Evolution in Electrical and Electronic Engineering Vol. 2 No. 2 (2021) 509-515

EEEE

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/eeee
e-ISSN : 2756-8458

Mitigation of Voltage Sag Caused by Single Line to Ground Fault in Distribution System by using Dynamic Voltage Restorer in Matlab/Simulink

Muhammad Afiq Mohamad Rosli[1], Dur Muhammad Soomro[1]*

[1]Faculty of Electrical & Electronic Engineering,
Universiti Tun Hussein Onn Malaysia, Parit Raja, Batu Pahat, 86400, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/eeee.2021.02.02.061
Received 04 July 2021; Accepted 18 July 2021; Available online 30 October 2021

Abstract: Power quality (PQ) has been concern for electrical engineers since last two decades. Distribution system has always been exposed to many type of disturbances. Review shows that about 70% of the faults in power system are of single line to ground fault (SLGF). The major problem that occur in distribution system is voltage sag cause by SLGF. One way to solve the problem is by using power custom devices like dynamic voltage restorer (DVR). In this project, distribution feeder system has been developed with three cases which are steady-state case, SLGF case and mitigation of SLGF cause. The DVR was designed and applied to mitigate the cause. The aim for the project is to mitigate voltage sag based on institute of electrical and electronics engineer (IEEE) standard 1159. The system was developed in MATLAB/Simulink (2018a). The result show that the DVR for compensating voltage sag caused by SLGF is successfully and the performance DVR against voltage sag.

Keywords: Power Quality, Single Line to Ground Fault, Dynamic Voltage Restorer

1. Introduction

Power quality (PQ) is used to measure and sustain the good PQ at the level of generation, transmission and utilization. PQ can be defined as the pollution in supply system in voltage, current and frequency terms. There are several types of PQ problems such as voltage sag, voltage swell, interruption, harmonics, transients, voltage flickers and power frequency variations [1]. The problems of PQ can have a detrimental effect on power system (PS). Review shows that about 70% of the total faults in distribution system is of single line to ground fault (SLGF) [2]. Therefore, it has been a major concern for the electrical engineers.

Fault in PS can produce a voltage sag in certain time. There are two type of PS faults which are open circuit fault and short circuit fault [3]. The open circuit fault can be divided into three cases i.e. one conductor open fault, two conductors open fault and three conductors open fault. Meanwhile for

Corresponding author: dursoomro@uthm.edu.my

the short circuit, there are symmetrical and unsymmetrical faults. In symmetrical faults, there are two cases i.e. three phase or line fault (LLLF) and three phase to ground fault (LLLGF). While for unsymmetrical case it has 3 types of faults i.e. line to line fault (LLF), single line to ground fault (SLGF) and double line to ground (LLGF) [4].

The most fault in the distribution system is SLGF [5]. Due to this fault, even for very short time, voltage sag is produced and its effect will lead to the unbalanced voltage in the system. Mostly faults happen at distribution line due to lightning or falling of trees on overhead lines. Therefore, it is important to focus for a research at distribution networks to mitigate them up based on standards.

Bus bar is one of the terminals in the distribution network feeding many loads. When a SLGF occurs, the voltage at the bus bar will drop and it will face a voltage sag. This also can cause a damage to the bus bar [6]. Thus, the mitigation of voltage sag need to be done. There are certain techniques such as uninterruptible power supplies (UPS), thyristor switched series capacitor (TSSC), static synchronous compensator (STATCOM), static synchronous series compensator (SSSC), thyristor controlled reactor (TCR), thyristor switched series reactor (TSSR) to overcome this voltage sag but in this project dynamic voltage restorer (DVR) is selected because of its advantages like static series conditioning and compensation in the distribution power system level, low maintenance cost and low power rating than shunt connected compensators.

