Analysis of the Effect of Adding Fuse Cut Outs (FCOs) on Reducing the Outage Area of the Distribution Network on PE4 Feeder of PT PLN (Persero) ULP Sidimpuan Kota

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Abstract

The reliability of an electric power distribution system is an important indicator for maintaining continuity of service to customers. One problem that frequently occurs in distribution networks is the extensive outage area caused by faults, resulting in many customers experiencing power interruptions. One effort to reduce the impact of these faults is to add Fuse Cut Outs (FCOs) at specific points in the distribution network so that faults can be isolated more selectively. This study aims to analyze the effect of adding Fuse Cut Outs (FCOs) on reducing the outage area on the PE4 Feeder of PT PLN (Persero) ULP Sidimpuan Kota. The research used a descriptive quantitative method with a comparative approach by analyzing conditions before and after the addition of FCOs based on fault data, outage area, number of affected customers, and fault duration. The results show that adding FCOs at Simarpinggan, Garonggang, and Siroccitan improved the fault-isolation capability of the distribution network. The average outage area decreased from 74 km to 48.5 km, or by 34.46%. In addition, the average number of interrupted customers decreased from 4,570 to 2,780 customers, or by 39.17%. The average fault duration also decreased from 2.53 hours to 1.15 hours, or by 54.55%. These findings show that adding FCOs is effective in reducing the outage area and the number of affected customers, as well as improving distribution-network reliability on the PE4 Feeder of PT PLN (Persero) ULP Sidimpuan Kota.

***Keywords**:* Fuse Cut Out (FCO), distribution network, outage area, system reliability, interrupted customers

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Introduction

The reliability level of the distribution system is one of the main indicators of PT PLN (Persero) service quality in meeting the community's electricity needs. Reliability is influenced by the system's ability to maintain continuity of electric-power delivery and to accelerate recovery when faults occur in the distribution network.

In 20 kV medium-voltage distribution networks, faults can be caused by various factors, such as trees touching conductors, lightning strikes, equipment failures, animals, and human activity around the network. These faults often cause outages over a wide area because the protection system disconnects supply to a large portion of the feeder. The wider the fault-affected area, the greater the number of customers who experience outages, thereby reducing distribution-system reliability.

The PE4 Feeder of PT PLN (Persero) ULP Sidimpuan Kota is a distribution feeder that serves customers over a relatively wide area using a radial network configuration. The characteristics of a radial network mean that a fault at one point can cause customers downstream of the fault location to lose supply. This condition results in a relatively large outage area and number of affected customers when it is not supported by a protection system capable of selectively isolating faults.

One effort to reduce the outage area is to add Fuse Cut Outs (FCOs) at strategic points in the distribution network. Fuse Cut Outs function as protective devices that can separate the faulted part of the network so that the affected area can be limited to a specific section. By dividing the network into segments using FCOs, a fault does not cause the entire feeder to lose electricity supply and the number of interrupted customers can be minimized.

Several previous studies have shown that optimizing protection coordination and locating fault-isolation equipment in distribution networks can improve system reliability by reducing the fault-affected area. However, the effectiveness of adding Fuse Cut Outs is strongly influenced by network conditions, feeder configuration, line length, and customer distribution in each network segment. Therefore, a more specific analysis of the PE4 Feeder of PT PLN (Persero) ULP Sidimpuan Kota is required to determine the effect of adding Fuse Cut Outs on reducing the outage area caused by faults.

This study analyzes network conditions before and after the addition of Fuse Cut Outs based on fault data, affected network length, and the number of customers experiencing outages. A comparative method is used to evaluate changes in the outage area after Fuse Cut Outs are installed at several network points. The results are expected to provide technical recommendations for improving distribution-system reliability through optimized placement of protection equipment in 20 kV distribution networks.

