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Research Article

Study on The Implementation of Overfrequency Generation Shedding (OFGS) In Improving The System Defense Scheme of Sulutgo at The Amurang Power Plant

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Abstract: A The North Sulawesi and Gorontalo (Sulutgo) power system comprises three subsystems or islands: Tanggari Island, Amurang Island, and Gorontalo Island. Each island has an imbalanced composition of generation and load. Consequently, if an island operation scheme is implemented, each island will experience either underfrequency or overfrequency issues. Amurang Island hosts the Amurang coal-fired power plant with a capacity of 2x21.5 MW and 2x27 MW, making it one of the largest power plants in Sulutgo. Therefore, if island operation occurs, Amurang Island's frequency will be affected, necessitating the implementation of an Overfrequency Generation Shedding (OFGS) scheme at the Amurang power plant. In the event of island operation, without an OFGS scheme, the frequency of Amurang Island would reach 54.89 Hz, but with the OFGS scheme in place, the frequency would improve to 50.13 Hz..

Keywords: OFGS Scheme, Island Operation Scheme, Overfrequency

1. Introduction

PLN Load Control Implementation Unit (UP2B) Minahasa System is part of the Sulawesi Transmission and Load Control Main Unit (UIP3B), which manages the electrical load in the North Sulawesi and Gorontalo systems.

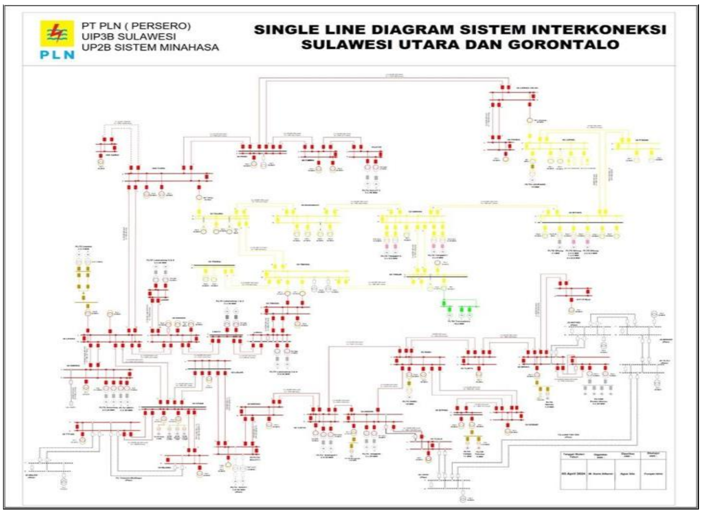

Figure 1. Single Line Diagram of the North Sulawesi and Gorontalo Power System

The Sulutgo system consists of 3 islands or subsystems: the Tanggari subsystem (Island 1), the Amurang subsystem (Island 2),

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and the Gorontalo subsystem (Island 3). The composition of the generation capacity and peak load in the Sulutgo system is as follows:

Table 1. Comparison of Generation and Load in the Sulutgo Subsystem

No	Island	Voltage (kV)	Power Plant DMN (MW)	Load Island (MW)	Difference
1	Tanggari	66	73	94	**-21**
2	Tanggari	150	214,90	61,88	**153,02**
	Total Tanggari		287,90	155,88	**132,02**
3	Amurang	150	236,52	164,93	**71,59**
4	Gorontalo	150	129,35	104,99	**24,36**
	Total		**653,77**	**425,81**	**227,96**

Based on the table above, it can be observed that each island's generation capacity exceeds the load island by a margin of 227.96 MW. If the generators are operated at maximum capacity, the system will experience overfrequency. To prevent this, frequency stabilization at 50 Hz is maintained during operation. However, to prevent potential overfrequency, an Overfrequency Generator Shedding (OFGS) scheme is required. The Under Frequency Load Shedding (UFLS) scheme is an emergency measure applied to prevent system collapse in the event of a large generation deficit relative to demand at a specific time. However, the effectiveness of traditional UFLS schemes may be compromised due to changes in network power flow caused by the growth of distributed generation and the reduction of system inertia [1].

