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Feasibility study of the Kerinci 350 MW hydro power plant

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ABSTRACT

The demand for electricity is currently growing rapidly. In accordance with the government's policy to optimize the use of renewable energy sources, including water, by constructing a hydroelectric power plant. The study of the potential utilization of the Batang river flow is aimed at how much of the optimum electric power potential there is in the utilization of the Batang Merangin river flow as a hydropower plant. The results of the calculation of the potential for electric power at the Kerinci PLTA show that the optimum electrical power that can be generated is 366.27 MW and the energy produced annually is 1,443.86 GWh. The cash flow of the Kerinci hydropower project consists of technical estimates, revenues, operating and maintenance costs, inflation, taxes, and depreciation. Benefit-cost ratio analysis is calculated according to probable economic conditions during construction and lifetime. The initial investment cost for the Kerinci hydropower plant is around 12,922,000,000,000. The net present value obtained is 423,372,934,373, the internal rate of return is 10.7%, the return on equity is 16.2 years and the benefit-cost ratio is 1.2. The results show that the Kerinci hydropower plant can be built in terms of both technology and money.

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1. INTRODUCTION

Utilization of new and renewable energy (RE) in Indonesia until 2020 has only reached 15% which is used as a source of electrical energy by PLN [1]. To achieve a 23% renewable energy mix by 2025, the government is aggressively building renewable energy-based power plants. One of the utilizations of new and RE is hydro power plant. The potential energy generated if the Kerinci hydropower plant with a capacity of 350 MW is built is 1287.7 GWh per year [2].

The Kerinci hydropower plant is designed as a run-of-river, whose operation is adjusted to the river's water discharge. One of the advantages of run-of-river is that there is no need for a giant reservoir like a reservoir type power plant. Because it utilizes the existing water flow, the run-of-river system only requires a daily pond [3]. This run-of-river system requires proper water management so that the flow of water flowing is sufficient to drive the turbine but does not make the downstream area dry or flooded [3].

There are 3 categories of hydro power plants, namely: reservoir, run-of-river, and pumped storage [4]. There are 2 main cost components for hydropower projects, namely: civil works and electromechanical equipment [5]. The working principle is to convert potential energy into kinetic energy which rotates a turbine to produce electricity [6]. Hydroelectric components consist of several parts, namely: dam, reservoir, intake gate, surge tank, penstock, and tailrace [7]. There are 3 types of water turbines, namely: pelton turbines, Francis turbines, and kaplan turbines [8].

In conducting the simulation and analysis of the project feasibility study whether the project is feasible or not, there are several indicators as follows, namely: the value of IRR, NPV, and Payback period [8]. If the NPV value > 0 means that the project is feasible to work on and vice versa [9]. The higher the IRR value, the more profitable it is for the company [10]. If the B/C ratio is > 1 then the project is feasible to work on and vice versa [11].

2. RESEARCH METHOD

In this study, a survey was conducted to the location of the hydropower project in Batang Merangin district, Kerinci pegency, Jambi province, which is about 350 km from the city of Jambi or about 380 km from the city of Padang. The study used RETscreen expert software. RETscreen clean energy project analysis software is a feasibility study tool to evaluate energy production, life cycle costs, and greenhouse gas (GHG) emission reductions for various renewable energy technologies. The RETscreen offers a proven methodology that focuses on pre-feasibility and feasibility studies, rather than developing a specially developed methodology [12]. In this study, the RETscreen modeling tool was used for feasibility analysis [13], [14]. This model evaluates energy production from various clean and renewable technologies including life cycle costs and reduced greenhouse gas (GHG) emissions [13]–[17]. In addition, RETScreen provides an integrated project financial analysis, sensitivity analysis, and risk analysis to determine the financial feasibility and risks of a project [15], [17]–[19].