Literature Review

2.1 Electric Power Distribution System

An electric power distribution system is part of the power system that delivers electrical energy from substations to customers. A distribution network consists of a primary distribution network (20 kV medium voltage), distribution substations, and a secondary distribution network (380/220 V). Distribution-system reliability is an indicator of electricity-service quality because it is directly related to the continuity of electrical-energy delivery to customers. Faults in the distribution network can cause power outages that affect customers and reduce system reliability.

2.2 Radial Distribution Network

A radial distribution network is the configuration most widely used in PLN distribution systems. In this system, electrical power is delivered from the substation to customers through a single supply path. The advantages of a radial network include:

1. Simple construction
2. Relatively low investment cost
3. Easier operation and maintenance

However, its weakness is that when a fault occurs at one point in the network, customers downstream of the fault point experience an outage until the fault can be isolated.

2.3 Faults in Distribution Networks

A fault is an abnormal condition that disrupts continuity of electrical-energy delivery. Faults in distribution networks can be caused by:

1. Natural factors
   a) Lightning strikes
   b) Strong winds
   c) Trees touching conductors
   d) Flooding
2. Equipment factors
   a) Broken insulators
   b) Broken conductors
   c) Fuse failure
   d) Arrester damage
3. External factors
   a) Animals
   b) Human activity
   c) Vehicles hitting poles

Faults can cause the protection system to operate, resulting in outages for some or all customers on the feeder.

2.4 Distribution Network Protection System

A protection system is a set of equipment that detects and isolates the faulted part of the system so that it does not affect other parts. The objectives of a protection system are:

1. Protect equipment
2. Reduce the fault area.
3. Accelerate system recovery.
4. Improve distribution reliability

Common protection equipment used in distribution networks includes:

1. Circuit Breaker (CB)
2. Recloser
3. Sectionalizer
4. Fuse Cut Out (FCO)
5.

2.5 Fuse Cut Out (FCO)

A Fuse Cut Out (FCO) is protection equipment used in medium-voltage distribution networks to protect equipment and lines from fault current. An FCO operates based on the melting of the fuse link when the fault current exceeds the permitted rated value. When the fuse opens, the faulted section of the network is isolated so that the fault does not spread throughout the feeder. The advantages of using FCOs include:

1. Relatively economical cost.
2. Easy installation.
3. Does not require an auxiliary power source.
4. Able to limit the outage area

In this study, the addition of FCOs is analyzed as a method for reducing the fault-affected area on the PE4 Feeder.

2.6 Outage Area

The outage area is the extent of the distribution-network area that loses electricity supply due to a fault. The size of the outage area is influenced by:

1. Fault location
2. Network configuration.
3. Number of sectionalizing points.
4. FCO placement.
5. Protection system

The smaller the outage area, the fewer customers are affected and the higher the distribution-system reliability.

2.7 Distribution System Reliability

The outage area is the length of the distribution network that loses electricity supply due to a fault. The larger the outage area, the more customers are affected and the lower the reliability of the distribution network. The following equation is used to calculate the average outage area:

$$L = \frac{\sum L_i}{n} \qquad (1)$$

Where:
L = Average outage area (km)
L_i = Outage area during the i-th fault (km)
n = Number of fault events

2.8 Percentage Reduction in Outage Area

The percentage reduction in outage area is used to determine the effectiveness of Fuse Cut Out (FCO) installation in reducing the fault-affected area.

$$\%L = \frac{L_{before} - L_{after}}{L_{before}} x100\% \qquad (2)$$

Where:
L_{Before} = Average outage area before FCO installation
L_{After} = Average outage area after FCO installation

2.9 Interrupted Customers

Interrupted customers are customers who lose electricity supply due to a fault in the distribution network. The number of interrupted customers is influenced by:

1. Fault location.
2. Network configuration.
3. Protection system.
4. FCO placement

The average number of interrupted customers can be calculated using the equation:

$$P = \frac{\sum P_i}{n} \qquad (3)$$

Where:
P = Average number of interrupted customers
P_i = Number of interrupted customers during the i-th fault
n = Number of faults

