© 2015 IJSRSET | Volume 1 | Issue 2 | Print ISSN : 2395-1990 | Online ISSN : 2394-4099
Themed Section: Engineering and Technology

Investigation on the Performance of a Series Voltage Compensator for Mitigating Voltage Sag and Swell in Power Distribution Networks

Bhaskar Lodh
Department of Electrical Engineering, Jalpaiguri Government Engineering College, Jalpaiguri, West Bengal, India

ABSTRACT

Among the power quality problems (sags, swells, harmonic etc.) voltage sag and swell are the harshest disturbances. In order to solve these problems the idea of custom power devices is introduced lately. One of those devices is the Dynamic Voltage Restorer (DVR), which is the most competent and efficient modern custom power device used in power distribution networks. Dynamic voltage restorer is also known as series voltage compensator. Other than voltage sag and swell compensation, such compensator has other added features like line voltage harmonic compensation, reduction of transient in voltage and fault current limitation etc. There are several methods that have been introduced so far to design and implement such controllers. In this paper, a Simulink based model is introduced to analyse the performance of series voltage compensator. Simulink is a graphical user interface based tool furnished by Matlab Inc. to built and analyse different types of linear and non linear systems. It is a very powerful tool for design engineers.

Keywords: Power Quality, Voltage Sag, Voltage Swell, Matlab – Simulink.

I. INTRODUCTION

Power Quality (PQ) related problems are of most worry nowadays. The widespread use of electronic equipment, such as information technology equipment, power electronic devices such as adjustable speed drives (ASD), programmable logic controllers (PLC), energy-efficient lighting, led to a complete change of electric loads nature. These loads are simultaneously the major causers and the major victims of power quality problems. All these loads cause disturbances especially in the waveform of voltage.

Sources of poor power quality can be classified in the following ways-(1) Adjustable speed drives (2) Switching power supplies (3) Arc furnace (4) Electronic florescent lamp ballast (5) Lightning strike (6) L-G fault (7) Non- linear load (8) Starting of large motors (9) Power electronic devices etc.

II. NEED OF SUPERIOR POWER QUALITY

There is an increased concern of improving quality of power for the following reasons

(1) Now-a-days different industrial loads require microprocessor and microcontroller based controls. Power electronic devices, are more sensitive to power system parameters variations than that equipments that were used long ago.

(2) Now-a-days, consumers have become aware of power quality issues. Utility customers are becoming better informed about such issues as interruptions, sags, and switching transients and are challenging the electric utility companies to improve the quality of power delivered.

(3) Most of the electrical networks are interconnected now-a-days. Integrated processes mean that failure of any component has much more important consequences.

III. INTRODUCTION TO DVR

A dynamic voltage restorer is a Power Electronic converter-based D-SSSC which can protect sensitive loads from all supply-side disturbances other than outages. It is connected in series with a distribution feeder and is also capable of generating or absorbing real and reactive power at its AC terminals. The basic principle of a DVR is simple: by inserting a voltage of the required magnitude and frequency, the DVR can restore the load-side voltage up to the desired amplitude and waveform even when the source voltage is either unbalanced or distorted. Usually, a DVR, as a lucrative solution when compared to very costly UPS agreements, is connected in order to protect loads and can be employed at both an LV level and an MV level, which gives a chance to protect high-power applications from voltage sags during faults in the supply system.

IV. INTRODUCTION TO MATLAB-SIMULINK ENVIRONMENT

In this paper, the simulation software used for constructing the model is MATLAB. It was first introduced in 1970 by a numerical analyst Cleve Moler, who wrote the first version of MATLAB. SIMULINK is a commercial tool furnished by Math Works Inc. that comes with MATLAB. It is used for modelling and analysing different types of linear and non linear systems. In this paper, a simulation model is obtained with the help of different building blocks available in SIMULINK toolbox. Simulink allows engineers for building any dynamic system using block diagram notation. There are several MATLAB functions and toolboxes accessible in MATLAB environment for constructing and plotting of waveforms from analysed data. Simulink gives a stage for professionals to plan, analyse, design, simulate, test and implement different type s of systems. Simulink-Matlab combination is very functional for developing algorithms, creation of block diagrams and analysis of different simulation based designs.

