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Impact Analysis of 20 kV Network Reconfiguration on the Android–Pinang Feeder: Voltage Profile and Power Losses Assessment Using DigSILENT PowerFactory

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ABSTRACT

The rapid increase in electrical energy demand in Indonesia compels PT PLN (Persero) to continuously maintain the quality and reliability of its distribution systems. PT PLN ULP Rimbo Bujang faces significant challenges regarding severe voltage drops and high technical losses on the 20 kV Medium Voltage Network (JTM) of the Android Feeder. This condition is primarily driven by the long distance between the load center and the Muara Bungo Substation, a total network length of 121 km, and bottlenecks caused by non-uniform conductor cross-sections (70 mm² and 150 mm²) within a radial configuration. This study aims to analyze the impact of power quality improvement efforts conducted by ULP Rimbo Bujang through network reconfiguration and operational pattern adjustments. The simulated interventions include: (1) transferring the power supply from the Muara Bungo Substation to the Sungai Rumbai Substation, effectively reducing the network length by 20 km; (2) upgrading conductors to A3CS 150 mm²; and (3) constructing a new Express Feeder to bifurcate the Android Feeder's load, partially transferring it to the Pinang Feeder. Simulations and analyses were performed using DIgSILENT PowerFactory software to compare end-point voltage and power losses before and after the operational changes. The simulation results demonstrate an increase in end-point voltage on the Android Feeder and a significant reduction in technical losses. These findings provide clear technical recommendations regarding the effectiveness of reconfiguration in maintaining voltage reliability standards as per SPLN No. 72 of 1987 and minimizing energy losses.

Keywords: Network Reconfiguration, Voltage Profile, Power Losses, Express Feeder, Medium Voltage Distribution Network

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1. Introduction

The rapid advancement of technology across all societal sectors has driven a significant increase in electrical energy demand in Indonesia [1], [2]. This demand is directly proportional to the annual growth of electricity consumption; statistical data shows that total energy sales in 2022 reached 273,761.48 GWh, with the industrial sector consuming 88,483.30 GWh [1]. This growth in sales must be balanced with the quality and reliability of the power system [3], [4]. A power system is considered highly reliable if it can continuously supply the energy required by consumers while maintaining high power quality in terms of both voltage and frequency regulation [5]. In line with this principle, ULP Rimbo Bujang strives to meet these criteria as its primary duty, specifically in maintaining reliability and quality across three regencies within its jurisdiction, with a particular focus on addressing voltage drop issues [6].

As the state-owned utility company, PT PLN (Persero) is committed to providing electricity with high reliability and quality to ensure optimal distribution to consumers [3], [7]. Proper operation of a power system requires that the voltage delivered to customers does not fall below PLN's standardized limits [6], [8]. According to SPLN No. 72 of 1987, the allowable voltage drop for Medium Voltage (JTM) and Low Voltage (JTR) networks is 2% for spindle/cluster systems and 5% for radial overhead and loop systems, depending on load density [9].

According to Effendi and Dewi, network reconfiguration is performed by modifying the status or location of switches, upgrading cable types, or altering the network structure [10], [11]. These measures aim to reduce total losses, balance loads, and stabilize voltage under normal operating conditions [12], [13]. However, reconfiguration must adhere to operational constraints, such as operating voltage limits, maximum thermal current capacity, and maintaining the network structure [14]. Furthermore, Winardi and Warsito state that reducing power losses and voltage drops are essential methods for improving network efficiency [15].

To mitigate voltage drops and technical losses on the Android Feeder, ULP Rimbo Bujang has implemented network reconfiguration [10], [12]. This process involves altering the distribution structure to reduce losses and balance system loads [13], [15]. Specifically, the reconfiguration of the Android Feeder involves constructing a new Express Feeder closer to the load center to bifurcate the load [11], [16]. This intervention is expected to increase end-point voltage and decrease technical losses [12], [17]. Consequently, this study utilizes DIgSILENT PowerFactory software to simulate and evaluate the impact of the Express Feeder construction, providing a comprehensive comparison of voltage profiles and losses before and after the implementation [18].

