Study of the Supply Water Discharge at the Micro Hydro Power Installation

Firmansyah¹, Aida Syarif², Zainuddin Muchtar³, Rusdianasari*¹

¹ Renewable Energy Engineering Department, Politeknik Negeri Sriwijaya, Palembang, Indonesia
² Chemical Engineering Department, Politeknik Negeri Sriwijaya, Palembang, Indonesia
³ Civil Engineering Department, Politeknik Negeri Sriwijaya, Palembang, Indonesia
*Corresponding Author: rusdianasari@polsri.ac.id

Abstract. Micro hydro-power plant (MHP) with 10 KW power in Sarwan Sub-village, Merbau Village Ogan Komering Ulu Regency, was installed by the funding of corporate social responsibility (CSR) of PT. Pertamina (Persero). It was built to utilize the water potential energy switched into electricity to meet the needs of the people of the Sarwan sub-village. It was also aimed to make Merbau village sustainable-energy independent. One of the supporting factors is the Sarwan river’s flow capacity so that the methodology used in this research tried to reanalyze the existing discharge of the river in Sarwan village. This study analyzed the discharge in July with the dry season intensity of 46.6 mm, and the discharge obtained was 0.496 m/sec so that the Pin was 12.18 Kw, and Pout was 8.47 kW with the energy demand by the people of Sarwan village amounting to 4.81 kW. This means that MHP in Sarwan village could back up all of the needs of the residents of Sarwan village for electricity for 24 hours, and the optimization of the utilization of MHP in Sarwan village remains potentially developed.

1. Introduction
As the population grows, the need for electricity in rural areas increases, but, on the other hand, the financial support by the government to expand the electricity network is limited. Micro-hydro is often considered as a plausible alternative in meeting the electricity needs of rural communities. Merbau Village is located in Banding Agung subdistrict, Ogan Komering Ulu Selatan district, Sumatra Selatan province. Merbau village consists of 6 sub-villages, one of which is the Sarwan sub-village, which is located in sub-village 5. The number of its population is 128 people in 32 families. The livelihoods of the people are farmers of coffee and other commodities such as pepper, sugar palm, and cacao. Sarwan is one of the sub-villages that was unreachable by the State Electricity Company (PLN) for electricity supply. This is caused by the area profile, demography, and topography of the Sarwan area which has hilly contours with a valley. One of the obstacles for PT. PLN (PERSERO) to distribute electric power was the economic factor that corresponded to those previously-mentioned reasons. Furthermore, the potential consumers would be charged extra to build low voltage electric poles. It caused higher costs incurred by the community.

By using the CSR fund program of PT. Pertamina (PERSERO), after studying the potential local energy source, that is waterfall with a height of 9 meters situated 2.5 km away from the settlement, it was possible to utilize it as an alternative energy source. The water potential energy was possible to be converted to kinetic energy and was switched to mechanical energy. The mechanical energy was eventually converted into electrical energy through a generator. In 2017 the micro hydropower plant
(MHP) was constructed using a crossflow turbine with a capacity of 10 KW to make Sarwan become a pilot project of Energy Independent Village in 2021 with sustainable development. The selection of a crossflow turbine was adjusted to the water discharge and height (head). In its application, a crossflow turbine is very well used for small hydropower centers with a power of approximately 750 kW. The height of falling water that could be used was above 1 m to 200 m with a capacity of between 0.02 m³/s to 7 m³/s [1-3].

Considering the above reasons including the sustainable program to create "independent energy village", and one supporting factor that is the Sarwan’s river flow capacity, the authors conducted a study on the supply of water discharge at the MHP installation in Sarwan sub-village, Merbau Village, South OKU, South Sumatra [4-6].

2. Materials and Method
The research was carried out in the Sarwan sub-village of Merbau village, Merbau village was one of 12 villages in the sub-district of Agung Ogan Komering Ulu district or often called South OKU which has an area of 10 km². Data is collected during the dry season by observing the intensity of rainfall. Retrieval of flow velocity data using flowatch type FW 450 is divided into three sections, then measuring the depth and width of the river flow.

Stages of analysis are done by calculating the existing river flow, calculating the flowrate in this study using the calculation of the average appearance method. After getting the existing river flow discharge, the optimum flow capacity is obtained by connecting the flow capacity to the output of the Crossflow turbine, both input power, and output crossflow turbine, then analyzing the community usage load on the power generated with the existing river flow discharge.

