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Optimization of Medium Voltage Overhead Line Design for PT Algae Marine Life at PT PLN Kariango Customer Service Unit

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SUTM design, reconfiguration, shrinkage and voltage drop

ABSTRACT
The addition of premium customers at PLN ULP Kariango has an impact on the electricity supply burden borne by PLN. This study uses an experimental research model. These designs will be tested and graded based on established standards. Data collection was carried out by observing and opening data specifications for electric power system equipment. Data analysis in this study used ETAP software. For Option 1 the SUTM design does not meet the technical requirements because there is a % power loss of 16.3 % and a % voltage drop of 31.1 %. For financial analysis, option 1 was not implemented because the technical requirements were not met. For the 2% option, the power loss of 46.2% does not meet the technical requirements. For financial analysis option 2 already meets the requirements. For option 3, the technical criteria for shrinkage is 10.87% and the voltage drop is 0.4%, which fulfills the technical requirements. For financial analysis, option 3 already meets the financial requirements. So that the results of the optimization of the three SUTM designs were chosen the best option 3 SUTM design.

INTRODUCTION

PT. PLN (Persero) ULP Kariango is an electricity company under the auspices of PT. PLN UP3 Pinrang, electricity at PLN ULP Kariango uses GI Pinrang for its power distribution. PLN ULP Kariango burdens electricity needs in Kariango sub-district, Pinrang regency which has 4 feeders including: Express feeder PT. BLG (F10), Kariango Feeder (F2), Jampue Feeder (F1), Langnga Feeder (F5). The load of each feeder is F10 of 145 A, F1 of Jampue 85 A, F5 Langnga of 46 A, F2 Kariango of 64 A.

With the increase in premium customers at PLN ULP Kariango by 2x 5,440 kVA, the burden increases. SLA (service level agreement) premium customers that require anti-outage services to make PLN ULP Kariango with the customer's load must be supplied from two different feeders, requiring PLN ULP Kariango to create a backup SUTM network for PT BLG's F10 feeder.

The contents of the SPJBTL agreement of PT. BLG with PT. PLN (Persero) namely Premium service is one type of service provided by PLN with guaranteed quality, guaranteed reliability, and guaranteed connection in accordance with the Service Level Agreement (SLA) agreement between PLN and customers. The content of the SLA is as follows:

- Guaranteed continuity of electricity supply for 24 hours a day

- Priority to provide a response in handling disorders to repair disorders as soon as possible.
- If the SLA is not met by PLN, in this case the PLN network system at PT. BLG is cut off, then fines are imposed on PLN as follows:
- Bill reduction of 10% from 40 hours on (221,600 kWh), applicable for 1 outage in 1 month except for outages due to maintenance and force majeure.
- 15% bill reduction from 40 hours on (221,600 kWh), applicable for 2 outages in 1 month except for maintenance and force majeure outages.
- 20% bill reduction from 40 hours on (221,600 kWh), applicable for 3 outages in 1 month except for maintenance and force majeure outages.
- Maximum bill reduction of 10% from 40 hours on (221,600 kWh), if there is a reduction in power (load curtainment) 1 or more times in 1 month.

To complete the design of the SUTM Backup Network PT BLG, a simulation must be carried out(Hassoun et al., 2022). The 3 options that are simulated in this SUTM design, are first, the design of SUTM express(Lappas et al., 2022). Second, the design of SUTM from the Soreang GI Pare-pare network, and the third simulation using PLTD Suppa. In the SUTM design simulation using ETAP software. In the simulation must take into account the criteria / requirements that must be met, namely; technical criteria (the smallest possible voltage drop, power loss or cost analysis), financial analysis(Arsalis, 2019).

This research is expected to be able to produce optimal SUTM design that meets TMP standards, both from technical and financial aspects, and reduce the impact that may arise for PLN as a provider of electrical energy (Kadir, n.d.). With careful planning, the continuity of PLN's electricity services to customers is maintained.

