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ANALYSIS OF THE RELIABILITY OF THE 20KV DISTRIBUTION SYSTEM OF PT PLN (PERSERO) ULP TARAKAN USING ROOT CAUSE PROBLEM SOLVING METHODS

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Abstract

The distribution system is one of the components of the power system that cannot be separated from the occurrence of interference or damage, which causes factors from within the equipment and factors from outside that can cause blackouts. In this final project, the reliability problems of SAIDI, SAIFI and CAIDI in 2021 at PT PLN (Persero) ULP Tarakan will be discussed using the RCPS (Root Cause Problem Solving) method. The parameters used to see the reliability of the distribution network are SAIDI (System Average Interruption Duration Index), SAIFI (System Average Interruption Frequency Index) and CAIDI (Customer Average Interruption Duration Index). By comparing the SAIDI, SAIFI and CAIDI reliability indices with the IEEE 1366-2003, SPLN 68-2: 1986 and WCS&WCC reliability indices. Where the comparison results of SPLN 68-2: 1986 and SAIDI = 21.09 j/p/t and 6.45 j/p/t (Meets Standard), SPLN 68-2: 1986 and SAIFI = 3.2 k/p/t and 7.38 k/p/t (Does Not Meet Standard), IEEE 1366-2003 and SAIDI = 2.3 j/p/t (Does Not Meet Standard), IEEE 1366-2003 and SAIFI = 1.45 k/p/t and 7.38 k/p/t (Does Not Meet Standard), IEEE 1366-2003 and CAIDI = 1.47 j/g/t and 9.89 j/g/t (Does Not Meet Standard), WCS&WCC and SAIDI = 3 j/p/t and 6.45 j/p/t (Does Not Meet Standard), WCS&WCC and SAIFI = 1.666 k/p/t and 7.38 k/p/t (Does Not Meet Standard). If it does not meet the predetermined standards, Root Cause Problem Solving analysis is carried out.

Keywords:
RCPS; reliability; distribution system; SAIDI; SAIFI; CAIDI

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1. Introduction

Distribution system is one of the components of the electric power system that cannot be separated from the occurrence of interference or damage, interference or damage that occurs in the distribution system either caused by factors from within the equipment itself or external factors will greatly affect the reliability of the distribution system in delivering electrical energy and will also result in disconnection of the network to the load resulting in blackouts [1].

There are several indices used to determine the level of service reliability based on how long an outage occurs during a year or known as the System Average Interruption Duration Index (SAIDI), how often an outage occurs during a year or known as the System Average Interruption Frequency Index (SAIFI), and how long the average outage felt by consumers for each interruption or known as the Customer Average Interruption Duration Index (CAIDI).

Reliability in distribution systems is a measure of the availability/level of service of providing electricity from the system to the user or customer. Reliability measures can be expressed as how often the system experiences outages, and how quickly it takes to restore conditions from outages that occur [2].

Blackouts result in losses both to customers and to PLN, so it is very necessary to analyze the reliability of the distribution system. One way to get to the root of the problem is to analyze using the Root Cause Problem Solving (RCPS) method.

2. Theory Foundation

A. Distribution System Faults

Disturbances in the distribution system are divided into two, namely:

1. Temporary Disturbance

Temporary disturbances are disturbances that occur for a short time and after that the system can return to normal work, but temporary disturbances that occur repeatedly can cause equipment damage.

2. Permanent Disturbance

Permanent disturbance is a disturbance that can be caused by damage to the equipment so that this disturbance only disappears after the damage is repaired, for example there is a branch that falls on the phase wire of the air duct so that this branch needs to be taken first so that the system can function normally again, in other words permanent disturbances can be overcome after the cause of the disturbance is eliminated.

B. Distribution System Faults

a. SAIFI (System Average Interruption Frequency Index)

SAIFI (System Average Interruption Frequency Index) is an index that informs about the average frequency of outages for each consumer within a year in an evaluated area.

Then SAIFI can be calculated by the formula:[3]

$$SAIFI = \frac{\text{number of customer outages}}{\text{number of customers served}} \text{ times/customers/year} \quad (1)$$

b. SAIDI (System Average Interruption Duration Index)

SAIDI (System Average Interruption Duration Index) is an index that informs about the average outage duration for each consumer within a year in an evaluated area.

Then SAIDI can be calculated by the formula:[3]

$$SAIDI = \frac{\text{Hours} \times \text{Customer Outage}}{\text{Number of Customers served}} \text{ Hours/customers/year} \quad (2)$$

c. CAIDI (Customer Average Interruption Duration Index)

CAIDI (Costumer Average Interruption Duration Index) is an index of the average duration or length of interruption for consumers affected by the interruption, formulated in (3):

$$CAIDI = \frac{SAIDI}{SAIFI} \text{ Hours/disturbance/year} \quad (3)$$

With:

SAIDI = Average outage duration index

SAIFI = Average outage frequency index

d. Standard Reliability index Value

This standard is intended to explain and determine the level of reliability of the power distribution system. The goal is to provide a directional guide in assessing the appearance and determining the level of reliability of the distribution system and also as a benchmark for progress or determine the projections that will be achieved by PT PLN (Persero) [3]. Reliability The SAIDI, SAIFI and CAIDI reliability index value standards based on SPLN, IEEE and WCS&WCC are shown in Table 1.

