Study on Selection of Turbine Design and Sizing of Transmission Cable for Development of Pico HydroPower Plant at Dewi Bukit Mangggung Tourism Place Tanjungsiang, Subang, West Java

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Abstract. Follow up on the collaboration between the Research Center for Appropriate Technology National Research and Innovation Agency with PT. Bukit Dewi Manggung, a study of the potential of micro hydro, was carried out in Rancamanggung village, Tanjung Siang sub-district, Subang district. Activities consisted of measuring the potential for water discharge, height difference, the site layout, and selecting the type of turbine suitable for the existing potential. Field measurements identified two alternative sites that could be developed. The first location had a head of 3 m, and the second location was 6 m. The flow rate was 0.51 ± 0.23 m^3 per second. The analysis showed that the turbine type suitable for use at both potential locations was cross-flow. The diameter of the turbine runner for both 3m and 6m heads was 269 mm, while the width of them was 1108 mm and 630 mm, respectively. The size of the cable used in the pico hydro plant, which had a head of 3 m and 6 m, was 16 mm^2 and 40 mm^2, respectively, with power losses of 1239 W and 1983 W, respectively.

Keywords: Micro Hydro · Pico Hydro · Turbine design

1 Introduction

The development of micro hydro power plants appears to be proceeding slowly in Indonesia, despite the country's abundance of resources for micro hydro. In Indonesia, more work is required to create micro hydro power plants. Genuine action should be taken to overcome some of the obstacles in the growth of micro hydro. The payback period for micro hydro power plants is the shortest of any resource. To achieve these goals, the Indonesian government should prioritise micro hydropower development over all other renewable energy sources [1].

Based on what Fulford's study found [2], that using micro-hydro for the community is a way to help the economy of rural areas. In rural areas, the success of micro-hydro installations depends on how well they are planned; This means knowing what the

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community needs, how feasible the project is, and how much money is available to help build micro-hydro installations.

Solar and wind power are more expensive than mini- or micro-hydro schemes for putting electricity into rural areas. New designs for propeller turbines, induction generators, and clever controllers have the potential to make these systems more cost-effective and affordable. Several novel designs for hydraulic turbines have been implemented. Simplified designs for cross-flow and Pelton Wheel turbines have been designed and tested. Large-diameter penstocks are inexpensive for Pico Hydro plants. However, the viability of these plans depends significantly on government initiatives and subsidy programmes. A combination of bank loans and government incentives should be used to attract participation from the private sector. It is anticipated that the adoption of micro hydro schemes with innovative, cost-effective designs will result in the expansion of local industries, so contributing to the economic and social development of developing nations as a whole [3].

Some advantages of micro hydropower plants include: micro-hydro plants cost less than residential solar power plants and home wind turbines that generate comparable amounts of electricity; Continuous operation day and night and in any wind conditions unlike solar plants or wind turbines; non-intrusive and efficient, unlike large hydro plants that employ dams and produce vast lakes; micro-hydro plants divert a small fraction of the stream and do not need a water storage pool, and micro-hydro dam-less electric plants do not cause the same environmental impact as huge hydro plants [4–7]. Therefore, a limitation that often arises in the field related to micro hydro installations is the existence of competition for water needs with the agricultural sector. The solution to this problem is usually resolved by agreeing on the timing of water use.

Subang Regency has much potential for micro-hydro because it has many mountains and big rivers for irrigation. Existing Micro Hidro Power Plants (MHPP) in Subang Regency include those belonging to plantation corporations, those with specific government incentives, and NGO initiatives with the local population. The Public Service Agency (BLU) Research and Development Centre for Electricity Technology, New Renewable Energy, and Energy Conservation (P3TKEBTKE), Research and Development Agency, Ministry of Energy and Mineral Resources, manages the 100 kW Melong MHPP in Jambelaer Village, Dawuan District. In 2021, the generated electricity will be distributed (on-grid) to PT. PLN (Persero) has a selling price of IDR 520/kWh for power annually [8].

