OPTIMIZATION OF MEDIUM VOLTAGE DISTRIBUTION NETWORK MANEUVER FOR FEEDER RELIABILITY IN FAULT CONDITIONS

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ABSTRACT

Network maneuvers in the medium voltage distribution system are performed during faults or maintenance to maintain continuity of electricity service. This study focuses on analyzing the network conditions during maneuvers in the Tasikmalaya area to identify the optimal feeder backup strategy and minimize voltage drops and power losses. The analysis was conducted using ETAP software with simulations of various load scenarios (40%, 80%, and 100%). The results show that the best voltage in the existing condition is found on the SBBC feeder, with a voltage value of 0.9710 p.u at a 100% load condition. Meanwhile, the smallest power losses occur on the TMSR feeder, amounting to 233.6 kW. In the maneuver scenario, the best results are obtained when the TMSR feeder is backed up by the PDYN feeder through the LBS RIMA switch, with a voltage of 0.9612 p.u on the TMSR feeder and 0.9533 p.u on the PDYN feeder, and total power losses of 606.6 kW. This study highlights the importance of in-depth analysis in selecting maneuver strategies to ensure network stability and minimize service disruptions. The decision to choose a backup feeder should not only consider the feeder's ability to support additional loads but also its impact on power losses and voltage quality across the network. Therefore, this research makes a significant contribution to more efficient medium voltage distribution network management, particularly in handling faults and maintenance.

Keywords: *ETAP Simulation, Distribution Network Maneuvers, Power Losses, Network Faults*

2.1 INTRODUCTION

With the advancement of science and technology, as well as the increasing demand for electricity, a large number of power electronic equipment and various non-linear loads have been integrated into the power grid [1]. This impacts the performance of the medium voltage distribution network (MVDN), which plays a crucial role in maintaining the reliability of electricity supply. The MVDN is designed to transmit electrical energy from substations to consumers, and in Indonesia, it typically operates at a voltage level of 20 kV. The electric power distribution system, especially the medium voltage distribution network, faces various challenges in maintaining power quality and voltage stability, particularly during network maneuvers under fault conditions.

The reliability of the power distribution system is a critical aspect of ensuring the continuity of electricity supply to consumers. Faults in the distribution network are often unavoidable and can lead to outages that harm customers [2]. To minimize the impact of such faults, network maneuvers are conducted, which involve modifying the network configuration to restore power supply to the affected areas [3]. Network maneuvers are carried out under abnormal conditions but still aim to serve customers according to service standards [4]. This maneuvering process is done to ensure that the electricity supply continues to operate optimally, even during faults or maintenance, while also considering power losses and voltage drops. Theoretically, the benefits of network maneuvers are to optimize the distribution network, reduce outage areas, and avoid power cuts for customers with critical loads [5][6].

One of the main issues often encountered during maneuvers is voltage drop and increased power losses in the network, especially when a normally operating feeder is burdened by a feeder undergoing maneuvers [7] [8] [9]. Significant voltage drops can degrade service quality and affect the performance of equipment on the consumer side [10]. Therefore, accurate analysis is needed to ensure that conductors can handle the additional load arising from the maneuver [11]. It is recommended that maneuver alternatives be selected on feeders with minimal power losses to achieve optimal system reliability [12]. Although network maneuvers can restore power supply, several challenges must be addressed. Load transfer to other feeders can cause overload, significant voltage drops, and increased power losses in the network [13]. Additionally, choosing a suboptimal maneuver path can result in slow supply recovery and larger
outage areas [14]. With the development of DC loads and distributed generation, medium voltage DC (MVDC) distribution networks are also being widely implemented [15]. In this context, switchgear is a critical component of medium voltage distribution networks. The use of condition-based monitoring (CBM) systems integrated with deep learning technology can effectively detect potential faults and enhance network reliability [16]. However, the malfunction of remotely controlled switches can significantly impact the reliability of the distribution system, requiring a reliable automation strategy to maintain network stability [17].

