

# Manuscript\_Elkomika\_Reza Sarwo Widagdo.pdf

*by* [elelsiregar@gmail.com](mailto:elelsiregar@gmail.com) 1

---

**Submission date:** 24-Jun-2025 10:55AM (UTC+0900)

**Submission ID:** 2684096828

**File name:** Manuscript\_Elkomika\_Reza\_Sarwo\_Widagdo.pdf (662.4K)

**Word count:** 4150

**Character count:** 23461

# **Analysis of the Effect of Subconductor Spacing on Power Losses in the 150 kV Transmission Line between Surabaya Selatan - Kalisari Substations at PT. PLN (Persero) Surabaya**

## **Article History:**

Received

xx December 20xx

Revised

xx December 20xx

Accepted

xx January 20xx

**REZA SARWO WIDAGDO<sup>1</sup>, PUJI SLAMET<sup>2</sup>, IFAN MAULANA<sup>3</sup>**

<sup>1,2,3</sup>Department of Electrical Engineering, Universitas 17 Agustus 1945 Surabaya, Indonesia  
email: rezaswidagdo@untag-sby.ac.id

## **ABSTRAK**

Saluran transmisi 150 kV yang menghubungkan Gardu Induk Surabaya Selatan dengan Gardu Induk Kalisari menggunakan konduktor ACSR Zebra dengan luas penampang 858 mm<sup>2</sup> dan panjang 5,48 km. Penelitian ini bertujuan menganalisis pengaruh variasi jarak antar subkonduktor terhadap resistansi, impedansi, tegangan kirim dan terima, serta rugi daya selama proses transmisi. Data diperoleh melalui pengamatan langsung pada panel kontrol Gardu Induk Surabaya Selatan selama 30 hari di bulan Januari 2025 pukul 13.00 WIB. Parameter yang dicatat meliputi tegangan, arus, dan rugi daya. Setelah data terkumpul, dilakukan pemodelan dengan variasi jarak antar subkonduktor. Hasil analisis menunjukkan bahwa peningkatan jarak antar subkonduktor berdampak pada meningkatnya rugi daya serta penurunan efisiensi transmisi. Nilai regulasi tegangan juga meningkat, menunjukkan selisih tegangan kirim dan terima yang lebih besar. Oleh karena itu, pemilihan jarak optimal antar subkonduktor penting untuk menekan kerugian energi dan menjaga keandalan pasokan listrik.

**Kata kunci:** ACSR Zebra, Saluran Udara Tegangan Tinggi, Regulasi Tegangan, Rugi Daya, Sub-Konduktor

## **ABSTRACT**

The 150 kV transmission line connecting Surabaya Selatan Substation to Kalisari Substation uses ACSR Zebra conductors with a cross-sectional area of 858 mm<sup>2</sup> and a total length of 5.48 km. This study aims to analyze the effect of varying the distance between sub-conductors on resistance, impedance, sending and receiving voltage, as well as power losses during transmission. Data were collected through direct observation of the control panel at the Surabaya Selatan Substation for 30 days in January 2025 at 1:00 PM local time. Recorded parameters included voltage, current, and power losses. After data collection, modeling was carried out with

*variations in the sub-conductor spacing. The analysis results showed that increasing the distance between sub-conductors led to higher power losses and lower transmission efficiency. Voltage regulation values also increased, indicating a greater difference between sending and receiving voltage. Therefore, selecting the optimal spacing between sub-conductors is crucial to minimize energy losses and ensure a reliable electricity supply.*

**Keywords:** ACSR Zebra, High Voltage Transmission Line, Power Loss, Voltage Regulation, Subconductor



## 1. INTRODUCTION

High-voltage transmission lines are fundamental in ensuring the reliable delivery of electric power from generation centers to end users (**Widagdo et al., 2025**). Among the many design considerations in transmission systems, the configuration and spacing of subconductors in bundled conductor arrangements such as the ACSR Zebra type significantly influence system performance (**Widagdo et al., 2024**). The ACSR Zebra conductor, commonly used in Indonesia's 150 kV transmission networks, offers advantages in current-carrying capacity and mechanical strength. However, its electrical behavior, particularly in relation to subconductor spacing, remains a critical factor affecting power losses, line impedance, voltage regulation, and overall transmission efficiency (**Slamet et al., 2025**).

