

# Analysis of the Effect of Changes in RLC Load on Transient Stability of Electric Power Systems

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## Abstract

Today, to fulfill human electricity needs, a power system is needed to transmit electrical energy from generators to consumers. The occurrence of disturbances in the network can result in changes in system response for a certain time. Therefore, transient stability analysis is needed to determine the response that occurs in the network. Transient Stability is the ability of a power system to maintain synchronization after experiencing a sudden major disturbance. In this study, the researcher wanted to analyze the effect of the type of RLC load on the transient stability of a power system. Power flow and transient response of the grid network are expressed using ETAP software. As a result, at the beginning generator, is operated under stable conditions, when the new load is connected to the power system, the generator output is changed depending on the load types and there is an oscillation in the generator output.

## Keywords

Power system, Transient stability, RLC Load

## INTRODUCTION

The power system is a complex system consisting of many interconnected generating units and transmission networks [1]. The electric power system has various problems, one of the problems in the electric power system is stability. The stability of an electric power system can be defined as a property that allows synchronous machines in a system to react to disturbances and return to their normal state [2]. The stability of the electric power system can be divided, there are steady state, transient, and dynamic [3].

Changes in system conditions, in general, can be caused by short circuit disturbances in the electric power system, as well as the sudden release or addition of loads [4]. With these changes, each generator is required to adjust its output power according to changes in the load on the system. If this is not done then the power balance in the system will be disturbed and the operating efficiency of the system will decrease.

If the system stability is poor, it not only causes blackouts but also causes serious accidents [5]. In this problem, it takes the ability of a system to withstand disturbances that occur. Transient stability studies provide information on the ability of the system to remain in sync when a disturbance occurs [6]. This evaluation is used as a guarantee that the new power system can meet electricity needs economically, efficiently, and safely. Therefore, an analysis of the stability of the power system is very important to do.

## LITERATURE REVIEW

The Electric Power System is a collection of centers/power plants and substations (load centers) which are connected by a transmission network so that it is an interconnection unit so that electric power can flow as needed [7]. The electric power system consists of several parts including generation, transmission, and distribution. The generator is one component of the electric power system that functions to convert kinetic energy and other energy sources into electricity. The transmission system is a component that functions to transmit electrical energy from the generator to a certain area in an electric power system. While the distribution system is part of the electric power system to distribute electrical energy to consumers. Electrical loads are equipment or components in an electric power system that uses electrical energy to operate. The AC power network has three types of electrical loads that must be supported by power plants, namely resistive loads (R), inductive loads (L), and capacitive loads (C). A resistive load is an electrical load caused by the use of electrical equipment that is purely resistive so that the load does not result in a phase shift of electric current or voltage. The inductive load is the load that results from the use of electric tools that contain wire coils (coils) while the capacitive load is the electrical load created by the capacitor in the electrical equipment used.

The ability of a power grid to recover to an acceptable equilibrium point after a disturbance is known as voltage stability [8]. Transient Stability is the ability of a power system to reach a stable state under new operating

conditions after the system has been disturbed. At the transient stability simulation, the system is dynamically modeled, the events and actions that occur are set by the user, and the solution of network equations and machine differential equations is solved interactively in viewing the response of the system and machine in the time domain. From this response, it is possible to determine the transient character of the system, conduct stability studies, determine the settings for protective equipment, and apply changes to the system to improve stability.

### PROCEDURE

The Electric Power System is a collection of centers/power plants and substations (load centers) which are connected by a transmission network so that it is an interconnection unit so that electric power can flow as needed [7]. The electric power system consists of several parts including generation, transmission, and distribution. The generator is one component of the electric power system that functions to convert kinetic energy and other energy sources into electricity. The transmission system is a component that functions to transmit electrical energy from the generator to a certain area in an electric power system. While the distribution system is part of the electric power system to distribute electrical energy to consumers. Electrical loads are equipment or components in an electric power system that uses electrical energy to operate. The AC power network has three types of electrical loads that must be supported by power plants, namely resistive loads (R), inductive loads (L), and capacitive loads (C). A resistive load is an electrical load caused by the use of electrical equipment that is purely resistive so that the load does not result in a phase shift of electric current or voltage. The inductive load is the load that results from the use of electric tools that contain wire coils (coils). While the capacitive load is the electrical load created by the capacitor in the electrical equipment used.

