Technical and financial analysis of a mini-hydro power plant
2x500 kW Bandung Regency, Indonesia

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Abstract. The new regulation of Indonesia Energy and Mineral Resource Minister PERMEN ESDM 50, 2017 changed the tariff of mini-hydro power plant in the Bandung Regency from Rp. 1,200/kWh to Rp.850/kWh. Although the tariff change, the regulation is going to be build owned after 20 years. It needs investment recalculation according to the new tariff. The technical studies show the potential electrical energy and the turbine’s type. The financial analysis provided the feasibility of the project used IRR, NPV, and Payback period method. The variable used is the EPC cost of some turbine brands and civil work. This paper informed that the project is feasible for investment and construction. The results of the calculation are IRR 9.69%, NPV Rp. 8,373,579,334 and the Payback period 7 years and 9 months.

1. Introduction
Electricity ratio in the Bandung Regency is 95.2% [1]. Electricity demand in this area is high. Although, it consists of the rural area but every village already connected to electricity [2]. The long rainy season and cascaded nature induced some streams for hydropower [3]. Hydropower is the one of renewable energy uses natural water to electricity. Water flows through the hydraulic turbine as the prime mover of the generator. Hence, the generator produces electricity to the load [4]. Hydropower is one of the highest efficiency among other renewable energy. The Efficiency of hydropower plants approximately 60-90%. Economic analysis of the micro hydropower plant shown the lowest payback period than solar and wind power plant [5].

Energy and Mineral Resource Minister Regulation PERMEN ESDM 19, 2015 informed that tariff of mini-hydro which connected to Medium voltage line about 9.3 cent $/kWh equals Rp. 1,242 /kWh [6]. The tariff of mini-hydro power plant connected to Low Voltage line with capacity up to 10 MW is 12 cent USD/kWh for the first year until 8th year, and 7.5 cent USD/kWh for 9th year – 20th year [7]. However, the new regulation PERMEN ESDM 50, 2017 stated that the tariff became consideration from PLN as a buyer and Investor as Seller [8]. The tariff of the mini hydropower plant in Bandung Regency is Rp. 850/kWh for the first year until 8th year and Rp.531/kWh for 9th year – 20th year.

In this study, the technical and financial studies proposed the investment feasibility of the plant after the tariff decreased. Micro hydro is an interesting energy because renewable, clean, and efficient. The development of new renewable energy in the developing country reduced environmental degradation and climate change. Among positive issues are the increase of live quality, road connection, tourism and environmental concern [9]. The advantages of micro-hydropower plants are so many and the negative issues are the distinct of biodiversity, water contamination, river flow excavation for sand or rock, and the threat of stealing generating systems [10].
The result of the financial study of this project is economically justified. The method used IRR, NPV, and payback period calculation. The result of the calculation is IRR 9.69%, NPV Rp. 8,373,579,334 and the Payback period 7 years and 9 months for the turbine “A”.

2. Methodology

2.1. Technical study
The reason for study in the Pangalengan, Bandung Regency because there is a lake with the existing hydropower plant. The spillway could be used as electrical energy. The power calculation can be calculated by flow rate, the density of water, height of fall, and gravity [11]. To simplify the calculation, the mini hydro power plant potential can be measured by the debit and height [7]. The flow rate and height measured from the survey. The collected data used as a reference for turbine selection in the discussion section.

2.2. Financial study
The financial calculation used IRR, NPV and Payback Period method from 2x500 kW mini-hydropower plant in Bandung Regency. The interest rate is important to calculate money’s value in the future. If the money’s value in the future more than investment, it is profitable (the project is accepted) [7]. The variables of the calculation are EPC cost regarding many turbine manufacturers and civil work price.

3. Result and discussion

3.1. Technical analysis
The location of Minihydro Power Plant in the Spillway of Situ Cileunca, Bandung Regency. The technical data measured are shown in Table 1.

| Description             | Remarks                      |
|-------------------------|------------------------------|
| Location                | Wanasari and Pulosari Village|
| Water Source            | Situ Cileunca                |
| Area of rain catches    | 12.7 km²                     |
| Debit                   | 2x1500 liter/second          |
| Height (Netto)          | 41 meter                     |
| Power Estimation        | 2 x 500 kW                   |

The data show, the height is 41 meter and the debit is 2x1500 liter/second. This data refers to medium height and debit. The turbine characteristic graph of the medium height and flow rate is francis type.
Figure 1. Application fields of water turbines with respect to height [12].