In power system about 70% is the SLGF of total faults. It causes voltage sag which is not only dangerous for the connected load to the line of fault but other lines connected to same bus bar. The voltage sag can damage the distribution system and cause a malfunction to equipment in the system. There are various method that can compensate voltage sag like UPS, TSSC, STATCOM, SSSC, TCR and TSSR. In this project, unsymmetrical fault of SLGF is a caused of voltage sag in the distribution system and located at the busbar. DVR is choose as its mitigation device to mitigate voltage sag. MATLAB/Simulink tool is choosing for simulating the cause and its mitigation. Main objective of this study to design DVR for compensating voltage sag caused by SLGF and to simulate the performance of DVR in distribution system against voltage sag using MATLAB/Simulink

2. Methodology

2.1 Block diagram of process voltage sag mitigation

Figure 1 shows the block diagram of the process for mitigating voltage sag due to SLGF in distribution system. Initially the source will supply to the load in a normal way. Then, the SLGF will be created in distribution system. According to the problem, a DVR will be designed and implemented to compensate the voltage sag. Each stage it will be observed through voltage (V) measurement.

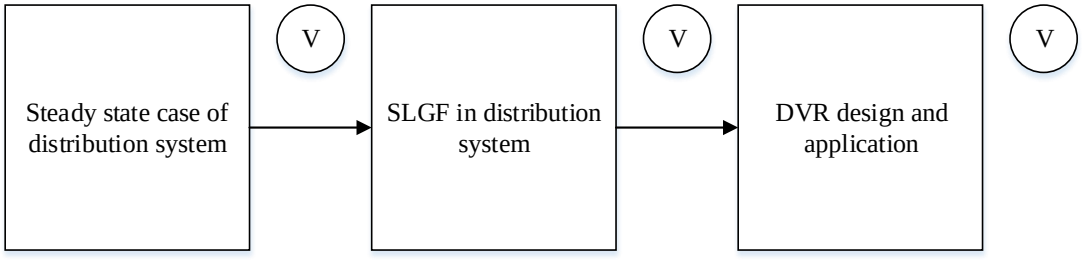

Figure 1: Process of voltage sag mitigation

2.2 Steady state case

Figure 2 shows the test case circuit configuration of a distribution system in steady state case (i.e. without fault). The source of voltage is set to 11 kV for the system. The transformer acts as the step-

down transformer which is from 11 kV to 400 V. Circuit breaker is used to connect transformer with load consisting of resistor (R) and inductor (L).

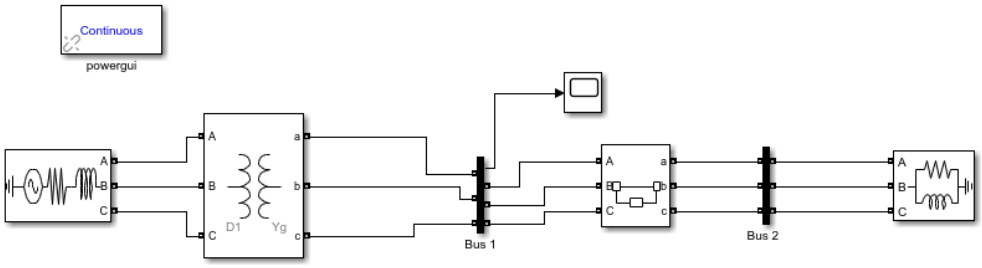

Figure 2: Distribution system in steady state condition

2.3 SLGF case

Figure 3 shows the SLGF setting while Figure 4 shows the temporary SLGF (in between phase A and ground) in distribution system. The time set for the fault is 0.04 seconds i.e. 0.03-0.07 seconds. The system will automatically return-back to the steady state after the fault time is elapsed. However, voltage sag will appear during measurement.