V. VOLTAGE SAG AND SWELL CAUSED BY FAULT IN TRANSMISSION LINE

Magnitude of voltage in the distribution system is sometimes, severely affected by faults in the transmission line. Type of fault in the power system is the first factor which affects sag characteristic. Depending whether the fault type is balanced or unbalanced, sag will be balanced or unbalanced in all three phases. The magnitude and phase angle of sag will also depend on the type of fault. Along with the type, the location of faults in the system has a great impact on the magnitude as well as the phase-angle jump of the sag. The sensitive load is at distribution level but the faults at distribution as well as at hundreds of kilometres away at the transmission level will have an influence on the magnitude as well as the phase-angle of the sag at Point of common coupling.

With change in the X/R ratio of the line there is change in the X/R ratio of fault to source impedance which will affect the magnitude as well as phase-angle jump. In the next context, a SIMULINK model is built with a balance three phase fault. Here the voltage injection is done by a “Controlled Voltage Source”, available in the Simulink Library Browser. The Controlled Voltage Source block converts the Simulink input signal into an equivalent voltage source. The generated voltage is driven by the input signal of the block. The single line diagram of the proposed model is shown in the following figure.

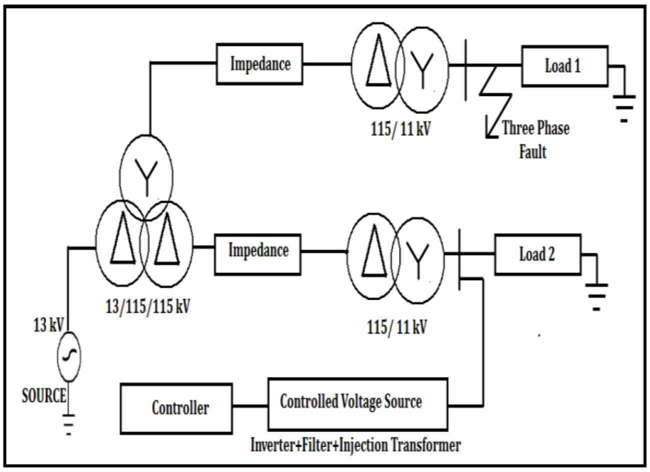

Figure 1: Single Line Diagram of the Series Voltage Compensator Test System

Single line diagram of the test system for DVR is shown above and the test system employed to carry out the simulations for DVR is shown in next context. Such system is composed by a 13 kV, 50 Hz generation system, feeding two transmission lines through a 3-winding transformer connected in Y/Δ/Δ 13/115/115 kV.

Such transmission lines supply two distributions networks through two transformers connected in Δ /Y, 115/11 kV. The aim of the control scheme is to maintain constant voltage magnitude at the point where a sensitive load is connected, under system disturbances.

The control system only measures the r.m.s voltage at the load point, i.e., no reactive power measurements are required. An error signal is obtained by comparing the reference voltage with the r.m.s voltage measured at the load point. The control circuit process the error signal generates the required angle to drive the error to zero, i.e., the load r.m.s voltage is brought back to the reference voltage. The Flow Chart for Modelling the DVR test system is shown in the figure below-

