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Analysis Of Power Distribution System Reliability Using System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) On Feeder KR04

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ABSTRACT
This study aims to analyze the reliability of the electricity distribution system using the SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index) in KR04 Sungai Mas. The results of the analysis show that frequent disruptions affect the reliability of the system, which has a direct impact on the level of customer satisfaction with electricity distribution services. The SAIDI value is 0.15235 hours/customer and SAIFI of 0.00017 times/customer in 2024 indicates that the system is not yet fully reliable. Reliability improvements are made through maintenance of network components, installation of lightning rods, and optimization of tree pruning. This study emphasizes the importance of reducing the frequency and duration of disruptions to improve system reliability and customer satisfaction.

Keywords: Distribution Reliability, SAIDI, SAIFI, Customer Satisfaction

INTRODUCTION

The power distribution system plays an important role in ensuring a reliable supply of electricity to consumers. The reliability of the distribution system is one of the main indicators of the quality of service provided by the electricity provider. This reliability is directly related to the system's ability to avoid disruptions, minimize the duration of outages, and manage the load efficiently. However, in reality, many regions, especially in the tropics, face various challenges that can affect the reliability of electricity distribution. Extreme climate conditions such as heavy rain, strong winds, and high humidity often cause damage to the distribution network infrastructure. This has an impact on the high frequency and duration of power outages felt by consumers. Therefore, an outage analysis is needed in order to reduce the high level of outages so that it can improve the quality of electricity and consumer services. There are several factors that must be known and calculated before calculating the reliability analysis of the electricity distribution system, including: failure frequency and duration of failure, which comes from failure of distribution network equipment or failure at the load point

To measure the reliability of the electric power distribution system, indicators such as the System Average Interruption Duration Index (SAIDI) and the System Average Interruption Frequency Index (SAIFI) are used. SAIDI measures the average duration of interruptions per customer in one year, while SAIFI calculates the average frequency of interruptions per customer in one year. These two indicators provide a clear picture of the performance of the distribution system and areas that need improvement. Electric power distribution must pay attention to distribution design so that services to consumers can be met properly. There are things that need to be considered, namely the issue of channel quality, continuity of service and channel

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reliability. Because these three things have a very important role, so that continuity is maintained in distributing electric power.

Several other types of research related to and supporting this research, including: Ibnu Hajar and Muhammad Hasbi Pratama (2018) with the title Analysis of SAIFI and SAIDI Values as an Index of Reliability of Electricity Supply at the Light Feeder of PT. PLN (PERSERO) Ciputat Area the results of the study are the SAIDI and SAIFI reliability indexes on the Light feeder in 2017 obtained SAIDI = 2.277 hours/customer/year and SAIFI = 2.406 times/customer/year. This is said to be reliable based on the SPLN 59:1985 standard. The cost loss due to the blackout at the Light feeder in 2017 was Rp. 12,794,305,-. Furthermore, Kevin Gabriel Manopo, Hans Tumaliang & Sartje Silimang (2021) with the title Analysis of the Reliability Index of the Electricity Distribution System Based on SAIFI and SAIDI at PT. PLN (Persero) North Minahasa Area Based on the results of calculations and analysis, it shows that almost all feeders in 2019 and 2020 have SAIFI and SAIDI values exceeding the standard except for SW 2 feeder with SAIFI and SAIDI values in 2019 of 0.00028 times/customer/year and 0.00083 hours/customer/year and in 2020 of 0.00011 times/customer/year and 0.00032 hours/customer/year. With total cost losses in 2019 and 2020 of Rp.2,069,227,200 and Rp.859,432,000. All feeders that do not exceed the standard can be said to be reliable and those that exceed the standard can be said to be unreliable.

SAIDI and SAIFI are reliability indices of an electric power system, especially in the transmission and distribution network. The reliability system in the distribution network plays a very large role in meeting the electricity needs of each consumer. Because of its very important role for consumers, electricity distribution must not be interrupted for 24 hours. The number of power interruptions that occur affects the SAIDI and SAIFI values so that the reliability value of a system decreases. Therefore, the problem that researchers want to examine is what are the main factors that affect the SAIDI and SAIFI values, what steps can be taken to improve the reliability of the electric power distribution system based on the results of the SAIDI and SAIFI analysis, and how is the relationship between the SAIDI and SAIFI values and the level of customer satisfaction with electricity distribution services. Therefore, the purpose of this study is to analyze the reliability of the electric power distribution system using the SAIDI and SAIFI indices. The results of this analysis are expected to be the basis for planning improvements to the distribution system, increasing operational efficiency, and reducing the impact of blackouts on customers. Thus, this study not only provides benefits for electricity providers, but also increases the comfort and productivity of the community as electricity users.

