Voltage Improvement on the Feeder Using the Load Breaking Method

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Abstract – *Based on observations made by PT. PLN (Persero), Plumpang Feeder has a large voltage drop and high-power loss. To analyze in more detail, a simulation was carried out using ETAP (Electrical Transient Analysis Program) software. The results of the ETAP simulation, the Plumpang Feeder has end voltage of 19,083 V from a nominal voltage of 20,000 V. The voltage drop is -4.58% and the power loss is 594.7 kW or -1122kVAR. To overcome this problem, a load split or breaking method is carried out by moving some of the load of the Plumpang Feeder to the New Plumpang Feeder so that the total load current of the Plumpang Feeder will decrease and the voltage drop and power loss will also decrease. The Load Breaking Method is carried out at each Cut Off (CO) Branch where the loads to be moved. After the Load Breaking Method is applied, based on ETAP simulation results, the end voltage at Plumpang Feeder increased from 19.083 V to 19.307 V or have a change in voltage drop from -4.58% to -3.47%. The power loss decreased from 594.7kW to 92.4kW or experienced a change in power loss from 0.0129% to 0.0043%.*

Keywords: *ETAP simulation, load breaking method, Plumpang Feeder, power loss, voltage drop*

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I. Introduction

Electrical energy is distributed starting from generation, transmission, until it is available to consumers through the distribution network [1]-[2]. In distribution network there are several important parts, such as medium voltage lines (overhead lines or ground cables), medium voltage distribution substations and transformers. The distribution network in Indonesia is divided into two parts, namely the primary distribution network for medium voltage networks (20 kV) and the secondary distribution network for low voltage networks (220V/380V) [3].

An electric power supply company in Indonesia named PT. PLN (Persero). Tuban Customer Service Unit of PT. PLN (Persero) gets a lot of customer complaints because voltage drops often occur which are detrimental to the consumer side and can reduce the performance and reliability of the power system. Based on observations made by the company, Plumpang Feeder has a high voltage drop and high-power loss. Voltage drop is the amount of voltage lost in a network conductor that occurs due to the length of a conductor in a medium voltage distribution line [4].

To analyze these problems in more detail, a simulation was carried out using the Electrical Transient Analysis Program (ETAP) software. A full-spectrum analytical engineering software provider, ETAP software specializes in the analysis, modeling, monitoring, control, optimization, and automation of electric power systems. The most complete and integrated system enterprise solutions, from modeling to operations, are provided by ETAP software [4]-[5]. Based on the ETAP simulation, the Plumpang Feeder has a large end voltage on the Medium Voltage Network of 19,083 V from a nominal voltage of 20,000 V or in other words there is a voltage drop of -4.58%. At a distribution voltage of 20 kV specified in SPLN 1:1995, the standard voltage fluctuation is within the range of +5 to -10% of the nominal voltage [6]-[7]. There is also a power loss of 594.7 kW or -1122kVAR. According to SPLN 72:1987 standard, the maximum power loss limit is -10% [8]. The voltage drop across the conductor will be greater if the current in the conductor is higher [9].

To reduce the voltage-drop, there are several methods that can be done, including uprating the conductor capacity, the load-breaking or load-splitting method, setting the OLTC transformer in the substation [11]-[12]. The load breaking method is considered to have a high level of efficiency from the conductor uprating method. This is because the conductor uprating method requires two processes, they are decreasing and increasing the capacity of the conductor, while splitting the load only increases the capacity of new conductors by moving the connections of some loads to other feeders or new feeders. The end voltage can also be corrected by changing the OLTC. However, the drawback of OLTC is that the load which is located close to the distribution transformer whose OLTC is changed will experience an increase in voltage which has the potential to experience overvoltage on the load [13]-[15].

Based on the problems existing and previous researches, this research aims to improve the voltage on the Plumpang Feeder side using the load breaking method. It is expected that with the improvement of the voltage at Plumpang Feeder, the voltage drop will be reduced and the power losses will also decrease.

II. Methodology

A. Single Line Diagram of Plumpang Feeder

Plumpang Feeder has 59 Poles Transformer Substations with a total of 20,612 customers. This feeder is supplied by the Tuban substation. The construction of the Plumpang feeder network is an air duct of the AAAC type measuring 70.110 and 150 mm^2. The single line diagram of the Plumpang Feeder can be seen in Fig. 1.