2. Research method

This study applies an engineering-based analytical and simulation methodology to evaluate the impact of distribution network reconfiguration on voltage profile improvement and technical loss reduction in the Android Feeder at ULP Rimbo Bujang. The research procedure begins with field data acquisition, followed by analytical calculations, network modeling, simulation, and performance evaluation using power system analysis software [5], [10], [12]. Primary data were collected directly from the distribution network, including feeder topology, conductor types, feeder length, transformer ratings, load distribution, and electrical parameters such as voltage, current, active power, reactive power, and power factor measured at several critical points along the feeder [6], [8], [13]. These data represent actual operating conditions and are essential for ensuring that the simulation model accurately reflects real system behavior.

To analyze power flow characteristics and identify the causes of voltage drop, fundamental electrical power equations were applied. Active power (P), reactive power (Q), and apparent power (S) are related through the power triangle, expressed as [5], [15]:

$$S = \sqrt{P^2 + Q^2} \tag{1}$$

The relationship between these quantities is used to assess load characteristics and their impact on voltage stability. Voltage drops along the feeder is calculated based on online impedance and load current using the following approximation [14], [15]:

$$\Delta V = I(R\cos\ \varphi + X\sin\ \varphi) \tag{2}$$

where ΔV is the voltage drop, I is the line current, R and X are the line resistance and reactance, and φ is the load power factor angle. The percentage voltage drop is then determined as:

$$\%\Delta V = \frac{V_s - V_r}{V_s} \times 100\% \tag{3}$$

where V_s is the sending-end voltage and V_r is the receiving-end voltage [9], [12].

In addition, total technical losses in the feeder are calculated using conductor resistance and current flow, expressed as [12], [15]:

$$P_{loss} = I^2 R \tag{4}$$

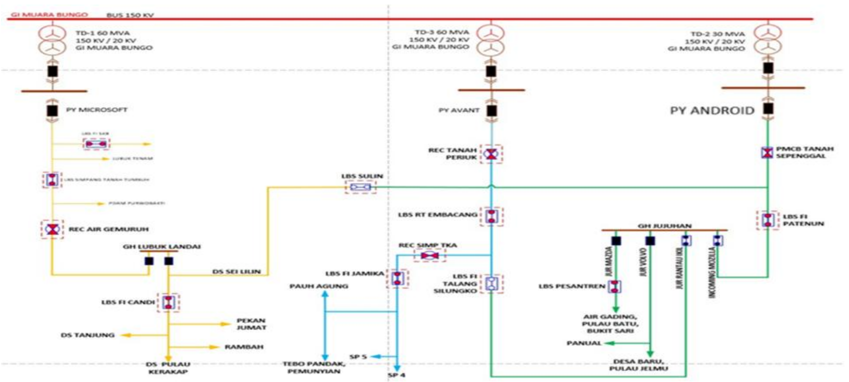
This analytical stage provides a preliminary understanding of voltage degradation and loss concentration in the existing feeder configuration.

Based on the analytical results, a network reconfiguration strategy was formulated to mitigate voltage drop and reduce losses. The proposed solution involves the construction of an Express Feeder located closer to the load center, aiming to shorten the electrical distance between the source and end users and redistribute loads more evenly [10], [11], [16]. This approach is designed to improve end-point voltage while maintaining operational constraints such as allowable voltage limits and conductor thermal capacity [14], [17]. The conceptual configuration of the existing network and the proposed Express Feeder arrangement is illustrated in Figure 1.

