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Planning of Uwe River PLTMH Jayawijaya Regency Capacity 2 X 750 KW

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ABSTRACT
Indonesia has great potential to develop renewable energy, especially through Micro Hydro Power Plants (MHP) that utilize river flow. The Papua region, including Jayawijaya Regency, has significant water resources potential but has not been optimally utilized to meet local energy needs. This study aims to evaluate the technical feasibility of building an MHP in Uwe River, Jayawijaya Regency, with a capacity of 2 x 750 kW as an effort to increase the electrification ratio in Papua Mountains. The research uses a quantitative approach with field survey methods and primary data collection, such as water discharge measurements and interviews with relevant parties. The data were analyzed using the FJ Mock method for water discharge estimation and hydraulic power calculation to assess the technical feasibility of MHP development. The results showed that Uwe River has a potential hydraulic power of 2063.965 kW with a capacity factor of 88%, which is able to support the operation of two turbines with a capacity of 733.76 kW each. The conclusion of this study shows that the construction of an MHP in Sungai Uwe is technically feasible and has great potential to increase the electrification ratio, support local economic development, and reduce dependence on fossil fuels in remote areas. The implication of these results is the importance of investment and policy support in the development of renewable energy projects in Papua to achieve national electrification targets.

Introduction

Efforts to overcome the increasing consumption of national energy needs for energy up to 6.9% of annual energy, and with consideration of the depletion of fossil fuel reserves used as the main fuel in most power plants that continue to decline (Holechek et al., 2022; Kabeyi & Olanrewaju, 2022; Poudyal et al., 2019). In order to meet the national power needs, the Government of Indonesia plans the use of new-renewable energy which the target in 2050 is expected to meet 31%.The potential for hydro energy in Indonesia is 75,000 MW. The research conducted in 2020 and subsequently the results of research and the search for potential source points were then included in a 2011 report Hydropower Plant Development. This research is related to the data-based hydro potential addition, which from the beginning the utilization of hydro potential of 75,000 MW found in 1,249 location points was then searched for potential locations, so that then it became 12,894 megawatts spread across 89 location points. The results of this research are planned to be included in the power plant expansion plan until 2027 (Humas EBTKE, 2019).

PLTMH is a power plant based on hydropower, which comes from the potential energy/power contained in water due to the difference in altitude, the first hydropower plant in the world was made in the United Kingdom by William Armstrong around 1878, the first hydropower plant in America was made at the Grand Rapid Michigan in 1880**,** while in Indonesia the development of the use of water as an energy source has started since 1900, namely in Java and Sulawesi. and The first hydropower plant in Indonesia was the Tonsea Lama Hydropower Plant in North Sulawesi with a capacity of 40 MW which operated in 1912, although it produces power on a small scale, has several advantages such as renewable energy, high efficiency between 70-85%, minimal hazardous waste, and does not cause environmental damage. In addition, the economic activities of the surrounding communities can increase, and community engineering capabilities can also develop.based on PLN's statistical report, Mountainous Papua has an electrification ratio of only 12.09%, making it one of the regions with the lowest electrification ratio in Indonesia. The 2021-2030 Electricity Supply Business Plan (RUPTL) lists new additional projects as the utilization of the potential of new-renewable energy (NRE) in the Mountainous Papua Province. This plan is in line with the development of a 150 kV interconnection system in Wamena to improve the reliability of the electricity system in Papua (Dewanto et al., 2018; Sofyan & Sudana, 2022; Wibowo, 2013).

The potential for the development of Micro Hydro Power Plants (PLTMH) in the Jayawijaya Regency area is very large, supported by favorable geographical and hydrological conditions (Purwoko, 2018; Shafira, 2020; Sukamta, 2018). This area has several large watersheds such as the Baliem watershed, where the Uwe River is a sub-watershed, as well as the Lorentz watershed, the Central Taritatu watershed, and the Sobger watershed. These rivers offer a fairly abundant and continuous flow of water, which is an important resource for the development of PLTMH. The Baliem Valley, with an altitude between 1500 - 2000 meters above sea level, provides a significant elevation difference to harness the potential energy of water. An average annual rainfall of 1,900 mm and conditions that support a steady flow of rivers throughout the year reinforce this potential. The air temperature that varies between 14.5°C to 24.5°C and the even distribution of rainfall throughout the year add advantages to the operational sustainability of the PLTMH. By utilizing locally available river water flows, PLTMH can be an environmentally friendly and sustainable solution to meet electrical energy needs, reduce dependence on fossil fuels, and increase electrification ratios in Mountainous Papua which is currently low. This potential not only contributes to meeting energy needs but also encourages local economic development and improves the quality of life of people in the region.

Indonesia has a large potential for renewable energy, especially from water resources which reaches 75,000 MW, but only a small portion has been utilized (Directorate General of EBTKE, 2020) (Departemen Energi dan Sumber Daya Mineral, 2009). Previous studies such as those conducted by Syukri (2017) and Purwanto(2020) have evaluated the technical feasibility of MHPs in other locations, but no research has specifically explored the potential of MHPs in Uwe River, Jayawijaya Regency, Papua. This study differs from previous studies in that it focuses on a unique geographical location, namely the mountainous region of Papua which has a very low electrification ratio of only 12.09% according to PLN (2022).