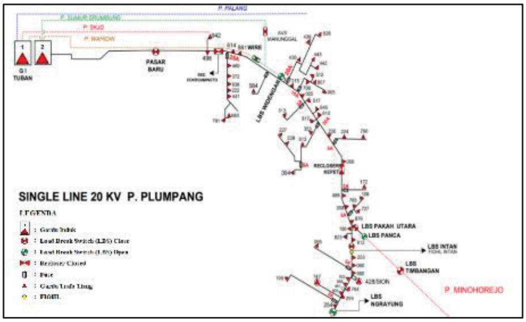


Fig. 1. Single line diagram of the Plumpang Feeder

To find out the voltage of the Plumpang feeder in more detail, the feeder is divided into 5 sections at Pasar Baru LBS, Cokroaminoto Recloser, Kepet Recloser, Intan LBS, and Ngrayung LBS as can be seen in Fig. 2. The voltage value at Ngrayung LBS is the end voltage of the Feeder Plumpang.

B. Load Breaking Method Scenario

The load breaking method is a method to reduce the voltage drop losses that occur in a feeder, carried out by removing some of the loads connected to the feeder so that the electric current flows less and the voltage drop will decrease. The load breaking method that is carried out at the Plumpang feeder is by releasing the load at each Cut Off (CO) Branches. There are eleven CO Branches with locations as can be seen in Fig. 3. The load released from the Plumpang Feeder will be connected to a new feeder, namely the New Plumpang Feeder where the feeder is an express feeder from the Tuban Substation directly.

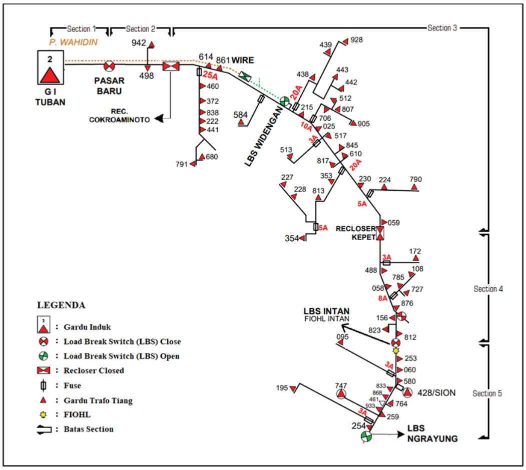


Fig. 2. Sections of Plumpang Feeder

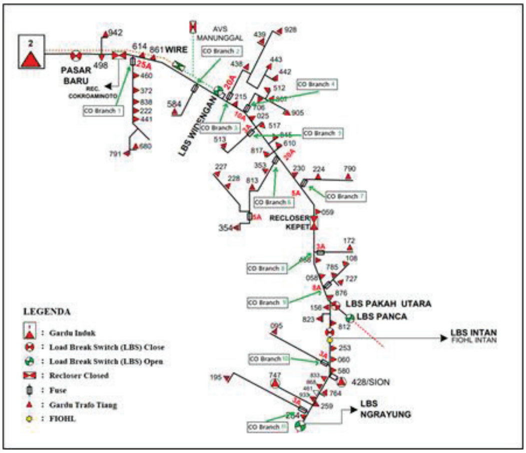


Fig. 3. CO Branches position at Plumpang Feeder

C. Modelling of Plumpang Feeder in ETAP

Based on the single line diagram in Fig. 1, Plumpang feeder model was made in ETAP. The data entered into ETAP is cable data and measured value of voltage and load current at each transformer substation pole. The analysis used in this research is power flow analysis to determine the characteristics of power flow in the power system. Modeling and simulation are carried out at the initial condition of the feeder, before the system is repaired using the load breaking method at each Cut Off (CO) Branch, and after the system is repaired. Model of the Plumpang Feeder before the load breaking method was applied can be seen in Fig. 4 and before the load breaking method was applied can be seen in Fig. 5. ETAP simulation results can be considered valid because the components used in ETAP have been adjusted to real data from PT PLN (Persero) such as conductor length and size, transformer power and feeder loading.