Several studies have explored the influence of conductor configuration on the electrical performance of transmission systems. **Khan & Ghassemi (2014)** highlighted the impact of conductor geometry on impedance and system losses. **Shaikh et al. (2022)** provided foundational equations for modeling bundled conductors, while **Shaikh et al. (2021)** studied the effects of bundle spacing on corona discharge and electric field stress. **Rabah et al. (2022)** emphasized electromagnetic interactions between subconductors that affect both inductance and capacitance. Similarly, **Khan et al. (2025)** investigated the potential of subconductor spacing in mitigating transient overvoltages. **Bindhu, V., & Ranganathan, G. (2021)** conducted simulation-based assessments on impedance variations due to spacing changes. **Zainuddin et al. (2020)** examined subconductor configuration in relation to thermal aging and mechanical durability. **Salceanu et al. (2020)** addressed the issue of radio interference in high-density regions caused by improper bundle spacing. Most recently, **Lutfiansjah et al. (2022)** presented field data on power losses in Indonesian transmission systems, although the study did not specifically analyze subconductor spacing.

While these studies have contributed significantly to the field, most rely on simulation models or laboratory conditions and lack real-time operational data from tropical networks such as those in Indonesia. Furthermore, the literature has not sufficiently addressed the relationship between subconductor spacing and voltage regulation in active 150 kV transmission lines. This presents a notable gap in understanding the practical impacts of physical conductor arrangements in actual transmission environments.

To address this gap, the present study investigates the effect of subconductor spacing on power losses and voltage regulation in the 150 kV overhead transmission line between Surabaya Selatan and Kalisari Substations, operated by PT. PLN (Persero). Unlike previous studies, this research utilizes 30 days of field data obtained from direct monitoring of voltage, current, and power factor at the control panel of Surabaya Selatan Substation. The novelty of this study lies in its integration of empirical measurements with analytical calculations to provide a comprehensive understanding of how subconductor spacing influences system losses and efficiency. The findings are expected to support optimal design and operation of transmission systems in tropical and developing regions.

## 2. METHOD

In this research, the method used to calculate power losses in the 150 kV transmission line between Surabaya Selatan Substation and Kalisari Substation at PT. PLN (Persero) Surabaya involves several key steps. The process begins with an electrical system analysis based on initial data related to the transmission line configuration, including subconductor spacing, nominal current, and conductor characteristics, which are collected from control panel observations and field surveys. The analysis of subconductor spacing is particularly important to identify conditions that may lead to significant power losses, which could have detrimental impacts on operational efficiency and energy delivery performance.

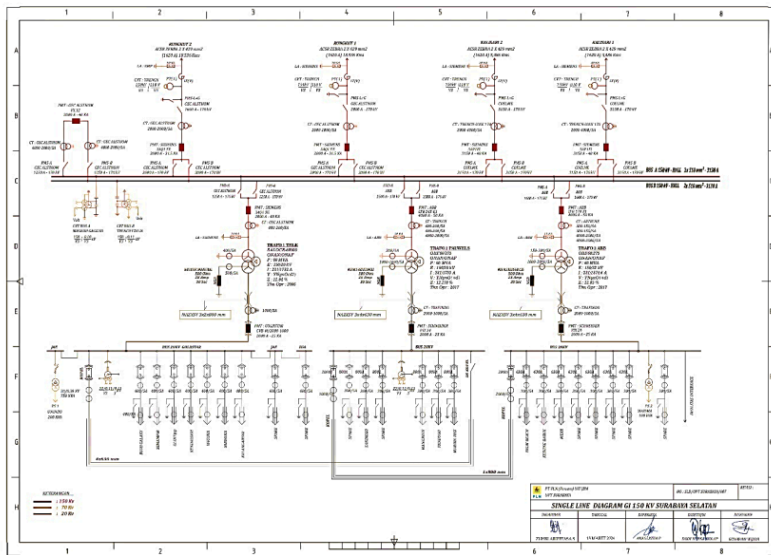


Figure 1. SLD of the 150 kV Substation from Surabaya Selatan to Kalisari

## 2.1 Resistance Analysis

This section presents the resistance analysis of the transmission line to determine the line resistance and total resistance in the 150 kV transmission system connecting Surabaya Selatan Substation and Kalisari Substation. The initial calculation is based on the following equation:

$$R = \frac{\rho \times l}{A} \quad (1)$$

Where the resistance is derived from the materials and components used in the 150 transmission line between Surabaya Selatan and Kalisari Substations. The total resistance of the ACSR conductor is calculated using the following equation:

$$R_{(Total\ ACSR)} = R \times l \quad (2)$$

Where,

- R : DC Resistance ( $\Omega$ )
- $\rho$  : Specific Resistivity of Aluminium ( $\Omega.m$ )
- l : Length of conductor (km)

