DESIGN ENGINEERING DETAIL OF SONO (OPAK RIVER) MICROHYDRO IRRIGATION PROJECT PARANGTRITIS KRETEK VILLAGE IN THE DISTRICT OF BANTUL OF YOGYAKARTA

Arief Budiyanto[1]

[1]SMK 1 Sedayu Kab Bantul, Vocational School of Sedayu of the District of Bantul
*Corresspondence : kla_ngon@yahoo.com

Abstract

Bantul District has many small river which have the potency to be converted to electrical energy. This research aims at determination the potency of hydropower and designing very low head water power plant. The observational step started by measuring head and flow rate. Designing of water turbine should be considered the power available. Since the turbine usually run at low speed and the generator speed is quite high (1500 rpm) it require speed increaser. Based on primary data, the electrical power can be generated up to 41.02 kilowatt kW .

The project's objective is to provide the village Irrigation Sono (Opak river) Parangtritis with a reliable,green clean and economically viable source of electrical energy.

A potential hydropower site in the vicinity of the villages was identified at Opak river. The salient features of the scheme are summarised as follows: Gross Head (Hgross) 2- 3.5 m , Net Head (Hnett) 2.5 m, Flow River 4,48 m3 /s, Design of flow rate (Q) =2.5 m 3/s. Electrical Power (Pelg) 61,31 KW. The project comprises of the following components: Water intake and conveyance structures, including sand trap, headrace canal, forebay, draft tube and tailrace. Powerhouse, including protection wall Generating equipment, comprising of a propeller turbine and synchronous generator Electrical turbine control system, ELC (Electronic Load Controller) Transmission facilities.

The implementation of the project will take approximately six to eight months including the finalisation of the preparatory work (detailed design, tendering, contract awarding), actual implementation of the project, testing, commissioning and training of operators. Two villagers will be assigned and trained as operators for the operation and maintenance of the plant. In order to optimize the viability of the water source office of Bantul, load management is deemed necessary to optimise the supply and demand situation, such as using energy pump for irrigation.

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1. Introduction

Microhydro Project (MHP) technology is the best technology to be developed in the area that has the potentials for microhydro power. Source of electrical energy with microhydro considered as clean technology to environment where the availability of water resources which to be supplied to power generator depends of the existence of the condition of the catchment areas. The catchment area is therefore well maintained (forest and environment).The diversity of microhydro technology can be integrated to the existing networks for the benefit of the society in developing activities for improving rural livelihoods and energy self-support.

For realizing the dream of the farmers to be able to continue producing throughout the year, it is necessary to get low-cost energy. One alternative source of cheap energy is the development of micro hydro power plant of Sono Irrigation at the groundsill (Opak river)

This study is a continuation of the technical feasibility study (FS) which has been declared eligible so this is a detailed technical report (Detailed Engineering Design / DED) to plan Development Program micro hydro power plant Irrigation Sono (Opak river) Parangtritis Kretek village in the district of Bantul Yogyakarta.

Figure 1. Pump and house of fasilities for flowing water from the opak river to the channels

The objectives of this Detailed design work is to conduct a study and analysis of the design criteria, detailed design, including pictures of construction, implementation schedule and project cost estimation and calculation of Volume of Work (Bill of Quantity)

2. Methodology

Location to be studied is one of the groundsill of (Sono Irrigation) Opak river in the village of Parangtritis, Kretek district of Bantul Yogyakarta, which is located around the coordinates of 7 ° 59 '02.27 "South latitude and 110 ° 18' 52.26" East longitude. At the location there is groundsill of Opak River for keeping stability of Parangtritis bridge.

Based on studies of hydrology, topography and altitude difference is obtained between the point plan the placement of turbines to the point of Weirs plan amounting to 2.5 meters (head) and debit is 2.5 m^3/s. calculation of potential energy of the Opak river water is as follows:

$$P = \rho \times H \times Q \times g$$

Where :

P = Power (kWatt)
ρ = Density (kg/m^3)
H = Head (m)
Q = Debit (m^3/s)
g = Gravitasi (9,81 m/s^2)

From the above equation, then the optimum debit on the results of analysis and head power potential of obtained by:

$$P = 1000 \text{ kg/m}^3 \times 2.5 \text{ m} \times 2.5 \text{ m}^3\text{/s} \times 9{,}81 \text{ m/s}^2$$
$$= 61{,}31 \text{ Kilowatt (KW)}$$

3. Results & Discussion

The detailed design covers the entire planning of the development scheme of potentials of microhydro (Opak River),village of Parangtritis Kretek District of Bantul Yogyakarta which have been technically studied not eligible so that details are needed to support feasebility detailed designs to be developed into a microhidro power plants (MHP).