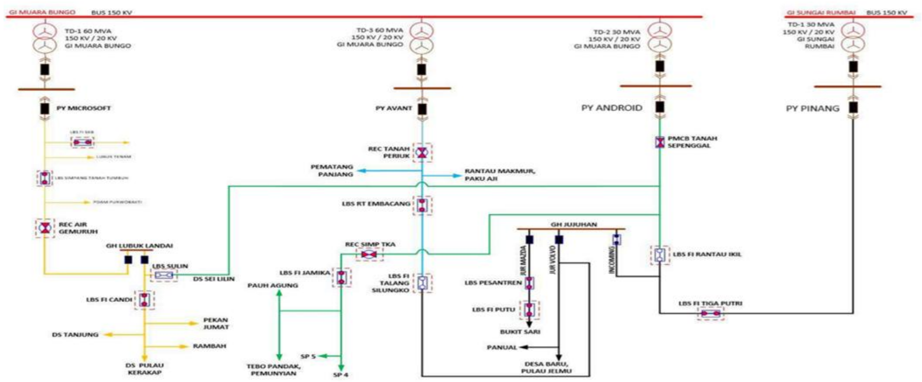
To quantitatively evaluate the effectiveness of the proposed reconfiguration, the distribution network was modeled and simulated using DIgSILENT PowerFactory software [16], [18]. Two simulation scenarios were conducted: the existing network configuration before reconfiguration and the modified configuration after the implementation of the Express Feeder. The simulation process includes load flow analysis to obtain voltage profiles, power losses, and current distribution along the feeder under normal operating conditions [11], [17].

Simulation outputs include voltage magnitude at each bus, total feeder losses, and load distribution changes before and after reconfiguration. These results enable a direct comparison of system performance and provide quantitative evidence of voltage improvement and loss reduction due to the Express Feeder implementation [12], [18].

Finally, the simulation results are analyzed to evaluate system performance based on key indicators, including voltage level compliance with SPLN standards, percentage voltage drop reduction, and total technical loss reduction [9], [15]. This evaluation forms the basis for assessing the feasibility and effectiveness of the proposed network reconfiguration strategy in improving power quality and operational efficiency in real distribution systems.



(a)



(b)

Figure 1. Single-line diagram of the Android Feeder distribution network: (a) existing configuration before reconfiguration and (b) proposed configuration with the addition of an Express Feeder. The proposed reconfiguration aims to shorten the electrical distance between the source and load center, thereby improving voltage profiles at the feeder end and reducing technical power losses.

3. Results and discussion

The simulation results obtained using DIgSILENT PowerFactory illustrate the steady-state voltage profiles and technical loss conditions of the Android Feeder before and after the implementation of the Express Feeder. The figures presented in this section represent the output of load flow simulations, while the network reconfiguration actions were implemented during the system modeling stage as described in the Research Methodology.

Simulation results for the Mazda Lateral indicate a voltage drop along the network segment starting from the Pulau Batu FCO (Fused Cut-Out). As shown in Figure 2, the voltage decreases from 19.96 kV at the FCO point to 19.7 kV at the terminal end of the feeder. This reduction is attributed to the cumulative load of 25 distribution transformers connected along the radial line and reflects the steady-state operating condition of the system obtained from the load flow simulation.