This study is important as it aims to evaluate the technical feasibility of constructing a Micro Hydro Power Plant (MHP) in Sungai Uwe, which could provide a sustainable solution to increase the electrification ratio and support local economic development. In addition, this study highlights the importance of investing in renewable energy projects in remote areas to achieve national electrification targets and reduce dependence on fossil fuels. Thus, this study contributes to the literature on MHP development in remote areas with typical geographical and hydrological conditions.

Materials and Methods

This study uses a quantitative methodology to compile research, where the main object of research is the results of direct surveys in the field as well as the taking of several samples and measurement and calculation variables to be used. Primary data was obtained through field observations, measurement of UWE River water discharge, and interviews with related parties. This data is used to understand the actual condition and potential development of PLTMH at the location. In addition, the author also collects secondary data from various relevant articles and browsing from the internet to enrich the information obtained from the field. The deepening of this material and data is carried out to produce technically relevant products so that they can be applied in future PLTMH development plans, as well as comparing them with previous literature and studies to ensure the validity and reliability of the findings. The results of this analysis are expected to provide a comprehensive overview of the technical feasibility of the construction of PLTMH on the UWE River, as well as practical recommendations for the implementation of the project that has a positive impact on the people of Yellai Village and its surroundings.

Results and Discussions

Data Analysis

Based on PLN's statistical report, Mountainous Papua has an electrification ratio of only 12.09% (PT PLN (Persero), 2022). This area is one of the regions with the lowest electrification ratio in Indonesia. Based on the 2021-2030 RUPTL, new additional projects to utilize the potential of NRE are planned in the Mountainous Papua Province, this plan is in line with the plan to develop a 150 kV interconnection system in Wamena as an effort to improve the reliability of the electricity system in Papua

PLTMH Uwe is located in Yellai Village, Wallaik District, Jayawijaya Regency, Papua Province. The location can be reached from Wamena city to Yellai Village as far as ±15 km with a travel time range of one hour,The location of the Uwe PLTMH plan is located in Yellai Village, Wallaik District at coordinates 260510.33 m E, 9540909.19 m S.
Based on the results of field visits/surveys to collect data and test samples, the following preliminary data were obtained

River Discharge

A watershed is an area bounded by topography and surface drenades, where rainwater that falls will flow and gather into a main river and its tributaries. The watershed includes all land and water surfaces that contribute to the flow to the main rivers, including tributaries, lakes, swamps, and other related water sources, geomorphologically the area of the Jaya Wijaya Protected Forest Management Unit (KPHL) is a stretch of high mountainous area that stretches from East to West and also from North to South so as to form a very wide valley area, namely the Baliem Valley. This area used to be the area of Jaya Wijaya Regency which then some time ago has been expanded into several administrative areas of the district government. With such geographical conditions, two large watershed areas have been formed in this region, namely in the northern part of the watershed group is in the Mamberamo watershed group, while those included in the Eilanden watershed group are river streams that flow to the southern area. KPHL Jaya Wijaya itself is located in a highland forest that enters several districts and the expanse of the Baliem valley plain, an alluvial valley that stretches in an area with an altitude of 1500 - 2000 m above sea level. The air temperature varies between 14.5 0C to 24.5 0C. In a year the average rainfall is 1,900 mm and in a month there are approximately 16 rainy days. The dry season and the rainy season are difficult to distinguish. Based on the data, March is the month with the largest rainfall, while the lowest rainfall is found in July.The surface water potential in the Jayawijaya Regency area is in the form of several watersheds, namely:

1. Baliem Watershed, Uwe River is a sub-watershed of the Baliem Watershed
2. Lorentz Watershed,
3. Central Taritatu Watershed, and
4. Sobger watershed.

In this final project/thesis study, the map used as the basis for making a map of the watershed is a map obtained from the National Survey and Mapping Coordinating Board (BAKOSURTANAL) with a scale of 1 : 50,000. The area of the Uwe PLTMH watershed is 397 km2.

The soil type in Jayawijaya Regency consists of most types of alluvial, lithosporic, podsolic, and metamorphic rocks (phyllite, quaternary, chrite) of the Pacific plate that is pressed by the Baltic embankments. The conditions of dispersal of the soil type are as follows:

In the valley district there are alluvial types of soil. This type of soil is characterized by low organic matter content, moderate to high wet saturation with large absorption power and low permeability, while soil sensitivity to erosion is very small;

In hilly areas there are types of lithosol soils. This type of soil is characterized by acidity properties, organic matter content, alkaline saturation, absorption power, permeability and nutrient content are very varied as well as sensitivity to large erosion;

Highland areas generally have brown podsolic types. This type of soil is characterized by soil acidity varying between slightly acidic at the top and wetter at the bottom. It has low organic matter, high wet saturation and high sensitivity to erosion. The use of this land is generally for forests and/or timber;

The data used for hydrological analysis at the Uwe PLTMH are meteorological and climatological data taken from the Wamena Meteorology, Climatology and Geophysics Agency (BMKG) Station in Jayawijaya Regency as well as a base map of the study location from BAKOSURTANAL with a scale of 1: 25,000. The distance between the PLTMH location and Wamena Airport is 15 km.