By determining the conductor's specific resistance and total length, the overall resistance of the transmission line can be accurately calculated. This value serves as the foundation for calculating power losses. Understanding line resistance allows engineers to evaluate how much of the electrical energy is converted into heat, which is critical in assessing system performance and energy efficiency.

## 2.2 Geometric Mean Ratio (GMR)

Geometric Mean Ratio (GMR) is a key parameter used in determining the inductive properties of bundled conductors. It reflects the self-inductance of a conductor group and influences the reactance (Xu et al., 2022). The GMR calculation is based on the following equation:

$$r_1' = \frac{1.725}{100} e^{-\frac{1}{4}} \quad (3)$$

$$GMR = R \sqrt{n \frac{r_1'}{R}} \quad (4)$$

Where,

- R : Half the spacing between two conductors
- S : Subconductor spacing
- n : Number of subconductors
- $r_1'$  : Effective radius of the subconductor

The effective radius and spacing between subconductors determine the GMR. These values are essential inputs for inductive reactance calculations. An accurate GMR estimation ensures

the system's inductance is correctly modeled, which directly affects the efficiency and stability of long-distance power transmission.

### 2.3 Geometric Mean Distance (GMD)

Geometric Mean Distance (GMD) is the average spacing between different phase conductors and determines the mutual inductance between phases (El Dein et al., 2022). The GMR calculation is based on the following equation:

$$GMD = \sqrt[9]{D_{12} \cdot D_{13} \cdot D_{15} \cdot D_{16} \cdot D_{23} \cdot D_{24} \cdot D_{26} \cdot D_{34} \cdot D_{35} \cdot D_{45} \cdot D_{46} \cdot D_{56}} \quad (5)$$

Where,

D : Distance between phase conductors

By analyzing the spatial layout of phase conductors, the GMD helps researcher understand inter-phase coupling, which plays a role in determining reactance. Precise GMD values contribute to reliable impedance calculations, enabling better planning and control of voltage stability in the transmission network (Romim et al., 2024).

### 2.4 Line Reactance and Impedance

Inductive reactance is caused by the magnetic field created around conductors due to alternating current. It plays a vital role in voltage regulation and system impedance. The line reactance calculation is based on the following equation:

$$X_L = 2\pi f L \times \ln \frac{GMD}{GMR} \quad (6)$$

$$X_L = 0,14467 \log \frac{GMD}{GMR} \quad (7)$$

Where,

$X_L$  : Inductive Reactance ( $\Omega$ )

$f$  : Frequency (Hz)

$L$  : Inductance (Henry)

$GMD$  : Geometric Mean Distance (m)

$GMR$  : Geometric Mean Ratio (m)

Reactance is directly influenced by the conductor geometry (GMR) and spacing between phases (GMD). It is a key component in the overall impedance of the line. Accurately determining reactance helps in maintaining voltage quality and minimizing transmission inefficiencies across long distances. Impedance is the total opposition a conductor offers to alternating current, combining both resistive and inductive elements. The line impedance calculation is based on the following equation:

$$Z = R + jX_L \quad (8)$$

This value combines real power losses (resistance) and reactive effects (inductance). It determines voltage drop and phase shift in transmission. By knowing the impedance, system operators can effectively assess line performance and make decisions on load management and power flow (Arief et al., 2022).

