The Potential of Hydroelectric Power of Kawiwi River in Ratahan District, North Sulawesi, Indonesia

B L Maluegha, C S C Punuhsingon and G D Soplanit

Mechanical Engineering Department, Faculty of Engineering, Sam Ratulangi University, Jalan Kampus Unsrat Bahu, Manado, 95115, Indonesia

E-mail: benny_maluegha@unsrat.ac.id

Abstract. This research was aimed at calculating the hydro energy potential for generating electricity from Kawiwi river in Ratahan District, North Sulawesi, Indonesia. The required data were the estimation of daily electrical loads of the buildings around Kawiwi river and the monthly average flow velocity of the river in a year. Data of electrical loads were obtained from questionnaires given to the people who is living by the river. Meanwhile, the data of the monthly average flow velocity for June, July and August 2019 were directly measured, and for other months were estimated based on monthly average rainfall in South East Minahasa regency, where Ratahan district is located. The monthly average flow velocity of Sungai Kawiwi are as follows: Januari 1.35 m/s, February 2.45 m/s, March 2.12 m/s, April 2.69 m/s, May 1.10, June 0.76 m/s, July 0.70 m/s, August 0.60 m/s, September 0.16 m/s, October 0.96 m/s, November 1.17 m/s, and December 2.20 m/s. The data, then, were analyzed by using HOMER 2.68 Beta with an assumption that the electricity produced from Kawiwi river was generated by Darrieus Hydro Turbine, a kinetic turbine. By HOMER’s calculation, it was found that the electricity produced from Kawiwi river was 16.880 kWh/year.

1. Introduction

Indonesia’s potential energy from hydro for generating electric power is quite immense that is more than 75 GW [1]. However, because of lack of reliable data, the assessment of the hydro energy potential for producing electricity becomes very limited. As a result, the use of hydro energy for power generation is much smaller than its potential. For that reason, research for identifying the potential energy of hydro resources, especially from rivers, should be increased.

Ratahan, a district in South East Minahasa regency in North Sulawesi province, Indonesia, is crossed by two rivers: Kawiwi and Palaus. The objective of this research is to calculate the hydro energy potential for generating electricity from one of the rivers, that is Kawiwi. The results of this research can be used to design an energy generating system with a kinetic turbine to increase the role of renewables to meet the electricity need of the people in Ratahan district.

There were some research on hydro energy and its technology have been made. Doda & Mohamad [2] conducted a study to calculate the potential of hydropower in Bone Bolango regency, Gorontalo, Indonesia which can produce 65 kW. The potential hydropower from a micro-hydro power station in Ngantang district, Malang regency, East Java has been investigated by Hanggara and Irvani [3]. The power station can provide electricity for 47 households. Anaza, et al. [4] overviewed the estimation of micro-hydro energy potential which depends on head and flow rate. Bhat [5] stated that hydropower can have a significant role in supplying electricity in the grid.
Studies on the technology of hydro energy were also conducted by some researchers. Kumar and Srivastava [6] analyzed the performance of Darrieus Hydro Kinetic Turbine with aerofoil blade profile and found that the aerofoil blade can be applied to a turbine for generating power in small scale. Chen and Engeda [7] investigated the use of ultra-low-head hydro energy and they found some satisfactory results. Sunoko, et al. [8] investigated the effect of runner angle positions on the efficiency of eight curved bladed kinetic water turbine. Boedi, et al. [9] conducted a study on the performance of a vertical axis hinged blade kinetic turbine by using Response Surface Methodology.

2. Research methods
This research was carried out in several main steps: data collection, data analysis and calculation. Those steps are explained in the following.

2.1. Data collection
The required data in this research were
1. estimation of daily electrical loads in buildings around Kawiwi river;
2. the monthly average flow velocities of the river in a year.

2.1.1. Daily electrical loads. These data were obtained from questionnaires given to the people living by Kawiwi river. The questionnaires included a question about the type of buildings based on their usage (such as: residential home, worship place, business place, etc.) and a series of questions about electrical equipment usage in the buildings. The questions were arranged in a form of a table which contains
- type of electrical equipment
- power of the electrical equipment (Watt)
- operational hours of the electrical equipment in a day
- total numbers of operational hours of the electrical equipment in a day (hours)
- total energy consumption of the electrical equipment in a day (Watt hours)
The data about electrical loads of the buildings around Kawiwi river was one of the required inputs to calculate the power that can be generated by the river.

2.1.2. Monthly average flow velocities. Since the equipment to measure flow velocity is not available, the monthly average flow velocities were determined by “float method”. The duration of a light object (i.e. a medium-sized half-filled plastic bottle) floating through a 10 meters distance was timed, and the velocity was determined by dividing the duration (in seconds) into the distance (10 meters). The data collection was conducted 20 times for every measurement in the river. Accordingly, the velocity of a month was the average number of the 20 velocities that have been previously calculated. Actually, the measurement of the average velocity should be carried out at least once for every month. However, due to the time limitation, the measurement could not be done for all month. The direct measurements were conducted only for three months, i.e. June, July, and August 2019. For other months, the average flow velocities were estimated by comparing data of average monthly rainfall from Statistics of South East Minahasa regency [10] with the calculated average velocity of a determined month.

