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Analysis of the Financial Feasibility Study of Investment in Electricity Infrastructure Development Using the Monte Carlo Method Case Study of the Construction of GITET 500 kV Cikande

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ABSTRACT
The development of electricity infrastructure is an important part of the planning of the electric power system in order to ensure that the condition of the electricity system can meet the load growth plan while still paying attention to safety and economic factors. The 500 kV Cikande Extra High Voltage Substation (GITET) and its 150 kV Outlet are one of the infrastructures that will be built by PT PLN (Persero) with an operational target in accordance with the General Plan for the Provision of Electricity (RUPTL) for 2021 – 2030 in 2025. To be able to carry out the infrastructure development, PT PLN (Persero) needs to prepare a large enough investment fund so that it is necessary to carry out a financial feasibility analysis at the time the investment will be carried out, but the financial feasibility analysis currently carried out still uses a deterministic method, where the input parameters used in the calculation of financial feasibility have not considered the element of uncertainty/risk that will affect the output of the calculation of the financial feasibility study. In this study, the Net Present Value (NPV), Internal Rate of Return (IRR) and Payback Period (PbP) values will be tested against the required investment value by simulating changes in several input parameters simultaneously using the Monte Carlo method. This research aims to ensure that the investment issued by PT PLN (Persero) meets the parameters of financial feasibility by considering the element of uncertainty/risk in the future.
Keywords: Financial Feasibility Study, Monte Carlo, Net Present Value (NPV), Internal Rate of Return (IRR) and Payback Period (PbP).

INTRODUCTION

The need for electricity supply has become one of the main needs of the community at this time (Alstone et al., 2015; Ceglia et al., 2020; Koirala et al., 2016). Therefore the development of an electric power system is one of the efforts that need to be made in order to meet the electricity supply against the growth of the load that occurs in the community. The average growth of national electricity consumption has increased by an average of around 5% per year over the past 5 years.

The need for electricity in an area is driven by several main factors, namely economic growth, population growth and the number of electricity tariffs as well as electrification programs and government programs, including building Special Economic Zones (SEZs), Industrial Areas, National Tourism Strategic Areas (KSPN), Integrated Marine and Fisheries Centers (SKPT) and the State Border Patrol Post (PLBN) power network (Aladejare, 2014; Berizzi et al., 2019; Bhattacharyya & Palit, 2016).

To ensure the availability of sufficient quantities of electrical energy, good quality and reasonable prices and realize sustainable development, it is necessary to add power plants, transmissions and substations, and distribution networks (Das et al., 2018; Sciences et al., 2017; Vahidinasab et al., 2020; Vegunta et al., 2019). The construction of transmission lines and substations is basically planned to evacuate power plants to load centres, improve system reliability, support electricity sales targets, mitigate bottlenecks, and provide system operation flexibility (Ayamolowo et al., 2019; Kishore & Singal, 2014; Nicolas et al., 2019). The transmission development plan in Indonesia until 2030 is 47,723 Km, while for substations, an additional capacity of 76,662 MVA is planned.

One area with considerable potential for growth in electrical energy needs is Banten Province, where the composition of electrical energy needs in these areas is dominated by the Industry, Household, Business and Public sectors. One of the electricity infrastructure development plans that will be built in this area is the 500 kV Cikande GITET along with SUTET and its 150 kV outlet, which aims to provide additional supply to the Cilegon subsystem.

The DKI and Banten Load Regulating Service Unit (UP2B) system currently consists of 11 Sub-Systems. The loading condition of the Cilegon Sub System 1,2 & 3 Cilegon – PLTGU Cilegon – PLTU Labuan is currently quite high, where the load on IBT 1, 2 and 3 at GITET Cilegon has reached 78%, 78% and 91%. This is due to the increase in natural load and the need to connect high voltage consumers (KTT), which is quite rapid in the area. Additional power supply to the Cilegon sub-system is needed to maintain N-1 contingency in the event of a disruption to one of the IBTs or 1 trip generating unit.

The peak load on UP2B DKI & Banten in 2022 occurred on Monday, April 18, 2022, at 13.30, amounting to 11,615 MW, where the load on the Cilegon sub-system was recorded at 1,426 MW. Currently, the Cilegon sub-system is supplied from IBT 1, 2 and 3, the Cilegon PLTGU and the Labuan PLTU, the majority of the load served by this sub-system is the industrial sector summit. With the condition of the Cilegon IBT load has > 60%, the limitation of gas primary energy for the Cilegon PLTGU and the potential outage of the Labuan PLTU, it can be seen that this sub-system no longer meets the N-1 contingency, if there is a disruption in one of the sub-systems, the load on the other IBT will be overloaded.