Network protection devices such as reclosers, sectionalizes, and fuses are designed to isolate faulted sections so that other parts of the network can continue receiving power [18] [12]. Furthermore, the integration of Supervisory Control and Data Acquisition (SCADA) systems has proven to improve efficiency in handling faults, allowing operators to monitor and control the network remotely [19] [4]. With the emergence of smart grid technologies, automation in power distribution has become an essential factor in ensuring network reliability. The implementation of advanced distribution management systems (ADMS) and self-healing networks enhances fault detection, localization, and restoration, thereby reducing outage durations and improving overall power quality [21]. Additionally, the integration of renewable energy sources and distributed energy resources (DERs) into smart grids requires adaptive control strategies to balance supply and demand dynamically.

Reliable electricity supply is essential, especially for customers with critical loads. During faults or maintenance, network maneuvers are conducted to reroute power to minimize outage time and maintain service continuity to customers [5]. However, these maneuvers must be performed carefully to avoid excessive voltage drops and high-power losses, which can affect overall network performance [20]. This study aims to analyze the conditions of the medium voltage distribution network in the Tasikmalaya area, particularly during maneuvers under fault conditions, and to provide recommendations for optimal maneuver strategies to reduce the impact of faults on the network.

2. RESEARCH METHODOLOGY

2.1 *Research Stager*

This research consists of several stages described as follows:

a. Secondary Data Collection: The initial stage of the research begins with the collection of secondary data from PT. PLN UP3 Tasikmalaya, including data on the distribution network, transformer data, conductor data, load data, as well as customer data for the feeder under study. This data is used for network simulation and analysis to evaluate conditions before and after the maneuver.
b. Secondary Data Recapitulation: The collected secondary data will be recapitulated and evaluated. This data includes feeder conditions, transformer capacity, line length, conductor type, and load data. Data requirement evaluation is conducted to ensure that all necessary variables for the study are available for simulation. This stage is crucial to minimizing potential errors that may occur due to data inaccuracies.
c. Field Survey: A field survey is conducted to validate the secondary data from PLN with actual conditions in the field. This survey includes verification of the physical condition of the network, transformer positions, and line lengths between buses and transformers. This is important because there are often discrepancies between secondary data and actual field conditions, such as changes in network configuration or unrecorded transformer additions.
d. Data Validation: The field survey data will be compared with PLN's secondary data. Validation is performed to ensure consistency between PLN's administrative data and the actual field conditions. Once the validation process is complete, the data will be ready for simulation and analysis.
e. Simulation and Analysis: Simulation and analysis are the core stages of this research. The validated data is used to run network maneuver simulations using ETAP (Electrical Transient Analyzer Program) software. Simulations are conducted under several load scenarios, such as 40%, 80%, and 100% load conditions, to assess the effects of network maneuvers on voltage drop and power losses. The analysis is then carried out to evaluate network conditions before and after the maneuver and to identify maneuver alternatives that produce the most optimal network conditions in terms of voltage drop and power losses.

2.2 *Research Location*

The research was conducted on the medium voltage distribution network in the PT. PLN UP3 Tasikmalaya area. The main focus of the study is the Tamansari feeder (TMSR), which frequently undergoes network maneuvers during faults or maintenance.

2.3 *Observed Variable*

Voltage drop is the decrease or loss of voltage in the conductor during network maneuvers. This voltage drop must be carefully monitored to ensure it remains within PLN standards, which range from +5% to -10% of the nominal voltage. Meanwhile, power losses are the loss of power that occurs in the conductor or transformer due to load transfer during maneuvers. These losses are calculated based on the square of the current flowing through the conductor and the conductor's resistance.

2.4 *Research Model*

This study uses simulation models. Primary data obtained from the field and secondary data from PLN are used as inputs for network maneuver simulation using ETAP software. This model allows the analysis of various network maneuver scenarios and optimal network conditions during faults or maintenance.

