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Research Article

Contingency Analysis of the Kendari Electrical System: A Case Study of IBT II 250 MVA

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Abstract: *The transmission system for electrical power must operate reliably and continuously; however, disruptions often affect the reliability and stability of the system. Equipment failures during operation can have adverse effects on the power distribution system. The Kendari Subsystem, connected through IBT at the Wotu Main Substation, plays a crucial role as the backbone in the Sulselrabar electrical system with high risks due to the operation of only one IBT unit, namely IBT II with a capacity of 250 MVA, while IBT I has a different capacity. This subsystem significantly influences the distribution of electrical energy from various generators, especially the Poso Hydroelectric Power Plant. This research employs power flow simulation to analyze contingencies in the Kendari Subsystem of the 150 kV electrical system, focusing on IBT-II 275/150 kV with a capacity of 250 MVA. The research findings reveal frequency fluctuations in contingency situations that subsequently recover continuously. Almost all bus voltages experience increases above the permissible limits, and adjustments to load and VAR generator settings are made according to established load procedures. These findings can serve as a reference for enhancing the operation of the power system under similar conditions.*

Keywords: *Contingency Analysis, IBT, System Reliability*

1. Introduction

The failure of this equipment during operation compromises the reliability of the power transmission system[1]. In the distribution of electricity, the energy generated by the generator flows to consumers through transmission lines, making these lines essential in the distribution process. Transmission line outages can create challenges in maintaining system reliability[2]. Disruptions in transmission components may involve line outages, requiring power to be redirected through alternative routes. Such disturbances can lead to changes in power flow within the electrical grid. These changes vary depending on the location of the disconnection. When power flow shifts, it can result in variations in line current, line overloads, overvoltages at buses, or undervoltages at buses, all of which can threaten the stability of the power system itself[3].

The Kendari Subsystem is part of the Sulselrabar Power System, located in the southeastern region. The Sulselrabar Power System is an interconnected network covering South Sulawesi, Southeast Sulawesi, and West Sulawesi. It is one of the assets managed by PT PLN (Persero) Unit Induk Penyaluran dan Pusat

Pengatur Beban (UIP3B) Sulawesi. Within this system, the Wotu Substation is equipped with two IBT 275/150 kV units, with capacities of 90 MVA and 250 MVA, respectively. The IBTs at the Wotu Substation serve as the backbone of the Sulselrabar power system, connecting the southern and southeastern regions. This line is considered critical, as only one IBT unit—IBT II with a capacity of 250 MVA—is operational, while IBT I has a different capacity. This line plays a significant role in transmitting electricity from various power plants, particularly the Poso Hydroelectric Power Plant (PLTA). Energy distribution is managed based on load flow demand.

As part of the PLN Group, PLN UIP3B Sulawesi is responsible for managing and ensuring the continuity of electricity in the Sulselrabar region. To maintain system reliability, PLN UIP3B Sulawesi is committed to proactively preventing potential hazards that could lead to current or future disruptions.

To ensure continuous and reliable operation of the power system, a relevant analysis is conducted. One approach utilized is contingency analysis, which aims to identify changes in power flow caused by outages in one or more components of the system. Outages may result from component failures or routine maintenance activities requiring temporary disconnection of those components. Contingency analysis also provides valuable insights for planning and optimizing operational security within the power system. The impacts of contingencies include changes in power flow and voltage at buses within a subsystem[4]. The application of contingency analysis in power systems has been widely studied, as evidenced by various research studies [5]–[18].

This study aims to assess vulnerable components in the Sulselrabar power system, particularly in the Kendari Subsystem, under emergency conditions. The goal is to prevent power outages. Simulations will be used to evaluate the frequency after interconnection disconnection, the voltage at each bus, operational conditions, and load maneuver strategies for IBT II, which represents the highest contingency index in blackout scenarios.

The findings of this research are expected to provide insights into which buses have the potential for overloads or voltage issues during contingencies. With this knowledge, solutions such as load maneuvers or VAR adjustments at power plants can be directly implemented, ensuring that the reliability of the power system remains intact.

2. Materials and methods

2.1. Research Procedure

Contingency is closely related to the power system's ability to distribute electrical energy during the outage of one of its components. There are three fundamental steps in contingency studies and analysis: developing contingency scenarios, parameter selection, and evaluation [20], [14].

