IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 12, Issue 6 Ver. II (Nov. – Dec. 2017), PP 86-92
www.iosrjournals.org

Potential of Aek Rambe river as mini hydro power plant in North Sumatera, Indonesia

Suhelmi, M. Irwanto, K. Saleh, M. Adri
Department of Electrical Engineering, Medan Institute of Technology, Indonesia
Corresponding author: mhd-irwanto@itm.ac.id

Abstract: *The water energy is a clean energy and one part of renewable energy. An electrical power plant produces a cheap electric, no pollution and no damage during electric operation and also the water can be used back for the other usage. This paper presents to study the potential of Aek Rambe River as mini hydro power plan. It is located in in the village of Mungkur, the subdictrict of Tarabintang, the regency of Humbang Hasundutan, North Sumatera, Indonesia. A design of mini hydro power plant is explained in this paper and applied for the data of Aek Rambe river. The results show that for the water flow, Q of 3.96m^3/s and head of Sibokkik water fall, H is 20 m, thus 388.5 kW mini hydro power plant can be constructed and supplied to 552 house if per house is 4 A.*

Keywords: *mini hydro power plant, river water, generator.*

Date of Submission: 17-11-2017 Date of acceptance: 18-12-2017

I. Introduction

River water flows from upper position to the lower position. There are two kinds of energy contained by the river water. The first kind of energy is potential energy, it is based on its position and stored in the river water. It is not be used in the specific position, but it can become useful when the river water starts to flow. The second kind of energy is kinetic energy. It is caused by the river water flow that has mass and velocity. This energy will cause a movement and can be converted become mechanical energy.

The useful of kinetic energy contained by the river water is used in the concept of mini hydro power plant. Many researchers have studied the potential of water as mini hydro power plant. A prototype of micro hydro power plant has been developed and constructed by [1] as an experimental system of electrical and mechanical education. The implemented system consist of three main parts. The first part is hydraulic part that has function to pump the water goes to pipe line and nozzle. It is as representative of penstock system in the real micro hydro power plant and it is a part of civil engineering works. The second part is electro-mechanic part that has function to convert the kinetic energy become electrical energy. In this part, the water sprayed through the pipe nozzle strikes the water turbine and produce a movement. It is due to the water turbine is coupled to the rotor of generator, thus the stator of generator will produce the electricity. This part is electro-mechanic engineering works. The last part is controller part that consist of programmable logic controller (PLC), power analyzer, DC copper, linear electrical activator, flow meter and pressure sensors.

Indonesia is lying along the equator, it has two seasons. The first season is dry season that falls between April and October. The second season is wet season that falls between November and March (monsoons with the wind blows from northwest), it has a high quantity of rainfall. It is due to that Indonesia has a lot of river with a high quantity of rainfall also. It becomes a good potential to construct a micro hydro power plant. A study of river potential has been conducted by [2] in Kapuas Hulu, West Kalimantan, Indonesia. There are 18 potential sites of river water to generate mini hydro power plant with power capacity 110 kW to 5.2 MW.

A micro hydro power plant has been designed by [3] for Hink river in Manokwari, Indonesia. The result of initial survey shows that the river has hydraulic potency about 29.5 kW. According to the result, a micro hydro power plant has been planned to this location. The power plant will use 25.2 kW of the hydraulic potency based on flow rate 0.3 m^3/s and head height 8.6 m. Turbine for the power plant is cross flow turbine type T-14 D-300 and the turbine will be coupled with a 3 phases synchronous generator to produce electrical energy about 17.32 kW.

This paper presents a potential of Aek Ramber river in North Sumatera, Indonesia as a mini hydro power plant. A electro-mechanical design is studied based on the data of water flow and head.

II. Methodology

3.1 Location of Aek Rambe river

Aek Rambe river is located in the village of Mungkur, the subdictrict of Tarabintang, the regency of Humbang Hasundutan, North Sumatera, Indonesia as shown in Fig. 1. The main water source is coming from Sibokkik water fall as shown in Fig. 2.