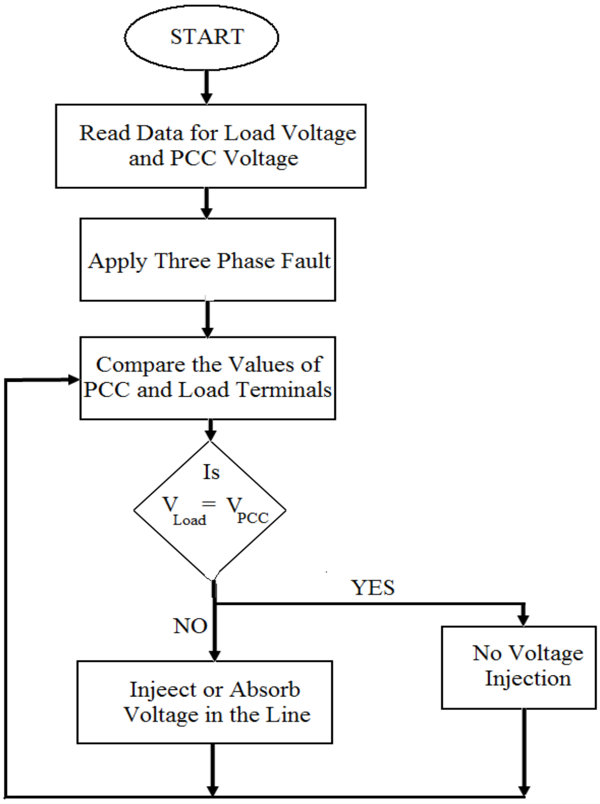

Figure 2: Flow Chart for Modelling the DVR test system

VI. PARAMETERS FOR THE COMPENSATOR TEST SYSTEM

SL NO.	System Quantities	Standards
1.	Source Voltage	3Phase,13kV
2.	Line Impedance	0.01Ohm 0.005 Henry
3.	Three Phase, Three Winding Transformer	13/115/115 kV
4.	Three Phase Transformer, Two Winding	115/11 kV
5.	Load Parameters	0.1 Ohm, 0.192 Henry
6.	Reference Voltage	15.5 kV
7.	Three Phase Fault	Fault Resistance =0.1 Ohm and Snubber Resistance =1 Mega Ohm

8.	Controlled Voltage Source	Parameter Type= AC with initial values set to zero

Table 1: Compensator Test system Parameters

With the above stated system parameters, a dynamic voltage restorer test system are built using the Matlab Simulink Toolbox. Here, a three phase system is taken with a source voltage of 13kV. From the Simulink Library a three phase fault is introduced in the system with the above stated parameters. This fault will introduce a voltage sag in the system. Also it may introduce a swell in the system. These disturbances will be mitigated by the proposed test system. The wave form of the voltages before and after operation of DVR will be shown.