Francis turbine is the middle class of Kaplan and Pelton. Kaplan turbine characteristic is low height (up to 40 m) and high flow rate. Otherwise, the Pelton turbine characteristic is high height (>100 m) and low flow rate [12-14]. The Output of francis turbine according to height 41 meters and flow rate 2x1500 m³/s is shown in Table 2.

Table 2. Power output of francis turbine [13].

| Percent of nominal flow (%) | 60   | 70   | 80   | 90   | 100  |
|-----------------------------|------|------|------|------|------|
| Turbine Eff (%)             | 89.1 | 91.4 | 92.5 | 92.2 | 90.7 |
| Generator Eff (%)           | 95   | 95   | 95   | 95   | 95   |
| Flow rate (liter/s)         | 900  | 1050 | 1200 | 1350 | 1500 |
| Design Height (m)           | 41   | 41   | 41   | 41   | 41   |
| Turbine Output (kW)         | 318  | 381  | 441  | 494  | 540  |
| Generator Output (kW)       | 303  | 362  | 419  | 470  | 513  |

Turbine power output 2x500 kW can be achieved regarding Table 2.

3.2. Financial analysis

Financial study to calculate the investment of minihydro Power Plant 2x500 kW used new tariff Rp.850/kWh for the 1st year – 8th year and Rp. 531/kWh for the 9th year -20th year. The fix variable is Interest rate, Capacity Factor (CF), Equity percentage and other variables show in Table 3.
Table 3. Fix variable parameter

| Variable                        | Value                      |
|---------------------------------|----------------------------|
| USD Exchange Rate               | Rp. 14.100/USD             |
| Selling price year 1-8          | Rp. 850                    |
| Selling price year 9-20         | Rp 531                     |
| Capacity Factor (CF)            | 65%                        |
| Interest rate                   | 6%                         |
| Tax                             | 10%                        |
| Water Tax                       | Rp 5/kWh                   |
| Construction Period             | 12 Months                  |
| Equity                          | 30%                        |
| Loan                            | 70%                        |
| OM Cost                         | Rp 98,7/kWh                |
| Aux Losses                      | 10 kW                      |
| Hour in 1 year                  | 8760                       |
| Electricity Transfer to Grid / year | 5.637 MWh     |

The Dollar’s exchange rate used in October 2019 [15]. The Capacity Factor minimum requirement is 65% regarding Permen ESDM No 50, 2017 [8]. The interest rate is 6% according to Bank Indonesia Rate June 2019 [16]. The Tax used is Value Added Tax (VAT) 10% and the Water Tax rate is Rp. 5 / kWh [7]. The time duration of the project is 12 months. The cost scheme is 30% Equity and 70% loan. The net energy transfers to the grid calculated by formula (1)

\[
E = P_{\text{netto}} \times \text{CF} \times \text{hour} / \text{year} \\
E = (1000-10) \text{ kW} \times 0.65 \times 8760/\text{year} \\
E = 5.673 \text{ MWh/year}
\]

The Operation and Maintenance (O&M) cost can be calculated by Nett Energy Times O&M cost/kWh. So, the total O&M cost per year is Rp.560,000,000,00. The Financial Analysis used assumption of the plant life until 20 years. So, The IRR, NPV and Payback period can be calculated. The variable is EPC cost of three Turbine manufacturer’s prices.

Table 4. Turbine price from different manufacturer.

| Brand | Price               | Origin |
|-------|---------------------|--------|
| A     | Rp. 9.000.000.000   | Asia   |
| B     | Rp.13.000.000.000   | Europe |
| C     | Rp.15.000.000.000   | Europe |

Turbine’s price included alternator and control system. This price can be added by civil work price according to Rp.17,000,000,00,-. The total price calculated by financial analysis method.

3.3. Financial analysis result
EPC cost according to each turbine manufacturer calculated by financial analysis, so the result is shown below.
**Table 5.** The result of financial analysis turbine “A”.

| Description   | Magnitude          |
|---------------|--------------------|
| IRR           | 9.69%              |
| NPV           | Rp. 8.373.579.334  |
| Payback period| 7 years and 9 months |

The calculation result of Turbine Manufacturer “A” is IRR 9.69% and the NPV Positive Rp. 8.373.579.334,-. And the payback period is 7 years and 9 months. So, this investment is economically justified and feasible.