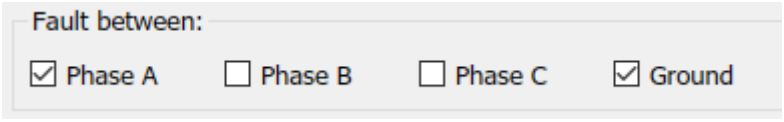

Figure 3: Fault setting for system

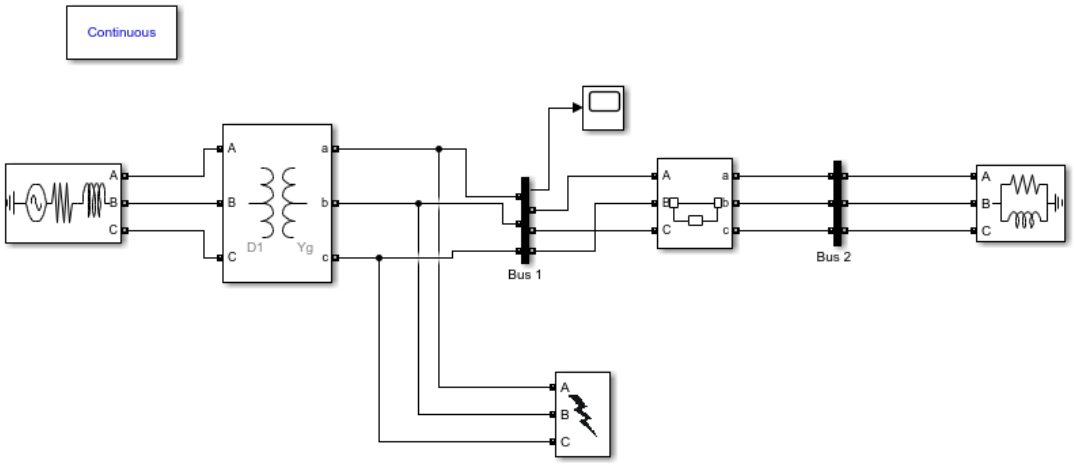

Figure 4: Distribution system in SLGF condition

2.4 DVR Design

DVR is a series device that compensates for power supply voltage sag. The main logic for DVR operation is based on a series transformer's injection voltage. DVR is regarded as an energy storage device that provides electricity for a limited period of time during sags. The injection transformer is used to minimize transients and disturbances from the source to the load side. At the system's disturbance voltage sag, the energy storage is fed to the module. The passive filters are used to reduce the harmonic at the system's injection value. When the DVR control system detects a drop in supply voltage, it starts injecting a voltage.

2.5 DVR Application in SLGF Case Causing Voltage Sag

The DVR will operate when voltage sag occurs due to SLGF. It will give the signals to the controller units when the measured voltage is different from the system. The control unit generates the voltage reference as input to the modulation unit and generate modulation signal for VSI of DVR. To compensate for the voltage sag, the DC link injects or absorbs the appropriate power. The harmonic in the DVR output is reduced by connecting an output filter between the VSI and the injection transformer. As a result, the VSI pulse-modulated voltage is converted to sinusoidal voltage by the filter. A series-injecting transformer injects the filtered voltage into the distribution system. The voltage injection of equal amplitude will be produced by DVR by monitoring the instant of sag that occur in the system due to SLGF to produce a perfect voltage sag compensation.

Figure 5 and Figure 6 shows the distribution system with DVR and connection of DVR terminals It contains the injection transformer, RL and RC for the filter, VSI i.e., insulated-gate bipolar transistor (IGBT) will be act as a switching devices with pulse width modulation (PWM), the energy storage unit and the controller for the system. Figure 7 shows the use of controller for the system to control the signal when unbalanced condition occurs. The output of the controller will compensate the voltage sag which is to inject the voltage to the system. The PWM generator will generate pulses to control the operation of DVR through IGBT

