Evaluation of Power Distribution based on Power Losses on Transmission Interconnection

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Abstract

This paper discusses the analysis of continuity of power delivery and network losses in the scenario of adding 150 kV to the Malang Raya transmission network. The discussion in this paper is based on the increasing load growth conditions in Malang Raya and the condition of the Malang 150 kV main system which is centralized in the Kebonagung Substation so that a scenario of adding 150 kV transmission network interconnection is needed to increase the capacity, reliability, and improvement of the Malang Raya system. Based on the simulation results before the scenario of adding 150 kV transmission network losses in the poor 150 kV main system by 0.02 MW, whereas after the scenario of adding 150 kV transmission network the overall losses in the 150 kV main unfortunate main system were 0.009 MW.

Keywords
Interconnection transmission network, Network addition scenario, Continuity of power distribution, Network losses.

1. Introduction

To date, the development in Greater Malang is at a high time, particularly in tourism, industries, and education; hence, new loads appeared. Besides, the huge project in the north and south area also supports the load growth [1]–[6]. The 150 kV primary system in Greater Malang is a central network system with the power distribution center located in Kebonagung Main Substation. The transmission network interconnected connects the JAMALI system power grid that is distributed through Lawang-Kebonagung Main Substations, PLTA Sutami-Wlingi that is distributed through the Sutami-Kebonagung Main Substations, Kebonagung-Sengkaling Main Substations, and Kebonagung-Pakis Main Substations. The primary system in Greater Malang serves three cities' load: Malang city overloads the Kebonagung Main Substation, Malang Regency overloads the Pakis Main Substation, and Batu City overloads the Sengkaling Main Substation.

Added with the central system topology, Sengkaling Main Substation and Pakis Main Substation depend on the condition of Kebonagung Main Substation. This situation influences the electricity condition of Greater Malang in the future. The increasing load could create overcapacity in Kebonagung Main Substation. In turns, the overcapacity creates further damage and disruption in Kebonagung Main Substation and disturbs the power distribution in Sengkaling and Pakis Main Substations. There needs an additional 150 kV transmission network interconnection that connects the Lawang-Pakis Main Substations, Lawang-Sengkaling Main Substations, Sutami-Sengkaling Main Substations, and Sutami-Pakis Main Substations to improve the capacity, reliability, and refinement of the system. Other than that, the scenario could produce an alternative power distribution scenario and losses analysis before and after the additional 150 kV transmission network.

2. Interconnection Network

Network interconnection connects several substations through an electrical network that serves the load in the electricity system [4], [7]–[9]. The interconnected network system that is used in Indonesia is 70 kV, 150 kV, and 500 kV. The advantages of the interconnected system are below:

- continuous reliability of electricity service,
- generator center does not need to work optimally to serve the load in a system with the interconnected network,
- power plants supplying electricity to one another through a central load regulator.

The 150 kV transmission network interconnection system is used in a transmission network with medium to the medium range at a considerable amount of power or energy. Network losses is a gap between the distributed energy with the used energy. Network losses can be categorized based on technical and non-technical losses [10]–[12]. Technical loss is caused by the network material or devices, while non-technical loss is caused by faulty installation and damage to material or network equipment. The material type and the length influence the magnitude of the transmission line reactant, and in turn, affect the transmission loss. Besides, the amount of current that stream in a transmission line also influences the loss because a loss is the result of multiplication between squared current with line reactant [13]–[15]. Therefore, higher current in a transmission line creates a more considerable loss. The new transmission line increases the power distribution continuity, reduces loss in the transmission network, and improve the reliability of the power plant system.

The 150 kV primary system in Greater Malang is a central network system with the power distribution center located in Kebonagung Main Substation. The transmission network interconnected connects the JAMALI system power grid that is distributed through Lawang-Kebonagung Main Substations, PLTA Sutami-Wlingi that is distributed through the Sutami-Kebonagung Main Substations, Kebonagung-Sengkaling Main Substations, and Kebonagung-Pakis Main Substations. The primary system in Greater Malang serves three cities' load: Malang city overloads the Kebonagung Main Substation, Malang Regency overloads the Pakis Main Substation, and Batu City overloads the Sengkaling Main Substation.