LITERATURE REVIEW

Electric Power System

The electrical power system functions to generate, transmit, and distribute electrical power from generating units to consumers. The electrical power system generally consists of generating units connected to channels to serve the load. An electrical power system that has many machines usually transmits power to the load through interconnection channels. The main purpose of the interconnection channel system is to maintain the continuity and availability of electrical power for the increasing load needs. The more developed the electrical power system can result in weak system performance when experiencing interference. One of the effects of interference is electrotechnical oscillation which if not properly dampened, the system will be

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disrupted and can leave its stability area, resulting in worse effects such as total blackouts. In general, the electrical power system can be divided into several parts as shown in Figure 1, namely:

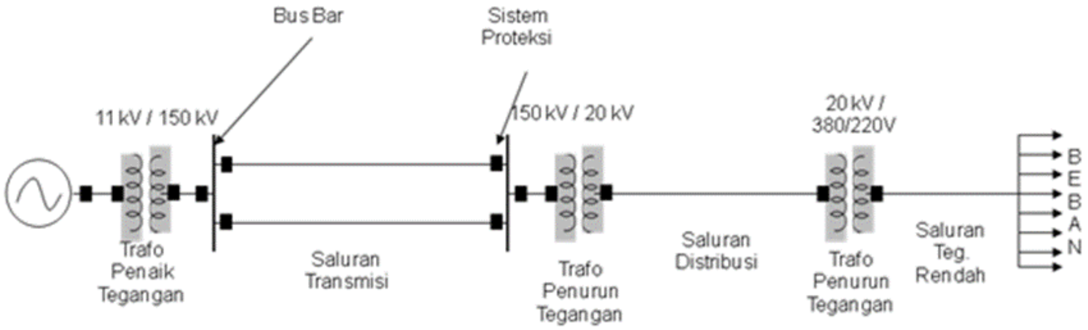

Figure 1. General electrical power system scheme

a. The Generating System functions to generate electrical energy through various types of power plants. In this power plant, natural energy sources are converted by the prime mover into mechanical energy in the form of speed or rotation and then mechanical energy is converted into electrical energy by the generator. In a generating system, several generators are operated in parallel and connected to the system to provide the total power required.
b. The Transmission System functions to distribute electric power from the power plant to the load center through the transmission line. In the transmission system, the voltage used is high voltage to reduce losses caused by heat due to the current flowing in the conductor cable.
c. Distribution System functions to distribute electric power to consumers in the form of factories, industries, housing and so on. Power transmission with high voltage or extra high voltage on the transmission line is converted at the substation into medium voltage or primary distribution voltage, which is then lowered again to secondary distribution voltage to serve residential and commercial consumers.
d. Load is something that must be received by the power plant. In everyday applications, it can be described that the electrical load is equipment that uses electrical power to function. In general, the load served by the distribution system is divided into several sectors, namely the residential sector, the industrial sector, the commercial sector and the business sector. Each of these load sectors has different characteristics. This is related to the energy consumption patterns of each consumer in the sector.

The largest part of the cost is for raw materials, besides the fluctuation of electricity usage is always related to the use of electricity by the load. The largest cost is located in the generators, so it is very necessary to operate the total generation efficiently. The many generator connections into an interconnection system provide the possibility of regulating the output of each generator and the generation cost can be regulated at a low/optimal level.

Reliability of Electric Power System

Reliability in electric power systems refers to the ability of the system to provide a

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continuous supply of energy to customers with quality that meets standards. Reliability in distribution systems is a measure of the availability/level of service of electricity supply from the system to users/customers. The measure of reliability can be expressed as how often the system experiences blackouts, how long the blackouts occur and how quickly it takes to restore conditions from the blackouts that occur (restoration). The reliability of the distribution network system is closely related to the problem of load shedding (blackouts) due to disturbances in the system. In this case, the reliability of the distribution system is inversely proportional to the level of load shedding (blackouts) in the system. The higher the level of load shedding that occurs, the lower the reliability will be. And vice versa. A system that has high reliability will be able to provide electricity whenever needed, while a system has low reliability if the level of power availability is low, namely frequent blackouts.

