Optimization of the Reliability Index of the 20 kV Distribution Network Through the Implementation of Routine Maintenance Without Outages Using Direct-Contact Substation PDKB at PT PLN (Persero) UP3 Pematang Siantar

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Abstract

The reliability of the electric power distribution system is one of the key indicators in assessing the quality of service provided by PT PLN (Persero) to its customers. Conventional network maintenance generally requires power outages, which can increase the frequency and duration of outages, leading to a decline in the distribution system's reliability index. One effort to address this issue is through the implementation of Live-Line Maintenance (LLM) for Medium Voltage using the Direct Contact method. This study aims to analyze the contribution of implementing Direct Contact Medium Voltage LLM toward optimizing the reliability index of the 20 kV distribution network at PT PLN (Persero) UP3 Pematang Siantar. The research method used is a descriptive quantitative method utilizing actual OWM work data from 2024–2025, which includes the number of jobs, electricity saved, rupiah value saved, and contributions to the SAIDI and SAIFI indices. The results show that the number of PDKB projects increased from 421 in 2024 to 456 in 2025, representing an 8.31% increase. The amount of electricity saved increased from 1,881,711.57 kWh to 2,589,536.99 kWh, representing a 37.62% increase, while the rupiah value saved rose from Rp2,021,733,540 to Rp2,864,812,831, representing a 41.70% increase. The contribution of PDKB to system reliability has also increased, as indicated by the SAIDI value rising from 514.870 minutes/customer to 602.335 minutes/customer and the SAIFI value rising from 5.112 times/customer to 6.928 times/customer. The research results show that the implementation of the Direct Touch TM PDKB is effective in reducing the potential for customer outages, improving the continuity of electricity service, and supporting the optimization of the 20 kV distribution network reliability index at PT PLN (Persero) UP3 Pematang Siantar

***Keywords**:* PDKB, Grid Reliability, SAIDI, SAIFI, 20 kV Distribution, Outage-Free Maintenance

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Introduction

The reliability of the distribution system is one of the key indicators of PT PLN (Persero)'s service quality, as it directly affects the continuity of electricity supply to customers. As the demand for electricity increases in the residential, commercial, industrial, and public facility sectors, the requirements for distribution network reliability are becoming increasingly stringent. [9], [11]

In a 20 kV medium-voltage distribution network, various routine maintenance activities must be performed to ensure the equipment remains reliable and to prevent outages. Such maintenance includes replacing insulators, repairing conductors, installing network equipment, addressing hot spots, trimming vegetation, and other technical work aimed at maintaining the performance of the distribution system. However, conventional maintenance generally requires a temporary outage on the feeder or the portion of the network under maintenance [11], [15].

Power outages caused by these maintenance activities have contributed to an increase in the frequency and duration of disruptions experienced by customers. This situation affects the reliability indices of the distribution system, particularly the System Average Interruption Frequency Index (SAIFI) and the System Average Interruption Duration Index (SAIDI). The more frequently and the longer customers experience outages, the higher the SAIFI and SAIDI values will be, resulting in a decline in service reliability [9], [13].

PT PLN (Persero) continues to strive to improve service quality through various strategies to enhance grid reliability. One of the methods developed is the Direct Contact Method for Live-Line Work (PDKB) on Medium-Voltage Lines. This method allows maintenance work to be performed without shutting down the grid, thereby ensuring the continuity of electricity supply to customers. With the implementation of the Direct Contact MV Live-Line Work method, maintenance work can be carried out more effectively without increasing the number or duration of outages that could potentially affect the system reliability index [6], [10].

UP3 Pematang Siantar is one of the customer service units that operates a 20 kV distribution network serving a fairly extensive customer base. The high demand for network maintenance requires work methods capable of maintaining the quality of the electricity supply while improving system reliability. Therefore, it is necessary to evaluate the extent to which the implementation of routine maintenance without outages using the Direct-Touch PDKB can contribute to improving the distribution network reliability index [9], [13]

Based on the above discussion, this study was conducted to analyze the impact of implementing the Direct Contact TM PDKB on improving the reliability of the distribution system, as measured by the SAIDI and SAIFI indices, so that the findings can serve as a basis for evaluation and recommendations regarding the management of distribution network maintenance at PT PLN (Persero)

Literature Review

Electric Power Distribution System

The electric power distribution system is part of the electric power system that functions to transmit electrical energy from substations to customers. The distribution system is divided into two main parts: the primary distribution network and the secondary distribution network. PLN's primary distribution network generally operates at a medium voltage of 20 kV and functions to transmit power from substations (GI) to distribution substations (GD). The electrical energy is then delivered to customers through a low-voltage

network of 380/220 volts. The reliability of the distribution system is one of the key indicators of the success of electric power service because it is directly related to the continuity of supply to customers [11], [12].