METHODS

The research model carried out is experimental research where the data will be analyzed mathematically with software based on the input data that has been collected (Kalinin, Krundyshev, & Zegzhda, 2021). The data will later be entered into the application and simulated by providing 3 criteria options for SUTM design(Achuthan, Raghavan, Shankar, Francis, & Kolil, 2021). This research began with a literature study and data collection. Data collection is carried out by observation and opening data on specifications of electric power system equipment. Literature studies are conducted for previous research that has been done and look for research gaps so as to give rise to the novelty value of this research. The data needed in the study are electric power system equipment data such as substation load, refiner length, refiner load, transformer load data.

The next stage is the data collection stage needed in research from equipment specifications to be entered into the ETAP application(Ghoroghi, Rezgui, Petri, & Beach, 2022). Then the data will be simulated with ETAP power flow to provide an initial picture of electricity at PT. BLG against the system (Pradana, 2022). Then the SUTM design will be carried out from 3 criteria that have been determined. The data will be simulated with these 3 criteria and analyzed criteria in optimizing SUTM design in terms of engineering and finance. The final decision is obtained the most optimal criteria in the design of SUTM at PT. BLG and become a recommendation for decisions that will be taken by management to design the SUTM. At the final stage, the final report will be made.

In this study, the data used was secondary information. The study began by collecting secondary data on equipment used in electric power systems(Pullinger et al., 2021). This data is obtained through the study of basic theoretical literature as well as from the technical specifications of the equipment (Kundur & Malik, 2022).

RESULT AND DISCUSSION

This chapter will discuss the results of research and analysis of data that has been collected from the data collection process(Sutton & Austin, 2015). Before the research / analysis is carried out, the data that has been collected is first entered into the ETAP software(Suhardi, Pakaya, Putra, & Faruq, 2022). After being entered into ETAP, the data is analyzed with ETAP software. The next working step is a feasibility analysis. Then create 3 Option options for SUTM designing. After that, analyze the 3 options from a technical and financial point of view, then optimize which of the 3 options is the most feasible for SUTM design(Seuken, Friedrich, & Dierks, 2022). The results of this analysis became the basis for the design to the stage of developing the SUTM plan for PT. BLG at PT. PLN ULP Kariango.

Technical Analysis Option 1 SUTM Design

After the design is carried out in ETAP for SUTM design, the next step is the ETAP power flow simulation figure 4.13 and table 4.4 explaining the results as follows:

From the simulation results of figure 4.13 and table 4.4 when the system is running, the voltage on the 235 busbar changes from 20 kV to 13.728 kV. For bus 237 it changed from 20 kV to 13.728 kV, and for bus 239 it changed from 20 kV to 13.92 kV. Based on TMP PT. PLN (Persero) by the Ministry of Human Resources set the allowable voltage drop value at 18 kV so that from the initial analysis results for buses 235, 237, and 239 did not match the TMP value to serve the power needs of premium customers of PT. BLG.

It can be seen in table 4.5 when the simulation of option 1 of SUTM design is carried out, there is a total energy shrinkage of 60.3 kW obtained in each branch / cable in the electrical system of PT. BLG for PLN system. The largest power loss occurs at the base up to LBS P25 of 26.9 kW. If the depreciation value is in rupiah as follows:

$$P = V.I. \cos P = V.I.\cos 〚\emptyset .t = 60.3 \text{ kW}*24*30 = 43.416 \text{ kWh} 〛$$

Then the total Rp. energy shrinkage = 43416 *1467 = Rp. 63,691,272

From the results of the power loss simulation in option 1, there was an improvement / reduction in power loss by 83.70%. The cause of power loss repair is the absence of connections in SUTM as in the initial drawing before design which causes power loss repair. The conclusion of the design of SUTM option 1 is as in table 4.6

Project economic feasibility study is a study of the economic feasibility of the project which discusses evaluation to assess the feasibility of an investment program. The values that will be assessed in the financial analysis are NPV, IRR, BCR, and Payback Period. For SUTM design, option 1 is no longer valued for financial analysis because the assessment of technical analysis is no longer appropriate.

