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Feasibility Study of Micro Hydro Power Plant in South Aceh Regency, Indonesia

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Abstract:

The Micro Hydro Power Plantat Alue Panton River, South Aceh Regency, Indonesia can be used as an electrical energy for local residents or connecting to the PLN electrical power source grid. For construction of the Micro Hydro Power Plant, it is necessary to study of feasibility for both of technical and financial perspective. The stages of this research include a site survey, calculate electrical energy that could be produce, topography and economic aspects. From results of this feasibility study, it is known that the water discharge that can be used for Micro Hydro Power Plant is 0.66 m^3/s and the head height is 15 m. From this data, 61.58 kW of electrical energy could be generated. Sales of power source in first year can generate income of 44% of initial investment construction of Micro Hydro Power Plant. However, there are a risk of avalanches at the location of Micro Hydro Power Plant so as deep study of this risk is needed.

Keywords **—MHP; microhydro,river,water, feasibility study**

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I. INTRODUCTION

Water is one of the most important minerals for humans and other living things. Water sustains life on earth, without water life on earth would not exist. Humans need water to survive, lack of water from the body can cause dehydration, constipation and kidney stones [1]. Besides being used to support life, water can also produce potential energy which could be converted into kinetic energy. The potential energy of the water flow rotates the turbine to produce kinetic energy. kinetic energy that produced then could be convert into electrical energy.

Based on the capacity of electrical energy produced by Hydroelectric Power Plants, Hydroelectric Power Plants is categorized into three groups. The first category is large Hydroelectric Power Plants, this category is capable of producing electricity with a capacity greater than 30 MW. The second category is small Hydroelectric Power Plants, which is capable of producing electricity with a capacity of 100 kW to 10 MW. The third category is Micro Hydro Power Plant (MHP), MHP is capable of producing electricity with a capacity of up to 100 kW [2].

Indonesia is a tropical nation and has a lot of renewable energy, but Indonesia yet not able to maximize the renewable energy used. Indonesia just dependent on energy that comes from fossils. Based on data 2017, 94% of energy used in Indonesia still using energy that came from fossils source (48% oil, 30% coal and 18% gas) [3]. The addition of power generating capacity in Indonesia from 2003 to 2017 increased by an average of 7.3%. The additional capacity was supported by gas by 10% and steam by 9.3%. Uses of renewable energy has not a significant increase. In 2016, renewable energy

originating from hydropower and already installed was 5,024 MW or around 5.3% of available water energy source. [4].

Indonesia has 75 GW of renewable energy potential for hydropower, this potential is in second place after Solar Power Plants (PLTS). [5]. Aceh Province, the western province in Indonesia, has hydropower potential of 5,062 MW [6] as shown in Table I. Based on data from [3] none of MHP available operating in Aceh Province, even though Aceh Province has a micro hydro potential of 1,538 MW. To support uses of renewable energy, government efforts are needed and also private sector so that the potential of MHP available in Aceh Province can be utilized for the benefit for local residents and industry. Another positive impact of MHP is increasing public awareness so that illegal logging can be minimized. Illegal logging can cause a decrease in water quality and a decrease in river water discharge. The decrease in water discharge will affect the production of electricity needed by the community and industry.

This study aims to determine the potential and feasibility of developing a MHP in South Aceh Regency. The potential includes the amount of discharge, potential for electrical power that could be generated, as well as economic, technical and risk aspects. The location of the river is in Panton Luas Village, Tapaktuan District, South Aceh Regency. The water discharge sampling location was carried out at coordinates 3°17'02.0"N 97°11'16.3"E as shown in Figure 1.

Based on the Köppen climate classification, Indonesia is classified as a tropical rainforest climate or an equatorial climate. This climate has high rainfall. South Aceh region has a fairly high rainfall of 2176.72 mm/year [7]. Meanwhile, the location of the potential and feasibility survey is located in the Tapaktuan District with, as shown in Figure 1, has a rainfall of 2,136 mm/year based on data from Table III. [8]. High rainfall greatly supports of MHP in producing electrical energy.