Based on the load flow simulation results of the Sulutgo system, the amount of power transfer between islands can be determined, allowing the identification of islands with generation supply shortages. Below is the transfer power between islands:

Table 2. Power Transfer at the Transfer Points Between Islands

No	Transfer	Transfer Point	Load (MW)
1	Island 1 (Tanggari) ke Island 2 (Amurang)	Likupang – Paniki	-23,7
		Ranomuut – Teling	-36,6
		Tomohon - Teling	-23,2
		Kawangkoan - Lopana	-6,6
2	Island 2 (Amurang) ke Island 3 (Gorontalo)	Boroko – Tanjung Karang	-24,4
	Total Transfer from Island 1 to Island 2		**-90,1**
	Total Transfer from Island 2 to Island 3		**-24,2**

Island 1 receives 90.1 MW from Island 2, indicating that the generation load on Island 1 is lower than the load on Island 2, which necessitates power transfer from Island 2. Meanwhile, Island 2, in addition to sending power to Island 1, also receives power transfer from Island 3. This occurs because Island 1 has a high load characteristic, causing the load to flow towards Island 1. On Island 2, power supply at GI Otam, GI Lolak, GI Molibagu, and GI Boroko comes from transfers from Island 3. If an islanding scheme occurs, the power supply on Amurang Island will exceed the load, leading to overfrequency.

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In cases of small discrepancies between generation and load, Automatic Generation Control (AGC) adjusts the generation set point from the isolated grid to balance generation and load for frequency stability [2].

The interconnected multi-area power system has become inevitable with the increasing size and capacity of modern power systems. The interconnection and complexity of modern power systems can increase the risk of overfrequency issues in the electrical grid [3].

The most convenient method to mitigate overfrequency is to shut down generators when the frequency exceeds a predetermined threshold. In other words, when the electrical frequency rises above a certain threshold, the generators will be automatically turned off to help balance the frequency in the system [4]. To prevent future power outages, it is crucial to design protection schemes that can quickly restore system stability. In this scenario, load shedding and generator disconnection are necessary as they help rapidly reduce load and generation capacity [5].

If the system frequency exceeds 52 Hz, the generator over-speed protection relay will disconnect it from the grid, ultimately leading to a system outage. The most important decision regarding generator shutdown is determining which generator should be shut down first. This is because the effects of shutting down steam turbine generators, hydro turbine generators, and wind turbine generators can differ significantly in terms of peak frequency and the rate of change in frequency after the generator is turned off [6].

The defense scheme is divided into several sections, including Manual Load Shedding, UFR Load Shedding, Island Operation, and Host Load [7].

2. Materials and methods

The research method used for the study of implementing overfrequency generator shedding at the Amurang Power Plant is through simulating an islanding scheme using the DigSILENT PowerFactory 2022 application. DigSILENT PowerFactory 2022 is an application used to analyze electrical power systems. By using this application, changes and responses in electrical parameters can be observed in a case study. Below is the modeling of the Amurang Power Plant in the Sulutgo system using the DigSILENT PowerFactory 2022 application:

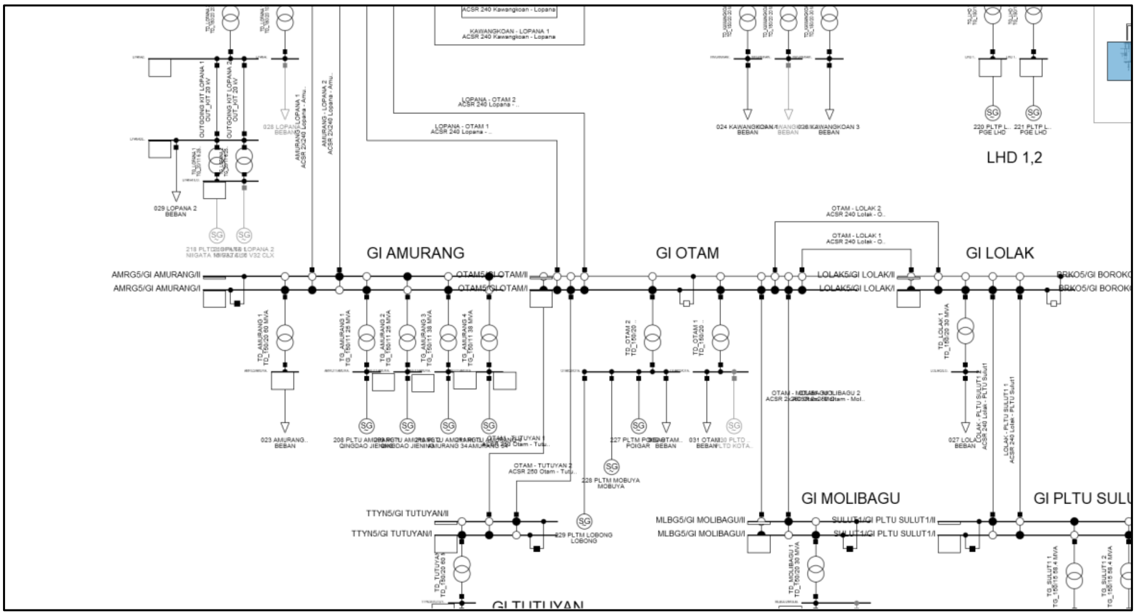

Figure 2. DigSILENT Model of the Amurang Power Plant

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Below is the flowchart for conducting the OFGS implementation study at the Amurang Power Plant:

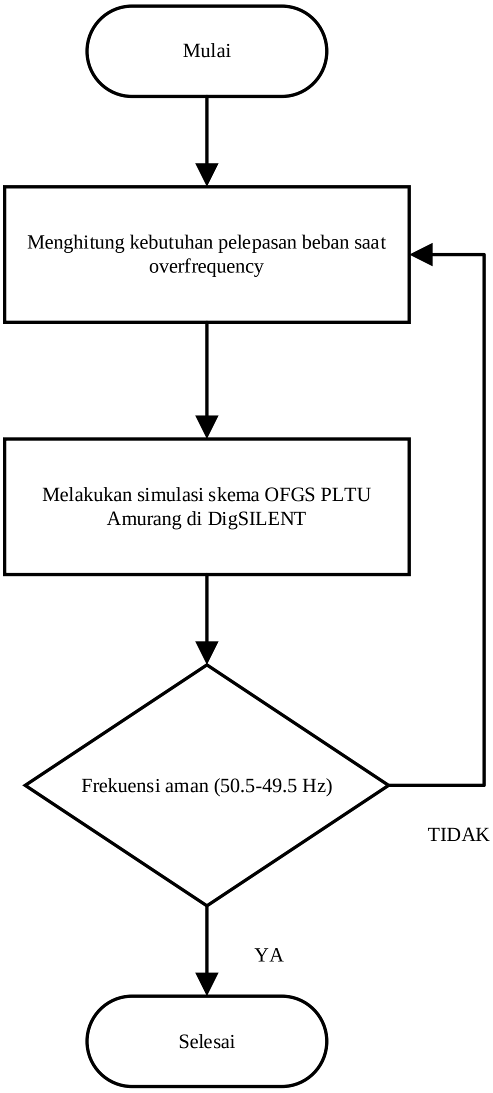

Figure 3. Flowchart of the OFGS Implementation Study for the Amurang Power Plant

3. Results and discussion

The Amurang Coal Power Plant has 2 units with capacities of 2x21.75 MW and 2x27 MW, making it one of the major power plants in the Sulutgo system. Therefore, if an islanding scheme occurs, the large supply from Amurang will cause overfrequency. The goal of Island Operation is to prevent the system from experiencing a blackout or total power outage [8].

In general, generator trip units are classified based on various criteria such as economic issues, dynamic response, availability at minimum load, and recovery time [9]. The application of appropriate delay times, the correct generator capacity tripping, and the avoidance of low-frequency load shedding have been prioritized for overfrequency mitigation [10]. The Overfrequency Generator Shedding (OFGS) scheme at the Amurang Power Plant is divided into 2 stages, which involve disconnecting generators when overfrequency occurs up to 51.5 Hz and 51.8 Hz. Each stage will disconnect the Amurang power plant as detailed in the following table:

Table 3. OFGS Settings for Amurang Power Plant

Stagge	Target	Load	Frequency Set	Time Dial
	PLTU Amurang #1	16 MW	51.5 Hz	Instant
Stage 1	PLTU Amurang #2	16 MW	51.5 Hz	Instant
	PLTU Amurang #3	20 MW	51.5 Hz	Instant
	Total	**52 MW**		
Stage 2	PLTU Amurang #4	20 MW	51.8 Hz	Instant
	Total	**72 MW**		

The plan to install the OFGS relay will be carried out at the Amurang Coal Power Plant with the following illustration [11]:

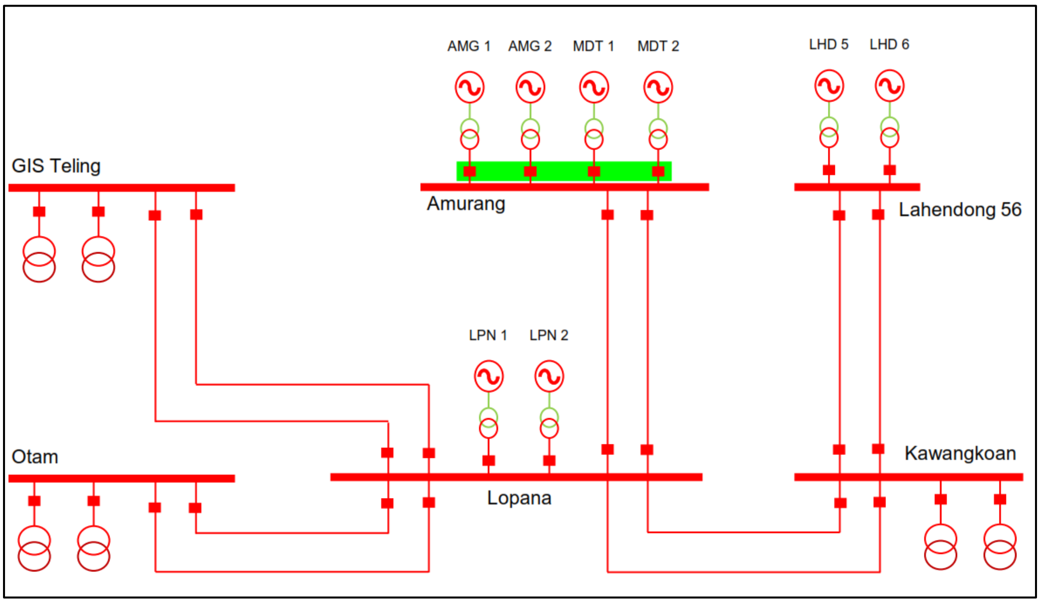

Figure 4. Plan for Installing OFGS Relay at Amurang Coal Power Plant

Based on the simulation results in DigSILENT PowerFactory, an islanding scheme was implemented by disconnecting the Sulbagut-1 Coal Power Plant by 2x40 MW, causing the UFR Island scheme to work and separate each island in the Sulutgo system.

