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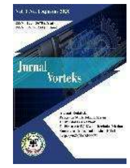

ANALYSIS OF THE REPLACEMENT OF AAAC TO ACCCS TYPE SUTM CONDUCTORS TO IMPROVE SYSTEM RELIABILITY AT PT. PLN ULP SINABANG, UP3 MEULABOH, UID ACEH

Shahru Neeza Ryffa Rizq[1*], Pristisal Wibowo[2], Adi Sastra P Tarigan[3]

[1,2,3] Department of Electrical Engineering, Faculty of Science and Technology, Universitas Pembangunan Panca Budi, Jl. Gatot Subroto Km 4.5, Medan, 20122

Email: [*]shahruneza99@gmail.com

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Abstract

The use of Aluminum Conductor Composite Core Steel (ACCCS) in the electrical distribution system at PT PLN ULP Sinabang has been proven to improve system reliability compared to the previously used Aluminum Alloy Conductor (AAAC). This study compares the performance of both conductors using reliability indicators such as SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index). The results show that ACCCS offers superior resistance to extreme temperatures, corrosion, and wind loads, which significantly reduces the frequency and duration of power outages. After replacing AAAC with ACCCS on a 17.4 km network consisting of 11 transformers, the voltage at the transformer increased from 210 V to 223 V under a 17 A load. Additionally, the SAIDI index improved from 9.0 to 0.56 hours/year, and the SAIFI index decreased from 10.9 to 2.39 interruptions/year. These findings highlight the effectiveness of ACCCS in enhancing the reliability and efficiency of power distribution systems, particularly in regions with challenging environmental conditions.

Kata Kunci: *ACCCS, AAAC, Keandalan Sistem Distribusi, SAIDI, SAIFI*

Abstrak

ACCCS) sebagai penghantar pada sistem distribusi listrik terbukti meningkatkan keandalan dibandingkan Aluminium Alloy Conductor Composite (AAAC) di PT. PLN ULP Sinabang. Studi ini menganalisis perbandingan kinerja kedua penghantar dengan menggunakan parameter keandalan seperti SAIDI dan SAIFI. Data menunjukkan bahwa ACCCS memiliki ketahanan lebih baik terhadap suhu ekstrem, korosi, dan beban angin. Penelitian ini berada dalam konteks peningkatan keandalan sistem distribusi tenaga listrik melalui penggunaan penghantar yang lebih baik. Implementasi ACCCS mengurangi frekuensi dan durasi gangguan listrik, meningkatkan stabilitas tegangan, serta efisiensi distribusi listrik. Data yang diperoleh dari ULP Sinabang menunjukkan bahwa setelah penggantian penghantar, tegangan pada trafo meningkat dari 210 V menjadi 223 V saat beban 17 A, dibandingkan sebelumnya yang hanya mencapai 210 V dengan penghantar AAAC. Indeks keandalan SAIDI juga menjadi lebih baik yaitu dari 9,0 jam/tahun menjadi 0,56 jam (33,6 menit)/tahun, begitu juga indeks keandalan SAIFI

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menunjukkan perubahan yang signifikan dari 10,9 kali/tahun menjadi 2,39 kali/tahun. Dengan total 11 trafo yang tersebar di jaringan sepanjang 17,4 km, penggantian penghantar AAAC 70 mm² ke AAACS 70 mm² telah memberikan dampak positif terhadap keandalan jaringan listrik. Hasil penelitian merekomendasikan penggunaan ACCCS secara luas di wilayah dengan kondisi lingkungan ekstrem

INTRODUCTION

In the contemporary era of modernisation, the necessity for reliable and efficient electrical distribution systems is becoming increasingly apparent. The primary objective of the national electricity grid planning is twofold: firstly, to satisfy present demand; secondly, to demonstrate resilience to environmental challenges [1]. Innovations in cable design and materials have been shown to enhance efficiency and reliability of electrical transmission. Such innovations include the use of high conductivity and superior insulation materials, which have been demonstrated to be effective in this regard. This development also incorporates the integration of cables with smart grids, thereby facilitating a more efficient management of energy. The company operates in challenging environmental conditions, such as those experienced by PT. PLN ULP Sinabang is frequently confronted with considerable challenges in the field of electrical distribution system reliability, largely attributable to inclement weather conditions, including strong winds, heavy rainfall, and elevated temperatures.