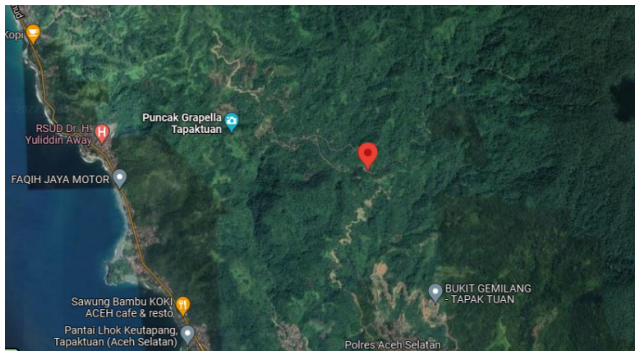

Fig. 1Location of river water discharge measurement

II. METHODOLOGY

A. Location of Feasibility Study

The location of this feasibility study research can be reached by 4 (four) wheeled vehicles. The location has distance of ± 450 km for around 9 hours trip from Banda Aceh city, Indonesia.

B. Measurement of River Water Discharge

Measurement of river water discharge with a current meter also called the measurement of the velocity and cross-sectional area of the flow method, because what is measured in this method is the speed and cross-sectional area of the water flow. The formula for water discharge which is [9]

$$Q = A.v \quad (1)$$

where Q = Water discharge, in m³/s, A = cross sectional area of water flow, in m² dan v = water flow velocity, in m/s.

The speed of river water flow on the current meter can be seen after the propeller part of the current meter is inserted into the water. The data is displayed on the current meter display.Measurement of river water discharge shown in Figure 2.

Fig. 2Water discharge measurement

TABLE I

HYDROPOWER RESOURCE IN INDONESIA IN MW [6]

No.	Region/Province	Hydro Potential
1	Papua	22,371
2	South Kalimantan, Central Kalimantan, East Kalimantan	16,844
3	South Sulawesi, Southeast Sulawesi	6,340
4	Aceh	5,062
5	West Kalimantan	4,737
6	North Sulawesi, Southeast Sulawesi	3,967
7	North Sumatra	3,808
8	West Sumatra, Riau	3,607
9	South Sumatra, Bengkulu, Jambi, Lampung	3,102
10	West Java	2,861
11	Central Java	813
12	Bali, West Nusa Tenggara, East Nusa Tenggara	624

C. *Electrical Power*

Water falling at a certain height has mass m, so potential energy of falling water, in Joules, can be defined as:

$$P = m.g.h \quad (2)$$

where m is water mass, g gravitational acceleration dan h high of falling water. m is the result from the multiplication of density and volume $m = \rho.Q$ so as result of electrical power formula in Watt which is [10]

$$P = \rho.Q.g.h \quad (3)$$

TABLE II

THE AVERAGE OF RAINFALL AND RAINY DAYS PER MONTH IN ACEH SELATAN 2014 [7]

No.	Month	The Average Rainfall (mm)	The Average Rainy Day
1	January	110	6.61
2	February	72	3
3	March	112	5.89
4	April	259	8.94
5	May	163	9.06
6	June	104	5.83
7	July	105	6.33
8	August	186	9.61
9	September	152	8.22
10	October	265	11.3
11	November	403	11.6
12	December	245,72	12.6

D. *Financing*

MHP construction costs are highly site dependent. The MHP construction site will affect the duration of civil construction, unit prices of materials and labor wages. In this research. the estimation of all costs refers to the base price in 2022. The base price is obtained from Aceh government regulations and from market price surveys.