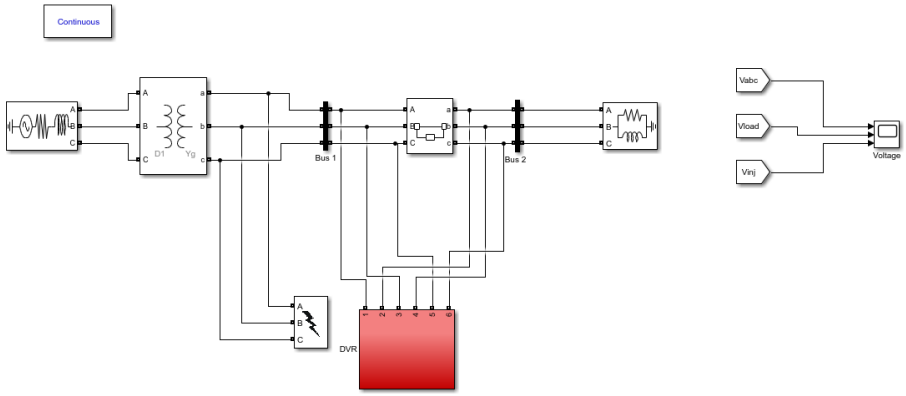

Figure 5: Distribution system with DVR

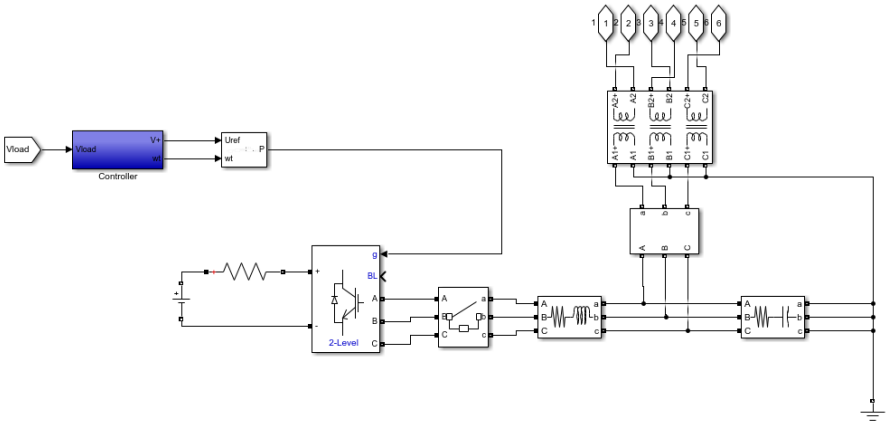

Figure 6: Connection of DVR terminals

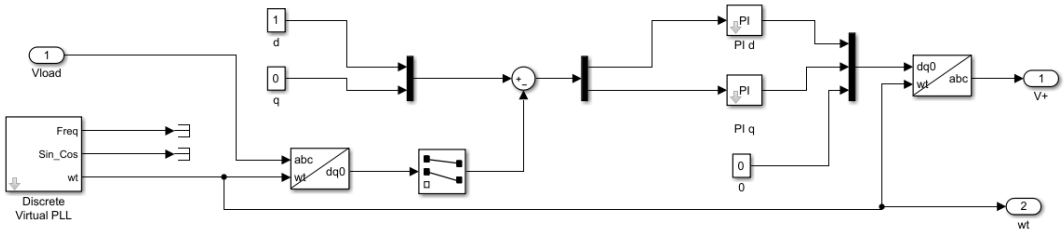

Figure 7: Controller unit

3. Results and Discussion

3.1 Steady State Case

Figure 8 shows the simulated results of steady state case. It shows the voltage waveform maintained its amplitude at value 1 p.u. in spite of the ongoing process during the simulation. Therefore, the voltage produced is stable.

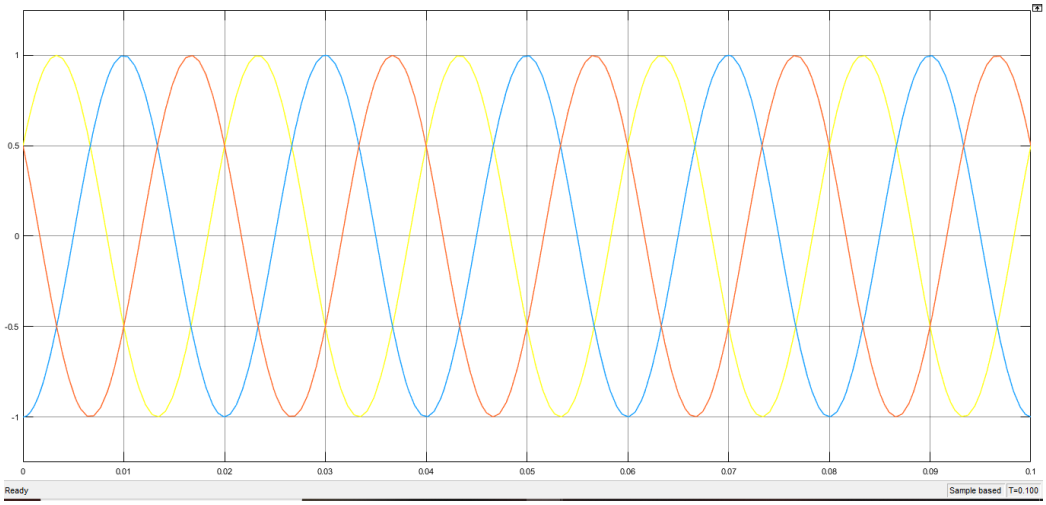

Figure 8: Voltage waveform during steady-state case

3.2 SLGF Causing Voltage Sag Case

Figure 9 shows the simulated result of voltage during SLGF case. It shows the voltage in (p.u.) against time when SLGF occurs during 0.03 - 0.07 second. The voltage waveform drops from 1 p.u. to below 0.5 p.u. that supplies the facility according to IEEE 1159 standard, hence it need to be mitigated.