Option 2: SUTM Design

The second option is carried out for SUTM design due to voltage drop, shrinkage, and the absence of backup SUTM for PT. PLN is by taking resources from PLTD Suppa. The reason for designing SUTM with sources taken from PLTD Suppa is because PLTD Suppa has not been used for transformer 2, so it is expected to be an option for SUTM design. Design Drawing option 2 can be seen in figure 4.14

Technical Analysis Option 2 SUTM Design

After the design is done in ETAP for SUTM design, the next step is to simulate ETAP power flow figure 4.15 and table 4.7 explaining the results as follows:

From the simulation results of figure 4.15 and table 4.7 when the system is run, the voltage on busbar 5 changes from 20 kV to 19.36 kV. For bus 7 it changed from 20 kV to 18.04 kV, and for bus 133 it changed from 20 kV to 19.34 kV. Based on TMP PT. PLN (Persero) by the Ministry of Human Resources set the allowable voltage drop value at 18 kV so that from the initial analysis results for bus 5, bus 7, and bus 133 it is in accordance with the TMP value to serve the power needs of premium customers of PT. BLG. The simulation results for energy loss can be seen in table 4.8

It can be seen in table 4.8 when the simulation of option 2 of SUTM design is carried out, there is a total energy shrinkage of 170.6 kW obtained in each branch / cable in the electrical system of PT. BLG for PLN system. The largest power loss occurs at the base up to LBS P2 of 63.3 kW. If the depreciation value is in rupiah as follows:

P= V.I. Cos P=V.I.cos 〖ø .t=170.6 kW*24*30=122.832 kWh 〗

Then the total Rp. energy loss = 122,832 *1467 = Rp. 180,194,544

From the results of the power loss simulation in option 2, there was an improvement/reduction in power loss by 53.8% against the initial simulation energy loss(Srivastava et al., 2023). But the energy shrinkage is still large at the base of the LBS P2 because there is cable joining, and also the type of cross-section used, namely aluminum and copper in the connection(Wang, Zhang, Xu, & Han, 2018). The repair of power loss is the absence of connections in the SUTM as in the initial drawing before design which causes the repair of power loss. The conclusion of the design of SUTM option 2 is as in table 4.9

Financial Analysis Option 2 SUTM Design

Project economic feasibility study is a study of the economic feasibility of the project which discusses evaluation to assess the feasibility of an investment program. The ones that will be assessed in the financial analysis are NPV, IRR, BCR, and Payback Period. Before doing calculations, it must first be done SUTM design as in table 4.10

After obtaining the RAB value for SUTM design in option 2, then an analysis is carried out based on the base case in table 4.11.

The lifetime value is according to Perdir 0299 PLN which states the product lifetime of 40 years. The investment cost based on the calculation of table 4.11 is Rp.21,575,735,000. The planning will start construction in 2023. For operational costs, the value of investment costs against the percent / average inflation of the rupiah. For Discount rate / interest 9.24% . For additional value, income is saving from Rupiah which is saved due to the design of this SUTM so that the value of power loss is reduced. From this data, a value of Rp.210,614,000 was obtained. For revenue growth, it is 10.64% of the KKO calculation.

After calculating the net cash flow and present value, the calculation of IRR, NPV, BC Ratio, Payback Period will be calculated as in table 4.14 Financial Calculation of SUTM Design Option 2.

The IRR value is obtained from the IRR formula from net cash flow to interest rates. The NPV value is obtained from the NPV net cash flow formula against interest rates. The B/C ratio is obtained by comparing the amount of profit divided by all total costs. For Payback Period is obtained from the largest payback period value.

Option 3: SUTM Design

The third option is carried out for the design of SUTM due to voltage drop, shrinkage, and the absence of backup SUTM for PT. PLN is with the construction of an express feeder from GI Pinrang. The reason for designing SUTM with sources taken from the construction of feeders / Express feeders is still possible because there are still 30 MVA transformers in GI Pinrang that have not been used, so it is expected to be an option for designing SUTM. Design Drawing option 3 can be seen in figure 4.15.