2.2 Reliability of the Distribution System

Distribution system reliability is the ability of an electric power system to continuously deliver electrical energy to customers in accordance with established quality standards. According to IEEE Std 1366, distribution system reliability can be evaluated using several reliability indices, including:

1. SAIFI
2. SAIDI
3. CAIDI
4. ASAI
5. ASUI

These indices are used to measure the frequency and duration of service disruptions experienced by customers during a specific period [9], [13].

2.3 Disruptions in the Distribution Network

A fault is an abnormal condition that disrupts the continuity of electrical power transmission. Causes of faults in distribution networks include:

1. Internal Factors
   a) Damaged insulator
   b) Broken conductor
   c) Loose connection
   d) Worn-out equipment
2. External Factors
   a) Trees coming into contact with power lines
   b) Lightning strikes
   c) Animals
   d) Extreme weather
   e) Human activity

Disruptions can cause outages that result in a decrease in the reliability of the distribution system [12], [13].

2.4 Distribution Network Maintenance

Maintenance is an activity carried out to keep equipment in good working order so that it continues to operate optimally. According to SPLN, distribution network maintenance is categorized into:

1. Corrective Maintenance
   Maintenance performed after damage has occurred
2. Preventive Maintenance
   Maintenance performed on a regular basis to prevent malfunctions
3. Predictive Maintenance
   Maintenance based on equipment condition monitoring results

The objectives of maintenance include reducing the number of malfunctions, extending the service life of equipment, ensuring service continuity, and improving system reliability [10], [15].

2.5 Work Under Voltage

PDKB is a method of performing electrical installation work without shutting down the power grid. PDKB was developed to:

1. Reduce customer outages

2. Maintain service continuity
3. Lower the ENS
4. Improve the reliability index

At PLN, there are several PDKB methods, namely:

1. Bare Hand
   The technician is working at the same potential as the conductor
2. Hot Stick
   Using special insulation equipment
3. Live Line Maintenance
   Technicians perform their work on-site while wearing protective gear and following specific safety procedures

The Direct Contact Method is widely used in 20 kV distribution networks because it is effective for various types of routine maintenance work [6], [10].

2.6 PDKB TM Direct Contact

PDKB TM Sentuh Langsung is a method for performing work on 20 kV medium-voltage networks without power outages [6], [10]. The types of work that can be performed include:

1. Insulator replacement
2. FCO replacement
3. Jumper repair
4. Lightning arrester replacement
5. Tightening connections
6. Cleaning the network

The advantages of this method include:

1. Reduce outage duration
2. Maintain service continuity
3. Reduce ENS
4. Improve customer satisfaction
5. Improve the reliability index

2.7 Distribution System Reliability Index

2.7.1 SAIFI (*System Average Interruption Frequency Index*)

SAIFI indicates the average frequency of outages experienced by customers in a year [13]

$$SAIFI = \frac{\sum N_i}{N_t} \quad \text{.....} \quad (1)$$

Where:

SAIFI = Outage frequency index (times per customer per year)
Ni = number of customers affected by an outage
Nt = total number of customers

The lower the SAIFI value, the better the system reliability

2.7.2 SAIDI (*System Average Interruption Duration Index*)

SAIDI indicates the average duration of power outages experienced by customers [13]

$$SAIDI = \frac{\sum U_i N_i}{N_t} \quad \text{.....} \quad (2)$$

Where:

SAIDI = outage duration index (hours/customer/year)

Ui = outage duration (hours)
Ni = number of affected customers
Nt = total number of customers
The lower the SAIDI value, the better the system's reliability.

2.7.3 CAIDI (*Customer Average Interruption Duration Index*)

CAIDI indicates the average duration of outages for each fault [13]

$$CAIDI = \frac{SAIDI}{SAIFI} \quad (3)$$

Where:
CAIDI = average outage duration
SAIDI = outage duration index
SAIFI = outage frequency index

2.7.4 ASAI (*Average Service Availability Index*)

ASAI indicates the availability level of the distribution system [13]

$$ASAI = \frac{8760N_t - \sum U_i N_i}{8760N_t} \quad (4)$$

Where:
8760 = number of hours in a year
Nt = number of customers
The closer the value is to 1, the more reliable the system is.

