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Electric Power Quality Enhancement by Reduced Voltage Sag/Swell

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Abstract— Electric Power quality is a term which has tacked increasing attention in power engineering in the recent years. The term power quality refers to maintaining a sinusoidal waveform of bus voltages at rated voltage and frequency. Voltage sag/swell caused by the short-circuit faults in transmission and distribution lines have become one of the most important power quality problems facing industrial customers and utilities. Currently many systems exist which can help to mitigate these voltage sags such as Dynamic Voltage Restorer and FACTS based devices. In this paper, mitigate voltage sag/swell condition and power quality improvement in distribution line using Static VAR compensator (SVC). The research is carried on in Matlab/Simulink making use of the SimPower Systems package and performance analysis of the system is presented for various levels of sag and swell. Also the compensator can maintain the load powers both real and reactive powers constant. Simulation results are presented for various conditions of sag and swell disturbances in the supply voltage to show the performance of the new mitigation technique.

Index Terms— Electric Power quality, Voltage sag, Voltage swell, Static VAR compensator, short-circuits faults.

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1 Introduction

Power Quality is a simple term, yet it's describes a multitude. (a large number of people or things) of issues that are found in electrical power system and is a subjective. Power quality is actually the quality of the voltage that is being addressed in most cases. The standards in power quality area are devoted to maintaining the supply voltage within the certain limits [1]. Power quality disturbances such as momentary under-voltage (sag), over-voltage (swell), surges and harmonics have been identified as the major sources of power quality problems. For example, momentary under-voltage (sag); voltage sag can cause sensitive equipment to trip thus effecting industrial production losses. Such occurrences have major economic impact as well as impact on the quality of product and services [2-3].

Power quality is a new whole area within electrical engineering where fundamental research involves basic concept and definitions; modeling and analysis measurement and instrumentation; sources; effect; and mitigation. The ultimate goal of power quality research is to maintain a satisfactory quality of electric supply. Scopes of this research is to Simulation studies of voltage sag/swell due to short circuit fault and to recognize the effects of fault type on voltage sag/swell.

2 Voltage Sag Characteristics

Voltage sag is defined as a decrease in rms voltage at the power frequency for durations of 0.5 cycles to 1 minute. This definition specifies two important parameters for voltage sag: the rms voltage and duration [4]:

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2.1 Magnitude

The magnitude of voltage sag can determine in a number of ways. The most common approach to obtain the sag magnitude is to use rms voltage. There are other alternatives, e.g. fundamental rms voltage and peak voltage. Hence the magnitude of the sag is considered as the residual voltage or remaining voltage during the event. In the case of a three-phase system, voltage sag can also be characterized by the minimum RMS-voltage during the sag. If the sag is symmetrical i.e. equally deep in all three phases, if the sag is unsymmetrical, i.e. the sag is not equally deep in all three phases, the phase with the lowest remaining voltage is used to characterize the sag. The magnitude of voltage sags at a certain point in the system depends mainly on the type and the resistance of the fault, the distance to the fault and the system configuration. The calculation of the sag magnitude for a fault somewhere within a radial distribution system requires the point of common coupling (pcc) between the fault and the load. Fig. 1 shows the voltage divider model. Where Z_S is the source impedance at the pcc and Z_F is the impedance between the pcc and the fault. In the voltage divider model, the load current before as well as during the fault is neglected. There is no voltage drop between the load and the pcc. The voltage sag at the pcc equals the voltage at the equipment terminals, the voltage sag can be found from the (1)

$$V_{sag}\frac{Z_F}{Z_S+Z_F}E \quad (1)$$

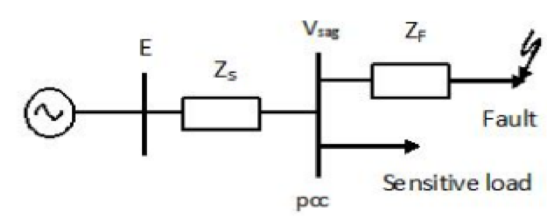


Fig. 1. Voltage divider model

2.2 Voltage Sag Duration

The duration of voltage sag is mainly determined by the fault–clearing time. The duration of voltage sag is the amount of time during which the voltage magnitude is below threshold is typically chosen as 90% of the nominal voltage magnitude. For measurements in the three-phases systems the three rms voltages have to be considered to determine duration of the sag. The voltage sag starts when at least one of the rms voltages drops below the sag-starting threshold. The sag ends when all three voltages have recovered above the sag-ending threshold.