Figure 1 describes the five steps in completing the feasibility study analysis model: energy model, greenhouse gas emission reduction analysis model, financial analysis model (FAM), and sensitivity and risk analysis model (SRAM) [20]. FAM includes pre-and post-tax cash flows, debt payments, income taxes, asset depreciation, and financial feasibility indicators, while SRAM includes impact charts, Monte Carlo simulations, validation of risk analysis models, and medians and confidence intervals [14], [17].

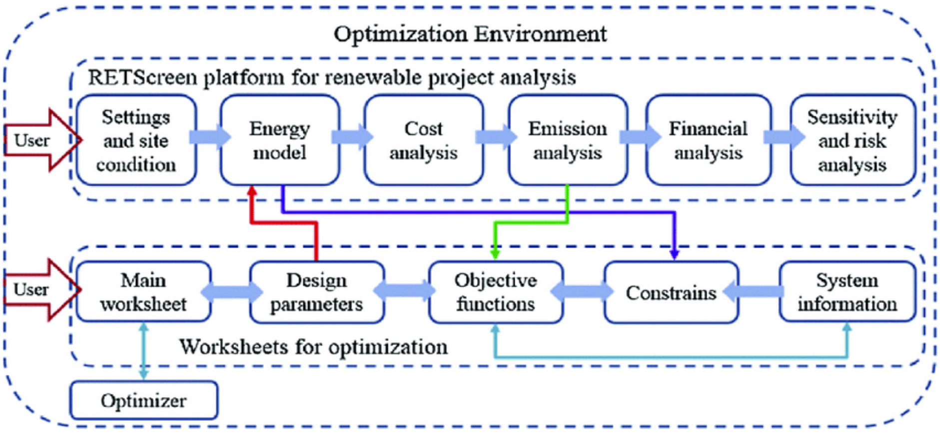

Figure 1. RETScreen flowchart

2.1. Design of Kerinci hydro power plant

In the upper reaches of the Batang Merangin river, namely Lake Kerinci, a water arrangement called the Regulating Weir was built which functions to divide water from Lake Kerinci which will be channeled partly to hydropower and the rest to maintain the lake's ecosystem. Figure 2 shows the design of the part of the regulating weir that will be installed in Lake Kerinci. The water that flows through the regulating weir will then be accommodated in a reservoir (dam). Some of the water in the reservoir will flow into a tunnel that has been built under the Bukit Barisan to be used as a power plant and to drive a turbine. Figure 3 shows the design of the reservoir and tunnel under the Bukit Barisan.

After that, the water flowing through the tunnel will flow through the penstock and the water will go to the powerhouse where hydropower is used to drive a water turbine and generate electricity. Figure 4 shows the tunnel design to the hydropower powerhouse. After the water turbine moves and produces electricity, it will then be flowed to a power transformer and increase the resulting voltage from around 13.8 kV to 150 kV. Then the electricity generated by the PLTA will be sent to the Sungai Penuh and Bangko Substations via the 150 kV Bangko–Sungai Penuh Kerinci transmission line which will later be distributed to increase Sumatra's electricity supply.