Based on the Feasibility Study of the GITET 500 kV Cikande Construction Project prepared by PT PLN (Persero) Main Unit of the Development of the Java-Bali Load Control Center (UIP2B), a power flow simulation was conducted using several cases considered to have a significant impact on the system. These cases include N-1 contingency of the 500/150 kV GITET Cilegon, N-1 contingency of the 150 kV transmission line in the Cilegon Sub-System, non-operation of Cilegon PLTGU, and the operation of one unit of Labuan PLTU. In the first case, the IBT loading simulation results showed that if there is a disturbance in one of the IBTs, it was found that under normal conditions, all IBTs operated above 100%, and in the N-1 condition with one of the IBTs, the load on the other IBTs reached 163% to 171%.

Furthermore, for the second case, a power flow simulation was carried out if there was a disturbance in one of the transmission sections connected to GITET Cilegon. The results of this power flow simulation indicated that the N-1 condition was not met on the transmission line sections. The 150 kV Serang – Ciruas SUTT transmission line section would be loaded at 133.8% if one of the circuits is not operating. The 150 kV Serang – Kramatwatu SUTT transmission line would be loaded at 113.1% if one of the circuits is not operational. Meanwhile, the 150 kV Cilegon Baru – Kramatwatu SUTT transmission line would be loaded at 127.7% if the 150 kV Cilegon Baru – Wilmar transmission line is not operational.

In addition, it is also a concern for transmission lines with a single phi SUTT configuration of 150 kV Cikande—Ciruas | Indah Kiat, where if one of the sections is not operating, the other section will be burdened by more than 80%. In accordance with the power flow analysis carried out above, it is necessary to build new infrastructure that can improve the reliability of electricity supply in the Cilegon subsystem.

In accordance with the RUPTL for 2021 – 2030, the construction plan of GITET 500 kV Cikande and its 150 kV Outlet is one of the planned infrastructures that can help the reliability of the Cilegon sub-system with a target of completion in 2025.

RESEARCH METHODS

This research uses quantitative research methods, which are also known as traditional, positivistic, scientific, and discovery methods. This method emphasizes using numerical or non-numerical data converted into numbers. Quantitative research is known for its rigorous application of the principle of objectivity, including using instruments tested for validity and reliability (Hayashi et al., 2019; Leung, 2015). In this study, the main objective is to analyze the financial feasibility of the GITET 500 kV Cikande electricity infrastructure development project using Monte Carlo simulation with the help of Crystal Ball software.

The object of this study is a study of the financial feasibility of the GITET 500 kV Cikande construction project. The data sources used in this study consist of primary data and secondary data. Primary data is obtained through verbal statements from informants or respondents that are trustworthy and relevant to the research variables. Secondary data comes from documents, photos, films, video recordings, and other sources that can enrich the information obtained from primary data.

The population in this study includes all data relevant to the GITET 500 kV Cikande construction project, while the research sample is taken from the most representative and relevant data to be analyzed in the financial feasibility study. The research techniques used include data collection through literature and document studies and data analysis using Monte Carlo simulations. The main tool used in this study is the Crystal Ball software, which allows to perform recalculations or iterations of input variables as many as 10,000 times based on a predetermined range of values and probability distribution types.

The analysis technique in this study involves several important steps. First, the structure of the financial feasibility calculation model is made in a spreadsheet, including the collection and organization of input data, such as the annual investment disburse plan, the projected revenue from the sale of electrical energy, the projection of the purchase of electrical energy, and the estimate of operational and maintenance costs. Next, basic assumptions are prepared, including projected burden growth, changes in interest rates, the life of the infrastructure, and the depreciation value of assets. After that, cash flow projections are made for all benefits and costs during the operation of the infrastructure, and output variables are calculated.

After the calculation model is completed, Monte Carlo simulations are carried out to generate data on the probability of the value of the output variables, considering the elements of uncertainty in each input variable at the same time. The results of this simulation are expected to help the management of PT PLN (Persero) in understanding the level of risk from investment and improving accuracy in decision-making. In addition, sensitivity analysis was carried out to obtain the percentage of confidence level of output variables by making adjustments to several input variables that have a high risk of change. The final stage of this research is to summarize the overall research results and provide suggestions that can be used as material for further research development.