2.5 Research Design

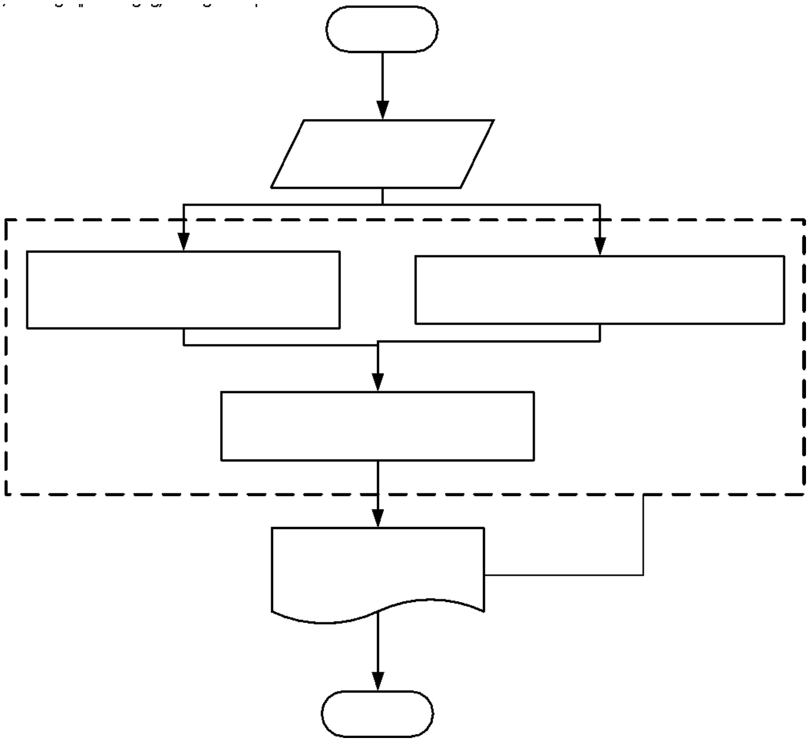

Figure 1. Flowchart Research

Figure 1 show research Flowchart Diagram Explanation:

a. Start: The research begins.

b. Validated Network Data: The first step is the collection and validation of network data. This data includes information about the validated power distribution network, both through field surveys and from available secondary data.

c. Simulation and Load Analysis of Faulted/Maintained Feeder: At this stage, simulation and load analysis are carried out on feeders experiencing faults or under maintenance. Simulations are performed under various load scenarios (e.g., 40%, 80%, 100%) to assess how load changes affect voltage drops and power losses.

d. Simulation and Analysis of Backup Feeder Conditions During Maneuver: Simulations are conducted on feeders serving as backup during maneuvers. This stage aims to evaluate whether the backup feeder can handle the additional load without causing disturbances or overloading.

e. Simulation and Feeder Condition Analysis During Maneuver: This simulation is conducted to assess feeder conditions during the maneuver. The analysis focuses on how power is transferred from the backup feeder and its impact on voltage drops and power losses.

f. Maneuver Alternatives That Yield Optimal Network Conditions: After the simulation is completed, maneuver alternatives that provide the most optimal network conditions—minimizing voltage drop and power losses—are identified.

g. Finish: The final stage where the research is completed after determining the best maneuver alternative.

3. RESULT AND DISCUSSION

The feeder studied during the maneuver condition is the Tamansari Feeder (TMSR), where during a fault or maintenance, the TMSR Feeder is backed up by two feeders: the Sambong Bencoy Feeder (SBBC) and the Padayungan Feeder (PDYN).

3.1 *Network Profile*

Based on the processing of secondary PLN data and field survey results, several different conditions were found. This is possible because the secondary data obtained from PLN is from early 2023, and there are likely some conditions that have not yet been recorded in the reporting system.

3.2 *TMSR Feeder*

PLN's secondary data mentions that the number of transformers/loads on the TMSR Feeder is 39 transformers, but during the field survey, there were 38 transformers. According to the survey results, five transformers had been relocated, and there were four additional transformers based on PLN's secondary data. The total installed transformer capacity on the TMSR Feeder is 6,300 kVA, compared to 6,360 kVA based on PLN's secondary data. This results in a reduction of the total capacity by 60 kVA.

3.3 *PDYN Feeder*

PLN's secondary data mentions that the number of transformers/loads on the PDYN Feeder is 31 transformers, but during the field survey, there were 36 transformers. According to the survey results, three transformers had been relocated, and there were eight additional transformers based on PLN's secondary data. The total installed transformer capacity on the PDYN Feeder is 6,920 kVA, compared to 5,880 kVA based on PLN's secondary data. This results in an increase in total capacity of 1,040 kVA.