Table 1. Reliability Index Value Standards SAIDI, SAIFI and CAIDI

Reliability Index Standard	Value Standard		
	SAIDI j/p/t	SAIFI k/p/t	CAIDI j/g/t
SPLN 68-2 : 1986	21,09	3,2	-
IEEE std 1366-2003	2,3	1,45	1,47
WCS&WCC	3	1,666	-

Description:

j/p/t = hours/customer/year

k/p/t = times/customers/year

j/g/t = hours/disturbance/year

C. Root Cause Problem Solving Method

Steps to perform the RCPS method:

1. Problem Definition

Knowing what problems actually occur and knowing the impact that occurs from these problems.

2. Problem Structure

Steps in problem structuring:

a. Pareto data

Grouping disturbance data based on the type of disturbance and the cause of the disturbance so that by grouping the disturbance data it will make someone more focused on taking the right solution to handle the disturbance.

Pareto diagrams are used to see or identify the most dominant problems, defect types, or causes so that we can prioritize problem solving. To simplify the pareto diagram, we must first create a percentage of defects.

$$\text{Percentage}=\frac{\text{Number of distractions per item}}{\text{Total number of distractions}}\times 100\% \quad (4)$$

b. Problem tree

Creating a problem tree aims to ensure consistency in the application of problem solving is maintained to solve the problem from the root of the problem so that parts of the problem will not overlap.

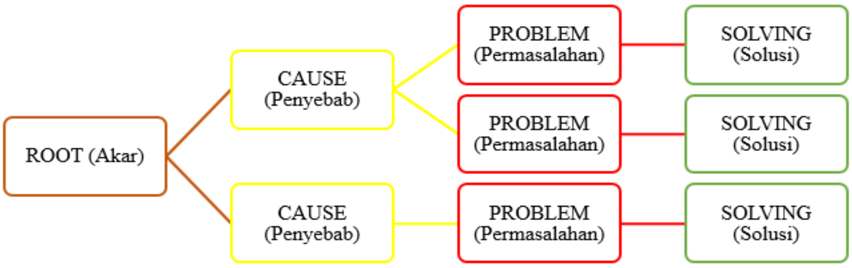

Figure 1. Problem Tree Diagram

3. Prioritize the Problem/Solution

Prioritizing issues can be done by creating a Priority Matrix.

a. Prioritization matrix

This is a comparison diagram between impact and ease of implementation as a stage of solution development.

3. Methods

A. Tools and Materials

The tools and materials used in analyzing and processing the research data consist of hardware and software, namely:

a. Hardware

The hardware used is 1 unit of computer/laptop, printer, stationery paper, cellphone and calculator.

b. Software

The software used is Microsoft Office 2013, including MS Word, MS Excel and MS Power Point and Google Web Browser.

B. Research Stage

The stages of research conducted by the author include:

a. Literature Study

Reading and collecting theories related to research including books, scientific journals, articles, internet services and others.

b. Data Retrieval,

The data that will be taken is the length of the disturbance, the number of times the disturbance, the total outage customers, and the total customers served.

c. SAIDI, SAIFI and CAIDI Calculation

From the data that has been collected, calculations are carried out to determine whether it meets the predetermined standards.

d. Analyzing using the RCPS Method
- Problem structure (pareto data, problem tree)
- Problem prioritization (pareto data analysis, priority matrix)

e. Making Conclusions & Suggestions

4. Results and Discussion

A. Monitoring Data for 2021

Recapitulation of PT PLN (Persero) ULP Tarakan Customer Monitoring Data in 2021 can be seen in Table 2.

Table 2. Customer Monitoring Data of PT PLN (Persero) ULP Tarakan in 2021

No	Month	Number of Customers	Number of Outage Customers	Outage Duration (Hour)	Hours x Number of Outage Customers
1	January	63.738	43.119	1,37	59.480,36
2	February	63.980	51.420	0,72	37.139,69
3	March	64.222	51.442	1,15	59.298,78
4	April	64.563	47.977	0,97	46.582,20
5	May	64.794	21.469	0,96	20.790,85
6	June	65.094	78.324	0,72	56.412,90
7	July	65.364	58.509	0,88	51.898,15
8	August	65.722	11.850	0,46	5.482,13
9	September	66.041	20.326	0,40	8.200,84
10	October	66.345	30.706	0,71	22.064,56
11	November	66.684	33.290	0,68	22.908,57
12	December	66.930	35.400	0,88	31.449,77

B. Calculation of SAIDI, SAIFI and CAIDI

The data used to find the system reliability index (SAIDI, SAIFI and CAIDI) is obtained from the 2021 Customer Monitoring Data Recapitulation data in Table 2.