### 2.5 Sending Voltage and Voltage Regulation

Sending voltage is the voltage level at the transmitting substation. It must account for the voltage drops along the transmission line to ensure stable delivery at the receiving end. Voltage regulation expresses how much the voltage changes between the sending and receiving ends of the transmission line (Hardi et al., 2025). The sending voltage and voltage regulation is based on the following equation:

$$V_S = V_R + I \times Z \quad (9)$$

$$\Delta V = \left| \frac{V_S - V_R}{V_S} \right| \times 100\% \quad (10)$$

Where,

$V_S$  : Inductive Reactance ( $\Omega$ )

$V_R$  : Frequency (Hz)

$Z$  : Inductance (Henry)

$\Delta V$  : Voltage Regulation (Volt)

This calculation incorporates the current and line impedance to estimate the required source voltage to maintain target voltage at the load side. Accurately determining the sending voltage helps in setting operational parameters and voltage compensation strategies. A lower voltage regulation percentage indicates a more efficient and stable transmission system. High values may result in undervoltage at the load end. Monitoring voltage regulation ensures that voltage levels remain within operational standards, maintaining power quality and system reliability (Hendri et al., 2024).

### 2.6 Power Loss

Power losses in transmission lines occur primarily due to conductor resistance. These losses are undesired as they reduce system efficiency. Using the current and resistance values, power losses for each phase can be estimated. This is essential for evaluating energy efficiency. Minimizing power losses not only improves operational economy but also supports a more sustainable and reliable power system (Marwan et al., 2024).

$$P_{LOSSES} = I^2 \times Z \quad (11)$$

Where,

$Z$  : Impedance ( $\Omega$ )

$I$  : Line Current (A)

### 3. RESULT AND ANALYSIS

This section presents a quantitative analysis of power losses and voltage regulation on the 150 kV transmission line connecting the Surabaya Selatan Substation and the Kalisari Substation, operated by PT. PLN (Persero). The study investigates three variations of subconductor lengths: real, short, and extended. The analysis includes key electrical parameters such as resistance, Geometric Mean Distance (GMD), Geometric Mean Radius (GMR), inductive reactance, total impedance, power losses, voltage regulation, and transmitted power. The results are compared to assess the impact of subconductor length variations on the overall performance and efficiency of the transmission system.

#### 3.1 Resistance of Lines

To determine the electrical characteristics of the transmission line, one of the key parameters that must be calculated is the resistance of the conductor. This value is essential for evaluating power losses and the overall performance of the system. In this study, the ACSR Zebra conductor is used, and its resistance is calculated using Equation (1). By substituting the known values into Equation (1), the resistance per meter of the ACSR Zebra conductor is obtained as:

$$R = \frac{2,826 \times 10^{-8} \times 5,48 \times 10^3}{858 \times 10^{-6}} = 0,000179 \text{ } \Omega/\text{km}$$

The total resistance of the conductor over the full length of the transmission line is then calculated using Equation (2):

$$R_{total} = 0,000179 \times 5,48 \times 10^3 = 0,980 \text{ } \Omega$$

This total resistance value is a critical input for further calculations, such as determining the total power loss, voltage drop, and impedance of the transmission system. Accurate estimation of conductor resistance ensures the reliability of subsequent performance evaluations.

#### 3.2 Geometric Mean Distance (GMD) and Geometric Mean Ratio (GMR)

The next step involves calculating the Geometric Mean Distance (GMD), which is a critical parameter for determining the inductive reactance of a transmission line. To accurately compute the GMD, it is necessary to refer to the specific configuration and dimensions of the suspension tower used in the transmission system. In this analysis, three subconductor configurations are considered. The GMD is calculated using the geometric mean of all mutual distances between the subconductors, as expressed in Equation (5):

$$GMD_{(real)} = \sqrt[12]{(9)^4 \cdot (18)^2 \cdot (20)^2 \cdot (17)^4 \cdot (16)^2} = 22,644 \text{ m}$$

Therefore, the Geometric Mean Distance (GMD) for the actual tower configuration is approximately 22.644 meters. This value is essential for calculating the inductive reactance of the transmission line in subsequent sections.