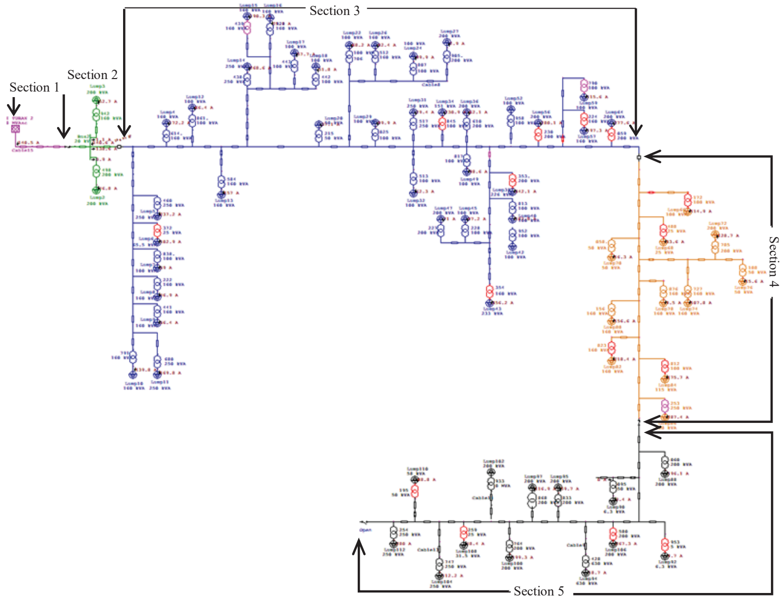


Fig. 4. The Plumpang Feeder Model in ETAP before the load breaking method was applied

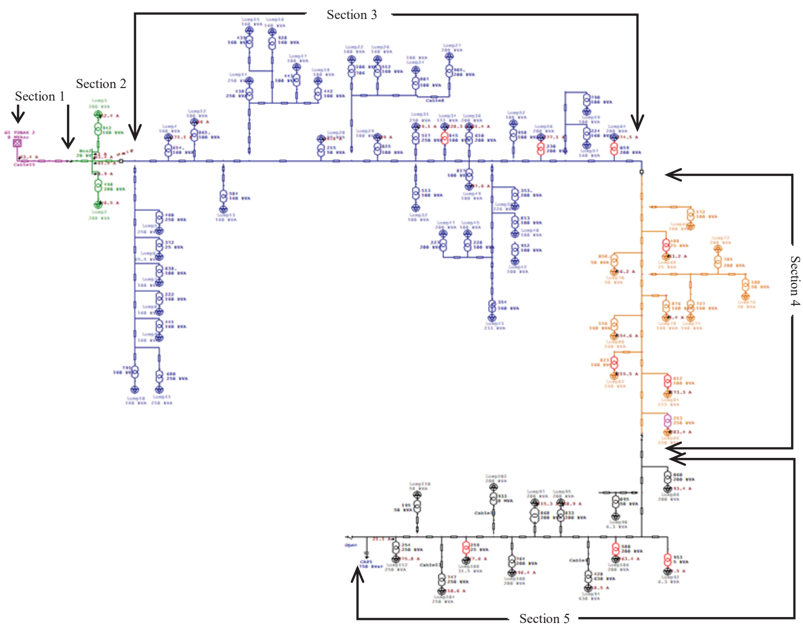


Fig. 5. The Plumpang Feeder Model in ETAP after the load breaking method was applied

III. Result and Discussion

Prior to the reconfiguration using the load breaking method, based on the simulation results at ETAP, the voltage at the end of the Plumpang Feeder was 19.083V as shown in Fig. 6.

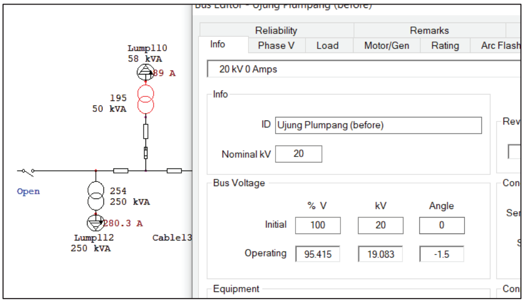


Fig. 6. ETAP Simulation Results of Plumpang Feeder End Voltage at Initial Conditions

Plumpang feeders have a total power loss of 594.7 kW of the total power delivered of 4,458 MW as shown in Fig. 7.