3.4 *SBBC Feeder*

PLN's secondary data mentions that the number of transformers/loads on the SBBC Feeder is 34 transformers, but during the field survey, there were 39 transformers. According to the survey results, two transformers had been relocated, and there were seven additional transformers based on PLN's secondary data. The total installed transformer capacity on the SBBC Feeder is 6,420 kVA, compared to 5,640 kVA based on PLN's secondary data. This results in an increase in total capacity of 780 kVA.

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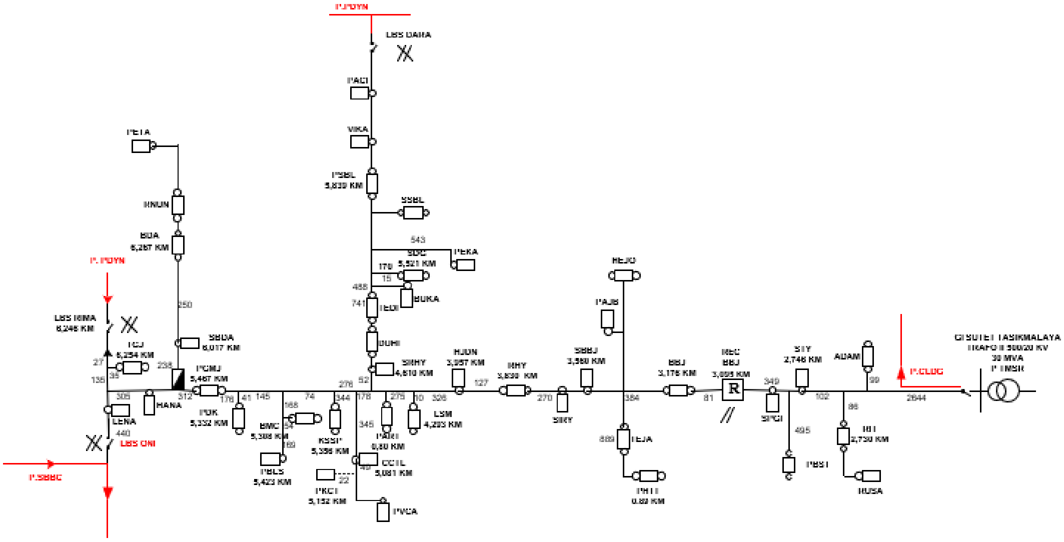