Rainfall Data

Rainfall and rainy day data used for hydrological analysis of the Uwe PLTMH were taken from the Wamena BMKG Station in Jayawijaya Regency which was recorded from 2001 to 2012 as follows.

The average annual precipitation is 2243.06 mm per year with the highest precipitation being 2646 mm (2005) and the lowest being 1478 mm (2004).

Climate Data

Based on observation data through the Meteorology, Climatology and Geophysics Agency (BMKG) of Wamena Jayawijaya Regency, in general, the average air temperature is in the range of 19oC. The average air humidity ranges from 69-73% with the average monthly solar exposure ranging from 44-58% (a low of 44% in September and a high of around 58% in May). In general, the average wind speed in 2001–2012 ranged from 3-8 knots/hour.

Reperiod

In planning Micro Hydro Power Plants (PLTMH), understanding the flood recurrence period is a critical aspect. This is because floods can significantly affect the performance and sustainability of PLTMH. Flood recurrence period is a statistical measure used to predict the likelihood of flooding of a certain scale within a given period of time, flood recurrence analysis helps in the design of infrastructure that is able to withstand extreme conditions. It includes site selection, dam design (Haryani et al., 2015; Wahyuridha, n.d.), water carriers, and other supporting facilities. Selection with a long re-discharge period which means a large rain discharge, the presentation of the risk of damage can be minimized, but the construction cost increases due to the large discharge capacity. Likewise, the selection of a small re-discharge period can reduce the construction cost budget, but the risk of damage loss due to flooding will increase.

Rainfall frequency is the likelihood of the amount of precipitation reaching or exceeding a certain amount of precipitation.There are several types of frequency distributions in statistics, and four types of distributions that are widely used in fields such as hydrology.

1. Normal Distribution
2. Normal Log Distribution 2 Parameters
3. Normal Log Distribution 3 Parameters
4. Gumbell Distribution
5. Pearson III Distribution
6. Pearson Log Distribution III

The data parameters used to be able to determine the right type of distribution are divided into 5 large parts of the measurement, namely: measurement or calculated average, standard deviation (standard deviation), awkwardness (coefficient of variation), and coefficient of sharpness (coefficient of curtosis). The results of the analysis of the maximum daily rainfall frequency with various methods tested with the Smirnov Kolmogorov Method.

To see the greatest chance deviation between the observational data and the theoretical data, the test method used is the Smirnov-Kolmogorov method. From the data testing of the Smirnov-Kolmogorov method that meets the requirements is the result of calculations using the Gumbel method.

Results of Flood Discharge Calculation

To compile flood hydrograph statistics on river flows that do not have data or are rarely observed by flood hydrographs, the first way is to find the characteristics or parameters of the river flow area first, for example, the peak time to reach the hydrograph, the width of the river bed, the area, the slope, the length of the longest channel, the runoff coefficient and so on.In this case, synthetic hydrographic maps developed in other countries are usually used, whose parameters must first be adjusted to the characteristics of the water catchment area considered (Soemarto, 1987).

Results of Measurement of the Instantaneous Discharge of the Uwe River

The measurement of the instantaneous discharge of the Uwe river is carried out downstream of the river, namely in the power house area close to the tributary.

From the results of the instantaneous discharge test using a current meter at the upstream and downstream locations, there is a difference in discharge values of about 2 m3/second.Figure 4.16 Location of Upstream Instantaneous Discharge Measurement (Weir), Source Pusenlis

From the image of the cut above, a momentary discharge calculation will be carried out based on the test results. The calculation was carried out by dividing the river area into 3 segments, each segment was calculated at several elevations, namely at a depth of 0.3h; 0.6 h and at the base. From each segment, an average discharge will be obtained, which will be accumulated as a whole to get a total discharge along the width of the river in the bending area (upstream).

Measurement of Downstream Instantaneous Discharge

Momentary discharge measurements for the downstream area were carried out in the power house area close to the tributary branch that surrounds Yellai village. The downstream area is relatively shallower compared to the upstream area of the weir, in the downstream area a momentary discharge of 10.09 m3/second is obtained.

Results of Calculation of Water Discharge Availability

One of the methods of estimating flow discharge based on the concept of water balance was proposed by FJ Mock. However, the estimation process is an approach, not as accurate as the basis of direct debit recording data. However, in the event that this information is urgently needed while there is no direct debit observation data, an estimate or estimate is needed. The results of the calculation are monthly debits from 1998-2014 which are then sought as mainstay debits for design needs.

Potential Power of UWE PLTMH

The data on the potential of UWE PLTMH is as follows:

Headgross : 17.83 m
Debit : 11.08 m3/s

Based on the data mentioned above, the potential for hydraulic power to be generated is as follows:

$$\mathbf{P = \rho \times Q \times H \times g}$$

The potential hydraulic power that can be generated is as follows:

P = 1000 kg/m3 x 11.08 m3/s x 9.81 m/s2x 17.83 m

P = 2,063,965 kW

Considering the aspects of maintenance and maintenance, as well as the continuity of the plant, in this planning PLTMH UWE is planned to use 2 turbines with identical capacity, the maximum power that can be produced by the turbine is:

P = ρ x x H x η x g Q_1

P = 1000 x 5.54 x 17.04 x 9.81 x 0.86

P = 796.428.53 Watts

P = 796.5 kw

If the efficiency assumption is taken into account, the total mechanical efficiency (turbines, bearings, couplings, seals) is 86%, the total electrical efficiency (generator 94%, transformer 98%) is 92.12%, then the power that can be generated by each turbine is as follows:

P = ηmechanic. ηelectricity. ρ.Q.g.He

= 0.86 x 0.9212 x 1000 x 5.54 x 9.81 x 17.04

= 733.76 kW

Capacity Factor

Capacity Factor of Micro Hydro Power Plant (PLTMH) or the ratio between the electrical energy actually produced by the plant during a certain period of time, from the Uwe river discharge probability data, a capacity factor of 88% was obtained with two turbine units operating.