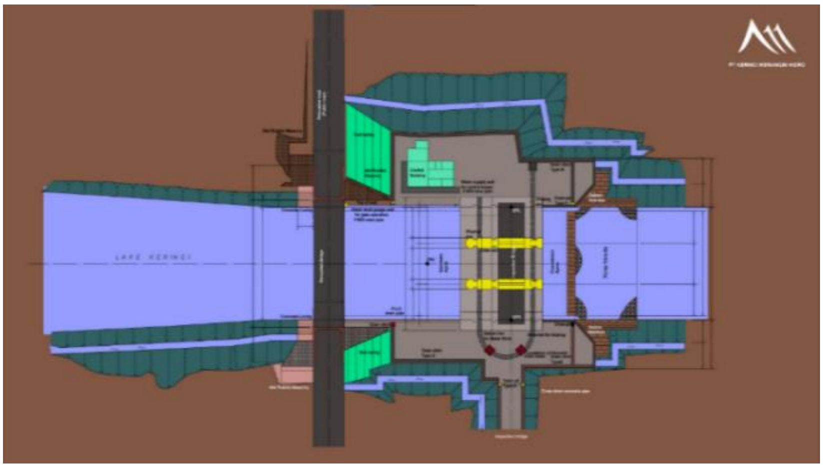

Figure 2. Regulating weir design to be installed in Kerinci lake

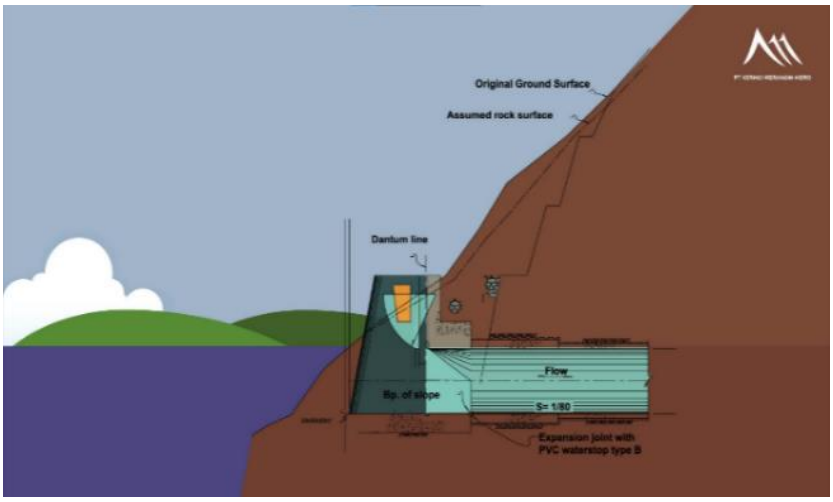

Figure 3. Reservoir and tunnel design under the Bukit Barisan

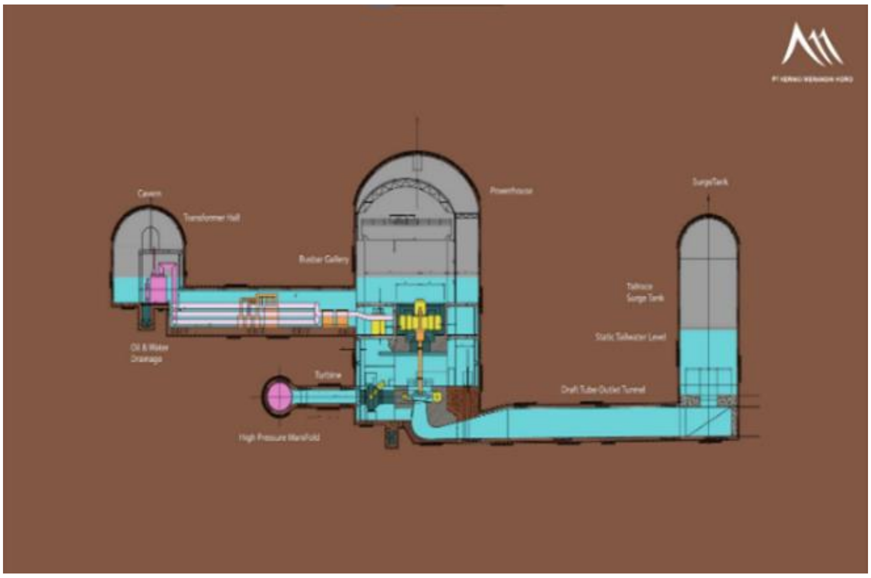

Figure 4. Power house design

3. RESULTS AND DISCUSSION

3.1. Technical aspects

3.1.1. Kerinci hydropower components

The Kerinci hydropower project consists of several main parts, namely regulating weir, intake dam, water way, powerhouse, penstock, tailrace, transmission network, and substation. For hydrology, The Kerinci hydropower has two water catchment areas, namely in the upstream area of Lake Kerinci covering an area of 1053 km^2 and located between the regulating weir and the intake dam covering an area of 353 km^2, so that the total catchment area is 1406 km^2. The surface area of Kerinci lake is 44.29 km^2 and is 75% of the entire Kerinci hydropower catchment area. With a lake capacity of 1.7 billion m^3, Kerinci lake can be used to regulate water flow and routes during peak loads.