RESULTS AND DISCUSSION

Input Variable Statistical Parameters

Investment Costs

The investment cost used as an input variable in the calculation of the financial feasibility analysis is not limited to the cost of electricity infrastructure development but includes supporting costs such as land acquisition costs, ROW compensation, licensing management to environmental permit fees (UKL/UPL/AMDAL). The value of this investment cost is influenced by various risks that can potentially increase costs such as price changes raw materials, changes in government policies, changes in technical standards, to social risks related to the land acquisition process / ROW compensation to communities affected by utility development, therefore it is necessary for this variable to be included in one of the variables used as a reference in the analysis of financial feasibility using the Monte Carlo method. The value of the investment cost used as a base case in the calculation of investment feasibility is Rp. 1,041,177,359,- with the type of log-normal probability distribution, so that by setting the certainty level at a value of 90%, statistical parameter data for investment costs is obtained as follows.

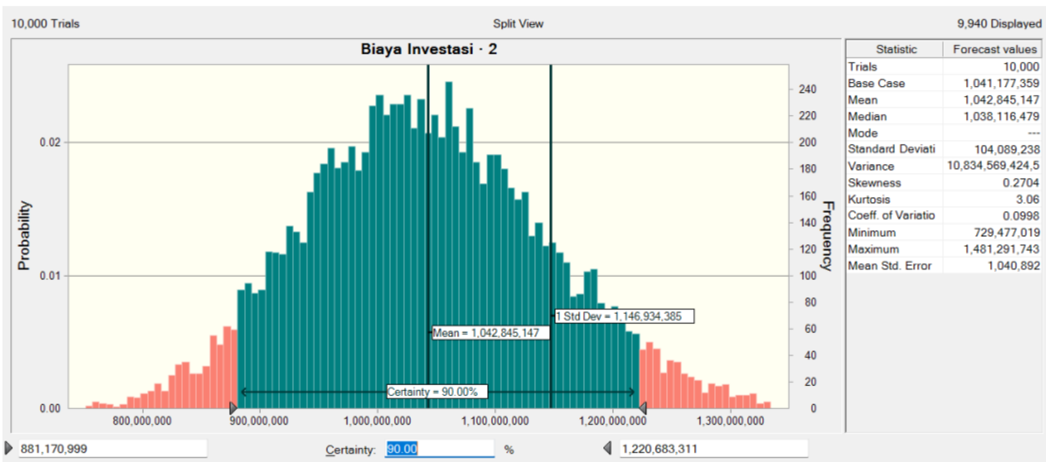

Figure 1. Statistical Parameters of Input Variables Investment Costs

Cost of Purchasing Electricity from Plants

For the input variable of the cost of purchasing electricity from the plant/transfer price of the plant, the type of distribution used is the Beta-PERT probability distribution with the determination of the Base Case value according to the Power Purchase Agreement (PPA) / Power Purchase Agreement (PJBTL) document and the determination of the Optimistic and Pessimistic value in accordance with the sensitivity analysis data contained in the KKP document as follows.

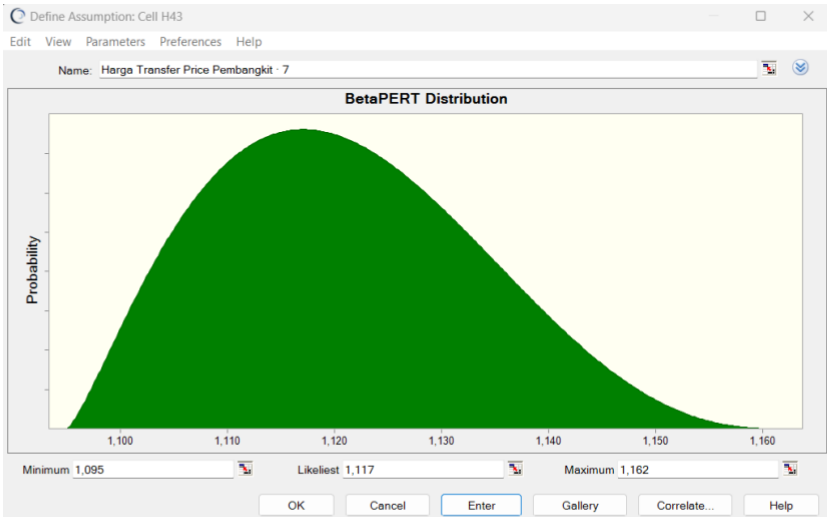

Figure 2. Probability Distribution of Input Variables for the Purchase of Electricity Costs from Plants

Growth of Electrical Energy

Growth/growth of electrical energy is one of the input variables used in financial feasibility analysis using the Monte Carlo simulation because it has a fairly high element of uncertainty/risk. One of the main risks is regulatory uncertainty and government policies that may change in line with changes in politics and national priorities, economic risks, such as fluctuations in fuel prices, the cost of new technologies, technical risks related to the reliability and safety of the power grid and the integration of renewable energy sources, as well as social risks, including public resistance to new energy projects and inequality of access to electricity, It can also affect the overall growth of electrical energy. The probability distribution used for this variable is a normal distribution, so by setting the certainty level of 90%, the following statistical value parameters are obtained.