VII. SIMULINK MODEL OF THE TEST SYSTEM

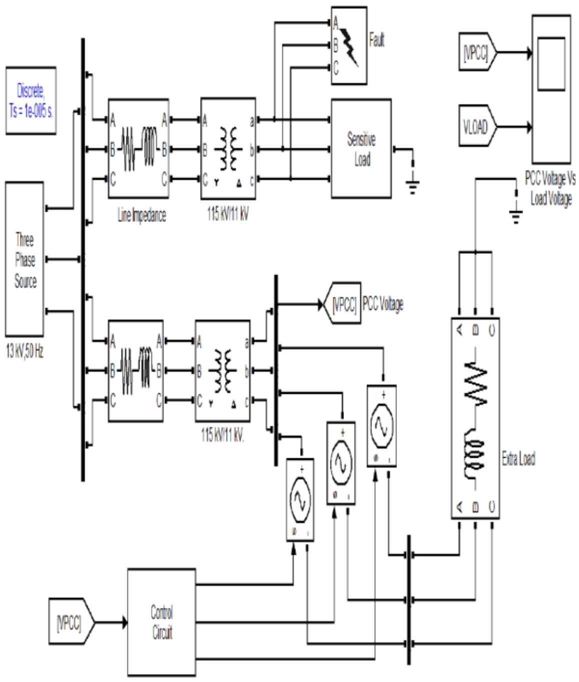

Figure 3: Power Circuit of the DVR Test System

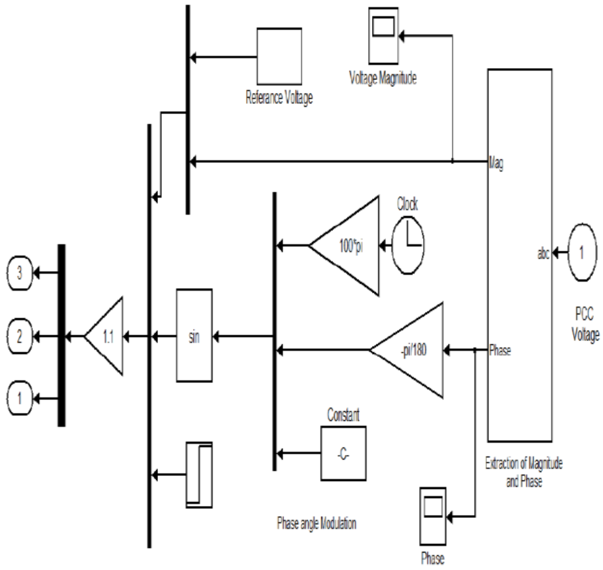

Figure 4: Control Circuit of the DVR Test System

VIII. RESULT OF SIMULATION

In the first simulation a three phase fault is applied with a transition status [1 0] and a transition time of 0.3 to 0.8 second. The three phase fault voltages will be as shown in the figure below-

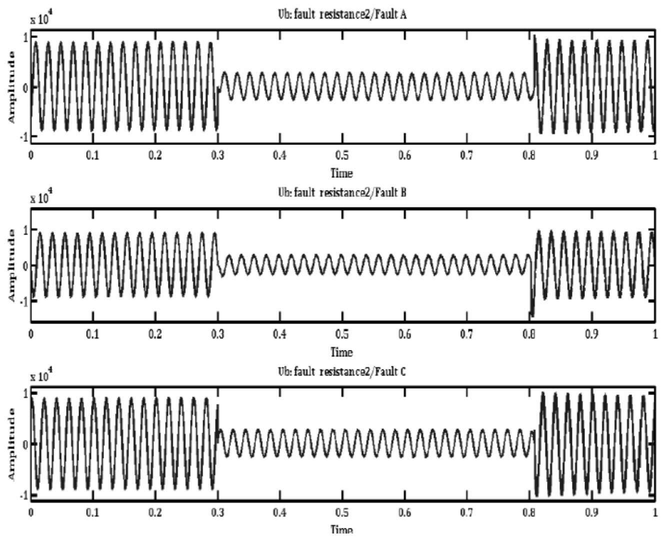

Figure 5: Three Phase Fault Voltage

Above figure shows the waveform of the three phase fault voltages. During 0.3 to 0.8 second, there is a drastic drop in the level of voltage. This will create voltage sag at the load end. Before the DVR operation the load voltage will be as shown in the figure below-

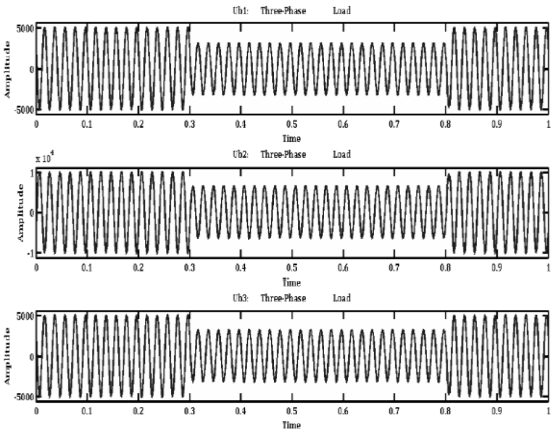

Figure 6: Three Phase Load Volatage before DVR operation

Following figure shows the sag introduced in the voltage at the point of common coupling and the voltage at load end after DVR operation. The DVR will be able to mitigate the sag promptly.

