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SVM Control Scheme for Voltage Sag Compensation in Medium- Level DVR

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ABSTRACT

This paper presents the medium voltage dynamic voltage restorer (DVR) based on application of space Vector Pulse Width Modulation (SVPWM) for three phases Voltage Source Converter (VSC) and it is the standard PWM techniques to utilize the DC-AC. The DVR is a power electronics device that is able to compensate voltage sags on critical loads. The DVR helps in restoring a voltage waveform and ensures constant load voltage. The DVR comprise of VSC, injection transformers, filters and energy storage. The efficiency of the DVR depends on the efficiency of the control technique involved in switching the inverter. Here a novel structure for voltage sags mitigation and for power quality improvement are proposed. An increasing trend of using space vector PWM (SVPWM) due to their easier digital realization and better dc bus. Here control algorithm is investigated through computer simulation by using MATLAB software. Simulation results show the performance of the proposed medium voltage dynamic voltage restorer. Results of a DVR using MATLAB software based on SVPWM technique showed that the effectiveness of the DVR in mitigating voltage sags. The DVR inject the appropriate voltage component to correct rapidly any disturbances in the supply voltage. It was analysed that the proposed low voltage dynamic voltage restorer works well in balanced conditions of voltages.

Keywords: Voltage source converter, voltage sag, Dynamic Voltage Restore, space vector pulse widthmodulation.

INTRODUCTION

The dynamic voltage restorer (DVR) is a series custom power device intended to protect sensitive loads from the effects of voltage sags at the point of common coupling (PCC). A typical DVR connected system circuit , the DVR consists of essentially a series connected injection transformer, a voltage source inverter (VSI), inverter output filter and an energy storage device connected to the dc-link. The power system upstream to DVR is represented by an equivalent voltage source and a source impedance. The basic operation principle of the DVR is to inject an appropriate voltage quantity in series with the supply through an injection transformer when a PCC voltage sag is detected. Loads connected downstream are thus protected from the PCC voltage sag. Voltage deviations, commonly in the form of voltage sags, can cause severe process disruptions and result in substantial production loss (Sabin,1996).The Dynamic Voltage Restorer (DVR) has been proposed to protect sensitive loads from such voltage sags. The DVR is connected in series with the sensitive load or distribution feeder and is capable of injecting real and reactive power demanded by the load during voltage sag compensation. The output of the DVR inverter is usually provided with an output LC filter to attenuate the harmonic contents appearing in injected voltage. The filter parameters are designed according to certain design aspects such as depth of the sag to be mitigated and the load voltage.

Basic concepts of dynamic voltage restorer: A Dynamic Voltage Restorer (DVR) is a recently proposed series connected solid state device thatinjects voltage into the system in order to regulate the load side voltage. The DVR was first installed in 1996. It is normally installed in a distribution system between the supply and the critical load feeder. Its primary function is to rapidly boost up the load side voltage in the event of a disturbance in order to avoid any power disruption to that load. There are various circuit topologies and control schemes that can be used use DVR. DVR can perform tasks such as: line voltage harmonics compensation, reduction of transients in voltage and fault current calculations. The DVR consists of a Booster transformer, a Harmonic filter, a Voltage Source Converter (VSC), DC charging circuit and a Control and Protection system as shown in figure 1. In most sag correction techniques, the DVR injects active power into the distribution line during the period of compensation. Thus, the capacity of the energy storage unit can become a limiting factor in the disturbance compensation process especially for sags of long duration.

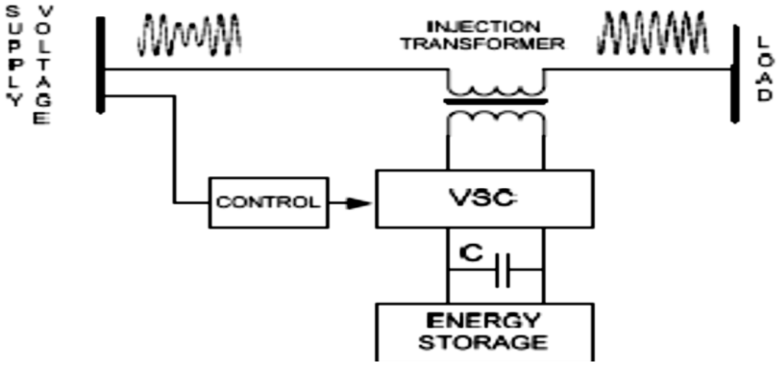

Figure.1.Typical DVR circuit topology (Single-phase representation)

Materials of the proposed system: In this paper, the materials of the proposed DVR use a 3-phase voltage source inverter (VSI) configuration. Figure 4(a) shows the overall system comprised of power system supplying three phase loads through a distribution transformer and a DVR system connected in series to the secondary side of the distribution system. In general a DVR system is comprised of a VSI, an energy storage (i.e. battery) supplying real power, a controller that provides gating signals functions to filter out switching harmonics in the injecting voltages. It is important to point out that LC filter will introduce phase shift in the injecting voltages and complicate the design of the control algorithm.

Proposed method of control system development: The aim of the control scheme is to maintain constant voltage magnitude at the point where a sensitive load. The VSC strategy concentrates space vector PWM technique which offers simplicity and good response. During a sag condition, the correct voltage must be injected so that the load voltage becomes 'normal' again. The reference phasor has three components: phase, frequency and magnitude. During normal network operation all will vary to some degree .In single and three-phase dc/ac power converters, normally it is used pulse width modulation (PWM) technique. However, using techniques such as SPWM presents some problems such as large noise peaks at the multiple numbers of carrier frequencies. In this way, a control method based on space vector PWM is applied to the power converter of the DVR is proposed. The block diagram of the control system used is shown in figure 4(b).The control system of a DVR plays an important role response in the face of voltage sags and variations in the connected load. Generally, there are two control schemes, open loop and closed loop, which are used. Here an extensive analysis to develop suitable control strategies for the DVRs (Gosh, