Assessment of the Kluet River's Potential for Hydrokinetic Power Generation

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Abstract

Electricity has become an essential necessity in modern human life, with all aspects of human existence relying on electrical energy. Securing a reliable location for electricity research poses challenges, particularly due to frequent maintenance issues with the Kluet Tengah Diesel Power Plant. The optimal solution lies in harnessing natural energy sources such as wind, water, among others, to mitigate the dwindling conventional energy resources each year. Utilizing the velocity of river flow for hydrokinetic applications is highly feasible, given the significantly higher density of water compared to air. A quantitative approach was employed in this study, involving observations of the flow velocity of the Kluet River in Lawe Melang Village. The results revealed an average velocity of 3.61 m/s, with the highest probability density function velocity recorded at 3.50 m/s. The kinetic energy generated, assuming a turbine cross-sectional area of 1 m^2, amounted to 97,43 Amperes, capable of supplying electricity to 24 households with a current limit of 4 A.

Keywords*: Potential, Hydrokinetics, Electricity, PLTHk, Kluet River.*

Abstrak

Listrik sudah menjadi kebutuhan yang penting bagi kehidupan manusia modern saat ini yang mana semua aspek kehidupan manusia bergantung pada energi listrik. Daerah tempat lokasi penelitian listrik merupakan hal yang sulit didapatkan secara konstan, dikarenakan PLTD Kluet Tengah sering perbaikan. Solusi terbaik adalah memanfaatkan energi alam seperti angin, air dan lain lain. Energi tersebut dimanfaatkan untuk mengurangi energi konvensional yang terus berkurang setiap tahunnya. Memanfaatkan kecepatan aliran sungai utuk diterapkan ke dalam sungai hidrokinetik sangat mungkin dilakukan karena mengingat densitas air 1000 kali lebih besar dibandingkan dengan densitas air. Metode yang digunakan adalah metode kuantitatif dengan melakukan observasi pengamatan kecepatan aliran sungai Kluet di Desa Lawe Melang. Hasil yang diperoleh diketahui bahwa kecepatan rata-rata dari sungai tersebut adalah 3,61 m/s, kecepatan nilai probability density function tertinggi 3,50 m/s. Energi kinetik yang dihasilkan jika asumsi luas penampang turbin 1 m^2sebesar 97,43 Ampere yang dapat disalurkan pada 24 rumah dengan batas arus 4 ampere.

Kata kunci*: Potensi, Hidrokinetik, Listrik, PLTHk. Sungai Kluet*

Introduction

Electricity has become an indispensable necessity in contemporary human life, with all facets of human existence reliant on electrical energy. To generate electricity, various types of power plants are employed, including Hydroelectric Power Plants (PLTA), Steam Power Plants (PLTU), Diesel Power Plants (PLTD), Solar Power Plants (PLTS), and others [1]. In Aceh Province there are two power plants, namely PLTU Nagan Raya with a capacity of 2 x 110 MW and PLTMG Arun with a capacity of 184 MW which have been fully operational since December 21 2015. The Peaker Gas Turbine Power Plant has a capacity of 180 MW [2-3].

Aceh Selatan, itself, is a regency surrounded by both small and large rivers. The implementation of the potential experiment on the Kluet River in Aceh Selatan could serve as a solution to the shortcomings of the current Diesel Power Plant (PLTD) [4]. Small-scale power plants are a relatively cost-effective technology compared to Diesel Power Plants (PLTD) and are a suitable solution for communities in riverside and remote areas that struggle to access electricity comprehensively[5-6].

Conventional energy is derived from sources that are finite on earth and non-renewable. This energy will eventually be depleted and will harm the environment. Renewable energy, on the other hand, is generated from sources such as the sun, wind, and water, which can be produced repeatedly[7]. These sources must always be available and should not harm the environment[8-10].

To prevent conventional energy sources from depleting further due to continuous fossil fuel consumption, which can lead to an energy crisis in Indonesia and environmental degradation, the Indonesian Government has enacted policies to promote the use of renewable energy, emphasizing energy management based on principles of justice, sustainability, and environmental consciousness [11]. Thus, scientists and practitioners persistently harness renewable energy, supported by current government initiatives such as Minister of Energy and Mineral Resources Regulation No. 50 of 2017 and its latest revision, Minister of Energy and Mineral Resources Regulation No. 04 of 2020, which regulate the utilization of renewable energy for electricity generation [12].

According to previous study on the potential of the Alue Keujrun River in Aceh Selatan, the average velocity of the Alue Keujrun River is 1.44 m/s. Despite its small flow, the Alue Keujrun River holds significant potential for hydrokinetic power generation[13].