The Cinta Mekar PLTMH was built in West Java's Serang Panjang sub-district by the Institute of People's Business and Economics (IBEKA). When the MHP was built in 2002, PLN could purchase a portion of the extra capacity. Since 2017, PLTMH Cinta Mekar has been stopped because of the low cost of electricity purchased by PLN [9]. In contrast, the Cinta Mekar PLTMH has a considerable capacity, drawing water from the Ciasem River, utilising the Cross-Flow Twin Turbine T-13, and generating a maximum of 120 kW of electrical energy [10].

The water source for the Cijambe PLTM is the Cileuleuy River in the Tambaksari plantation, located in Cijambe Village, Cijambe District, Subang Regency. PTPN VIII also owns a Gunung Tua PLTM, which gets water from the Cigadog River, Tambaksari Plantation, Gunung Tua Village, Cijambe District, and Subang Regency. The Gunung

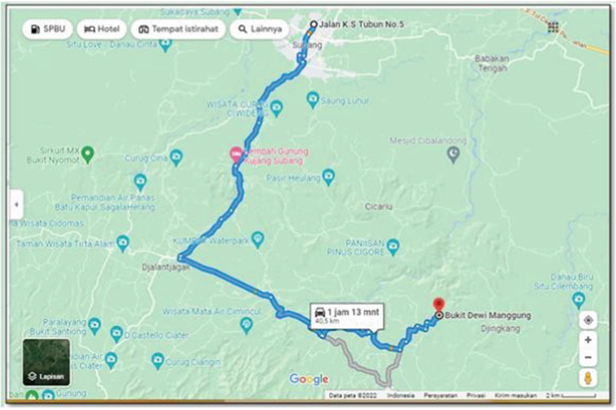

Fig. 1. Location of Bukit Dewi Manggung

Tua PLTM has a potential water discharge of 3.45 m^3/s and a potential net capacity of 1,348 kW [11].

Dewi Manggung Hill is one of the attractive innate tourism potentials with its photo spots which residents are currently developing through tourism awareness groups. Dewi Manggung Hill is located in southern Subang, precisely in Tanjungsiang District, Subang, West Java, at a latitude of 6042′33.88"S, the longitude of 107049′57.96", with an elevation of 441 MAML (Meter Above Mean Sea Level). Dewi manggung hills in the area Rancamanggung Tanjungsiang with topology field area width 113.6 Ha, yard 435 Ha, forest 32 Ha and settlement 3090 peoples, most of them are farmers 1460 people. There are have groups for economics society, 6 farmer groups and 1 government agencies [12]. In addition to developing tourism objects, Bukit Dewi manggung is also trying to create educational facilities, including implementing micro-hydro to generate electricity. In addition to educating the public, it is hoped that the Dewi Manggung tourist attraction can be independent in the supply of electrical energy, i.e., not depending on the grid of the state electricity company. This work aimed to map the parameters of the existing potential concerning the development of micro-hydro, which consisted of measuring water discharge, and elevation and selecting the appropriate turbine for the current potential (Fig. 1).

1.1 Materials and Methods

Dewi Manggung Hill in southern Subang, exactly in Tanjungsiang District, Subang, West Java, at a latitude of 6°42′33.88"S, a longitude of 107°49′57.96", and an elevation of 441 MAML (Meter Above Mean Sea Level) was the location of the data collection. The data comprises river width, flow velocity, and height difference measurements. Eleven river width measurements were taken using the cross-sectional approach, and river current velocity measurements were taken using the floating method. The utilized equipment includes a GPS (Global Positioning System) device, waterlevel, a tape measure, a stopwatch, a meter stick for measuring depth, prominent buoyant objects, stakes and rocks

Table 1. Configuration of hydroelectric power plants [18].

Large and Medium types	
Accumulation type Pumped storage Weir type	Using reservoir with dam or surging weir Using two reservoir Using river regulation weir
Smal, Micro and Pico types	
Weir type Pumped storage	Using existing weir originally built for water level regulation or newly built surging weir. Using two reservoir or lake and water tank with sufficient head.
Derivative or diversion types (Run-of River types)	Using diversion weir or not using weir at all.
1. No pressured derivation 2. Positive pressure derivation 3. Negative pressure derivation 4. Combined derivation (No pressured and positive pressure or No pressured and negative pressure)	Using diversion canal, side canal, adjusted river arm or river bed. Using penstock. Using siphon tube. Using diversion canal and then penstock or siphon tube.

for anchoring the tape measure to the channel banks [13, 14]. Turbine design and sizing of transmission cable is done using JLA software [15, 16] run by DOSBox 0.74–3.

