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Comparative Analysis Of Medium Voltage And Low Voltage Distribution Networks On Voltage Losses And Costs In Industrial Electricity Distribution Systems

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Abstract

Industrial power distribution systems must maintain voltage quality and cost efficiency to ensure reliable power delivery to load points. This study aims to compare the technical and economic performance of medium-voltage and low-voltage distribution networks in an automotive component manufacturing company in Karawang Regency. The study employed a quantitative approach with comparative analysis based on single line diagrams, block diagram system, conductor length, conductor type, load data, conductor resistance, voltage drop, and network cost. The results showed that the medium-voltage network had lower voltage drop, ranging from 0.402% to 1.827%, compared with the low-voltage network ranging from 2.312% to 3.234%. From the economic perspective, the total cost of the medium-voltage network was IDR 2,541,900,000, while the low-voltage network reached IDR 23,551,831,333. In conclusion, the medium-voltage network was proven to be technically more efficient and more economical for implementation at the research site.

Keywords power distribution system; medium voltage; low voltage; voltage drop; cost analysis

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INTRODUCTION

The electric power distribution system plays an important role in ensuring the continuity, quality and efficiency of the distribution of electrical energy from the source to the load. In industrial environments, distribution system reliability becomes increasingly important because any disruption or distribution inefficiency can affect production processes, equipment performance and overall operational costs. Therefore, planning and selecting distribution network configurations must be carried out carefully so that they are able to meet power needs while maintaining voltage quality (Eaton, 2017; Schneider Electric, 2025). One of the main problems in distribution systems is the occurrence of voltage losses in the lines, especially when the distribution distance, current magnitude and conductor characteristics are not designed optimally (Schneider Electric, 2022; Srivastava et al., 2023).

Voltage loss is the decrease in voltage from the source point to the load point due to impedance in the conductor. The magnitude of the voltage loss will affect the quality of the voltage received by the load. If the value is too large, the performance of electrical equipment can decrease and the efficiency of the distribution system will be disrupted (Schneider Electric, 2022). In the context of industrial installations, this issue is not only technical but also has direct economic implications. The greater the voltage loss, the greater the potential for energy inefficiency and the costs involved in building and operating the distribution system (Mathenge et al., 2024; Pedrini & Donadel, 2025).

In addition to voltage loss, cost is also an important consideration in determining the type of distribution network to be implemented. The choice of a medium-voltage or low-voltage network is determined not only by the system's capacity to transmit power, but also by the size of the material investment, the length of the transmission lines, and the need for supporting infrastructure (Eaton, 2017; Schneider Electric, 2025). On the one hand, medium-voltage networks generally offer better power delivery over a given distance because lower currents can reduce voltage drops. However, on the other hand, their implementation may require different system components and equipment than low-voltage networks. Conversely, low-voltage networks are simpler in some installation aspects, but can incur greater voltage losses when used to serve loads over a given distribution distance (Jaskólski et al., 2025; Pedrini & Donadel, 2025).

These issues demonstrate that selecting an alternative distribution network cannot be based on a single indicator. An integrated evaluation must be conducted, taking into account both technical indicators, such as voltage loss, and economic indicators, such as network implementation costs. This ensures that decisions made not only result in a technically feasible

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system but also provide cost-effective benefits. This approach is particularly important in industrial environments, where the need for a reliable and economical distribution system must be balanced (Horowitz et al., 2018; Jaskólski et al., 2025; Pedrini & Donadel, 2025).

This research was conducted at an automotive component manufacturing company in Karawang Regency, which needs power distribution from the source to several operational load points. Based on available technical data, there are alternative implementations of medium-voltage distribution networks and low-voltage distribution networks that can be analyzed to determine their respective performance levels. The availability of data in the form of single-line diagrams, system block diagrams, line length data, conductor characteristics, voltage drop values, and cost estimates allows for quantitative technical and economic evaluations. This provides an adequate basis for objectively comparing the two network alternatives.