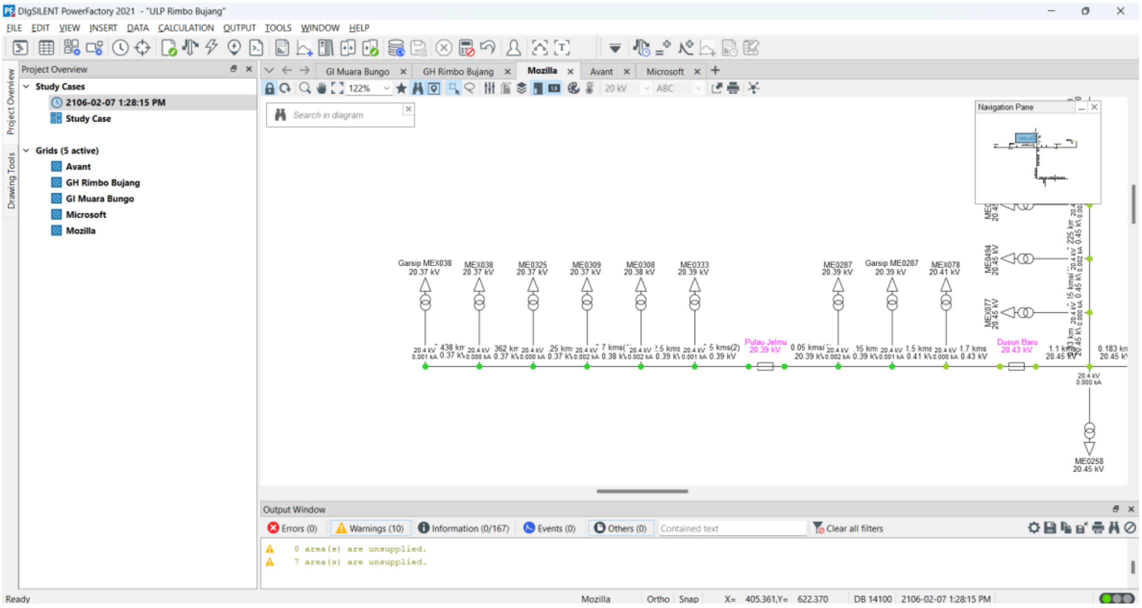


Figure 2. Steady-state voltage profile along the Mazda Lateral obtained from DIgSILENT PowerFactory load flow simulation, showing a voltage decrease from the Pulau Batu FCO to the terminal end of the feeder under the existing network configuration

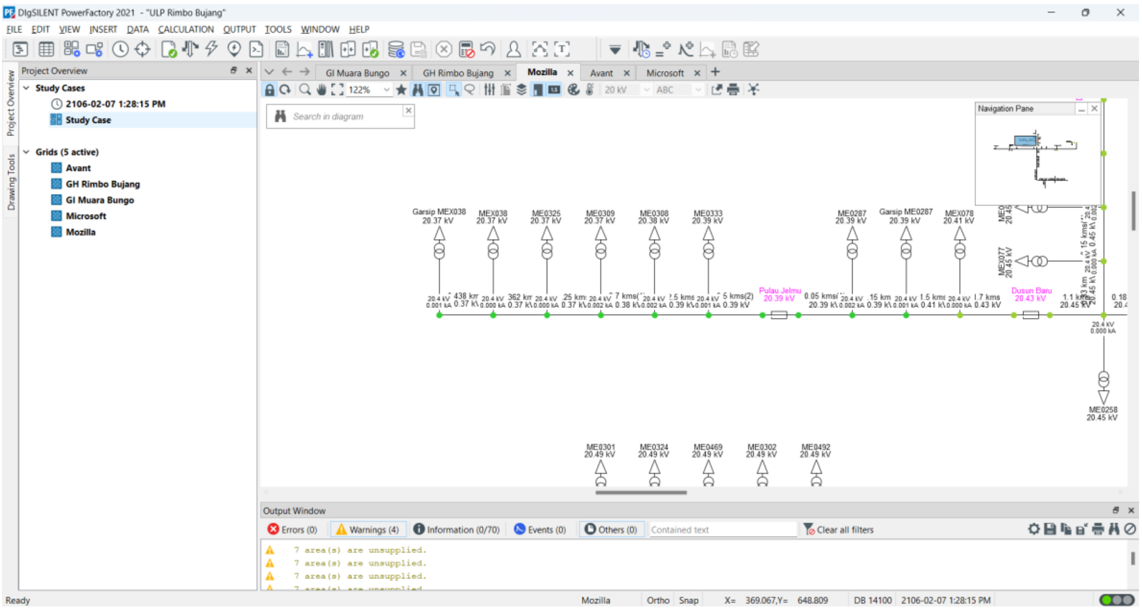


Figure 3. Steady-state voltage profile along the Volvo Lateral obtained from DIgSILENT PowerFactory load flow simulation, illustrating the voltage distribution across the feeder under steady-state operating conditions

Simulation results for the Volvo Lateral are presented in Figure 3. This lateral consists of four switching points supplying a total of 20 distribution transformers. Compared to the Mazda Lateral, the voltage reduction observed along the Volvo Lateral is less pronounced. This difference highlights the influence of feeder length, load concentration, and network topology on voltage performance across different branches of the Android Feeder. The voltage values shown represent the operational condition of the feeder under steady-state simulation rather than any physical switching sequence.