PLUMPANG FULL BEFORE — Study Case: LF

CKT / Branch	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage	
ID	MW	Mvar	MW	Mvar	kW	kvar	From	To
Line159	-0.281	-0.206	0.281	0.206	0.0	-0.1	95.4	95.4
Line146	0.256	0.187	-0.256	-0.187	0.0	0.0	95.4	95.4
Line72	4.440	1.653	-4.415	-1.628	25.4	24.2	99.5	98.8
Line243	-4.440	-1.653	4.451	1.666	10.3	13.1	99.5	99.8
					594.7	-1122.3		

Fig. 7. Power Loss Report of Plumpang Feeder at Initial Condition

The percentage of voltage drop and power loss before reconfiguration are listed in Table I.

TABLE 1
SIMULATION DATA OF VOLTAGE DROP AND POWER LOSS BEFORE RECONFIGURATION

End Voltage	% Voltage drops	P. Losses	% P. Loss
19.083 V	-4.58	594.7 kW	0.0133

The display of the voltage simulation results for sections 1 to 5 before the load breaking method is applied can be seen in Fig. 8 to Fig. 12.

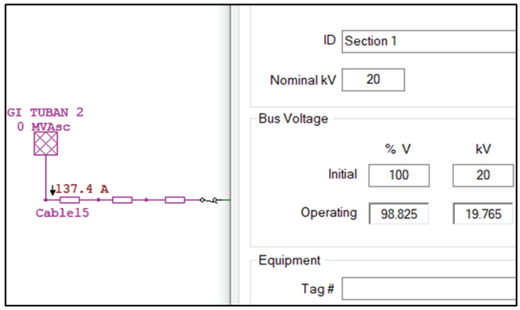


Fig. 8. ETAP Simulation Results of Plumpang Feeder Section 1 before the Load Break Method

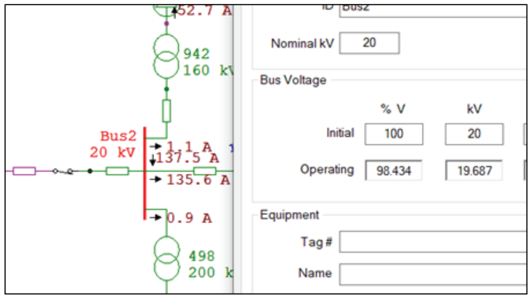


Fig. 9. ETAP Simulation Results of Plumpang Feeder Section 2 before the Load Break Method

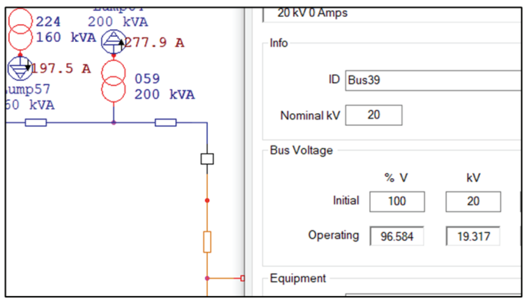


Fig. 10. ETAP Simulation Results of Plumpang Feeder Section 3 Before the Load Break Method

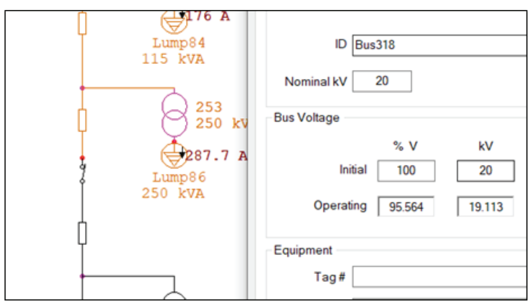


Fig. 11. ETAP Simulation Results of Plumpang Feeder Section 4 Before the Load Break Method

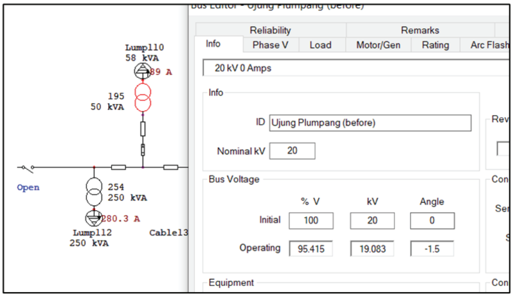


Fig. 12. ETAP Simulation Results of Plumpang Feeder Section 5 Before the Load Break method

After being reconfigured using the load breaking method, based on the simulation results using ETAP, the Plumpang feeder has an end voltage of 19.307 V. Display of the voltage simulation results in sections 1 to 5 after the load breaking method is carried out can be seen in Fig. 13 to Fig. 17.