3. Method

This research aimed to predict the continuity and loses in the scenario of another 150 kV transmission network in Greater Malang. A literature study was used as the base of analysis. The initial design condition simulation is shown in the following figures. Scenario 1 was another transmission network in Lawang-Sengkaling Main Substations, Scenario 2 was a new transmission network in Lawang-Pakis Main Substations, Scenario 3 was a new transmission network in Sutami-Sengkaling Main

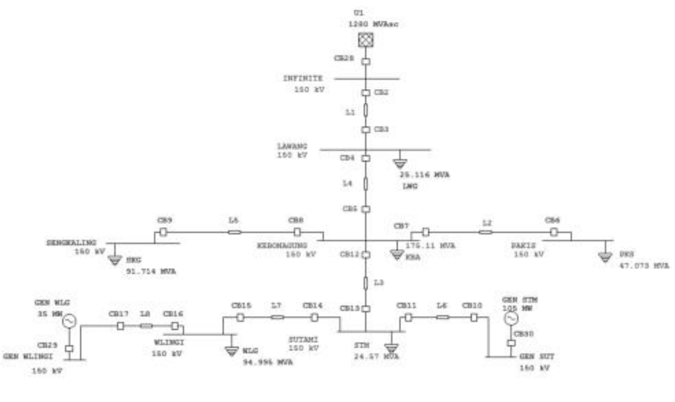

Fig. 1. The Initial Design of the 150 kV Main System in Greater Malang

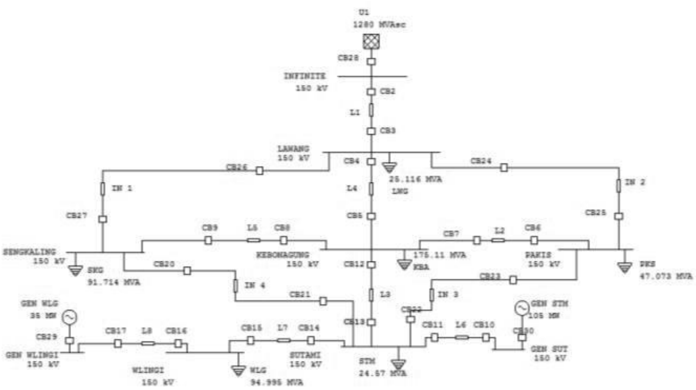

Fig. 2. The Design After Additional 150 kV Transmission Network Interconnection in Greater Malang

4. Result

The additional scenarios were performed through five scenarios. Scenario 1 was a new transmission network in Lawang-Sengkaling Main Substations, Scenario 2 was a new transmission network in Lawang-Pakis Main Substations, Scenario 3 was a new transmission network in Sutami-Sengkaling Main Substations, Scenario 4 was a new transmission network in Sutami-Pakis Main Substations, and Scenario 5 was a combination of the above four scenarios. The purpose of the additional network interconnection was to increase the capacity, reliability, and quality refinement of customer service. Based on Table II, the initial condition stated that the losses were 0.02 MW and -1.012 MVAR, whereas after new interconnection (Scenario 5) the losses changed into 0.009 MW and -1.892 MVAR. The additional transmission network interconnection was simulated using the ETAP 12.6.0 software.

TABLE 1. AMP FLOW (A) AND LOSSES (KW) IN A TRANSMISSION LINE

Id	Before New Interconnection		After New Interconnection	
	Amp flow (A)	Losses (kW)	Amp flow (A)	Losses (kW)
In 1	0	0	8.461	0.001
In 2	0	0	37.78	0.015
In 3	0	0	310.9	2.322
In 4	0	0	390.9	2.795
L1	202.8	2.709	97.29	0.623
L2	181.2	0.301	95.65	0.084
L3	1100	16.072	506.7	3.405
L4	107.4	0.141	31.75	0.012
L5	353	1.077	45.81	0.018
L6	1193	0.092	1297	0.109
L7	1.126	0	1.242	0
L8	366.4	0.009	366.5	0.009

