Sustainable Civil Building Management and Engineering Journal Vol: 1, No 4, 2024, Page: 1-11

Optimization of the Weir as a Micro Hydro Power Plant in Bayang Nyalo Padang, West Sumatra

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DOI: https://doi.org/10.47134/scbmej.v1i4.3135
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Received: 01-08-2024
Accepted: 15-09-2024
Published: 31-10-2024

Abstract: The objective of this research is to guarantee that the building of PLTMH Bayang Nyalo achieves maximum energy output and utilizes possible renewable energy sources in a sustainable and efficient manner. This research is a study that aims to describe and analyze data using a quantitative technique. The quantitative research technique is used when study data is in numerical form. Quantitative descriptive research is a method used to examine obtained data by providing a detailed and accurate description of the data. This study aims to determine the optimal value for designing small-scale hydropower plants (PLTMH). In order to do research for this thesis, the author investigates the number of studies performed in the Bead Dam Nyalo Kec. Nagari Bayang North, South Coast Regency West Sumatra. The PLTMH project aims to harness the water flow from the subterranean river, which has a discharge rate of 14.67 liters per second. The power plant is designed to have a power capacity of 623.32 kW, using a high discharge waterfall with an effective height of 5 m. Based on the examination of technological elements, we have reached conclusions: The civil component of this PLTMH includes a gravity concrete dam that is prepared for operation, while the electrical components consist of a Cross flow Turbine. The development of mechanical transmission is ongoing.

Keywords: Hydro, Power Plant, Dam

Introduction

Indonesia has many potential primary resources, including renewable energy (wind, solar, water, geothermal, and biomass). However, this renewable energy provides only one percent of the current energy needs of society. According to RUPTL PT PLN (Persero) from 2015–2024, Sumatran electricity demand is expected to increase from 31.3 TWh in 2015 to 82.8 TWh in 2024.

On the other hand, electricity demand in the West Sumatra region is expected to reach 6,734 GWh by 2024, an increase from 3,695 GWh in 2015. Currently, the electricity supply is generated from 16 substations with interconnecting systems. However, the potential for the development of power plant sources in this region is huge.

All living things on Earth need water to live, whether human, animal, or plant. The river flows from top to bottom. There are many large and small rivers throughout Indonesia. This is an excellent opportunity to develop electrical energy in certain places, especially in areas that do not yet have access to electrical energy (Kumoro et al., 2022).

With output of less than 100 kilowatt hours, microhydro power plants use hydro power such as waterways, rivers, or natural waterfalls. They use potential energy falling water (head) to generate electricity. The higher the water fall, the more water potential energy can be converted into electricity. When compared to large-scale hydroelectric power, microhydroes produce relatively small amounts of energy.

This is because of its relatively simple equipment and the area required to install and operate it. Therefore, microhydro generation systems are ideal for increasing the availability of power grids in remote and rural areas. One alternative renewable energy is micro-hydro (PLTMH) electric drive.

Indonesia's renewable energy potential is huge, but it has not been fully utilized. These include 4.8 kilowatt hours of solar energy per day, 458 MW mini/micro hydro energy, 49.81 gigawatt hour biomass, 3-6 megawatt hour wind power, and 3 gigawatt hour nuclear energy.

The current PLTMH utilization rate is only about 21 MW, or only about 4% of the potential, and the Indonesian government expects to meet the country's share by 7% by 2025. Therefore, there are still many opportunities that have not been explored or even not explored well.

Many regions of Indonesia are located near the river stream, and many of them have adequate flow to be used for small-scale power plants. By utilizing the potential that exists, it is expected that the community can meet its own energy needs. This will allow them to anticipate rising energy prices or problems with national power grids.

For the growth and development of the developing world economy, the availability and cost of energy resources is essential (Hernandez et al., 2021). It takes new and renewable alternative energy as the availability of fossil fuels is decreasing. Indonesia has a lot of water. so there is an opportunity to develop new renewable energy sources. However, to meet the energy needs, fossil energy is still a major focus, and has not been fully utilized to replace it (Hernandez et al., 2019).

Hydroelectric power plants are a more stable and environmentally friendly way to meet your energy needs. The Indonesian government has established the regulations of electric energy policy to reduce the amount of fossil fuels used to generate electricity(Eshra et al., 2021). By lowering the level of carbon dioxide (CO2), the national energy resistance sector is helping government programs.

In fact, electricity is an important component in the growth of a country. Population growth rates and increased energy consumption indicate increased electricity requirements.

Alternatively, the utilization of new energy resources through available natural resources must be done. A great opportunity for the community to develop small-scale power plants lies in utilizing the potential of river water natural resources spread throughout Indonesia.