III. RESULTS AND DISCUSSION

A. *Topography*

Topographic survey was conducted in the Alue Panton River, Tapak Tuan District, South Aceh Regency. Some of the survey that carried out were measurements of water discharge and head height. Based on measurement of water discharge using a current meter, the flow velocity in the Alue Panton River is 0.95 m^3/s, to maintain the sustainability of living things that live in the river, in this study only

70% of the available water discharge was use. By using 70% of the available water discharge, then could be obtain water discharge around 0.66 m^3/s. Based on the results of field measurements, it is also known as height of head, height of the water from tranquilizer tank and location of water expense is 15 m. Location of the waterfall and location of the turbine house based on the geological map are right in the Tapaktuan (Mult) volcanic formation which consists of limestone, calcilutite and sparite. Granite stones resulting from breakthroughs from the Samadua granite intrusion formation (TMis) were often found at the research site. This Samadua Granite Intrusion Formation rise through the fault in the late jura.

In general, the water found in South Aceh Regency is a type of meteoric water, which is water that comes from the hydrological cycle process. Judging from its morphology, South Aceh Regency has a recharge area and a groundwater discharge area. The catchment area consists of morphology of mountain and hill. Water recharge area because this area is the first area touched by rainwater. For the discharge area is an area that has plain morphology. Water released area is an area where groundwater runs off, area where water collected before heading to the sea.

Rainwater that not completely absorbed by soil layer on soil surface will flow into ponds, lakes, rivers and the sea is called surface run off. Flowing water is caused because rainwater that reaches the ground does not undergo an infiltration process or it caused by other factors, such as the condition of the soil surface being water saturated (no longer able to accommodate a large water capacity) so that water flows to lower areas. Rainwater that has entered under soil surface (subsurface) come out back to the soil surface as springs and flow to a lower place. Based on data and rainfall tables from the Cut NyakDhien climatology station, Meulaboh, it can be estimated that the intensity of rain for various return periods with a duration of 1 hour is around 55 m^3/hour.

TABLE III

THE AVERAGE OF RAINFALL AND RAINY DAYS PER MONTH PER DISTRICT IN ACEH SELATAN REGENCY 2014 [8]

No.	District	The Average Rainfall (mm)	The Average Rainy Day
1	Trumon	-	-
2	Trumon Timur	11	1.1
3	Trumon Tengah	215	9.1
4	Bakongan	173	5.7
5	Bakongan Timur	102	4.9
6	Kota Bahagia	-	-
7	Kluet Selatan	-	-
8	Kluet Timur	10	0.9
9	Kluet Utara	193	7
10	Pasie Raja	164	6.6
11	Kluet Tengah	154	9.9
12	Tapaktuan	178	8.4
13	Samadua	151	7.5
14	Sawang	91	5
15	Meukek	91	10.5
16	Labuhanhaji	202	7.3
17	Labuhanhaji Timur	197	5.1
18	Labuhanhaji Barat	236	10

B. Electrical Power Analysis

The resulting electric power was calculated using equation3. Assuming water density is $\rho = 1{,}000\ kg/m^3$, then from the following equation results are obtained:

$$P = \rho.Q.g.h$$

$$P = 1{,}000\ kg/m^3 \times 0.66\ m^3/s \times 9.81\ m/s^2 \times 15\ m$$

$$P = 97.75\ kW$$

Power of 97.75 kW from turbine output power regardless of turbine efficiency. If turbine efficiency is 70%, then output power produced is

$$P = 97.75\ kW \times 70\%$$

$$P = 68.42\ kW$$

with generator efficiency as 90% then output power produced by the generator is

$$P = 68.42\ kW \times 90\%$$

$$P = 61.58\ kW$$

C. Economic Aspects

Building cost of MHP estimated around IDR 20,000,000.00 to IDR 30,000,000,00 per 1,000 Watt [11]. Base of cost accumulation for MHP builds at Alue Panton River in South Aceh Regency could be assuming IDR 25,000,000.00 per Watt. Assumption of this price base of materials cost in Aceh area which is high priced, in mean of location near from local city, so that assumption building cost of MHP in South Aceh Regency is