2.3. Reliability Index (SAIDI and SAIFI)

Based on SPLN No. 59 of 1985, the Reliability Index is a quantity to compare the performance of the distribution system. SPLN No. 59 of 1985, then clarified again by SPLN No. 68-2 of 1986. The two reliability indices most often used in the distribution system are the average outage frequency index (SAIFI) and the average outage duration index (SAIDI). To calculate the outage frequency, a table of estimated numbers of distribution system component outputs is required. Based on SPLN No. 59 of 1985 and SPLN No. 68-2 of 1986, the average outage frequency value is = 3.21 times/year. Meanwhile, for the duration of the outage (SAIDI) = 21.094 hours/year. So that the CAIDI value standard is obtained, namely 21.094 hours/year divided by 3.21 times/year of 6.57 hours/time. For the standard in PLN Area Pakam Rayon Delitua based on the UP3 Lubuk Pakam Management Contract in 2018, the SAIFI standard is 1.31 times/plg, and the SAIDI standard is 185.64 minutes/plg or 3,094 hours/plg in one year. So the CAIDI standard of 185.64 minutes/plg is divided by 1.31 times/plg, which is 141.71 minutes/plg or 2.36 hours/plg.

System Average Interruption Duration Index(SAIDI) is the average duration of interruption per customer in a certain period. SAIDI can be calculated using the following equation:

$$\text{SAIDI} = \frac{\sum(\textit{Durasi gangguan x Jumlah pelanggan terdampak})}{\textit{Total jumlah pelanggan}} \quad (1)$$

$$\mathbf{SAIDI} = \frac{\mathbf{U_i . N_i}}{\mathbf{Nt}} \quad (2)$$

Where, U_i = Duration of disturbance on channel i
N_i= Number of subscribers on channel i
Nt = Amounttotal number of customers served

SAIDI indicates the ability of a system to restore service after an interruption occurs.

System Average Interruption Frequency Index(SAIFI) is the average frequency of interruptions per customer in a certain period. SAIFI can be calculated using the following equation:

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$$\text{SAIFI}=\frac{\sum(\textit{Jumlah pelanggan terdampak})}{\textit{Total jumlah pelanggan}} \quad (3)$$

$$\textbf{SAIFI} = \frac{\lambda_i . N_i}{Nt} \quad (4)$$

Where, λ_I = Failure rate on channel i
This N_i = Number of subscribers on channel i
Nt = Total number of customers served

SAIFI reflects how often customers experience power outages.

Electric Power Distribution System

The distribution system is the final stage in delivering electrical energy to consumers. This system consists of primary and secondary distribution networks, distribution substations, and protection devices. Factors that affect the reliability of the distribution system include:

a. Quality of equipment and infrastructure.
b. Protection and maintenance systems.
c. Load management on the network.

The frequency and duration of power outages have a direct impact on customer activity, especially in the industrial, commercial and residential sectors. SAIDI and SAIFI analysis helps electricity service providers identify the root causes of outages and design strategies to minimize the impact of outages.

METHODS

This study uses a quantitative approach with descriptive and analytical methods to analyze the reliability of the electric power distribution system using the index.*System Average Interruption Duration Index*(SAIDI) and System Average Interruption Frequency Index (SAIFI).The following are the methodological steps applied:

1. Types of research
   Descriptive research to measure the level of reliability of the electricity distribution system using the SAIDI and SAIFI indices, as well as analysis of factors that influence the reliability. Furthermore, analysis and calculations were carried out at the Electrical Engineering Laboratory of Pancabudi Development University.
2. Location and Object of Research
   The research location is at the KR04 feeder in Sungai Mas City. The object of the research is the reliability data of electricity distribution, including SAIDI and SAIFI values, during a certain period.
3. Variable Operational Parameters
   The parameters observed in this study are:
   1) Electric power distribution system
   2) The number of disturbances that occur
   3) How long does the disruption last?
4. Population and Sample
   In this study, the population and samples were taken from the observed parameter data

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and then analyzed and calculated to obtain conclusions from this analysis.