In addition, hydroelectric projects can be used for various purposes, such as fisheries, irrigation, flood control and water supply, as well as for access to modern energy services that are essential to meet basic social needs and drive economic growth, and affect productivity, health, education, clean water services and communication.

Micro Hydro Power Plant is a power plant with a capacity of less than 100 kilowatt hours. Many rural areas in Indonesia are close to river streams that allow power plants at this smaller capacity (Córdoba et al., 2019). By utilizing the potential in these villages, it is expected to meet its own energy needs, regardless of the increase in energy prices or constraints facing the national power grid. River water can be used as a renewable energy source.

Microhydro power plants (PLTMH) are small-scale technologies that use water resources to convert water potential into electrical energy. Microhydro development should be considered as the right choice for the supply of electric energy as it is an alternative resource (M. Syaiful Alim et al., 2024). Even Microhydro Power Plant (PLTMH) is capable of generating power up to 100 kW, but some PLTMH in Indonesia, including in Bayang Nyalo, produce less than expected.

The general purpose of PLTMH development is to help address the lack of electricity in rural areas that are not yet affordable, optimize the use of renewable resources, and empower communities in terms of social, technical, and economic terms. The special purpose of the construction of PLTMH is to utilize renewable energy in the form of PLTMH in the area to be used as a study site and minimize the use and negative effects of utilizing non-renewable energy. There are two systems that can be used to use river water as a powerhouse center: direct river flow system (ROR) and reservoir system.

As a result, microhydro power plants should be optimized to produce the ideal amount of power. In addition, the kinetic energy of water flowing from the Bayang Nyalo River is used by Microhydro Power Plant in the City of Byang Nyalo. This plant is known as the River Flow System or Run of River (ROR). This study focuses on the technical and economic feasibility of PLTMH Bayang Nyalo.

In this study, the flagship discharge of the river Bayang Nyalo influences the magnitude of the power generated; the diameter of the carrier pipe (Deff) affects the high calculation of the falling effective (Heff); the magnitude of the investment cost to build microhydro power plants; and the cost of operation and maintenance as the basis for determining economic feasibility.

In addition, the focus of this research is water resource management. The study aims to find out the results of the FDC so that it can be used to select discharge plans, perform high analysis of falls and diameter of the carrier pipe thus reducing high loss, and find the right turbine for the Beadang Nyalo PLTM.

The purpose of this study is to ensure that the construction of PLTMH Bayang Nyalo gets optimal amounts of energy and sustainable and efficient utilization of potential renewable energy sources. The study will offer an overview of how to use the natural wealth of river water as a source of electric power to address the electric crisis in rural communities

Methodology

This research is a descriptive study with a quantitative approach. Quantitative research approach due to research data in the form of numbers. Quantitative Descriptive is a type of research used to analyze data by describing or describing data that has been collected as it is. This research is done to find optimization value on PLTMH planning. To carry out research on this thesis the author does how many studies are conducted in the Bead Dam Nyalo Kec. Nagari Bayang North, South Coast Regency West Sumatra.

Population

According to some opinions the population is the same as the whole area consisting of objects / subjects that have quantity and characteristics that are thoroughly studied for the study and the use of the subject. In the study on this thesis, the population in question is the area / area of the Balang Nyalo Dam that has water potential can be used in the utilization of electric energy as electric energy. With the dam is already an additional device for planning PLTMH in the dam.

Sample

Samples are part of some of the number of characteristics that the population has, or a small part of that population.

Sampling

Sampling or sampling technique is a way of sampling. The sampling method used in this study is non probability sampling through systemats sampling technique. Systematic Sampling is a sequential sampling technique of the population.

Data Collection Techniques

Data Collector Technique is the most decisive step of a study, because data analysis serves to conclude the results of the study. Stages in the collection of the following data:

1. Observation

Data collection is done by observation where river areas and water potential. The retrieval of the data is documented in the form of data in the field during the research.

2. Interview

Interviews are conducted directly with dam operators, sexy heads and Project Heads related to the Balang Nyalo dam project.

3. Data Analysis

Analysis is conducted with data into formulation methods with the help of Ms software. Excell.

Data Analysis Technique

In this study, data analysis techniques are needed as a way to unite and summarize research data. The following data analysis phases:

a. At the data retrieval stage, researchers retrieved data for data needs from the population that was used as a sample.
b. At the planning stage, researchers conducts the plan of research design
c. At the evaluation stage, researchers analyzed the results of the plan in economic analysis.

Result and Discussion

The Balang Nyalo river flowing area of 2175.70 km2 across the South Coastal district and is one of the water sources in West Sumatra. With the development of and increasing water needs in various sectors, Balang Nyalo is expected to meet the needs of water in its wide flowing area. Therefore, to find out the potential of existing water to be managed and utilized sustainably and optimally in the future, an analysis that evaluates whether water availability and needs are balanced.

