

MICROHYDRO POWER PLANT DESIGN IN WAILELA RUMAH TIGA VILLAGE AMBON

Djon Kafiane Elwarin¹, Denny R. Pattiapon², Daniel Pesurnay³, Johanis Leuwol⁴

^{1,2,3,4}Electrical Engineering Department of Ambon State Polytechnic

Email : djonkafiane@gmail.com, redgiecilia@gmail.com, dfpesurnay@gmail.com,
johanesleuwol@gmail.com

ABSTRACT

This micro hydro power plant plan is located in Rumah Tiga Village which utilizes the Wailela river water flow. In this study, the measurement of the water discharge used the floating method and the measurement of the height of the drop used the water fitting method. From the measurement of water discharge and water fall height, it is used to determine the MHP design, which includes the dimensions of the rapid pipe, the type of water turbine, the dimensions of the water turbine, and to determine the capacity of the 3-phase synchronous generator according to the design of the PLTMH Sungai Wailela. The results of the calculation show that the theoretical power potential that can be generated at PLTMH Gunung Sawur 3 is 4.06 kW with a water flow rate of 0.225 m³ / s. and the height of falling clean water (head nett) 3.65 meters. From the water discharge and the height of the water fall, a rapid pipe design with a length of 20 meters and a diameter of 0.345 meters is obtained and a turbine dimension with a diameter of 35 cm and a width of 171 cm. From the calculation of the generated power of 4.06 kW, the capacity of the 3-phase synchronous generator used is 5 kVA with a load control system using ELC with a capacity of below 5 kW.

Keywords: Water discharge, water fall height (head), power potential, rapid pipe, water turbine, generator

INTRODUCTION

Electricity is a major need in everyday life and an important factor to improve the quality of life. Access to reliable and affordable electricity is a prerequisite for economic growth and poverty reduction (Purwanto et al, 2016). However, basically current power generation efforts are still dominated by non-renewable fossil energy, namely coal as much as 67%, followed by the use of gas which is the second largest power plant, as well as several combinations of generating power from renewable and non-renewable energy (Purnomo et al, 2014) . It is necessary to pay attention to efforts to find new power plants from renewable energy.

Indonesia is an archipelagic country where there are still many remote areas that have not been reached by PLN, while electricity is needed so that these areas develop and increase the productivity of their people. Therefore, to meet the electricity needs of remote areas, it is necessary to create a tool that can reach remote places that is cheap and environmentally friendly, namely Micro Hydro Power Plants.

In this study, turbine generators with certain specifications are used as energy conversion media, namely the driving force of flowing river water into electrical energy so that later it can be seen how much voltage is generated. To find out the magnitude of the voltage value, an experiment was carried out with water flowing in the rivers and the Wailela river which is the object of our

research with the title of Final Project: Planning a Micro-hydro Power Plant (PLTMH) Using Water Flow in the Wailela River.

LITERATURE REVIEW

Micro Hydro Power Plant (PLTMH)

PLTMH is a power plant with water as the main ingredient to produce power. The power capacity that can be generated is no greater than a Hydroelectric Power Plant with an output of below 500 kW. The power generated is not too large so it can only supply a small amount of electricity.

In addition, these power plants are also often referred to as white resources. If translated the result is white energy. The purpose of this white energy is that electricity generation uses natural resources and is friendly to the environment



This Micro Hydro Power Plant (PLTMH) which is currently under development and further research has several advantages or advantages compared to other power plants. One of them is that the resource it uses is water, which has the potential to be abundant in nature. In addition, its natural resources are renewable natural resources (alternative energy) through a continuous water cycle.

It is not strange if this power plant is mentioned as an environmentally friendly power plant. In its utilization there is no waste or other gas emissions produced. So that in terms of material requirements it is relatively cheap and does not cause environmental pollution which was also stated by the International Energy Agency in Paris.

The resulting efficiency is also high, namely 75% to 80%. Environmentally friendly in question also includes no air pollution or noise that disturbs the community. When compared to using materials from fossils, the operational costs and maintenance provided are also cheaper.

Through PLTMH, the community is also invited to participate in increasing the value of a natural resource so that it is no longer consumed arbitrarily. This will also form a good relationship between the forest and the community so that awareness can arise independently to maintain the function of the forest as it should so that the forest is also sustainable. The local community can manage the power plant for their own needs and it is hoped that this will affect the economy as well as socio-culture. This is of course for the sake of creating conditions for a

more prosperous society.

