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The Analysis of Performance Reliability Electric Power System in 20 Kv Distribution Network in PT. PLN

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ABSTRACT

The reliability of the electric power distribution system plays a crucial role in ensuring a stable and continuous power supply to consumers. This study analyzes the performance reliability of the 20 kV distribution network at PT. PLN (Persero) UP3 North Medan by evaluating key reliability indices, including SAIDI (System Average Interruption Duration Index), SAIFI (System Average Interruption Frequency Index), and CAIDI (Customer Average Interruption Duration Index). The research methodology involves data collection from historical outage records, fault analysis, and statistical evaluation of reliability indices. The findings indicate that the reliability performance of the 20 kV distribution network in UP3 North Medan is influenced by various factors, such as equipment failures, weather conditions, and external disturbances. Based on the analysis, strategies for improving reliability are proposed, including preventive maintenance, network automation, and enhanced fault detection systems. By implementing these measures, PLN can improve service quality and reduce power outages, ultimately enhancing customer satisfaction and system efficiency.

Keyword : Reliability, Power Distribution, , PT. PLN (Persero) UP3 North Medan

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1. INTRODUCTION

This Study Analyzes The Reliability And Maximizes The Performance Of The Electric Power System On The 20 Kv Distribution Network At PT. PLN (Persero) Customer Service Implementation Unit (UP3) North Medan. The Reliability Index Assessment (RIA) Method Is Used To Measure System Reliability Using Indicators Such As SAIDI, SAIFI, And CAIDI. Thus, This Study Evaluates The Factors That Affect The Performance Of The Distribution Network, Including The Frequency And Duration Of Disruptions, As Well As Improvement Efforts Made To Improve System Reliability. The Results Of The Analysis Show The Level Of Network Reliability And Recommendations For Maximizing Electricity Distribution Performance To Ensure Continuity Of Service To Customers.

This Study Also Discusses Optimization Strategies That Can Be Applied To The 20 Kv Distribution Network To Minimize Disruptions And Improve Operational Efficiency. Some Of The Proposed Methods Include The Use Of Section Techniques To Isolate Disruptions In Certain Parts Of The Network, So That They Do Not Affect A Wider Area. In Addition, Preventive And Predictive Maintenance Is Applied Based On Historical Disruption Data To Reduce The Frequency Of Blackouts.

Through Simulation And Analysis, This Study Provides Solutions To Improve Network Reliability And More Efficient Load Management Strategies. The Results Of This Study Are Expected To Contribute To Improving The Quality Of Electricity Services In North Medan And Its Surroundings, As Well As Providing Insight Into The Development Of A More Reliable Electricity Distribution System In The Future.This Study Also Integrates The Fault Tree Analysis (FTA) And Reliability Block Diagram (RBD) Methods To Map Potential System Failures And Determine Critical Factors Affecting The Reliability Of The 20 Kv Distribution Network. With This Approach, Components With The Highest Risk Of Failure Are Identified, Allowing PT. PLN (Persero) UP3 North Medan To Prioritize Maintenance At Points That Are Most Vulnerable To Disruptions.

In Addition, Analysis Of Disruption Data From The Past Few Years Is Used To Develop A Predictive Model, Which Projects Future Disruption Patterns And Provides A Basis For Decisions Related To Infrastructure Investment And System Improvements. This Model Also Identifies Peak Loads And Uneven Energy Distribution, Which Can Cause Load Imbalances And Increase The Risk Of System

Failure.So That The Study Provides Specific Recommendations Such As The Implementation Of An Automatic Recloser System At Strategic Points To Accelerate The Recovery Process After A Disruption, As Well As Improving The Quality Of Load Management Through The Integration Of Smart Grid Technology. With The Proposed Optimization, It Is Expected To Achieve Significant Reduction In Power Losses, Increase Network Stability, And Decrease Service Downtime. This Solution Is Designed To Maximize Operational Efficiency While Improving Customer Experience In Terms Of Continuity And Quality Of Power Supply.