Regulating weir is located in Kerinci Lake. The normal water level elevation is 784.50 m and the discharge in the regulating weir (P = 95%) is 11.35 m^3/s. With the construction of the regulating weir, the active volume of Lake Kerinci is 9190 m^3. The spillway is designed based on the MPF discharge of 130 m^3/s. To increase the ability of Lake Kerinci to withstand flooding, the outlet area will be deepened and the downstream river regulating weir will be deepened. With this action, the normal elevation of the lake will be 783.40 m and the dead storage elevation will be 781.40 m.

The intake dam is a concentrate gravity dam and is located downstream of the regulating weir with a water storage area of 353 km^2. The flow in the dam (P = 95%) was 24.80 m^3/s. The volume of the reservoir formed upstream of the dam is 1,650,000 m^3. The spillway has two arc-type doors with an energy dissipator type in the form of bottom flow energy dissipation. The intake dam is located 50 m upstream to the left of the dam with a flow of 99.2 m^3/s. Figure 5 shows the shape of the hydropower intake dam.

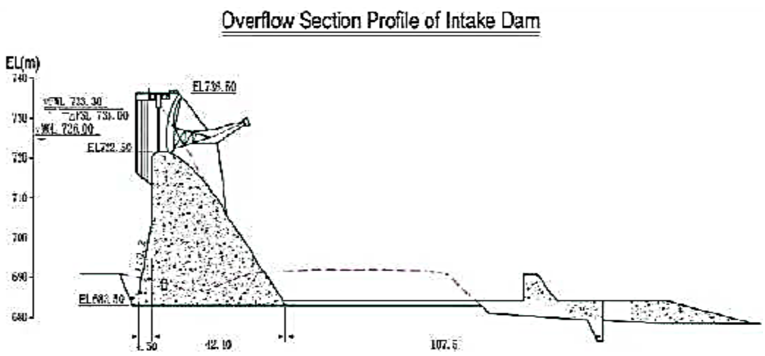

Figure 5. Intake dam

The waterway for the Kerinci hydropower consists of a headrace tunnel, a surge shaft, and a penstock. The headrace is a tunnel with a length of 7,260.1 m with a diameter of 5.62 m. The elevation of the surge shaft with the crest is 758 m, the highest point is the surge water level is 753 m and the lowest point is the surge water level is 708 m. The length of the penstock is 581.4 m with a slope angle of 55° and a diameter of 5 m. The inlet invert elevation is 596 m and the invert end elevation is 312 m. Under normal conditions, the water pressure in the penstock is 3.9 Mpa.

The Kerinci hydropower powerhouse is an underground powerhouse located at a depth of 320 m in metamoIDRhic rocks. In it are installed 4 sets of generator units at an elevation of 312 m with an installed capacity of 350 MW and will produce annual energy of 1287.7 GWh. In the powerhouse, there is an across tunnel of 1.6 km, a come-and-go tunnel of 878 m, and an end tunnel of 224 m. The powerhouse and switchyard will be connected by a 262 m long shaft.

The tailrace structure consists of a tailwater tunnel and a tailrace surge chamber. The length of the tailwater tunnel is 3,149.40 m with a diameter of 5.62 m. The inlet elevation is 313.15 m and the outlet is 310 m with an internal pressure of 0.15 Mpa during operation. The tunnel is lined with concrete. The tailrace surge chamber is located 50 m downstream of the powerhouse and is constructed between the tailwater inlet and tailwater pipe with impedance type and upper chamber.

3.1.2. Water debit data

Water debit data is one of the important components to find out how much potential electrical energy is produced by hydropower. Water debit data is taken using data from the nearest water station which is considered representative. In Table 1, the Batang Merangin river water discharge data is taken from the Tamiai water post data for 2018-2019.