A. Development of Contingency Scenarios

The object of the simulation is the Sulselrabar power system, particularly the Kendari Subsystem, as it is one of the most vital subsystems in Sulawesi. This involves identifying and analyzing potential disruptions or outages of the 275/150 kV IBT II transformer with a capacity of 250 MVA. The development of contingency scenarios considers variations in load, operational conditions, and outages of critical components.

B. Selection of Parameters and Variables

The selection of relevant parameters and variables includes system frequency, bus voltage, and the operational conditions of IBT II. Variables such as system loading and load maneuvering strategies are also key areas of focus in this step.

C. Simulation Result Evaluation

The final step involves conducting power flow simulations to evaluate the impacts of the developed contingency scenarios. The evaluation includes analyzing fluctuations in frequency and voltage at the buses. These simulation results are used to identify buses that are vulnerable to voltage contingencies.

2.2. Research Methodology

In this study, contingency analysis is performed using a power flow simulation method with the DIgSILENT PowerFactory simulation software to evaluate contingencies in the power transmission system of the Kendari Subsystem, specifically focusing on the IBT-II 275/150 kV unit with a capacity of 250 MVA. A descriptive quantitative method is applied, combining the collection of historical operational data and simulation results. The contingency analysis scenarios are predefined with various considerations, so the simulated scenarios may not necessarily represent the worst-case scenarios. A contingency index is required to rank the impact of a system element outage on post-contingency system conditions.

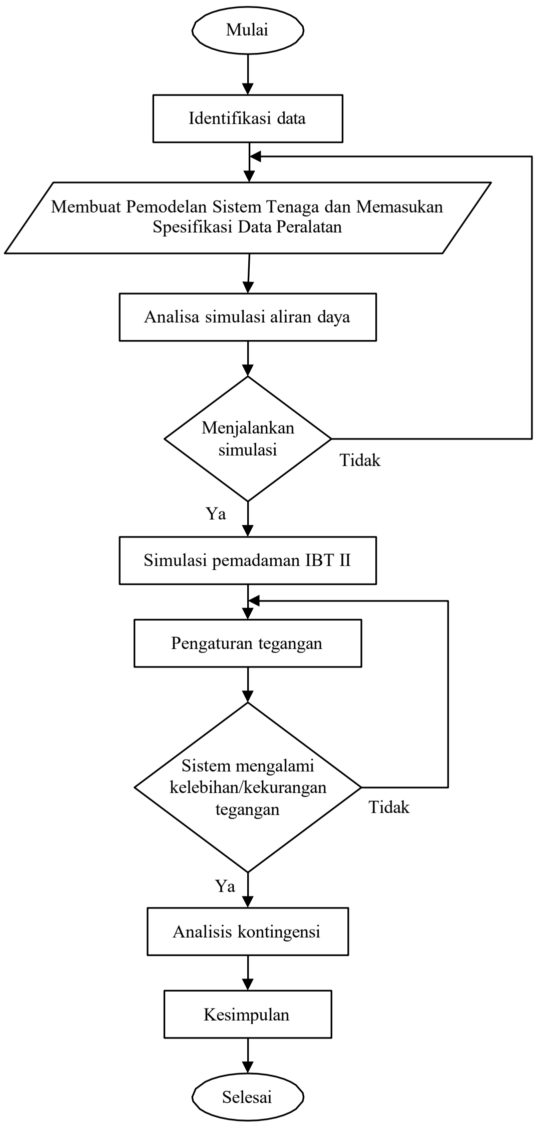

Figure 1. Step by step Research

This study begins with data collection, followed by data identification to determine which data are necessary for the simulation. Once the data are gathered, simulations are carried out, and researchers perform an analysis to find the best scheme to avoid power outages. The analysis is performed using the power flow method with the DIgSILENT PowerFactory simulation software. Below is the single-line diagram of the Kendari Subsystem.