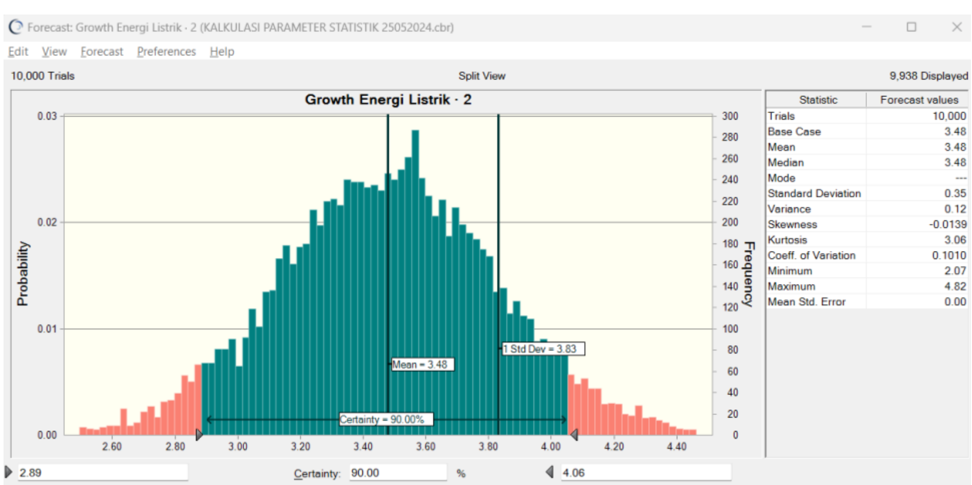

Figure 3. Statistical Parameters of Input Growth Variables

Channeled Electrical Energy

The value of the channelled electrical energy used in the calculation of financial feasibility is adjusted to the operating pattern contained in the calculation of the Operational Feasibility Study contained in the KKP, where the IBT 1 and IBT 2 transformers are burdened by 60%. In this analysis, the data on electrical energy channelled to customers is used to estimate revenue from the sale of electrical energy so that it can provide a more accurate picture of the strategic decision-making process. The value of electrical energy channelled to customers is also influenced by risks that can disrupt the stability and continuity of electricity supply, such as the risk of disruption to transmission/distribution network infrastructure, extreme weather or natural disasters as well as operational risks related to network management and management that can cause the value of electrical energy distributed to customers not in accordance with the assumptions that have been set at the beginning. The type of probability distribution used in this variable is Log-Normal, so by setting a certainty level of 90%, the following statistical value parameters are obtained.

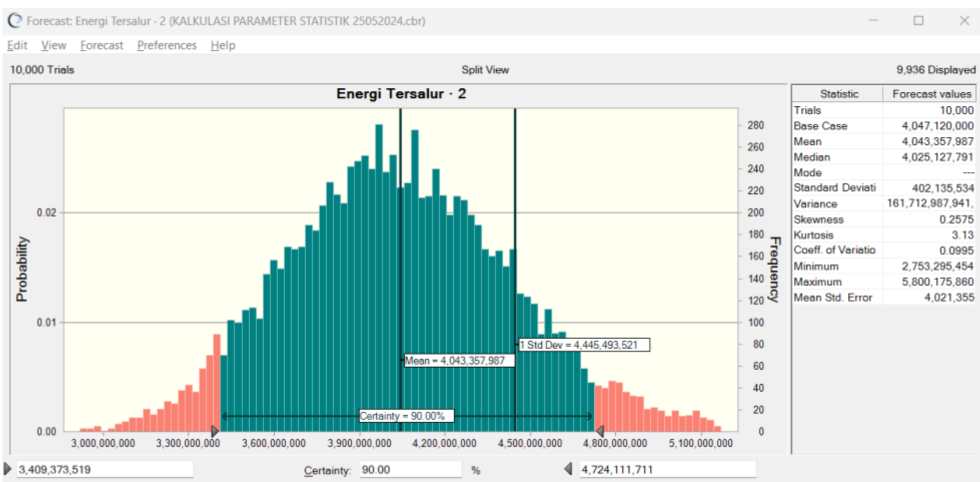

Figure 4. Statistical Parameters of Variable Input of Distributed Electrical Energy