2.7.5 ASUI (*Average Service Unavailability Index*)

ASUI indicates the level of service unavailability [13]

$$ASUI = 1 - ASAI \quad (5)$$

A low ASUI value indicates a more reliable system

2.7.6 Energy Not Supplied (ENS)

ENS refers to electrical energy that cannot be transmitted due to a disruption or power outage [10], [13].

$$ENS = P\,x\,t \quad (6)$$

Where:
ENS = Energy Not Supplied (kWh)
P = load power (kW)
t = duration of outage (hours)
The ENS value is used to determine the benefits of implementing PDKB in saving energy that would otherwise be lost due to power outages

2.8 The Relationship Between PDKB and Distribution System Reliability

Conventional maintenance requires partial power outages, which increases the SAIDI and SAIFI values. With the implementation of the Direct-Touch MV PDKB, maintenance work can be performed without power outages, so that:

a. The number of customers affected by outages has decreased.
b. The duration of outages can be avoided.
c. ENS can be reduced.
d. The SAIDI value has decreased.
e. The SAIFI value has decreased.
f. System reliability has improved

Therefore, the implementation of the TM Direct Contact PDKB is one of the effective strategies for optimizing the reliability index of the 20 kV distribution network

Research Methodology

3.1 Type of Research

This study employs a descriptive quantitative method, specifically designed to analyze the contribution of implementing Medium-Voltage Live-Line Maintenance (PDKB) using the Direct Contact method toward improving the reliability of the 20 kV distribution network at PT PLN (Persero) UP3 Pematang Siantar. Quantitative methods were used to calculate and evaluate the reliability index values achieved through the implementation of OVM work, including the System Average Interruption Duration Index (SAIDI), the System Average Interruption Frequency Index (SAIFI), the number of customers spared outages, the amount of electrical energy saved, and the economic value gained by avoiding power outages during maintenance work [13]

3.2 Research Location and Time

The study was conducted on the 20 kV medium-voltage distribution network in the operational area of PT PLN (Persero) UP3 Pematang Siantar, which is the operational area of the Direct Contact Medium-Voltage PDKB Team. The study covered all routine maintenance work performed without power outages on 20 kV distribution feeders during the study period:

1. 20 kV Feeder
2. Customer data
3. Outage data
4. Power outage data
5. PDKB TM Direct Access to Work Data

The study uses data on PDKB's project implementation from January 2024 through December 2025.

3.2 Research Subject

The subjects analyzed in this study are:

1. Number of Direct-Contact PDKB TM Projects
2. Number of customers spared from power outages.
3. Amount of electricity saved (kWh).
4. Amount saved in rupiah.
5. SAIDI improvement resulting from PDKB implementation.
6. SAIFI improvement resulting from PDKB implementation.
7. Maintenance frequency for each distribution feeder

3.3 Data Collection Techniques

3.3.1 Literature Review

The literature review was conducted by examining various references related to [9], [10]:

1. Electric Power Distribution System
2. Distribution network reliability.
3. Medium-Voltage PDKB.
4. SAIDI and SAIFI.
5. SPLN.
6. IEEE Std 1366.
7. Books and scientific journals related to power system reliability

3.3.2 Documentation

The documentation method involved collecting operational data obtained from PT PLN (Persero) UP3 Pematang Siantar in the form of [10]:

1. PDKB project data for 2024
2. PDKB project data for 2025.
3. Data on customers saved.
4. Data on energy saved.
5. Data on rupiah saved.
6. Data on SAIDI contributions.
7. Data on SAIFI contributions

3.3.3 Observation

The observation was conducted by studying the implementation process of the Direct Contact TM PDKB on the 20 kV distribution network, as well as the mechanism for calculating the reliability index used by PLN

3.4 Research Data

Primary data was obtained through:

1. Interview with PDKB staff.
2. Field observations.
3. Discussion with the network maintenance department

Secondary data was obtained from PDKB's 2024–2025 work implementation reports. The data used includes:

Table 3.1 Data on PDKB Project Implementation for 2024–2025

No	Research Data
1	Number of PDKB Projects
2	Feeder Name
3	Project Type
4	Project Duration
5	Number of Customers Benefited
6	Energy Saved (kWh)
7	Rupiah Saved
8	SAIDI Contribution
9	SAIFI Contribution