Numerous studies in the field of electric power distribution systems generally focus on analyzing power losses, voltage losses, system reliability, or optimizing network configurations. However, in industrial distribution planning practice, studies directly comparing medium-voltage and low-voltage networks based on two key indicators: voltage losses and implementation costs are still relatively limited. Yet, such comparisons are crucial for technical decision-making in the field (Jaskólski et al., 2025; Pedrini & Donadel, 2025). Thus, this study has practical relevance because it provides an evaluation basis for selecting a distribution system that not only meets technical requirements, but is also more economical to implement.

However, previous studies have focused more on linguistic, social, and historical aspects. Almost no research has comprehensively assessed bilingual education from an economic perspective. This gap represents a major research gap and underlies the urgency of CBA-based research. This article aims to apply a cost-benefit analysis to a Thai-Malay bilingual program in a private Islamic school in Southern Thailand, to assess the extent to which investment in the program is economically, socially, and educationally justified. Theoretically, this study enriches the study of the economics of education in the context of a multilingual society. Practically, the research findings are expected to provide a more measurable policy basis for schools, educational foundations, and local governments in developing sustainable and effective bilingual programs. Against this backdrop, this article aims to conduct a cost-benefit analysis of a Thai-Malay bilingual program in a private Islamic school in Southern Thailand. Theoretically, this research will enrich the literature on the economics of education in a multilingual and ethnic minority context. Practically, the analysis is expected to provide empirical input for school administrators, local communities, and policymakers on whether bilingual programs are feasible to continue, and how

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to design financing and strategies to make bilingualism more efficient, inclusive, and sustainable.

METHODS

This study uses a quantitative approach with a comparative analysis method. This approach is used to compare the performance of medium-voltage and low-voltage distribution networks based on voltage loss values and network implementation costs. The results of this comparison are used to determine the most technically efficient and economical network alternatives at the research location.

The research was conducted at an automotive component manufacturing company in Karawang Regency. The object of the study was the electricity distribution network system from the power source to load points in the company's operational area. The analysis focused on two alternative distribution systems: a medium-voltage network and a low-voltage network.

The data used is secondary data obtained through documentation studies. This data includes single-line diagrams, system block diagrams, channel length data, conductor type and size, load current, cable resistance values, voltage drop data, and network cost data. All data is inventoried and categorized according to the needs of the technical and economic analysis.

The initial stage involves identifying the distribution network configuration based on available technical documents. This identification aims to determine the power distribution path from the source to the load points in each network alternative. The results of this stage serve as the basis for determining the parameters to be analyzed.

Voltage loss calculations are performed on each distribution line using data on conductor length, load current, and cable resistance. Voltage loss values are calculated for medium-voltage and low-voltage networks and then expressed as a percentage. The results of these calculations are used to assess the technical efficiency of each network alternative.

Cost calculations are based on the network material requirements, particularly the type of conductor and the length of the distribution lines for each alternative. The costs for each line are summarized to obtain the total cost of the medium-voltage and low-voltage networks. These results are used to compare the economics of the two alternatives.

A comparative analysis was conducted by integrating the results of voltage loss and network cost calculations. The alternative with the lower voltage loss was deemed more technically efficient, while the alternative with the lower total cost was deemed more economical. Based on these two indicators, the most appropriate network alternative for implementation at the research location was determined.

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The data analysis techniques used were quantitative descriptive analysis and comparative analysis. Quantitative descriptive analysis was used to present technical and cost data in tabular form and brief descriptions. Comparative analysis was used to compare voltage loss and costs between medium-voltage and low-voltage networks. The results of the analysis served as the basis for drawing conclusions regarding the most efficient and economical network alternatives.

RESULT AND DISCUSSION

Voltage Loss Analysis in Medium Voltage and Low Voltage Networks

The voltage loss analysis in this study was conducted to compare the voltage drop characteristics of several types and sizes of cables used in the distribution system, namely NYY 1 × 240 mm², NYY 1 × 300 mm², XLPE 1 × 240 mm², and XLPE 1 × 300 mm². The evaluation was carried out at various distances ranging from 50 m to 300 m to observe the tendency of changes in voltage loss as the length of the conductor path increases. The calculation results show that voltage loss increases consistently in all types of cables as the distribution distance increases. This finding confirms that conductor length is one of the main factors influencing the magnitude of voltage drop in the electric power distribution system.