2.10 Percentage Reduction in Interrupted Customers

The percentage reduction in interrupted customers is used to determine the effect of FCO installation on the number of customers affected by faults.

$$\%P = \frac{L_{before} - L_{after}}{L_{before}} x100\% \quad (4)$$

Where:
P_{Before} = Average interrupted customers before FCO installation
P_{After} = Average interrupted customers after FCO installation

2.11 Fault Duration

Fault duration is the length of time customers experience an outage from the occurrence of a fault until the system returns to normal. Fault duration is an important parameter in evaluating distribution-network reliability. The average fault duration is calculated using the following equation:

$$T = \frac{\sum T_i}{n} \quad (5)$$

Where:
T = Average fault duration (hours)
T_i = Duration of the i-th fault (hours)
n = Number of faults

2.12 Percentage Reduction in Fault Duration

The percentage reduction in fault duration is used to determine the improvement in system-recovery speed after FCO installation.

$$\%T = \frac{L_{before} - L_{after}}{L_{before}} x100\% \quad (6)$$

Where:
T_{Before} = Average fault duration before FCO installation
T_{After} = Average fault duration after FCO installation

2.13 Relationship Between Adding FCOs and Distribution-System Reliability

Adding Fuse Cut Outs (FCOs) to a distribution network functions as sectionalizing points that limit the spread of faults within a network segment. The better the network segmentation using FCOs, the smaller the outage area when a fault occurs. Reducing the outage area decreases the number of affected customers and accelerates the system-restoration process. Therefore, FCO installation can improve distribution-network reliability and the quality of electricity service to customers.

Research Methodology

3.1 Researc Location and Period

This research was conducted on the PE4 Feeder of PT PLN (Persero) ULP Sidimpuan Kota, a 20 kV medium-voltage distribution network with a radial configuration. The research object focused on analyzing the effect of adding Fuse Cut Outs (FCOs) on reducing the distribution-network outage area. Data were collected from network operation data, fault data, customer data, and Fuse Cut Out (FCO) installation data for the 2025–2026 period
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3.2 Research Object

The object analyzed in this study was the PE4 Feeder, with a total network length of 109 km, serving 8,285 customers through 135 distribution substations. Based on field data, the network section that is the focus of analysis is 74 km long and received additional Fuse Cut Outs (FCOs) at several strategic points.

3.3 Research Method

The method used in this study was a descriptive quantitative method with a comparative approach (before–after analysis). This method compares distribution-network conditions before and after the addition of Fuse Cut Outs (FCOs) based on:

1. Outage area
2. Number of affected customers.
3. Fault duration.

The comparison results were used to determine the effectiveness of FCO installation in reducing the impact of faults on the PE4 Feeder.

3.4 Data Collection Technique

The data used in this study were obtained from PT PLN (Persero) ULP Sidimpuan Kota. The collected data include:

1. General feeder data

General feeder data were used to identify the characteristics of the network under study, including:

   a) Feeder name
   b) Operating voltage.
   c) Network length.
   d) Number of distribution substations.
   e) Number of customers

2. Single-Line Diagram data

Single-Line Diagram data were used to identify the distribution-network configuration and the locations where Fuse Cut Outs (FCOs) were installed.

3. Fault data

Fault data were used to identify:

   a) Fault location
   b) Fault duration
   c) Number of interrupted customers

4. FCO installation data

These data were used to identify FCO locations before and after the addition.

5. Outage-area data

Outage-area data were used to determine the length of the network that loses electricity supply when a fault occurs.

3.5 Research Stages

The research stages were carried out systematically from data collection to drawing conclusions:

1. Literature review

At this stage, references related to the following were collected:

   a) Electric power distribution systems
   b) Distribution-network protection systems
   c) Fuse Cut Outs (FCOs)
   d) Distribution-network faults
   e) Distribution-system reliability

References were obtained from books, scientific journals, SPLN standards, IEEE standards, and other scientific sources.