Hydrokinetic Power Generation is a renewable energy power plant that harnesses the velocity of river currents without considering the difference in water flow height[14-18]. It utilizes the flow rate of river water to drive turbines, thus generating kinetic energy or motion energy, enabling the rotation of generators to produce electricity. Leveraging the river discharge of the Kluet River is one of a solution to provide electrical access in the Menggamat area, Kluet Tengah, Aceh Selatan.

Method

a. Observation

Observation in this study involves a data collection technique wherein the direct measurement of river velocity is systematically conducted over a period of 7 days. During this phase, the researcher measures the velocity of the river current using a Water Current Meter, positioned at 3 predetermined locations, and observes the measurement results. Subsequently, the researcher records the findings of the research object conducted over a span of 7 days and 1 hour per location. Measurements are carried out in the morning, afternoon, and evening. The research workflow is presented in Figure 1.

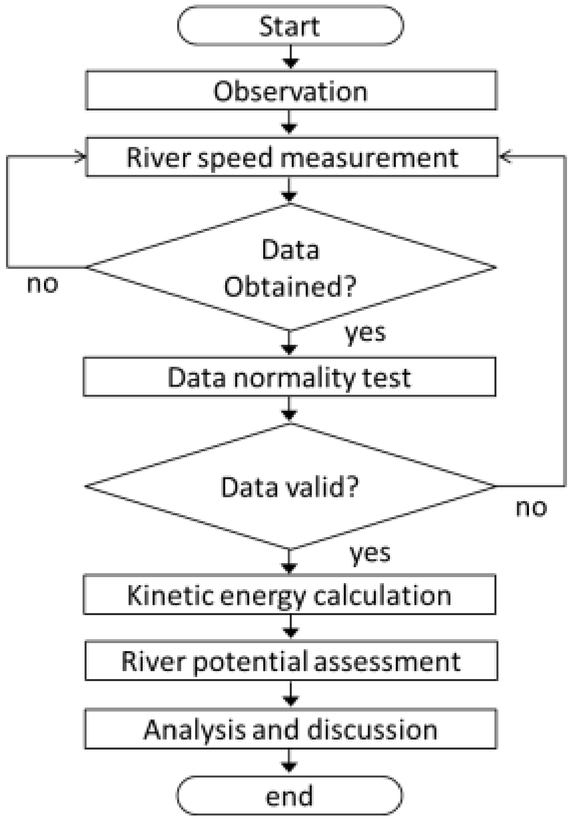

Figure 1. Research workflow

Data collection was carried out under two river conditions: normal and rainy. During the data collection, the researcher divided the river into 3 locations within a 50-meter distance to observe variations in river velocity. The researcher obtained measurement data at each location, comprising 20 data points per location and 60 data points per day, resulting in a total of 420 data points over the 7-day measurement period.

b. Documentation

Documentation serves as a supplement to the use of observational methods. In this stage of the research, researchers require the data obtained from the study results to support, enhance credibility, and provide evidence during the research process. Figure 2 illustrates the data collection process at the Kluet River.

(a) (b)

Figure 2. Documentation (a) data collection of Kluet river velocity at Lawe Melang site (b) data collection depth

c. Description of Research Location

This research was conducted on the Kluet River in Lawe Melang Village, Kluet, Tengah, Aceh Selatan, with coordinates 3°13'33" N 97°23'29" E. This river serves as a stamp transport port. The river location is observed 0.55 km away from residential areas. The details of the river's physical conditions can be observed in Table 1.

Table 1. Research Location Description

Description of the Research Location	
Research Sites	Lawe Melang Village Central Kluet District South Aceh Regency
River Length	5 KM
River Width	50-80m
River Depth	1 -2,5 m
Data Collection Distance	1,3m

The width of this river is approximately 80 meters. The depth of the river was determined after conducting interviews with local residents. The researcher interviewed a nearby resident named Saliman, aged 46, who works as a shop owner at the port. He estimated the depth of the river to be approximately 1 to 2.5 meters. In the middle of the river, it is estimated to be as deep as 2.5 meters

Result and Analysis

a. Measurement Data

The measurement data is obtained with varying velocity (m/s), determined by the river's characteristics. The processed measurement data can be seen in Table 2.