In the NYY cable group, the voltage loss values obtained tend to be much greater than those of XLPE cables across the entire observation distance range. The 1 × 240 mm² NYY cable showed a voltage loss of 1.066% at a distance of 50 m and increased gradually to 6.396% at a distance of 300 m. Meanwhile, the 1 × 300 mm² NYY cable produced a voltage loss of 0.991% at a distance of 50 m and increased to 5.946% at a distance of 300 m. These results indicate that increasing the cross-sectional area from 240 mm² to 300 mm² is able to reduce the voltage loss, although the reduction is not enough to keep the voltage loss value below the threshold at longer distribution distances.

When compared to the 4% voltage loss limit, the 1 × 240 mm² NYY cable begins to exceed this limit at a distance of 200 m with a value of 4.264%, while the 1 × 300 mm² NYY cable is still slightly below the limit at the same distance, namely 3.964%, and only exceeds it at a distance of 225 m with a value of 4.459%. This condition shows that the NYY cable is still suitable for use on shorter distribution lines, but becomes less efficient when applied to longer lines. Thus, for systems using NYY cables, increasing distribution distance has a very significant effect on increasing voltage losses. This also shows that selecting a larger cable size can only reduce, but not eliminate, the tendency for voltage losses to increase at longer distribution distances.

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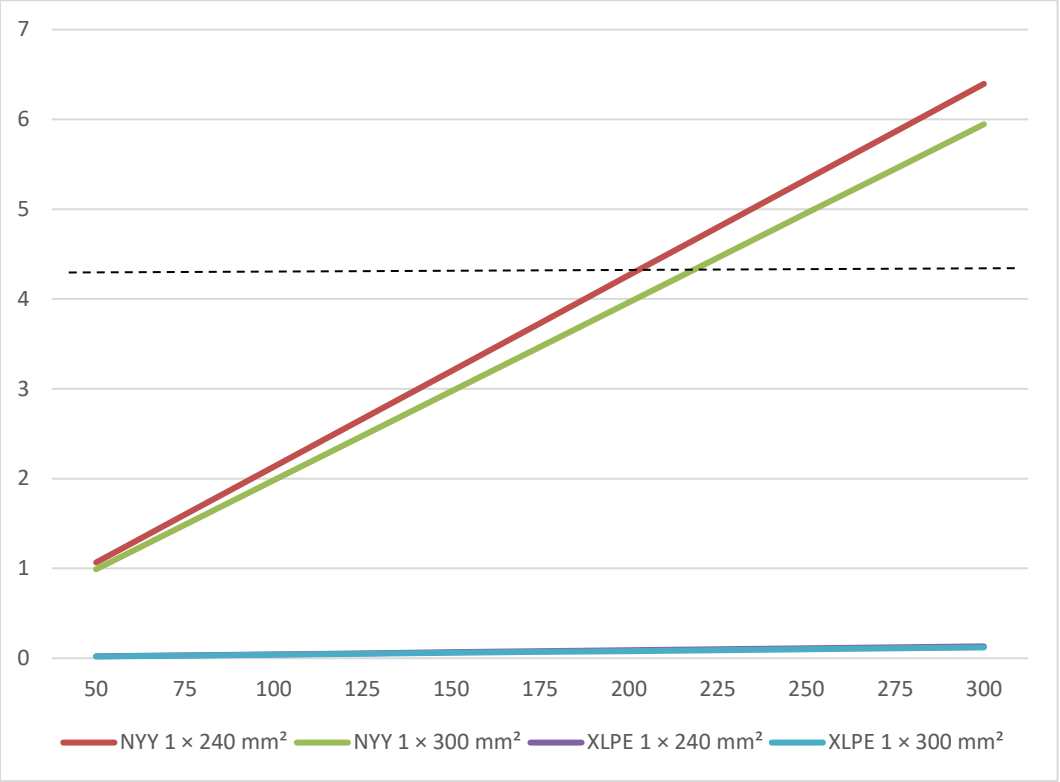


Figure 1 Relationship between Distance and Voltage Loss

In contrast to NYY cables, calculations for XLPE cables show very low voltage losses across all distance variations. A 1 × 240 mm² XLPE cable produces a voltage loss of 0.022% at a distance of 50 m, increasing to 0.132% at a distance of 300 m. Meanwhile, a 1 × 300 mm² XLPE cable shows a voltage loss of 0.020% at a distance of 50 m, increasing to 0.120% at a distance of 300 m. These values are significantly lower than those of NYY cables, indicating that XLPE cables demonstrate significantly better voltage transmission performance in maintaining voltage stability on the load side.

