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Case Study Analysis Using FMEA Method in Evaluating the Reliability Performance Index of the 20 kV North Feeder Distribution Network System at PT. PLN ULP Painan-UP3 Padang

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***Abstract*— The reliability of the electric power distribution system is a key factor in ensuring adequate, high-quality, and reliable supply for customers. Quality, continuity, and availability of electrical power services are often major issues in distribution systems, especially in the 20 kV distribution network at PT. PLN (Persero) ULP Painan. This study aims to evaluate the reliability of the distribution system in the North Feeder of PT. PLN (Persero) ULP Painan using the Failure Modes and Effects Analysis (FMEA) method, which includes analysis of failure rates, repair time, and recovery time (switching time) for each component in the distribution network. The data used was obtained from UP3 Padang, which recorded a line length of 35.71 km, 46 load points, and 2,729 customers on the North Feeder, with a total of 65,434 customers at ULP Painan. The FMEA calculations resulted in a SAIFI value of 7.17 (events/customer/year), SAIDI of 21.68 (hours/customer/year), CAIDI of 0.3 (hours/frequency/customer), and average ASAI value of 0.999946208 and ASUI of 0.021792699. Based on these results, it can be concluded that the distribution system on the North Feeder of PT. PLN ULP Painan shows unreliable performance and still requires significant improvements, as these values do not meet the reliability standards set by PT. PLN. This study emphasizes the importance of systematically identifying and system failures to improve the quality and continuity of electricity service to customers.**

***Keywords*— Performance Index, Failure Modes Effect and Analysis (FMEA), SAIFI, SAIDI, ASAI, ASUI, & CAIDI.**

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I. INTRODUCTION

Electricity distribution is the process of transmitting electrical energy from power plants to consumers, which is vulnerable to disruptions such as equipment failure and extreme weather conditions. One of the main issues at PT. PLN (Persero) ULP Painan is the frequent disturbances on the North Feeder Line, which serves 2,729 customers. This leads to an unstable power supply and losses for customers, especially with the increasing electricity demand in the city of Painan and Pesisir Selatan Regency. To improve the reliability of electricity distribution, it is important to evaluate the performance of the distribution system, particularly through reliability indices measured by the Failure Modes and Effects Analysis (FMEA) method.

This study aims to assess the reliability of the 20 kV North Feeder distribution system using the FMEA method and compare it with the performance standards set by PT. PLN. The analysis aims to identify performance indices such as SAIDI, SAIFI, CAIDI, and ASAI, which will be compared with the standards established by the state electricity company. The results of this research are expected to provide insights into the effectiveness and quality of the existing electricity distribution services, as well as offer recommendations for improvements and increased system reliability. The research methodology involves surveys and simulations using Excel, where data from PT. PLN ULP Painan will be analyzed to obtain performance index values based on FMEA. This study is expected to serve as a reference for further development in assessing the performance of electricity distribution services and contribute to the enhancement of both the quality and quantity of electricity services in the region

II. METHOD

This study employs a quantitative approach with a case study research design, focusing on the technical analysis of the reliability of the 20 kV distribution system on the North Feeder of PT. PLN (Persero) ULP Painan. The analysis method used is Failure Modes and Effects Analysis (FMEA), which allows for the identification and evaluation of potential failures in the distribution network components and their impact on the overall system performance. The study aims to calculate the reliability indices, including SAIFI (System Average Interruption Frequency Index), SAIDI (System Average Interruption Duration Index), CAIDI (Customer Average Interruption Duration Index), ASAI (Average System Availability Index), and ASUI (Average System Unavailability Index). The calculated reliability indices are then compared with the standards set by PT. PLN (Persero) to assess whether the North Feeder distribution system meets the desired reliability criteria or requires further improvements. Research tools : The hardware used includes a computer/laptop, printer, and calculator, The software used includes Microsoft Office 2013, ETAP 12.6.0, MS Excel, MS Word, and MS PowerPoint.