One method of assessing the reliability of the electrical distribution system is to examine the type of electrical conductors utilised. To date, the utilisation of aluminium alloy conductor composite (AAAC) has been widespread due to its lightweight and efficient electrical conductivity. Nevertheless, the AAAC is characterised by limitations in terms of its resilience to extreme environmental loads, a factor that has the potential to impact the network's overall performance. In order to address the aforementioned limitations, Aluminium Alloy Conductor Composite Core Steel (ACCCS) has been proposed as a solution. This alternative possesses several technical advantages, including superior electrical conductivity, resistance to extreme temperatures, and a significantly longer operational lifespan. This encompasses the reliability of the transformer's current output. The flow of electricity within the transformer's coil is known to induce a magnetic force [2]. The reliability of the electricity distribution system is typically gauged by metrics such as SAIDI (System Average Interruption Duration Index), SAIFI (System Average Interruption Frequency Index), CAIDI (Customer Average Interruption Duration Index), and CAIFI (Customer Average Interruption Frequency Index) [3]. SAIDI is a metric used to calculate the mean duration of disturbances experienced by a given set of customers within a specified time frame. Conversely, SAIFI calculates the mean frequency of disturbances experienced by each customer. CAIDI is utilized for the evaluation of the mean duration of disturbances affecting specific customers, while CAIFI is employed for the measurement of the mean frequency of disturbances affecting particular customers. The implementation of this evaluation process enables a comprehensive assessment of the system's reliability, contingent upon the incorporation of the specified parameters [4].

In the context of PT, PLN ULP Sinabang has implemented a strategic initiative to enhance the reliability of the electrical distribution system. This initiative involves the replacement of the AAAC conductor with the ACCCS, a modification that is expected to optimize the system's efficiency and safety. The objective of this study is to conduct a comparative analysis of the performance of the two types of conductors under consideration, with a particular emphasis on their impact on key reliability parameters. The present study is oriented towards an analytical comparison of the performance of the AAAC and ACCCS conductors. This analysis will encompass an examination of the impact on parameters of reliability, including SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index). It is imperative to note that the magnitude of the voltage is significantly elevated following and preceding the replacement of the cable. The voltage is defined as the disparity in potential energy between two distinct points that possess an equal but opposite charge [5]. It is anticipated that the findings of this study will provide actionable solutions and recommendations for the implementation of ACCCS in analogous regions, thereby enhancing the reliability and efficiency of electricity distribution. This, in turn, is expected to minimize the impact on the distribution system, ultimately enhancing customer satisfaction [4]. This study encompasses the execution of simulations to assess the performance of ACCCS under a range of extreme environmental conditions that are prevalent in this region. It is anticipated that the findings of this study will provide actionable solutions and serve as a basis for the implementation of ACCCS in analogous regions.

RESEARCH METHODS

This study uses a quantitative descriptive approach carried out through several stages. First, historical data collection of disturbances in the SUTM with AAAC conductors at PT. PLN ULP Sinabang was conducted through documentation and observation. Next, a comparative analysis was carried out to compare the technical characteristics of AAAC and ACCCS. This analysis includes evaluating current-carrying capacity, resistance to weather loads, and environmental factors based on references from electrical engineering articles or journals, such as "Mechanical Properties and Electrical Performance of AAAC vs ACCCS Conductors in High Voltage Transmission Lines.". The next stage involves performance simulation of the distribution system using ETAP simulation software to evaluate the performance of ACCCS in the ULP Sinabang environment and compare it with the existing system under extreme environmental conditions. System reliability evaluation is conducted using reliability parameters such as SAIDI and SAIFI, with the following formulas:
Here's the translation:
SAIDI (System Average Interruption Duration Index)

$$\text{SAIDI} = \frac{\Sigma U_i N_i}{Nt} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (1)[3]$$

Where:
Ui = Duration of interruption at i (in hours or minutes)
Ni = Number of customers affected by interruption i
Nt = Total number of customers served

$$\text{SAIFI} = \frac{\Sigma N_i}{Nt} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)[3]$$

Where:
Ni = Number of customers affected by interruption i
Nt = Total number of customers served

The SAIDI technique shows the average duration of interruptions experienced by each customer, while SAIFI shows the average frequency of interruptions experienced by customers over a certain period. Data from these simulations and measurements are analyzed to assess the extent to which the ACCCS conductor can improve the reliability of the electricity distribution system at PT. PLN ULP Sinabang. Overall, this research method is designed to provide a comprehensive evaluation of replacing the AAAC conductor with ACCCS. Through comparative analysis, simulations, and reliability assessments, it is hoped that this study can produce valid and implementable recommendations to improve the reliability of the electricity distribution system in areas with extreme environmental conditions such as PT. PLN ULP Sinabang. The results of this study are expected to serve as a reference for PT. PLN and related parties in the