2. Field data collection

At this stage, data were collected from PT PLN (Persero) ULP Sidimpuan Kota in the form of:

a) PE4 feeder data
b) Customer data.
c) Fault data.
d) FCO installation-location data.
e) Outage-area data

3. Data grouping

The obtained data were then grouped into:

a) Data before the addition of FCOs
b) Data after the addition of FCOs

4. Data processing

The grouped data were then processed to obtain:

a) Average outage area
b) Average interrupted customers.
c) Average fault duration

5. Data analysis

The analysis was performed by comparing calculation results before and after FCO installation using the equations described in Chapter II.

6. Drawing conclusions

The final stage consisted of concluding the analysis results and providing recommendations regarding the effectiveness of FCO installation in improving distribution-network reliability.

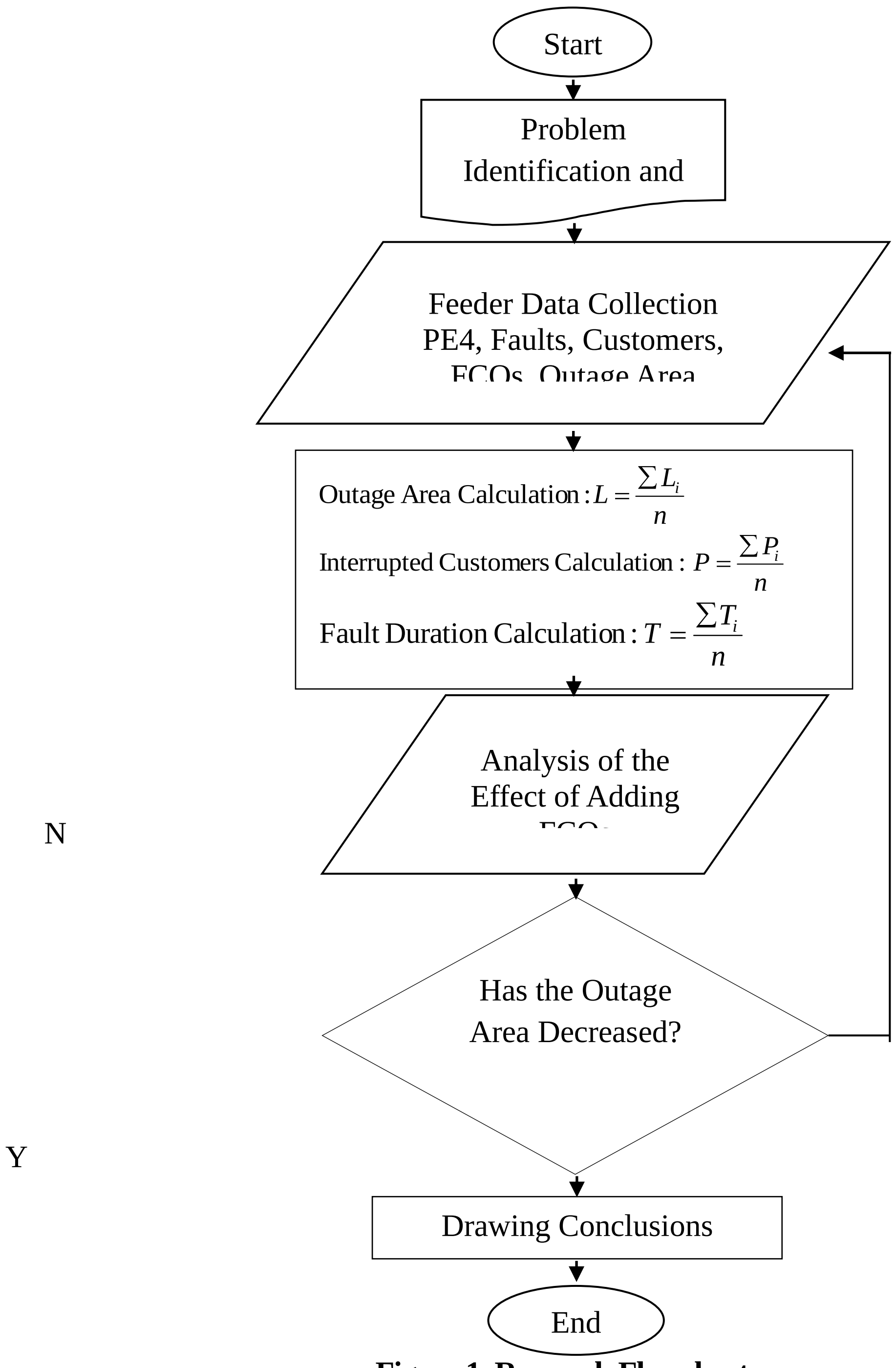

Figure 1. Research Flowchart

Results

The PE4 Feeder is one of the 20 kV distribution feeders in the service area of PT PLN (Persero) ULP Sidimpuan Kota. This feeder has a total network length of 109 km, 135 distribution substations, and serves 8,285 customers. The network uses a radial system; therefore, a fault at one point can potentially cause an outage over a relatively wide area when it is not supported by an adequate protection system.

Table 4.1. General Data of the PE4 Feeder

Parameter	Value
Feeder Name	PE4
Operating Voltage	20 kV
Network Length	109 km
Number of Distribution Substations	135 Units
Number of Customers	8,285 Customers
Network System	Radial
Location	ULP Sidimpuan Kota

4.1 Protection-System Conditions Before and After Adding FCOs

Before additional FCOs were installed, the PE4 Feeder had only two protection points: the Hanopan FCO and the Napa FCO. This condition caused the fault-affected area to remain relatively large because the network had not yet been optimally segmented. After the network was evaluated, three new FCO units were added at Simarpinggan, Garonggang, and Siroccitan. These additions were intended to limit the spread of faults so that the outage area could be reduced.