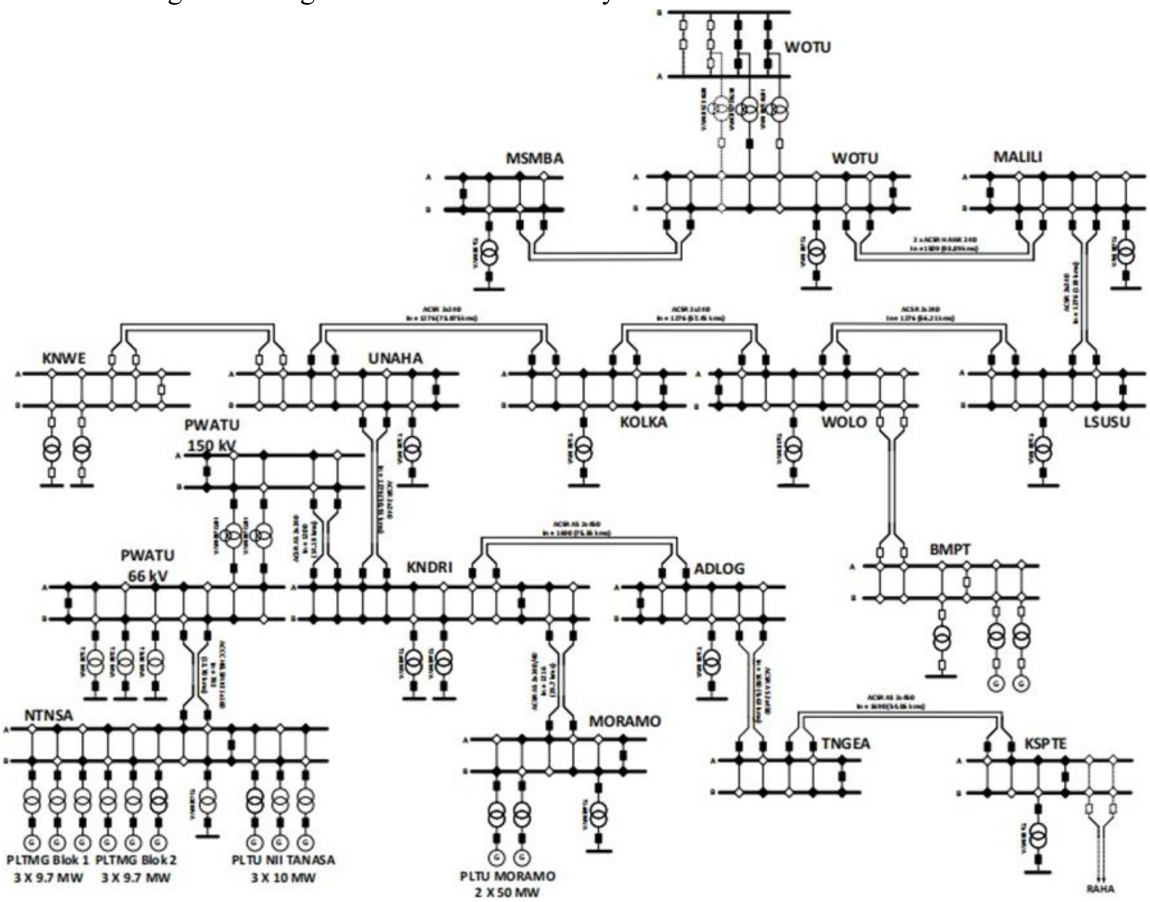

Figure 2. Single line diagram of the Kendari Subsystem

Figure 2 shows the single-line diagram of the electrical system in the Kendari Subsystem, with IBT-II as the simulated object. From the simulations conducted, it will be observed how the system behaves when the IBT is disconnected from the system.

3. Results and discussion

3.1. Normal Condition

When the system is in normal condition, it is assumed that all components are connected to the system. The data includes voltage values in kV and load values in MW and MVAR. Next, the focus will be on analyzing each bus to see if there are any buses that exceed the voltage limits within the +5% to -10% range of 150 kV[19]. Below is the voltage graph for normal conditions at each bus:

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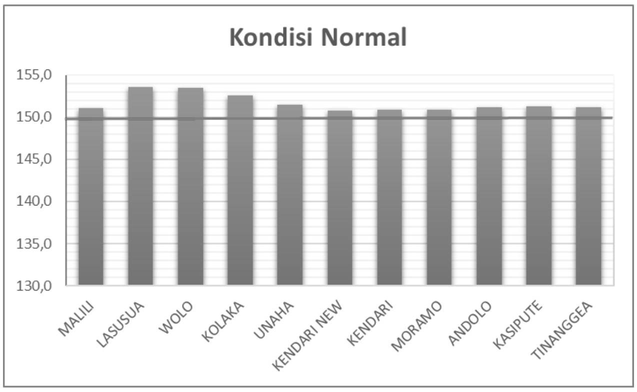

Figure 3. Busbar voltage under normal conditions.