3.1.3. Precipitation data

Precipitation data is one component to find out how much water potential will be accommodated in hydropower plants as a source of water for power plants and as raw water. Precipitation data were taken using data from the Kerinci meteorological and climatological agency station and NASA. Table 2 is the rainfall data taken from the Kerinci meteorological and climatological agency data for the last 5 years.

Table 1. Average monthly debit (m^3/s) Batang Merangin river

Monthly average debit (m^3/sec)		
Month	2018	2019
January	239.8	242.5
February	287.5	301
March	426.8	450.5
April	226.6	233.9
May	250	262.1
June	197.1	192.9
July	130.7	126.3
August	108.6	111.7
September	262.4	265
October	299.4	294.9
November	163	170.5
December	173.9	178.2

Table 2. Precipitation data in Kerinci 2016-2020

Month/Year	Precipitation (mm^3)				
	2016	2017	2018	2019	2020
January	141	37.7	89.5	268	174.2
Februari	203.2	281.9	250	217.6	154
March	132.6	283.6	199.7	323.4	197.5
April	101.5	191.8	240.2	222.2	180
May	283.2	154.7	129	265.1	130.2
June	91.5	38.7	174.9	197.5	112.2
July	95.2	122	54.5	25.5	117.8
August	121.1	104.2	37.8	90.8	106.3
September	136.7	136.7	150.8	136.7	146.4
October	183	145.1	94.8	183.2	199.6
November	202.9	259.1	118.7	207.8	229.2
December	114.8	297.4	342.5	43.4	198.4
Average	150.6	170.9	156.9	181.8	162.15

a. Electrical power potential

Electrical power can be generated using equation (1) [7]. The discharge is obtained from the average discharge of the Batang Merangin river a year with a potential discharge for hydropower of Q= 99.2 m^3/s, with a waterfall height of H= 123 m, the number of generators = 4, capacity factor CF = 45%, turbine efficiency = 0.85 and generator efficiency = 0.9. Thus, the electrical power that can be generated is:

$$P = k \times H \times Q \times \eta \text{ turbin} \times \eta \text{ generator} \times 4 \quad (1)$$

So, P = 9.81 × 123 × 99.2 × 0.85 × 0.9 × 4 = 366,274.95 kW = 366.27 MW. Then, to calculate the annual energy production at the hydro power plant can be calculated by the following formula (2).

$$E = P \times 365 \times 24 \times CF \quad (2)$$

So, E = 366.27 × 365 × 24 × 0.45 = 1,443,856 MWh = 1,443.86 GWh

The electrical power that can be generated is 366.27 MW and the energy produced annually is 1,443.86 GWh.

b. Financial aspect

Table 3 shows the technical and financial assumptions used for the following financial analysis. To find out how much is the estimate and details of the initial costs for the Kerinci hydropower project, the author consulted directly with the finance department of PT. Kerinci Merangin Hydro is related to some financial data of the Kerinci hydropower plant. The details of the financial data of the Kerinci hydropower plant are summarized in Table 4.

The project cost is one of the important components in determining how much budget allocation should be spent on the project. The following are the cost components of the Kerinci hydropower project which are summarized in Table 5. From Table 5, it can be seen that the largest component cost in the construction of the Kerinci hydropower project is civil construction, which is around 30% of the total project cost and the cost of electrical and mechanical equipment is around 9% of the cost of the hydropower project.

3.3. Calculation results and simulation analysis

The financial analysis in this Kerinci hydropower research used a simulation from the RETScreen Expert software by entering the assumption data and financial data of the Kerinci hydropower plant into the simulation. The results of the simulation are shown in Tables 6 and 7. From the results of the financial simulation of the Kerinci hydropower plant using RETScreen, the total cash collected for 30 years is IDR. 23,632,170,721,418. With the construction of a hydropower plant, the energy production cost is IDR. 1,277/kWh. For the NPV value in the financial analysis of the Kerinci hydropower plant, it is IDR.