1. SAIDI analysis can be calculated through the equation:
   - January Month

SAIDI $= \frac{\text{Hours} \times \text{Customer Outage}}{\text{Number of Customers served}}$

$= \frac{59.480,36}{63.738}$

= 0,93 Hours/customer/month

- February Month

SAIDI $= \frac{\text{Hours} \times \text{Customer Outage}}{\text{Number of Customers served}}$

$= \frac{37.139.69}{63.980}$

= 0,58 Hours/customer/month

2. SAIFI analysis can be calculated using the equation:
- January Month

SAIFI $= \frac{\text{Number of outages}}{\text{Number of customers served}}$

$= \frac{43.119}{63.738}$

= 0,67 Times/customer/month

- February Month

SAIFI $= \frac{\text{Number of outages}}{\text{Number of customers served}}$

$= \frac{51.420}{63.980}$

= 0,80 Times/customer/month

3. CAIDI analysis can be calculated using the equation:
- January Month

CAIDI $= \frac{\text{SAIDI}}{\text{SAIFI}}$

$= \frac{0,93}{0,67}$

= 1,38 Hours/disturbance/month

- February Month

CAIDI $= \frac{\text{SAIDI}}{\text{SAIFI}}$

$= \frac{0,58}{0,80}$

= 0,72 Hours/disturbance/month

The calculation results of SAIDI, SAIFI and CAIDI are summarized in Table 3.

Table 3. SAIDI, SAIFI and CAIDI Calculation Results

No	Month	SAIDI (j/p/b)	SAIFI (k/p/b)	CAIDI (j/g/b)
1	January	0,93	0,67	1,38
2	February	0,58	0,80	0,72
3	March	0,92	0,80	1,15
4	April	0,72	0,74	0,97

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5	May	0,32	0,33	0,96
6	June	0,86	1,20	0,71
7	July	0,79	0,89	0,88
8	August	0,08	0,18	0,44
9	September	0,12	0,30	0,4
10	October	0,33	0,46	0,71
11	November	0,34	0,49	0,69
12	December	0,46	0,52	0,88
Total		6,45	7,38	9,89

Table 3 shows the results of the calculation of the reliability index of the 20kV distribution system. Where the data taken as research for the calculation there are 10 feeders. For the highest SAIDI = 0.93 j/p/b in January, the highest SAIFI = 1.20 k/p/b in June, and the highest CAIDI = 1.38 j/g/b in January.

C. Comparison Results

Table 4. SAIDI and SAIFI Comparison Results with SPLN 68-2: 1986 Standard

No	Standard SPLN 68-2: 1986	SAIDI	Description
1.	21,09 j/p/t	6,45 j/p/t	Meets Standard
No	Standard SPLN 68-2: 1986	SAIFI	Description
2.	3,2 k/p/t	7,38 k/p/t	Does not meet the standard

Table 5. SAIDI, SAIFI, and CAIDI Comparison Results with IEEE 1366-2003 Standards

No	Standard IEEE 1366-2003	SAIDI	Description
1.	2,3 j/p/t	6,45 j/p/t	Does not meet the standard
No	Standard IEEE 1366-2003	SAIFI	Description
2.	1,45 k/p/t	7,38 k/p/t	Does not meet the standard
No	Standard IEEE 1366-2003	CAIDI	Description
3.	1,47 j/g	9,89 j/g/t	Does not meet the standard

Table 6. SAIDI and SAIFI Comparison Results with WCS&WCC Standards

No	Standard WCS&WCC	SAIDI	Description
1.	3 j/p/t	6,45 j/p/t	Does not meet the standard
No	Standard WCS&WCC	SAIFI	Description
2.	1,666 k/p/t	7,38 k/p/t	Does not meet the standard

Based on Table 4 to Table 6 above, the reliability index that is categorized as reliable is only the SAIDI value in SPLN 68-2: 1986, and for other reliability index values it is categorized as less reliable.

D. Disturbance Analysis Using RCPS Method

1. Disruption Analysis with Pareto Data

Analysis of disturbances that occur at PT PLN (Persero) ULP Tarakan using pareto data as follows:

Table 7. Outage Disruption in 2021

Disorder	Causes of Disorder	Causes of Disorder
APP	In the investigation.	Loose connection/Loss of contact.
	Lifetime.	Overload.
	Insulation media leaks/fails.	Fire.
	Procedure error.	Failure of lightning protection equipment.
	Installation error.	
SR Cable	Lifetime.	Loose connection/Loss of contact.