2. RESEARCH STAGES

Energy is the ability to perform actions or work. (effort). The word "Energy" comes from the Greek word "ergon" which means work. In doing something, we always use energy either consciously or unconsciously or Energy can be defined as power or force to do something or even the act of moving and shifting, which in general can be defined as the ability to do a job (Parta Setiawan, 2021). The following are the properties of energy:

1. Energy Transformation means that Energy can be changed into another form. For example, Electrical Energy into Light Energy.
2. Energy Transfer with the intention of Heat Energy from a material or place can be transferred to another place or material. For example, heating water in a pan, with heat energy originating from the fire transferred through the pan material so that it heats the water and after passing the boiling point of water, the water will evaporate
3. Energy can be transferred from another object by a force that causes a shift/displacement. In this case it is often referred to as Mechanical Energy.
4. Energy is eternal, Energy cannot be created or destroyed. Energy can be converted into equivalent Energy, but Energy cannot be destroyed, but can be converted from one form of Energy to another form of Energy. This is called the law of Conservation of Energy. One of the forms of energy is the form of Electrical Energy.

$$W = Q \times V$$
$$Q = I \times t \quad (1)$$

Information:
W = Electrical energy (Joule)
Q = Electric charge (Coulomb)
V = Voltage (Volt)
I = Current (Ampere)
T = Time (Seconds)

At the charge per unit time is the current flowing, the following is the derivative the size:

$$W = V \times I \times t \quad (2)$$

Information :
W = Electrical Energy (*Joule*)
V = Voltage (*Volt*)
I = Current (*Ampere*)
T = Time (Seconds)
If this equation is connected with Ohm's law, we obtain formulation as follows:

$$W = I^2 \times R \times t \quad (3)$$

Information.
W = Electric Enerrgy (*Joule*)
V = Voltage (*Volt*)
I = Current (*Ampere*)
T = Times(Detik)
R = Resistance(Ohm)

Electrical power can be defined as the electrical energy used in unit of time. The following is a derivative of the formula for the quantities of electrical energy used:

P = V x I .... (4)

Information
P = Electrical Power *Watt*)
W = Electrical Energy (*Joule*)
V = Tegangan (*Volt*)
I = Arus (*Ampere*)
T = Waktu (Detik)

2.1 Electric Power System.

An electric power system consists of three main parts, namely the power plant center, transmission lines and distribution system. In general, the good or bad of the electric power transmission and distribution system is mainly reviewed from the quality of power received by consumers. Good power quality includes adequate power capacity and constant voltage at nominal voltage. Voltage must always be kept constant, especially at voltage losses that occur at the end of the line. Unstable voltage can cause damage to equipment that is sensitive to voltage changes (especially electronic devices).

Voltage that is too low will cause electrical equipment to not operate properly. Likewise, voltage that is too high can potentially damage electrical equipment, including changes in frequency values that will be greatly felt by electricity users whose use is related to/depends on frequency stability. Consumers in this group are usually industrial/factory consumers who use automatic machines using time/frequency settings such as motor equipment. Therefore, frequency and voltage stability must always be controlled to avoid possible risks so that damage to system failure can be avoided (Jefri Arianto, 2015). For an illustration of the electrical power system in Indonesia in general, it can be seen in Figure 1 below:

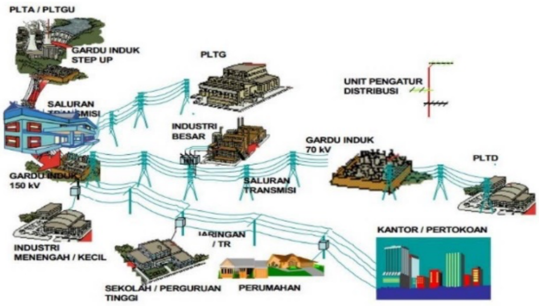

Figure 1. Electric Power Distribution System

Distribution Network serves to channel and distribute electric power from distribution substations to customers/electricity consumers with adequate service quality. One element of service quality is service continuity which depends on the topology and construction of the network and medium voltage equipment.

2.2 Distribution System Network.

This system can use overhead lines, overhead cables, or underground cables according to the desired level of reliability and environmental conditions and situations. This distribution channel is stretched along the area that will be supplied with electricity to the load center. The Distribution System Network is divided into 2 (two), namely the Primary Distribution System Network and the Secondary Distribution System Network. Where the Primary Distribution Network System is a medium voltage electric power distribution network (20 kV). The primary distribution network is a feeder network. The primary distribution network starts from the secondary side of the power transformer installed at the substation to the primary side of the distribution transformer installed on the line poles (Suhadi et al., 2008). The network configuration pattern in primary distribution consists of 4 types, including:

1. Radial Distribution Network.

The radial system in the distribution network is an open system, where the electric power distributed radially through the substation to consumers is done separately from each other. This system is the simplest system among the other systems and the cheapest, because according to its construction this system requires very little use of electrical materials, especially if the distribution distance between the substation and the consumer is not too far. This open radial system is the least reliable, because the distribution of electrical power is only done using one channel. This model network when it gets a disturbance will stop the distribution of electric power enough long before the disturbance is repaired again. Therefore, the continuity of service in this open radial system is less reliable. In addition, the longer the distance of the line from the substation to the consumer, the voltage conditions are increasingly unreliable, in fact getting worse because the voltage losses will be greater. This means that the service capacity for this open radial system is very limited (Shade et al., 2008).