3 SWELLS CHARACTERISTIC

A swell is defined as an increase to between 1.1 and 1.8 pu in rms voltage or current at the power frequency for durations from 0.5 cycle to 1 min. As with sags, swells are usually associated with system fault conditions, but they are not as common as voltage sags. One way that a swell can occur is from the temporary voltage rise on the unfaulted phases during an single line ground (SLG) fault. Fig. 2 illustrates a voltage swell caused by an SLG fault. Swells can also be caused by switching off a large load or energizing a large capacitor bank [5].

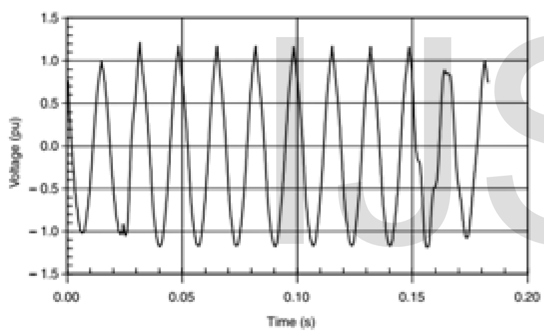


Fig. 2. Instantaneous voltage swell caused by an SLG fault

4 SOLUTION OF POWER QUALITY PROBLEM

A power quality issue, especially, voltage problem is the vital concern in most distribution system today. The voltage problem is mainly from under-voltage (voltage sag) condition due to a short circuit or fault. Solving power quality problems depends on acquiring meaningful data at the optimum locations and within an expedient time frame [6].

Different devices are currently available for the mitigation of power quality problems. A flexible alternating current transmission system (FACTS) is a system composed of static equipment used for the AC transmission of electrical energy. It is generally a power electronics-based system [7].These devices are capable of mitigating multiple power quality problems which is applicable to distribution systems to provide power quality solutions.

FACTS devices can be divided into three categories such as series controller, shunt controller, and combined controller.

Series connected controllers: Static Synchronous Series Compensator (SSSC), Thyristor-Switched Series Capacitor (TSSC), Thyristor-Switched Series Reactor (TSSR), Dynamic voltage restorer (DVR), etc.

Shunt connected controllers: Static Synchronous Generator (SSG), Static Var Compensator (SVC), Static Synchronous Compensator (STATCOM), Thyristor-Controlled Reactor (TCR), Thyristor-Switched Capacitor (TSC), etc.

Combined controllers: Unified Power Flow Controller (UPFC), Thyristor- Controlled Phase Shifting Transformer (TCPST), etc.

This paper deals with simulation of Static Var Compensator (SVC) in order to mitigate the voltage sag occurred due to short circuit faults. SVC is the first generation FACTS device which is connected in shunt with the power system [8]. Shunt reactive power compensators are generally used to supply or absorb reactive power at their point of connection. The SVC is an impedance matching device, designed to bring the system closer to unity power factor. A combination of different static and mechanically-switched var compensators whose outputs are coordinated as shown in Fig. 3.

5 RESULTS AND DISCUSSION

In this paper, MATLAB/Simulink with SimPowerSystems is chosen as the simulation platform. The line fault model developed in Simulink is show in Figure 4. The line fault model is used to simulate voltage sag caused by line fault. The line fault model consists of 11 kV, 30 MVA, 50 Hz three-phase source block feeding through 11 kV/0.4 kV, 1 MVA delta/star transformers to a 10 kW resistive and 100VAR inductive load. There are instantaneous waveform and RMS measurement scopes located at 11 kV and 0.4 kV buses. Only fault block located at the 11 kV bus to simulate line fault. This line fault model is capable of simulating various line faults including single line to ground, double line to ground, line-to-line, and three phase fault.

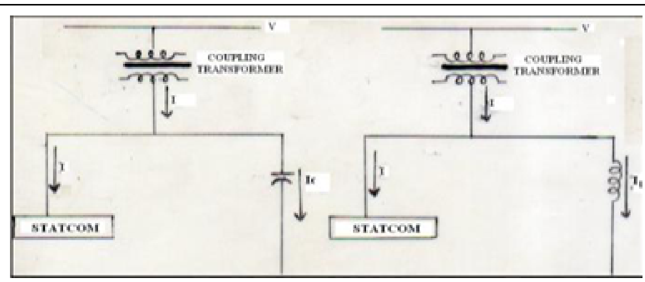


Fig. 3. (a) Static Var Compensator with capacitor. (b) Static Var Compensator with inductor.

