installed the turbine-generator. A V-belt featuring a flywheel arranges and connects the turbines and generators. Pulleys are positioned on turbines and generators such that the diameter of the turbine pulley exceeds that of the generator pulley, resulting in a faster speed for the generator compared to the turbine. Using a flywheel will help keep the turbine spinning steadily and control humidity, which improves the quality of the voltage and reduces sudden changes in the generator's voltage caused by quick changes in power demand.

RESULTS AND DISCUSSIONS

The objective of the initial activity is to estimate the electrical power potential and develop the mechanical and electrical components of the turbine-generator to harness the water's potential energy for street lighting purposes. The river discharge (Q) was calculated by multiplying the flow velocity (V) by the cross-sectional area (A) at the selected site for the picohydro power plant. Measurements of river water velocity were conducted at two designated points along the river flow.

The distance between Location 1 and Location 2 is 15 meters. The employed approach is the buoy method, which involves measuring the travel time of a buoy propelled by river currents over a distance of 8 meters at both location 1 and location 2, thus enabling the calculation of river flow velocity. We conducted speed measurements three times at each site, specifically at location 1 and location 2. To reduce measurement mistakes, the water flow velocity at each measurement point is an average of three speed data points. Table 1 displays the acquired results. At position 1, a ping pong ball takes 20.15 seconds to traverse an 8-meter river, resulting in a speed V1 of 8 meters divided by 20.15 seconds, which equals 0.39 m/s.

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The second and third measurements yielded velocity results of 0.37 m/s and 0.36 m/s, respectively. We calculate the average speed by summing the three speed measurements, dividing the total by 3, and arriving at 0.37 m/s.

Table 2. Assessment of flow velocity

	V(m/s)			L (metre)	V average
Location 1	V1 (t =20,15 second)0,39 m/s	V2 (t =21,10 second)0,37 m/s	V3 (t =22,25 second)0,36 m/s	8	0.37 m/s
Location 2	V1 (t =15,13 second)0,309 m/s	V2 (t =18,05 second)0,42 m/s	V3 (t =21,75 second)0,41 m/s	8	0.45 m/s

Source: data processing

We conduct river cross-section measurements at site 1 and location 2, assessing the river's depth at four points across its width. The river's width is approximately 2.5 meters, with each measuring point spaced 50 cm apart. The measurement results are depicted in Figure 3. At site 1, the river's depth measured at distances of 50 cm, 100 cm, 150 cm, and 200 cm from one bank is 23 cm, 27 cm, 25 cm, and 15 cm, respectively. This data is graphed to estimate the cross-section of the riverbed's depth. We segment the river into five divisions (I–V) to calculate the cross-sectional area per segment. The cross-sectional area is the aggregate of the areas of segments I through V. The areas of segments I to V are 0.0575 cm², 0.125 cm², 0.130 cm², 0.085 cm², and 0.0375 cm², resulting in a total cross-sectional area of 0.4350 cm².

We used velocity data and cross-sectional area measurements to calculate the discharge at location 1 (Q1) and the discharge at location 2 (Q2).

Discharge position 1 (Q1): $Q1 = 0.9 * x\ V1 x\ A1 = 0.9\ x\ 0.597\ m/s\ x\ 0.4350\ m^2 = 0.2237\ m^3/s$

Discharge location 2 (Q2): $Q2 = 0.9 * x\ V2\ x\ A2 = 0.9\ x\ 0.234$ m/s x 0.4063 m² = 0.0866 m³/s

Head refers to the vertical distance from the water level to the turbine spoon, situated at the midpoint of the turbine's height. According to the measurements obtained using the waterpass method, the water surface elevation was 2.5 m (h1), and the height of the waterfall on the turbine was 1.3 m (h2); therefore, Head = h1 - h2 = 2.5 - 1.4 = 1.1 m C. The electrical power potential is calculated using the discharge results at point A and the head at point B, as per equation (1) [9].

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Pin turbine = ρair x g x head x Q = 1000 kg/m³ x 9.8 m/s² x 1.1 m x 0.1038 m³/s = 1.220 watts. A Pelton turbine represents the electrical power derived from the potential energy of water that enters to drive the turbine. The output power supplied by the generator is contingent upon the efficiency of the turbine generator. Given that the generator turbine operates at an efficiency of 65%, the power capacity of the generator is as follows [10]:

The power generated by the generator can be calculated using the formula: Power generator = pin turbine x turbine efficiency generator = 1,220 watts x 0.65 = 793 watts

The turbine comprises a steel plate with a thickness of 2.5 mm. The outside diameters on both the right and left sides consist of steel plates measuring 90 cm in diameter. Nine turbine spoons, measuring 25 cm by 21 cm, are affixed between two exterior plates using electric welding. The 25 cm dimension represents the interior of the spoon, while the 21 cm dimension denotes its width. The interior of the welded spoons is affixed to a deep cylindrical plate with a diameter of 48 cm. At the core of the turbine resides a steel axle, fitted with bearings on both the right and left sides, serving as a support for turbine rotation powered by hydraulic energy.

One side of the turbine is equipped with a pulley, while a bearing is affixed to the axle. The implementation of pulleys on the turbine facilitates the mechanical transmission of turbine rotation via a V-belt, enabling mechanical rotation at varying speeds. In this turbine, the pulley conveys spin to the flywheel, which has a diameter smaller than that of the turbine pulley, resulting in the flywheel's rotation being faster than that of the turbine. Incorporating a flywheel will enhance the generator's performance by stabilizing the output voltage among load fluctuations.

Turbine generators are in the generating house. A U-steel iron frame of 5mm thickness constructs the generating house. Four support legs are embedded in cement to enhance the structural integrity of the power plant facility in response to the vibrations generated by turbine spinning. The turbine shafts on both sides are designed to be symmetrical and of identical height to mitigate vibration caused by water flow to the turbine blade. The turbine holds the generator in place. To minimize vibrations during the rotation of the generator axle and extend the generator's lifespan, the generator installation must align symmetrically with the pulley. The installation parameters apply to pulleys, generators, and turbines. The generator stand is constructed from pine wood, employing the natural resources surrounding the turbine-coupled generating facility, with the generator operating via a V-belt. A pulley with a smaller diameter than the turbine pulley is affixed to the generator shaft, resulting in a greater rotational speed for the generator compared to the turbine. Due to the comparatively large diameter of the turbine in comparison to the generator shaft pulley, an intermediary pulley is put between the generator turbines to enhance the rotational speed transferred to the generator pulley.

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CONCLUSIONS

Community service initiatives have accomplished their objectives. The measurements indicated a river water discharge of 0.1038 m^3/s and a fall height of 1.1 meters, resulting in a calculated potential power of 1,220 watts. With an efficiency of 65%, a generator output power of 793 watts will be achieved. This power capacity is adequate to meet the anticipated demand for electrical energy for street lighting. The installation of turbine generators at the power plant has been successfully completed, and it is prepared to proceed to the next phase, which involves civil construction and the distribution of electrical energy for street lighting. The implementation of technology in the construction of this picohydro plant will enhance safety and comfort, particularly during nighttime, foster community awareness regarding the sustainability of the water catchment area, and serve as a model for the utilization of renewable energy derived from local resources.

ACKNOWLEDGEMENTS

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