1.2 Micro-hydro Power Plant System

Understanding small scale in the use of water energy in the range of 2.5–25 MW is mini-hydro for sizes of 500 kW–2 MW, micro-hydro for 10 kW–500 kW, and pico-hydro for capacities below 10 kW [17]. Meanwhile, according to reference [2], the grouping of water energy utilisation is as follows: Picohydro is small, has a power output of less than 5 kW, and is used for household needs. Micro-hydro: a small system with a capacity of 5–100 kW that is applied to meet the needs of a village. Mini-hydro: medium-sized with a 100 kW–5 MW capacity, applied to meet several villages' needs and connected to a large-scale electricity grid. Full-scale hydropower plant: large (full-sized) and directly connected to a large power grid with a more than 5 MW capacity.

There are several topological configurations in the installation of a hydro electric power plant depending on the function of the plant, as shown on Table 1. Besides functioning to produce electricity, a power plant can also function for irrigation, drinking water, and industrial water supply needs.

Micro-hydro power plants have three main components, including water as an energy source, turbines as a successor to kinetic energy and generators as producers of electrical energy. In principle, micro-hydropower plant works by utilizing waterfall (head), the higher the waterfall, the greater the potential energy that can be converted into electrical energy. Water from the main river source is dammed and partially deflected to be channeled through the overflow channel, then passed by the carrier channel to the pipe

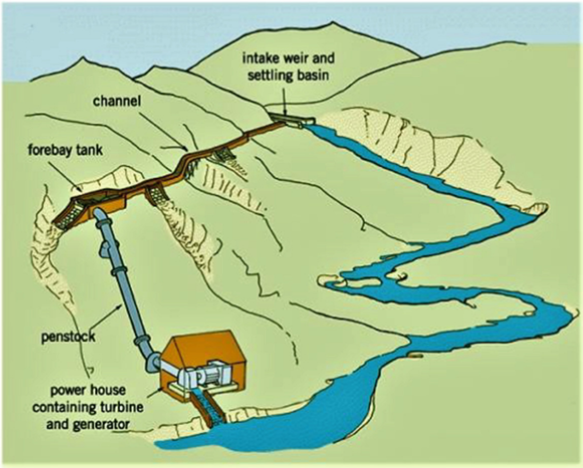

Fig. 2. Typical the micro hydro scheme [19]

rapidly to move the turbine shaft that is in the powerhouse. The turbine is connected to a generator and will produce electrical energy which is then distributed through the network to the user, the micro hydro system scheme is shown in Fig. 2.

1.3 Determination of Discharge

The source of water used comes from the Cikaramas river. Water flow measurement was carried out using the cross-section method. The flow velocity was the average velocity of the measurement results using a current meter, the Flowatch-JDC, and the floating method. The flow rate was calculated using the following equation: [20, 21]

$$Q = V \times A \tag{1}$$

where: Q = Discharge (m^3/sec), V = Velocity (m/sec), A = Cross section area of river (m^2)

The difference in height between the forebay and the turbine, is calculated using the gradual water level method.

$$\Delta H = H_2 - H_1 \tag{2}$$

where: ΔH = Head between A-B, H_1 = Elevation A, H_2 = Elevation B (Fig. 3).

1.4 Determination of Turbin

Determination of the turbine type was carried out by referring to the Fig. 4.