A comparison between 1 × 240 mm² and 1 × 300 mm² XLPE cables also shows a consistent pattern: larger cross-sections result in lower voltage losses. However, the difference between the two XLPE cables is relatively small compared to the difference observed in the NYY cable group. This indicates that technically, both XLPE cables are still at an excellent efficiency level for the entire observation distance. In other words, from a voltage loss perspective, the use of XLPE cables provides a safer technical margin against the permissible voltage loss limit.

The analysis results show that cable type has a significant impact on the magnitude of

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voltage losses in the distribution system. NYY cables tend to produce greater voltage losses, especially on long distribution lines, while XLPE cables show significantly lower voltage losses under all observation conditions. Furthermore, increasing the cable cross-sectional area from 240 mm² to 300 mm² has been shown to reduce voltage losses in both NYY and XLPE cables. Therefore, in the context of this research, the selection of cable type and size is an important factor in determining the technical efficiency of medium and low voltage distribution networks.

When linked to the distribution system requirements at the research site, cables with lower voltage losses are more appropriate for distribution lines with longer runs or larger loads. Conversely, cables with voltage losses that increase sharply with distance require special attention because they have the potential to degrade voltage quality at the load point. Thus, the results of this analysis indicate that evaluating voltage losses is not only important for determining the technical performance of the network but also serves as a basis for selecting more efficient and reliable distribution configurations.

Network Implementation Cost Analysis

The table of voltage loss and cost calculations for the low-voltage distribution network shows the technical and economic parameters for each distribution line from the power house to the mezzanine area. This table contains five main lines, namely PUTR-3, PUTR-4, PUTR-5, PUTR-6, and PUTR-7, with loads ranging from 3,000 A to 5,000 A, conductor lengths ranging from 115 m to 431 m, and conductor resistance values ranging from 0.008 to 0.011. Based on the calculation results, the voltage loss in the low-voltage distribution network is in the range of 2.312% to 3.234%, while the total cost of implementing the network reaches Rp23,551,831,333. These results indicate that each line has different technical characteristics and cost consequences according to the load, path length, and cable configuration used.

In detail, the line from Power House 1 to Mezzanine 1 consists of two branches, namely PUTR-3 and PUTR-4. PUTR-3 with a 4x7 (1c×300) mm2 NYY cable, a load of 3,000 A, and a length of 158 m produces a voltage loss of 2.312% with a cost of Rp2,314,858,000. Meanwhile, PUTR-4 with a 4x8 (1c×300) mm2 NYY cable, a load of 4,000 A, and the same length produces a voltage loss of 2.697% with a cost of Rp3,527,402,667. This comparison shows that on the same line, increasing the load contributes to increasing voltage losses and network costs.

On the path to Mezzanine 2, namely PUTR-5, a NYY 4x9 (1c×300) mm2 cable is used with a load of 5,000 A and a conductor length of 431 m. This path produces a voltage loss of 2.997% with a cost of Rp10,824,996,000, which is the largest cost among all paths in the low voltage

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network. On the path to Mezzanine 3, namely PUTR-6, the cable used is NYY 4x7 (1c×300) mm2 with a load of 3,000 A and a length of 221 m, resulting in a voltage loss of 3.234%, which is the highest voltage loss value, with a cost of Rp4,317,161,333. The route to Mezzanine 4, namely PUTR-7, uses a 4x8 (1c×300) mm2 NYY cable with a load of 4,000 A and a length of 115 m, and produces a voltage loss of 2.697% at a cost of Rp2,567,413,333.