For years, the Balang Nyalo River has been used in the South Coast region for human and animal purposes, as well as to irrigate some agricultural areas in Nagari Balang sub-district. Technically, there are only 449 ha of rice fields that are irrigated, but the condition of the region allows development to be 2,228 ha.

The nearest rain station provides annual rainfall data of Balang Nyalo PLTM PLTM. For Balang Nyalo PLTM DAS, the average rainfall area is calculated using daily rainfall data. To calculate average rainfall in the Balang Nyalo WAS, the Thiessen Polygon method is used. This method takes into account the area represented by influential stations as a correction factor in calculating average rainfall.

The above rainfall table shows that the highest annual rainfall of 138.26 mm occurred in 1999. Balang Nyalo PLTM DAS uses the Thiessen Polygon method with three rain stations to calculate annual average rainfall. This Balang Nyalo River does not have a complete discharge record. Therefore, flagship discharge is calculated using the method of rain simulation into flow (Rainfall-runoff model).

To estimate the magnitude of discharge at the location of the PLTM plan, the Model Tank method is used to model the discharge simulation. Plan rainfall is the largest annual rainfall that may occur somewhere with a certain possibility, or rain with a certain period of re-period. Analysis of rainfall plan includes several steps.

First, the data consistency test uses a double mass arch test, which compares the accumulation of the station's annual rainfall data with the accumulation of average rainfall data of a group of stations in the same period. Second, determine maximum daily rainfall for each year of records.

Lastly, rainfall analysis was conducted using Normal Distribution methods, Log Pearson Type III, and E.j. Gumble. To determine the availability of water in the streaming area (DAS) at the location of the Balang Nyalo PLTM plan, especially the magnitude of low flow discharge, the mainstay discharge analysis of Balang Nyalo PLTM feasibility study was done using the Tank Model method and then compared to the run results of the HEC-HMS software.

The completion and calculation of each model including fixed components and variables, parameters, and cones For the analysis of this study, the selected hydrological model is as follows:

1. Rain (precipitation)

The rain model method uses User Gage Weights. This method uses rain gauge data that affects a system of River Flow Regions (DAS) in vulnerable years. This is in accordance with the facilities contained in HEC-HMS, as well as the necessary data availability factors.

2. Flow Volume (runoff volume)

The groundwater content calculation model (SMA) contained in the HEC-HMS program package is used for continuous modeling in determining flow volume.

This model has the ability to simulate the behavior of a WAS in both wet and dry weather. The purpose of using this model is to know the availability of water at a specific WAS. In this study, the purpose of the model simulation was to collect rain data measured from 2023 to 2024 For model simulations, the DAS parameters are used for HEC-HMS model optimization results.

The results of the simulation of the HEC-HMS model from 2023 to 2024 resulted in a peak discharge of 138.8 m3/dt. The flow of water required to ensure the presence of aquatic biota habitat in the river is called maintenance discharge or ecological flow.

Flow ecology can include a variety of flow conditions that indicate average flow over a long period of time. These flow variables include flow with low discharge and irregular high discharge, such as when flooding occurs. Based on previous hydrological analysis, the average annual flow of the Nyalo Balang PLTM DAS from 1993 to 2009 was 16,150 m3/sec.

The magnitude of the ecological flow with the Montana Method is 10% x 16,150 m3/second = 1,615 m3/second. To compare, reference from Nippon Koei is used for Asahan Power Plant, which has an ecological flow of 0.200 to 0.500 m3/sec/100 km2. Based on Montana theory and controlled by reference of Asahan-3 Plant Power designed by Nippon Koei, the ecological flow of Balang Nyalo PLTM is projected at 1,615 m3/sec. As shown in the flow duration curve chart (FDC), flagship discharge in the river flowing area (DAS) plan location Balang Nyalo PLTM plan has a diverse probability and high energy fall (head net) of 142.98 meters.

With a flagship discharge of 45% of 8.165 m3 per second, the optimization calculation of various discharges and economic value (energy costs that must be spent) to produce energy of 1 kilowatt-hour has shown that a 45% probability discharge provides the best result with an energy cost of Rp 557.54/kilowatt-hour.

During the planning process for the construction of a Small Hydropower Plant (PLTM), a topographic survey was conducted. The purpose of this survey was to collect data on the land contour and types of rocks found at the study site. The data obtained from this survey will be used to determine the maximum head for the purpose of determining the layout of the main components and supporting structures of the PLTM. To complete the survey and measurement work at the study site, the following stages were used: the preparation stage involved the preparation of equipment and staff, coordination with the project parties, and gathering information and approval regarding the location, site boundaries, and obtaining permission from the project parties.