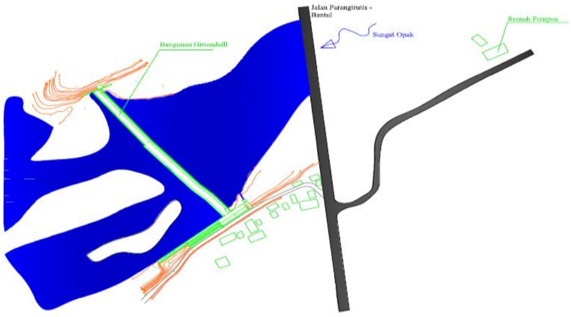

Figure 2. Profile of Sono Irrigation

Scheme MHP System

The Scheme and the system layout of microhydro development plan. The basic scheme described plans to drain river water towards intakeunit and flows the water, after being used in turbines. The layout should include technical and economic aspects.

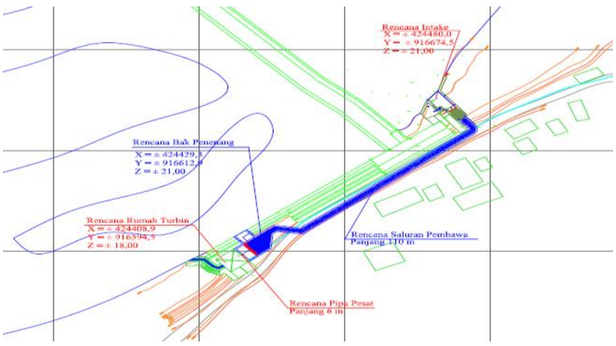

Figure 3. Scheme of MHP basic Design Sono Irrigation

The Detailed Design includes:

a. Civil Buildings
The design of the main civil building consisting of intake, headrace, forebay tank, penstock and the Powerhouse.

b. Electrical-Mechanical Facilities
The electrical-mechanical design consists of a turbine design, mechanical transmission , generators, control equipments/electrical support, electricity transmission network.

Civil Buildings

Detailed design of the main buildings include planning of civilian buildings required. the projects planned buildings are dam along with all the accessories, but in this case, they were not needed since they are already exist such as the groundsill, intake, channels, forebay precipitating and tranquilizers, penstock, turbine house.

a. Building Design of the intake

The Intake will be positioned close to the groundsill without changing the existing construction. Construction materials will be flood spillway for the reason of efficiency of materials and work efficiency, as well as to maximize the potential and natural resources that exist in the location of the project. From the analysis of the hydrological studies have obtained the design debit of 2.5 m3 / sec. While the flood level rises 2 feet of tree top level of the building. After being studied from various conditions and consideration, then the specified technical parameters intake as follows:

- Base Elevation intake: + 21.00 m
- High Wing Intake: 3.00 m
- Intake Front Width: 5.30 m
- Central Intake Width: 3.00 m
- Intake Edge Width: 1.80 m.
- Sluice (2 pieces): 1.20 m x 1.20 m