Fig. 5 shows the RMS analysis of single line to ground fault (Fault is created in phase A) voltage sag waveforms in Fig. 6.The voltage of phase A drops, while the voltage of phase B and C remain at its prefault value.

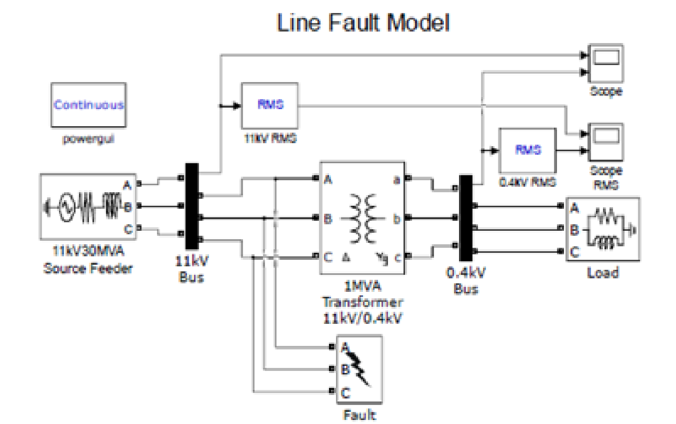


Fig. 4. Simulink model of Voltage Sag and Voltage Swell

Fig. 8 shows the RMS analysis of double line to ground fault voltage sag waveforms in Fig. 7.

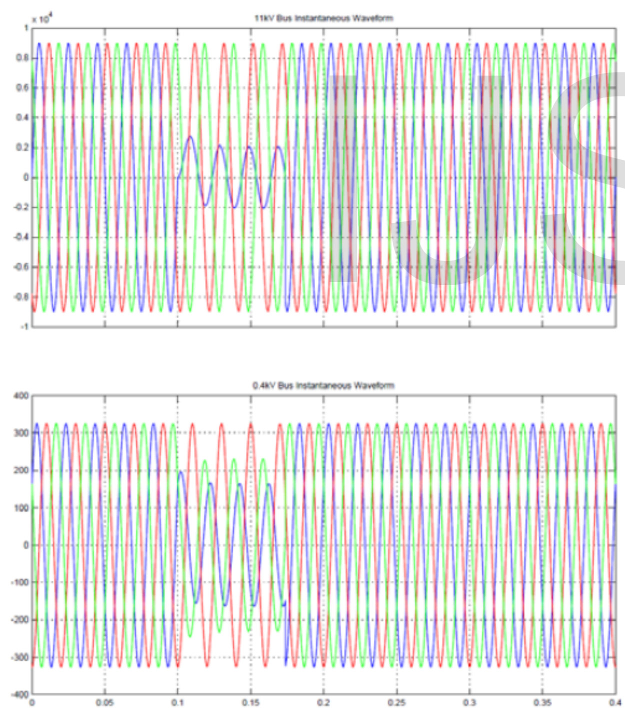


Fig. 5. Voltage sag and swell caused by single line to ground fault at 11 kV line.