$$cost = 61580\ W\ x\ IDR\ 25{,}000{,}000.00$$

$$cost = IDR\ 1{,}539{,}500{,}000.00$$

by rates 1 USD = 14,500 IDR, so that building cost of MHP which is

$$cost = USD\ 106.172$$

Based on the Regulation of the Minister of Energy and Mineral Resources No.19 of2015 purchase price of electricity by PT. Perusahaan Listrik Nasional (PLN) for low voltage up to 250 kW is USD 0.144/kWh for the first 8 year usage and USD 0.09 for the 9th year to the 20th year usage. [12].

Estimated revenue is the estimated profit per year obtained from the sale of a business products. In MHP business, annual income is obtained from sale of electrical energy which is calculated using the equation

$$R = KT\ (\%)\ x\ KD\ (kW)\ x\ H\ (USD)\ x\ T\ (Hour)$$

where Ras revenue, $KT$is absorbed power in percent, $KD$is installed power capacity in kW, $H$is selling price, and $T$is hours accumulated in month. With KT percentage around 60% then income could be obtained in first year as much:

$$R = 60\%\ x\ 61.58\ kW\ x\ USD\ 0.144\ x\ 8{,}760\ hours$$

$$R = USD\ 46{,}608.$$

This income does not include taxes and other expenses.

D. Technical Aspects and Risks

Noticing into local geological conditions which are entirely composed of Tapaktuan Volcano Formation (Mult) rocks units, construction of the MHP in Tapaktuan Regency, precisely in Panton Luas Village, which close to weak zone, fault zone which is in contact between rocks of the Tapaktuan Volcano Formation (Mult) and rocks of the Tapaktuan Volcano Formation (Muvt). These faults can be caused by the breakthrough process of the Samadua Granite Intrusion Formation (Tmis) rock units, causing fractures.

As such geological conditions, construction of the MHP in Tapaktuan City, precisely in Panton Luas Village, cause feared to be very risky and has potential disaster and technical failure. Risk of technical failure is due to the high rainfall in the rainy season so that soil surface of the rock becomes slippery and can cause landslides. Landslides also predicted to be dominant due to tectonic plate activity that causing movements in the Sumatera Fault System.

The Tapaktuan Volcano Formation (Muvt) is not fully able to bind rocks for the Tapaktuan Volcano Formation (Mult). Claystone which is expected to act as cement (base masses) is unable to withstand the increased load due to the volume of rainwater. Considering the physical properties and characteristics of claystone, it can absorb water but cannot transmit or passing the water, and when exposure water happened, claystone will expand to the limit of its elasticity so that the volume of clay increases, slip area on contact surface between the rocks becomes slippery so that the rock becomes unstable and causing avalanche. For this reason, it is necessary to studying and considering technical analysis in depth of accordance with specifications and characteristics of the rocks found in the research area.

For recommend that if construction of MHP will continue to carry, important to prior deep study before carrying out the work on MHP construction, a technical study of physical properties mechanics and dynamics of rocks is conducted to determine extent of resistance and elasticity as well as ability

of these rocks to face threats from the influence of developing geological forces so that impact of risk technical failures can be avoided or at least can be minimized

IV. CONCLUSIONS

Based on analysis of the results of feasibility study for construction of MHP in Alue Panton River, Tapaktuan District, South Aceh Regency, it was found that water discharge was 0.95 m^3/s. In this study, not all of the water discharge was utilized, just for around 70% of water discharge was utilized or about 0.66 m^3/s. Height of the falling water or height of the head is 15 m. From the river water source, 61.58 kW of electrical energy could be generated with assumption that the turbine efficiency is 70% and the generator efficiency is 90%. Based on economic analysis, in the first-year usage, income received was 44% of investment from construction costs of MHP. Based on technical and risk analysis, at MHP construction site, landslides can occur due to high rainfall and base on locate of tectonic plates.

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