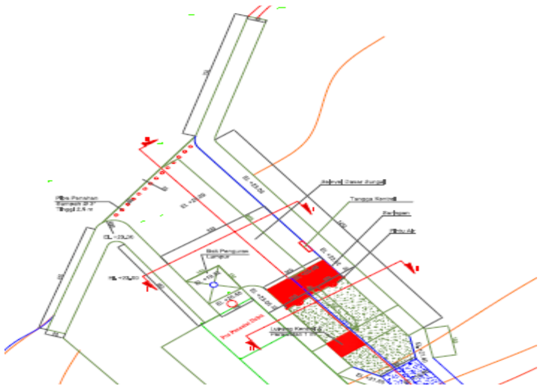

Figure 4. The width of the dam

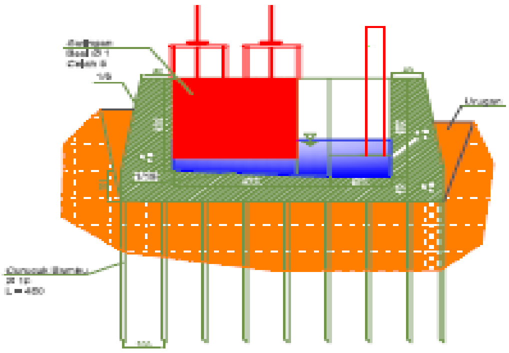

Figure 5. The width of the dam

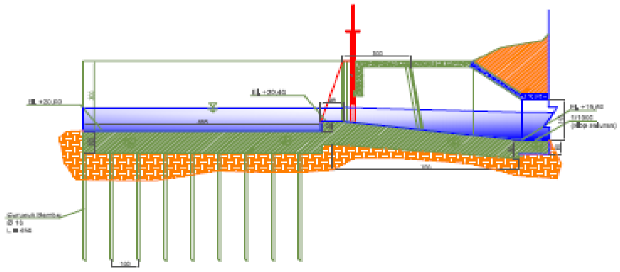

Figure 6. High Intake

b. Headrace

The position oh headrace will meet the situation contour of the land. The length of the headrace will meet the head . The design of headrace will be as close as possible to the power house for minimum of penstock to minimize cost. The design of headrace is based on topographical studies, hydrology, and geotechnical. Consideration can be described as follows:

- Headrace at the level of + 19.60 m above sea level with a decrease of 0.11 m high slope with channel length of 110 meters.
- Headrace is designed to drain as much water as 3.00 m3 / s.
- Headrace is designed as follows:
  - Width = 1.80 m
  - Into = 1.20 m
  - Front-free water level = 0.30 m
  - Length = 110 m
  - Slope / slope = 1/800

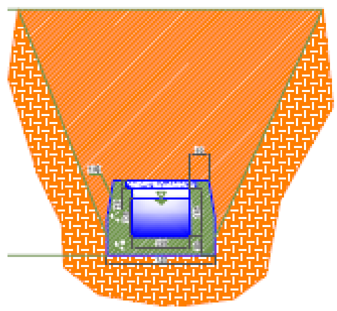

Figure 7. Headrace

When the bearer channel construction work requires a very large excavation work in the form of in land with 7 meters from the base of along the channel 110 meters. This is done to avoid the demolition of the building wing groundsill

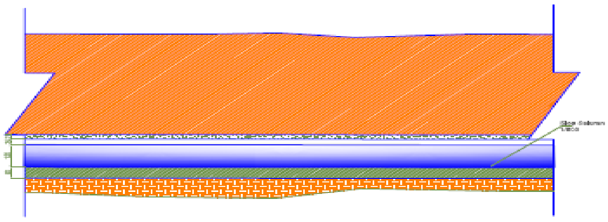

Figure 8. Long channels

c. Forebay

Forebay tank is used to deposit sendiment such as mud and sand which are carried in to the chanel, so that the water running into penstock. The forebay tank will be positioned as closed as posible to the power house to keep same level as the weir

The basic form of the tank will be sloped for eliminating turbulence and equipped with a spillway and drain door widths of 100 x 100 cm. The forebay thank will be 16.15 meters long consisting of transition 8.30 m long, 4.60 m long sediment and 3,250 m of length sedative. Depth slope of the carrier channel to a depth of 1.2 m of 3.25 meters.