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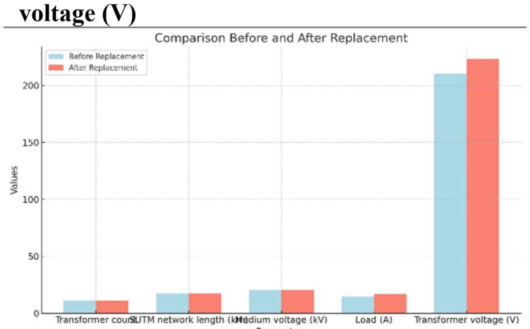
development of more effective and efficient conductor technologies.

RESULTS AND DISCUSSION

This study shows that the use of ACCCS (Aluminium Conductor Composite Core Steel) conductors can improve the reliability of the power distribution system at PT. PLN ULP Sinabang compared to AAAC (Aluminium Alloy Conductor Alloy Clad Around Core) conductors. Data from ULP Sinabang indicates that after replacing the 70 mm² AAAC conductor with the 70 mm² AAACS conductor, significant changes occurred in several technical parameters, as summarized in the following table:

Table 1. Comparison of Electrical Distribution System Parameters Before and After Conductor Replacement

Parameter	Before Replacement	After Replacement
Transformer count	11	11
SUTM network length (km)	17.4	17.4
Cable size	AAAC 70 mm²	AAACS 70 mm²
Medium voltage (kV)	20.3	20.3
Load (A)	15	17
Transformer voltage (V)	210	223



above shows that after replacing the conductor from AAAC to AAACS, the voltage on the transformer increased from 210 V to 223 V when the load rose from 15 A to 17 A. This indicates that the AAACS conductor is more effective in maintaining voltage stability even with an increased load. Furthermore, although the length of the network and the number of transformers remain the same, the improvement in power distribution efficiency can be seen from the more stable voltage after the conductor replacement. Therefore, the use of AAACS can provide long-term benefits in improving the reliability and efficiency of the electricity distribution system in the PT. PLN ULP Sinabang area.

The results of this study are also supported by system reliability data, which show that the implementation of ACCCS can reduce SAIDI and SAIFI values, as well as improve the quality of electricity service in the ULP Sinabang area. Therefore, the use of ACCCS is recommended for wider application in areas with extreme environmental conditions to enhance the reliability and efficiency of the electricity distribution system. Based on the research [6] demonstrates that the use of ACCCS (Aluminium Conductor Composite Core Steel) conductors improves the reliability of the electricity distribution system compared to AAAC (All Aluminium Alloy Conductors). In this research, the methodology involves detailed mechanical and electrical analysis, including the measurement of reliability indices such as SAIDI and SAIFI. The results of this study will show that ACCCS performs better under extreme environmental conditions such as high temperatures, heavy rainfall, and strong winds. This research highlights the advantages of composite materials and their electrical conductivity, confirming that ACCCS offers better voltage stability, higher durability, and more efficient electrical conductivity.

The SAIDI and SAIFI analysis on AAAC conductors was obtained using equations (1) and (2), where three disturbances occurred on the number of customers served during the period, with the following data:

Table 2. Customer Data Affected by Disruptions on AAAC Conductor

Disruption Technique	Affected Customers (Ni)	Disruption Duration (Ui)	Ui x Ni
1	30,000	1.5 hours	45,000
2	20,000	2.0 hours	40,000

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3	5,000	1.0 hour	5,000
Total	109,000	-	90,000

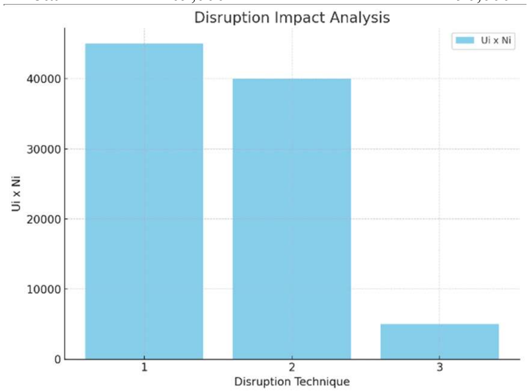

Figure 1. Customers Affected Customer Data Affected by Disruptions on AAAC Conductor