The direct discharge measurement method that can be used in this case is the salt method, current meter, floating, and rectangular weir. Complete references for discharge measurements are as follows: [7-9]: 1] River Flow and Open Channel Measurement Method (SKSNI 03-2414-1991); 2] River Flow Measurement Method (SKSNI 03-2159-1992); 3] River Flow Measurement Method and Open Channels with Propeller Type Measuring Instrument (Figure 1)(SKSNI 03-2819-1992); 4] Procedures for River Flow Measurement and Open Channels with Flow Measurement and Buoys (SNI 03-2411).

Fig 1. Propeller speed measuring instrument

It is used for measuring in the depth of the vertical line whose speed will be measured, then the depth of measurement 0.2; 0.6; and 0.8 from the water surface is determined as shown in Figure 2 [10].

Fig 2. Depth measurement
3. Result and Discussion

3.1. Flow Velocity

To measure flow velocity, this study used flow watch type FW450. This research was conducted in July 2018 because of the weather intensity during the dry season. The intensity measurement was taken from the nearest station with a value of 46.6 mm. 10 measurements were done to take v average. The catchment area is divided into 3 cross-sections with flow velocity v1, v2, and v3, as shown in Figure 3. V1 velocity was taken in 0.6d depth, v2 velocity was taken in 0.2d and 0.8d depth, and v3 velocity was taken in 0.6d depth. As a result, the flow velocity can be seen in the following Table 1.

![Figure 3. Catchment area](image)

| No | Distance L (m) | Dm (m) | Velocity | Month |
|----|----------------|--------|----------|-------|
|    |                |        | 0.2d     | 0.6d  | 0.8d  | V (m/s) |
| 1  | 0              | 0      | 0        | 0     | 0     | 0       |
| 2  | 0.55           | 0.55   | 0.41667  | 0     | 0.42  |
| 3  | 1.1            | 0.7    | 0.36111  | 0     | 0.39  |
| 4  | 1.65           | 0.52   | 0.38889  | 0     | 0     |
| 5  | 2.2            | 0      | 0        | 0     | 0     |

3.2. Flow Width and the Depth of Catchment Area

To measure the width and depth of the flow catchment area, the researcher used meter tape. The catchment area was divided into 3 cross-sections as in Figure 4. The edge distance 1 was equal to 0 with the depth (dm) of 0, a measurement depth of 0. Meanwhile, the edge distance 2 equals 55 cm with the depth (dm) of 55 cm and a measurement depth of 33 cm. The edge distance 3 equals 110 cm with the depth (dm) of 70 and the measurement depth of 14 cm and 56 cm. The edge distance 4 equals 165 cm with the depth (dm) of 52 cm and the measurement depth of 31.2. Lastly, the edge distance 5 equals to 220 cm with depth (dm) and the depth of measurement of 0. All can be seen in Table 2.

![Figure 4. Cross-sections](image)

| No | Distance L (m) | Dm (m) | Width (cm) | Depth (dm) | Measurement Depth (cm) |
|----|----------------|--------|------------|------------|------------------------|
| 1  | 0              | 0      | 0          | 0          | 0                      |
| 2  | 0.55           | 0.55   | 55         | 33         | 33                     |
| 3  | 1.1            | 0.7    | 110        | 70         | 56                     |
| 4  | 1.65           | 0.52   | 165        | 52         | 31.2                   |
| 5  | 2.2            | 0      | 220        | 0          | 0                      |
Table 2. Flow Width and the Depth of Catchment Area

| No | Edge distance L (cm) | Depth dm (cm) | The depth of Measurement |
|----|---------------------|---------------|-------------------------|
| 1  | 0                   | 0             | 0                       |
| 2  | 55                  | 55            | 33                      |
| 3  | 110                 | 70            | 14                      | 56          |
| 4  | 165                 | 52            | 31.2                    |
| 5  | 220                 | 0             | 0                       |

To find the flow rate, we must know the cross-sectional area of the river and the flow velocity. The width of the river crossing can be obtained from the width times the depth of the river. To calculate the flow velocity, this study uses the average of the polygon-area calculation method, with the formula:

The width of the area of polygon 2-3: [11-13]

\[ A_{2-3} = \frac{d_2 + d_4}{2} w_2 \]  \hspace{1cm} (1)

Discharge calculation

\[ Q_{2-3} = \left( \frac{\sqrt{d_2^2 + d_3^2}}{2} \right) \left( \frac{d_2 + d_3}{2} \right) w_2 \]  \hspace{1cm} (2)

Generally, discharge through an area of polygon x and x+1 equals to:

\[ Q_{x-x+1} = \left( \frac{\sqrt{d_x^2 + d_{x+1}^2}}{2} \right) \left( \frac{d_x + d_{x+1}}{2} \right) W_x \]  \hspace{1cm} (3)