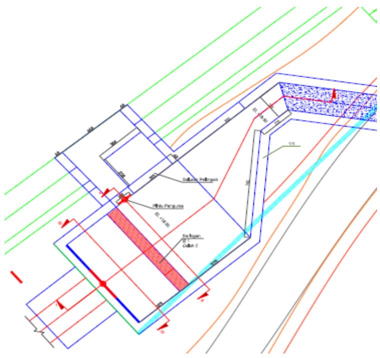

Figure 9. Forebay tank

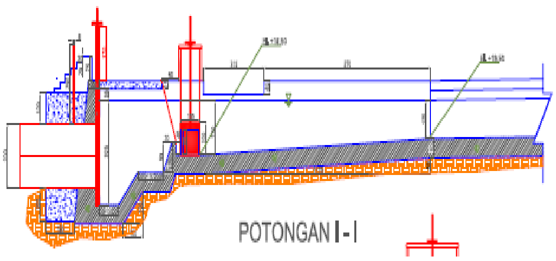

Figure 10. Forebay tank

d. Penstock

Penstock will be designed according to the water debit in to the turbine, the length of from the forebay to the power house and also the loads of water and pipe weight, hidrostatic and hidrodinamic preasure as well as water hamer.Considering topography aspec single penstock will be used with 5 meters long.

Special penstock to a low height difference using cross-sectional shape of a square-shaped pipe to optimize the potential of the existing height difference and in accordance with the calculation of the pipe cross-section measuring 200 x 200 cm for water flow of 3.0 m3 /s and pipe rapid transition from a square shape 200 x 200 cm to the diameter of 1.50 m according the turbine inlet diameter.

Penstock placement type design used is rapidly pipe surface, necessitating rapid pipe supports made foundation stone masonry plastered times 1 PC: 2 Ps. To maintain rapid pipe does not shift and turn it necessary archery called anchor blocks at each bend, construction anchors using cast concrete blocks.

The Microhydro design problem long expansion can be neglected because of this rapid pipes buried underground so it does not need to put the expansion joint.

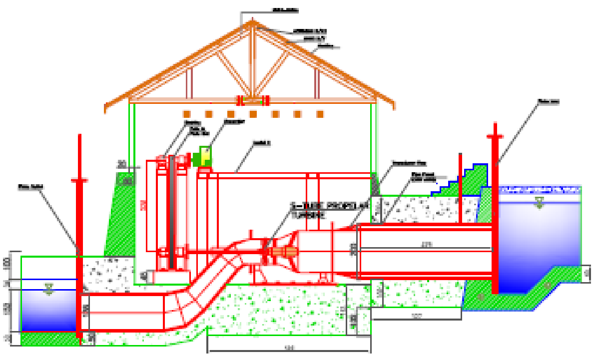

Figure 11. Penstock and power house

e. Powerhouse

The house was designed according to the condition, contour, geotechnical, the equipments that will be placed as well as the architecture of the building art. The position of the power hose should be above the level of flood water, for anticipating overflowed water of Opak river because inside the power house there are electricals components. The width of the power house will be of 7 X 8,5 meter. (Fig. 12)

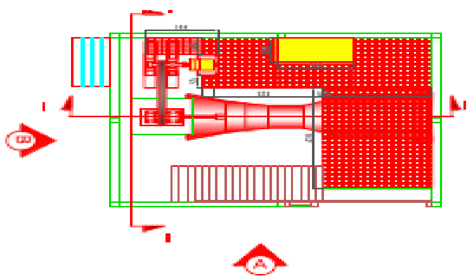

Figure 12. Powerhouse

Based on the data of flood that occurs every rainy season, the position of the ground floor will be damped, the 1st floor will be under water so that damages of mechanical transmision equipment can not be avoided. In can also, occurs in the second floor where the electrics equipments are kept.

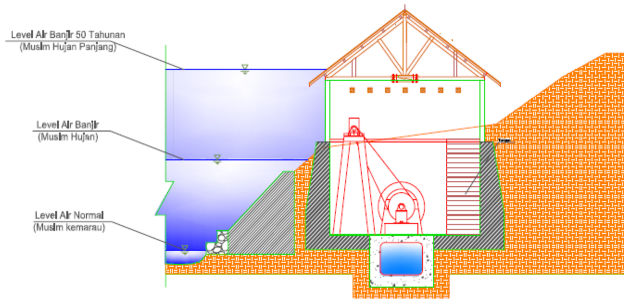

Figure 13. The position of the water level to the powerhouse

f. Spillway

To run the water that has been used by the turbine spillway of 13 meters long, 2 meters width and 1,2 meter of depth that will be positioned beneath the power house.

Mechanical and Electrical Facilities

a. The Turbine

Selection of turbine type is based on the water debit and planned heigh of water fall. Figure 14. shows that S-tube propeler and cross flow turbines for they can work on height difference of 2,5 meter.