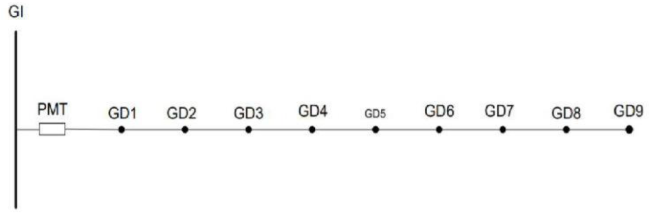

Figure 2. Radial Distribution System Network
Source: Author, 2021

Information :
GI = Main Substation
PMT = Circuit Breaker
GD = Distribution Substation

2. Spindle Distribution Network.

In addition to the basic forms of existing distribution networks, modified forms have also been developed, which aim to improve the reliability and quality of the electrical system. One popular modified form is the spindle form, which usually consists of maximum of 6 feeders in loaded condition, and one feeder in working condition without load. The 6 feeder channels operating in loaded condition are called "working feeders" or working channels, and one channel operated without load is called "express feeder" (Suhadi et al., 2008).

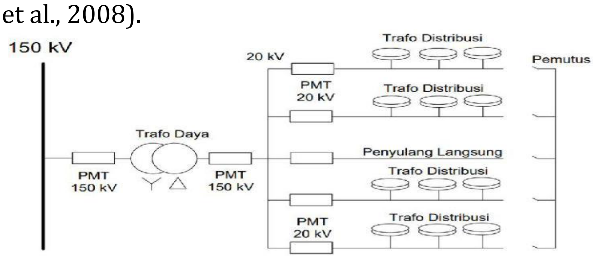

Figure 3 Spindle Distribution System Network

Information :
PMT = Circuit Breaker
kV = kilo Volt

3. Ring (loop) Distribution Network.

A closed circuit system in a distribution network is a distribution system through two or more feeder channels that are interconnected to form a ring-shaped circuit. This system is economically profitable, because disturbances in the network are limited only to the channels. only the disturbed ones. While for other channels can still distribute electric power from other sources in an undisturbed circuit. So that the continuity of electric power source service can be guaranteed properly. What needs to be considered in this system is that if the load served increases, the capacity condition of this closed circuit system will get worse. However, if more than one source point (Power Plant) is used in this network system, this system will be widely used, and will produce better voltage quality, and its voltage regulation tends to be small (Suhadi et al., 2008).

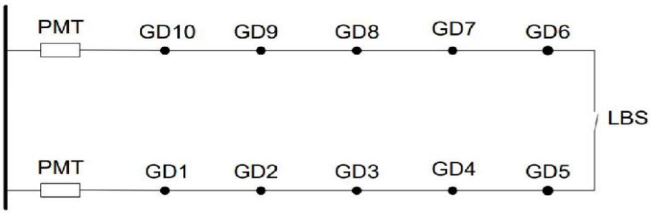

Figure 4. Ring Distribution System Network

Information :
GI = Main Substation
PMT = Circuit Breaker
GD = Distribution Substation
LBS = Load Breaker

4. Interconnection Radial Channel.

This interconnection system is a development system of the network/mesh system. This system distributes electric power from several Power Plants that are desired to work in parallel. So that the distribution of electric power can continue (uninterrupted), even though the area of load density is quite high and wide. It's just that this system requires higher costs and more mature planning. For future developments, this interconnection system is very good, reliable and is a system that has higher quality. In this interconnection system, if one of the Power Plants is damaged causing a power outage, then the distribution of electric power can be diverted to another Power Plant. For Power Plants that have a small capacity, they can be used as assistants to the Main Power Plant (which has a large power capacity). If the normal daily load can be provided by the Power Plant, the generation costs can be reduced. In this interconnection system, the Power Plants work alternately regularly according to a predetermined schedule. So that there is no Power Plant that works continuously. This method will be able to extend the life of the Power Plant and can maintain the stability of the generation system (Suhadi et al., 2008)