Research Location : The study is conducted on the 20 kV Painan Feeder distribution line within the ULP Painan area of PT. PLN (Persero), with data collection carried out at the PT. PLN UP3 Padang office located in Ulak Karang, Padang City, West Sumatra. This location is selected as it represents a part of the 20 kV distribution network relevant for analyzing the reliability of the electrical distribution system in West Sumatra, particularly in the ULP Painan area, with the required data :

1. Substation Coordinates: Geographic coordinates of each distribution substation.
2. Conductor Specifications: Data on the type and capacity of conductors used in the distribution network
3. Substation Data and Customer Count: Information on the capacity of distribution substations and the number of customers connected to each substation.
4. Length of Conductor between Distribution Transformers: The distance between distribution transformers, affecting power flow and outage duration.
5. One-Line Diagram: A one-line diagram of the distribution network to illustrate power flow and the interconnection of components.
6. History of Trips (1 Year): Historical data of electrical disturbances over the past year, including the time of occurrence, duration, and location of disturbances.
7. Load Flow Analysis Data (ETAP): Data from ETAP software on load flow analysis, providing insights into load distribution and power flow capacity.
8. Reliability Standards Data from PT. PLN (Persero): Data on the reliability standards set by PT. PLN (Persero) for comparison with the calculated reliability indices.

Data Calculation and Reliability Index Evaluation Method : The method used to calculate the distribution system's reliability indices is FMEA. This method is selected for its ability to provide an in-depth analysis of potential failures in key components of the distribution network and their impacts on system performance.

Data Calculation Steps:

1. **Identification of Failure Modes for Each Component:** The first step in FMEA is identifying potential failure modes for the main components of the distribution network, such as circuit breakers (CB), distribution transformers, medium voltage overhead lines (SUTM), and sectionalizers
2. **Assessment of Failure Impact on Load Points:** After identifying failure modes, the next step is to analyze the impact of each failure on the load points (customer connection points), including outage duration and the number of affected customers
3. **Calculation of Reliability Indices:**
    a. SAIFI (System Average Interruption Frequency Index): Measures the frequency of interruptions experienced by customers.
    b. SAIDI (System Average Interruption Duration Index): Measures the average duration of interruptions experienced by customers.
    c. CAIDI (Customer Average Interruption Duration Index): Measures the average interruption duration per customer per event.
    d. ASAI (Average System Availability Index): Measures the average availability of the system.
    e. **ASUI (Average System Unavailability Index):** Measures the level of system unavailability
4. **Comparison with PT. PLN (Persero) Reliability Standards:** Once the reliability indices are calculated, the results are compared with the reliability standards set by PT. PLN (Persero). This comparison helps assess whether the North Feeder distribution system meets the desired reliability standards or needs improvements. Through FMEA, the study aims to provide a clearer picture of the distribution system's performance and recommend

improvements to enhance system reliability.eliability Index Evaluation: The calculated reliability indices will be evaluated to identify system weaknesses and suggest appropriate corrective actions. FMEA analysis will provide insights into potential failures and their impacts, which will guide the necessary steps to improve service quality and the continuity of power supply. This systematic FMEA approach is expected to offer a clear understanding of the performance of the 20 kV distribution system on the North Feeder of PT. PLN (Persero) ULP Painan, and contribute to reducing disturbances while improving the reliability of the electricity distribution system in the area

III. RESULT AND DISCUSSION

Based on the analysis using the Failure Modes and Effects Analysis (FMEA) method, the reliability index values for the 20 kV Feeder Utara distribution system at PT. PLN (Persero) ULP Painan are as follows: **SAIFI 7.17 times/customer/year**, **SAIDI 21.68 hours/customer/year**, and **CAIDI 0.33 hours/frequency/year**. These results represent the frequency of disturbances, the duration of outages, and the average recovery time per disturbance event in the analyzed distribution system.

