Mitigation of Voltage Sag/Swell by Dynamic Voltage Restorer for Power Quality Improvement

G. Sravani,
Ph.D Scholar,
Department of Electronic and Electrical Engineering,
Shri Jagdishprasad Jhabarmal Tibrewala University,
Email: gsravani.271@gmail.com.

Dr. A. Rajesh,
Associate Professor,
Department of Electronics and Communications Engineering
CVR College of Engineering, Hyderabad, Telangana,
Email: arajeshmtech@gmail.com

Abstract-Power quality has become a major constraint for any type of load to get the better voltage quality. When the power quality is considered ,the voltage sag/swell plays predominant role at different types of loads which decreases the quality of voltage at consumer end. Inorder to overcome this situation, a Dynamic Voltage Restorer is connected in series to the system. Dynamic voltage restorer (DVR) is a series connected power electronic based device which will quickly mitigate the voltage sags in the system and restore the load voltage to the pre-fault value. DVR is considered as the best solution to overcome the problem of voltage sag/swell.

The primary advantage of the DVR is keeping the users always on-line with high quality constant voltage maintaining the continuity of production. In this paper, the usefulness of including DVR in distribution system for the purpose of voltage sag and swell mitigation is described. Results of simulation using Matlab- Simulink are demonstrated to prove the usefulness of this scheme.

*****

Introduction

Nowadays, Power quality is known as one of the extremely serious problems in electric power transmission and distribution, due to its dangerous impact on electricity suppliers, makers and users. Typically we will outline power quality as the deviation of voltage, current and frequency from its normal values in a power grid. Out of these power quality issues, voltage sag or swell causes more serious problems in power system, both at transmission and distribution level. Faults on electrical power system like short circuit due to insulation breakdown at heavy load conditions can cause voltage sag.

Nowadays everyone is demanding for reliable and quality of power supply which can be accomplished by custom power technology, which will take care of reliability and quality of power supplied to the customer. Mainly there are three devices in custom power technology which are – Dynamic Voltage Restorer (DVR), Distribution STATCOM (DSTATCOM) and Unified Power Quality Conditioner (UPQC). Among which DVR is the best suitable device to mitigate the voltage sag or swell and maintains the load voltage constant.

Dynamic Voltage Restorer

Dynamic Voltage Restorer (DVR) is considered as the most economic and efficient solution for various power quality problems. It regulates the load side voltage continuously just in case of any power quality problems like voltage sag or swell therefore preventing any power interruption to the sensitive load.

1.Principle of operation:

Dynamic Voltage Restorer is one of custom power device specially used to maintain the load voltage constant in the distribution system. DVR has two operating modes. In normal operation mode it is in standby mode in which voltage injection by DVR is zero. Most of the time DVR will be in standby mode and hence reduces the losses.

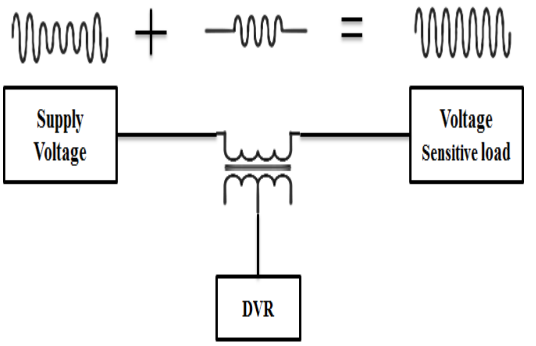

Figure: DVR Operation

The operation of DVR is based on the fundamental principle that a voltage waveform is injected through an injection transformer that is the difference between pre-sag and sagged voltage. This is often made possible by the supply of required real/active power from an energy storage device together with reactive power. The turns ratio of injection transformer and ratings of the energy storage device can put limitations on the maximum injection capability of DVR.

The Fundamental Components of DVR

The fundamental components of DVR are :

1. Injection or Booster transformer
2. Harmonic filter.
3. Voltage Source Inverter (VSI)
4. DC Energy Storage Device and charging circuit.
5. Control system.