A quantitative comparison of end-point voltage values before and after the construction of the Pinang Express Feeder is summarized in Figure 4 and Table X. The results show that the voltage on the Mazda Lateral increased by 0.62 kV (from 19.11 kV to 19.73 kV), while the Volvo Lateral experienced an increase of 0.61 kV (from 19.77 kV to 20.38 kV). These improvements confirm that the reconfiguration effectively enhanced the voltage profile across different branches of the Android Feeder.

Overall, the simulation results validate that network reconfiguration through the construction of the Express Feeder improves voltage quality and reduces technical losses. However, despite the observed improvements, the resulting voltage levels remain insufficient to fully satisfy the SPLN No. 72 of 1987 standards, indicating the need for further network reinforcement in long radial distribution systems.

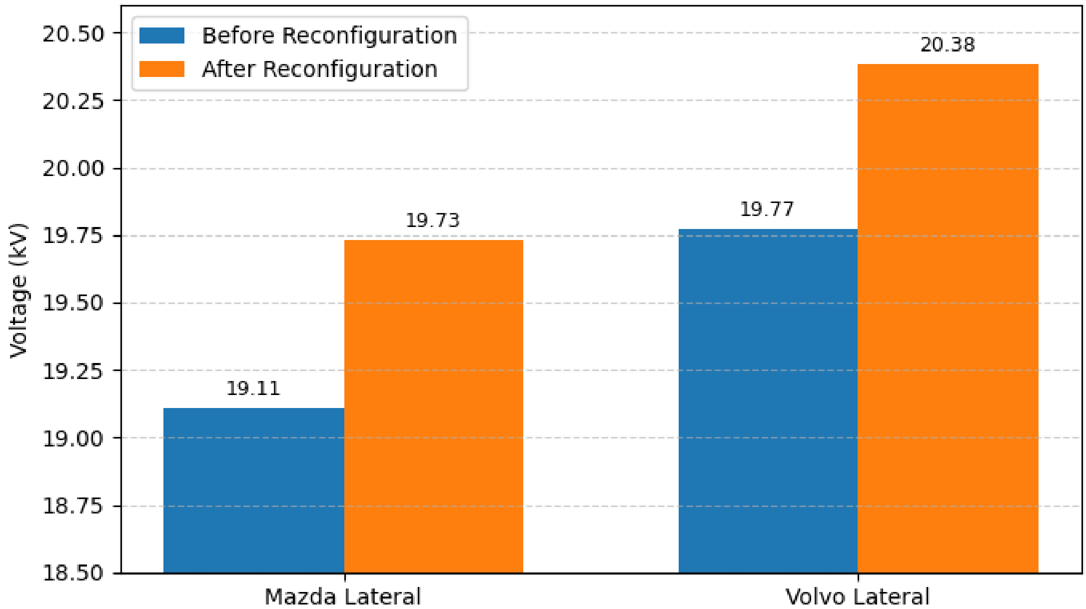


Figure 4. Comparison of end-point voltage values before and after the construction of the Pinang Express Feeder for the Mazda and Volvo Laterals, as derived from DIgSILENT PowerFactory load flow simulation results

4. Conclusions

This study evaluated the impact of 20 kV distribution network reconfiguration on voltage profile improvement and technical loss reduction along the Android–Pinang Feeder using DIgSILENT PowerFactory. The simulation results show that long feeder length and concentrated load distribution contribute significantly to voltage drops in radial distribution systems. The implementation of the Pinang Express Feeder effectively improved end-point voltage levels on both the Mazda and Volvo Laterals and reduced technical losses from 7.7% to 6.8%. However, the resulting voltage levels still do not fully comply with the limits specified in SPLN No. 72 of 1987, indicating the need for additional network reinforcement measures. Overall, network reconfiguration using an Express Feeder is shown to be an effective approach for enhancing voltage quality and operational efficiency in medium-voltage distribution networks.

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