Tuliskan Nama Penulis sebagai header halaman genap

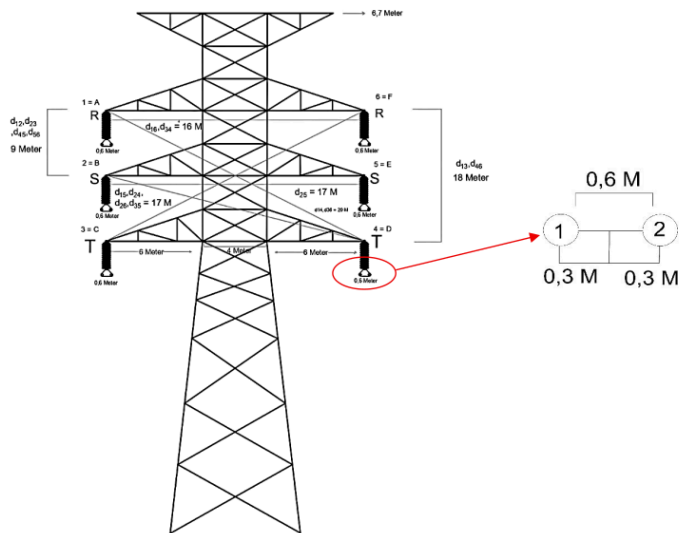


Figure 1. Construction of 150 kV Tower Surabaya Selatan - Kalisari

Table 1. GMR and GMD with Various Subconductor Length

Distance	Subconductor Length		
	Reality	Short	Extended
$d_{12}, d_{23}, d_{45}, d_{56}$	9 m	4,5 m	18 m
$d_{15}, d_{24}, d_{26}, d_{35}$	17 m	8,5 m	34 m
$d_{13}, d_{46}$	18 m	9 m	36 m
$d_{14}, d_{36}$	20 m	10 m	40 m
$d_{16}, d_{34}$	16 m	8 m	32 m
S	0,6 m	0,3 m	1,2 m
GMD	22,644 m	10,087 m	51,600 m
GMR	0,08 m	0,063 m	0,125 m

Before calculating the Geometric Mean Radius (GMR), it is necessary to determine the value of the equivalent radius ( $r_1'$ ), which depends on the spacer distance between subconductors in a bundled conductor system. Based on the 150 kV transmission system design, the distance between subconductors (spacer distance) is given as:

$$S = 0,6 \text{ m}$$

$$R = \frac{1}{2} 0,6 \text{ m} = 0,3 \text{ m}$$

Table 2. Inductive Reactance and Total Impedance with Various Subconductor Length

Parameter	Subconductor Length		
	Reality	Short	Extended
Inductive Reactance ( $X_L$ )	0,354 $\Omega$	0,318 $\Omega$	0,378 $\Omega$
Total Impedance ( $Z$ )	1,042 $\Omega$	1,031 $\Omega$	1,050 $\Omega$

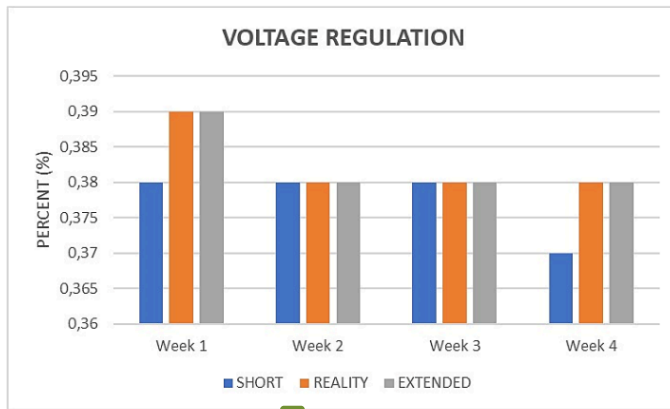


Figure 2. Voltage Regulation on the 150 kV South Surabaya - Kalisari Transmission Line



Figure 3. Power Losses on the 150 kV South Surabaya - Kalisari Transmission Line

Tuliskan Nama Penulis sebagai header halaman genap

$$r_1' = \frac{1,725}{100} e^{-\frac{1}{4}} = 0,0134 \text{ m}$$

The GMR for a bundled conductor consisting of two subconductors can then be calculated using Equation (4):

$$GMR_{(real)} = 0,3 \sqrt[2]{\frac{1,725 \times e^{-\frac{1}{4}}}{100 \times 0,3}} = 0,0896 \text{ m}$$

Therefore, the Geometric Mean Radius (GMR) for the actual bundled conductor configuration is approximately 0,0896 meters. This value is required for calculating the inductive reactance in the transmission line.