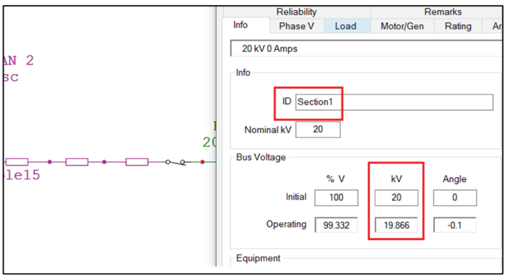


Fig. 13. ETAP Simulation Results of Plumpang Feeder Section 1 after Load Breaking Method

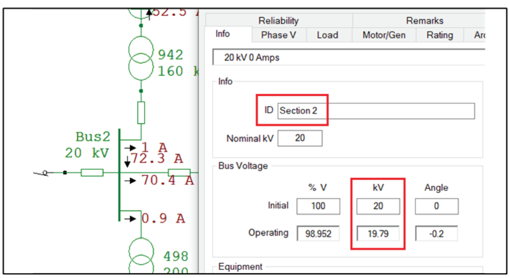


Fig. 14. ETAP Simulation Results of Plumpang Feeder Section 2 after Load Breaking Method

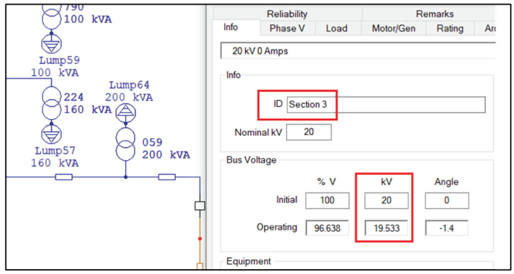


Fig. 15. ETAP Simulation Results of Plumpang Feeder Section 3 after Load Breaking Method

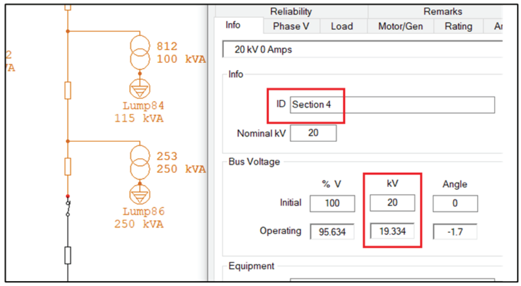


Fig. 16. ETAP Simulation Results of Plumpang Feeder Section 4 after Load Breaking Method

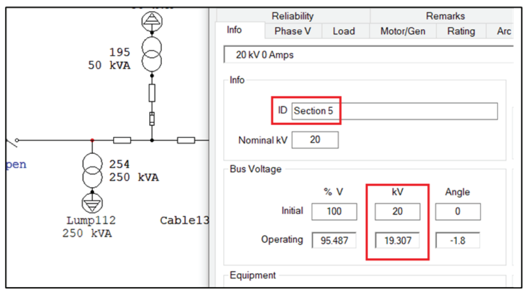


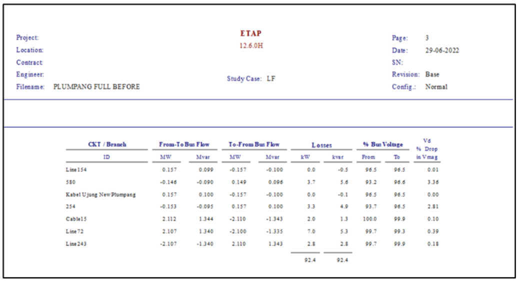
Fig. 17. ETAP Simulation Results of Plumpang Feeder Section 5 after Load Breaking Method

Comparison of the voltage values in each section and the total percentage of voltage drop in all sections can be seen in Table II.