423,372,934,373, the IRR value is 10.7% and the B/C Ratio is 1.2. The simulation results show NPV > 0 which means that the construction of the 350 MW PLTA Kerinci provides benefits and benefits for the company. In addition, the results of the B/C Ratio > 1 indicate that this project is feasible to work on. In addition, within a period of 16.2 years is required to recoup the expenditure of the initial investment. Figures 6 and 7 show a graph of the cash flow of the Kerinci hydropower plant.

Table 3. Mainassumption

No	Assumption	Value	Description
1	Average Inflation Rate/year (%)	1.68%	Source: www.bi.go.id may 2021
2	Exchange rate, US$/IDR (Middle Rate)	14,300	Source: www.bi.go.id may 2021
3	Capacity (MW)	350	
4	Power generated/year (GWh)	1,287,7	
5	Hydropower Operation Hours / day	6 hours	
6	Capacity Factor (CF)	45%	Source: PT. Kerinci Merangin Hidro
7	BPP Sumsel, Jambi, Bengkulu (S2JB) (IDR/kWh)	1,061	Source: Decree of the Minister of Energy and Mineral Resources of the Republic of Indonesia No. 55 2019

Table 4. Kerinci hydropower financial data

No	Parameter	Value	Description
1	Initial Investment Fee	IDR 36,920,000	IDR / MW
2	O&M Fee	3%	from initial investment cost
3	Electricity Price	7.45	US$ ¢ / kWh
4	Discount Rate	10%	
5	Debt Ratio	80%	
6	Benefit Cost (B/C)	1.2	
7	Component C (Water Fee)	6	US$ ¢ / kWh
8	Bottom-Up Hydropower	10.75	

Table 5. Kerinci hydropower project cost

No	Component	Cost (US$)	
1	Prepatory Works	$	25,394,063
2	Civil Works	$	265,417,659
3	Metal Works	$	42,654,796
4	E&M Equipment	$	81,694,778
5	Transmission Line & Substation	$	45,365,906
6	Remote Monitoring System	$	8,946,663
7	Consulting Service	$	70,398,487
8	Environment	$	9,037,033
9	Administration	$	27,472,580
10	Tax (VAT)	$	57,656,271
11	Contigency	$	181,553,993
	Direct Cost (1-6)	$	469,473,864
	Subtotal (1-11)	$	815,592,228
12	Interest during Construction	$	88,111,072
	Total	$	903,703,300