5. Data collection
   Primary data were obtained from direct observation of the electricity distribution system in the research area as well as interviews with distribution system operators and related experts and secondary data were obtained from distribution system reliability reports from electricity supply companies and historical data on power outages, duration, and frequency of outages.
6. Data Analysis Techniques
   In this study, the data analysis method is used, namely by calculating the SAIDI and SAIFI values based on the obtained disturbance data and analyzing the disturbance pattern to determine the time and area that often experiences blackouts. As well as analyzing the factors that affect reliability using descriptive analysis to identify the main causes of disturbances, such as infrastructure conditions, weather, or technical errors and comparing the results of the SAIDI and SAIFI values with applicable reliability standards. The research flowchart is as shown in the following image:

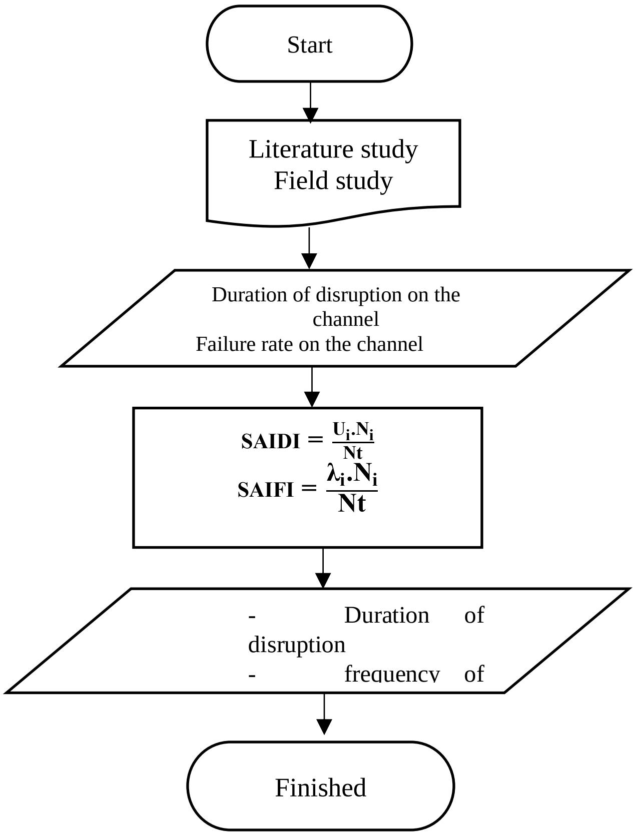

Figure 2. Research Flowchart

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RESULTS AND DISCUSSION

Result

The KR04 feeder has the longest network compared to other feeders. This feeder has more disturbances than other feeders because the area supplied by this feeder is a location with quite challenging geographical conditions. The disturbances that occurred in the KR04 feeder during a year are shown in the following table.

Table 1. KR04 Feeder Disturbance

Month	This (please)	Nt (plg)	f (times)	t (hour)
January	120	46149	2	1.1
February	61	46339	2	1.88
March	61	46490	2	43.85
April	61	46634	3	5.77
May	1064	46896	4	9.57
June	153	47085	6	33.84
July	340	47238	2	9.19
August	6144	47446	12	28.52
September	2532	47577	6	7.53
October	2683	47614	6	2.52
November	231	47760	1	0.15
December	118	47899	1	2.08
Total	3801	518978	47	146

Information: This = Number of customers experiencing disruption
Nt = Total number of customers
f = Number of disturbances
t = Duration of disturbance

In accordance with the failure rate and failure duration equations, the failure rate and failure duration for the KR04 feeder can be calculated using these equations. The calculation will be carried out per month, so the observation time (T) is 31 days. For example, for January, the number of failures of the KR04 feeder was 2 times. So the failure rate of the KR04 feeder in January 2024 is:

$$\lambda = \frac{f}{T} \quad \text{(times/month)}$$

$$\lambda = \frac{2}{31} = 0{,}0645 \text{ times/month}$$

Meanwhile, the failure duration of the KR04 feeder in January 2024 was 1.1 hours. So the duration of the failure of the KR04 feeder in January is:

$$U = \frac{t}{T} \quad \text{(hours/month)}$$

$$U = \frac{1{,}1}{31} = 0{,}0354 \text{ hours/month}$$

Using the same equation, the failure rate and duration for the months of February to

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December on the feeder can be calculated. The results of the failure rate and duration calculations are shown in table 2. below.