Figure 1. Location of Aek Rambe river [4]

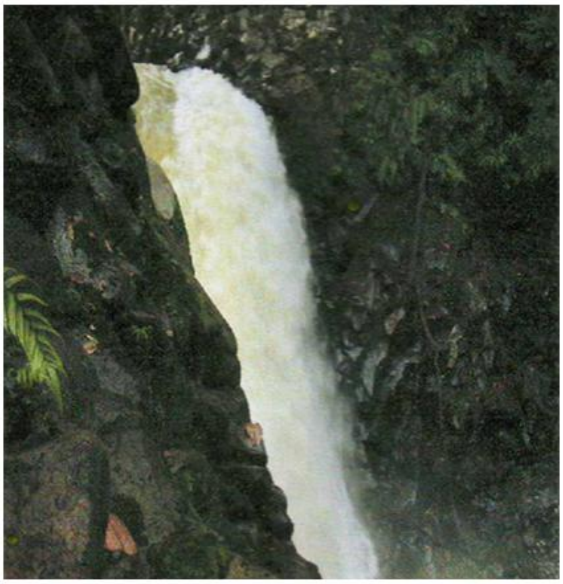

Figure 2. Sibokkik Water fall [5]

3.2 Electro-mechanic design of mini hydro power plant

Nowadays, hydro power plant has limitation of power capacity from some kilowatts to some hundred megawatts. The hydro power plant can be classified into [6]:

a. Large hydro power plant. It is an electrical power plant that has power capacity above 100 megawatts. It is usually connected to big electricity power grid.
b. Medium hydro power plant. It is an electrical power plant that has power capacity between 15-100 megawatts. It is also connected to big electricity power grid.
c. Small hydro power plant. It is an electrical power plant that has power capacity between 1-15 megawatts. It is also connected to electricity power grid.
d. Mini hydro power plant. It is an electrical power plant that has power capacity between 100 kilowatts-1 megawatt. It is usually stand alone or also connected to electricity power grid.
e. Micro hydro power plant. It is an electrical power plant that has power capacity between 5 kilowatts-100 kilowatt. It is usually for small community or rural area that has no national utility grid.
f. Pico hydro power plant. It is an electrical power plant that has power capacity of some hundred watts -5 kilowatts.

The electro-mechanic design of mini hydro power plant is based on the measurement result of water flow, *Q* and head, *H*. Based on the mini hydro power plant scheme as shown in Fig. 3 that the electro-mechanic design consist of [7,8]:

a. Choice of turbine type
b. Choice of generator type
c. Grounding system
d. Choice of electric protection system
e. Choice cable size