2.2. Data analysis and calculation
Those data, then, were inputted into HOMER 2.68 Beta. HOMER can analyze the data and calculate the electric energy that can be generated from Kawiwi river. Beside those data, some components should be selected in the software so that the analysis and calculation could be performed by HOMER 2.68 Beta. The selected components would be used to form a power generation system that produced the electricity. In this research, it was assumed that the electricity would be generated by a kinetic turbine. So, the Darrieus Hydro Turbine from HOMER’s turbine database was selected to drive a generator to produce electricity. Since the objective of this research only to obtain the hydroelectric power generated by Kawiwi river, the default values provided in HOMER 2.68 were used as the inputs of other
parameters. Furthermore, other technical and economic aspects were inputted based on a rough estimation. These will not affect the calculation result of the hydroelectric power in this research.

3. Results and discussions

3.1. Daily electrical loads

From the questionnaires, only data about electrical consumption from residential houses were given. The data from other types of buildings (such as shops, offices, worship places, etc.) were not available. Therefore, the profile of daily electrical usage of the buildings around Kawiwi river was determined by multiplying the data of one residential house by the number of residential houses around the river. A village where Kawiwi river cross in Ratahan district is West Tosuraya village which has 524 residential houses [12]. Accordingly, the electrical energy consumption from a questionnaire of a residential house was selected and multiplied by 524 to obtain the electrical loads of buildings around Kawiwi river. The daily electrical usage of a selected residential house in West Tosuraya village is shown in Table 1.

| No | Electrical Equipment          | Power (Watt) | Operational Hours | Number of Operational Hours | Energy Consumption (Wh) |
|----|-------------------------------|--------------|-------------------|-----------------------------|-------------------------|
| 1  | Lamp A                        | 20           | 18.00 – 23.00     | 5                           | 100                     |
| 2  | Lamp B                        | 20           | 18.00 – 22.00     | 4                           | 80                      |
| 3  | Lamp C                        | 5            | 19.00 – 05.00     | 10                          | 50                      |
| 4  | Lamp D                        | 10           | 18.00 – 22.00     | 4                           | 40                      |
| 5  | Iron                          | 300          | 15.00 – 16.00     | 0,86                        | 258                     |
| 6  | Television                    | 150          | 08.00 – 15.00     | 7                           | 1050                    |
| 7  | Refrigerator                  | 100          | 00.00 – 24.00     | 24                          | 2400                    |
| 8  | Magic jar (cooking)           | 350          | 05.30 – 06.00     | 0,5                         | 175                     |
| 9  | Magic jar (heating)           | 60           | 06.00 – 20.00     | 14                          | 840                     |

Total of Daily Electrical Energy Consumption of a Household 4993

\(^{a}\) From the questionnaire, it was found that the iron is used three times in a week for two hours for each usage. To simplify the analysis, it was assumed that the iron is used for 0,86 hours every day (six hour divided by seven days) from 15.00 to 16.00.

After multiplying by 524, the daily electrical usage must be presented in hours as can be seen in the following table.
Table 2. Profile of hourly electrical consumption in West Tosuraya village in a day.

| Hour in a day | Electrical consumption (W) | (kW) |
|---------------|-----------------------------|------|
| 00.00 – 01.00 | 55,020                      | 55,02|
| 01.00 – 02.00 | 55,020                      | 55,02|
| 02.00 – 03.00 | 55,020                      | 55,02|
| 03.00 – 04.00 | 55,020                      | 55,02|
| 04.00 – 05.00 | 55,020                      | 55,02|
| 05.00 – 06.00 | 144,100                     | 144,10|
| 06.00 – 07.00 | 83,840                      | 83,84|
| 07.00 – 08.00 | 83,840                      | 83,84|
| 08.00 – 09.00 | 162,440                     | 162,44|
| 09.00 – 10.00 | 162,440                     | 162,44|
| 10.00 – 11.00 | 162,440                     | 162,44|
| 11.00 – 12.00 | 162,440                     | 162,44|
| 12.00 – 13.00 | 162,440                     | 162,44|
| 13.00 – 14.00 | 162,440                     | 162,44|
| 14.00 – 15.00 | 162,440                     | 162,44|
| 15.00 – 16.00 | 219,032                     | 219,03|
| 16.00 – 17.00 | 83,840                      | 83,84|
| 17.00 – 18.00 | 83,840                      | 83,84|
| 18.00 – 19.00 | 110,040                     | 110,04|
| 19.00 – 20.00 | 112,660                     | 112,66|
| 20.00 – 21.00 | 81,220                      | 81,22|
| 21.00 – 22.00 | 81,220                      | 81,22|
| 22.00 – 23.00 | 65,500                      | 65,50|
| 23.00 – 24.00 | 55,020                      | 55,02|
| Total         | 2,616,332                   | 2,616,33|

The profile of hourly electrical consumption in West Tosuraya village in a day from Table 2 can be presented in the form of a graph as shown in Figure 1.
Figure 1. Profile of hourly electrical consumption in a day in West Tosuraya village.