Table 2. Failure Rate and Failure Duration of KR04 Feeder

Month	λ (times/month)	U (hour/month)
January	0.0645	0.0355
February	0.0690	0.0648
March	0.0645	1.4145
April	0.1000	0.1923
May	0.1290	0.3087
June	0.2000	1,1280
July	0.0645	0.2965
August	0.3871	0.9200
September	0.2000	0.2510
October	0.1935	0.0813
November	0.0333	0.0050
December	0.0323	0.0671

Information: λ = Failure rate
U = Failure duration

After the failure rate and failure duration are obtained, the reliability index SAIDI, SAIFI can be calculated. Similar to the calculation of the failure rate and duration, to calculate the reliability index of each feeder can also be done with the available equation. The failure rate for the KR04 feeder in January is 0.0645 times/month and failure duration 0.0355 hours/month. By using the SAIDI equation, the SAIFI equation, the reliability index of the KR04 feeder during January 2024 is:

1) **SAIDI reliability index**

$$SAIDI = \frac{Ui.N_i}{Nt}$$

$$\text{SAIDI} = \frac{0{,}0355 \times 120}{46149} = 0{,}00009 \text{ jam/bln}$$

2) **SAIFI reliability index**

$$\text{SAIFI} = \frac{\lambda_i.N_i}{Nt}$$

$$\text{SAIFI} = \frac{0{,}0645 \times 120}{46149} = 0{,}00009 \text{ kali/bln}$$

Using the same equation, the reliability index SAIDI, SAIFI for February 2024 to December 2024 for each feeder can be calculated. The results of the calculation of the reliability index for the KR04 feeder are shown in table 3 below.

Table 3. Feeder Reliability IndexKR04

Month	SAIDI (hour/time)	SAIFI (times/times)
January	0.00009	0.00017
February	0.00009	0.00009
March	0.00186	0.00008
April	0.00025	0.00013
May	0.00700	0.00293
June	0.00367	0.00065
July	0.00213	0.00046
August	0.11914	0.05013
September	0.01336	0.01064
October	0.00458	0.01091
November	0.00002	0.00016
December	0.00017	0.00008
Total	0.15235	0.00017

The table shows that, the reliability index of the KR04 feeder for one year is obtained that SAIDI = 0.15235 hours/plg or 3.8709 minutes/plg. Meanwhile, the SAIFI value is obtained 0.00017 times/plg.The total number of distribution network disruptions throughout 2024 is47times. Every disturbance that occurs must have a cause. The cause of the disturbance that occurs can be known based on the following graphic image:

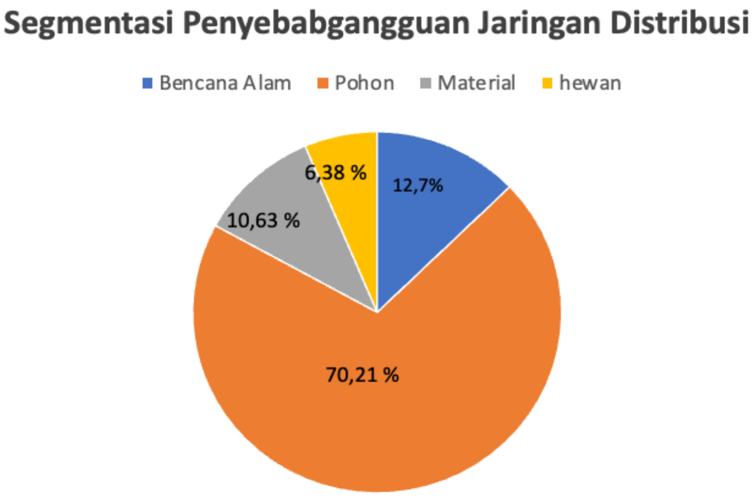

Figure 3. Causes of Distribution Network Disturbances

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From the graph, it can be seen that the most common causes of disruptions are due to disturbances during rain or lightning and momentary disturbances. Heavy rain, lightning, and strong winds are often the main causes of disruptions in the distribution network. These weather factors cause infrastructure damage such as broken cables, damaged insulators, or even collapsed electricity poles, which increase the SAIDI and SAIFI values. The KR04 Feeder Area covers an area with challenging geography, where vegetation density is a dominant factor. Trees that grow too close to the power grid often cause disruptions, especially when exposed to strong winds. External factors such as wild animals, kites, or even foreign objects touching the network cause momentary disruptions. Although temporary, these disturbances still affect the SAIDI and SAIFI values.