3.5 Research Variables

3.5.1 Independent Variable (X)

Implementation of Live-Line Maintenance (LLM) on the Direct-Contact Medium-Voltage System, consisting of:

1. Number of PDKB jobs
2. Maintenance frequency
3. Job duration

3.5.2 Dependent Variable (Y)

A reliability index for a distribution system consisting of:

1. SAIDI.
2. SAIFI.
3. Number of customers saved.
4. Electricity saved.
5. Economic value saved

3.6 Research Phases

The research was conducted in the following stages:

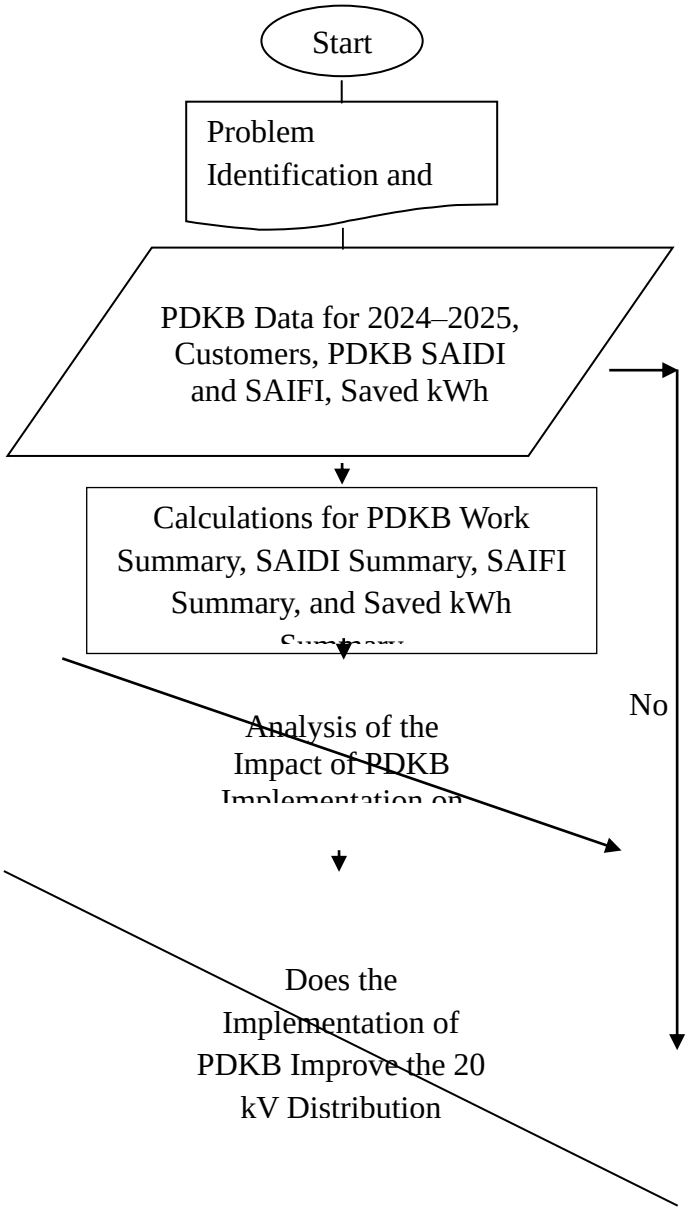
1. Identify distribution network reliability issues.
2. Collect data on PDKB projects for 2024–2025.
3. Verify and categorize the data.
4. Calculate the PDKB's contribution to the SAIDI.
5. Calculate the PDKB's contribution to the SAIFI.
6. Analyze the number of customers and the amount of energy saved.
7. Evaluate the PDKB's contribution to improving system reliability.
8. Draft conclusions and recommendations

3.7 Data Analysis Methods

Data analysis was conducted by comparing the actual results of PDKB's work in 2024 and 2025 based on:

1. Number of PDKB projects.
2. Number of customers served.
3. Electricity saved.
4. Rupiah saved.
5. SAIDI contribution.
6. SAIFI contributio

Next, an analysis of the trend in reliability improvement was conducted based on changes in these values over the study period [13]