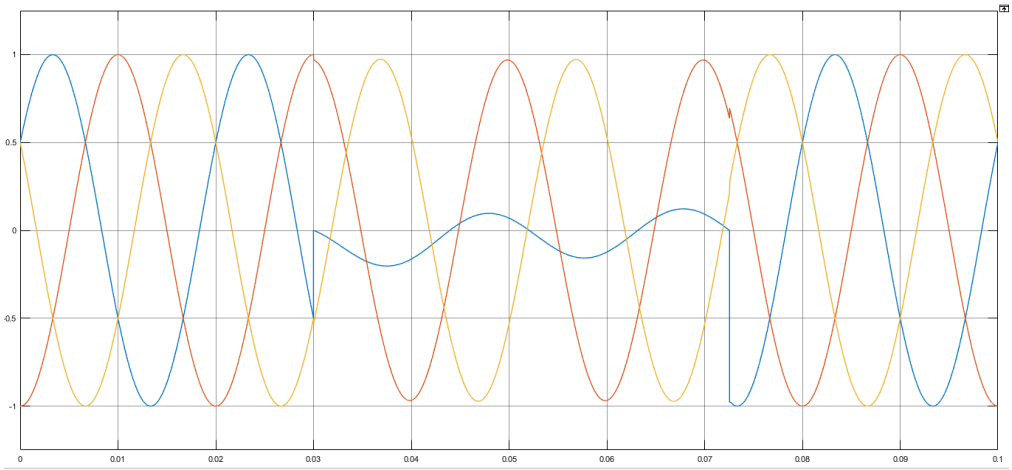

Figure 9: Voltage during SLGF

3.3 Mitigation of Voltage Sag with DVR Case

The designed DVR was applied in a SLGF case for mitigation of this V sag. Figure 10 shows the simulated result of mitigated voltage sag with DVR during the SLGF case. From the waveform it can be seen that there is voltage notching of magnitude of -1 to -1.5p.u. after 0.07 second. This is because of switching circuit in the DVR. Figure 11 shows the voltage injection from DVR. The voltage injection of equal amplitude will be produced by DVR by monitoring the instant of sag that occur in the system due to SLGF to produce a perfect voltage sag compensation.