Water Discharge Analysis

Water discharge is the amount of water flowing through a certain cross section of the river per unit time. In order to get the capacity of a PLTMH, it is inseparable from calculating how much water can be relied upon to generate a PLTMH. The design discharge or mainstay discharge of a proposed MHP is 1.2 or a percentage of 120% of the minimum discharge of a river. Mainstay debit is discharge with a certain level of reliability which is planned as a source of water for PLTMH operations. (Sulaiman, 2012)

To determine the magnitude of the reliable discharge, a long discharge data series is needed which is owned by each discharge observation station. The method often used for mainstay discharge analysis is the statistical method (series). The determination of the series is carried out using probability analysis with the Weibul formula. 80% reliable discharge means that the probability of that discharge to be equaled or exceeded is 80% which also means that failure is likely to occur with a probability of 100% minus 80% or so to say 20%. (Budiyanto, 2013). After obtaining the mainstay bit, then the mainstay discharge is used for the calculation of hydropower capacity.

Generated Power

Power is the effort delivered per unit time. In PLTMH planning, power is obtained by using the formula:

$$P = \eta \times \rho \times g \times H_{eff} \times Q \text{ (watts)}$$

Where:

P = estimated power generated (kW)

$$1 \text{ watt} = 1 \text{ h/s} = (1 \text{ nm})/\text{s} = (1 \text{ kg m}^2/\text{s}^3)$$

ρ = density of water (1000 kg/m³)

g = acceleration due to gravity (9.81 m/s²)

Q = reliable discharge (m³/sec)

H_{eff} = effective fall height (m)

(Patty, 1995)

The theoretical equation above needs to be added to the penstock efficiency, turbine efficiency and generator efficiency, so that the generated power equation is as follows:

$$\text{Awakening: } P = 9.81 \cdot \eta_p \cdot \eta_t \cdot \eta_g \cdot Q \cdot H(2-2)$$

Where : η_p : 0.90 – 0.95 (depending on the length of the penstock)

η_t : 0.7 – 0.85 (depends on turbine type)

η_g : 0.80 – 0.95 (depends on generator capacity)

RESULTS AND DISCUSSION

Geographical Conditions of Ambon City and Wailela River

The city of Ambon is mostly within the territory of the island of Ambon. and geographically located at the position: 3 – 4 South Latitude and 128 – 129 East Longitude, where as a whole Ambon City is bordered by Central Maluku Regency. Ambon City oversees 5 (five) Districts, namely Teluk Ambon Baguala District with an area of 158.79 Km² has 6 villages and 1 subdistrict, Sirimau District covers an area of 112.31 Km² has 4 villages and 10

subdistricts and Nusaniwe District covering 88.35 Km² has 5 villages and 8 sub-district, South Leitimur Sub-district 78.67 Km² has 8 villages and Teluk Ambon Sub-District has 93.67 Km² has 7 villages and 1 sub-district.

The topographic condition of the Ambon City area, 73% of the land area can be classified as hilly to steep slopes, with a slope of above 20%. The climate in Ambon City is a tropical climate and monsoon climate, where the climate is strongly influenced by the ocean and takes place simultaneously with the monsoon climate, namely the West or North season and the East or Southeast season. The change of seasons is always interspersed with the Transition season which is a transition from the two seasons. The West season generally lasts from December to March, where April is the transition period to the East season. While the East season lasts from October, where November is a transitional period to the West season.

The Wailela River is one of the rivers in the city of Ambon, which is in the Teluk Ambon sub-district, with a population of 45,898 people in the sub-district. The length of the Wailela river is 7.8 km which is in the village of Rumah Tiga.

PLTMH location

The design of a micro-hydro power plant is located in Rumah Tiga Village, Wailela Hamlet, Ambon City Regency.

PLTMH design

1. Water discharge

In this study, the water discharge was measured directly using the floating method. The following discharge measurement data is weekly discharge measurement data with momentary measurements for dry season discharge and wet season discharge.

From the dry season measurement table above, it is used as a reference to determine the design discharge, where the ideal design discharge is a discharge with a percentage of 120% of the minimum discharge. So that the design discharge is obtained at 0.225 m³ /s.