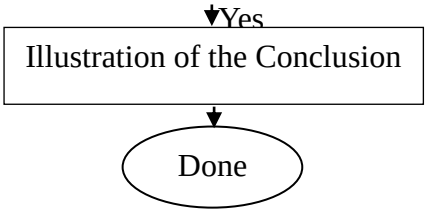


Figure 3.1 Research Flowchart

Results

Results and Analysis

4.1 Overview of the Implementation of the TM Direct Contact PDKB

The implementation of Live-Line Maintenance (PDKB) for medium-voltage lines using the Direct Contact method is one of the initiatives undertaken by PT PLN (Persero) UP3 Pematang Siantar to improve the reliability of the 20 kV distribution network without causing power outages for customers. This method allows network maintenance work to be performed while the system remains energized, thereby ensuring the continuity of electricity supply. The live-line maintenance activities carried out include replacing insulators, replacing fuse cutouts (FCOs), repairing jumpers, installing and maintaining conductors, maintaining network connections, securing the Right of Way (ROW), and other technical work on the 20 kV distribution network. Based on data on the implementation of PDKB work during 2024 and 2025, there are several feeder lines that are prioritized for maintenance because they require work more frequently than other feeder lines

Table 4.1 Frequency of Feeder Maintenance in 2024

Feeder	Total Maintenance
PS.03	51
PS.02	44
PT.07	38
PM.03	35
PM.05	27
PM.02	25
RN.03	19
PM.06	17
PM.01	14
PT.01	12

Table 4.2 Frequency of Feeder Maintenance in 2025

Feeder	Total Maintenance
PS.03	59
PM.03	36
PM.05	33
PM.02	30
PT.04	30

PT.07	24
PT.03	23
SM.08	19
RB.01	15
PT.01	15

Based on Table 4.1 and Table 4.2, it can be seen that feeder PS.03 had the highest maintenance frequency for two consecutive years. This indicates that this feeder is one of the main focuses of the PDKB Team's network maintenance program. The high frequency of maintenance is intended to ensure that network equipment remains reliable and capable of supporting the continuity of electricity service to customers

4.2 PDKB Performance Summary for 2024–2025

Based on the work completion data for the PDKB TM Sentuh Langsung project obtained from PT PLN (Persero) UP3 Pematang Siantar, the performance summary is as shown in the following table:

Table 4.3 Summary of PDKB Performance for 2024–2025

Parameters	2024	2025
Number of PDKB Jobs	421	456
Total Job Weight	1.106	1.151
Customers Affected by Outage × Duration of Outage	3.559.965	4.231.204
Number of UP3 Customers	702.945	728.156
kWh Saved	1.881.711,57	2.589.536,99
Rupiah Saved	Rp2.021.733.540	Rp2.864.812.831
SAIDI Contribution (minutes/customer)	514,870	602,335
SAIFI Contribution (times/customer)	5,112	6,928

Table 4.3 shows that all PDKB performance indicators improved in 2025 compared to 2024. This improvement indicates that the implementation of PDKB is increasingly contributing positively to enhancing the reliability of the 20 kV distribution network

4.3 Analysis of PDKB Work Volume

The number of PDKB projects carried out during the study period is shown in the following table:

Table 4.4 Number of PDKB Projects

Year	Number of Jobs
2024	421
2025	456

The percentage increase in the number of jobs is calculated using the equation:

$$\frac{456}{421} x100\% = 8{,}31\%$$

The results show that the number of PDKB jobs increased by 8.31% in 2025 compared to 2024. This increase indicates that the use of outage-free maintenance methods is becoming increasingly effective in maintaining the condition of the distribution network

4.4 Analysis of Saved Electrical Energy

Saved electrical energy is energy that can still be supplied to customers because maintenance work is performed using the PDKB method without power outages.

Table 4.5 Number of PDKB Projects

Year	Energy Saved (kWh)

2024	1.881.711,57
2025	2.589.536,99

The difference in energy saved is 2,589,536.99 − 1,881,711.57 = 707,825.42 kWh. Percentage increase in energy saved

$$\frac{707.825,42}{1.881.711,57} x100\% = 37,62\%$$

The 37.62% increase in energy saved indicates that more electrical energy can continue to be supplied to customers because maintenance work is carried out without power outages

4.5 Analysis of the Saved Value of the Rupiah

The fact that the value of the rupiah was preserved demonstrates the economic benefits the company gained because it was able to continue supplying electricity to its customers