Figure 1 depicts that the highest consumption occurs at 15.00 when iron is used. Whereas the lowest happens from 23.00 to 04.00 when refrigerators and some lamps are still on.

3.2. Monthly average flow velocities

The data of monthly average flow velocities taken from direct measurement at Kawiwi river (for June, July and August 2019) and also from the calculation based on the rainfall data in South East Minahasa regency in 2018 (other months) [10] are presented in Table 3. In the calculation, the average flow velocity of June was used as the basis of comparison.

| Month   | Rainfall (mm³) | Monthly average flow velocity of Kawiwi river (m/s) |
|---------|----------------|---------------------------------------------------|
| January | 156            | 1.35                                              |
| February| 284            | 2.45                                              |
| March   | 246            | 2.12                                              |
| April   | 312            | 2.69                                              |
| May     | 127            | 1.10                                              |
| June    | 88             | 0.76                                              |
| July    | 98             | 0.70                                              |
| August  | 46             | 0.60                                              |
| September| 19           | 0.16                                              |
| October | 111            | 0.96                                              |
| November| 135            | 1.17                                              |
| December| 255            | 2.20                                              |
Table 3 shows that the highest average velocity is in June, and the lowest is in the September. The variation of the average velocity is mainly caused by seasonal effects.

3.3. Data analysis and calculation by using HOMER 2.68 Beta

Data analysis and calculation using HOMER 2.68 Beta were carried out in the following steps.

3.3.1. Selecting loads and components. After opening the software, the load and components for electrical generation system must be selected. As can be seen in Figure 2, the selected load and equipment are
- Primary Load 1
- Darrieus H Turbine
- Converter

Since Tosuraya Barat village has connection with grid from State Electricity Company (PLN), the option of “System is connected to grid” must be chosen.

3.3.2. Inputting primary load. The primary load inputted in the software is the profile of hourly electrical consumption in West Tosuraya village in a day as presented Table 2 and Figure 1. The result of inputting primary load can be seen in Figure 3.
3.3.3. **Inputting resource data.** As explained earlier, it was assumed that the electricity would be produced by a hydro kinetic turbine. Because the feature of kinetic turbines and wind turbines is quite similar and also the resource input for kinetic turbine is not available in HOMER 2.68 Beta, “Wind Resource Inputs” was used to input the monthly average flow velocities of Kawiwi river. However, the data must be prepared in a Microsoft Excel file and, then, was inputted through “Import time series data file”. This must be done so that HOMER will not consider other advanced parameters for wind turbines (such as Weibull k). The result of resource input can be seen in Figure 4.
3.3.4. **Inputting turbine data.** Darrieus Hydokinetic Turbines (DHT) is the only kinetic turbine available in the database of HOMER 2.68 Beta. Figure 5 shows the result of the turbine input.
3.3.5. *Inputting converter data*. The electricity produced from Darrieus Hydokinetic Turbines (DHT) is DC. Therefore, a converter is required to change the DC current to AC current. The input of converter data is shown in Figure 6.
Figure 6. Converter data input

3.3.6. Calculation. After all data were inputted, the schematic of the power generation system was displayed in HOMER 2.68 Beta as can be seen in the following figure.

Figure 7. Schematic of the power generation system
Figure 7 depicts the power generation system from the river consisted of the Darrieus Hydro Turbine and a converter, and it is shown that the electricity was also supplied by grid. The load is 2.6 MWh/day with 410 kW peak. Afterwards, the calculation was performed, and two type of power generation systems for satisfying all the loads will be displayed (Figure 8). The first system shows that the grid is the only supplier of the electricity. This system was ignored because it is not in accordance with the objective of this research.

![Double click on a system below for simulation results.](image)

**Figure 8.** Power generation systems resulted from the calculation

Finally, the number of electricity produced by the turbine was obtained in the “DHT” tab after double-clicking the second system. As shown in Figure 9, the total production of electricity from Darrieus Hydro Turbine was 16.880 kWh/year.

![Simulation Results](image)

**Figure 9.** Electricity produced from Darrieus Hydro Turbine

4. Conclusion

In conclusion, the power generation system for Kawiwi river which consisted of the Darrieus Hydro Turbine and a converter can only supply electrical energy as much as 16.880 kWh/year.
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