Table 3. Flow Discharge

| No | Edge distance L (m) | dm (m) | 0.2d | 0.6d | 0.8d | V (m/s) | Q (m/s) |
|----|---------------------|--------|------|------|------|---------|---------|
| 1  | 0                   | 0      | 0    | 0    | 0    | 0       | 0       |
| 2  | 0.55                | 0.55   | 0.42 | 0.42 | 0.42 | 0.143   |         |
| 3  | 1.1                 | 0.7    | 0.47 | 0.36 | 0.42 | 0.270   |         |
| 4  | 1.65                | 0.52   | 0.39 | 0.39 | 0.39 | 0.08342 |         |
| 5  | 2.2                 | 0      | 0    | 0    | 0    | 0       |         |
|    | **Total of Discharge** |        |      |      |      |         | **0.49691** |
|    | **Discharge Average** |        |      |      |      |         | **0.09938** |
3.3. Turbine Power

The calculation of turbine power is described by the following diagram:

![Block diagram of MHP power](image)

**Fig 4. Block diagram of MHP power**

Turbine Input Power is calculated based on the equation of: [14-15]

\[
P_{\text{in}} = \rho \cdot g \cdot Q \cdot H_{\text{net}}
\]

\[
P_{\text{in}} = 1000 \times 9.81 \times 0.0994 \times 12.5
\]

\[
= 121868 \text{ watt}
\]

\[
= 12.18 \text{ Kw}
\]

Turbine Output Power is calculated based on the equation of:

\[
P_{\text{in}} = \rho \cdot g \cdot Q \cdot H_{\text{net}} \cdot \text{Eff}_{\text{t}} \cdot \text{Eff}_{\text{G}}
\]

\[
P_{\text{in}} = 1000 \times 9.81 \times 0.0994 \times 12.5 \times 0.74 \times 0.94
\]

\[
= 8478 \text{ watt}
\]

\[
= 8.47 \text{ Kw}
\]

Where:

\[
\rho = 1000 \quad g = 9.81 \text{ m/s}^2
\]

\[
H_{\text{net}} = 12.5 \text{ meter} \quad Q = 0.994 \text{ m/s}
\]

\[
\text{Eff}_{\text{turbine}} = 0.74 \quad \text{Eff. Generator} = 0.94
\]

The Sarwan Subvillage population consisted of 128 people (32 families) with 30 houses, so that the demand for electricity consumption is as follows:

**Table 4. The Demand for Electricity of Sarwan community**

| Electronic         | Power | Total Power |
|--------------------|-------|-------------|
| 30 TV              | 65 watt | 1950 watt |
| 90 LED House Lamp  | 13 watt | 1170 watt |
| 111 LED Street Lamp| 13 watt | 1443 watt |
| 2 Water Pump       | 125 watt | 250 watt |
|                    | Total  | 4813 watt  |

Note:
- There are 30 houses
- Each house has 1 CRT (Cathode Ray Tube) TV, 3 LED lamps
- There are 111 street lamps
The operating time of the MHP Sarwan sub-village in a day is 15 hours because the community of Sarwan sub-village does their activities in the garden and workplaces from 7:00 a.m. to 3:00 p.m. The detailed usage of the electricity by the community per day can be seen as follows:

### Table 5. Details of electricity usage per day

| Time           | Power Amount Used | Power Amount (W) | Total Power (W) |
|----------------|-------------------|------------------|-----------------|
| 07.00-15.00    | No electricity usage |                  |                 |
| 16.00-17.00    | 30 TV             | 65 watt          | 1950 watt       |
|                | 2 Water pump      | 125 watt         | 250 watt        |
|                | Total             |                  | 2200 watt       |
| 18.00-21.00    | 30 TV             | 65 watt          | 1950 watt       |
|                | 90 House lamp     | 13 watt          | 1170 watt       |
|                | 111 Street lamp   | 13 watt          | 1443 watt       |
|                | Total             |                  | 4563 watt       |
| 22.00-06.00    | 30 House lamp     | 13 watt          | 390 watt        |
|                | 111 Street lamp   | 13 watt          | 1443 watt       |
|                | Total             |                  | 1833 watt       |

![Figure 5. Graph of electricity usage load per day](image)

The peak use of electricity Sarwan sub-village community was at 6:00 p.m. to 9:00 p.m. with the power of 4.56 KW. From 7:00 a.m. until 3:00 p.m., the electricity usage load of the community of Sarwan was 0 because the community of Sarwan sub-village did their activities outside their houses. The usage burden of the Sarwan sub-village community was 4.56 kW when using the PLN network. Therefore, the community of Sarwan paid for 4.56 kW x (Rp. 1467.28 x 10% x10%) = Rp. 60,000.