Table 2 Descriptive statistic data

Weather condition	N	Mean	Std. Deviation	Min.	Max.
Normal	60	3.2250	.43981	2.10	4.00
Normal	60	3.4617	.19406	2.90	4.00
Normal	60	3.5350	.35502	2.50	4.50
Normal	60	3.3633	.31460	2.60	4.10
Rain	60	3.9050	.36005	3.10	4.80
Rain	60	3.8450	.26897	2.90	4.50
Rain	60	3.9400	.26946	3.30	4.70

Based on Table 2, it is observed that the minimum velocity obtained is 2.10 m/s, while the maximum is 4.80 m/s during rainfall. The measurement data will be further processed to determine the Probability Density Function (PDF) values, which will be utilized for the necessary calculations

b. Probability Density Function

Probability, also known as the likelihood of an event, is defined as the chance of an event occurring. It is an experimental measure of the likelihood of an event happening in an experiment or trial conducted under certain conditions [19]. For data observation processing, it is necessary to calculate the probability values of events in each data distribution collected to identify the highest Probability Density Function (PDF) value from the observation data, as can be seen in on Figure 3.

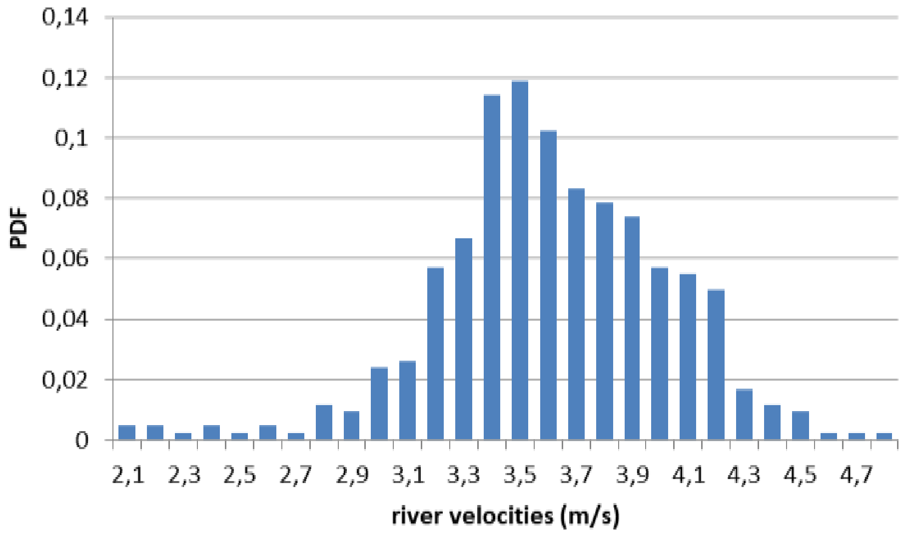

Figure 3. PDF of velocity measurement data

The data was collected under two river conditions: normal and rainy. After determining the maximum and minimum values of each condition and data collection day, the next step is to ascertain the probability values of the events. The histogram curve in Figure 3 takes on a bell-shaped form with a maximum probability of 3.50 m/s. This curve forms a symmetrical upper midline, indicating that the majority of the data cluster around the mean and are evenly distributed on both sides. A histogram graph is considered normal if the data distribution forms a bell-shaped curve, with no skewness to the left or right. The decision to conduct a normality test on the research data is based on whether the curve of the histogram resembles a symmetrical bell shape; if so, the research data is considered to be normally distributed.

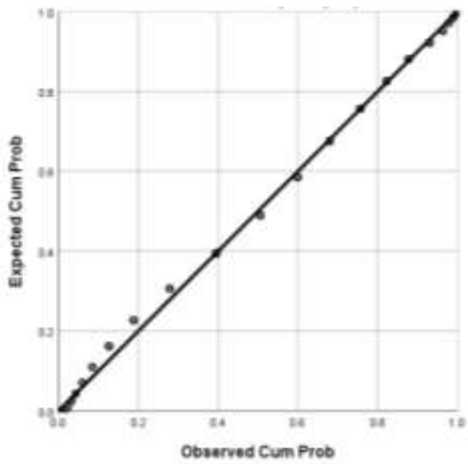

Figure 4. P-P Plot for Normality Testing

Figure 4 depicts a P-P Plot graph. The P-P Plot graph can be understood by examining the data distribution along the diagonal line of the graph. The P-P Plot graph is said to fail the normality assumption test if the data deviates significantly along the diagonal line and does not follow the direction of the diagonal line (Ghozali, 2016:156). The P-P plot in the above figure shows that the data is distributed along the diagonal line and follows the direction of the diagonal line, with the data spread not deviating significantly along the diagonal line. Therefore, the observation data from the research is deemed to be normally distributed or meets the assumption criteria for normality testing.

c. Kluet River Kinetic Power

Kinetic power refers to the rate at which kinetic energy is generated or transferred. It quantifies the amount of kinetic energy produced or utilized per unit of time. The calculation of kinetic power can be performed using (1)[22-23].

$$P = \frac{1}{2}\rho A V^3 \qquad (1)$$

Where P represents power (watts), ρ represents the density of water (kg/m^3), A represents the cross-sectional area (m2), and v represents the velocity of the river flow (m/s). It is known that the river flow velocity is 3.50 m/s as the maximum velocity, the density of water is 1,000 kg/m^3, and the cross-sectional area is assumed to be 1 m^2. Therefore, the power obtained is 21,435 watts.

d. Sensitivity Analysis

Sensitivity analysis was conducted for different turbine cross-sectional areas, allowing the comparison of the resulting kinetic power. The disparities in kinetic power are depicted in Figure 5.