Interest Rate

Interest rate is one of the key variables in the calculation of the financial feasibility analysis of a project as an important component in the calculation of Net Present Value (NPV) and Internal Rate of Return (IRR). The base case value used is adjusted to PLN's Weighted Average Cost of Capital (WACC) value in 2022 of 9.28%. Fluctuations in interest rates in the calculation of financial feasibility analysis can also affect the feasibility of an investment proposal therefore in this study, the value of optimistic and pessimistic The results used were 10.208% and 8.35%, respectively, according to the sensitivity analysis data contained in the MPA with a triangular probability distribution.

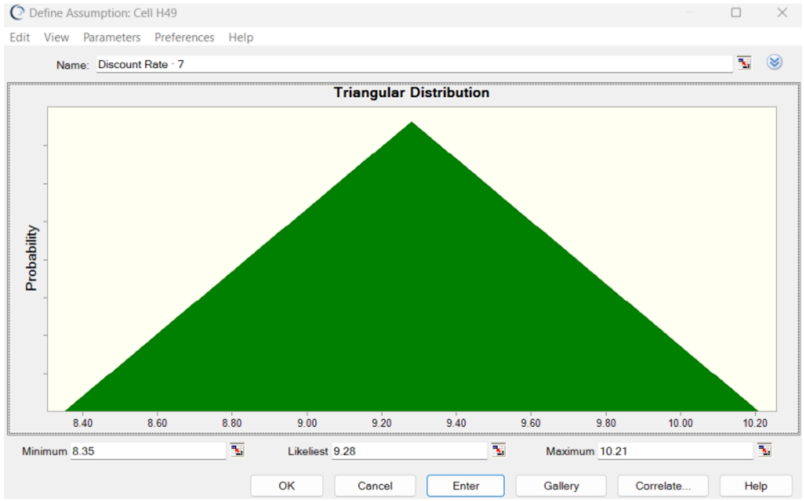

Figure 5. Probability Distribution of Interest Rate Input Variables

Monte Carlo Simulation Output Variable

In this study, the calculation of the financial feasibility analysis of the construction of GITET 500 kV Cikande and its 150 kV Outlet will be carried out using the Monte Carlo method to obtain output parameters in the form of IRR, NPV and Payback Period values using the parameter assumptions contained in table 2. The simulation was carried out 10,000 times using crystal ball software integrated with Microsoft Excel. Before the simulation using the Monte Carlo method, the author made a calculation model for the financial feasibility study based on predetermined parameters; this calculation model represents the values of the input parameters into an estimate of the cash-in and cash-out value of this investment plan

Analysis of the results of the Net Present Value (NPV) simulation

The NPV value is calculated by changing the values of several input variables in accordance with the probability distribution range of each variable due to the element of uncertainty/risk. The results of the NPV calculation simulation are as follows.

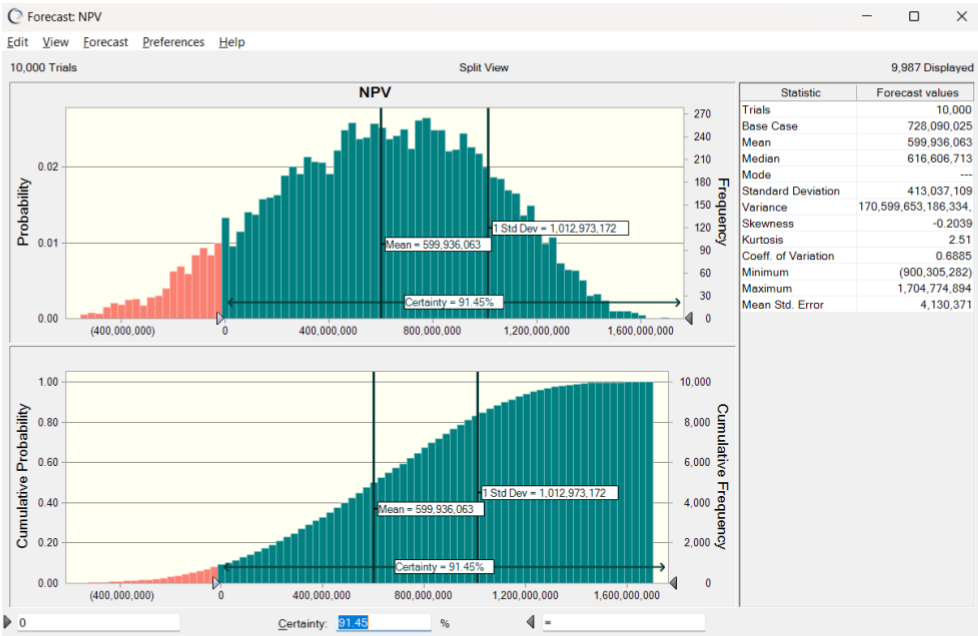
Figure 6. Monte Carlo Simulation Results on NPV Parameters