Selection of Turbine Type

Based on the type of coupling to be used, namely the direct couple type to the generator for generators with a frequency of 50 Hz, in the literacy process, a turbine rotation of 300 rpm (20 poles, 50 Hz) is selected, then the specific speed can be calculated with the following equation:

From the data it is known:

Head (H): 17.04 meters

Power (P): 733 kW

Rotary speed (N): 300 RPM

Turbine Specific Number Formula (NQE):

$$NQE = \frac{N\sqrt{P}}{H^{5/4}}$$

So:

$$NQE = \frac{300\ x\ 27,07}{34,6}$$

NQE=228.12

With an NQE of around 228.12, from the data of table 4.20 below, the most suitable turbine is the Francis turbine. With a head value of 17.04 meters, a power of 733 kW and a rotary speed of 300 RPM, the Francis turbine is the right choice based on NQE calculations. Francis turbines are highly efficient for medium head and medium flow rate conditions, which are suitable for field conditions.

Table 1. Turbine Type Based on specific speed

Ns	Tipe Turbin
4-35	Pelton wheel with 1 mozzel
17-50	Pelton wheel with 2 mozzel

24-70	Pelton wheel with 4 mozzel
80-120	Francis Turbin, low speed
120-220	Francis Turbin, Normal
220-350	Francis Turbin, high speed
350-430	Francis Turbin, express
300-1000	Propeller and Kaplan Turbin

If the Selection of Turbine Type is based on lugaression and mass

$$N_{QE} = \frac{1{,}924}{H^{0{,}512}}$$

$$N_{QE} = \frac{1{,}924}{17{,}04^{0{,}512}}$$

$$N_{QE} = 0{,}44$$

Table 2. Selection of Turbine Type Based on Specific Speed of Rotation (ESHA 2004)

It	Turbine Type	NQE Specific Speed Values
1	Pelton one Nozzles	0.005 ≤ nQE ≤ 0.025
2	Pelton n Nozzles	0.05 ≤ nQE ≤ 0.025.n° ,50
3	Francis	0.05 ≤ nQE ≤ 0.33
4	Kaplan,Propeller,Bulbs	0.19 ≤ nQE ≤ 1.55

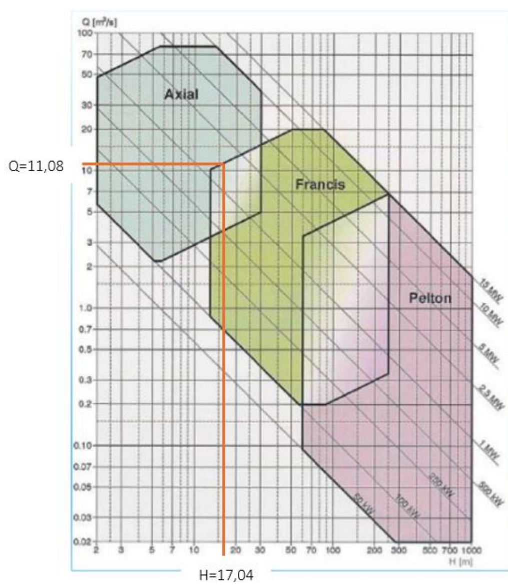

Figure 1. Graph of Turbine Type Selection Based on Discharge and Head (ESHA 2004)