**Table 6.** The result of financial analysis turbine “B”.

| Description   | Magnitude          |
|---------------|--------------------|
| IRR           | 7.93%              |
| NPV           | Rp. 4.654.319.234  |
| Payback Period| 9 years and 1 Months |

The calculation result of Turbine Manufacturer “B” is IRR 7.93% and the NPV Positive Rp. 4.654.319.234,-. And the payback period is 9 years and 1 month. So, this investment is not feasible because of the payback period more than 8 years.

**Table 7.** The result of financial analysis turbine “C”.

| Description   | Magnitude          |
|---------------|--------------------|
| IRR           | 7.18%              |
| NPV           | Rp 2.794.689.185   |
| Payback Period| 9 Years and 9 Months |

The calculation result of Turbine Manufacturer “C” is IRR 7.93% and the NPV Positive Rp. 4.654.319.234,-. And the payback period is 9 years and 9 months. So, this investment is not feasible because of the payback period more than 8 years. The feasible investment only turbine “A” because the price is cheaper than other turbine manufacturers. So, the return of investment greater than the other brands.

**4. Conclusion**

The technical and financial analysis of Minihydro Power Plant 2x500 kW in the Bandung Regency is feasible according to Turbine Manufacturer “A”. The value of IRR is 9.69% in which greater than the interest rate 6%. The value of NPV is positive Rp. 8.373.579.334,-. It means that the project return of investment in the present is Rp.8.373.579.334,-. The payback period is 7 years and 9 months, the duration of the payback period is less than 8 years. So this project is economically justified.
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References
[1] ESDM Jawa Barat Book 2018
[2] Puji A 2009 Study on infrastructure of Electricity and Telecommunication (Bandung, Indonesia: Bandung Institute of Technology, Magister Perencanaan Wilayah dan Kota)
[3] Kishani K E, de Alwis A D D, Dimitra M K S, de Silva K I R, Perera H R and Wijayapala W D A S 2018 Technical, Environmental and Economic Feasibility of Introducing Added Storage to Run of River Mini Hydro Plants to Improve Dispatchability Moratuwa Engineering Research Conference (MERCon) 488-493 IEEE
[4] Naeem D, Hashmi A, Iftikhar H, Khan M B and Khan W A 2014 Investing in hydro power sector for Pakistan's energy security International Conference on Energy Systems and Policies (ICESP) 1-6 IEEE
[5] Gokhale P, Date A, Akbarzadeh A, Bismantolo P, Suryono A F, Mainil A K and Nuramal A 2017 A review on micro hydropower in Indonesia Energy Procedia 110 316-321
[6] Ministry of Energy and Mineral Resources 2015 Regulation of the Minister of Energy and Mineral Resources no. 19 year 2015 on 'Purchase of Electricity from PLTA (Hydroelectric Power Plant) with Capacity up to 10 MW (Ten Megawatt) by PT PLN (State Power Plant) [Online]
[7] Sudibyo H, Subekti R A and Susatyo A 2017 Feasibility study of energy conversion system of minihydro scale in Garut Regency, West Java International Conference on Sustainable Energy Engineering and Application (ICSEEA) 98-105 IEEE
[8] Ministry of Energy and Mineral Resources 2017 Regulation of the Minister of Energy and Mineral Resources no. 50 year 2017 on ‘Pelaksanaan Kegiatan Fisik Pemanfaatan Energi Baru dan Energi Terbarukan serta Konservasi Energi [Online]
[9] Eshun M E and Amoako-Tuffour J 2016 A review of the trends in Ghana’s power sector Energy, Sustainability and Society 6 1-9
[10] Negi G C S and Punetha D 2017 People’s perception on impacts of hydro-power projects in Bhagirathi river valley, India Environmental monitoring and assessment 189 4 138
[11] Jui F S, Alam S, Alam M D and Chowdhury S 2015 A feasibility study of mini hydroelectric power plant at Sahasradhara waterfall, Sitakunda, Bangladesh International Conference on Advances in Electrical Engineering (ICAEE) 80-83 IEEE
[12] Kamran M, Asghar R, Mudassar M and Abid M I 2019 Designing and economic aspects of run-of-canal based micro-hydro system on Balloki-Sulaimanki Link Canal-I for remote villages in Punjab, Pakistan Renewable Energy 141 76-87
[13] Ciric R M 2019 Review of techno-economic and environmental aspects of building small hydro electric plants–A case study in Serbia Renewable Energy 140 715-721
[14] Globalhydro 2018 Francis Turbine 500 kW Datasheet
[15] https://www.bi.go.id/id/moneter/informasi-kurs [online]
[16] https://www.bi.go.id/id/moneter/bi-7day-RR [online]