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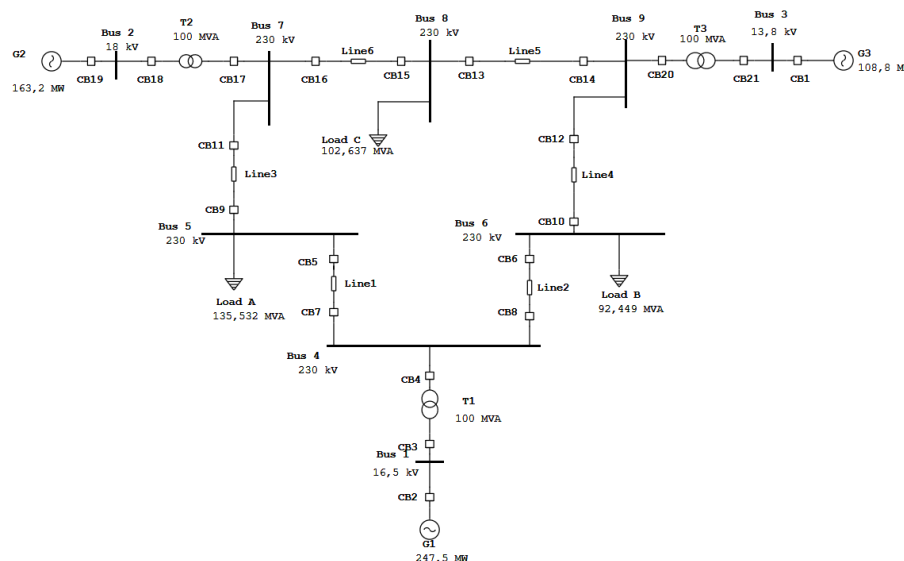


Figure 1. IEEE 9-Bus System

This study discusses the effect of changes in the RLC load on the 9-bus IEEE system. Single line diagram data from the IEEE 9-bus system along with other component data will be simulated using ETAP software. Power flow analysis is an analysis of the calculation of the voltage, current, and power contained at various points in a system.

Power flow analysis can determine the voltage on each bus, also the power that flows in each line of a system. With this power flow analysis, it can be seen whether the condition of the equipment in the system meets the specified limits in distributing electrical energy. Transient stability analysis is an analysis of the response of a system to sudden disturbances. Transient stability analysis in this study will be in the form of a graph of the transient stability response of electrical equipment in the system. From the graph, it can be seen how the response and performance of a system when there is a disturbance in the form of an additional load on the system.

## RESULT

### *Power Flow Analysis Results*

The results of the analysis of the power flow in the 9-bus IEEE system are obtained from the simulation results in the ETAP application. The results of the analysis of the power flow before the additional load occurs when time  $t = 0s$  are as follows:

TABLE I  
RESULT OF LOAD FLOW  $T=0s$

Bus ID	kV	Voltage		Generation		Load	
		%mag.	Ang.	MW	Mvar	MW	Mvar
Bus 1	16.5	104	-2.4	0	0	0	0
Bus 2	18	102.5	6.534	0	0	0	0
Bus 3	13.8	102.5	1,892	0	0	0	0
Bus 4	230	102.573	-4,741	0	0	0	0
Bus 5	230	99.597	-6.56	0	0	123,996	49,598
Bus 6	230	101.177	-6,368	0	0	92,132	30,71
Bus 7	230	102.535	0.971	0	0	0,002	0
Bus 8	230	101,476	-2.101	0	0	102,973	36,04
Bus 9	230	103.182	-0.808	0	0	0	0
G1	16.5	105.685	0	75.69	30.87	0	0
G2	18	105.081	16,978	163	37,539	0	0
G3	13.8	101,846	10,379	85	2,631	0	0

### *Scenario 1*

In this scenario, the used scenario is when  $t=0s$  LoadRR, LoadRL, and LoadRC are disconnected from the circuit. Then at  $t=0.1s$  LoadRR is connected to the circuit, while LoadRL and LoadRC are disconnected. At  $t=1.1s$  LoadRR and LoadRC are disconnected and LoadRL is connected to the circuit. Then at  $t=2.1s$  LoadRC is connected then LoadRR and LoadRL are disconnected from the circuit.