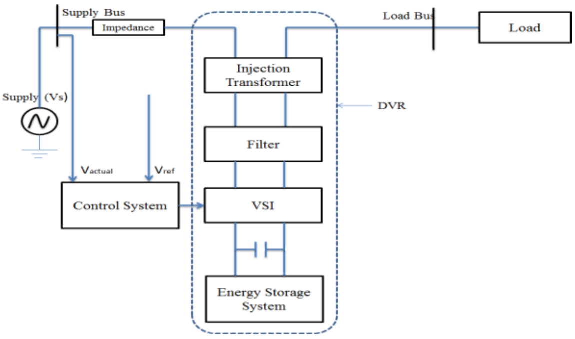

Figure:Block Diagram of DVR

2.Equivalent Circuit of DVR:

The equivalent circuit of DVR is as shown in the figure. On detection of any reduction in the supply voltage V_{source} from any set value, the DVR injects a voltage, V_{DVR}, in series through the injection transformer such that the desired load voltage, V_{load} can be maintained at the load end.

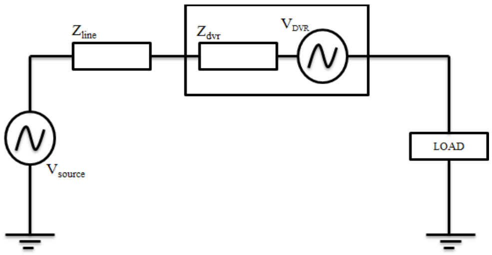

Figure:Equivalent Circuit of DVR

The DVR injection voltage is as written as in

$V_{DVR} = V_{load} + Z_{line}\, I_{load} - V_{source}$

Where

V_{load} = Desired load voltage
Z_{line} = Line impedance
I_{load} = Load current
V_{source} = System voltage during any fault conditions
V_{DVR} = DVR injected voltage

3.Operating Modes of DVR:

The operating modes of DVR can be classified into three as below:

a. Protection mode:

In case of high inrush current and short circuit fault on load, the over current on the load side exceeds an allowable limit. Then the DVR will get cut off from the systems by using the bypass switches and providing alternate path for current flow.

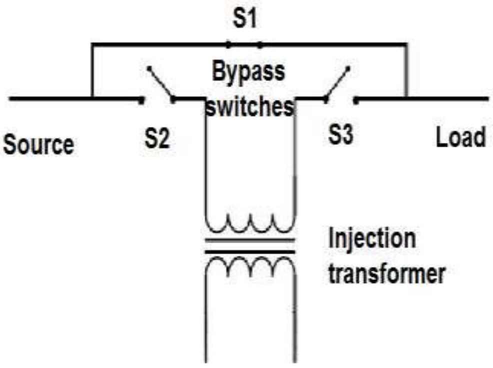

Figure:Protection Mode of DVR

b. Standby mode:

Switching of semiconductors of VSI will not occur during this mode and therefore the full load current can pass through the primary winding of injection transformer. The low voltage winding of the injection transformer is shorted through the converter during this mode.

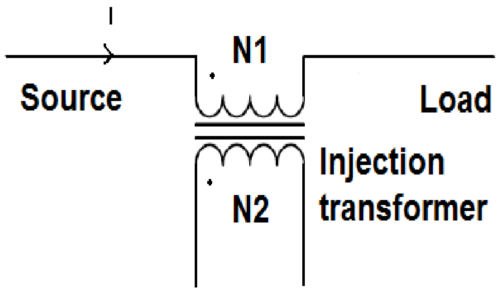

Figure:Stand-by mode of DVR

c.Injection mode :

DVR injects voltage through the injection transformer to compensate for any disturbance detected in the supply voltage.

4.Voltage Compensation strategies of DVR

Compensation is achieved via real power and reactive power injection. Based on the compensation level required by the

 ISSN: 2454-4248
98 – 102

load, there are three types of compensation strategies as mentioned below.

a. Pre-sag compensation:

Non linear loads need both magnitude as well as phase angle compensation. In pre-sag compensation technique, DVR provides the difference between pre-sag and sag voltage therefore restoring the voltage magnitude as well as the phase angle to that of the pre-sag value. Therefore this method is suited to nonlinear loads. However this method needs a higher rated energy storage device and voltage injection transformers.

b. In-Phase compensation:

The DVR compensates only for the voltage magnitude in this particular compensation method, i.e. the compensated voltage has an equivalent phase as that of sagged voltage and it only compensates for the voltage magnitude. So this method minimizes the voltage injected by the DVR. Therefore it is suited for the linear loads, which do not need phase angle compensation.

c. In-Phase Advanced Compensation Method (IPAC):

In this technique the real power spent by DVR is minimized by decreasing the power angle between the sag voltage and the load current .In the two previous cases, namely pre-sag and in-phase compensation, active power is injected into the system by the DVR during disturbances.