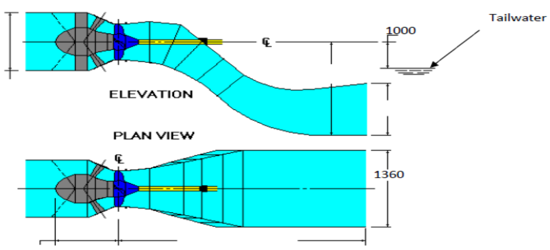

Figure 14. S-Tube Turbine Propeller

Based on these considerations, the turbine can not operate all year round will even to water in wet weather conditions so as not worthy of aspects of turbine selection.

In determining the amount of the turbine unit to be used is based on an analysis of:

- Flow Duration Curve
- Energy Needs
- Part Load Operation (Operating Expenses Part)
- Construction Unit Cost
- Optimization of potential

Selection of the number of units of flow duration curve turbine to affect the magnitude of the minimum and maximum discharge flow. Based on the discharge of 2.5 m3 plan /s of discharge plan this Kaplan turbine performance, then the number is 1 unit.

Turbine performance has associated with waking design and manufacturing capabilities. Currently turbine manufacturing capabilities that Indonesia still lags behind the manufacturing of industrial countries but must have the courage to make this turbine as a first step in the technological development of Indonesia which was designed by the son of the nation. As a first step the performance of Kaplan

Turbine Type /turbine spiral is its efficiency of 70% (Indonesia Product).

Considering the planned debit and effective high level the dimensions and characteristics of the turbine are as follows :

Table 1. S-tube propeler turbine

S-TUBE PROPELER TURBINE		
Generated power	46	kW
Turbine	1	unit
Unit capacity @ 100%	46	kW
Unit capacity @ 115% Overcapacity	48	kW
Shaft speed	250	Rpm
Runner centerline to TW	1000	mm
Inlet width	2060	Mm
Runaway speed	757	Rpm
Runner diameter/ pitch diameter	909	mm
Runner blade qty	3	Blade
Draft tube	Straight	
Exit width	1910	Mm
Exit height	1360	Mm
Length	4360	Mm
Estimated weight	1100	Kg

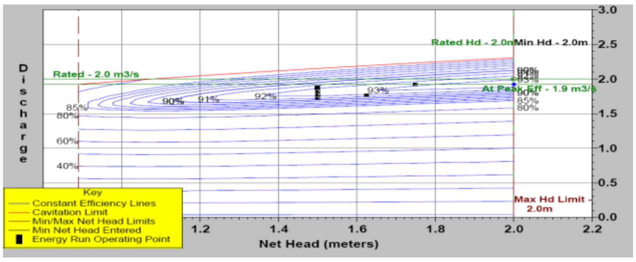

Figure 15. Characteristics of S-Tube Turbine Propeller

b. Mechanical transmision system / Pully

Mechanical transmission system is used to change turbine of round in accordance as the ones in generator. Generator used 1500 rpm and turbine rounded will be of 250 rpm . The needed pulley are as follows :

Table 2. The mechanical transmission system

No	Description	Symbol	Value	Unit
1	Comparison of round turbine &generator	n	6.0	
2	Driven pulley diameter Generator	d1	200	mm
3	Driven pulley diameter Turbine	d2	1200	mm
4	Arc of contact on smaller pulley	b	164	0
5	Center distance*	e	3814	mm
6	Belt speed	V	15.707	m/s
7	Peripheral force to be transmitted	Fu	3354	N
8	Load factor**	c	1.10	-
9	Max peripheral force to be transmitted	Fumax	3689.7	N
10	Specific peripheral force to be transmitted***	F'u	27	N/mm
11	Basic belt tension****	E	1.75	%
12	Belt supply width	bo	136.657	mm
13	Belt pully width	b	156.657	mm
14	Geometrical belt length	L	9826.07	mm

c. Power Capacity

Based on design flow and the effective height difference, dimensions and characteristics of the turbine, generator and transmission system, the power capacity that can be generated by this microhydro