Table 4.2. Comparison of the Number of FCOs

Condition	Number of FCOs
Before Addition	2 Units
After Addition	5 Units

Three FCO units were added, representing an increase of

4.2 Fault Analysis Before Adding FCOs

Fault data from 2025 show that each fault caused outages for 4,570 customers. Fault duration ranged from 1.8 to 3.3 hours. This condition indicates that the fault-affected area was still relatively extensive.

Table 4.3. Faults Before Adding FCOs

Fault Location	Duration (Hours)	Interrupted Customers
LBS Napa	2.3	4,570
Simarpinggan	1.8	4,570
Garonggang	2.7	4,570
Siroccitan	3.3	4,570

4.3 Calculation of Average Fault Duration Before FCO Installation

$$T_{before} = \frac{2{,}3 + 1{,}8 + 2{,}7 + 3{,}3}{4}$$

$$T_{before} = 2{,}53\,\text{hours}$$

4.4 Calculation of Average Interrupted Customers Before FCO Installation

$$P_{before} = \frac{4570 + 4570 + 4570 + 4570}{4}$$

$$P_{before} = 4570 \text{ customers}$$

4.5 Fault Analysis After Adding FCOs

After FCOs were added in 2026, the number of customers experiencing outages decreased. In addition, fault duration became shorter than under the previous condition.

Table 4.4. Faults After Adding FCOs

Fault Location	Duration (Hours)	Interrupted Customers
LBS Napa	0.9	4,570
Simarpinggan	0.6	3,350
Garonggang	1.2	2,100
Siroccitan	1.9	1,100

4.6 Calculation of Average Fault Duration After FCO Installation

$$T_{after} = \frac{0{,}9 + 0{,}6 + 1{,}2 + 1{,}9}{4}$$

$$T_{after} = 1{,}15 \, Hours$$

4.7 Calculation of Average Interrupted Customers After FCO Installation

$$P_{after} = \frac{4570 + 3350 + 2100 + 1100}{4}$$

$$P_{after} = 2780 \, Customers$$

4.8 Outage-Area Analysis

The outage area is the main parameter used to determine the effect of FCO installation on the distribution network. In this study, the analyzed area has a length of 74 km.