After the design is carried out in ETAP for SUTM design, the next step is the ETAP power flow simulation figure 4.16 and table 4.15 explain the results as follows:

From the simulation results of figure 4.16 and table 4.15 when the system is running, the voltage on busbar 7 changes from 20 kV to 18.728. For busbar 999 it changed from 20 kV to 18.72 kV, and for busbar 1001 it changed from 20 kV to 18.72 kV. For busbar feeder 10 BLG changed from 20 kV to 19.44 kV, and for busbar Pinrang 1 changed from 20.5 kV to 19.92 kV Based on TMP PT. PLN (Persero) by the Ministry of Human Resources set the allowable voltage drop value at 18 kV so that from the initial analysis results for pseudo it is in accordance with the TMP value to serve the power needs of premium customers of PT. BLG.

It can be seen in table 4.16 when the simulation of option 3 of SUTM design is carried out, there is a total energy shrinkage of 40.2 kW obtained in each branch / cable in the electrical system of PT. BLG for PLN system. The largest power loss occurs in GITAF-GITAH25 of 40 kW. If the depreciation value is in rupiah as follows:

P= V.I. Cos P=V.I.cos 〖∅ .t=40.2 kW*24*30=28.944 kWh 〗

Then the total Rp. energy shrinkage = 122,832 *1467 = Rp. 42,460,848

From the results of the power loss simulation in option 2, there was an improvement / reduction in power loss by 89.13% against the initial simulation energy loss. But the energy shrinkage that is still large in GITAF-GITAH25 is still the joining XLPE cable on cable9 size 150 mm2 with A3C cable 250 mm2 aluminum material in the system. The repair of power loss is the absence of connections in the SUTM as in the initial drawing before design which causes the repair of power loss. The conclusion of the design of SUTM option 3 is as in table 4.17

Project economic feasibility study is a study of the economic feasibility of the project which discusses evaluation to assess the feasibility of an investment program. The values that will be assessed in the financial analysis are NPV, IRR, BCR, and Payback Period. Before doing calculations, it must first be done SUTM design as in table 4.18.

The voltage value used is 20 kV. For the maximum capacity of power passed using KKO technical specifications according to the rating of the conductor used. The maximum energy passed according to the operating pattern. For the value of load growth from RUPTL data of 7.4% with a power loss of 6.3% based on UIW data.

The lifetime value is according to Perdir 0299 PLN which states the product lifetime of 40 years. The investment cost based on the calculation of table 4.15 is Rp.13,524,750,234. The planning will begin construction in 2024. For non-fixed costs of power generation 454 Rp/kWh. The transfer price of the transmission is 1,468 Rp/kWh.operational is the value of investment costs against the percent/average inflation of the rupiah. For maintenance costs of Rp. 270.495.000 / year. For maintenance escalation costs of 2%/year. For Discount rate / interest 9.28% . For additional value, income is saving from Rupiah which is saved due to the design of this SUTM so that the value of power loss is reduced. From this data, a value of Rp. 210,614,000 is obtained. For the assumed value of the exchange rate of Rp. 15,000 / USD and pph of 22%. For revenue growth, it is 10.64% of the KKO calculation.

After calculating the net cash flow and present value, the calculation of IRR, NPV, BC Ratio, Payback Period will be calculated as in table 4.22 Financial Calculation of SUTM Design Option 3.

The IRR value is obtained from the IRR formula from net cash flow to interest rates. The NPV value is obtained from the NPV net cash flow formula against interest rates. The B/C ratio is obtained by comparing the amount of profit divided by all total costs. For Payback Period is obtained from the largest payback period value.

SUTM Design Optimization

Before optimizing the 3 SUTM design options for PT. BLG at PLN ULP Kariango then illustrates the simulation results of 3 SUTM design options as in table 4.23.