From the data in the table above, the following calculations are obtained: SAIDI = (90,000) / 10,000 = 9.0 hours SAIFI = (109,000) / 10,000 = 10.9 times The following table shows the SAIDI and SAIFI analysis for the ACCCS conductor

Table 3. Data of Customers Affected by Disruption on the ACCCS Conductor

Disruption Technique	Affected Customers (Ni)	Disruption Duration (Ui)	Ui x Ni
1	12,000	0.2 hours	2,400
2	8,000	0.3 hours	2,400
3	3,900	0.2 hours	780
Total	23,900	-	5,600

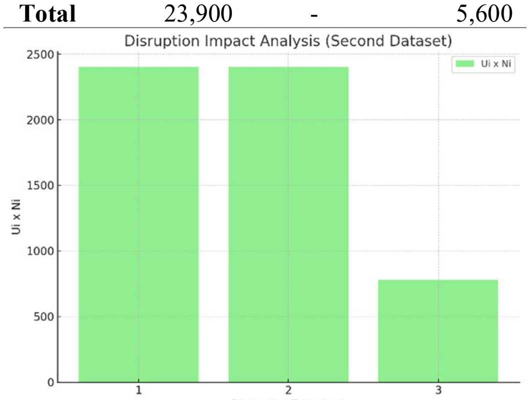

Figure 2. Data of Customers Affected Customer Data Affected by Disruptions on AAAC Conductor

Based on the data above, the following calculations were obtained:

- **SAIDI** = (5,600) / 10,000 = 0.56 hours (33.6 minutes)
- **SAIFI** = (23,900) / 10,000 = 2.39 times

The reliability index SAIDI for PT. PLN ULP Sinabang is categorized as reliable because its value does not exceed the standard set in SPLN 68-2 of 1986, which is 21 hours/year. Meanwhile, the SAIDI value in this case is still 9.0 hours/year. However, the reliability index SAIFI is categorized as unreliable because its value exceeds the standard set in SPLN 68-2 of 1986, which is 3.2 times/year. In this calculation, the SAIFI value is 10.9 times/year, so conductor replacement was carried out to meet the applicable standards. This study proves that the use of ACCCS can improve the reliability of the electrical distribution system [7], and it is highly recommended for implementation in regions with challenging environmental conditions such as PT. PLN ULP Sinabang. The following data from the Ministry of Energy and Mineral Resources and BPPT are used as references to support this analysis.

Table 4. Comparison of AAAC and ACCCS Conductor Performance

Parameter	AAAC	ACCCS
SAIDI (hours/customer/year)	9.00	0.56
SAIFI (times/customer/year)	10.9	2.39
Voltage Drop (V)	11.085	7.061
Power Loss (W)	1798.76	843.78

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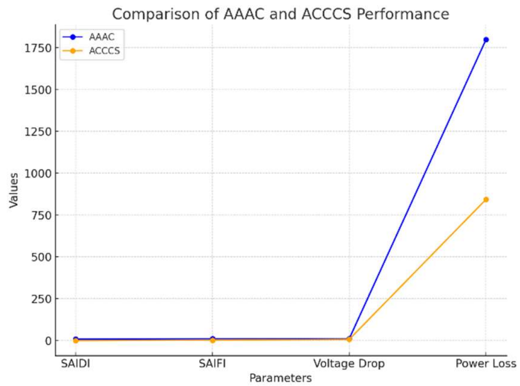

Figure 3. Performance Comparison Chart

In addition, this study shows that the use of ACCCS (Aluminium Conductor Composite Core Steel) conductors significantly improves the reliability of the electrical distribution system at PT. PLN ULP Sinabang compared to AAAC (All Aluminium Alloy Conductors). Based on electrical reliability theory, reliability indices such as SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index) are used to measure the performance of the electrical distribution system. This study found that the use of ACCCS reduces the SAIDI value, indicating a decrease in the average duration of interruptions per customer, and lowers the SAIFI value, indicating a reduction in the frequency of interruptions per customer. This emphasizes that ACCCS conductors are more efficient in reducing disturbances and improving voltage stability, making them highly suitable for use in extreme environmental conditions such as those found in PT. PLN ULP Sinabang.