Table 1 Results of Voltage Loss and Cost Calculations in Low Voltage Distribution Networks

No	Penghantar		Beban	Jarak	R	Loses Tegangan	Biaya
1	Dari Power House 1 ke Mezzanine 1						
	Panel PUTR-3	Kabel NYY 4x7 (1cx300) mm2	3.000 A	158	0,011	2,312%	2.314.858.000
	Panel PUTR-4	Kabel NYY 4x8 (1cx300) mm2	4.000 A	158	0,009	2,697%	3.527.402.667
2	Dari Power House 1 ke Mezzanine 2						
	Panel PUTR-5	Kabel NYY 4x9 (1cx300) mm2	5.000 A	431	0,008	2,997%	10.824.996.000
3	Dari Power House 2 ke Mezzanine 3						
	Panel PUTR-6	Kabel NYY 4x7 (1cx300) mm2	3.000 A	221	0,011	3,234%	4.317.161.333
4	Dari Power House 2 ke Mezzanine 4						
	Panel PUTR-7	Kabel NYY 4x8 (1cx300) mm2	4.000 A	115	0,009	2,697%	2.567.413.333
						Total Rupiah	**23.551.831.333**

The table of voltage loss and cost calculations for the medium-voltage distribution network shows the technical and economic parameters for each distribution path from the power house to the mezzanine area. The table lists four main paths: Mezzanine 1, Mezzanine 2, Mezzanine 3, and Mezzanine 4, with loads ranging from 3,000 A to 7,000 A, conductor lengths ranging from 115 m to 431 m, and a uniform conductor resistance value of 0.098. Based on the calculation results, the voltage loss in the medium-voltage distribution network ranges from 0.402% to 1.827%, while the total cost of implementing the network reaches Rp2,541,900,000.

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These results indicate that the medium-voltage network has good technical performance with relatively small voltage losses and lower cost requirements compared to alternative low-voltage networks. In detail, the path from Power House 1 to Mezzanine 1 uses N2XSY 3 × 240 mm2 cable through Cubicle 1 PUTR 3 & PUTR 4 with a load of 7,000 A and a conductor length of 158 m. This path produces a voltage loss of 0.938% with a cost of Rp434,184,000. This value shows that at a fairly large load, the medium voltage network is still able to maintain voltage drops at a low level. This condition indicates that the use of a higher voltage level provides benefits in power distribution efficiency.

Table 2 Calculation Results, Voltage Losses in Medium Voltage Distribution Networks

No	Penghantar		Beban	Jarak	R	Loses Tegangan	Biaya
1	Dari Power House 1 ke Mezzanine 1						
	Cubicle 1 PUTR 3 & PUTR 4	Kabel N2XSY 3 x 240 mm2	7.000 A	158	0,098	0,938%	434.184.000
2	Dari Power House 1 ke Mezzanine 2						
	Cubicle 2 PUTR 5	Kabel N2XSY 3 x 240 mm2	5.000 A	431	0,098	1,827%	1.184.388.000
3	Dari Power House 2 ke Mezzanine 3						
	Cubicle 3 PUTR-6	Kabel N2XSY 3 x 240 mm2	3.000 A	221	0,098	0,402%	607.308.000
4	Dari Power House 2 ke Mezzanine 4						
	Cubicle 4 PUTR-7	Kabel N2XSY 3 x 240 mm2	4.000 A	115	0,098	0,536%	316.020.000
						Total Rupiah	**2.541.900.000**

On the route to Mezzanine 2, namely Cubicle 2 PUTR 5, an N2XSY 3 × 240 mm2 cable was used with a load of 5,000 A and a conductor length of 431 m. This route resulted in a voltage loss of 1.827% and a cost of Rp1,184,388,000, representing the highest cost and voltage loss among all the lines in the medium-voltage network. This high value is understandable because this line has the longest distribution path, making the influence of conductor length on voltage drop and

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cost requirements more dominant. These findings indicate that although the medium-voltage network is more efficient, line length remains a factor affecting the technical and economic performance of the system.