Table I displays the amp flow and losses condition in each line, before and after. Figure 2 shows the initial design, while Figure 3 presents the design after a new interconnection. Table I shows that the losses in L1–L5 transmission line after new interconnection was reduced. This reduction occurred because of the new power distribution scenario. The decrease in the current amount that flows through the line also meant a decrease in losses. Meanwhile, the current that flew in the L7 transmission line experienced an increase after new interconnection because the power distribution was given by the closest source, the PLTA Wlingi. Table II presents the Loading (MW) and Amp loading (A) condition in a bus before and after scenarios. Based on that table, the buses experienced an increase and decreased in both conditions. Similar to the explanation for Table I; these conditions were caused by the scenario.

The data in Table III is the simulation results after the additional new network in Lawang-Sengkaling (Scenario 1), Lawang-Pakis (Scenario 2), Sutami-Sengkaling (Scenario 3), and Sutami-Pakis (Scenario 4). The data explained the effect of additional interconnections to the system when the addition was performed in stages. Additional interconnection in Lawang-Sengkaling (Scenario 1) and Lawang-Pakis (Scenario 2) did not show significant power flow. This occurrence was caused by the new interconnected influenced the closest location, and in this case, was Jamali-Lawang and Lawang-Kebonagung system power grid. New transmission network in Scenario 3 and 4 experienced capacity increase in Sutami and Wlingi generations because the new transmission was located closer. Therefore, to meet the overall load in the generator, there needed a capacity improvement in the power plant.

Based on the analysis, it can be concluded that due to Scenario 5, if there are network maintenance and repairment or disruption, the power distribution could still work continuously by diverting the power distribution to the possible alternative line. In this case, they are Scenario 1, Scenario 2, Scenario 3, and Scenario 4. Thus, the primary system in Greater Malang would no longer be centered in Kebonagung Main Substation and the load growth would not result in overcapacity.

TABLE II. LOADING (MW) AND AMP LOADING (A) IN BUSBARS BEFORE AND AFTER SCENARIOS

BUS ID	Before New Interconnection		After New Interconnection	
	Loading (MW)	Amp Loading (A)	Loading (MW)	Amp loading (A)
Sutami Generation	274.634	1193	299.843	1297
Wlingi Generation	79.736	366.4	79.766	366.5
JAMALI system power grid	46.639	202.6	21.421	97.12
Kebonagung	275.619	1207	155.24	674
Lawang	46.637	202.8	31.07	133.2
Pakis	41.167	181.2	75.023	310.9
Sengkaling	79.225	353	90.856	396.6
Sutami	274.86	1194	300.097	1298
Wlingi	79.736	366.4	79.766	366.5

TABLE III. CONDITION RESULTS IN EACH SCENARIO

ID	Initial	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Load- MW	401.01	401.01	401.01	401.02	401.02	401.03
Load- MVAR	220.03	219.91	219.88	219.68	219.79	219.17
Generation- MW	401.01	401.01	401.01	401.02	401.02	401.03
Generation- MVAR	220.03	219.91	219.88	219.68	219.79	219.17
Loss- MW	0.02	0.02	0.02	0.015	0.012	0.009
Loss- MVAR	-1.012	-1.129	-1.166	-1.372	-1.267	-1.892

5. Conclusion

Additional scenarios were needed to increase the power distribution continuity, improve the capacity, reliability, and refinement, and reduce losses in the primary system. There were five scenarios. Scenario 1 was an additional transmission network in Lawang-Sengkaling Main Substations, Scenario 2 was an additional transmission network in Lawang-Pakis Main Substations, Scenario 3 was an additional transmission network in Sutami-Sengkaling Main Substations, Scenario 4 was an additional transmission network in Sutami-Pakis Main Substations, and Scenario 5 was a combination of the above four scenarios. If these scenarios were realized, the 150 kV primary system would not be centered in one main substation but interconnected to all primary substations. Thus, there were higher power distribution continuity and lower losses with a value of 0.009 MW.

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