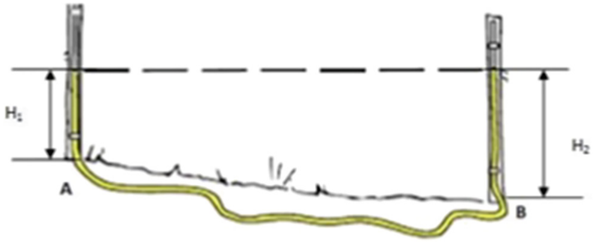

Fig. 3. Measurement of height difference using a hose

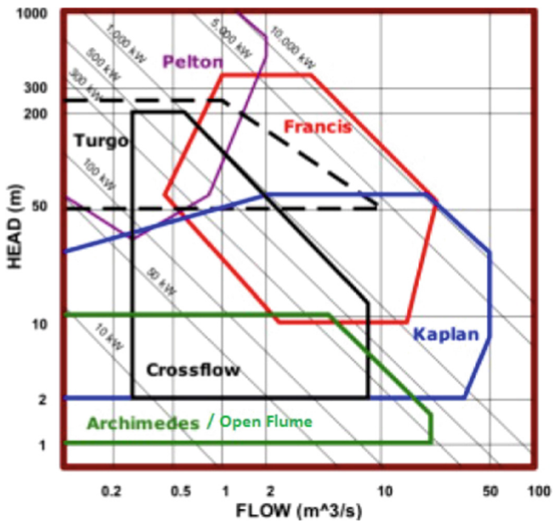

Fig. 4. Classification of turbines based on discharge and head [21]

1.5 Determination of Power Generated Estimation

Roughly speaking, to find out the power that can be generated, the Empirical Formula [11b] is used as follows:

$$P = e_o \times 9.8 \times Q \times H \tag{3}$$

where:

P = Power that can be generated, Kw
e_o = overall efficiency 0.50
e_o = eff. Turbine 0.75
eff. 0.80 transmission
eff. Generator 0.90
9.8 = Constant of gravity, m^2/sec
Q = Flow Flow, m^3/sec
H = Height Difference, m

Table 2. Designed Turbin Characteristic

Q l/sec	Generated Power,kW	Available Electrical Power, kW
406	9.2	7.35
306	7.3	5.84
204	4.5	3.60
153	3.6	2.87
102	2.2	1.76
81	1.6	1.28
61	0.9	0.71
Speed of turbine:		219 Rpm
Over speed:		394 Rpm

By applying the existing constants, the above empirical formula can be simplified into:

$$P = 5\ QH \tag{4}$$

2 Results and Discussions

The calculation result of the river flow is $0.51 \pm 0.23\ m^3$ per second. Henceforth, the flow rate that will be used in the turbine design is 300 L per second. As for the height difference, there are two alternatives: the height difference of 3 m and 6 m. Referring to Fig. 4, the type of turbine suitable for application is the type of crossflow turbine.

The dimensions of the crossflow turbine are determined using the DOS application (exe) JLA program. From the calculation results for the 3-meter height difference, the minimum penstock diameter is 309 mm, and the maximum is 504 mm. In the design, the penstock diameter of 400 mm has been chosen with a thickness of 1.9 mm of iron pipe. The general assembly drawing of the turbine design results is presented in Figs. 5 and 6. Table 2 shows the characteristics of the turbine.

From the calculation results for the 6-meter height difference, the minimum penstock diameter was 309 mm, and the maximum was 504 mm. By applying a penstock diameter of 400 mm along 30 m in the design, it was necessary to have a penstock pipe thickness of 2.4 mm. The general assembly drawing of the turbine design results is presented in Figs. 7 and 8. The characteristics of the turbine are presented in Table 3.

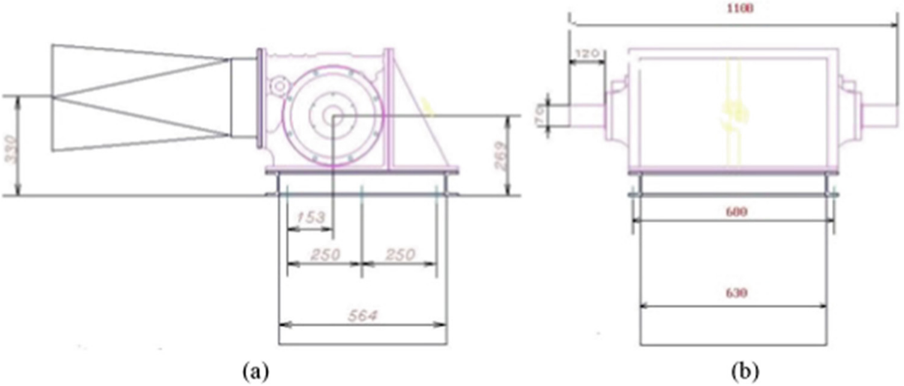

Fig. 5. (a) Profile view of designed crossflow turbine for 3 m head, (b) Front view of designed crossflow turbine for 3 m head