Table 3. Power Capacity

No.	Description	Symbol	Value	unit
1	Gross Head*	Hg	2.5	m
2	Total losses	ht	0.11	m
3	Net Head	2.39		m
4	Volume Flow	Q	3.000	m^3/s
5	Gravity constant	g	9.81	m/s^2
6	Net hydraulic power potential	Pw	70	kW
7	Turbine effeciency**		0.7	-
8	Turbine's shaft output power	Pt	49	kW
9	Mechanical transmition effeciency***		0.97	-
10	Mechanical Power transfered to Generator	Pd	48	kW
11	Generator effeciency****		0.86	-
12	Electric power generated	Pel	**41.02**	kW

Based on the calculation above that which can be generated by the turbine at 41.02 kilowatts.

d. Generator

Selection of the appropriate type generator with microhydro capacity is kind of synchronous generator with excitation alone has the horizontal axis. Induction generator is not suitable because of the lack of availability of a number of other synchronous generators in the distribution network to supply reactive power of the induction generator. Selection of the generator capacity should be adjusted with a commercially available generator. Based on the availability of generators on the market are as follows

Table 4. Selection of Generators

No	Description	Symbol	Value	unit
1	Type : Syincronous Generator			
2	Rating Power (estimate)		51.3	kVA
	Rating Power (market)	peak	68.0	kVA
3	Power Factor	Pf	0.80	
4	Voltage Star connection/Delta	V	380/220	V
5	Frequence		50	Hz
6	Speed		1500	rpm
7	Phase		3	

e. Controlling systems

Design of controlling water flowing into the turbine as being planned. This methode will manage the usage of electrical power by controlling the debit into the turbine.

f. Distribution system / network transmission electical

Technical aspects of the planning system distribution is the safety factor for the environment (power pole height 7 meters) and power quality remains good dikonsumen specified standards (220 volts and 50 Hz). Distrubusi system / network MHP will use the low voltage network with a voltage of 380/220 V, cable twister 4 x 35 mm2, iron pole 7 meters which is equipped with fixed bracket, suspension, steinles strip plate, double-bolt connector.

Plan cost

Financing needs and schedule of construction activities micro hydro power plants this. Detailed design recommendations to be a reference in the calculation of the financing needs and the MHP's development schedule. The calculation of the cost is calculated based on the unit price multiplied by the volume of work these jobs. (Assumption 1 USD = Rp 12,500). Based on the volume of work in development of micro hydro power plants is need processing time for 8 months of the calendar

Table 5. Global Cost Needs

NO		DESCRIPTION	SUB TOTAL	TOTAL
			Rp	**Rp**
I		FEASIBILITY STUDY AND ENGINEERING DESIGN DETAILS		
II		CONSTRUCTION MHP		
	1	JOB PREPARATION	23,532,925.69	
	2	CIVIL WORKS	1,640,398,505.90	
	3	MECHANICAL AND ELECTRICAL WORK	455,000,000.00	
	5	TRANSMISSION WORK	66,375,000.00	
		Total I		**2,185,306,431.58**
II		SUPERVISION AND KOMISONING (4%)	87,412,257.26	
		Total II		**2,272,718,688.85**
III		Tax (PPN 10 %)	227,271,868.88	
		Total III		**2,499,990,557.73**
		Grand Total Rp		2,499,990,558
		Rounded **Rp**		**2,500,000,000**

4. Conclusion

Microhydro power plant (MHP) of Parangtritis is expected to be a solution in supplying power to the pumps to raise water from the Opak river into the irrigation canals for the needs of irrigating the farm lands of the village of Parangtritis. Engineering design of micro power plants Details preceded by a feasibility study in the form of secondary data collection, field surveys (topographical, geotechnical, hydrological and social, analysis and calculation. From the results of hydrologic calculations, it can be seen that the optimal design flow, which amounted to 2.5 m3 / sec and head 2.5 m maka potensi daya mikrohidro 61.31 KW

With the effective height of 2.3 m, then the MHP can generate power of 41.02 kilowatts. In hydrology, technical, non-technical and plant financing is feasible, but in terms of laying topography, theMHP scheme is not good because of the location of the turbine house was flooded to the base floor of the house. It will make the turbine and its components be under water so that the layout of the house is not feasible.

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