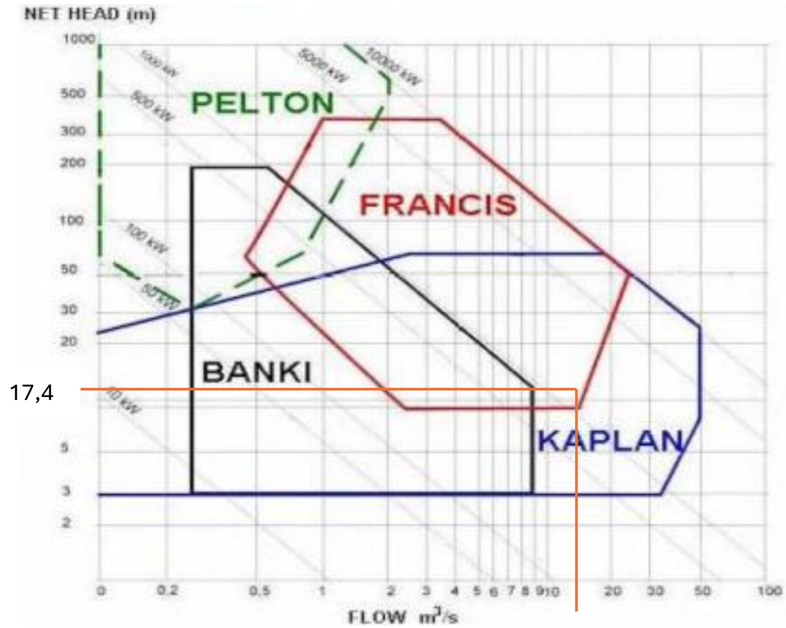

Figure 2. Turbine Selection Chart Based on Discharge

Table 3. Turbine Selection Based on Turbine Character

HYDRAULIC TURBINE		HEAD (m)	DEBIT (m^3/dt)	DAYA (Kw)	Ns (rpm in kW, m)
Reaktion	Kaplan and Propeller (Axial Flow)	2-20	3-50	50-5000	200-700
	Francis (High specific velocity)	10-40	0,7-10	100-5000	100-250
	Francis (Low specific speed)	40-200	1-20	500-15000	30-100
Impuls	Pelton	60-1000	1-50	200-15000	< 30
	Turgo	30-200	0,2-5	100-6000	
	Crossflow	2-50	0,01-0,12	2-15	

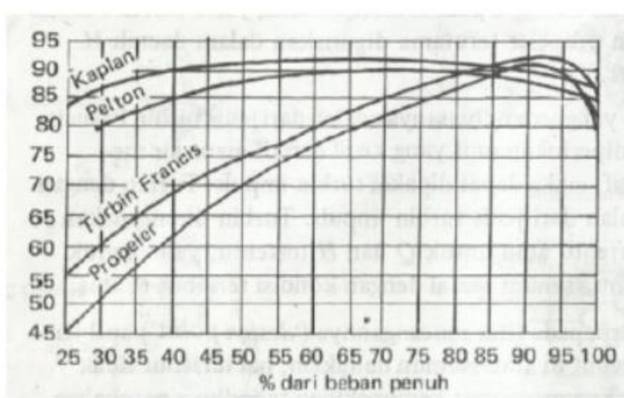

Figure 3. Turbine Efficiency Curva Based on Load Percentage

Runer Materials

The maximum possible load that occurs in the Turbine Housing is due to hydrostatic compressive load assuming the guide vane is closed 100%, the amount of load that occurs is:

$$\mathbf{P = \rho g H}$$

So that it is obtained:

P = (1000 x 9.81 x 17.83)

P = 174912.3 Pa

The load that occurs on the runner is the water pressure load and on the runner there is no water hammer so from the results of the hydrostatic pressure calculation that occurs is as follows: 74912.3 Pa

- The runner material is G-X5 CrNi 13.4 with a tensile yield strength of 550 Mpa (JIS SCS 6 and ASTM A487 Grade CA6NM)
- G-X5 CrNi 13.4 material has resistance to corrosion caused by water, moisture and chloride-containing environments.

Rapid Pipe (Penstock)

Rapid pipelines at Micro Hydro Power Plants (PLTMH) are an important part of this power generation system. The rapid pipeline functions as a channel to drain water from the water source to the PLTMH turbine. Rapid pipes must be carefully designed to withstand considerable water pressure and optimize the flow of water to the turbine. The materials used for rapid pipelines are usually made of materials that are resistant to pressure and corrosion due to water, such as stainless steel or concrete. In addition, rapid pipeline maintenance is also very important to maintain the performance of PLTMH. Regular inspections should be carried out to ensure that there is no damage or leakage in the rapid pipeline. If damage is found, immediately repair it so as not to interfere with the flow of water and the overall performance of the PLTMH.

With planning, proper material selection, and good maintenance, the PLTMH rapid pipeline can work optimally to support the generation of electricity from environmentally friendly water energy, in the rapid pipeline planning several things need to be considered:

1. Number of Rapid Pipes to be used
2. Suitable Rapid Pipe Diameter
3. Rapid Pipe Thickness
4. Pressure on Rapid Pipes

Number of Rapid Pipes

Some considerations to consider to determine the number of rapid pipelines needed, namely: Capacity, Generation, Water Source Characteristics, Geographical Location and Topography of the Water Source, Turbine Design, System Efficiency

$$\sum \mathbf{P} = \frac{\rho \; x \; Q \; x \; g \; x \; H_n \; x \; \eta}{P_P}$$

So the number of rapid pipelines needed is:

$$\sum P = \frac{1000 \; x \; 11{,}08 \; x \; 9{,}81 \; x \; 17{,}04 \; x \; 86\%}{796.428{,}53}$$

$$\sum P = 2$$

From the results of the calculation above, the number of rapid pipes based on discharge is using 2 units of rapid pipes.