Table 4.6 Value of Rupiah Saved

Yeaar	The Rupiah Is Saved
2024	Rp2.021.733.540
2025	Rp2.864.812.831

The increase in the value of the rupiah is calculated as follows: Rp2,864,812,831 − Rp2,021,733,540 = Rp843,079,291. Percentage increase:

$$\frac{843.079.291}{2.021.733.540} x100\% = 41,70\%$$

The results show that the implementation of PDKB provides significant economic benefits to companies

4.6 Analysis of the Contribution of Pdkb to Saidi

SAIDI indicates the average duration of power outages experienced by customers. In this study, the SAIDI value reduced as a result of the implementation of PDKB was used

Table 4.7 SAIDI Contribution to PDKB

Year	SAIDI (Minutes/Customer)
2024	514,870
2025	602,335

Increase in SAIDI contribution: 602,335 − 514,870 = 87,465. Percentage increase:

$$\frac{87,465}{514,870} x100\% = 16,99\%$$

The increase in SAIDI's contribution indicates that the implementation of PDKB has reduced the potential duration of customer outages that would have occurred if the work had been carried out using conventional outage methods.

4.7 Analysis of PDKB's Contribution to SAIFI

SAIFI indicates the average frequency of power outages experienced by customers

Table 4.8 SAIFI Contributions to PDKB

Year	SAIFI (River/Customer)
2024	5,112
2025	6,928

Increase in SAIFI contribution: 6,928−5,112 = 1,816. Percentage increase:

$$\frac{1{,}816}{5{,}112} x100\% = 35{,}52\%$$

The results show that the frequency of power outages successfully avoided through the implementation of PDKB increased significantly in 2025.

Discussion

Based on the research findings, the implementation of Medium-Voltage Live-Line Maintenance (PDKB) using the Direct Contact method has made a positive contribution to improving the reliability of the 20 kV distribution network at PT PLN (Persero) UP3 Pematang Siantar. This is evidenced by the increase in the number of OVM jobs from 421 in 2024 to 456 in 2025, representing an 8.31% increase. This increase in the number of jobs is directly proportional to the increase in electricity saved, which amounted to 707,825.42 kWh—a 37.62% increase. In addition, the economic value saved also increased by Rp843,079,291, or 41.70%, compared to the previous year. In terms of system reliability, the SAIDI increased from 514.870 minutes/customer to 602.335 minutes/customer—a rise of 16.99%—while the SAIFI rose from 5.112 times/customer to 6.928 times/customer—an increase of 35.52%. These results show that performing maintenance without power outages can reduce the potential duration and frequency of outages that customers would experience if the work were carried out using conventional methods. Overall, the implementation of the Direct Contact MV PDKB has proven effective in optimizing the reliability index of the 20 kV distribution network by improving service continuity, reducing the potential for customer outages, increasing the amount of electricity delivered, and enhancing economic benefits for the company.

Conclusion

Based on the results of a study on the implementation of Live-Line Maintenance (LLM) for medium-voltage systems using the direct-contact method on the 20 kV distribution network of PT PLN (Persero) UP3 Pematang Siantar, the following conclusions can be drawn:

1. The implementation of the TM Direct Contact PDKB increased from 421 projects in 2024 to 456 projects in 2025, representing an 8.31% increase, which indicates increasingly optimal execution of outage-free network maintenance
2. The implementation of the PDKB successfully increased the amount of electricity that can be consistently supplied to customers from 1,881,711.57 kWh in 2024 to 2,589,536.99 kWh in 2025, representing a 37.62% increase
3. The implementation of PDKB provides economic benefits to the company, with the value of rupiah saved increasing from Rp2,021,733,540 in 2024 to Rp2,864,812,831 in 2025, or an increase of 41.70%
4. The PDKB TM Direct Touch program has been proven to contribute to the optimization of the 20 kV distribution network's reliability by increasing the SAIDI from 514.870 to 602.335 minutes per customer and the SAIFI from 5.112 to 6.928 times per customer, thereby reducing the potential duration and frequency of customer outages during network maintenance activities