Moreover, the active power supplied is limited to the stored energy in the DC link and this part is one of the most expensive components of the DVR. By creating the injection voltage phasor perpendicular to the load current phasor the minimization of injected energy is achieved. In this technique one can change only the phase of the sag voltage because the values of load current and voltage are fixed in the system In brief, IPAC technique uses only reactive power and unfortunately, all the sags cannot be mitigated without real power, as a result, this technique is only appropriate for a limited sag range.

5. Proposed Control Scheme:

The control scheme implemented here is with the help of dqo transformation. Once a voltage disturbance occurs, the output of the inverter can b e adjusted in phase with the incoming ac source while the load voltage is regulated. The output of inverter is equipped with inductors and capacitors for filtering purpose.

The role of DVR controller is the recognition of voltage sag/swell issues in the power system; calculation of the compensating voltage, trigger pulse creation for the sinusoidal PWM inverter, correction of any errors in the series voltage injection and extinction of the trigger pulses once the fault is cleared.

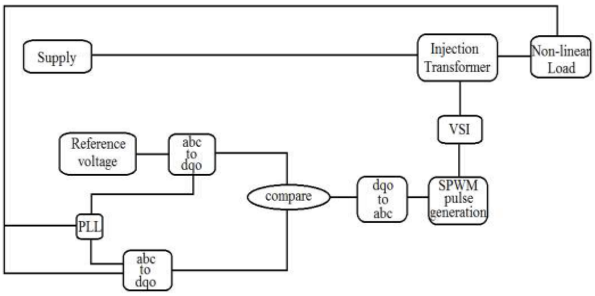

Figure: Simulation block diagram of DVR

The dqo technique provides the magnitude of sag and details of phase shift with their beginning and finishing times. The quantities are expressed as the instantaneous space vectors. The voltage is converted from a-b-c reference frame to d-q-o reference. We ignore zero sequence components for simplicity. The control is implemented by comparing a set reference voltage and the measured load phase voltage (Va, Vb, Vc).

The dqo transformation or otherwise called Park's transformation is implemented here in the DVR controller. The dqo technique provides the magnitude of sag and details of phase shift with their beginning and finishing times. We ignore zero sequence components for simplicity. The control is implemented by comparing a set reference voltage and the measured load phase voltage (Va, Vb, Vc).

The error signal formed b y the above comparison is used as a control signal that generates a commutation sequence pattern for the power switches of the VSI using Sinusoidal Pulse Width Modulation technique (SPWM); voltages are controlled by modulation.

The equation that transforms the three phase a-b-c system to stationary dqo frame is given below equation

$$\begin{bmatrix} V_d \\ V_q \\ V_o \end{bmatrix} = \begin{bmatrix} \cos(\theta) & \cos\left(\theta - \frac{2\pi}{3}\right) & 1 \\ -\sin(\theta) & -\sin\left(\theta - \frac{2\pi}{3}\right) & 1 \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \begin{bmatrix} Va \\ Vb \\ Vc \end{bmatrix}$$

The abc to dqo Transformation computes the direct axis, quadratic axis, and zero sequence quantities in a two-axis rotating reference frame for a three-phase sinusoidal signal. In this transformation, phase A is aligned to the d-

ISSN: 2454-4248
98 – 102

axis that is in quadrature with the q -axis. The theta (θ) is defined by the angle between phase A and the d-axis.

6. Simulation Circuit and Results:

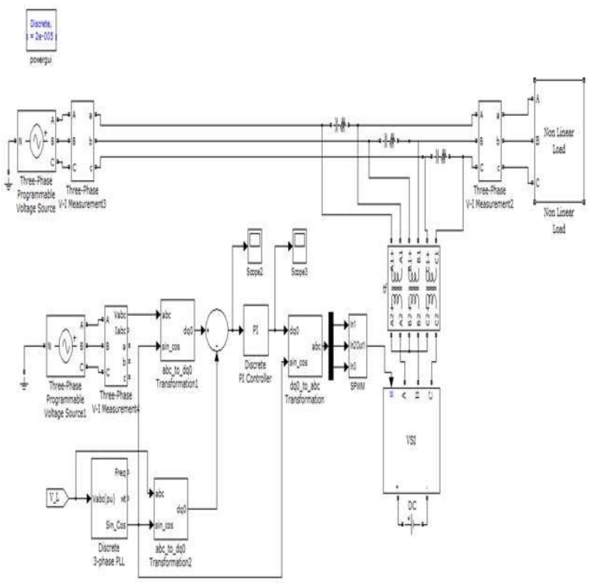

Figure: Simulation Circuit developed in MATLAB

A detailed simulation of the above DVR control system is performed using MATLAB/SIMULINK program to verify its operation under sag and swell conditions.The input supply voltage , injected voltage and satisfactory voltage compensation results are as shown in the below waveforms.