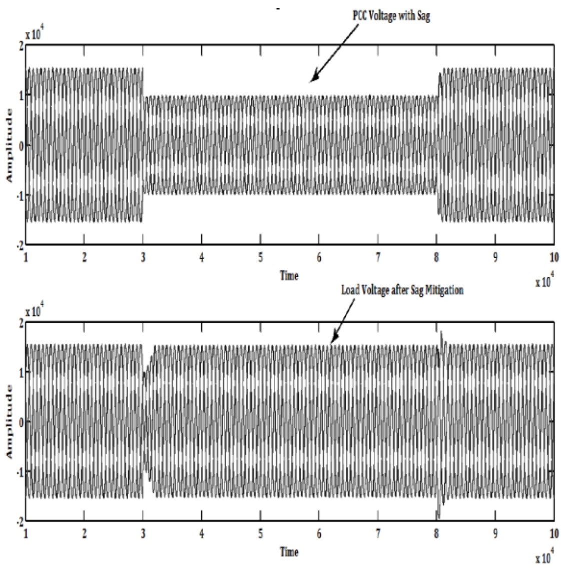

Figure 7: PCC Voltage and Load Voltage after Sag Mitigation

Following figure shows the phase voltages at the load end after successful operation of DVR-

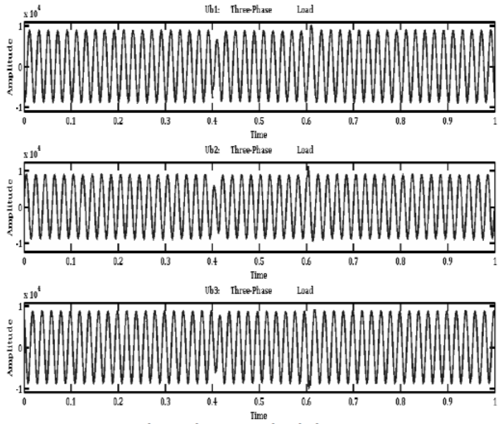

Figure 8: Phase Voltage at Load end after Sag Mitigation

In the second simulation a three phase fault is applied with the transition status [0 1] and a transition time of 0.3 to 0.8 second. The three phase fault voltage will be as shown in the figure below-

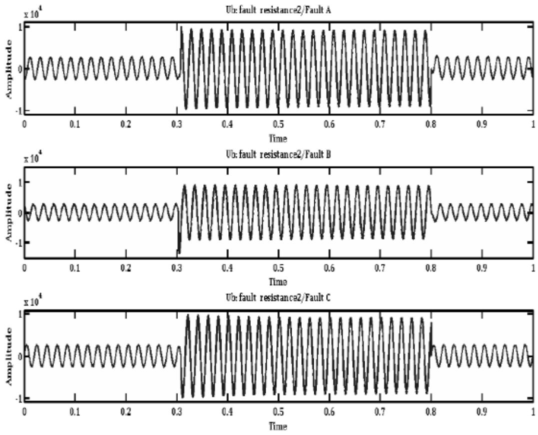

Figure 9: Three Phase Fault Voltages

This will create a voltage swell at the load end, shown in the figure below.

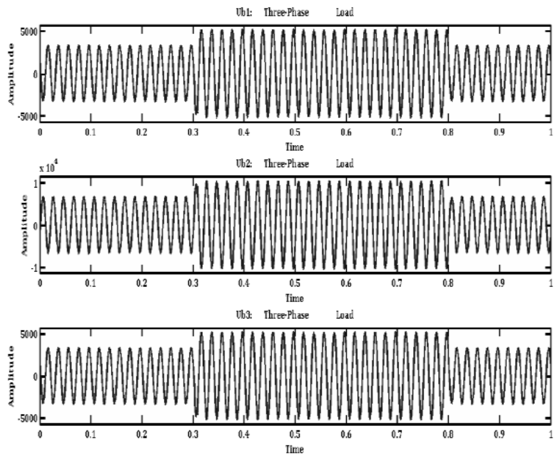

Figure 10: Load Voltage before DVR Operation

Also, it will be shown that the DVR system will be able to mitigate the voltage swell promptly.