	Vehicle.	Vandalism (Destruction by people).
	Foreign objects.	Third-party construction workers.
	Trees.	Landslides.
	In the investigation.	Fire.
	Insulation media leaks/fails	Animals.
	Overload.	Installation error.
PHBTR	Lifetime.	Animals.
	In the investigation	Fire.
	Overload.	Mechanical system malfunction.
JTR Cable	Trees.	Third-party construction workers.
	Overload.	Installation error.
	Lifetime.	Earthquake.
	Foreign objects.	Fire.
	In the investigation	Loose connection/Loss of contact.
	Vehicle.	Vandalism (Destruction by people).
	Animals.	
Conductor	Foreign objects.	Animals.
	Trees.	Kite/Wire.
	In the investigation	Lifetime.
Maintenance	Substation maintenance.	Repeater Maintenance.
	JTR maintenance.	Feeder maintenance.
	APP maintenance.	
Recloser	Foreign objects.	Trees.
	In the investigation	Animals.
DS/LBS	Foreign objects.	Animals.
	In the investigation	Trees.
Primary/Secondary Cable	Overload.	In the investigation
	Trees.	Loose connection/Loss of contact.
	Animals.	
MV Cell	In the investigation	Protection coordination.
	Corrosive/Salting.	Failure of lightning protection equipment.
	Overload.	
TR Pole	Trees.	In the investigation
	Corrosive/Salting.	Landslides.
Hardware M A	Lifetime.	Flashover.
	In the investigation	
Construction	Pole Replacement.	Cable construction.
Arrester	Lifetime.	Insulation media leaks/fails
	Foreign objects.	
Transformer	Insulation media leaks/fails	In the investigation
CO Branch	In the investigation	Lifetime.
Outgoing Cable to First Pole	-	-
Capacitor / AVR	-	-
Relay Outgoing Feeder	-	-
Pole	-	-
CT/PT kwh Meter Exim	-	-
Termination	-	-
Cable	-	-
Jointing	-	-
FCO Transformer	-	-

After making observations, the causes and frequency of interference are obtained as in Table 7 above. And for the percentage calculation, it is calculated using the following formula:

- APP

$$\text{Percentage} = \frac{\text{Total APP fault frequency}}{\text{Total fault frequency}} \times 100\%$$
$$= \frac{1435}{3002} \times 100\%$$
$$= 47{,}80\%$$

- SR Cable

$$\text{Percentage} = \frac{\text{Total frequency of SR Cable faults}}{\text{Total frequency of faults}} \times 100\%$$
$$= \frac{953}{3002} \times 100\%$$
$$= 31{,}75\%$$

From the above calculations, the percentage of disturbances are all still within reasonable limits because they are still below the percentage of 80%, the disturbance percentage table can be seen in Table 8.

Table 8. Frequency of Disturbance in 2021

NO	Disturbance	Frequency Disturbance	Percentage Disturbance	Cumulative Percentage
1	APP	1435	47,80%	47,8%
2	SR Cable	953	31,75%	79,5%
3	PHBTR	181	6,03%	85,6%
4	JTR Cable	94	3,13%	88,7%
5	Conductor	92	3,06%	91,8%
6	Maintenance	85	2,83%	94,6%
7	Recloser/PMCB	47	1,57%	96,2%
8	DS/LBS	32	1,07%	97,2%
9	Primary/Secondary Cable	25	0,83%	98,1%
10	MV Cell	14	0,47%	98,5%
11	TR Pole	13	0,43%	99,0%
12	Hardware Mounting Assembly	12	0,40%	99,4%
13	Construction	7	0,23%	99,6%
14	Arrester	6	0,20%	99,8%
15	Transformer	4	0,13%	99,9%
16	CO Branch	2	0,7%	100,0%
17	Outgoing Cable to First Pole	0	0,0%	100,0%
18	Capacitor / AVR	0	0,0%	100,0%
19	Relay Outgoing Feeder	0	0,0%	100,0%
20	Pole	0	0,0%	100,0%
21	CT/PT kwh Meter Exim	0	0,0%	100,0%
22	Termination	0	0,0%	100,0%
23	Cable	0	0,0%	100,0%
24	Jointing	0	0,0%	100,0%
25	FCO Transformer	0	0,0%	100,0%
Grand Total		**3002**	**100,0%**	

Because it calculates a reliability, a cumulative percentage is used to find out disturbances whose cumulative percentage is below 100.0%, it will be prioritized to be repaired using a problem tree.