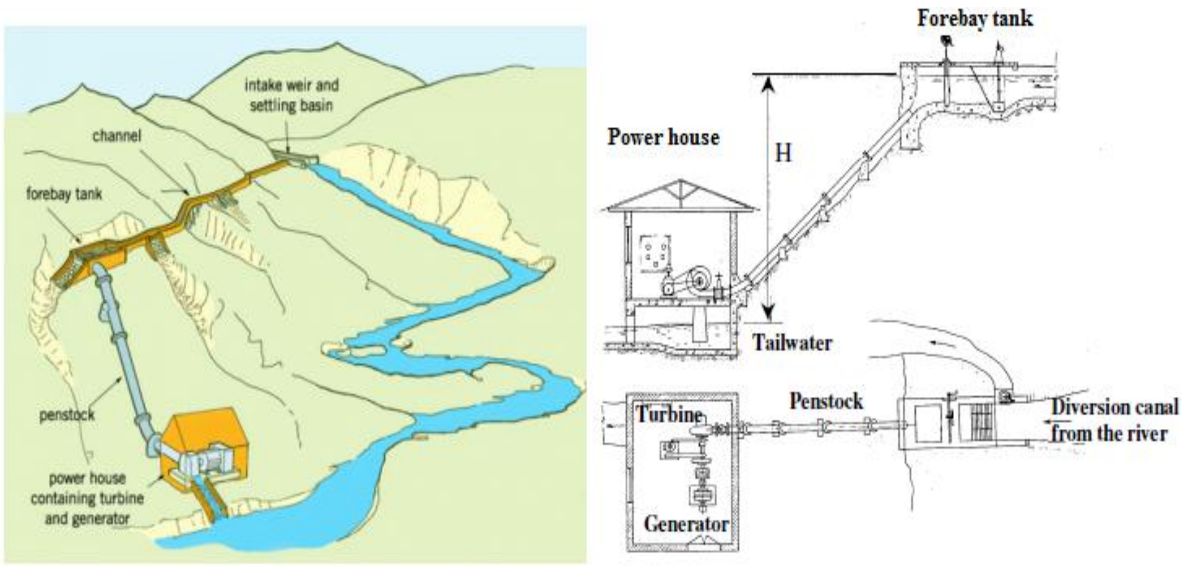

Figure 3. Mini hydro power plant scheme [7,8]

3.2.1 Choice of turbine type

The choice of turbine type is based on the characteristic system. They are water flow, *Q*, head, *H* and mechanic power, P_m. Table 1 shows standard turbine that can be applied in the mini hydro power plant [8].

Table 1. Resume of application range of standard turbines (based on several manufacturers data)

Hydraulic Turbines		H (m)	Q (m^3/s)	P_m (kW)	N_s (r.p.m.) (kW, m)
Reaction	Bulb	2 - 10	3 - 40	100 - 2500	200 - 450
	Kaplan and propeller – axial flow	2 - 20	3 - 50	50 - 5000	250 - 700
	Francis with high specific speed - diagonal flow	10 - 40	0.7 - 10	100 - 5000	100 - 250
	Francis with low specific speed – radial flow	40 - 200	1 - 20	500 - 15000	30 - 100
Impulse	Pelton	60 - 1000	0.2 - 5	200 - 15000	<30
	Turgo	30 - 200		100 - 6000	
	Cross-flow	2 - 50	0.01 – 0.12	2 - 15	

3.2.2 Choice of generator type

The generator converts the mechanic energy from turbine to be electrical energy. The energy always loses when it is converted from one process to the other process. In case of water power, it will be loses during it flows through the penstock to the turbine. It is due the friction loses. The total efficiency is taken around 50% in the design of mini hydro power plant [6]. The theoretical of electrical power generator is calculated by the formulation (1). The choice of generator type is based on the equation (1) and Table 2.

$$P_e = QxHxgx0.5 \quad \text{(kW)} \qquad (1)$$

where:

Q = water flow (m^3/s)

H = head (m)

g = gravity (9.,81 m/s^2)

Table 2. Choice of generator type

Size of scheme	Up to 10 kW	10 to 15 kW	More than 15 kW
Generator	Synchronous/Induction	Synchronous/Induction	Synchronous
Phase	Single or Three Phase	Three Phase	Three Phase

3.2.3 Grounding system

The objective of grounding system is to protect the machines, equipment, cable, power house and human due to the lightning or short circuit. One of requirement should be fulfilled is that the total grounding resistance should be below 5 Ω. It can be calculated by using formulation (2) with the soil resistivity value as shown in Table 3.

$$R = \frac{\rho}{2\pi L}\left\{\ln\left(\frac{4L}{d}\right)-1\right\} \tag{2}$$

where
R = grounding resistance (Ω)
ρ = resistivity (Ω.m)
L = length of electrode (m)
d = electrode diameter (m)

Table 3. Soil resistivity

No	Type of soil	Resistivity (Ω.m)
1.	Soil contented salt water	10
2.	Marshland	10
3.	Clay	20
4.	Wet sand	50
5.	Wet cobblestone	200
6.	Dry cobblestone and sand	10000
7.	Stone	2000

3.2.4 Choice of electric protection system

The function electric protection system is to protect the over current causes the short circuit or over load. MCCB/MCB can be applied to protect the system. The choice of MCCB/MCB should be higher or equals the nominal current. The size of MCCB/MCB in ampere is given by [9].

$$\text{Size of MCCB/MCB (A)} = \frac{1.25 x P_e}{V_{LN}\, x pf} \tag{3}$$

where:
1.25 = value factor 25%
V_{LN} = netral to line voltage (volt)
pf = power factor