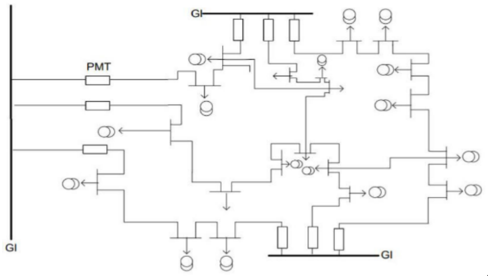

Figure 5. Interconnection Radial Distribution System Network

Information :

GI = Main Substation
PMT = Breaker
GD = Distribution Substation

Based on the 4 types of Primary Distribution System Networks, what is meant by the Secondary Distribution System Network is an electric power network that is included in the low voltage category (380/220 Volt system), namely a rating that is the same as the voltage of the equipment being served. The Secondary Distribution Network starts from the secondary side of the distribution transformer and ends at the customer's measuring instrument (meter) (Suhadi et al., 2008). The secondary distribution network system is distributed to customers through insulated wires. The secondary distribution network can be seen in Figure 6 below:

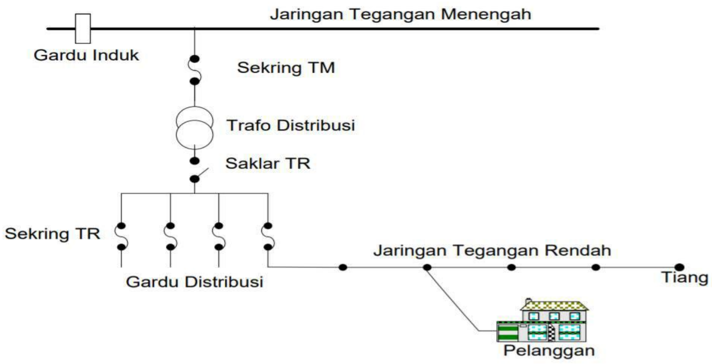

Figure 6. Secondary Distribution System Network

Information :
TM = Medium Voltage
TR = Low Voltage

Based on its location, this distribution system is a part that is directly connected to consumers, so this system, in addition to receiving electrical power from the power source (distribution transformer), will also send and distribute the power to consumers. Given that this part is directly connected to consumers, the quality of electricity should be considered.

3. RESULTS AND DISCUSSION (10 PT)

The type of research in this final project **is** quantitative, focusing on the reliability analysis of the medium-voltage distribution system using the RIA method, Section Technique method, and a combined Section Technique-RIA method**.** The results of this study will compare the three methods used and further compare them with PLN Standard (SPLN 68-2) of 1986**.** The comparison will be based on reliability indices of the distribution system, such as SAIFI, SAIDI**,** and CAIDI**.** The data used in this study is secondary data from the year 2024**,** which is directly obtained from PT. PLN (Persero) UP3 North Medan**.**

To complete this research, the following data is required:

1. Single-line diagram of the feeder for the year 2024.
2. Data on the number of customers and the capacity of each load point for the year 2024.
3. Data on the feeder line length for the year 2024.
4. Component parameters based on SPLN No. 59 of 1985.

In a research study, literature review plays a crucial role as it serves as a logical foundation for solving problems scientifically. The literature review is conducted by studying relevant theories to achieve the research objectives.

Additionally, this study requires data collection through direct field observations and gathering system-related data relevant to the research. The field data collected pertains to the year 2024 from PT. PLN UP3 North Medan, specifically at the ULP Labuhan unit.