Figure 2. SLD of the TMSR Feeder

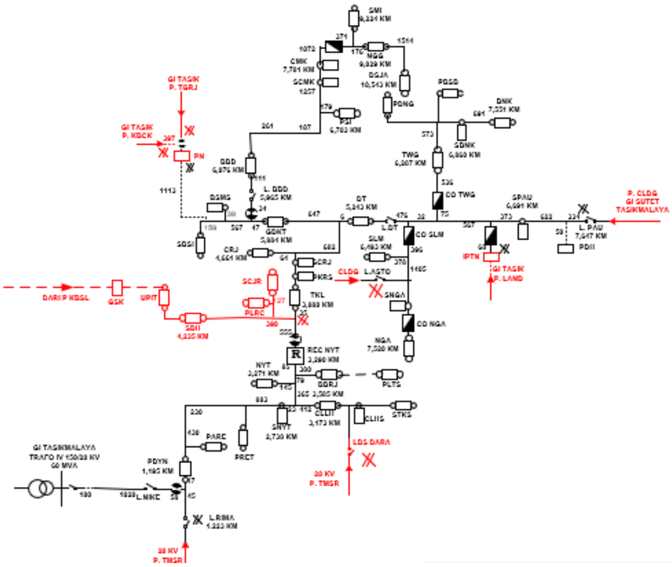

Figure 3. SLD of the PDYN Feeder

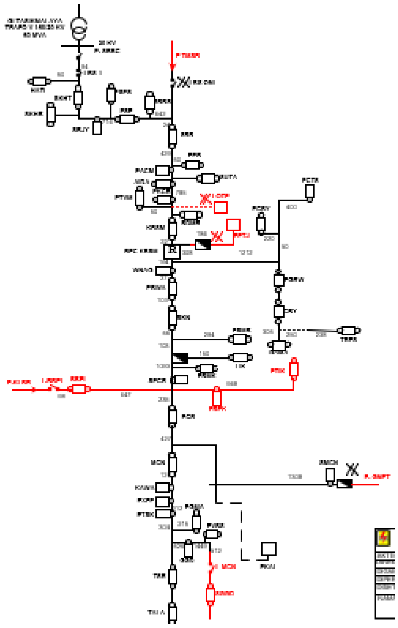

Figure 4: SLD of the SBBC Feeder

3.5 *Existing Network Conditions*

The existing conditions show the network status under normal conditions. In this case, all loads are assumed in three scenarios: 100%, 80%, and 40% load. This represents normal loading conditions on a transformer where transformer overload occurs at 100% of its total capacity. Meanwhile, the maximum recommended load on a transformer is 80% of its total capacity, and the minimum load is 40%.

3.6 *TMSR Feeder*

In general, the voltage conditions on the TMSR Feeder can be considered normal at 40%, 80%, and even 100% load. The lowest voltage value under existing conditions is found on the PETA bus.

Table 1: Lowest Voltage Conditions of the TMSR Feeder under Existing Conditions

Load Condition	***Lowest Voltage (p.u)***	***Description***
Load 100%	*0,9612*	*Within standard*
Load 80%	*0,9695*	*Within standard*
Load 40%	*0,9852*	*Within standard*

Power losses on the TMSR Feeder are divided into two types: power losses due to conductors and power losses due to transformers. The total power losses from both conductors and transformers on the TMSR Feeder at 100% load are 233.6 kW, at 80% load are 146.2 kW, and at 40% load are 33.8 kW.

3.7 *PDYN Feeder*

In general, the voltage conditions on the PDYN Feeder can be considered normal at 40%, 80%, and even 100% load. The lowest voltage value under existing conditions is found on the DSJA bus.

Table 2: **Lowest Voltage Conditions of the PDYN Feeder under Existing Conditions|**

Load Condition	*Lowest Voltage (p.u)*	*Description*
Load 100%	*0,9533*	*Within standard*
Load 80%	*0,9633*	*Within standard*
Load 40%	*0,9823*	*Within standard*

Power losses on the PDYN Feeder are divided into two types: power losses due to conductors and power losses due to transformers. The total power losses from both conductors and transformers on the PDYN Feeder at 100% load are 344.8 kW, at 80% load are 213 kW, and at 40% load are 49.2 kW.

3.8 *SBBC Feeder*

In general, the voltage conditions on the SBBC Feeder can be considered normal at 40%, 80%, and even 100% load. The lowest voltage value under existing conditions is found on the PVBS and TLS buses.

Table 3: Lowest Voltage Conditions of the SBBC Feeder under Existing Conditions

Load Condition	*Lowest Voltage (p.u)*	*Description*
Load 100%	*0,9710*	*Within standard*
Load 80%	*0,9771*	*Within standard*
Load 40%	*0,9889*	*Within standard*

Power losses on the SBBC Feeder are divided into two types: power losses due to conductors and power losses due to transformers. The total power losses from both conductors and transformers on the SBBC Feeder at 100% load are 268.5 kW, at 80% load are 167.7 kW, and at 40% load are 38.8 kW.

3.9 *Maneuver Conditions*

During the maneuver condition, the TMSR Feeder can be backed up by two feeders, PDYN and SBBC. The backup from the PDYN Feeder is through LBS Dara and LBS Rima, while the backup from the SBBC Feeder is through LBS ONI.

Scenario 1 (TMSR-PDYN Maneuver): The voltage condition in this first scenario is still considered normal, with the voltage of each bus remaining above 90% of its ideal condition at 40%, 80%, and 100% load. The lowest voltage based on this first maneuver scenario is found on the BMC bus of the TMSR Feeder and the DSJA bus of the PDYN Feeder.