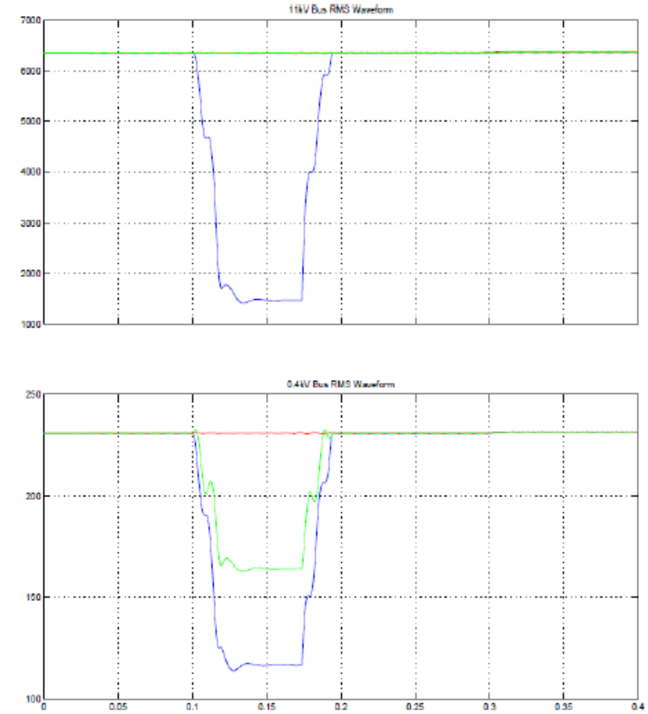
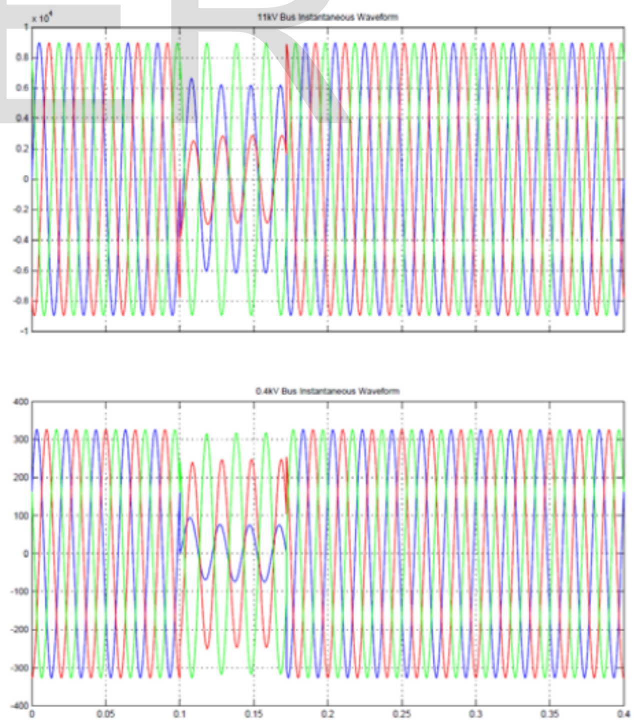


Fig. 6. Voltage sag and swell in RMS waveform



Time offset: 0

Fig. 7. Voltage sag and swell caused by double line to ground fault at 11 kV line.