Rapid Pipe Diameter

The method for finding the diameter of a rapid pipe typically involves calculations that consider several factors, such as the flow rate, type of fluid, pressure loss, and desired flow rate. The following are some of the common methods used to find rapid pipe diameters, The choice of method depends on the complexity of the project, the availability of data, the need for precision, and the resources available. A combination of the above methods or modifications of existing methods is also often used to meet the specific needs of planning a project, and the preparation of the final project / thesis method learned during lectures

$$\mathbf{Dp = 2.69 \left(\frac{n^2.Qp^2.L_p}{Hp}\right).^{0,1875}}$$

$Dp = 2.69 \left(\frac{0,014^2.5,54^2.73}{17,04}\right).^{0,1875}$

$Dp = 2.69 \left(\frac{0,4391354128}{17,04}\right).^{0,1875}$

$Dp = 2.69\ (0,0257708576).^{0,1875}$

Dp = 1.35 m rounded to 1.5 m

Rapid Pipe Water Pressure Calculation

In the planning and design of a Micro Hydro Power Plant (PLTMH), the calculation of water pressure in the rapid pipeline (penstock) is a very important step. This water pressure affects the overall performance of the PLTMH system and determines the technical specifications required for the material and construction of penstock pipes, the water pressure in the pipeline can be calculated using the following formula:

Pa = (ρ .g . Hp) + Po

The location of the Uwe PLTMH is planned to be at an altitude of 2152.17 MDPL so that the atmospheric pressure at the location is:

= ρg (10 -) = 790.771 PaP_A $\frac{2152,17}{900}$

Then the rapid pipe pressure can be calculated by the following equation:

Pa = (ρ .g . Hp) + Po

Pa = (1000 x 9.81 x 73) + 790.771

Pa = 716,920 N/m2

Rapid pipeline design in PLTM uses SS400 material, SS 400 material is a type of carbon steel that has a low carbon content of less than 0.3%, with a material Tensile Strength (σ) of 245 Mpa = 25085013.6 Kg /m2 = 246000000 N /m2

1. Economical Price
   SS400 is relatively inexpensive compared to stainless steel or other high-alloy steels, making it an economical choice for a wide range of construction and manufacturing applications.
2. Resistance to Corrosion:
   As a low-carbon steel, SS400 has limited corrosion resistance and typically requires plating or surface treatment to increase its durability in corrosive environments.

3. Formability:
   SS400 has good formability, allowing this material to be cut, shaped, bent, and welded easily.
4. Welding Ability:
   SS400 can be welded easily using a variety of conventional welding techniques such as manual metal arc welding (SMAW), gas metal arc welding (GMAW), and submerged arc welding (SAW).

Rapid Pipe Thickness

In the planning and design of Microhydro Power Plants (PLTMH), determining the thickness of the rapid pipeline (penstock) is an important step to ensure the reliability and safety of the system. The thickness of the pipe must be strong enough to withstand the internal pressure of flowing water without undergoing damage or deformation, the rapid thickness of the pipe can be calculated using the following formula:

$$\mathbf{Tp} = \frac{Pa\ x\ Dp}{2\ x\ \sigma s\ x\ g\ x\ \mu} + \mathbf{0,002}$$

σs = Tensile Tension of Pipe Material (25085013.6 Kg/m2)

g = gravity (9.81 m/s2)

μ = Welding Efficiency (90 %)

$$\text{Tp} = \frac{716.920\ x\ 1{,}5}{2\ x\ 25085013{,}6\ x\ 9{,}81\ x\ 0{,}9} + 0{,}002$$

Tp = 0.00200 m

To anticipate oxidation in the pipe, the pipe must be added about 1 -3 mm, the minimum requirement for pipe thickness needs to be considered:

1. Up to 0.8 m in diameter.... 5 mm.
2. Up to 1.5 m in diameter.... 6 mm.
3. Up to 2.0 m in diameter ..... 7 mm (O.F. Patty, 1995).

So the Pipe Thickness is rapid with a diameter of 1.5 meters, using a minimum thickness of 6 mm.

Flow Speed

Flow velocity is affected by various factors such as hydraulic gradient, channel roughness, and flow cross-sectional shape. Therefore, accurate measurement and analysis of flow velocity is essential to ensure the efficiency and success of water-related projects. In the context of PLTMH, knowing the flow velocity allows for a precise calculation of the potential energy that can be produced, which will ultimately determine the design and feasibility of the project, so that the flow velocity can be calculated by the following equation:

Q = A x V

$$V = \frac{Q}{\frac{1}{4}.\pi\ .D2}$$

$$V = \frac{5{,}54}{\frac{1}{4}.3{,}14\ .150^2}$$

V= 3.1 m/s

Saddle Support Spacing

The precise design of the saddle support distance on the penstock will ensure that the pipe remains in a safe and efficient position, avoiding damage due to overload or environmental conditions. This not only increases the operational life of the penstock but also ensures the smooth operation of the overall PLTMH.

$$\mathbf{Wp = 1/4\ \pi\ (D_0^2 - D_1^2)\Upsilon s}$$

Υs = Specific gravity of steel

Wp = 1/4 .3.14 $(1{,}5^2 - 1{,}494^2)$7.800

Wp = 109.1 Kg/m

Wt = 1/4 π $\Upsilon w D_1^2$

Wt = 1/4 x 3.14 x x $10001{,}494^2$

Wt = 1.752.14 Kg/m

Wf = Wp + Wt

Wf = 109.1 Kg/m + 1,752.14 Kg/m

Wf = 1.861.24 Kg/m

L max = 182.61 $\left((\frac{Dp+0{,}0147}{Wt}).^2 - Dp^4\right).^{0{,}333}$

L max = 182.61 $\left((\frac{1{,}5+0{,}0147}{1.681{,}24}).^2 - Dp^4\right).^{0{,}333}$