Figure 1 illustrates the construction of a 150 kV transmission tower on the Surabaya Selatan – Kalisari substation line, featuring a double-circuit configuration where each phase consists of two bundled conductors spaced 0.6 meters apart. The diagram on the right shows the arrangement of the bundled conductors, each positioned 0.3 meters from the center.

Table 1 presents the distances between conductors and the calculated values of GMD (Geometric Mean Distance) and GMR (Geometric Mean Radius) for three different sub-conductor length scenarios: Reality (actual length), Short, and Extended. These values are essential for analyzing transmission line parameters such as impedance, inductance, and power losses. It can be observed that increasing the sub-conductor length leads to higher GMD and GMR values, which directly influence the performance and efficiency of the transmission system.

### 3.3 Inductive Reactance and Total Impedance

Before calculating the impedance of the transmission line, it is necessary to determine the inductive reactance ( $X_L$ ) of the ACSR Zebra conductor. The inductive reactance can be calculated using Equation (6):

$$X_{L(real)} = 0,14467 \log \frac{22,644}{0,08} = 0,354 \Omega$$

Therefore, the inductive reactance of the ACSR Zebra conductor is 0,354 ohms.

Once both the resistance and inductive reactance have been determined, the total impedance of the transmission line can be calculated using Equation (7):

$$Z_{real} = R + X_L = 0,980 + j0,354 = 1,031 \angle 19,861^\circ \Omega$$

Thus, the total impedance of the 150 kV transmission line for the actual subconductor configuration is expressed in complex form as  $Z = 1,031 \angle 19,861^\circ \Omega$

### 3.4 Voltage Regulation

Voltage regulation indicates the percentage difference between the sending-end and receiving-end voltages, reflecting the voltage drop across the transmission line. It is calculated using Equation (10):

$$\Delta V_{(real)} = \left| \frac{245-147}{245} \right| \times 100\% = 0,40 \%$$

Thus, the voltage regulation for the 150 kV transmission line between Surabaya Selatan and Kalisari substations is approximately 40%. Figure 2 illustrates the voltage regulation performance of the 150 kV Surabaya Selatan – Kalisari transmission line over a four-week period. It compares three sub-conductor configurations: Short, Reality, and Extended. The vertical axis represents the percentage of voltage regulation, ranging from 0.36% to 0.395%. In Week 1, the Extended and Reality configurations exhibit slightly higher voltage regulation than the Short Subconductor. In Weeks 2 and 3, all three configurations demonstrate similar performance, while in Week 4, the Reality configuration shows the highest regulation, followed by Extended and then Short. Overall, the graph suggests that longer sub-conductor lengths (Extended) tend to result in slightly higher voltage regulation compared to shorter ones.

### 3.4 Power Loss

Once the total resistance of the line has been determined, the next step is to calculate the power losses in each phase (R, S, and T) of the high-voltage transmission network between Surabaya Selatan Substation and Kalisari Substation. The power loss for each phase is calculated using Equation (8):

$$P_{Loss (Total)} = 0.0104 + 0.0096 + 0.0082 = 0.0282 \text{ MW}$$

Therefore, the total real power loss on the 150 kV transmission line for the actual subconductor configuration is 0.0282 MW. This value represents the sum of losses from all three phases and can be used for further energy loss evaluations over time, such as monthly energy loss calculations. Figure 3 presents the power losses observed on the 150 kV Surabaya Selatan – Kalisari transmission line over a four-week period for three different sub-conductor configurations: Short, Reality, and Extended. The vertical axis shows power losses in megawatts, ranging from 0.022 to 0.028 MW. In Week 1, the Reality and Extended configurations experience the highest losses, while the Short configuration has slightly lower losses. In Weeks 2 and 3, a similar trend continues, with the Extended showing consistently higher losses. By Week 4, all configurations show a reduction in losses, but the Short configuration remains the most efficient. Overall, the graph indicates that shorter sub-conductors tend to reduce losses, whereas longer sub-conductors slightly increase them. These findings align with previous studies that emphasize the role of conductor configuration in influencing transmission efficiency. Earlier research has also shown that increased spacing between sub-conductors can elevate corona and line losses under certain conditions.