3.2.5 Choice of cable size

The cable is used to send the electric power from generator to load. The cable size is calculated based on the formulation (4) [9] and Table 4.

$$\text{Cable size (A)} = \frac{1.7 x P_e}{V_{LV}\, x pf} \tag{4}$$

where
1.7 = value factor 70%

Table 4. Specification of aluminum conductor steel reinforce (ACSR)

ACSR Code number	Type of ACSR	Resistance Ohm/km	Current rating max Amps	Equivalent Copper area mm^2	Inductive Reactance Ohm/km	Sp. Weight (kg/km)
1	Squirrel	1.374	76	13	0.355	80
2	Gopher	1.098	85	16	0.349	106
3	Weasel	0.9116	95	20	0.345	128
4	Rabbit	0.5449	135	30	0.335	214
5	Otter	0.3434	185	50	0.328	
6	Dog	0.2745	205	65	0.315	394

3.3 Data of Aek Rambe river

The measurement result based on the topography of Aek Rambe river shows that the head of Sibokkik water fall is 20 m. The length and depth of Aek Rambe river are 26 km and 1.5 m, respectively. The water velocity, v cross section area, A and water flow, Q of the river are shown in Table 5.

Table 5. Measurement result of water velocity using flow rate sensor

Variable	value
Water velocity, v (m/s)	0.66
Cross section area, A (m^2)	6
Water flow, $Q = v \times A$ (m^3/s)	3.96

III. Result and Discussion

Based on the measurement result as shown in Table 5 shows that the water flow, Q is 3.96m^3/s and head of Sibokkik water fall, H is 20 m. The electro-mechanic design of mini hydro power plant can be stated following the sub sectionbelow.

3.1 Choice of turbine type

Based on Table 1 for the water flow, Q is 3.96m^3/s and head of Sibokkik water fall, H is 20 m, thus the suitable turbine type is Kaplan and propeller-axial flow.

3.2 Choice of generator type

The capacity of electric power, P_e is calculated based on the equation (1) as stated below. Based on the Table 2, thus the suitable generator is three phase synchronous generator with power capacity is 388.5 kW.

$$\begin{aligned} P_e &= QxHxgx0.5 \\ &= 3.96x20x9.81x0.5 \\ &= 388.5 \quad kW \end{aligned}$$

3.3 Grounding system

The electrode bar of copper is used in the grounding system, its diameter, d and lenght, L are 0.0159 m and 2 m. The soil type of under the power house is clay with resistivity, ρ is 20 Ωm. The grounding resistance, R is given by

$$\begin{aligned} R &= \frac{\rho}{2\pi L}\left\{\ln\left(\frac{4L}{d}\right)-1\right\} \\ &= \frac{20}{2x3{,}14x2}\left\{\ln\left(\frac{4x2}{0{,}0159}\right)-1\right\} \\ &= 8.3 \quad \Omega \end{aligned}$$

To obtain the value of grounding resistanc ebelow 5 Ω, thus two electrode bars are connected in parallel, thus the total resistance become 4.15 Ω.

3.4 Choice of protection system

In the generator type, the chosen generator is three phase synchronous generator with power capacity is 388.5 kW. It is a three phase power, for power per phase should be divided by three, it equals 129.5 kW. This power is used to calculate the size of MCCB/MCB per phase and given by.

$$\text{Size of MCCB/MCB (A)} = \frac{1.25 x P_e}{V_{LN} x pf}$$

$$= \frac{1.25x129500}{220x0.8}$$

$$= 919.7 \text{ A}$$

3.5 Choice of cable size

The cable size can be calculated following equation below.

$$\text{Cable size (A)} = \frac{1.7 x P_e}{V_{LV}\, x pf}$$

$$= \frac{1.7x129500}{220x0.8}$$

$$= 1250.9 \text{ A}$$

3.6 One line diagram of mini hydro power plant

The calculation result shows that 388.5 kW three phase synchronous generator or 129.5 kW single phase synchronous generator with per phase current is 735.8 A. If a house in the village of Mungkur, the subdictrict of Tarabintang, the regency of Humbang Hasundutan, North Sumatera, Indonesia is given 4 A, thus the mini hydro power plant can serve 184 houses per phase and the total house that can be supplied by the mini hydro power plant is 552 houses. The one line diagram of mini hydro powe plant is shown in Fig. 4.