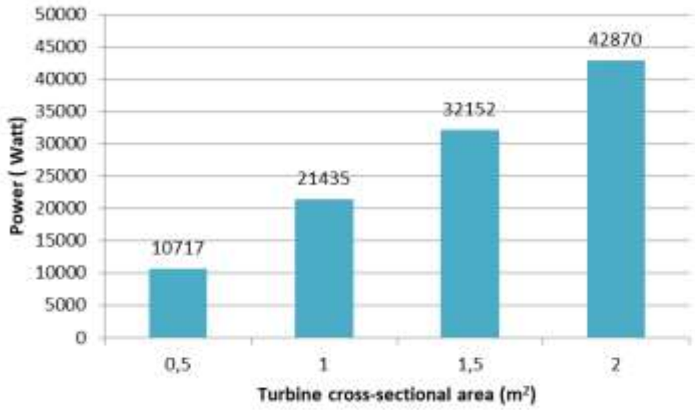

Figure 5. Sensitivity Graph for Cross-Sectional Area Differences

If we assume a cross-sectional area of 0.5 m2, then the electrical power generated would be 10,717 watts. For a cross-sectional area of 1, it would be 21,435 watts, for a cross-sectional area of 1.5 m2, it would be 32,152 watts, and for a cross-sectional area of 42,870 watts.

e. Analysis of Electrical Power Capacity

It is necessary to determine the number of households that can be provided with electrical power for a turbine of a specific cross-sectional area. Since the data collected during field measurements is only for 1 hour per day, the researcher uses 3.50 m/s as the maximum PDF value to analyze the sensitivity of electricity that can be distributed to a simple house with a capacity of 4 amperes. The cross-sectional area is assumed based on the river's depth and commercially available turbines. To find out how many households will receive electricity, given that the velocity v = 3.50 m/s, power 21.435 watts, and power factor 0.85, it can be calculated using (2).

$$I_{hk} = \frac{P}{V\,cos\varphi} = \frac{21435}{220 \cdot 0.85} = 114.63 \text{ A} \approx 115 \text{ A} \quad (2)$$

Where I_{hk} is the current generated by the hydrokinetic turbine. If the consumer is a single simple household with a limit of 4 A, then

$$Number\ of\ households = \frac{I_{hk}}{I_c} = \frac{115}{4} = 28.75 \approx 29 \quad (3)$$

If a sensitivity analysis is conducted on the turbine's cross-sectional area, the number of households that can be served can be observed in Figure 6.

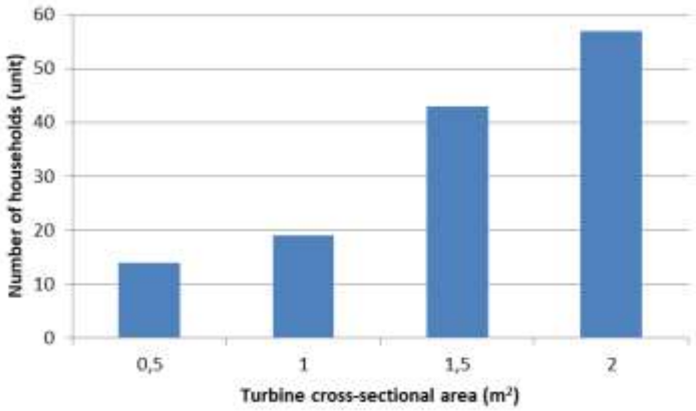

Figure 6. The number of households that can be served based on sensitivity analysis

Conclusion

Hydrokinetic power generation emerges as a viable solution for remote regions, offering an alternative to reduce reliance on conventional energy sources. Harnessing the flow velocity of rivers, hydrokinetic technology utilizes the natural kinetic energy available. In the case of the Kluet Lawe Melang River, the minimum velocity recorded stands at 2.10 m/s, while the maximum reaches 4.80 m/s, with an average velocity of 3.61 m/s. The highest probability velocity observed is 3.50 m/s, occurring 50 times within the data distribution. Assuming a cross-sectional area of 1 m^2, the power output achievable amounts to 21,435 watts. This energy capacity can effectively be distributed to power 29 households, each equipped with a 4 ampere electrical capacity.

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