#### 4. CONCLUSION

Based on the analysis conducted during the research, it is concluded that power losses in the 150 kV transmission line between Surabaya Selatan Substation and Kalisari Substation are significantly influenced by the configuration of the distance between sub-conductors. An increase in the distance between sub-conductors leads to higher power losses and voltage regulation issues. Manual calculations over a 30-day period show that a configuration with the optimal distance can significantly reduce power losses compared to a larger spacing. Moreover, the difference between sending and receiving voltages indicates the importance of voltage regulation in maintaining the efficiency of the transmission system.

#### REFERENCE

- Arief, Y. Z., Masdi, H., Roslan, N. I., Saad, M. H. I., Eteruddin, H., & Al Hakim, R. R. (2022, September). Investigation of various faults of 500 kV transmission line design in Sarawak, Malaysia using Power Systems Computer Aided Design. In *2022 Fifth International Conference on Vocational Education and Electrical Engineering (ICVEE)* (pp. 146–150). IEEE.
- Bindhu, V., & Ranganathan, G. (2021). Effective automatic fault detection in transmission lines by hybrid model of authorization and distance calculation through impedance variation. *Journal of Electronics*, *3*(1), 36–48.
- El Dein, A. Z., Gouda, O. E., Lehtonen, M., & Darwish, M. M. (2022). Mitigation of the electric and magnetic fields of 500-kV overhead transmission lines. *IEEE Access*, *10*, 33900–33908.
- Hardi, S., Bukit, F. R., Nofri, I., Wirasari, R. R., Idris, M. H., & Isa, M. (2025). Back flashover voltage on transmission tower of 275 kV extra high voltage line (Case study: Galang-Binjai). *Iranian Journal of Electrical & Electronic Engineering*, *21*(2).
- Hendri, Z., Fadilah, R. D., Harun, N., Ulum, M. E. R., Pratama, R. W., & Corio, D. (2024). Optimizing the capacity of 150 kV transmission lines through the addition of shunt capacitors: Case study at PT. PLN (Persero) West Sumatra subsystem. *Journal of Electrical Technology UMY*, *8*(1), 17–27.
- Khan, M. A., Arafat, E., Chowdhury, S., & Ghassemi, M. (2025). Optimally located subconductors and phases to achieve transmission lines with high natural power and narrow corridor width. *IEEE Access*.
- Khan, M. A., & Ghassemi, M. (2023, October). Corona loss calculation for unconventional high surge impedance loading transmission lines. In *2023 North American Power Symposium (NAPS)* (pp. 1–6). IEEE.
- Lutfiansjah, I., Aryani, N. K., Putra, D. F. U., Ali, H., & Salile, A. Y. (2024, September). Study of transmission losses reduction in Java-Madura-Bali system with 500 kV transfer constraint adjustment using quasi-dynamic simulation. In *2024 International Conference on Technology and Policy in Energy and Electric Power (ICTPEP)* (pp. 199–204). IEEE.
- Marwan, M., Ratnasari, A. L., Ashar, A., Sofyan, S., Idris, A. R., & Faraby, M. D. (2024, December). Increasing voltage profile and reducing power loss in transmission line under a network reconfiguration approach. In *2024 7th International Seminar on Research of Information Technology and Intelligent Systems (ISRITI)* (pp. 800–804). IEEE.