During the simulation of the system under normal conditions, the Lasusua Substation (GI Lasusua) showed a voltage of 102.40%, which is 2.40% higher than the minimum allowable voltage standard set by PLN. This is caused by a lack of consumers and the substation's location being far from the generation source. This will likely affect the voltage stability at the surrounding buses.

3.2. Contingency Condition

When a contingency occurs, the simulation is performed by removing the corresponding component, namely IBT-II in the Sulselrabar system path leading to the Kendari Subsystem. In this simulation, the changes and impacts that may arise, which could disrupt the power flow values, will be analyzed.

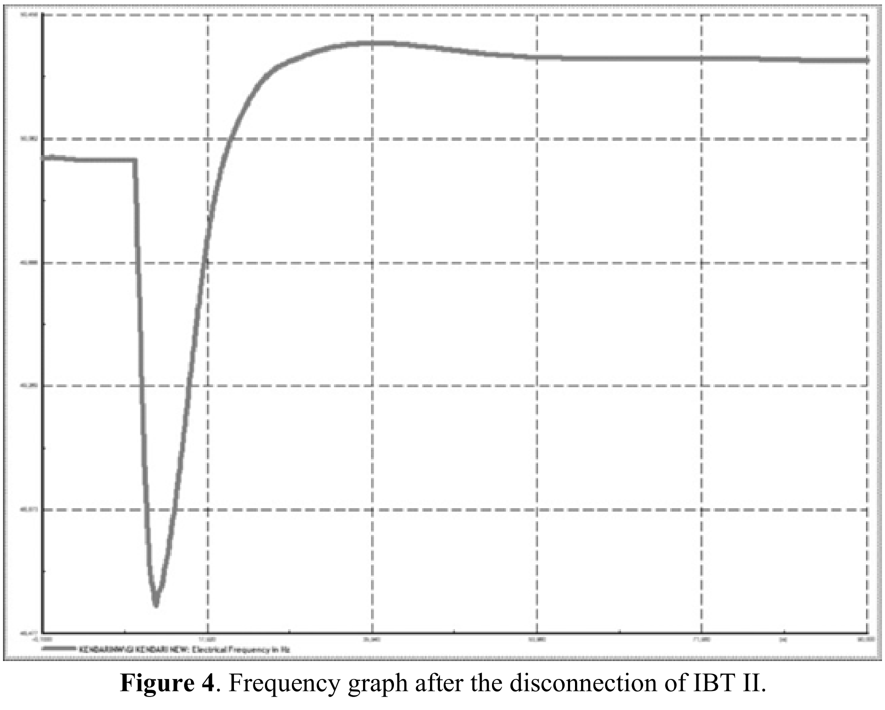

Figure 4. Frequency graph after the disconnection of IBT II.

It can be seen from Figure 4 that when a contingency occurs, there is a significant change in frequency, which shows a downward trend caused by a lack of generation. This is detrimental both to PLN as the electricity provider and to consumers. When IBT-II fails, the system becomes unstable due to insufficient energy supply. The large power that should be shared by two IBTs is now borne by the single IBT, causing it to exceed its capacity.

The simulation results indicate that the system has experienced an abnormal operating voltage. If this persists for a prolonged period, the system is at risk of a blackout. Below is the voltage graph.

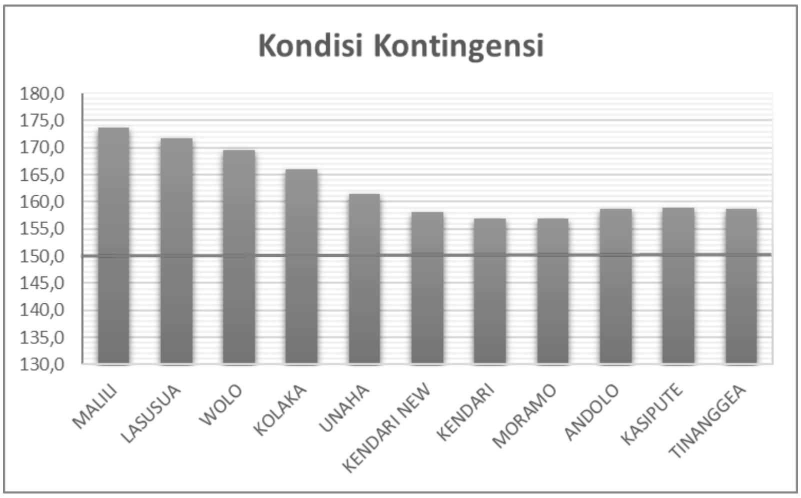

Figure 5. Busbar voltage under contingency conditions.