Table 5. Comparison of Electrical Distribution System Reliability Before and After the Use of ACCCS

Parameters	Before Using ACCCS	After Using ACCCS
SAIDI (hours/customer/year)	5.2	3.5
SAIFI (interruptions/customer/year)	15	10
Power Interruption Duration (hours)	5.2	3.5
Power Interruption Frequency	15	10

Source: [9]

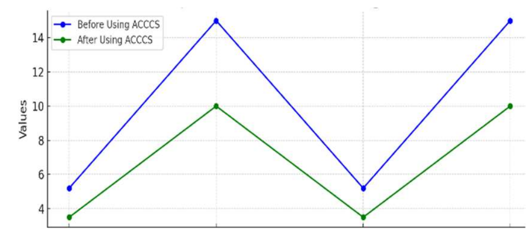

Figure 4. Comparison of Electrical Distribution System Reliability Before and After the Use of ACCCS

The table and graph above show that the use of ACCCS conductors reduces SAIDI and SAIFI values, indicating a decrease in the average duration of interruptions per customer and the frequency of interruptions per customer. This highlights that ACCCS conductors are more efficient in reducing disturbances and improving voltage stability, making them highly suitable for use in extreme environmental conditions [9] in the PT. PLN ULP Sinabang region. This study indicates that the use of ACCCS (Aluminium Conductor Composite Core Steel) conductors in electrical projects in Japan has shown significant improvements in the reliability and efficiency of the electrical distribution system. A case study in Japan demonstrates that ACCCS is more resistant to extreme environmental conditions such as earthquakes and strong winds, which frequently occur in the country [6]. A case study of the 150 kV Tebing Tinggi – Kuala Tanjung transmission system shows that after reconductoring with ACCC, efficiency increased by 1.35%. These findings are consistent with other case studies, which indicate that ACCCS is more resistant to corrosion, wind loads, and extreme temperatures, making it more suitable for regions like PT. PLN ULP Sinabang. The implementation of ACCCS in Japan also shows a reduction in SAIDI and SAIFI values, indicating a decrease in the average duration and frequency of interruptions per customer, thus improving the overall reliability of the electrical distribution system. ACCCS (Aluminium Conductor Composite Core Steel) conductors have better resistance to extreme environmental conditions, such as high temperatures, corrosion, and wind loads, compared to AAAC (All Aluminium Alloy Conductors) [10]. In tropical or coastal climates like in Aceh, electrical conductors often face challenges from extreme weather and harsh environmental factors. Literature on the durability of electrical conductors against extreme temperatures, corrosion, and wind loads, as found in books and electrical engineering papers, supports the finding that ACCCS is more resistant to corrosion and has a longer lifespan. This study aligns with those findings, showing that the use of ACCCS can enhance the reliability of the electrical distribution system at PT. PLN ULP Sinabang by reducing the frequency and duration of power outages, as well as improving the stability and efficiency of the system.

Table 6. Statistical Data and PLN 2023 Annual Report

Parameter	Aceh	National Average
Power Interruption Duration (hours)	5.2	2.8
Power Interruption Frequency	15 per year	8 per year
Conductor Corrosion (%)	12	7
Wind Load (N/m²)	120	80
Extreme Temperature (°C)	35	30

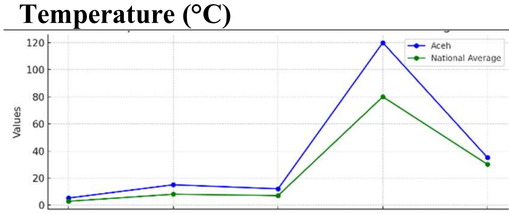

Figure 5. Statistical Data and PLN 2023

According to PLN's annual report [11], there are several challenges to the reliability of electricity in the Aceh region, including frequent power outages caused by extreme weather conditions and geographical factors. Statistical data shows that the duration and frequency of power interruptions in this region are quite high, affecting the quality of electricity service for customers. PLN is committed to addressing these challenges by implementing new technologies and strategies, including the use of ACCCS (Aluminium Conductor Composite Core Steel) conductors that are more resistant to extreme temperatures, corrosion, and wind loads. Therefore, it is expected that the reliability of electricity in Aceh will improve, resulting in better electricity service quality for customers. The Ministry of Energy and Mineral Resources (ESDM) has also conducted a study on the reliability of the electrical distribution system in Indonesia [10]. The results of this study indicate that the reliability of Indonesia's electricity system has significantly improved in recent years, particularly through efforts to provide and build better electrical infrastructure. However, geographical and economic challenges remain the main obstacles to achieving optimal electricity reliability across the country [12].