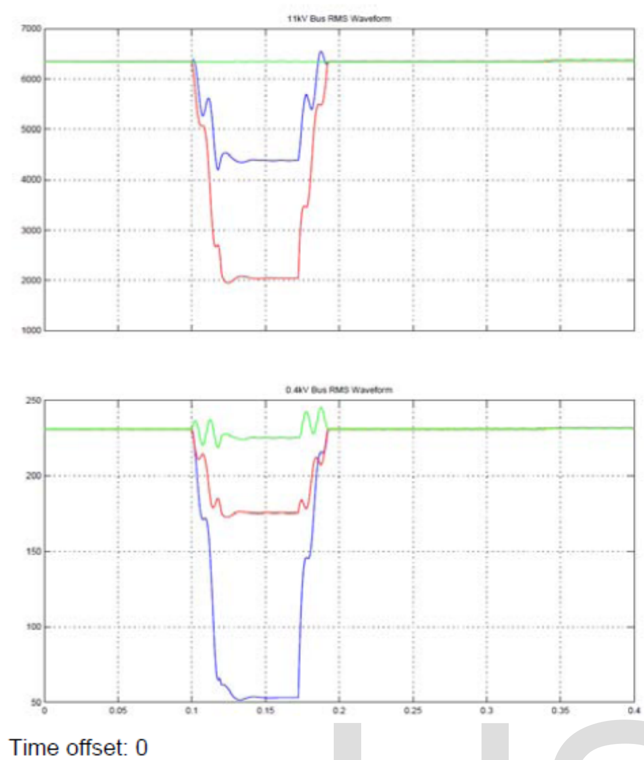


Fig. 8. Voltage sag and swell in RMS waveform

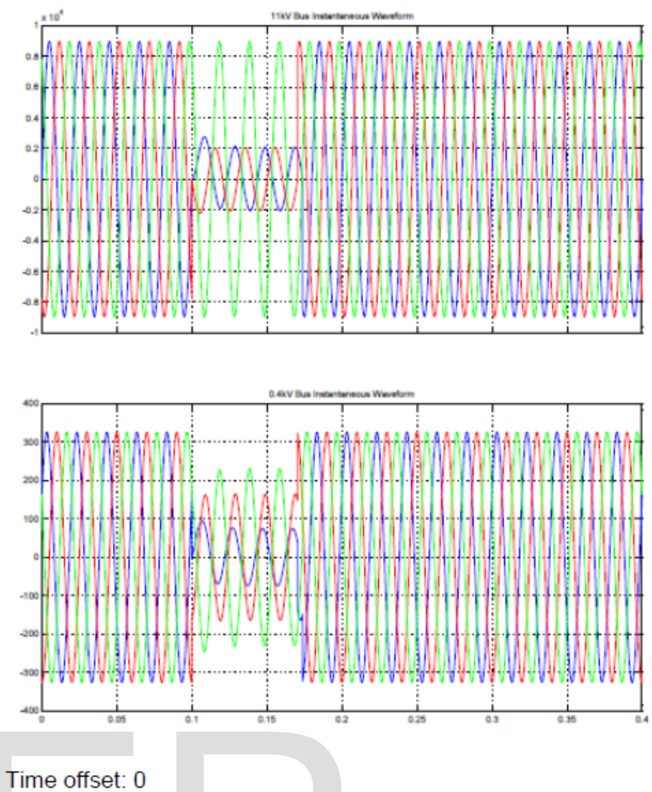


Fig. 9. Voltage sag and swell caused by line-to-line fault at 11 kV line.

Fig. 10 shows the RMS analysis of line-to-line fault voltage sag waveforms in Fig. 9. The sag magnitudes for each phase can be clearly visualized. The slight oscillation occurs at the pre- and post-sag and swell is due to the phase shift during fault.

Fig. 12 shows the RMS analysis of three phase fault voltage sag waveforms in Fig. 11.

Fig. 13 shows case study for voltage sag mitigation solution for line-to-line fault with SVC

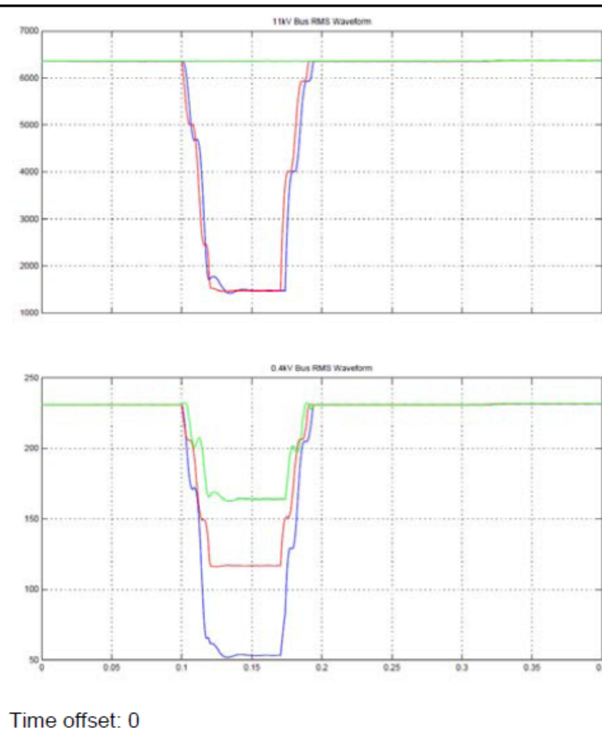


Fig. 10. Voltage sag and swell in RMS waveform

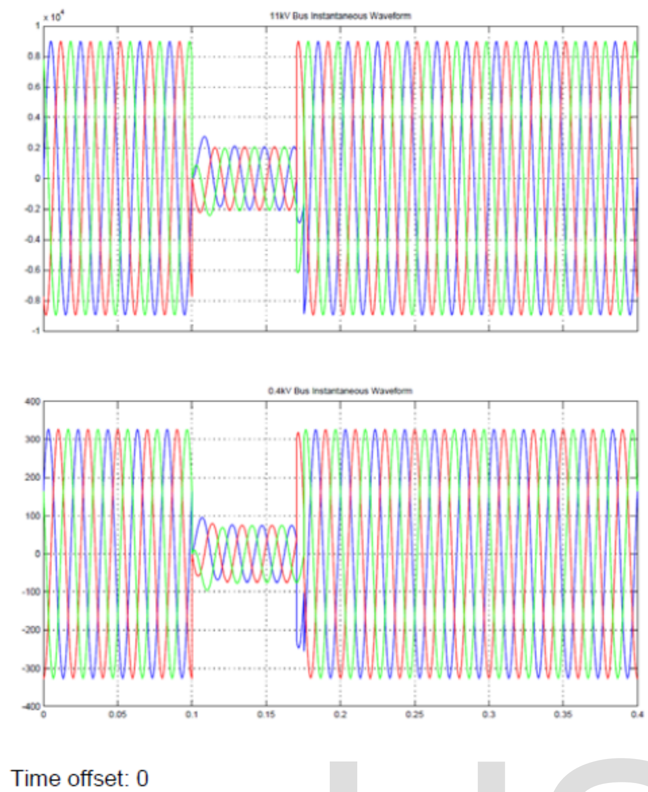


Fig. 11. Voltage sag and swell caused by three phase fault at 11 kV line.