On the route from Power House 2 to Mezzanine 3, namely Cubicle 3 PUTR-6, an N2XSY 3 × 240 mm2 cable was used with a load of 3,000 A and a conductor length of 221 m. This line produces a voltage loss of 0.402%, the lowest voltage loss, at a cost of Rp607,308,000. Meanwhile, the line from Power House 2 to Mezzanine 4, Cubicle 4 PUTR-7, uses the same cable with a load of 4,000 A and a conductor length of 115 m, and produces a voltage loss of 0.536% at a cost of Rp316,020,000, the lowest cost in this system. This comparison demonstrates that the combination of shorter conductor lengths and relatively moderate loads provides better technical and economic results.

Overall, the table of voltage loss and cost calculations for the medium-voltage distribution network shows that all lines fall well below the 4% voltage loss limit, making them technically feasible. Variations in voltage loss and cost values for each line are still visible, but they are still relatively small compared to the low-voltage network. The path to Mezzanine 2 has the greatest voltage loss and cost due to its longest distribution length, while the paths to Mezzanine 3 and Mezzanine 4 show more efficient performance. Thus, the results in this table provide a strong basis for the medium-voltage distribution network to have better technical and economic advantages at the research location.

Comparison of Network Efficiency and Economics

A technical efficiency comparison was conducted to assess the ability of medium-voltage and low-voltage networks to maintain voltage quality during power distribution. The indicators used in this evaluation were the minimum and maximum voltage loss values, as well as the voltage loss range for each system. The lower the voltage loss value, the better the network's technical performance in delivering power to the load points. The results of the technical efficiency comparison of the two systems are presented in the following table.

Table 3 Comparison of Voltage Losses in Medium Voltage Networks and Low Voltage Networks

Parameter	Jaringan TM	Jaringan TR
Rugi tegangan minimum	0,402%	2,312%
Rugi tegangan maksimum	1,827%	3,234%
Rentang rugi tegangan	0,402%–1,827%	2,312%–3,234%

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Posisi terhadap batas 4%	Seluruh jalur jauh di bawah batas	Seluruh jalur masih di bawah batas, tetapi lebih mendekati batas
Efisiensi teknis	Lebih efisien	Kurang efisien

Based on the table above, the medium-voltage network demonstrates superior technical performance compared to the low-voltage network. This is evident from the voltage loss values in the medium-voltage network, which range from 0.402% to 1.827%, while the low-voltage network ranges from 2.312% to 3.234%. Although both systems remain below the 4% voltage loss limit, the medium-voltage network has a much safer technical margin. Therefore, based on the voltage loss indicator, the medium-voltage network can be considered more efficient in maintaining voltage quality at the load point.

In addition to technical aspects, an evaluation of the two network alternatives was also conducted from an economic perspective. This assessment was based on the total cost of network implementation, identifying the alternative system with the lowest cost to serve the power distribution needs at the study site. Cost comparison is crucial because the selection of a distribution system must be not only technically feasible but also economically rational. The results of the economic comparison of the medium-voltage and low-voltage networks are presented in the table below.

Table 2. Comparison of Medium Voltage Network Costs and Low Voltage Network Costs

Parameter	Jaringan TM	Jaringan TR
Total biaya jaringan	Rp2.541.900.000	Rp23.551.831.333
Selisih biaya		Rp21.009.931.333
Tingkat biaya	Lebih rendah	Lebih tinggi
Keekonomisan	Lebih ekonomis	Kurang ekonomis

Based on Table 2, the medium-voltage network has a total implementation cost of Rp2,541,900,000, while the low-voltage network requires a cost of Rp23,551,831,333. The cost difference between the two systems reaches Rp21,009,931,333, indicating a significant difference in economics. These results confirm that the medium-voltage network not only offers technical advantages but is also significantly more economical than the low-voltage network. Therefore,

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based on cost indicators, the medium-voltage network is a more profitable alternative for implementation at the research site.

The comparison results indicate that the medium-voltage network is superior to the low-voltage network in terms of both technical efficiency and economics. From a technical perspective, the medium-voltage network produces lower voltage losses across all distribution lines, thus better maintaining voltage stability at the load side. From an economic perspective, the medium-voltage network also requires a significantly lower total implementation cost than the low-voltage network. Therefore, the medium-voltage network can be identified as the most efficient and economical distribution system alternative for implementation at the research site.