Steps in Improving the Reliability of Electric Power Distribution Systems Based on SAIDI and SAIFI Analysis

From the results of the reliability index calculation that has been obtained, it can be seen that overall this distribution network is not yet reliable. Efforts to improve or increase the reliability of the distribution network itself can be done by reducing the frequency of disruptions and reducing the duration of the disruption. Looking at the results of the distribution network reliability index, the duration of the disruption is still below the set target. However, the frequency of disruptions is already at a cautious level, so the focus of increasing its reliability itself is on the frequency of disruptions. December is a month specifically dedicated to improving the reliability of the distribution network. This is also due to the New Year's alert which is focused on providing the best service to customers. Improvement efforts that have been made include:

a) Perform maintenance on network components
b) Installing safety equipment or lightning protection equipment such as lightning arresters
c) Perform tree pruning
d) Carrying out group maintenance involves officers from other guard offices.

After several efforts were made to improve the reliability of the distribution network, the results can be seen in the disruptions in December which decreased compared to previous months.

Relationship Between SAIDI and SAIFI Values and Customer Satisfaction Levels for Electricity Distribution Services

SAIDI and SAIFI values have a direct relationship with the level of customer satisfaction with electricity distribution services. SAIDI reflects the average duration of disruptions experienced by customers, while SAIFI measures the frequency of disruptions. A high SAIDI value indicates a long duration of disruption, which can reduce customer satisfaction due to its impact on daily activities, especially in the industrial and commercial sectors. Conversely, a high SAIFI value indicates frequent disruptions that disrupt the continuity of electricity services.

In the KR04 feeder, the SAIDI value of 0.15235 hours/customer per year and SAIFI of 0.00017 times/customer per year are still within tolerable limits, but require attention to be improved. Customers tend to be more satisfied when power outages occur infrequently and are short in duration. Reducing SAIDI and SAIFI values through strategies such as routine

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maintenance, installation of protective equipment, and better network management will improve customer perceptions of service quality.

SAIDI and SAIFI values have a direct relationship with customer satisfaction levels because both reflect the reliability of electricity distribution services.

a) Duration of Interruption (SAIDI)
High SAIDI values indicate a long duration of disruption, which has a significant impact on customer activity. Industrial and commercial customers feel the direct economic impact of this disruption, such as decreased productivity and potential financial losses. Meanwhile, household customers will feel disturbed, especially if the disruption occurs at night or during peak hours.

b) Interference Frequency (SAIFI)
A high SAIFI value indicates frequent power outages. This creates a negative perception of the quality of service provided, even if the outage is temporary.

c) Impact on Customer Satisfaction
Customers tend to be more satisfied if power outages are rare and can be resolved quickly. Conversely, high SAIDI and SAIFI values indicate system unreliability, which reduces customer confidence in the company's services.

Overall, maintaining SAIDI and SAIFI values within tolerance limits is a key step to improve customer satisfaction while optimizing the performance of the electricity distribution system.

CONCLUSION

This study shows that the reliability of the electricity distribution system at the KR04 Sungai Mas Feeder still needs improvement, although the SAIDI and SAIFI values show acceptable performance. Frequent disruptions result in customer inconvenience, thus strengthening the negative relationship between high SAIDI/SAIFI values and customer satisfaction levels. Reliability improvement efforts such as network maintenance, installation of safety devices, and tree pruning have proven effective in reducing disruptions and improving service quality. It is recommended that PT. PLN increase the frequency of preventive and predictive maintenance on distribution network components, especially in areas prone to disruptions. The use of IoT-based technology for real-time monitoring can help detect potential disruptions before they occur. In addition, educating customers about efforts to improve system reliability can improve customer understanding and support for the services provided. Periodic evaluation of SAIDI and SAIFI values also needs to be carried out to ensure that the strategies implemented are effective.

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