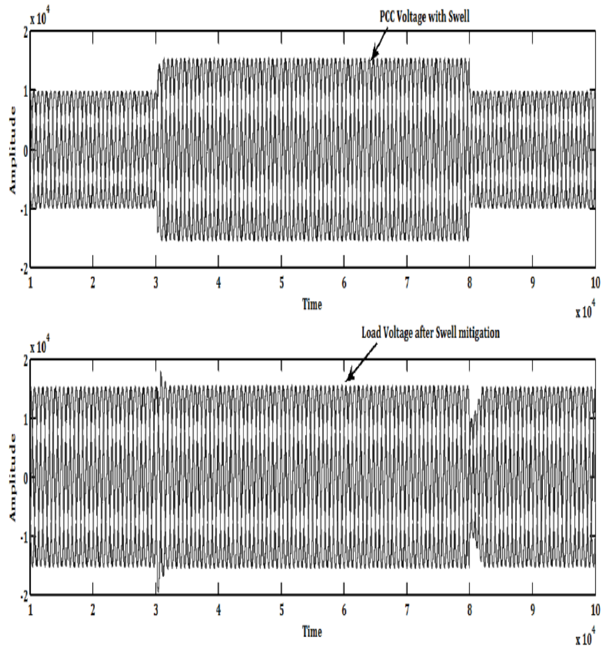

Figure 11: PCC Voltage and Load Voltage after Swell mitigation

Following figure shows the phase voltages at the load end after successful operation of DVR-

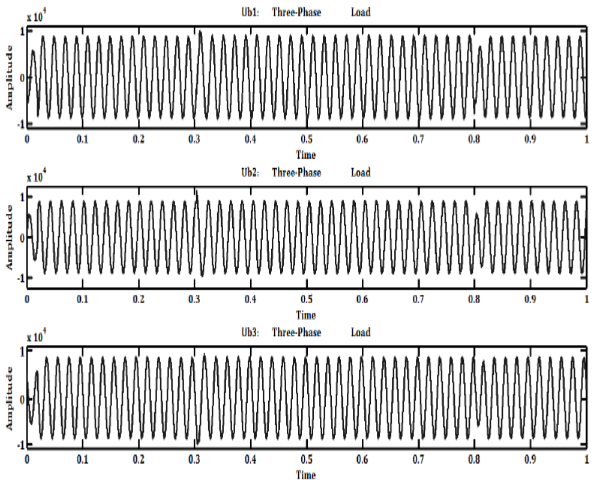

Figure 12: Phase Voltage at Load end after Swell mitigation

IX. CONCLUSION

In this context, a distinct control strategy for mitigating voltage and swell using Dynamic voltage restorer is shown. In the constructed simulation model, a self supported transformer less DVR is built. It is evident from the simulation result that, in occurrence of both voltages sag and swell, the DVR was able to mitigate the power quality related issues effectively. The Voltage waveform was restored to its original shape. That is the lost voltage was compensated by the DVR efficiently.

X. REFERENCES

[1] Roger C. Dugan, Mark F McGranham, Surya Santoso, H. Wayne Beaty "Electrical Power System Quality," McGraw Hill , 2010.

[2] K.R. Padiyar, "FACTS Controllers in Power Transmission and Distribution", New Age International Publishers

[3] A.K. Tyagi, "MATLAB and Simulink for Engineers", New Delhi, Oxford University Press, 2012

[4] P.Ajay-D-Vimal Raj, M.Sudhakaran, S.Senthil Kumar, Sapta Rishi Roy, T.G.Palanivelu, MULTI LEVEL INVERTER BASED DYNAMIC VOLTAGE RESTORER WITH PI AND FUZZY LOGIC CONTROLLER; XXXII NATIONAL SYSTEMS CONFERENCE,NSC 2008,December 17-19,2008

[5] S.LEELA,S.S.DASH, CONTROL OF THREE LEVEL INVERTER BASED DYNAMIC VOLTAGE RESTORER, Journal of Theoretical and Applied Information Technology, January 2005.

[6] Chris Fitzer, Mike Barnes, Member IEEE, Peter Green, Member IEEE, Voltage Sag Detection Technique for a Dynamic Voltage Restorer; © 2002 IEEE

[7] Arindam Ghosh, Senior Member, IEEE, Amit Kumar Jindal, Student Member, IEEE, and Avinash Joshi, Design of a Capacitor-Supported Dynamic Voltage Restorer (DVR) for Unbalanced and Distorted Loads; IEEE TRANSACTIONS ON POWER DELIVERY, VOL. 19, NO. 1, JANUARY 2004