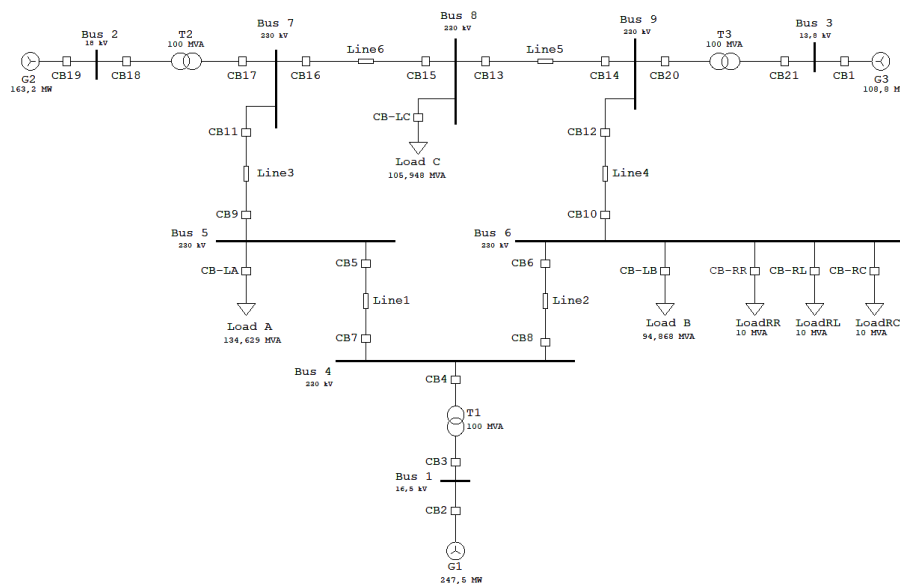


Figure 2. Single Line Diagram for Scenario 1

The results obtained from the simulation obtained a graph of the response of the generator and bus contained in the circuit. The results obtained are as follows:

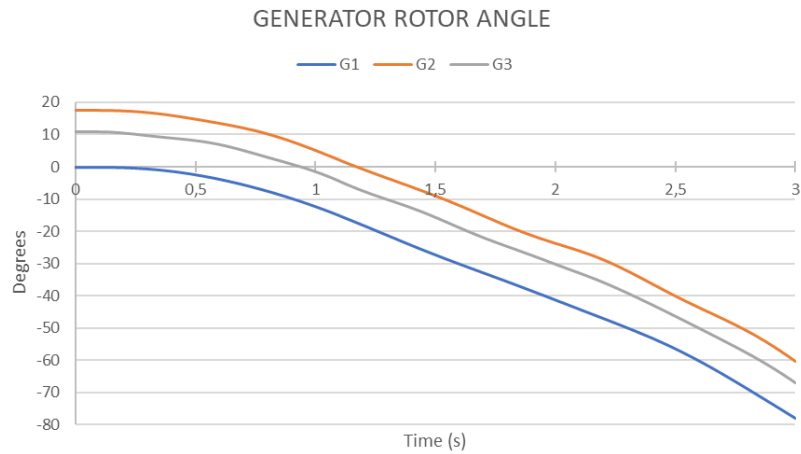


Figure 3. Scenario 1 Generator Rotor Angle

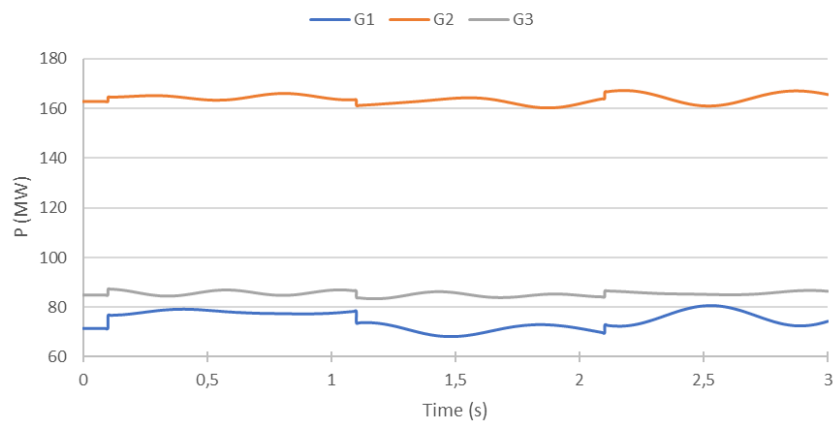


Figure 4. Scenario 1 Generator Electrical Power

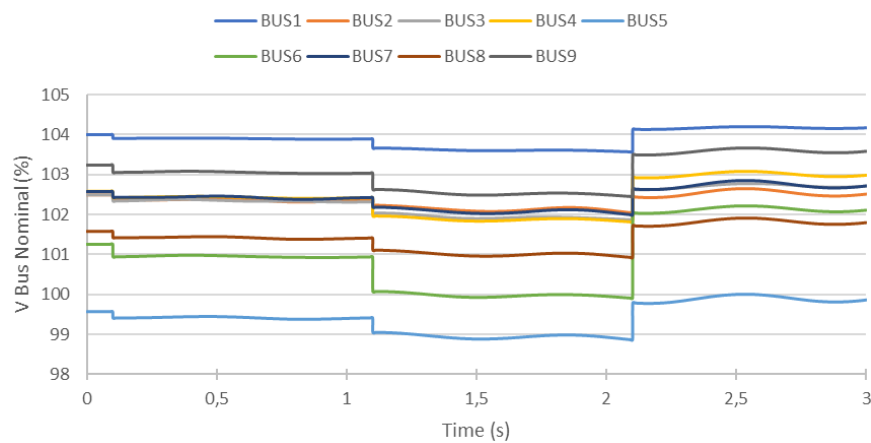


Figure 5. Scenario 1 Bus Voltage

Figure 3 is a graph of the large difference in the rotor angle of each generator in the circuit concerning the reference axis. Based on the graph above, before the load was added, the power angle for each generator was in a

stable state. The rotor angle of the G1 generator is 0 degrees. When there is an increase in the LoadRR load, there is a decrease in the difference in the rotor angle on each generator. At 0.1 seconds, the rotor angle of the G1 generator is 0 degrees and then drops to -14.74 degrees at 1.091 seconds. Then on changing the load to LoadRL, the generator rotor angle continues to decrease and oscillation occurs. The rotor angle of the G1 generator is -15 degrees at 1.1 seconds and continues to decrease to -43.84 degrees at 2.091 seconds. Furthermore, on the replacement of the LoadRC load, it continues to decrease and experience oscillations.

*Scenario 2*

The scenario used is when  $t=0s$  LoadA2, LoadB2, and LoadC2 are disconnected from the circuit. Then at  $t=0.1s$  LoadA2 is connected to the circuit, while LoadB2 and LoadC2 are disconnected. At  $t=1.1s$  LoadA2 and LoadC2 are disconnected and LoadB2 is connected to the circuit. Then at  $t=2.1s$  LoadC2 is connected then LoadA2 and LoadB2 are disconnected from the circuit.