In Figure 6, there is a green and red chart bar; the green chart bar shows the probability of NPV value > 0, while the red chart bar shows the probability of NPV value <0. Based on the results of the simulation, it can be seen that the probability of an NPV value of > 0 is 91.45%, with the optimum NPV value shown at the mean value of Rp. 599,936,063,- so from the results of the simulation, it can be concluded that the value of this investment is still fairly feasible. Using the Monte Carlo method, it is also possible to quantify the level of probability of NPV values.

Analysis of the Results of the Internal Rate of Return (IRR) Simulation

The calculation of IRR is also carried out with the same assumption as the calculation of the NPV value; the Monte Carlo simulation is carried out to obtain the probability value of the IRR > from the WACC VALUE OF PT PLN (Persero) in accordance with the KKP document, which is 9.28%. The results of the IRR value calculation simulation are as follows.

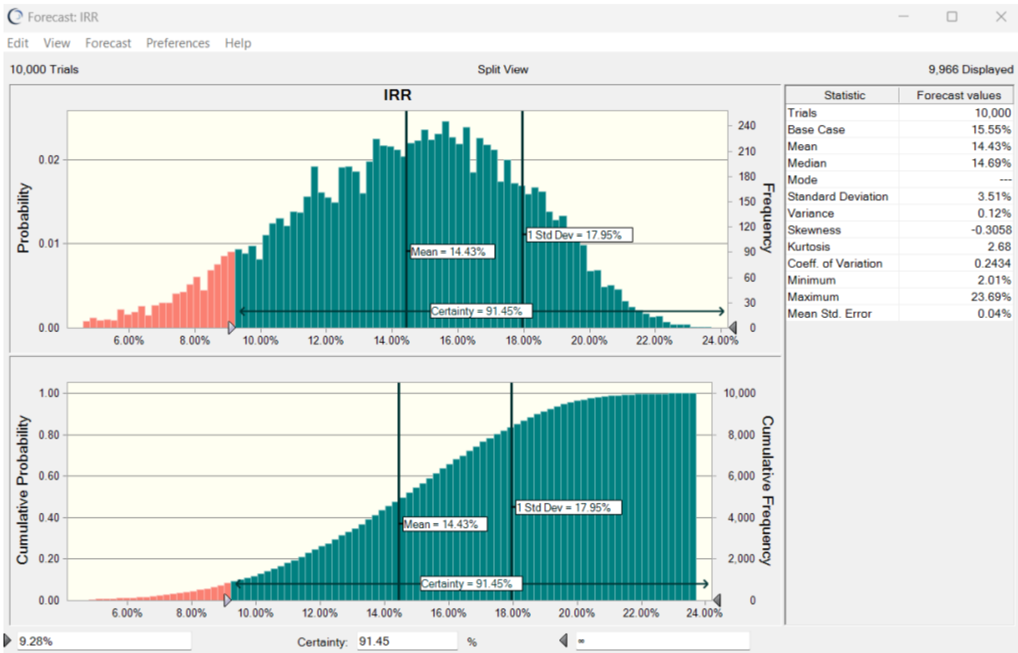

Figure 7. Monte Carlo Simulation Results on IRR Parameters

Based on the simulation results in Figure 7. The results of the probability of the IRR value were obtained after 10,000 simulations. The optimum value of IRR is 14.43%; the simulation results show that, after including the element of uncertainty/risk in several input variables, the level of confidence in the IRR > WACC (9.28%) is 91.45%. Thus, it can be interpreted that from 10,000 calculation attempts with a combination of changes in several input variables, the level of investment confidence that is profitable is more than 90%.

Payback Period (PbP) Result Analysis

The calculation of the payback period results is also carried out to get the most optimal return time by considering every potential risk that will occur in implementing the investment. This data is needed to be used as one of the considerations in the decision-making process for investment implementation. The results of the simulation of the payback period calculation are as follows.

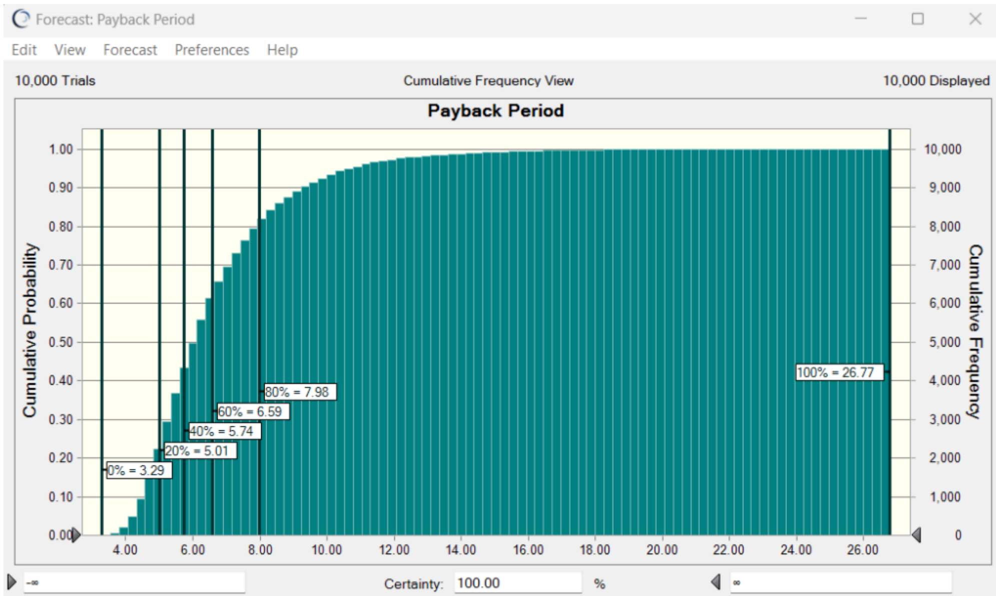

Figure 8. Monte Carlo Simulation Results on Payback Period Parameters

Based on the results of the Payback Period calculation simulation of 10,000 times, the probability value divided into percentages is obtained as follows:

1. The probability of the Payback Period value for 3.29 years is 0%
2. The probability of the Payback Period value for 5.01 years is 20%.
3. The probability of the Payback Period value for 5.74 years is 40%.
4. The probability of the Payback Period value for 6.59 years is 60%.
5. The probability of the Payback Period value for 7.98 years is 80%.
6. The probability of the value of the Payback Period for 26.77 years is 100%.

From these results, the average return on investment is 6.68 years, which is included in the 80% percentile. This value already represents most simulation results, so if infrastructure development projects can be completed according to the COD schedule 2025, then the Break Event Point (BEP) can be projected in mid-2032. The average return on investment from the results of the 10,000 times Monte Carlo simulation is shown in Figure 9.

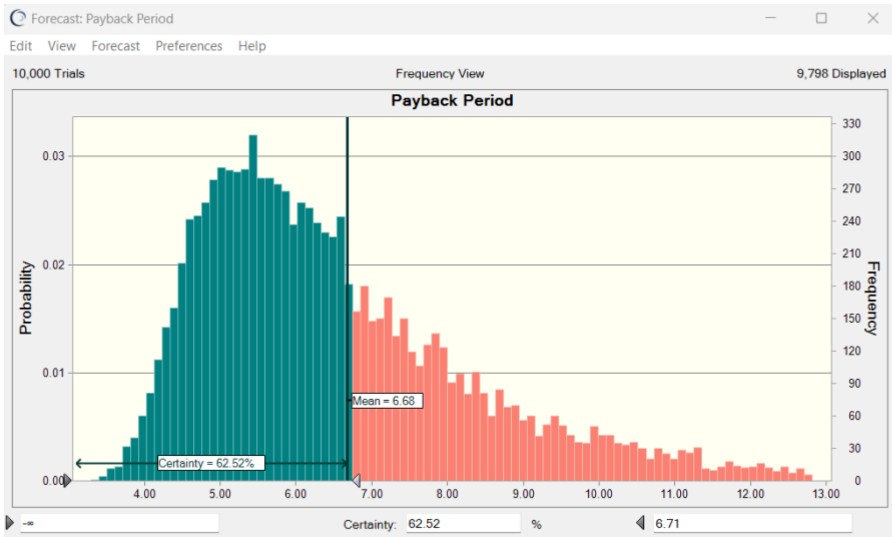

Figure 9. Average Return on Investment

Comparison of Monte Carlo Method Results with Deterministic Method

Table 1 compares the results of the financial feasibility analysis using the deterministic method and the Monte Carlo method after the simulation.