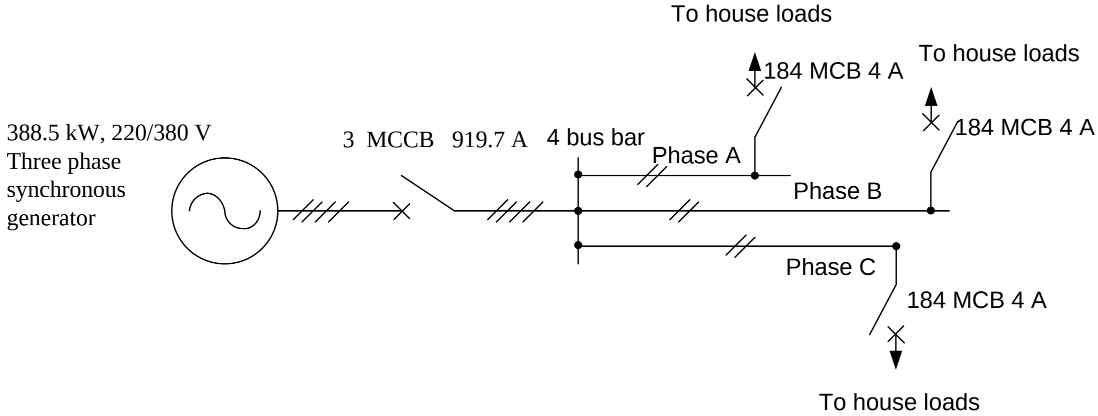

Figure 4. One line diagram of mini hydro power plant in village of Mungkur, the subdictrict of Tarabintang, the regency of Humbang Hasundutan, North Sumatera, Indonesia

IV. Conclusion

Aek Rambe river has good potential to constructed a mini hydro power plant. It is due that it has the main water source from a water fall. The measurement result shows that 388.5 kW mini hydro power plant can be constructed. It can supply the house number of 552 houses.

References

[1] M. T. Ozdemira ., A. Orhan, An experimental system for electrical and mechanical education: Micro hydro power plant prototype. *Procedia - Social and Behavioral Sciences*, 47 (2012) 2114 – 2119.

[2] D. Setiawan, Potential Sites Screening for Mini Hydro Power Plant Development in Kapuas Hulu, West Kalimantan: a GIS approach. *Energy Procedia*, 65 (2015) 76 – 82.

[3] Y. R. Pasalli, A. B. Rehiara, Design Planning of Micro-hydro Power Plant in Hink River. Procedia Environmental Sciences, 20 (2014) 55 – 63.

[4] https://upload.wikimedia.org/wikipedia/id/thumb/a/a4/Peta_Lokasi_Kecamatan_Tarabintang_Kabupaten_Humbang_Hasundutan.svg/1280px-Peta_Lokasi_Kecamatan_Tarabintang_Kabupaten_Humbang_ Hasundutan.svg.png

[5] http://humbanghasundutankab.go.id/pariwisata-kecamatan-tarabintang.
[6] ……. Micro-Hydro Power. Practical Action, The Schumacher Centre for Technology & Development, Bourton Hall, UK.
[7] https://fauziyusupandi.files.wordpress.com/2017/08/hidro2.jpg?w=736.
[8] H. Ramos, Guidelines for Design of Small Hydro Power Plants. (WREAN (Western Regional Energy Agency & Network) and DED (Department of Economic Development), Belfast, North Ireland. 2000).
[9] P. Chitrakar, Micro-Hydro Power Design and Manual. (Kathmadu. 2005)

Suhelmi "Potential of Aek Rambe river as mini hydro power plant in North Sumatera, Indonesia." IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE) 12.6 (2017): 86-92.