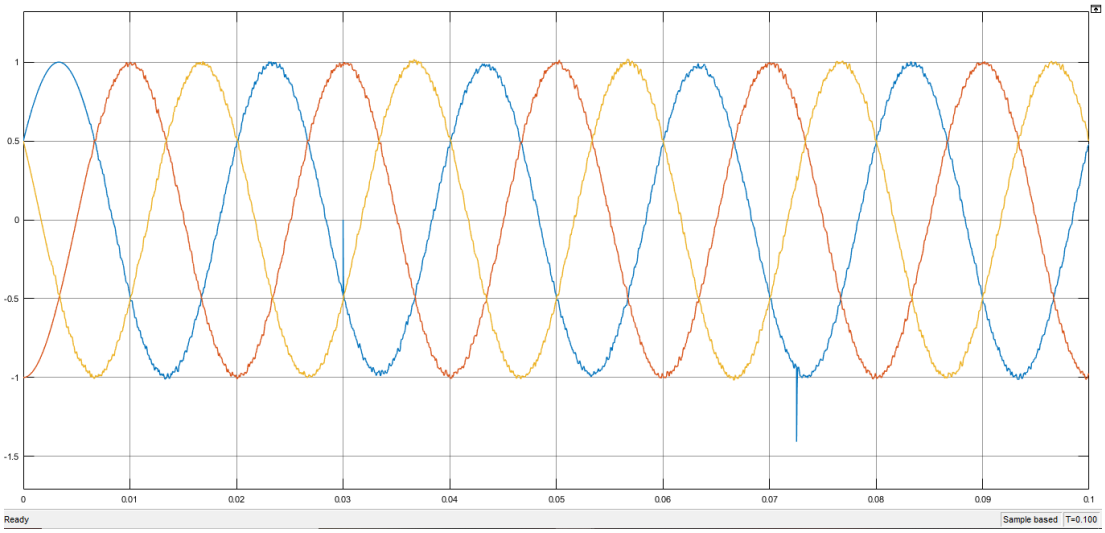

Figure 10: Mitigated voltage sag waveform with DVR during SLGF case

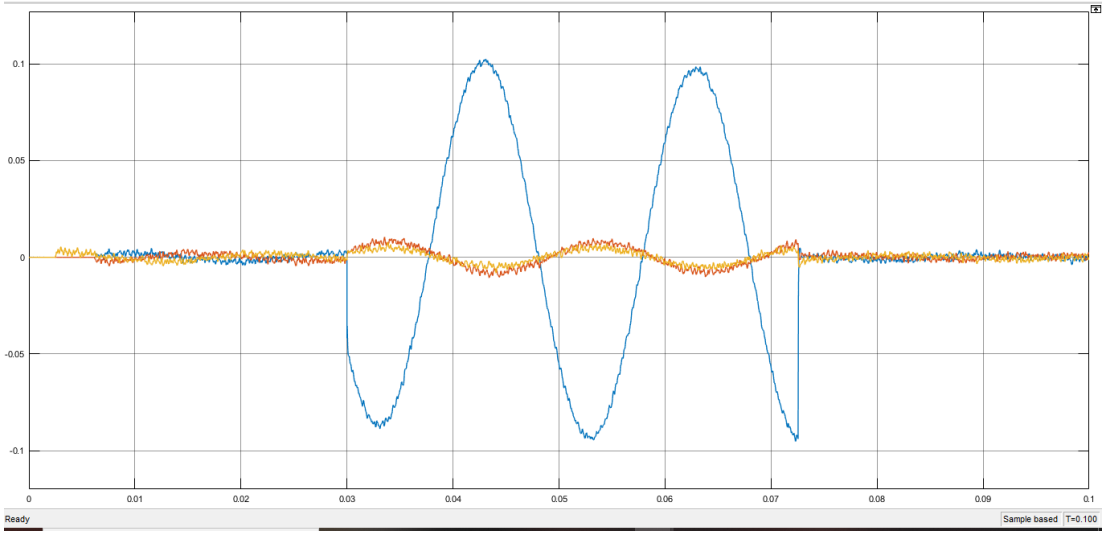

Figure 11: Voltage injection from DVR

4. Conclusion

In conclusion, the objectives of this project to design DVR for compensating voltage sag caused by SLGF are achieved. The performance of DVR in distribution system against voltage sag has been developed by using MATLAB/Simulink (2018a). Also SLGF is considered in distribution line. This is due to 70% of the SLGF occurred in power system. The problem of voltage sag has been determined by referred in three cases which is steady state, SLGF case and its mitigation with DVR. The outcome show that all result are obtained successfully based on the three cases.

Acknowledgement

The authors would like to thank the Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] A. S. Hussein and M. N. Hawas, "Power quality analysis based on simulation and MATLAB/Simulink," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 16, no. 3, pp. 1144–1153, 2019, doi: 10.11591/ijeecs.v16.i3.pp1144-1153

[2] M. F. Alves and T. N. Ribeiro, "Voltage sag: an overview of IEC and IEEE standards and application criteria," *Proc. IEEE Power Eng. Soc. Transm. Distrib. Conf.*, vol. 2, no. August, pp. 585–589, 1999, doi: 10.1109/tdc.1999.756117

[3] L. R. Almobasher, "Review of Power System Faults," no. November, 2020

[4] M. Zahri, "Simplified Method for Single Line to Ground-Fault Location in Electrical Simplified Method for Single Line to Ground-Fault Location in Electrical Power Distribution Systems," no. April, pp. 221–230, 2015, doi: 10.11591/ijece.v5i2.pp221-230

[5] S. S. Gururajapathy, H. Mokhlis, and H. A. Illias, "Fault location and detection techniques in power distribution systems with distributed generation : A review a b a b c b c," *Renew. Sustain. Energy Rev.*, vol. 74, no. January, pp. 949–958, 2017, doi: 10.1016/j.rser.2017.03.021

[6] A. Abbawi and O. S. Alyozbaky, "Comparison between Two Methods to Analyze Multiple Faults in IEEE 14-Bus," pp. 188–193, 2020