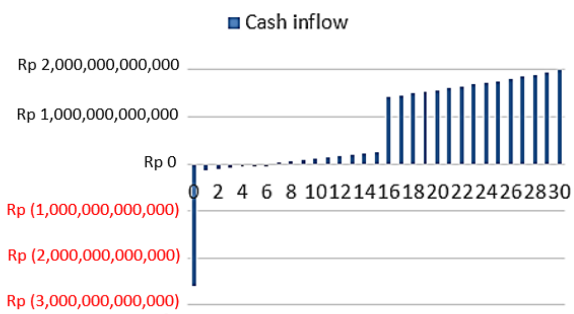

Figure 6. Graph of cash inflows for the Kerinci hydropower plant

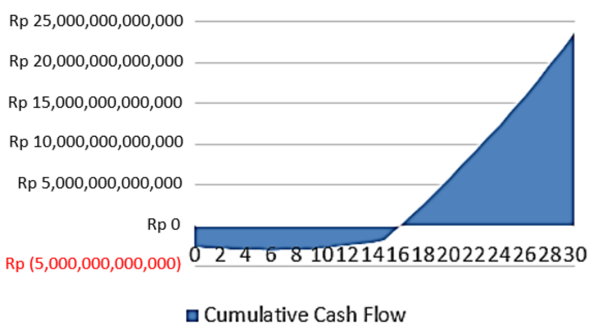

Figure 7. Graph of cumulative cash flows for the Kerinci hydropower plant

Table 6. Simulation results of the Kerinci hydro power plant financial analysis

	Parameters	Value
Annual income	Electricity generated (GWh)	1287.7
	Electricity Price (IDR/kWh)	1,061
	Income	IDR 1,366,270,920,000
	Electricity increase rate	2.2%
GHG reduction	Gross GHG reduction (tCO2/year)	971,675
	Gross GHG reduction - 30yrs (tCO2)	29,150,243
Total cost and revenue	Initial Investment Fee	IDR 12,922,000,000,000
	O&M Fee	387,660,000,000
	Income	IDR 1,366,270.920.000
	Simple Payback (year)	13.2
	Equity Payback (year)	16.2
	IRR	10.7%
	NPV	423,372,934,373
	Annual life cycle saving (IDR/year)	44,911,082,609
	Benefit-Cost (B/C) ratio	1.2
	GHG reduction cost (IDR/tCO2)	46,220,28
	Energy production cost (IDR/kWh)	1,277

Table 7. Kerinci hydro power plant cash flow

Year	Cash Inflow (IDR)	Cumulative Cash Flow (IDR)
0	-2,584,400,000,000	-2,584,400,000,000
1	-132,856,720,069	-2,717,256,720,069
2	-108,759,585,862	-2,826,016,305,931
3	- 84,097,879,777	-2,910,114,185,708
4	- 58,858,602,725	-2,968,972,788,433
5	- 33,028,459,919	-3,002,001,248,352
6	- 6,593,854,205	-3,008,595,102,557
7	20,459,120,757	-2,988,135,981,800
8	48,144,87,463	-2,939,991,294,337
9	76,477,391,694	-2,863,513,902,643
10	105,472,109,801	-2,758,041,792,842
11	135,144,056,154	-2,622,897,736,688
12	165,508,790,761	-2,457,388,945,927
13	196,582,227,055	-2,260,806,718,872
14	228,380,639,856	-2,032,426,079,016
15	260,920,673,510	-1,771,505,405,506
16	1,429,232,262,523	- 342,273,142,983
17	1,463,306,990,828	1,121,033,847,845
18	1,498,175,574,348	2,619,209,422,194
19	1,533,856,220,645	4,153,065,642,839
20	1,570,367,550,326	5,723,433,193,164
21	1,607,728,606,339	7,331,161,799,503
22	1,645,958,863,479	8,977,120,662,982
23	1,685,078,238,103	10,662,198,901,085
24	1,725,107,098,066	12,387,305,999,151
25	1,766,066,272,880	14,153,372,272,031
26	1,807,977,064,092	15,961,349,336,123
27	1,850,861,255,909	17,812,210,592,032
28	1,894,741,126,046	19,706,951,718,078
29	1,939,639,456,824	21,646,591,174.902
30	1,985,579,546,516	23,632,170,721,418

4. CONCLUSION

Based on the calculation, the optimum electric power potential in the utilization of the Batang Merangin river as a hydropower plant is 366.27 MW and the energy produced annually is 1,443.86 GWh. Judging from the technical aspects of the Kerinci 350 MW hydropower plant, the Kerinci hydropower plant is worthy of being built because the Kerinci climate is very wet, the average water discharge is quite high, namely 368 m3/sec, the rainfall is quite high, around 150.6 mm, the capacity factor is 42%, the bottom-up of hydropower is 10.75, and the energy produced per year is around 1,287.7 GWh. The life of the equipment and the use of hydropower as a generator is also long, with a minimum of 30 years and even up to 100 years. Judging from the financial aspect of the 350 MW Kerinci Hydropower Plant, the Kerinci Hydropower Plant is worthy of being built because the NPV value is > 0, the IRR is 10.7%, the B/C Ratio value is > 1, and the equity payback is 16.2 years. Compared to the BPP value of South Sumatra, Jambi, and Bengkulu (S2JB), which is IDR. 1,061/kWh with a difference of IDR. 216/kWh.

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