Table 4: **Lowest Voltage Conditions for Scenario 1 Maneuver**

Load Condition	*Lowest Voltage (p.u)*		*Description*
	Feeder TMSR	*Feeder PDYN*	
Load 100%	*0,9500*	*0,9428*	*Within standard*
Load 80%	*0,9687*	*0,9552*	*Within standard*
Load 40%	*0,9849*	*0,9784*	*Within standard*

The total power losses in scenario 1 consist of power losses due to conductors and power losses due to transformers. The total power losses from both conductors and transformers in scenario 1 at 100% load are 606.6 kW, at 80% load are 382.96 kW, and at 40% load are 86.9 kW.

Scenario 2 (TMSR-PDYN Maneuver): The voltage condition in this second scenario is still considered normal, with the voltage of each bus remaining above 90% of its ideal condition at 40%, 80%, and 100% load. The lowest voltage based on this second maneuver scenario is found on the PBST bus of the TMSR Feeder and the PDYN and SBBC buses of the PDYN Feeder.

Table 5: **Lowest Voltage Conditions for Scenario 2 Maneuver**

Load Condition	*Lowest Voltage (p.u)*		*Description*
	TMSR Feeder	*PDYN Feeder*	
Load 100%	*0,9161*	*0,9181*	*Within standard*
Load 80%	*0,9248*	*0,9364*	*Within standard*
Load 40%	*0,9690*	*0,9698*	*Within standard*

The total power losses in scenario 2 consist of power losses due to conductors and power losses due to transformers. The total power losses from both conductors and transformers in scenario 2 at 100% load are 975.2 kW, at 80% load are 588.2 kW, and at 40% load are 135 kW.

Scenario 3 (TMSR-SBBC Maneuver): The voltage condition in this third scenario is still considered normal, with the voltage of each bus remaining above 90% of its ideal condition at 40%, 80%, and 100% load. The lowest voltage based on this third maneuver scenario is found on the PBST bus of the TMSR Feeder and the PDYN bus of the SBBC Feeder.

Table 6: **Lowest Voltage Conditions for Scenario 3 Maneuver**

Load Condition	*Lowest Voltage (p.u)*		*Description*
	Feeder TMSR	*Feeder SBBC*	
Load 100%	*0,9471*	*0,9494*	*Within standard*
Load 80%	*0,9585*	*0,9603*	*Within standard*
Load 40%	*0,9800*	*0,9809*	*Within standard*

The total power losses in scenario 3 consist of power losses due to conductors and power losses due to transformers. The total power losses from both conductors and transformers in scenario 3 at 100% load are 724.2 kW, at 80% load are 448.5 kW, and at 40% load are 105.2 kW.

4. CONCLUSION

Based on the survey results, several discrepancies were found between the field data and the secondary data obtained from PLN. These differences are likely due to changes in network conditions that have not yet been recorded in the secondary data held by the research team. These changes include transformer capacity alterations, the addition of new transformers, and the reduction in the number of transformers in the distribution network. The existing voltage conditions at each bus show results that comply with PLN standards, with a minimum voltage of 90% of the ideal condition. The best lowest voltage was found on the SBBC feeder, specifically at the PVBS and TLS buses, with a value of 0.9710 p.u. under 100% load conditions. Although the SBBC feeder showed better voltage under existing conditions, the smallest power loss at 100% load occurred on the TMSR feeder, amounting to 233.6 kW. Regarding maneuver selection, the best results were obtained in scenario 1, where a maneuver was conducted on the TMSR network supplied by the PDYN feeder through the LBS DARA. The lowest voltage in this scenario was 0.9612 p.u. on the

TMSR feeder and 0.9533 p.u. on the PDYN feeder. Additionally, the total power loss resulting from the maneuver in scenario 1 was the smallest, amounting to 606.6 kW under 100% load conditions. Future research should focus on real-time data synchronization, advanced forecasting models, and the integration of smart grid automation to enhance network efficiency and reliability. Future research should focus on real-time data synchronization, advanced forecasting models, and the integration of smart grid automation to enhance network efficiency and reliability.

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