Table 3. Designed Turbin Characteristic

Q l/sec	**Generated Power,kW**	**Available Electrical Power, kW**
320	14.5	11.60
240	11.5	9.20
160	7.1	5.67
120	5.7	4.55
80	3.5	2.80
64	2.5	2.00
48	1.5	1.20
Speed of turbine:		311 Rpm
Over speed:		559 Rpm

Table 4 presents the results of transmission cable sizing. The conductor area of the cable chosen in the pico hydro plant of 3 m head was 16 mm^2, and that of 6 m head was 40 mm^2. Power loss in plants of 3 m and 6 m head was 1239 Watts and 1983 W respectively as, for three, and single-phase voltage was 427/246 and 417/241 V respectively.

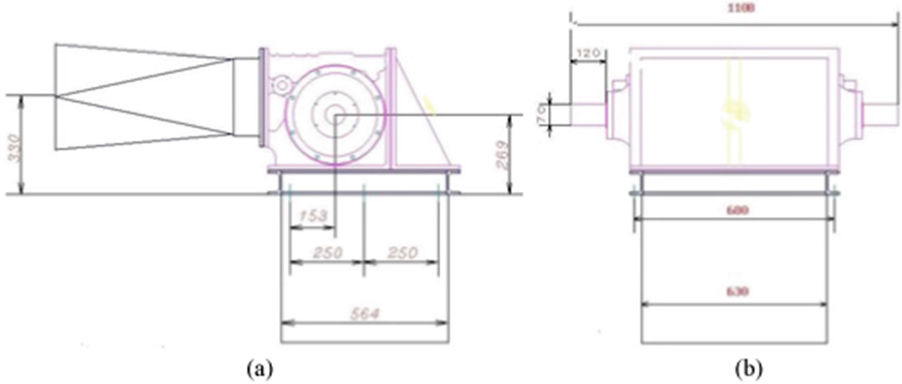

Fig. 6. (a) Profile view of designed crossflow turbine for 6 m head, (b) Front view of designed crossflow turbine for 6 m head

Table 4. Sizing of transmission cable

	Head = 3 m	Head = 6 m
Hit 1+ sigle phse/3 = tree phase:	3	3
Power to drive, Kw:	5	5
Power actor:	0.5	0.5
Apparent power, Kw:	10	20
Line to line voltage for the load:	380	380
Line current:	15	30
Line length, m:	1000	1000
Spacing of conductor, m:	0.01	0.01
Hit 1 = Copper/0 = Aluminium:	0	0
Desing line loss, %:	5	5
Area of Conductor:	55	55
Choice of area conductor:	16	40
Resist, OHM:	1.79	0.716
Ind. React., OHM:	0.115552	0.086978
Imped. Total, OHM:	1.793726	0. 7212635
Generated voltage in power house, V:	427/246	417/241
Power loss, w:	1239	1983

3 Conclusion

Results of the study found that the flow rate of the water resource was 0.51 ± 0.23 m^3. Two alternative locations could be developed for implementing pico hydro, i.e., the location with heads 3 and 6 m. By applying 300 l/s flow rate and heads 3 and 6, the generated powers were 5.71 kW and 10.4 kW, respectively. The turbine type matched with the potential location, which has 3 m head or 6 m, was a cross-flow turbine. The diameter of the turbine runner for both 3 and 6 m head was 269 mm, while the width of the runner was 1108 mm and 630 mm, respectively. In the line length of 1000 m, with the area conductor of 16 mm^2 for 3 m head and that 0f 40 mm^2 for 6 m head, the power loss was 1239 W and 1983 W, respectively, with the three/single phase voltage of 427/246 V and 417/241 vV respectively.

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