- Rabah, D., Lahdeb, M., Ghoneim, S. S. M., & Mahi, D. (2022). Combined effects of electrostatic and electromagnetic interferences of high voltage overhead power lines on aerial metallic pipeline. *Facta Universitatis, Series: Electronics and Energetics*, 35(3), 349–377.
- Romim, M., Aryza, S., & Lesmana, D. (2024). An Analysis of the Reliability 150 kV High Voltage Air Line Conductors Towards Electric Field Strength. *Jurnal Scientia*, 13(4), 1622–1633.
- Salceanu, A., Vornicu, S., Bordeianu, D. F., & Neagu, C. D. (2020, October). Study upon the influence of bundle configurations on corona losses. In *2020 International Conference and Exposition on Electrical and Power Engineering (EPE)* (pp. 674–679). IEEE.
- Shaikh, M. S., Hua, C., Hassan, M., Raj, S., Jatoi, M. A., & Ansari, M. M. (2022). Optimal parameter estimation of overhead transmission line considering different bundle conductors with the uncertainty of load modeling. *Optimal Control Applications and Methods*, 43(3), 652–666.
- Shaikh, M. S., Hua, C., Jatoi, M. A., Ansari, M. M., & Qader, A. A. (2021). Parameter estimation of AC transmission line considering different bundle conductors using flux linkage technique. *IEEE Canadian Journal of Electrical and Computer Engineering*, 44(3), 313–320.
- Slamet, P., Widagdo, R. S., & Hariadi, B. (2025). Study of ACSR conductor characteristics on power losses and voltage drop in 500 kV transmission lines: A case study at Krian-Ungaran. *Wahana: Tridarma Perguruan Tinggi*, 77(1), 65–80.
- Widagdo, R. S., Kastiawan, I. M., Tauladan, I. S., & Hermawan, I. B. (2025). Voltage regulation and power loss analysis on 500 kV EHV transmission line Krian-Grati. *International Journal of Electrical, Energy and Power System Engineering*, 8(1), 40–54.
- Widagdo, R. S., Slamet, P., & Ubaidillah, M. (2024). Prediction of transformer age based on temperature due to loading using linear trend method: Case study of 60 MVA transformer. *Journal of Applied Electrical Engineering*, 8(1), 1–8.
- Xu, C., Li, Q., Zhou, Q., Zhang, S., Yu, D., & Ma, Y. (2022). Power line-guided automatic electric transmission line inspection system. *IEEE Transactions on Instrumentation and Measurement*, 71, 1–18.
- Zainuddin, N. M., Rahman, M. A., Kadir, M. A., Ali, N. N., Ali, Z., Osman, M., ... & Nasir, N. M. (2020). Review of thermal stress and condition monitoring technologies for overhead transmission lines: Issues and challenges. *IEEE Access*, 8, 120053–120081.

ORIGINALITY REPORT

<b>11</b> %	<b>9</b> %	<b>5</b> %	<b>4</b> %
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

<b>1</b>	<b>ijeepse.id</b> Internet Source	<b>3</b> %
<b>2</b>	<b>Submitted to Universitas Komputer Indonesia</b> Student Paper	<b>2</b> %
<b>3</b>	<b>Turan Gonen. "Electrical Power Transmission System Engineering - Analysis and Design, Third Edition", CRC Press, 2019</b> Publication	<b>1</b> %
<b>4</b>	<b>Submitted to Universitas Jenderal Achmad Yani</b> Student Paper	<b>1</b> %
<b>5</b>	<b>Submitted to Universitas PGRI Adi Buana Surabaya</b> Student Paper	<b>1</b> %
<b>6</b>	<b>www.irphouse.com</b> Internet Source	<b>&lt;1</b> %
<b>7</b>	<b>A. P. Sakis Meliopoulos. "Power System Grounding and Transients - An Introduction", CRC Press, 2017</b> Publication	<b>&lt;1</b> %
<b>8</b>	<b>journal2.uad.ac.id</b> Internet Source	<b>&lt;1</b> %
<b>9</b>	<b>adoc.pub</b> Internet Source	<b>&lt;1</b> %
<b>10</b>	<b>journal.um-surabaya.ac.id</b> Internet Source	<b>&lt;1</b> %

11 [discovery.researcher.life](https://discovery.researcher.life) <1 %  
Internet Source

---

12 [psasir.upm.edu.my](https://psasir.upm.edu.my) <1 %  
Internet Source

---

13 [www.mdpi.com](https://www.mdpi.com) <1 %  
Internet Source

---

14 Bhabasis Mohapatra, Binod Kumar Sahu, Swagat Pati, Mohit Bajaj, Vojtech Blazek, Lukas Prokop, Stanislav Misak. "Optimizing grid-connected PV systems with novel super-twisting sliding mode controllers for real-time power management", Scientific Reports, 2024  
Publication

---

15 Turan Gonen. "Electrical Power Transmission System Engineering - Analysis and Design, 2nd Edition", CRC Press, 2019  
Publication

---

16 Ailson Pereira de Moura, Adriano Aron Freitas de Moura, Ednardo Pereira da Rocha. "Transmission of Electrical Energy - Overhead Lines", CRC Press, 2020  
Publication

---

17 [ejournal.itenas.ac.id](https://ejournal.itenas.ac.id) <1 %  
Internet Source

---

Exclude quotes On

Exclude matches Off

Exclude bibliography On