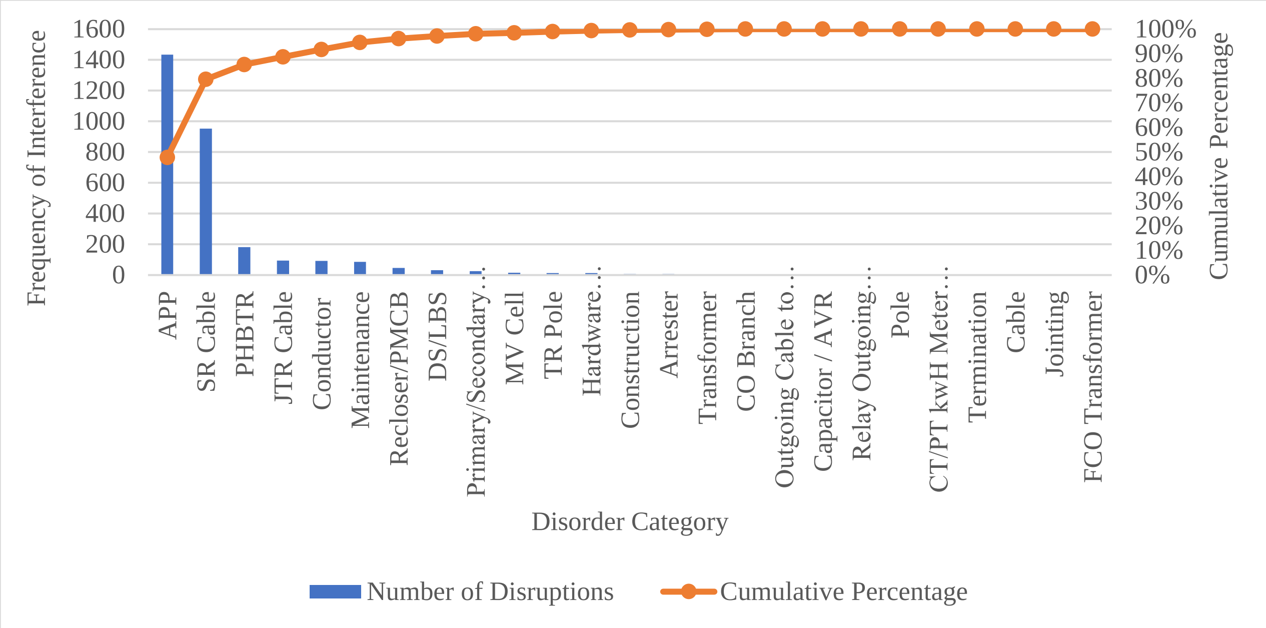

Figure 2. Pareto Diagram of the Causes of Outage Disorders in 2021

2. Disturbance Analysis with Problem Tree and Prioritization Matrix
   a. Problem Tree

Figs. 3 to 6 below are the mapping of the problems causing the Tarakan city disorder depicted in the RCPS diagram (Problem Tree). To facilitate reading, the following colors are used Brown as Root, Yellow as Cause, Red as Problem, Green as Solving.

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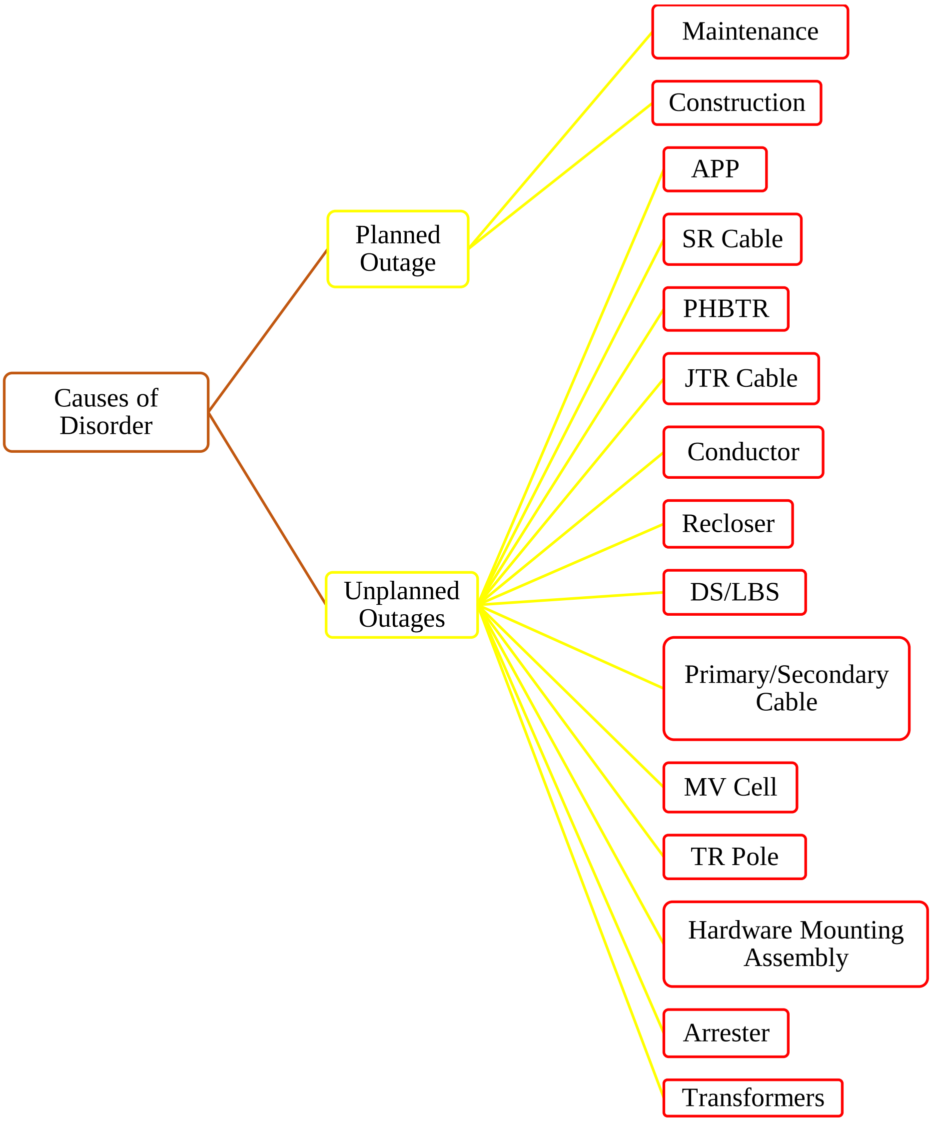