The following measurements were taken during the measurement process. Benchmarks were made and installed from cast concrete with a 4-inch diameter pipe. In the middle, a 1 cm diameter bolt was installed with a cross-cut end. Ten reference benchmarks were needed to measure the polygon cross-check BM that existed. The benchmarks had to be cast with a length of 70 cm, buried 50 cm, and protruding 20 cm above the ground.

Solar azimuth observation has the purpose of determining the latitude and longitude of a point (location) on Earth, or its astronomical coordinates, as well as the azimuth direction between two points on the Earth's surface. Determining the azimuth direction between two points on the Earth's surface is very important for the process of procuring basic points for mapping, both terrestrially and photogrammetrically. Azimuth is not only needed to provide a north orientation on the map, but also more importantly to adjust the angle size for triangulation and polygon measurements. Polygon Measurement: The polygon measurement method—also called "polygon measurement"—is used to measure the horizontal control framework.

PLTM installed power refers to Flow Duration Curve (FDC) obtained from hydrograph data and analysis. The FDC curve indicates the possibility of discharge that will flow within a certain period of time, as it means that in that period, there are many discharges that can be used when building a PLTM. Flow discharge can be set using the FDC curve, which is then used in the calculation of installed power that has been obtained. illustration for calculating capacity factors at 55% probability of Sinamar Rods.

The area of the shaded area (AbcCD) and the area of the ABCD field can be compared to knowing capacity factors (FC). The area of the shaded field (AbcCD) is the magnitude of the discharge that can be used in a certain period of time for PLTMH, while the field of ABCD is the maximum discharge that is selected and will always appear in a certain period of time. As a result of the extensive calculation, FC for probability of 55% is 69.31%, or 0.6931.

Project Management is the process of combining the best science, skills and technical capabilities with limited resources to achieve set goals and goals to achieve optimal results in terms of performance, cost, quality and time, and work safety. One of the things to consider in project management so that the project output is in accordance with the goals and goals set.

The amount of power is generated and the electrical system used determines the selection of generators. It has been obtained 9.4 MW, which is the installed power or the installed power generator, and the generator capacity is 11.06 MVA with a power factor of 0.85 (the equation of 3.45). Chosen 3 phase 6.6 kV synchronous generator due to the 500 rpm turbine speed that is embedded with the generator. Based on equations (3.37) and Table 3.6, the number of polar generators is obtained to get the output frequency of 50 Hz.

The methodology of implementing the PLTM construction project in Balang Nyalo consists of three stages: preconstruction, construction, and postconstruction. Here is an explanation of the components of the activity at each stage of the project.

Technically, this feasibility analysis aims to convince various parties that the Balang Nyalo PLTM construction project that will be implemented at the site of the plan can be implemented and run well. Its technical plan meets the applicable guidelines and standards, so that construction can be started and implemented, and will absorb local materials and labor.

Civil feasibility analysis requires data and information on the state of topography, geology, and soil mechanics to be used for main buildings and waterways routes. Data must support the quality of buildings—core buildings including dams, intakes, settler tubs, carrier channels, tranquilizers, dumping channels, turbine houses, and more.

This feasibility analysis aims to provide an overview and assure the relevant agencies and local communities that the construction of a PLTM at the site will not cause significant environmental damage. In addition, it is informed that if there are negative impacts, there are already plans to reduce them. It is important to raise awareness of the local community and institutions about the importance of maintaining the environment.

A) Type and scope of research:

This analysis covers all related economic aspects in the PLTM development project. The analysis was conducted with five methods: Net Present Value (NPV), internal rate of return (IRR), Benefit Cost Ratio (BCR), and Break Even Point (BEP).

B) Eligibility Criteria

To conduct financial analysis, the cash flow of the PLTM project must be clear. All the cost components required for economic analysis are explained in this little bit.

Conclusion

Planning of construction of PLTMH Bayang Nyalo, Nagari Bayang District North, South Coast Regency. Can be used to develop and encourage community development activities. From the research results of analysis and field studies as follows:

1. PLTMH is planned to utilize the water flow of the underground river with a discharge of 14.67 liters/second. Power capacity of this power plant is planned at 623.32 kW with high discharge water fall effectively 5 m. From the analysis of technical aspects, we have conclusions:
2. The civil component of this PLTMH consists of gravity concrete type dam is ready to work while the electrical components of PLTMH are composed of Cross flow Turbine, Mechanical transmission is still in progress
3. Based on location selection, the appropriate head and discharge for the Nyalo Turbine Open Flume Balang Dam was selected because the flow of vertical water falls, with a low head of 3.2 meters, and the current building layout is not possible to build a rapid pipe (penstock). The position of the plant house becomes lower if using a rapid pipe (penstock), which will cause problems during the increase of water discharge (flood) in Balang Nyalo.

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