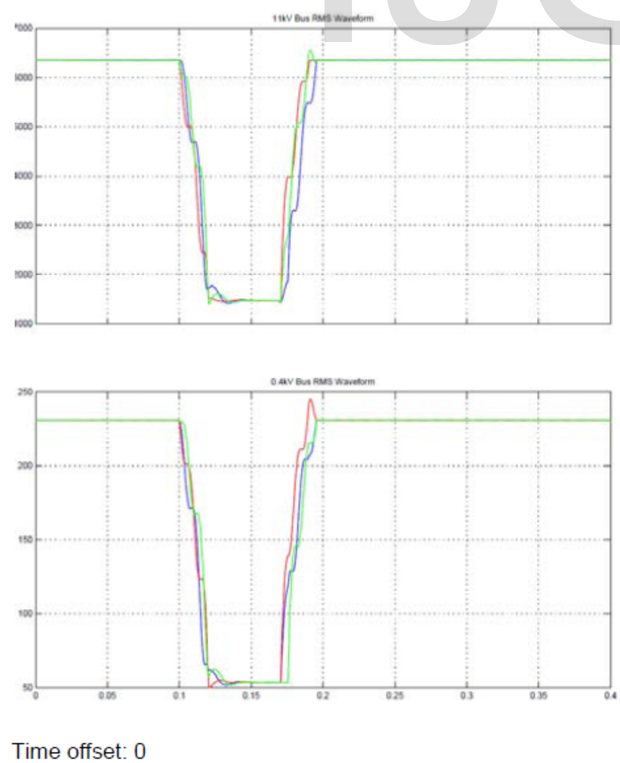


Fig. 12. Voltage sag and swell in RMS waveform

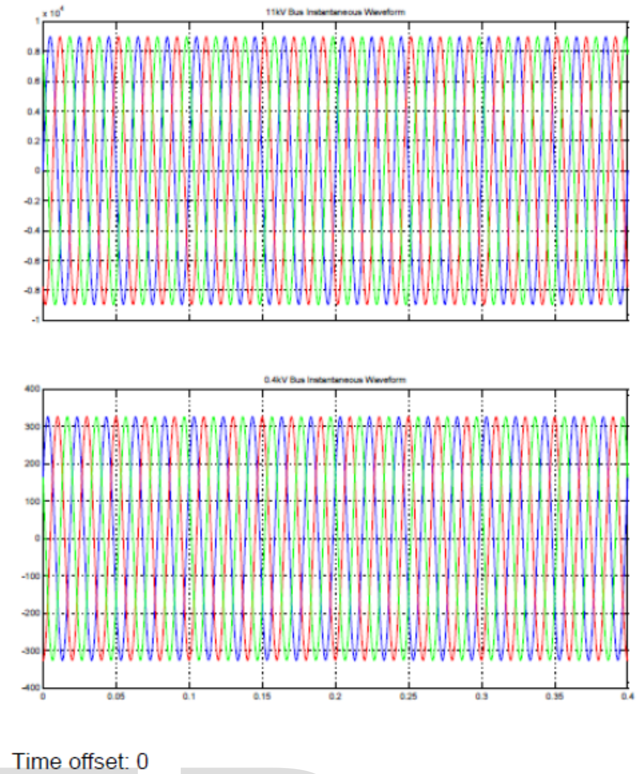


Fig. 13. voltage waveform with SVC

6 Conclusion

Voltage sag/swell has been mainly characterized by magnitude and duration. This paper describes the problem of voltage sag/swell caused by the single line to ground, double line to ground, line-to-line, and three phase faults in distribution lines has been applied to simulation model distribution system. Simulation results carried out by Matlab/Simulink software verify the performance of the simulation model under study. The investigation on the role of Static var compensator (SVC) can compensate the voltage sag and swells conditions. In order to achieve improved power quality levels simulated with or without SVC connected to the distribution system. The Simulation results show that the SVC can compensate the voltage sag and swell conditions and improves the power quality. Furthermore, simulation results verify that the proposed device is effective in compensating the voltage sag disturbances.

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