TABLE II
SIMULATION RESULT IN EACH SECTION

Simulation Condition	Voltage at each Section (Volt)					Total percentage of voltage drop across all sections
	S-1	S-2	S-3	S-4	S-5	
Before Load Breaking Method was Applied	19.765	19.687	19.317	19.113	19.083	-4.58%
After Load Beraking Method was Applied	19.866	19.790	19.533	19.334	19.307	-3.47%

The power loss at the Plumpang Feeder also decreased from 594.7 kW or -1122 kVAR (with a total sent power of 4,458 MW) to 92.4 kW or 92.4 kVAR (with a total sent power of 2,112 MW) after load breaking as shown in Fig. 18 to Fig. 19.



Project:
Location:
Contract:
Engineer:
Filename: PLUMPANG FULL BEFORE

ETAP
12.6.0H

Study Case: LF

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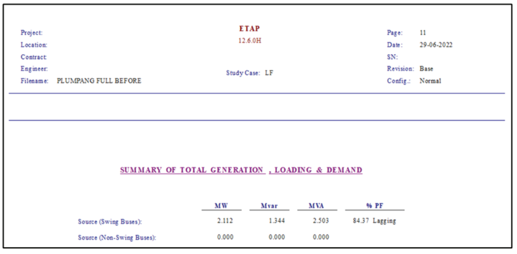
Date: 29-06-2022
SN:
Revision: Base
Config.: Normal

CKT / Branch	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop in Vmag
ID	MW	Mvar	MW	Mvar	kW	kvar	From	To	
Line154	0.157	0.099	-0.157	-0.100	0.0	-0.5	96.5	96.5	0.01
580	-0.146	-0.090	0.149	0.096	3.7	5.6	93.2	96.6	3.36
Kabel Ujung New Plumpang	0.157	0.100	-0.157	-0.100	0.0	-0.1	96.5	96.5	0.00
254	-0.153	-0.095	0.157	0.100	3.3	4.9	93.7	96.5	2.81
Cable15	2.112	1.344	-2.110	-1.343	2.0	1.3	100.0	99.9	0.10
Line72	2.107	1.340	-2.100	-1.335	7.0	5.3	99.7	99.3	0.39
Line243	-2.107	-1.340	2.110	1.343	2.8	2.8	99.7	99.9	0.18
					92.4	92.4			

Fig. 18. Power Loss Report of Plumpang Feeder after the Load Breaking Method



Project:
Location:
Contract:
Engineer:
Filename: PLUMPANG FULL BEFORE

ETAP
12.6.0H

Study Case: LF

Page: 11
Date: 29-06-2022
SN:
Revision: Base
Config.: Normal

SUMMARY OF TOTAL GENERATION , LOADING & DEMAND

	MW	Mvar	MVA	% PF
Source (Swing Buses):	2.112	1.344	2.503	84.37 Lagging
Source (Non-Swing Buses):	0.000	0.000	0.000	

Fig. 19. The Total Sent power from the Substation after the Load Breaking Method

IV. Conclusion

Based on this research, it can be concluded as follows.

1. From the simulation results using ETAP, in the initial conditions, the Plumpang Feeder has an end voltage of 19,083 V and a total power loss of 594.7kW out of a total sending power of 4,458MW.
2. The load breaking method is the method chosen to improve the voltage at the Plumpang feeder by reducing the load so that the current supplied by the substation for the feeder will decrease and the voltage drop value will be smaller. The Plumpang feeder experienced a decrease in total current from 140.5A to 72.3A after the load breaking method was applied.
3. After carrying out the load breaking method, the end voltage of the Plumpang Feeder has increased, based on the ETAP simulation, from 19.083 V to 19.307 V or from -4.58% to -3.47%. Also, the power loss has decreased from 594.7kW with a total transfer power of 4.458MW to 92.4kW with a total transmitted power of 2112MW or a change in power loss from 0.0129% to 0.0043%.
4. From the results of the Load Flow Analysis simulation using the ETAP application, there are several transformers at the Pole Transformer Substation that experience underload and overload. This can be overcome by mutation or exchange of transformers to increase voltage and reduce power losses in addition to repairs using the load breaking method.

Conflict of Interest

The authors declare no conflict of interest in the publication process of the research article.

Author Contributions

Author 1: data analysis and draft editing; Author 2: data verification and draft review; Author 3: consultation and research collaboration; Author 4: project administration.

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