2. Falling height of water

In measuring the height in the field, the difference in elevation or the height of the fall between the location of the dam and the turbine house is 6.82 meters. In the design of the dam, the fall height is added by 1.2 meters, but there is a decrease in the contour of the channel channel by 7.5 cm, at the exhaust channel at the turbine house by 80 cm and the height of the flood guard is 20 cm. So the gross height of this PLTMH design is 3.65 m.

3. Dams and Intakes

The determination of the location of the dam in this study is based on site measurements in the field, the dam is planned with a length of 3 meters, a height of 1 meter and a design width of 2.5 meters, with a 1 m wide flush door and is equipped with an overflow channel with a width of 3 meters, a height of 1 meter and 2m long. Intake building design with a length of 0.5 meters, a width of 0.15 meters and a distance of 0.20 meters from the water surface. From the design of the weir and intake

in this study, it is planned that the water level will be 1 meter from the base of the building with a discharge of 0.225 m³/s.

4. Carrier Channel

In this study, the carrier channel is planned to use an open channel with a rectangular geometry and a length of approximately 20 meters and a width of 0.50 meters. The 5% carrier canal contour means that for every 10 meters of canal length, the height is lowered by 15 cm. So for a length of 20 meters the height of the canal drops 10 cm, with a water level $h = 0.043$ m. From the calculation of the water level above, the height of the carrier channel is around 0.5 meters. The speed of water in the carrier can be found as follows = 7.475 m³/s

5. Calming Tub

The design of the calming tub in this study is as follows:

From this design, the height of the calming tub is 1.5 m.

The volume of the head tank is as follows : 3 m³

6. Rapid Pipe

The penstock pipe design in this study is as follows:

a. The diameter of the penstock pipe

To get the diameter of the penstock pipe, the following equation can be used:
0.34256 meters

b. Velocity of water in the rapid pipe

The speed of water in the penstock pipe can be calculated by the following equation: $V = 2.4425$ m/s

c. Pipeline Thickness

The design of the penstock thickness in this study = 0.02725 meters

d. Losses in the rapid pipe

Due to friction on the pipe = 0.191817 meters

e. Minor height loss in pipelines

In this study, the design of the penstock pipe does not change the size of the pipe and bends in the pipe so that the minor height loss in the pipe network caused by pipe joints is: = 0.06081 meter

f. Energy Loss Due to Filter

To find out the energy loss due to the filter, it can be calculated by the following equation = 0.03339 meters

From the calculation above, if there are 3 connections on the penstock, then the effective fall height can be obtained by the following calculation:

$$\begin{aligned} h_{eff} &= 3,65 - 0,191817 - 3 \times 0,06081 - 0,03339 \\ &= 3,607223 \text{ meter} \end{aligned}$$

In this study, the effective fall height used was the gross fall height multiplied by the penstock efficiency of 0.9, so that 3.24 meters was obtained.

7. Water Turbine

Water turbine as a working fluid has several classifications based on fall height and discharge velocity factor, angular velocity, unit discharge, and specific velocity. In this study the turbine design has a discharge of 0.225 m³/s and also an effective fall height of 3.24 meters. Based on the turbine selection graph in Figure 2.1, the selected turbine is the Banki/Crossflow turbine.

8. Water Turbine Characteristics

Speed Factor: 0.74234

Unit Speed=62.80266 rad/s

Unit discharge = 1.06521 m³/s

Specific Speed = 323.957 rad/s

9. Turbine Dimensions

Diameter and Width of Runners

The diameter and width of the runner are known by substituting equations 2.15 with 2.16. so that the equation becomes as follows: = 929.27295, turbine width $L = 171.413 \text{ cm} \approx 171 \text{ cm}$ and $D = 35 \text{ cm}$. Turbine rotation Based on the results of selecting the diameter and width of the turbine above, the turbine rotation = 204.097 rpm. The distance between the blades = 6.086 cm. Number of blades = 7 pieces. Radial Circumference = 2.3409 inches = 5.946 cm . Blade curvature = 4.924 cm. Beam Distance from Shaft Center = 2.876 cm . Beam distance from inside edge of Runner = 1.521 cm

10. Mechanical Transmission

In this study the mechanical transmission design uses an indirect transmission system because the power generated is below 20 kW, which is 15.87 kW. This transmission system uses a V-belt with other supporting components such as pulleys and bearings. With a pulley and belt transmission system as shown in Figure 2.9, the rotating speed of the generator turbine can be adjusted to a certain value based on the rotational speed of the turbine so that $r_2 = 0.082 \text{ m}$