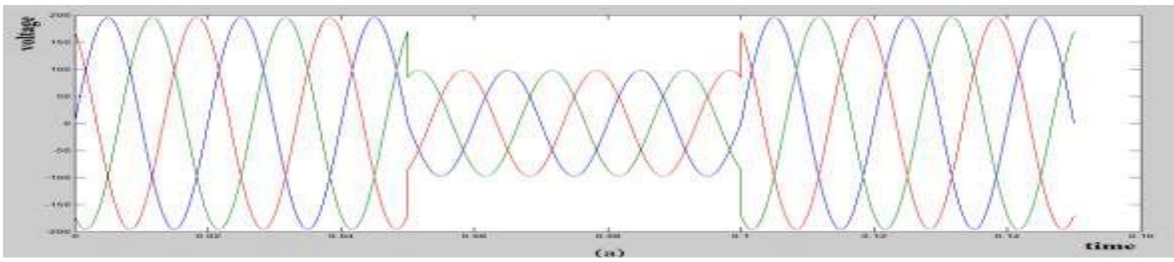

Figure: Source voltage of the DVR

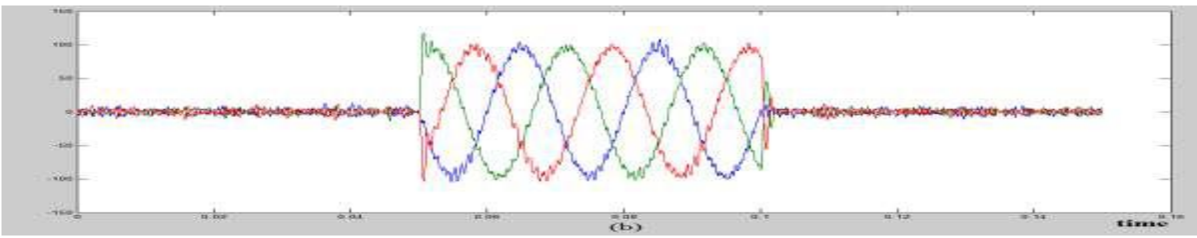

Figure: Voltage injected by DVR as a response to Sag

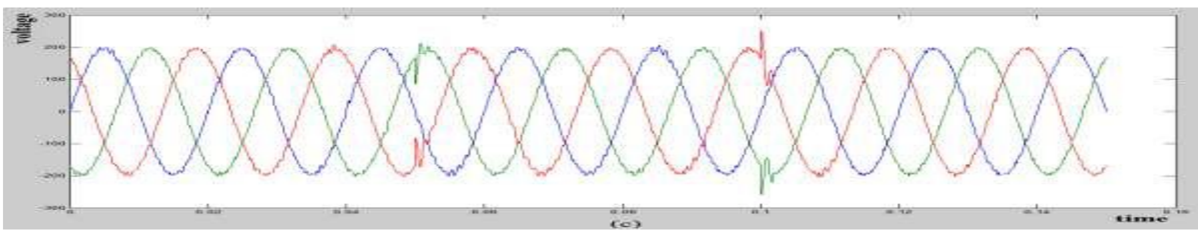

Figure: Voltage of the load after sag compensation

The Voltage swell of the DVR and its compensation is as shown in the waveforms.