Figure 3. Root Cause of the Problem

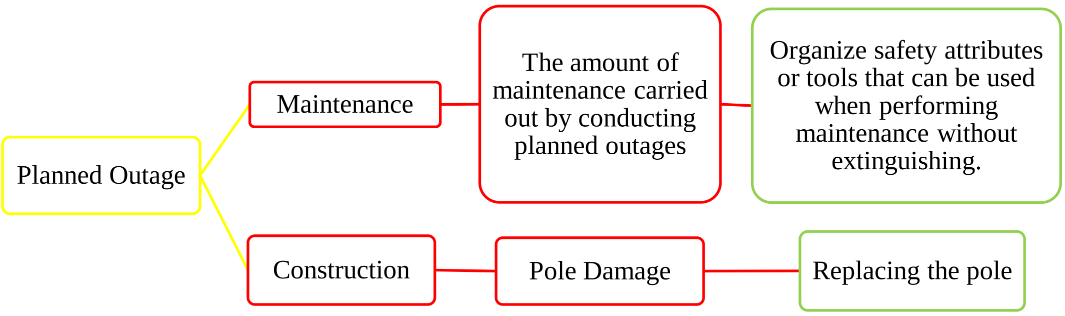

Figure 4. Cause Problem Solving

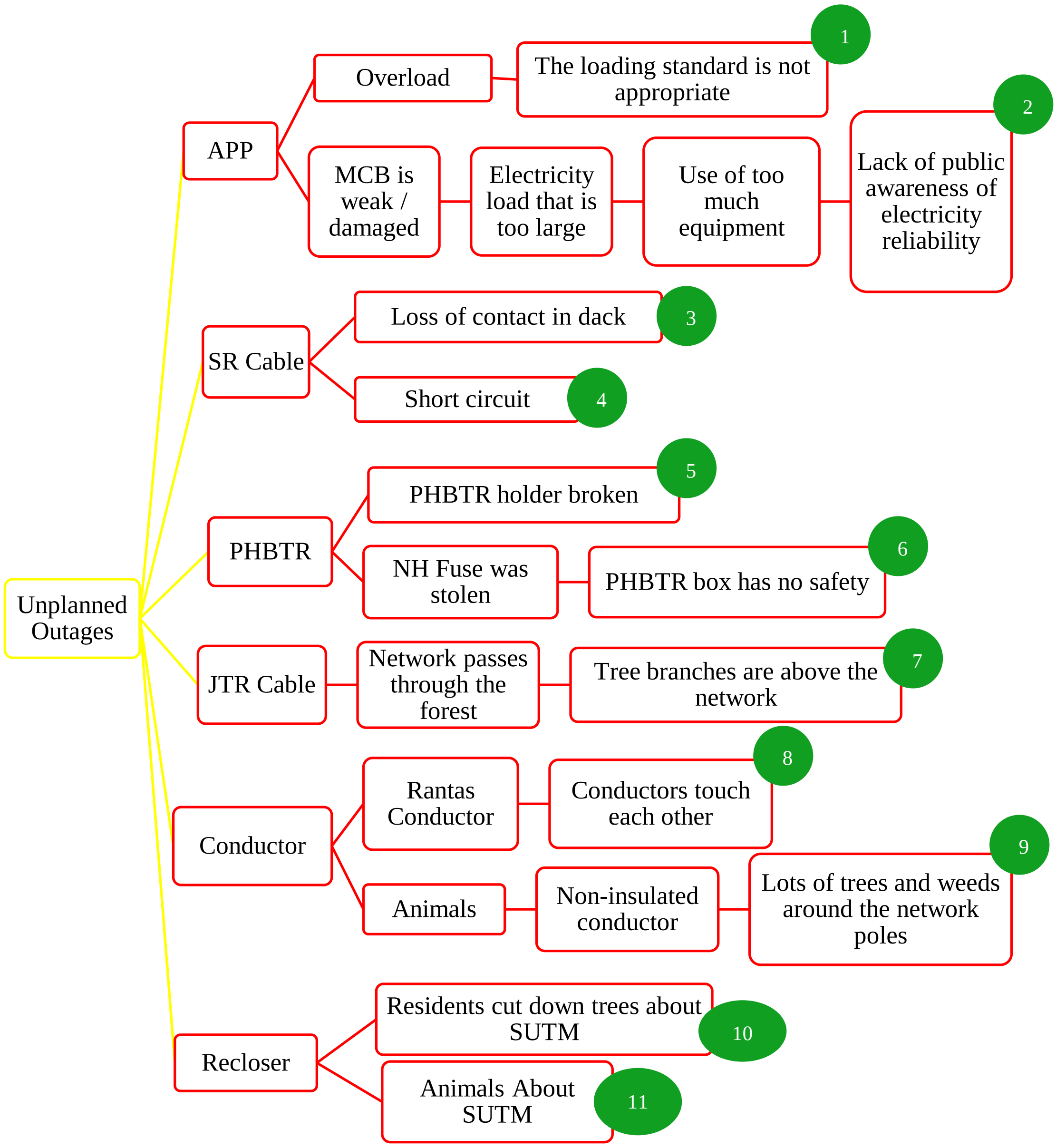

Figure 5. Cause Problem 1

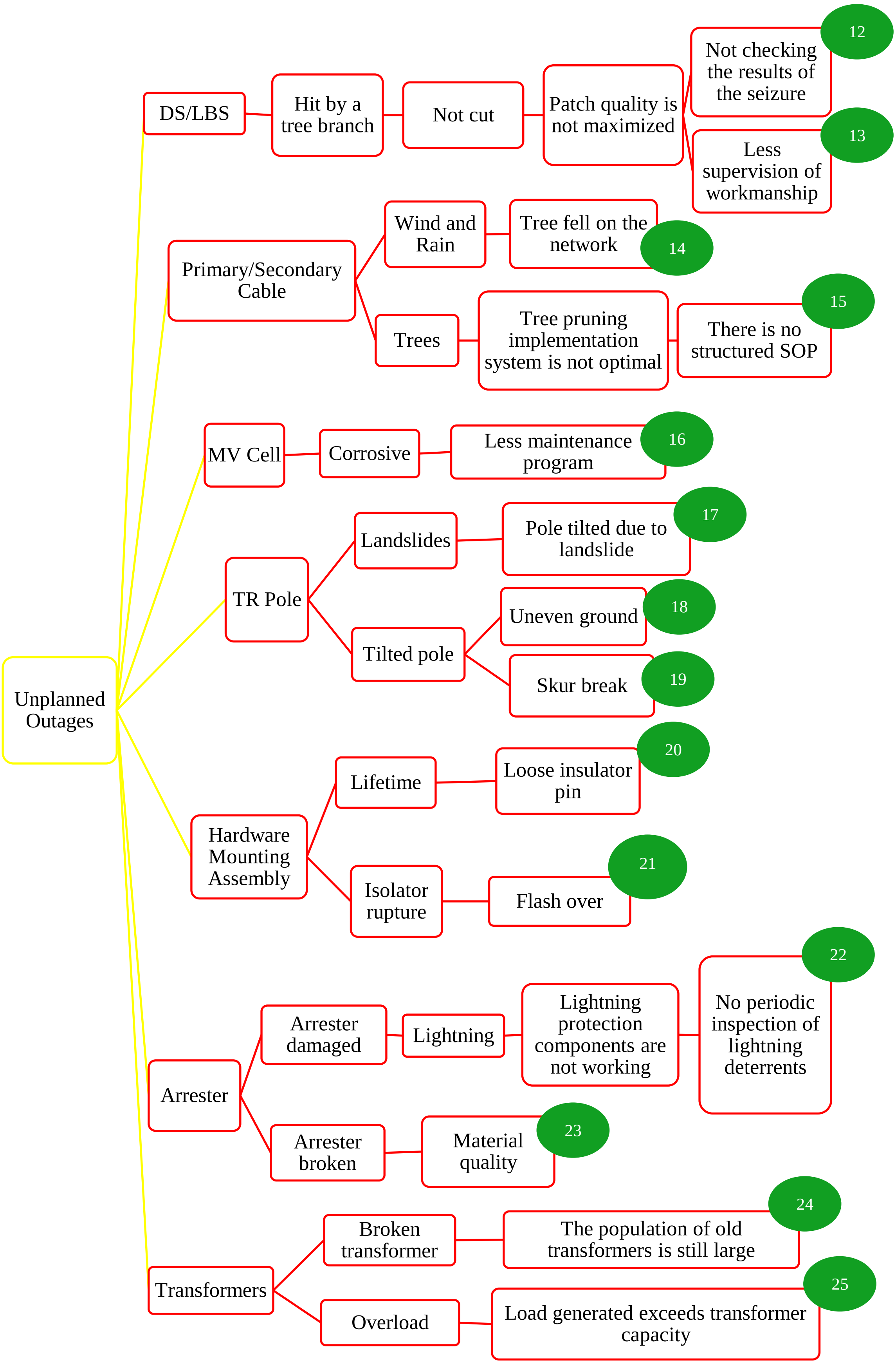

Figure 6. Cause Problem 2

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b. Improvement Initiatives and Prioritization

After creating the problem tree, the existing problems can be identified. From these problems will be obtained improvement ideas that can be done to overcome the problem of the number of disturbances that occur in the feeder in the city of Tarakan.