Figure 5 shows that the voltage at GI Malili reaches 115.87%, GI Lasusua reaches 114.53%, GI Wolo reaches 113%, GI Kolaka reaches 110.73%, GI Unaha reaches 107.6%, GI KendariNew reaches 105.4%, GI Kendari and GI Moramo reach 104.67%, GI Andolo reaches 105.8%, GI Kasipute reaches 105.93%, and GI Tinanggea reaches 105.87%. In other words, nearly all substations experienced a voltage increase.

When a contingency condition occurs, part of the operating system should immediately make decisions to manage the load and adjust the voltage in coordination with the field operators. Maneuvering should be a final decision and not made arbitrarily, as this could create new issues. Therefore, simulation is crucial to perform before an actual outage occurs.

3.3. Recovery Condition

In this simulation, solutions for load and voltage regulation were developed as a result of the IBT-II outage in the electrical system of the Kendari Subsystem. The load regulation process is carried out when the IBT is shut down, which causes the Under Frequency Relay (UFR) to activate in order to limit the frequency resulting from the loss of power supply from the Sulselrabar system. Next, teleprotection is activated to disconnect the overloaded lines or loads that cannot be directly accessed by field operators, especially for loads on radial networks. Communication is then established with power plants in other regions to supply power to the affected load areas or lines targeted by Over Load Shedding (OLS), while waiting for the IBT to be restored so that consumers do not experience a blackout. If the issue with the disconnected IBT persists and the power supply from other regions still cannot meet the system's needs, rolling blackouts will be implemented until the disconnected IBT can be brought back online.

Once the load regulation is completed, if the voltage remains high, voltage regulation can be done in two ways: reactive power adjustment from the power plant and network adjustment. The first approach involves requesting reactive power adjustments from the power plant under lagging conditions until the system voltage returns to normal. The second method involves disconnecting one transmission line at the farthest end of the subsystem from the power plant. This is done to reduce the load on the system and effectively lower the voltage. Below is the voltage at each bus after recovery, shown in Figure 6.

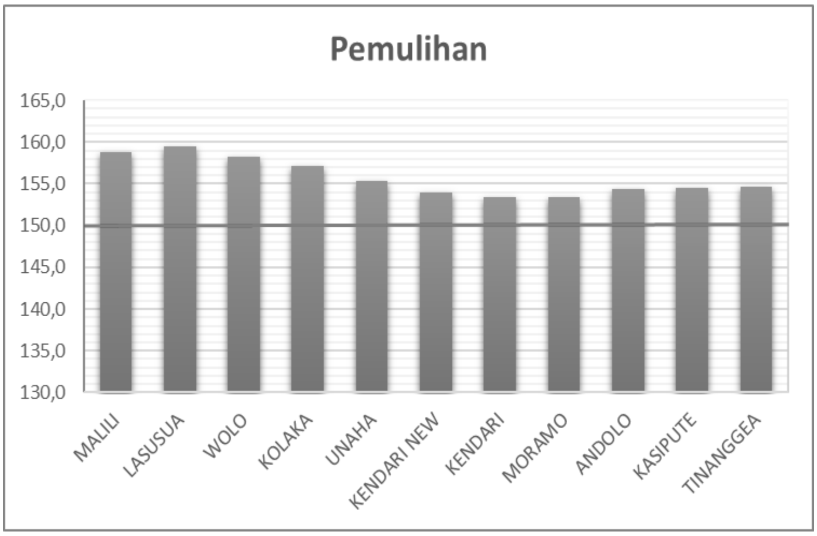

Figure 6. Busbar voltage under recovery conditions.

4. Discussion & Conclusion

The simulation results show that under normal conditions, the busbar voltage values are within the allowed limits, with the highest voltage occurring at GI Lasusua. When a contingency condition occurs, nearly all bus voltages increase and are at risk of causing a power outage. Therefore, this situation must be anticipated by implementing load regulation and voltage control. Contingency analysis can serve as a solution for planning power system operations by identifying weak components to minimize the impact of failures that could lead to component disconnection.

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