L max = 5.7 m rounded to 6 m

Deflection Control

To ensure that the penstock pipe is functioning properly and does not suffer structural damage, the deflection must be controlled within safe limits. One of the important parameters used to calculate and control the deflection is the moment of inertia (I) of the pipe cross-section. This moment of inertia reflects the stiffness of the pipe and its ability to withstand loads without undergoing significant deformation.

$$\mathbf{I = \pi \frac{1}{64} D_1^4}$$

$\delta = \frac{6 \text{ x Wf x } L^4}{384 \text{ x E x I}}$

$\delta = \frac{6 \text{ x } 18{,}61 \text{ x } 500^4}{384 \text{ x } 2141404{,}05 \text{ x } 24{,}837{,}890{,}6}$

δ = 0.00034 cm

So:

Maximum $\delta = \frac{L}{240}$

Maximum δ = = 2.50 m$\frac{600}{240}$

So 0.00034 < 2.50 cm

Maximum Moment

The maximum moment on the penstock pipe is calculated to ensure that the pipe and its supports are designed to withstand the load received without damage. These loads can come from the pressure of the water inside the pipe, the weight of the pipe itself, as well as external loads such as ground pressure and other environmental factors.

M mak = 1/8 x Wt x (L x cos α).^{2}

M mak = 1/8 x 1.75214 x (600 x 0.97) .^{2}

M mak = 7.41 tons/m

so

V_A==1/2 x Wt x L x cos αV_B

= 1/2 x 1.75214 x 600 x 0.97

= 5.09 tons

Energy Loss In Penstock

Inlet Penstock

One of the main components of energy loss in penstock is energy loss in the inlet (inlet) of penstock. This loss can be calculated using the following formula:

$$\mathbf{he = K\frac{V^2}{2g}}$$

h_e= 0.05 $\frac{3{,}1^2 m/det}{2 \text{ x } 9{,}81}$

h_e= 0.024 m/s

Penstock Wall Friction

$$\mathbf{h_e = f \text{ x } L \text{ x } Dx\frac{V^2}{2g}}$$

Where f = 0.035 (Obtained from the absolute roughness table)

So

Relative Roughness = E/D

$= \frac{0{,}035}{1.500}$

= 0.0000233

Reynold Number $= \frac{3.1 \text{ x } 1.494}{0{,}8 \text{ x } 10^{-6}}$

= 4.922.7366

From the relative roughness value and the Reynolds number, the value of f = the coefficient of the pipe wall in the moody diagram can be found, and the f value of 0.01 is obtained. Then the friction of the penstock wall

$$\mathbf{h_e = f \text{ x } L \text{ x } Dx\frac{V^2}{2g}}$$

h_e= 0.01 x 73 x 1.5x$\frac{3{,}1^2}{2x\ 9{,}81}$

h_e= 0.53 m

Stock Outlets

he = 1 $\frac{V^2}{2g}$

he = 1 $\frac{3{,}1^2}{2 \text{ x } 9{,}81}$

He = 0.49 m

Energy Loss Due to Pipe Turns

$H_1 = K_b = \frac{V^2}{2g}$

$H_1 = 0.31\ \frac{3{,}1^2 m/det}{2 \times 9{,}81}$

$H_1 = 0.15$ m

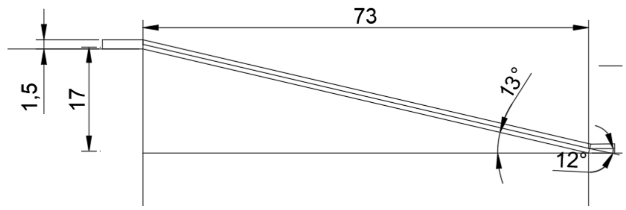

Figure 1. Penstock Turn Angle Simulation with Auto CAD

Table 4.1 Stockpile Turn Coefficient Value

α	10°	20°	30°	40°	50°	60°	75°
K_b	0,078	0,31	0,49	0,60	0,67	0,72	0,72

Source: Hidraulika H. Prof. Dr. Ir. Bambang Triatmojo. CES. DEA. 2014

Total Energy Loss = he Inlet + he wall penstook +he outlet + he turn
= 0.024 + 0.53 + 0.49 + 0.15
= 1.19 m

Maximum Limit of Energy loss = 10 % x Hgross
= 10 % X 17.83
= 1.78 m

Energy Loss = 1.19 m < 1.78 Falls into the Ok category

Generator Selection

Generator Capacity

In determining the minimum capacity for the generator, we must know the capacity of the turbine that will be installed as the main drive in the Uwe PLTMH. From the processing of water potential data at the Uwe PLTMH, the power plant capacity to be built is 2 x 750 kW. The value of the generating capacity is included in the following equation:

$$Pg = Pt \times \eta g$$

Pg = 750 x 0.95

Pg = 712.5 kW

In the market availability, the generator capacity is listed in the unit of apparent power (kVA) To obtain the apparent power value of the generator, the generator power factor is 0.8 and is included in the following equation:

$$P = S \times \cos \varphi$$

S===890,625 KVA$\frac{P}{Cos\varphi}\frac{712{,}5}{0{,}8}$

With the known value of the apparent power of the generator of 890,625 kVA, the capacity of the generator that will be used in the Uwe PLTMH takes into account the availability of the power supply.