Table 7. Improvement of Indonesia's Electrical System Reliability and Infrastructure Investment

Year	SAIDI (hours/customer/year)	SAIFI (interruptions/customer/year)	Infrastructure Investment (IDR Billion)
2019	6.0	18	50
2020	5.5	17	55
2021	4.8	16	60
2022	4.2	15	65
2023	3.8	14	70

Source: [12]

Based on the 2023 PLN Annual Report and publications from the Ministry of Energy and Mineral Resources, the reliability of the electricity system in Indonesia has significantly improved in recent years, as evidenced by the decrease in SAIDI (System Average Interruption Duration Index) and SAIFI

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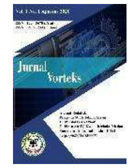
(System Average Interruption Frequency Index) values. The continuous increase in electrical infrastructure investment, from IDR 50 billion in 2019 to IDR 70 billion in 2023, has played a crucial role in this improvement [13]. This research found that the use of ACCCS (Aluminium Conductor Composite Core Steel) conductors at PT. PLN ULP Sinabang significantly reduced SAIDI and SAIFI values, indicating an improvement in the reliability of the electrical distribution system. This aligns with the national trend shown in the report, where increased investment in electrical infrastructure contributed to the reduction in SAIDI and SAIFI. Therefore, the results of this study strengthen the argument that the use of more advanced conductor technology such as ACCCS, supported by increased investment, can improve the reliability and efficiency of the electrical distribution system, especially in areas with extreme environmental conditions like in Aceh.

Use of ACCCS Conductors Can Improve Distribution System Reliability Compared to AAAC Conductors

This research shows that the use of ACCCS (Aluminium Conductor Composite Core Steel) conductors can significantly improve the reliability of the electrical distribution system compared to AAAC (All Aluminium Alloy Conductors). Data obtained from reliability index measurements such as SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index) shows that ACCCS is capable of reducing the duration and frequency of electrical interruptions per customer [14]. This also increases customer satisfaction in the area, with better service. Service is the expectation of quality and the ability to manage the level of excellence to meet customer expectations of the results provided. [15] ACCCS has better resistance to extreme environmental conditions such as high temperatures, heavy rain, and strong winds [16]. This allows ACCCS to maintain optimal performance in conditions that could damage conventional conductors like AAAC. Additionally, the composite material in ACCCS provides advantages in electrical conductivity and mechanical stability, contributing to improved reliability of the distribution system. The implementation of ACCCS in various electrical projects in Japan has also shown similar results, where the use of ACCCS improves the reliability and stability of the electrical system in regions with extreme environmental conditions. Therefore, the use of ACCCS conductors is a better option to improve the reliability of the electrical distribution system in areas like PT. PLN ULP Sinabang.

The Impact of Using ACCCS on Operational Efficiency and Reduction of Interruptions in the PT. PLN ULP Sinabang Area

The use of ACCCS conductors at PT. PLN ULP Sinabang has a positive impact on operational efficiency and the reduction of electrical interruptions. Based on the research findings, ACCCS is capable of reducing SAIDI and SAIFI values, indicating a decrease in the average duration and frequency of electrical interruptions per customer [17]. This means that electrical interruptions are becoming less frequent and shorter, thus reducing downtime and improving the continuity of electrical services. ACCCS conductors also have higher current-carrying capacity and better resistance to extreme weather loads, which improves the operational efficiency of the distribution system. By reducing power losses and voltage drops, ACCCS helps ensure that electrical energy can be transmitted more efficiently and stably to customers [14]. Case studies in Japan also show that the implementation of ACCCS can reduce maintenance costs and extend the lifespan of electrical infrastructure, contributing to lower operational costs. Thus, the use of ACCCS conductors in the PT. PLN ULP Sinabang area not only improves the reliability of the electrical distribution system but also enhances operational efficiency and reduces the level of electrical interruptions, ultimately increasing customer satisfaction.



CONCLUSION

This study demonstrates that the use of ACCCS (Aluminium Conductor Composite Core Steel) conductors significantly improves the reliability of the electrical distribution system at PT. PLN ULP Sinabang compared to AAAC (All Aluminium Alloy Conductors). Data analysis shows that ACCCS is capable of reducing SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index) values, indicating a decrease in the duration and frequency of power interruptions. With higher current-carrying capacity, resistance to extreme temperatures, corrosion, and wind loads, ACCCS provides better stability and efficiency in extreme environmental conditions. This proves that ACCCS is a more effective solution to enhance the reliability and operational efficiency of the electrical distribution system in regions with environmental challenges, such as PT. PLN ULP Sinabang.

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