Table 1. Comparison of the Results of Financial Feasibility Analysis of Deterministic Methods By Monte Carlo Method

Output Variables	Unit	Deterministic Method (KKP Document)	Monte Carlo Method		Difference
			Value	Confidence Level	
Net Present Value (NPV)	IDR	730,165,180	599,936,063	91.45%	130.229.117
Internal Rate of Return (IRR)	%	15.57	14.43	91.45%	1,14
Payback Period	Tahun	5.70	6.68	62.05%	0,98

From the table above, the difference in the value of the output parameters produced by the deterministic and Monte Carlo methods is obtained. The difference is because the deterministic method only uses one point of assumption on the input variable, while in the Monte Carlo method, the input variable processed by the financial model is a range of values according to the type of probability distribution of each variable so that the output produced is not only the optimal value of the output variable but also the percentage of confidence in these results.

Sensitivity Analysis Calculation

Based on the simulation results shown in table 4.1, with the condition of the input variable used using the base case value according to table 3.4, it can be concluded that the investment in the development of electricity infrastructure of GITET 500 kV Cikande and its 150 kV outlet is very feasible with a confidence level of >90%. However, in this study, sensitivity analysis is still carried out by widening the range of possible uncertainty for several input parameters. The sensitivity analysis was carried out by simulating the increase in investment costs, the decrease in the value of the growth percentage, and the gradual decrease in the value of energy channelled to customers, up to 30%. This sensitivity analysis aims to obtain the percentage of confidence level of positive NPV value and IRR value greater than WACC. The results of the sensitivity analysis are shown in Table 2.

Table 2. Results of Sensitivity Analysis to Changes in Investment Costs, Growth and Channeled Energy

Output Variables	Confidence Level					
	Investment Costs, Channeled Energy Growth					
	Base Case	Investment Fee +10% Growth & Energy -10%	Investment Fee +15% Growth & Energy -15%	Investment Fee +20% Growth & Energy -20%	Investment Fee +25% Growth & Energy -25%	Investment Fee +30% Growth & Energy -30%
Internal Rate of Return (IRR) > WACC	91.45%	84.51%	79.84%	71.64%	61.27%	48.35%
Net Present Value (NPV) Positif	91.45%	84.25%	79.34%	71.35%	61.22%	48.51%

In the sensitivity analysis simulation, the value of investment costs was increased, the growth value decreased, and the estimated energy channelled to customers was gradually reduced from 10% to 30% to get a sense of what percentage of confidence in IRR and NPV is still acceptable. From these results, it can be seen that the investment in the development of electricity infrastructure at GITET 500 kV Cikande and 150 kV outlets is still safe if there is an increase in investment costs, a decrease in growth and a decrease in energy channelled to customers of up to 25%, this is shown by the results of the probability that the positive IRR > WACC and NPV values are still at > 60%, but if there is an increase in investment costs, The decrease in growth and the decrease in energy channelled to customers >25% to 30%, this investment will be very risky financially with a positive level of confidence in the value of IRR > WACC and NPV < 50%, so the implementation of the investment is recommended not to continue.

CONCLUSION

This study calculates the financial feasibility analysis of the proposed investment in electricity infrastructure development using a different method from the one used in the project feasibility study document. Based on the results of the analysis and discussion in the previous chapter, the following conclusions can be drawn: First, by using the Monte Carlo simulation in analyzing the financial feasibility of an investment plan, it is possible to quantify the confidence level in the output variables' results against their respective eligibility criteria. Second, Monte Carlo simulations of several input variables simultaneously can describe more realistic conditions in sensitivity analysis calculations compared to using deterministic methods. Third, according to the results of the sensitivity analysis, the safe threshold for an increase in investment costs, a decrease in growth, and a decrease in channeled energy that is still acceptable is 25% of the base case value (initial assumption). This research can be further developed by paying attention to several points: First, conducting a comprehensive risk analysis is necessary to obtain the variables with the most uncertainty/risk impacting the results of the financial feasibility calculation. Second, this method can be used to calculate the financial feasibility of PT PLN (Persero)'s electricity infrastructure investment plan.

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