References

[1] D. Erivianto, A. Dani, and H. Gunawan, “Electric Energy Conversion Systems as an Alternative Energy Source for Household Needs,” Scenario (Seminar on Social Sciences, Engineering, and the Humanities), pp. 323–334, 2020
[2] S. Aryza, S. Efendi, H. Mardiansyah, et al., “Enhancing Mobile Computing to Improve Data Acquisition Quality in Simulation,” 2021
[3] R. F. Sinurat, S. Aryza, and A. S. P. Tarigan, “Study on the Improvement of Electrostatic Precipitator (ESP) Interference Protection Systems at Pangkalan Susu Coal-Fired Power Plant Units 1 and 2,” 2022
[4] E. W. Hafiz, A. S. P. Tarigan, and S. Aryza, “Improved Microcontroller-Based Protection for a 3-Phase Induction Motor Against Various Interruptions,” 2022
[5] Z. Lubis, S. Aryza, and H. Alam, “Analysis of a Hybrid Hydroelectric and Solar Power Plant as an Alternative Source of Electricity to Replace PLN,” 2024
[6] S. Aryza, Z. Lubis, and K. Putra, “Outreach on the IoT-Based Overvoltage Protection System at the Kelambir Lima Village Office,” Journal of Community Service (JURIBMAS), vol. 3, no. 1, pp. 38–46, 2024
[7] Y. W. D. Lumbantoruan, P. Siagian, and H. Gunawan, “Analysis of Electrical Energy Consumption of the P21C Cooling Tower Circulation Pump Using an Inverter at PT Unilever Oleochemical Indonesia,” Serambi Engineering Journal, vol. X, no. 2, 2025
[8] A. K. M. D. Panggabean, H. Gunawan, and M. E. Dalimunthe, “PID Controller System Analysis on an Automatic Voltage Regulator (AVR) for Regulating the Excitation Voltage of a 3-Phase Synchronous Generator,” 2025
[9] R. Billinton dan R. N. Allan, Evaluasi Keandalan Sistem Tenaga Listrik, edisi ke-2. New York: Plenum Press, 1996. ISBN: 9780306440637
[10] R. Billinton dan W. Li, Penilaian Keandalan Sistem Tenaga Listrik Menggunakan Metode Monte Carlo. New York: Springer, 1994. ISBN: 9780306447490
[11] T. Gönen, Teknik Distribusi Tenaga Listrik, edisi ke-3. Boca Raton: CRC Press, 2014. ISBN: 9781482208332
[12] J. J. Grainger dan W. D. Stevenson, Analisis Sistem Tenaga Listrik. New York: McGraw-Hill, 1994. ISBN: 9780070612933
[13] IEEE Power and Energy Society, IEEE Std 1366-2023: Panduan IEEE untuk Indeks Keandalan Distribusi Tenaga Listrik. New York: IEEE, 2023
[14] IEEE Power and Energy Society, IEEE Std 493-2007: Praktik yang Direkomendasikan untuk Desain Sistem Tenaga Listrik Industri dan Komersial yang Andal. New York: IEEE, 200
[15] PT PLN (Persero), SPLN 68-2: Electricity Service Quality Standards. Jakarta: PT PLN (Persero), 1986
[16] PT PLN (Persero), Handbook on Electricity Distribution Network Maintenance. Jakarta: PT PLN (Persero), 2010.
[17] PT PLN (Persero), Construction Standards for 20 kV Medium-Voltage Networks (JTM). Jakarta: PT PLN (Persero), 2017
[18] Ministry of Energy and Mineral Resources, Minister of Energy and Mineral Resources Regulation No. 18 of 2019 on Electricity Service Quality Levels. Jakarta: Ministry of Energy and Mineral Resources, 2019
[19] National Standardization Agency, PUIL 2020 (General Requirements for Electrical Installations 2020). Jakarta: BSN, 2020. ISBN: 9786232660408
[20] A. Pahwa, *Electrical Power Systems Quality*, 3rd ed. New York: McGraw-Hill Education, 2019. ISBN: 9781260458225

[21] Institute of Electrical and Electronics Engineers, IEEE Std 1366-2023: IEEE Guide for Electric Power Distribution Reliability Indices, New York, 2023.
[22] PT PLN (Persero), SPLN 68-2: Electric Power Service Quality Standards, Jakarta, 1986.
[23] PT PLN (Persero), Guidelines for the Maintenance of Electric Power Distribution Networks, Jakarta, 2010.
[24] National Standardization Agency, PUIL 2020 (General Requirements for Electrical Installations 2020), Jakarta, 2020.
[25] Roy Billinton and Ronald N. Allan, Reliability Evaluation of Power Systems, 2nd ed., Plenum Press, 1996.
[26] Turan Gönen, Electric Power Distribution Engineering, 3rd ed., CRC Press, 2014