Generator Speed

In determining the rotational speed of the generator we also need to pay attention to the rotation of the turbine that will be used and uses the following equation:

$$\mathbf{n = \frac{120 \times f}{P}}$$

From the results of the simulation calculation, the value of the rotation of the Uwe PLTMH water turbine was obtained at 300 rpm. The following table shows the data of the nominal rotation of synchronous generators for several types of generators with different poles.

With the selection of a generator speed of 300 rpm, there is no need for a transmission speed increaser with a turbine. The transmission is used directly couple turbine with generator in one shaft.

Generator Excitation System

The generator chosen is a type of three-phase synchronous generator with a frequency of 50 Hz and has its own excitation or amplification system with a brushless type or brushless rotating diode. The advantages of brushless excitation systems include:

1. The energy required for excitation is obtained from the main shaft, so its reliability is high.
2. Maintenance costs are reduced because the brushless excitation system does not have brushes, commutators and slip rings.
3. In the brushless excitation system, there is no insulation damage due to the adhesion of carbon dust to the farnish due to the charcoal brush.
4. During operation no brush replacement is required, so improving the reliability of the operation can continue for a long time.

Output Voltage

The thing that must be considered in determining the output voltage of the generator is the network system and the capable power that can be generated at the Uwe PLTMH. The distribution network system of PLTMH Uwe uses a medium voltage system of 20 kV and the capable power produced by the plant is relatively small, so in this PLTMH a generator with an output voltage of 400 V is used.

Discussion Results

The analysis of the results shows that the Uwe PLTMH has significant potential to increase the electrification ratio in Mountainous Papua, the following are the results of the discussion:

Table 5. Discussion Results

No	Data	Value	Unit	Description
1	Discharge Probability	80	%	
2	Reliable Discharge	11,08	m3/s	
3	Nett Head	17,04	m	

4	Output Power	733,78	Kw	@ Unit
5	Capacity Factor	88	%	
6	Francis Turbin	300	rpm	High speed
7	NQE	228,12		
8	Output Power	750	kW	@ Unit
9	Penstock			Mild steel SS400
10	Total of Penstock	2	Unit	
11	Diameter	1,5	m	
12	Thickness	6	mm	
13	Flow Velocity	3,1	m/det	
14	Pressure	716,920	N/m²	
15	Total Energy Loss	1,19	n	
16	M Max	5,09	ton	
17	Generator	1000	KVA	20 Pole, 50 Hz, Brushles Excitation
		300	rpm	

Conclusion

The conclusion of the discussion of the final project report as well as the analysis and results of data processing regarding the Uwe Micro Hydro Power Plant (PLTMH) plan in Yellai Village, Jayawijaya Regency, Papua, this conclusion includes a detailed analysis of hydrological aspects, power potential, turbine selection, penstock design, and water availability, all of which are very important for the efficient and reliable planning and implementation of the Uwe PLTMH. Location and Geographical Conditions: PLTMH Uwe is located in Yellai Village, which can be reached in one hour drive from Wamena City. The region has two main watersheds: the Mamberamo watershed in the north and the Eilanden watershed in the south. Electricity Condition :D Mountainous Papua has a low electrification ratio when compared to the Papua area in general, which is 12.09%, this is because the Papua area has not been fully covered by the interconnection electricity network. In the mountainous Papua area, currently only operates the type of PLTD plant that is operated to meet power needs, 7 PLN PLTD & 1 PLTD leased with an installed capacity of 6.2 MW with a power supply capacity of 5.6 MW Hydrological data: The area of the Uwe PLTMH watershed is 397 km^2. The average annual rainfall is 2243.06 mm, with the highest rainfall recorded at 2646 mm in 2005 and the lowest at 1478 mm in 2004.The water discharge of the Uwe river has an event probability of 88.2% and a biennial flood discharge of 78.2 m^3/s, as well as a centennial flood discharge of 145.9 m^3/s. Water Discharge and Power Potential: Using the FJ Mock method, the water availability discharge of the Uwe river is calculated for various probabilities, with a mainstay discharge of 11.08 m^3/s. The potential hydraulic power generated is approximately 2,063,965 kW, with a planned installation of two turbines with a capacity of 733.76 kW per turbine after mechanical and electrical efficiency is taken into account. Turbine Selection: Based on the calculation of the specific speed of the turbine, the Francis high speed turbine with a capacity of 750 kw was selected as the most efficient turbine for the condition of the Uwe PLTMH. Generator Selection : the one chosen is 1000 KVA, 400 V, Efficiency is about 95% with a rotation of 300 rpm (20 poles, 50 Hz). Penstock Selection: The diameter of the rapid pipe used is 1.5

meters with SS 400 Material and a minimum thickness of 6 mm to anticipate oxidation. Capacity Factor: Based on the calculation of the Capacity Factor of PLTMH planning, it is obtained by 88%, this value is still above the standard CF value required by PLN, which is 60%, System Performance and Reliability: The generator excitation system was selected using a brushless excitation system to improve reliability and reduce maintenance costs. The generator output voltage is selected as 400 V in accordance with the distribution network system of PLTMH Uwe.

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