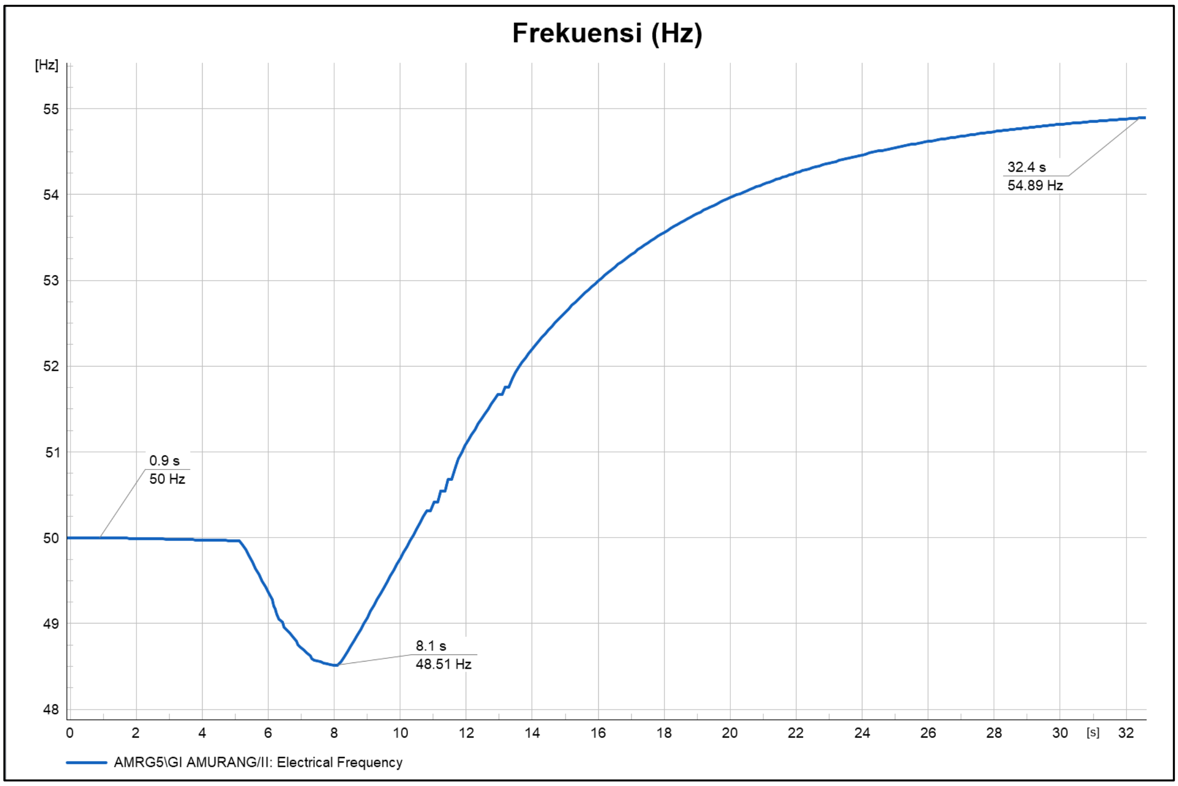

Figure 5. Frequency Without the OFGS Scheme at Amurang Coal Power Plant

In the simulation results, when the Sulbagut-1 Coal Power Plant (PLTU) trips by 2x40 MW without the OFGS scheme, the frequency on the Amurang island will drop to 48.51 Hz, causing the island operation scheme to activate. On the Amurang island, the frequency will then rise to 54.89 Hz, resulting in overfrequency. This will trigger the overfrequency relay, which serves as protection for the power plant's generator.

The system frequency can increase significantly, prompting the operation of overfrequency generator disconnect switches. This cyclical process can lead to a system collapse and power outage, causing substantial economic losses [12].

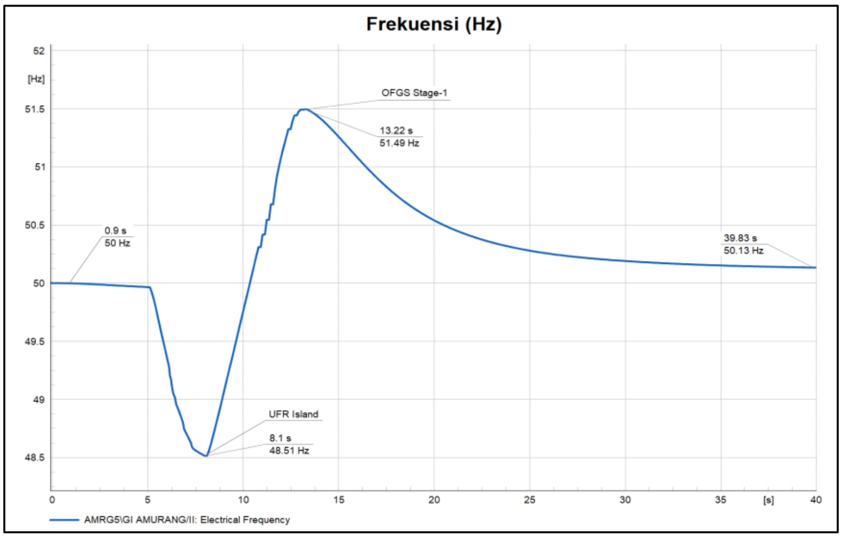

Figure 6. Frequency with the OFGS Scheme at Amurang Coal Power Plant

In the simulation results, when the Sulbagut-1 Coal Power Plant (PLTU) trips by 2x40 MW with the OFGS scheme, the frequency on the Amurang island will drop to 48.51 Hz. Then, when the frequency reaches 51.49 Hz, the first stage of the OFGS scheme operates by disconnecting Amurang Coal Power Plant Unit 1, Unit 2, and MDT 1. As a result, the frequency stabilizes at 50.13 Hz, within the safe range according to the grid code regulations [13] [14] [15].

4. Conclusion

Based on the results obtained from the simulation and analysis in this case study, the following conclusions can be drawn:

1. The condition of each island in the Sulutgo system has an imbalanced composition between the generation load and the demand load. Therefore, if an island operation scheme occurs, the islands in the Sulutgo system will experience underfrequency and overfrequency.
2. After the OFGS scheme is installed at the Amurang Coal Power Plant (PLTU), it will improve the frequency experiencing overfrequency from 51.49 Hz to 50.13 Hz.

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