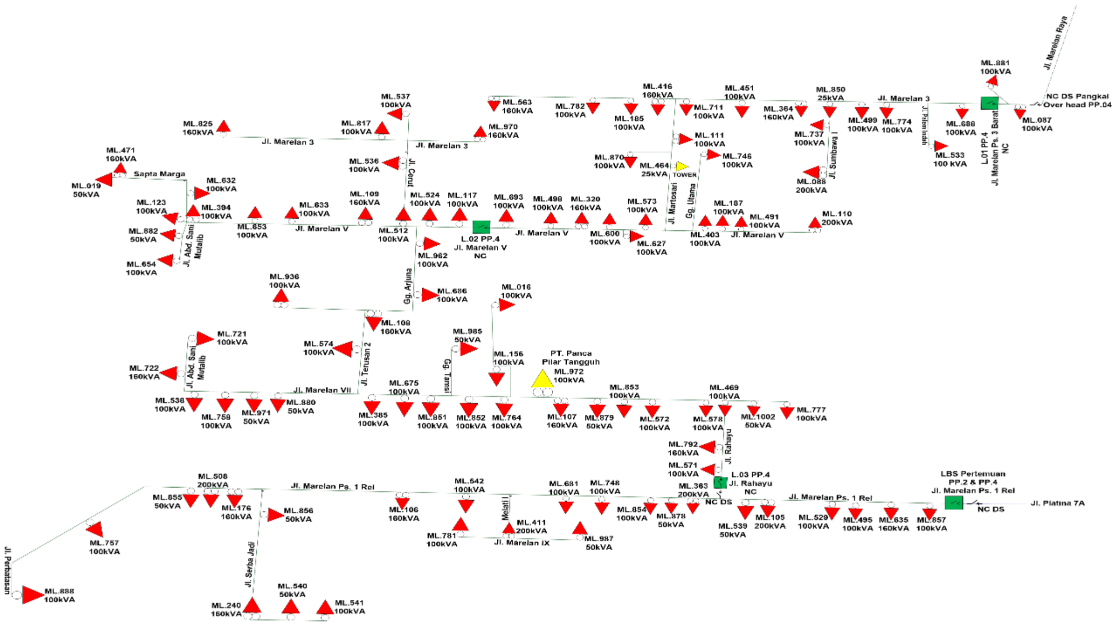

Figure 7. Single-Line Diagram of Feeder PP.4

The number of customers is used to calculate and determine the total customers at each load point on a feeder in the year 2024**.** The total number of customers at PT. PLN (Persero) UP3 North Medan **is** presented in Table 1

Table 1. Total Customers of UP3 North Medan

TOTAL CUSTOMER			**POWER CONNECTED**
1	East Medan	139.916	374,76 MVA
2	Labuhan	101.125	508,35 MVA
3	Belawan	77.376	239,19 MVA
4	Helvetia	98.832	196,72 MVA
5	Medan Denai	153.602	234,44 MVA

The length of the channel is used to determine the length of the distribution channel at PT. PLN (Persero) UP3 Medan Utara in 2024. Data on the length of each feeder channel can be seen in the following table 2:

Table 2. Length of Feeder as of November 2024

Feeder Length		
1	East Medan	336,84
2	Labuhan	266,24
3	Belawan	187,91
4	Helvetia	495,24

5	Medan Denai	232,51
Total UP3 North Medan		**1518,75**

After the required data from PT. PLN (Persero) and theories have been fulfilled from various valid sources, then calculate and analyze the reliability indexes using the RIA method, Section Technique method and a combined method of the Section Technique-RIA method. Based on the data and also formulas from related references. After the reliability indexes such as SAIDI, SAIFI, and CAIDI are fulfilled in each method, the reliability indexes obtained from each method will be compared between one method and another and then analyzed according to the Reliability Index Standard.

Table 3. Reliability index standards

Index	(SPLN 68-2) : 1986	IEEE 1366-2003
SAIFI	3.2 Times /Years	1,45 Times /Years
SAIDI	21 Hours / Years	2,30 Hours/Years
CAIDI	6.56 Hours /Years	1,47 Hours/Years

The results of the RIA method, Section Technique method and combined Section Technique-RIA method are SAIFI (System Average Interruption Frequency Index), SAIDI (System Average Interruption Duration Index), and CAIDI (Customer Average Interruption Duration Index). After obtaining the reliability index on the RIA method, Section Technique method and combined Section Technique-RIA method in the form of SAIDI, SAIFI, and CAIDI, then these results will be compared between one method and another to find which method is effective to use to calculate the reliability index. Here we will see the level of accuracy of the RIA method, Section Technique method, and combined Section Technique-RIA method. And then the results of each method are analyzed according to PLN standards. The results of network reliability calculations on feeders are carried out using the RIA method, Section Technique method, and combined Section Technique-RIA method in the form of SAIFI, SAIDI, and CAIDI. This study aims to analyze the differences in reliability calculations using the RIA method, Section Technique method, and combined Section Technique-RIA method which will be compared with PLN Standards.

3.1 Benefits of Research Objects.

Based on the FCO disturbance monitoring list, the following are the causes of FCO fires, including:

1. Outside the System (External Factors).
   a. Weather conditions.
   b. Human negligence.
   c. Tree branches hit SUTM.
   d. Creeping animals and flying animals.

2. System (Internal Factors).
   a. *Fuse Link*non-standard.
   b. Thermovision and Ultra Vision inspections are not optimal.
   c. Mapping of FCOs prone to potential disruption is not yet optimal
   d. Limited disruption engineering officer.