11. Power Calculation

In this study the height of the falling water is 3.65 meters. To find the effective fall height, the fall height is reduced by the height losses in the penstock pipe. Obtained fall height of 6.36 m. However, in this study the effective fall height used is the gross fall height multiplied by the efficiency of the penstock. So that the fall height is 3.24 m. theoretical electric power generated due to the difference in height is = 4.06 Kw

12. Generators

In this study, the generated power is around 4.06 kW. Referring to the Mechanical-Electrical Feasibility Study manual, taking into account generator losses and to guarantee generator performance, a safety factor of at least 25% of the generated power is required. Then the selected generator capacity is 5 kVA. The planned control system uses an Electronic Load Controller (ELC) that integrates with the control panel and as a load balancer uses a ballast load air heater with a capacity of 60% of the generator power, which is 5 kW.

CONCLUSION

From the discussion in this study, it can be concluded:

1. Based on the data obtained, the average discharge in the Wailela river is 0.225 m³/s, for the ideal design discharge is 1.2 x minimum discharge, so that the design discharge is 0.27 m³/s and the effective head is 3.65 m. From the discharge and head in this study, the generator power that can be generated by the PLTMH is 4.06 kW.
2. The planned civil component consists of:
 - a. The dam is 3 m long, 2.5 m wide and 1 m high.
 - b. The spillway is 2 m long, 3 m wide and 1 m high.
 - c. Intake with a height of 0.2 m and a width of 0.15 m.
 - d. The carrier channel is 20 m long, 0.5 m wide and 0.2 m high.
 - e. The settling tank is 1.5 m long, 2 m wide and 1.5 m high.
 - f. The penstock is a PVC pipe with a diameter of 0.342 m and a length of 20 m.
 - g. The discharge channel is 6.82 m long, 0.8 wide and 0.2 m high.
3. The planned electrical mechanical components consist of:
 - a. Based on head and discharge, the turbine used in this study is a cross flow turbine.
 - b. The turbine diameter is 33 cm and the width is 171 cm.
 - c. The design of the runner in this study is the distance between the blades = 6.086 cm, the number of blades = 7 pieces, the width around the radial = 5.946 cm, the curvature of the blades = 4.924 cm, the distance of the jet from the center of the shaft is 2.876 cm, the distance of the beam from the edge of the runner is 1.521 cm
 - d. The mechanical transmission system uses pulleys and V-belts with a ratio of 0.6 : 0.082
 - e. The capacity of the 3-phase synchronous generator used is 5 kVA
 - f. The load control system used is the Electronic Load Controller (ELC) with a ballast load capacity of less than 5 kW

BIBLIOGRAPHY

- Arismunandar,A. dan Susumu Kuwahara. 2000. Buku Pegangan Teknik Tenaga Listrik Jilid I. Jakarta: PT Pradnya Paramita.
- Dandekar, M.M dan K.N Sharma. 1991. Pembangkit Listrik Tenaga Air. Jakarta: Universitas Indonesia.
- Hagendoorn,J.J.M. 1989. Kontruksi Mesin 2. Jakarta: PT Rosda Jayaputra.
- Linsley, Ray.K. 1989. Teknik Sumber Daya air. Jakarta: Erlangga
- Kurniawan, A, dkk. 2009. Pedoman Studi Kelayakan Hidrologi. Jakarta: Integrated Microhydro Development and Application Program
- Kurniawan, A, dkk. 2009. Pedoman Studi Kelayakan Mekanikal-Elektrikal. Jakarta: Integrated Microhydro Development and Application Program.
- Niemann, G. dan H. Winter. 1992. Elemen Mesin. Jakarta: Erlangga
- Patty, O.F., 1995, Tenaga Air, Jakarta : Erlangga.
- Susatyo, Anjar. 2003. Pengembangan Turbin Air Type Cross-flow Diameter Runner 400 mm. Bandung : Pusat Penelitian Tenaga Listrik Dan Mekatronik Lembaga Ilmu Pengetahuan Indonesia

- Wibowo, Nan Ady. 2013. Studi Perencanaan Pembangkit Listrik Tenaga Mikro Hidro (PLTMH) Wamena di kabupaten Jayawijaya Provinsi Papua. Malang: Teknik Pengairan Fakultas Teknik Universitas Brawijaya.
- Zuhal. 1991. Dasar Teknik Tenaga Listrik. Bandung: ITB