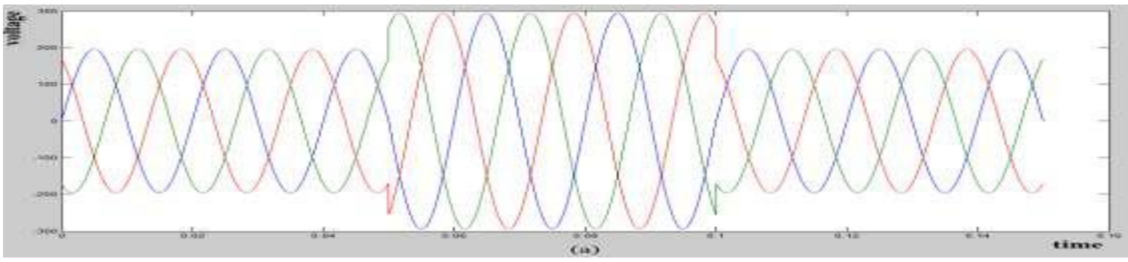

Figure: Source voltage with Swell of 1.5 pu

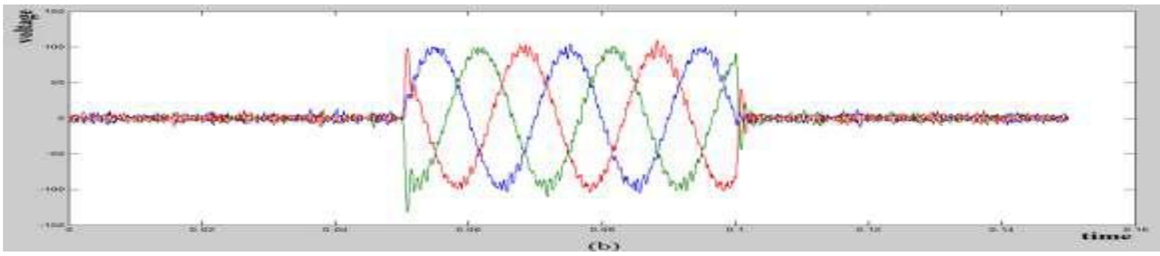

Figure: Voltage injected by DVR as a response to Swell

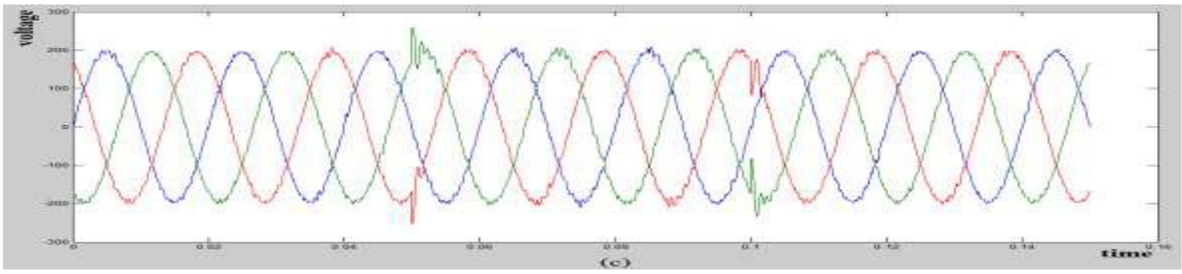

Figure: Load voltage after compensation of the Swell

7.Conclusion:

In this paper, the modelling and simulation of a DVR for 3Φ 415V, 50 Hz distribution system with Sinusoidal PWM based controller has been developed by using Matlab/Simulink. The simulation results show that the DVR compensates the sag and swell and provides excellent voltage regulation. The control system implemented here relies on dqo technique which is a scaled error between supply side of the DVR and its set reference value.

8.References:

[1]. Chellali Benachaiba, Brahim Ferdi, "Voltage Quality Improvement Using DVR," Electrical Power Quality and Utilisation, Journal Vol. XIV, No. 1, 2008.

[2]. H.Ezoji, A.Sheikholeslami, M.Tabasi and M.M. Saeednia, "Simulation of Dynamiv Voltage Restorer Using Hysteresis Voltage Controller," European Journal of Scientific Research ISSN 1450-216X Vol.27 No.1 (2009), pp.152- 166.

[3]. Abrarkhan I. Pathan, S.S. Vanamane, "Simulation and Analysis of Dynamic Voltage Restorer for Power Quality Problems ," Proceeding of International Conference on Electrical and Electronics Engineering (ICEEE), March 2013,Hyderabad.

[4]. C. Benachaiba, and B. Ferdi "Power quality improvement using DVR", American Journal of Applied Sciences 6 (3): 396-400, 2009.

[5]. Consalva J. Msigwa, Beda J. Kundy And Bakari M.M.Mwinyiwiwa, "Control Algorithm for Shunt Active Power Filter using Synchronous Reference Frame Theory," World Academy of Science, Engineering and Technology 58,2009.

[6]. Priyanka Kumari, Vijay Kumar Garg, "Simulation of Dynamic Voltage Restorer Using Matlab to Enhance Power Quality in Distribution System", International Journal of Engineering Research and Applications (IJERA), Vol. 3, Issue 4, Jul-Aug 2013, pp.1436-1441.

[7]. M. Tumay, A. Teke, K. C. Bayindir, M. U. Cuma, "Simulation and modeling of a dynamic voltage restorer", Electrical & Electronics Engineering, pp.1-5, 2006.

[8]. Arindam Ghosh and G.Ledwich, "Compensation of Distribution System Voltage using DVR," IEEE Transaction on Power Delivery, Vol 17, No 4,October 2002