4.9 Conditions Before Adding FCOs

Table 4.5. Outage Area Before Adding FCOs

Fault	Outage Area (km)
LBS Napa	74
Simarpinggan	74
Garonggang	74
Siroccitan	74

Average outage area

$$L_{before} = \frac{74 + 74 + 74 + 74}{4}$$

$$L_{before} = 74 \, kms$$

4.10 Conditions After Adding FCOs

Table 4.6. Outage Area After Adding FCOs

Fault	Outage Area (km)
LBS Napa	74
Simarpinggan	60
Garonggang	36
Siroccitan	24

Average outage area:

$$L_{after} = \frac{74+60+36+24}{4}$$

$$L_{afterh} = 48{,}5\,kms$$

4.11 Analysis of Outage-Area Reduction

The percentage reduction in outage area was calculated using Equation (2):

$$\%L = \frac{74-48{,}5}{74}x100\%$$

$$\%L = 34{,}46\%$$

The calculation results show that FCO installation reduced the average outage area by 34.46%.

4.12 Analysis of Reduction in Interrupted Customers

The percentage reduction in interrupted customers can be calculated using Equation (4):

$$\%P = \frac{4570-2780}{4570}x100\%$$

$$\%P = 39{,}17\%$$

These results show that adding FCOs reduced the number of customers experiencing outages by 39.17%.

4.13 Analysis of Fault-Duration Reduction

The percentage reduction in fault duration can be calculated using Equation (6):

$$\%T = \frac{2{,}53-1{,}15}{2{,}53}x100\%$$

$$\%T = 54{,}55\%$$

The average fault duration decreased by 54.55% after FCOs were installed at several network points.

Discussion

Based on the analysis results, adding Fuse Cut Outs (FCOs) to the PE4 Feeder had a significant effect on reducing the impact of faults in the distribution network. Adding FCOs at Simarpinggan, Garonggang, and Siroccitan divided the network into several segments so that faults could be isolated more quickly and did not spread throughout the feeder. The calculation results show that the average outage area decreased from 74 km to 48.5 km, or by 34.46%. In addition, the average number of interrupted customers decreased from 4,570 to 2,780 customers, or by 39.17%. The largest reduction occurred at Siroccitan, where only 1,100 customers were affected compared with 4,570 customers under the previous condition. In terms of service continuity, the average fault duration decreased from 2.53 hours to 1.15 hours, or by 54.55%. This shows that FCO installation can not only limit the outage area but also accelerate the distribution-system restoration process. Overall, adding Fuse Cut Outs (FCOs) to the PE4 Feeder proved effective in improving distribution-network reliability by reducing the outage area, decreasing the number of affected customers, and shortening fault duration. These findings show that the strategy of adding FCOs can serve as a technical solution for improving electricity-service quality in 20 kV distribution networks.

Conclusion

Based on the analysis of the effect of adding Fuse Cut Outs (FCOs) on reducing the distribution-network outage area on the PE4 Feeder of PT PLN (Persero) ULP Sidimpuan Kota, the following conclusions can be drawn:

1. Adding Fuse Cut Outs (FCOs) at Simarpinggan, Garonggang, and Siroccitan improved the fault-isolation capability of the PE4 Feeder, dividing the distribution network into several segments that more effectively limit the spread of faults.
2. The average outage area decreased from 74 km before FCO installation to 48.5 km after FCO installation, resulting in a 34.46% reduction in outage area.
3. The average number of customers affected by faults decreased from 4,570 to 2,780, resulting in a 39.17% reduction in interrupted customers after FCOs were added.
4. The average fault duration decreased from 2.53 hours to 1.15 hours, or by 54.55%, showing that adding FCOs effectively improves distribution-network reliability and continuity of electricity service on the PE4 Feeder of PT PLN (Persero) ULP Sidimpuan Kota.

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