DISCUSSION

The results of the study indicate that medium-voltage networks have lower voltage losses than low-voltage networks across all analyzed distribution lines. In this study, the voltage losses in medium-voltage networks ranged from 0.402% to 1.827%, while those in low-voltage networks ranged from 2.312% to 3.234%. This finding suggests that using higher voltage levels provides better distribution capability in maintaining voltage quality on the load side. Theoretically, this condition aligns with Eaton, Schneider Electric, and Srivastava et al., who assert that voltage quality in distribution networks is strongly influenced by system configuration, voltage levels, and the characteristics of the conductors used (Eaton, 2017; Schneider Electric, 2025; Srivastava et al., 2023).

These performance differences can be explained by the relationship between voltage level, current, and voltage drop across the conductor. At higher voltage levels, the same power can be transmitted with a smaller current, resulting in a lower voltage drop along the line. In this study, this trend is clearly visible when the medium-voltage network still produces relatively low voltage losses despite serving quite long distribution lines, including the 431 m line to Mezzanine 2. Conversely, in the low-voltage network, voltage losses tend to be larger and closer to the permissible limits, resulting in a narrower system technical margin. This pattern is consistent with Schneider Electric, Mathenge et al., and Owosuhi et al., which show that increasing current and line length will increase the potential for voltage losses and reduce the technical efficiency of the distribution system (Mathenge et al., 2024; Owosuhi et al., 2024; Schneider Electric, 2025).

The results of this study also indicate that the length of the distribution path is a significant factor in determining the magnitude of voltage losses in each path. The path to Mezzanine 2, which is 431 m long, shows a tendency for higher voltage losses compared to the path to

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Mezzanine 4, which is only 115 m long. This confirms that the difference in load position relative to the supply source causes the technical characteristics of each distribution branch to be inconsistent. In addition, the results of cable analysis indicate that NYY cables produce significantly greater voltage losses than XLPE cables at all distance variations, while increasing the cross-sectional area from 240 mm² to 300 mm² is proven to be able to reduce voltage losses in both types of cables. These findings are in line with those of Agha and Alzaareer, Shin et al., and Ananwattanaporn et al., who emphasized that cable size, conductor type, and path length are the main determinants of voltage profile performance in distribution systems (Agha & Alzaareer, 2025; Ananwattanaporn et al., 2024; Shin et al., 2024).

When linked to the 4% voltage loss limit, all lines in both systems are still in the feasible category. However, the medium-voltage network is in a much safer position because all values are well below the threshold, while the low-voltage network is closer to the limit. From an industrial operational perspective, this larger technical margin is important because distribution systems are not only required to operate under nominal conditions, but also must be able to maintain voltage stability when load variations occur or the system is expanded in the future. Thus, the results of this study reinforce the views of Pedrini and Donadel, Jaskólski et al., Pham et al., and Rastgou that distribution network selection must consider the system's long-term technical capabilities, not just its immediate feasibility under existing conditions (Jaskólski et al., 2025; Pedrini & Donadel, 2025; Pham et al., 2025; Rastgou, 2024).

The results of this study confirm that medium-voltage networks are superior to low-voltage networks in terms of voltage losses. This superiority is not only due to the higher voltage levels, but also to their ability to maintain voltage quality over longer distribution lines and uneven load distribution. In the context of the study site, which has several mezzanine areas with varying distribution distances, the medium-voltage system provides a better level of technical efficiency and a greater margin of reliability. Therefore, from a voltage loss perspective, medium-voltage networks can be seen as a more appropriate alternative to support the power distribution needs of industrial environments.

Furthermore, the research results show that the cost of implementing a medium-voltage network is significantly lower than that of a low-voltage network at the research location. The total cost of the medium-voltage network was recorded at Rp2,541,900,000, while the low-voltage network reached Rp23,551,831,333. The cost difference of Rp21,009,931,333 indicates that the choice of voltage level has very significant economic consequences. This finding confirms that distribution system evaluations should not be conducted solely from a technical perspective,

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but should also consider the overall cost implications (Horowitz et al., 2018; Jaskólski et al., 2025; Pedrini & Donadel, 2025).