When compared to the reliability standards set by PT. PLN (Persero) and referring to **KEPMEN ESDM No. 424.K/TL.04/DJL.3/2022**, which sets the reference values as follows: **SAIFI 7 times/customer/year**, **SAIDI 7 hours/customer/year**, and **CAIDI 0 hours/frequency/year**, the FMEA analysis results show that the performance of the Feeder Utara distribution system does not meet the established standards. The **SAIFI value of 7.17 times/customer/year** slightly exceeds the limit, which allows a maximum of 7 disturbances per customer annually. **SAIDI of 21.68 hours/customer/year** is far above the maximum allowable limit of 7 hours, while **CAIDI of 0.33 hours/frequency/year** is higher than the required value of 0 hours, meaning no recovery time should be allowed for each disturbance. Therefore, it can be concluded that the 20 kV Feeder Utara distribution system is still considered unreliable. This condition is caused by several factors, including the failure of key components such as **circuit breakers**, **transformers**, and **distribution lines**, which increase disturbance frequency and outage duration, negatively impacting customer satisfaction. I**mprovement Efforts**: To enhance the reliability of the distribution system, corrective and preventive actions must be implemented. Replacing components that frequently fail, improving the quality of preventive maintenance, and optimizing repair times are essential. Additionally, strategies such as **installing fuses** and **sectionalizers** to reduce disturbance frequency and duration can also be helpful. D**ifferences with PLN Real Data**: The differences between the FMEA results and real data from PLN are due to several factors. PLN's real data reflects the impact of external factors, such as weather and unforeseen events, and the reliance on corrective maintenance, while FMEA is a predictive approach. Furthermore, system reliability can vary based on load fluctuations and operational recovery actions, influencing the discrepancies between the two methods.

R**ecommendations for Improving Reliability**: Reducing the number of disturbances can be achieved through routine maintenance, inspection of protective equipment, and root cause analysis of recurring disturbances. Network reconfiguration, including the addition of fuses and sectionalizers, can also improve service continuity and reduce outage times. Technologies such as **smart grids** can be used to monitor and detect disturbances in real-time, enabling faster and automatic isolation of disturbances. Therefore, the results of this study provide a clear overview of the weak points in the Feeder Utara distribution system, which can serve as a basis for more informed decision-making in planning and implementing improvements in the distribution system's reliability in the future

IV. CONCLUSION

The reliability indices calculated using the Failure Modes and Effects Analysis (FMEA) method for the 20 kV feeder system at ULP Painan PT PLN (Persero) are as follows: SAIFI 7.16 (interruptions/customer/year), SAIDI 21.6 (hours/customer/year), CAIDI 0.33 (hours/frequency/customer), ASAI 0.999946208, and ASUI 0.021792699. These indices represent the performance of the distribution system, reflecting the frequency and duration of interruptions experienced by customers, as well as the availability and unavailability of service provided by the system.Comparing these results to the standards set by ULP Painan PT PLN (Persero)—SAIFI 7 (interruptions/customer/year), SAIDI 7 (hours/customer/year), and CAIDI 0 (hours/frequency/customer)—it is evident that the 20 kV feeder system does not meet the required performance standards. The calculated reliability indices significantly exceed the established thresholds, indicating that the distribution system is unreliable. The failure frequency on the distribution lines contributes notably to the overall system failure rate compared to the failure of equipment such as circuit breakers and fuses, affecting the SAIFI index. Additionally, the SAIDI index increases due to the duration of line failures. Therefore, the implementation of components such as fuses and sectionalizers is necessary to ensure the system performs reliably. To improve the performance and reliability of the distribution system, several measures are recommended E**nhance Maintenance Quality and Frequency**: Increasing both the quality and frequency of maintenance on critical components—such as poles, transformers, and cables—will reduce the likelihood of failures and minimize service interruptions & E**valuate Operational Patterns**: The distance between generation centers and load centers may lead to load imbalance and significant voltage variations during distribution. This results in higher power losses and voltage fluctuations, which affect service quality. A comprehensive evaluation of the distribution system's operational patterns, including load distribution and network configuration, is crucial. Unbalanced operation can worsen system reliability, increase power losses, and reduce the quality of energy delivered. By addressing these factors, PT PLN (Persero) can enhance the reliability of the 20 kV distribution system, ensuring better service quality and meeting the established reliability standard

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