For the summary results of kWh and Rupiah saved from the installation of the Urgent Cut Out cylinder, it was obtained that:

1. Number of kWh Saved = 15,676 kWh
2. Amount of Rupiah Saved = Rp. 21,193,314,-
3. Production cost = Rp. 44,000,-

If the handling of the damaged/burned/broken FCO cylinder must be replaced with a new (complete) FCO, it takes time for the replacement process and the availability of materials in the unit warehouse, so if a request for material availability from the ULP to the related UP3 is made, it may not be immediately available for the request, then by using this Urgent Cut Out cylinder, the calculation of real rupiah efficiency saved is obtained as follows:

Real Rupiah Efficiency = Amount of Rupiah Saved - Production Cost
= Rp. 21,193,314 – Rp. 44,000
= Rp. 21,149,314,-

Based on the calculation of the real rupiah efficiency saved by installing the Urgent Cut Out tube, the calculation of the real kWh efficiency saved is:
Real kWh Efficiency = Real Rupiah Efficiency : Rupiah Per kWh
= Rp 21,149,314 : Rp 1,352
= 15,643 kWh

3.2 **Non-Financial Benefits of Research Objects.**

Recapitulation of SAIDI, SAIFI, ENS and Recovery Time values.

Table 4. Summary of SAIDI, SAIFI, ENS and ENS Values Recovery Time

No	Mark	Unit	BR 241	BR 202	BR 390
1	Blackout Duration	Minute	60	60	60
2	Burden	Ampere	193	162	178
3	Customer Blackout	Customer	25	10	8
4	Total Customer Served	Customer	120	80	50
5	Saidi	Minute	12.5	7.5	9.6
6	Saifi	Times	0.2	0.12	0.16
7	Ens	KWH	5.676	4.764	5.234
8	Rupiah Saved	Rupiah	7.674	6.441	7.077
9	Recovery Time	Minute/ Customer	2.4	6	7.5

So from the data in table 4 several things can be stated as follows:
a. Emphasis on SAIDI value and minimizing blackout areas.
b. Disturbing SAIFI value and increasing the risk of repeated blackouts.
c. Reducing ENS value.
d. Accelerating recovery time and making it easier for officers to ensure material availability.
e. Utilizing ex-dismantled FCO cylinder materials.
f. Maintaining the reliability of the 20 kV protection system and equipment due to the protection system still being installed on the network.
g. Maintaining continuity of electricity and service to customer satisfaction.

3.3 Risk Analysis Data.

Based on the implementation of the installation of Research Objects that have been carried out during the planned period in table 3.2 (Research Schedule), there are several things that must be considered, including the following:

1. In handling disturbances on damaged/burned/broken FCOs, this is done by replacing the material, especially the FCO tube. In addition to the acceleration of handling disturbances being influenced by the distance traveled, this acceleration is also influenced by the availability of materials, the condition of the terrain traversed and the number of technical officers available for the number of disturbances being served at that time.
2. This tool has not been tested for long-term installation, therefore, in accordance with its name which is urgent, the installation should be temporary and in this research object, the installation lasted 1 (one) month and then the material was replaced with a new FCO, which caused another blackout.
3. Given the many types of FCOs currently installed, it is possible that the length and width of the FCO hanger (Hang) may not match the object of this research, but this can be anticipated by re-measuring the length of the existing FCO tube and cutting the pipe according to needs.

4. When connecting the pipe and socket, it should be installed as tightly as possible so that there are no gaps for water to enter the FCO tube, causing a short circuit. Therefore, it would be better to provide adhesive glue so that it can cover the gaps between the pipe socket and the PVC pipe tube.
5. In addition to providing adhesive glue between the pipe and socket, the connection will still have the potential for a short circuit if the Urgnet Cut Out tube is used for a long period due to the connection.

4. CONCLUSION

Based on the analysis of the 20 kV distribution network at PT. PLN (Persero) UP3 North Medan, the following conclusions can be drawn:

1. The study assessed the reliability of the distribution system using SAIFI, SAIDI, and CAIDI indices and calculated indices were compared with PLN Standard SPLN 68-2 (1986) to determine whether the system meets reliability requirements.
2. The Reliability Index Assessment (RIA) Method provided a basic evaluation of the system's failure rate and outage duration also The Section Technique Method enhanced the accuracy by considering sectional outages and component-specific failures.
3. The Combined Section Technique-RIA method yielded the most comprehensive and accurate reliability analysis, demonstrating improved predictive capability for network performance. Also The results indicate that some feeders exceed the permissible SAIDI and SAIFI thresholds, highlighting areas for improvement.

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