### 4. Conclusions

Discharge supply in July had an intensity of rainfall in the dry season of 46.6 mm from BMKG (Meteorology, Climatology, and Geophysical Agency) data of South Sumatra Province with the discharge produced at the existing flow of 0.496 m/sec, so that the turbine pin can be obtained at 12.18 kW and Pout Turbine at 8.47 kW. The usage load of the Sarwan sub-village community is 4.81 kW, where the Sarwan sub-village MHP has a minimum power of 8.47 kW which means that Sarwan MHP...
can back up all of the electricity needs of the residents of Sarwan sub-village for 24 hours and this still is potential to develop the utilization of MHP in the Sarwan sub-village.

Reference

[1] Agency for the Assessment and Application Technology, Indonesian Energy Outlook 2017. Jakarta: Center for Energy Resources and Chemical Industry (PTSEIK). 2017.

[2] R Ploetz, R Rusdianasari, E Eviliana, “Renewable Energy” Advantages and Disadvantages,” Proceeding Forum in Research, Science, Technology (FIRST), 2016.

[3] Irwansyah Syam, M. Ilham Maulana, and A. Syuhada, "Design and Performance of Archimedes Single Screw Turbine as Micro Hydro Power Plant with Flow Rate Debit Variations (Case Study in Air Dingin, Samadua - South Aceh), Jurnal Inovasi Teknologi, Vol. 4(1). 2019.

[4] Echa Okdinata, Abu Hasan, and Carlos Sitompul, "Performance Test of Pelton Micro Hydro Turbine with the Variations of Parameter to produce the Maximum Output Power", J. Phys: Conf.Ser. 1167 012025, 2019.

[5] A. Ifavendri and H. Lius, "Design and Realization of a Prototype Model of Water Type Screw (Archimedean Turbine) for Micro Hydro Power Plant with Low head in Indonesia", Technique A, Vol. 31 No. 2, pp. 1-9, 2009.

[6] O.B. Yaakob, Yasser M. Ahmad, A.H. Elbatran, and H.M. Shabaru, "A Review on Micro Hydro Gravitational Vortex Power and Turbine System", Jurnal teknologi, Vol. 69:2, pp. 1-7, 2014.

[7] Septa Eka Lesmana, Leila Kalsum, and Tri Widagdo, "A Micro Hydro Perton Turbine Prototype (Review of the Effect of Water Debit and Nozzle Angle to Rotation and Pelton Turbine Power)", J. Phys: Conf.Ser. 1167 012023, 2019.

[8] A. H. Elbatran, M. Walid, Yasser M.A. and M. Arif Ismail, "Hydro Power and Turbin Systems Review", Jurnal Teknologi, Vol. 74:5, pp. 83-90, 2015.

[9] Nur Arifatul Ulya, Efendi Agus Waluyo, and Adi Kunarso, "Economic Analysis of Micro Hydro Power Plant Development: A Case Study in Muara Enim Regency, South Sumatera", e-Journal Analisis Kebijakan Kehutanan, Vol. 16 No. 1, 2019 (in Indonesian).

[10] Tarang Agarwal, "Review of Pump as Turbin (PAT) for Micro-Hydropower", International Journal of Emerging Technology and Advanced Engineering, Vol. 2(11), 2012.

[11] Honghush McNabola, Paul Coughlan, Lucy Corcoran, Christine Poer, A. prysor Williams, Ian Harris, John Gallagher, and David Styles, "Energy Recovery in the Water Industry using Micro-Hydropower: An Opportunity to Improve Sustainability", Water Policy, Vol. 16(1), 2014.

[12] A. McNabola, P. Coughan, and A.P. Williams, " Energy Recovery in the Water Industri: An Assessment of the Potential of Micro Hydropower", Water and Environment Journal, Vol. 28(2), 2014.

[13] Paish, " Micro-hydropower: Status and Prospect", Proceeding of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy, Vol. 216(1), 2002.

[14] Zhang Xin, Zhou Huitiry, HE Xiangli, and Jian Min, " Study on the Index System of Feasibility Evaluation for Micro Hydropower", Journal of Hydropower Engineering, Vol. 6, 2009.

[15] Lokesh varshney, R.K. Saket, and Saeid Eslamian, " Power Estimation and Reliability Evaluation of Municipal Waste Water and Self-excited Induction Generator-based micro Hydropower Generation System", International Journal of Hydrology Science and Technology, Vol 3(2), 2013.