The following problem solving to solve the problem of interference in the repeater in the city of Tarakan

Table 9. Problem Solving

No	Problem	Solving
1	The loading standard is not appropriate	Re-installation by paying attention to the standards that have been set again
2	Lack of public awareness of electricity reliability	Socialization and installation of safety signs
3	Loss of contact in dack	Repairing and replacing cables that have lost contact
4	SR cable emits sparks	Repairing or replacing cables that are short-circuited
5	PHBTR holder broken	Inspect components and replace components that are not suitable for use.
6	PHBTR box has no safety	Installing security such as a padlock on the PHBTR box.
7	Tree branches are above the network	Pruning or removing trees.
8	Conductors touch each other	Repairing or replacing damaged wires.
9	Large number of trees and weeds around network poles.	Pruning or removing trees and clearing weeds around network poles.
10	Residents cut down trees about SUTM	Socialization
11	Animals about SUTM	Installing alkaduri or animal guards
12	Less supervision of work	Appoint a daily supervisor or make a daily supervisor schedule
13	Not checking the results of the seizure	Inspecting and evaluating the results of the demolition
14	Tree fell on the network	Replace broken network cables caused by fallen trees
15	There is no structured SOP	Make SOP
16	Lack of maintenance program	Conduct thorough inspections and follow up on inspection results
17	The pole is tilted because it is prone to landslides	Straighten poles, and conduct checks
18	Uneven ground	Perform casting on poles that are prone to collapse
19	Skur broke	Installing skur
20	Loose insulator pin	Replacing insulator pins
21	Flash over	Replacing the insulator
22	No periodic inspection related to lightning deterrence	Make a regular inspection schedule related to lightning deterrence
23	Low material quality	Replace damaged equipment, use and buy quality materials
24	The population of old transformers is still very large	Conduct a distribution transformer assessment (transformer condition assessment)
25	The load generated exceeds the transformer capacity	Adding transformer power

From these improvement initiatives, it is necessary to prioritize initiatives based on the level of convenience and impact that will be obtained if the initiative is carried out. The following is a priority matrix for reducing outage interference based on the results of the analysis:

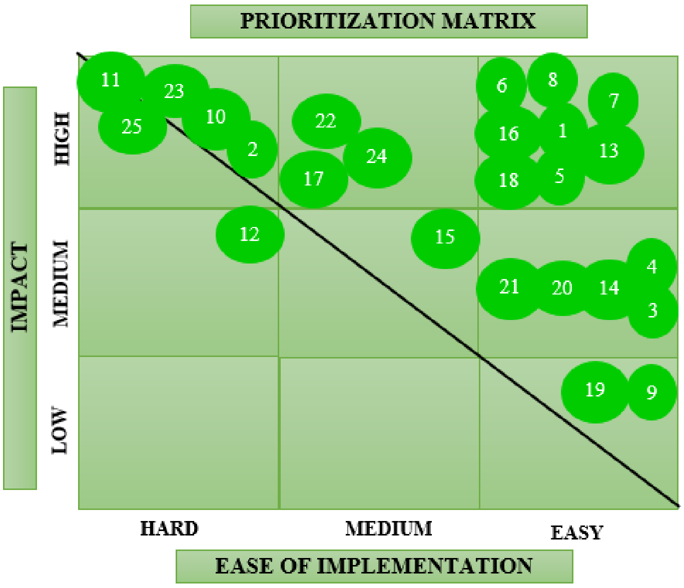

Figure 7. Prioritization Matrix

5. Conclusion

From the results of analysis and calculation, it can be concluded:

a. Based on the data on blackout disturbances in 2021, the most disturbances are disturbances of Limiting and Measuring Devices (APP) with a total number of 1435 disturbances and a duration of 587.1 hours.
b. Based on the 2021 fault frequency data, there are 15 faults out of 25 that are prioritized for repair, namely APP, SR Cable, PHBTR, JTR Cable, Conductor, Maintenance, Recloser/PMCB, DS/LBS, Primary/Secondary Cable, MV Cell, TR Pole, Hardware Mounting Assembly, Construction, Arrester, and Transformer.
c. Based on the reliability of SPLN 68-2: 1986, IEEE, and WCS&WCC, the reliability index of PT PLN (Persero) ULP Tarakan is categorized as reliable and less reliable because the SAIDI, SAIFI and CAIDI values meet the standards and some do not meet the standards, which meet the standards are SPLN 68-2: 1986 with a value of 21.09 j/p/t and SAIDI with a value of 6.45 j/p/t. And those that do not meet the standard are SPLN 68-2: 1986 and SAIFI with values of 3.2 k/p/t and 7.38 k/p/t, IEEE and SAIDI with values of 2.3 j/p/t and 6.45 j/p/t, IEEE and SAIFI with values of 1.45 k/p/t and 7.38 k/p/t, IEEE and CAIDI with values of 1.47 j/g/t and 9.89 j/g/t, WCS&WCC and SAIDI with values of 3 j/p/t and 6.45 j/p/t, WCS&WCC and SAIFI with values of 1.666 k/p/t and 7.38 k/p/t.
d. The highest SAIDI value in January was 0.93 j/p/b, the lowest SAIDI value in August was 0.08 j/p/b. And for the annual SAIDI value of 6.45 j/p/t.
e. The highest SAIFI value in June was 1.20 k/p/b, the lowest SAIFI value in August was 0.18 k/p/b. And the annual SAIFI value is 7.38 k/p/t.
f. The highest CAIDI value in January was 1.38 j/g/b, the lowest CAIDI value in September was 0.4 j/g/b. And the annual CAIDI value is 9.89 j/g/t.

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