For Option 1 Source of UP3 Pare-pare, the technical analysis was not fulfilled because the % of large shrinkage and voltage drop of 31.1% exceeded the TMP requirement set by the Ministry of Energy and Mineral Resources by 10%. Financial analysis is not elaborated further because the technical analysis is not fulfilled.

For Option 2 Source from PLTD Suppa, the technical analysis was not fulfilled because the % of large shrinkage and voltage drop of 4.05% was still within the limits set by the Ministry of Energy and Mineral Resources. So for technical parameters option 2 is considered not to meet the specified requirements. The financial analysis for option 2, namely Positive NPV, is if the chosen business is feasible to run and brings profits in the form of money, so that the NPV value meets the requirements. For the IRR on option 2 of $12.38 already > discount rate of $9.38, the investment made will generate a greater return than previously designed, so that it meets the requirements. For the value of option 2's Benefit Ratio of 1.94% is determined to meet the requirements because the benefits of the project are greater than the expenses so that the project can be accepted or worth continuing. Meanwhile, the payback period value of 14.68 years is determined to meet the requirements

For Option 3 Express feeder source, the technical analysis is fulfilled because the smallest % shrinkage of the 3 existing options and a voltage drop of 0.4% is still within the TMP criteria of EMR metrics of 10%. So for technical parameters option 3 is considered to meet the specified requirements. The financial analysis for option 3, namely Positive NPV, is if the chosen business is feasible to run and brings profits in the form of money, so that the NPV value meets the requirements. For the IRR in option 3 of 10 already > discount rate of 9.38 the investment made will produce a greater return than previously designed, so that the IRR value in value meets the requirements. For the value of option 3's Benefit Ratio of 1.03% is determined to meet the requirements because the benefits of the project outweigh the expenses so that the project can be accepted or worth continuing. Meanwhile, the payback period value of 10.56 years is in the value of meeting the requirements

For more details, see appendices 1 to 5 for the results of technical analysis with ETAP software and financial analysis of each criterion for SUTM design in this study.

CONCLUSION

Based on the findings of research results that have been presented in Chapter IV, some research conclusions can be put forward as follows: To design possible options in the design of SUTM PT. BLG for PT. PLN ULP Kariango has 3 possible options, namely, Option 1 SUTM Design with sources from UP3 Pare-Pare, Option 2 SUTM Design with sources from PLTD Suppa, Option 3 SUTM Design with sources from express BLG

The simulation results of 3 SUTM design options are as follows: For Option 1 with Source from UP3 Pare-Pare obtained the simulation results as follows: % shrinkage of 16.3%, voltage drop of 31.1%. Option 1 financial analysis is not continued because technical analysis no longer meets the requirements. For option 2 with a source from PLTD Suppa obtained a simulation result of % shrinkage of 46.2%, voltage drop of 4.05%. The financial analysis of option 2 standard criteria for NPV value is 15,503,833,000, IRR of 12.38 is above the interest rate of 9.24%, Benefit Cost Ratio of 1.94 is >0 and Payback Period is 14.68 years. For Option 3, power loss of 10.87%, voltage drop of 0.4%. The financial analysis of option 3 has met the standard criteria for VPV value of 1,497,078,131,000, IRR 10 is above the interest rate of 9.24%, benefit cost ratio value of 1.03 is >0 and payback period value is 10.56 years

SUTM design optimization for Option1 SUTM design does not meet engineering requirements because there is a power loss of 16.3% and a voltage drop of 31.1%. For financial analysis, option 1 was not exercised because the technical requirements were not met. For option 2 % power loss of 46.2 % does not qualify the technique. For financial analysis, option 2 already meets the requirements. For option 3, the engineering criteria of shrinkage of 10.87% and % voltage drop of 0.4% meet the technical requirements. For financial analysis, option 3 already meets the financial requirements.

Thus, SUTM Design for PT. BLG at PT. PLN ULP Kariango chose option 3 with source from express BLG because it meets technical and financial criteria than the other 2 options.

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