These cost differences can be explained by the system configuration and material requirements for each network alternative. In low-voltage networks, each distribution line requires a larger number and capacity of NYY cables to serve the load on a given line. This condition causes increased material requirements, especially on lines with heavy loads and long line lengths. Conversely, in medium-voltage networks, the use of 3 × 240 mm2 N2XSY cables on each line indicates that power distribution can be carried out with a more compact configuration and more efficient material requirements. This explanation is in line with Eaton, Schneider Electric, and Agha and Alzaareer, who emphasized that distribution system design is strongly influenced by the relationship between distribution capacity, conductor size, and installation cost efficiency (Agha & Alzaareer, 2025; Eaton, 2017; Schneider Electric, 2025).

The effect of path length on costs is also very evident in this study. In the low-voltage network, the path to Mezzanine 2 with a length of 431 m resulted in the highest cost, namely Rp10,824,996,000, while the path to Mezzanine 4 with a length of 115 m resulted in a much smaller cost, namely Rp2,567,413,333. The same pattern is also seen in the medium-voltage network, where the path to Mezzanine 2 has the highest cost of Rp1,184,388,000, while the path to Mezzanine 4 has the lowest cost of Rp316,020,000. This indicates that the longer the distribution path, the greater the need for conductors and the higher the cost of network implementation. This finding is consistent with Rastgou, Ryu et al., and Pham et al. who stated that the length of the network and the structure of the distribution branch are dominant factors in planning investment in electric power distribution systems (Pham et al., 2025; Rastgou, 2024; Ryu et al., 2025).

From an economic perspective, the results of this study imply that industrial distribution system planning cannot be based solely on assumptions of ease of installation or the familiarity of a particular system. The significant cost difference between medium-voltage and low-voltage networks in this study indicates that the system selection decision will directly impact investment efficiency. Therefore, cost evaluation must be an integral part of the technical evaluation from the initial planning stage. In this context, the results show that medium-voltage networks are better able to balance technical performance and cost requirements, making them more rational for implementation in industrial areas with high power requirements and extensive distribution coverage. This implication aligns with Jaskólski et al., Rastgou, and Ryu et al., who emphasized that distribution network development requires an integrated techno-economic approach

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(Jaskólski et al., 2025; Rastgou, 2024; Ryu et al., 2025).

Overall, the implications of this research confirm that medium-voltage networks are more worthy of consideration as the primary choice in industrial electricity distribution planning in areas with wide load distribution and varied distribution paths. These results can be used as a basis for developing, rearranging, and evaluating distribution systems in industrial facilities with similar characteristics. In addition to providing practical contributions in selecting network alternatives, this research also shows that voltage loss and cost analysis can be used as an effective decision-making tool in designing more reliable, efficient, and economical distribution systems.

CONCLUSION

Based on the research results, it can be concluded that the medium voltage distribution network is a superior alternative compared to the low voltage distribution network at the research location, both from a technical and economic perspective. From a technical aspect, the medium voltage network produces lower voltage losses, which are in the range of 0.402% to 1.827%, while the low voltage network is in the range of 2.312% to 3.234%, so the medium voltage network has a better ability to maintain voltage quality at the load point. From an economic aspect, the medium voltage network also shows a much lower implementation cost, which is Rp2,541,900,000 compared to the low voltage network of Rp23,551,831,333, making it more efficient to be implemented in industrial areas with a fairly wide load distribution and varying distribution line lengths. This finding confirms that the selection of a distribution system cannot be based on only one indicator, but must consider voltage losses and network costs in an integrated manner to obtain a more rational decision that is in accordance with field conditions.

Thus, the medium voltage network can be recommended as the most efficient and economical distribution system at the research location, while for further development of similar research it is recommended to add power loss analysis, system reliability, power quality, and simulations in load development scenarios so that the evaluation results are more comprehensive and can be used as a basis for planning more adaptive industrial electricity distribution.

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