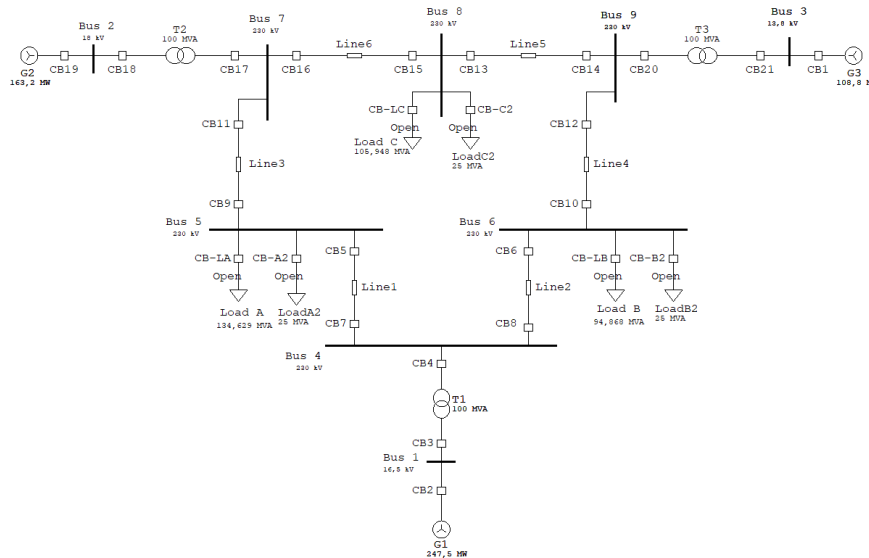


Figure 6. Single Line Diagram for Scenario 2

The results obtained from the simulation on the ETAP application obtained a graph of the response of the generator and bus contained in the circuit. The results obtained are as follows:

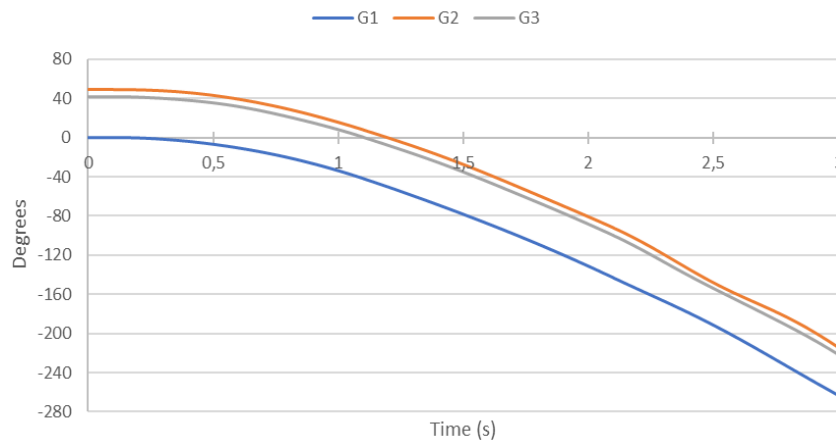


Figure 7. Scenario 2 Generator Rotor Angle

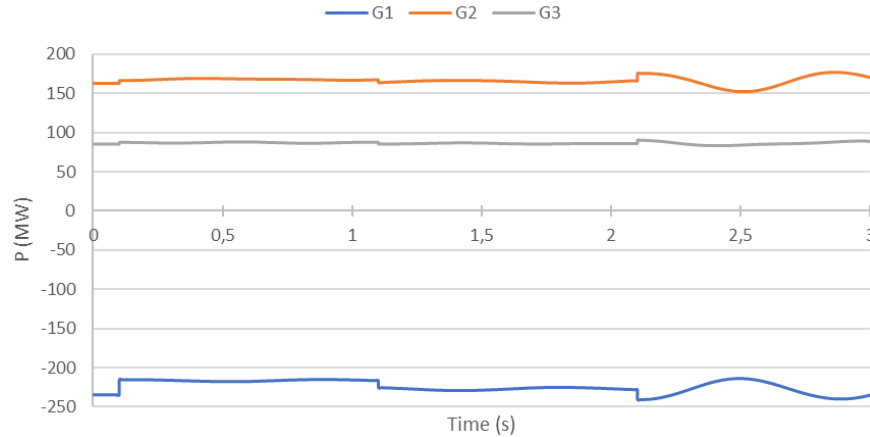


Figure 8. Scenario 2 Generator Electrical Power

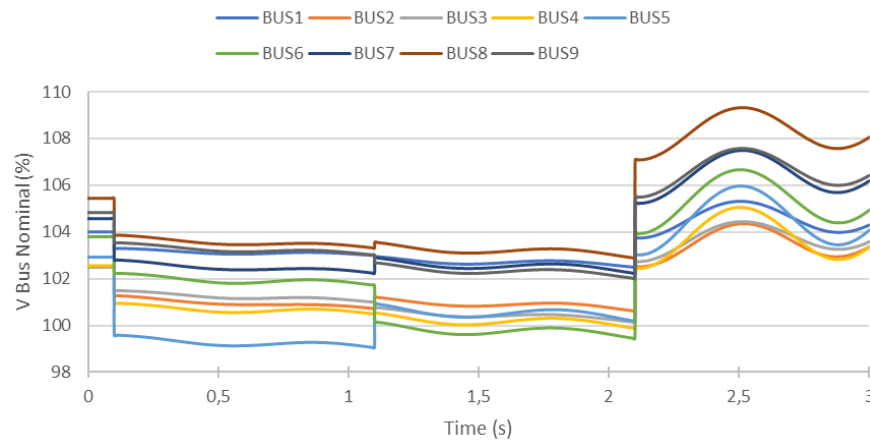


Figure 9. Scenario 2 Bus Voltage

Figure 7 is a graph of the large rotor angle on each generator in the circuit. Based on the graph above, before the load was added, the rotor angle on each generator was in a stable state. The value of the rotor angle in the G2 generator reaches 48.83 degrees. When there is an increase in the LoadA2 load, there is a decrease in the rotor angle on each generator. The rotor angle of the G2 generator at 0.101 seconds is 48.83 degrees, then drops to 7.76 degrees at 1.1 seconds. Then on changing the load to LoadB2, the generator rotor angle continues to decrease. At 1.101 seconds, the rotor angle of the G2 generator reaches 7.6 degrees and then decreases from 2.1 seconds to -92.15 degrees. Furthermore, in the replacement of the LoadC2 load, the rotor angle in each generator again decreases. G2 generator rotor angle continues to decrease from -92.38 degrees at 2.101 seconds become -214.31 degrees in 3 seconds.

### Scenario 3

In this scenario, at time  $t=0s$  LoadA2, LoadB2, and LoadC2 are disconnected from the circuit. Then at  $t=0.1s$  LoadA2 is connected to the circuit, while LoadB2 and LoadC2 are disconnected. At  $t=1.1s$  LoadA2 and LoadC2 are disconnected and LoadB2 is connected to the circuit. Then at  $t=2.1s$  LoadC2 is connected then LoadA2 and LoadB2 are disconnected from the circuit.

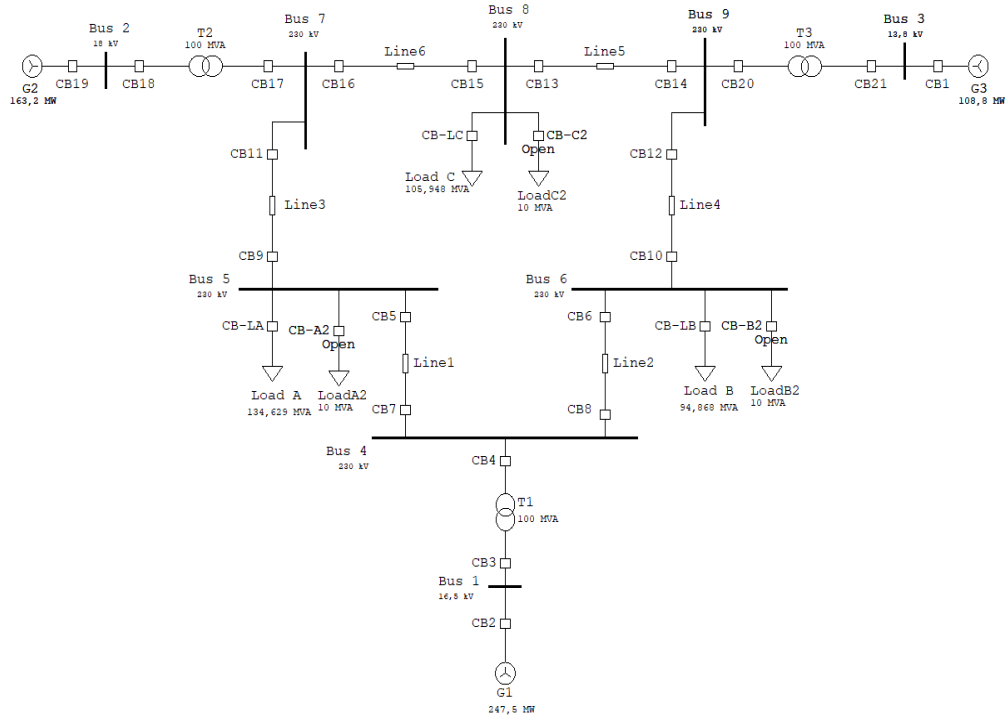


Figure 10. Single Line Diagram for Scenario 3

The results obtained from the simulation obtained a graph of the response of the generator and bus contained in the circuit. The results obtained are as follows:

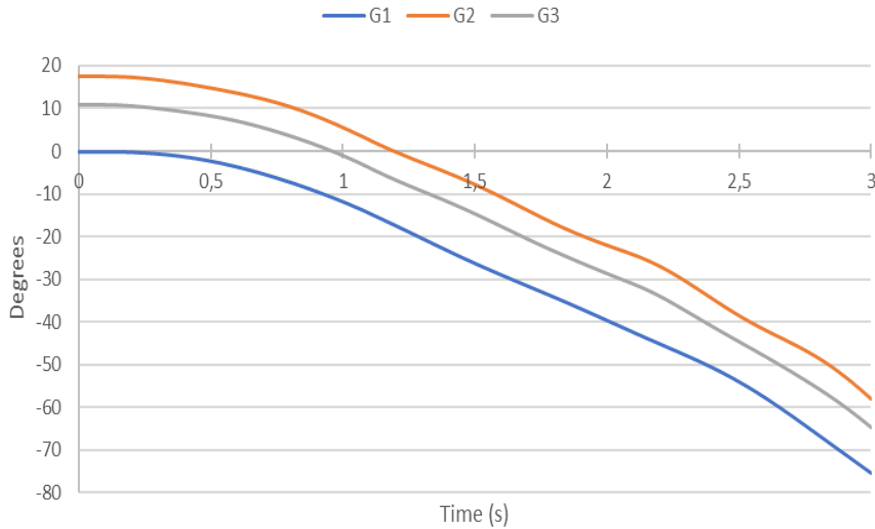


Figure 11. Scenario 3 Generator Rotor Angle

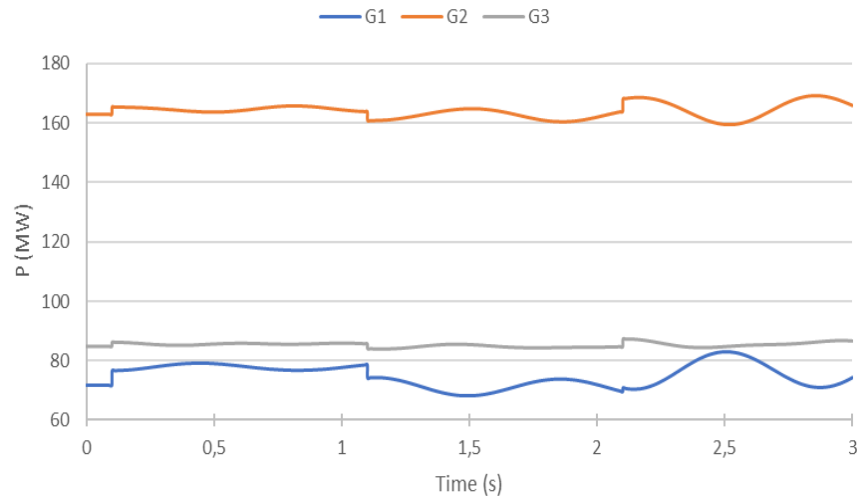


Figure 12. Scenario 3 Generator Electrical Power

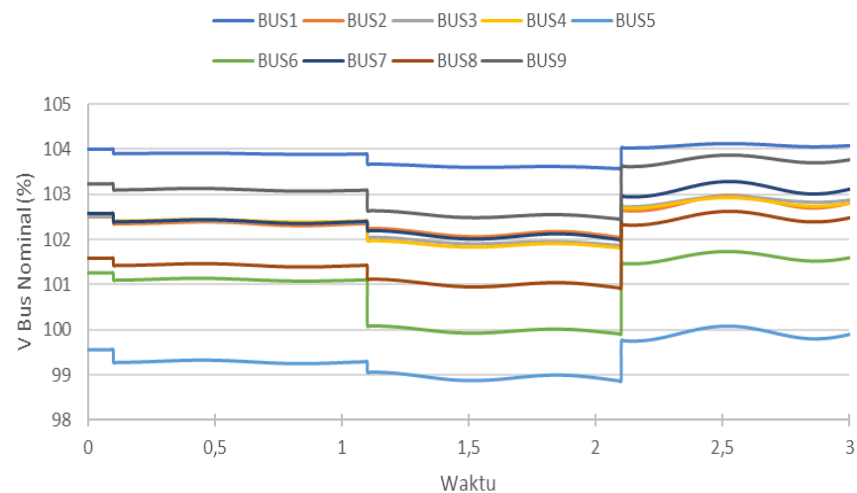


Figure 13. Scenario 3 Bus Voltage

The result shown in Figure 11 is a graph of the rotor angle on each generator. From the graph, before the additional load, the power angle on the generator was in a stable condition. At this time the power angle on the G3 generator is 10.89 degrees. When there is an increase in the LoadA2 load, there is a decrease in the rotor angle on each generator. The rotor angle of the G3 generator decreased because at 0.101 seconds the G3 generator rotor angle was 10.89 degrees reduced to -3.82 degrees at 1.1 seconds. Then on changing the load to LoadB2, the generator rotor angle continues to decrease. The rotor angle of the G3 generator at 1.101 seconds is -3.88 degrees, then drops to -31.09 degrees at 2.1 seconds. Furthermore, on load replacement LoadC2, the rotor angle in each generator again decreases. At 2.101 seconds, the rotor angle of the G3 generator reaches -31.14 degrees and then decreases until at 3 seconds to -64.72 degrees.

## CONCLUSION

The result shows, that at the beginning generator is operated in stable condition. Then, when the new load is connected to the power system, the generator output is changed increasing or decreasing depending on the load types and there is an oscillation in the output which represents the generator's loss of synchronism. When the new

load is changed to another load type, the generator output is changed depending on the new load type and the oscillation in the generator output is enlarged.

### REFERENCES

- [1]. K.R., H., V., M., R., V., & Kurian, A. A. (2015). Analysis of Voltage Stability Enhancement of a Grid and Loss Reduction Using Series FACTS Controllers. IEEE International Conference on Power, Instrumentation, Control and Computing (PICC).
- [2]. Youssef, E., El Azab, R., & Amin, A. (2015). Comparative Study of Voltage Stability Analysis for Renewable Energy Grid-Connected Systems Using PSS/E. Proceedings of the IEEE SoutheastCon 2015. Fort Lauderdale: IEEE.
- [3]. Kumar, G., & Kalavathi, M. (2011). CPF, TDS based Voltage Stability Analysis using Series, Shunt and Series-Shunt FACTS controllers for Line Outage Contingency. 2011 International Conference on Power and Energy Systems. Chennai, India: IEEE.
- [4]. da Costa V.M., N. Martins dan J.L.R. Pereira. 1999. Developments in the Newton Raphson Power Flow Formulation Based on Current Injections. IEEE Transactions on Power Systems, 14(4), 1320-1326. Available: <https://ieeexplore.ieee.org/document/801891>
- [5]. Hridya, K.R dkk. 2015. Analysis of Voltage Stability Enhancement of a Grid and Loss Reduction Using Series FACTS Controllers. 2015 International Conference on Power, Instrumentation, Control and Computing (PICC), Thrissur: 9-11 Desember 2015.
- [6]. Jmii, H., A. Meddeb dan S. Chebbi. 2018. Newton-Raphson Load Flow Method for Voltage Contingency Ranking. 2018 15th International Multi-Conference on Systems, Signals & Devices (SSD), Hammamet: 19-22 Maret 2018.
- [7]. Potingku, J., Tuegeh, M., & Tumaliang, H. (2014). Analisa Stabilitas Transien Untuk Menentukan Waktu Pemutusan Kritis (Critical Clearing Time) Pada Jaringan Transmisi 70 kV PLTA Tanggari II-GI awangan Dengan Menggunakan Program Matlab. e-journal Teknik Elektro dan Komputer.
- [8]. U. Princy, dkk. (2017). Voltage Stability Analysis of Power System Network Integrated With Renewable Source and SVC. International Conference on Innovations in Power and Advanced Computing Technologies..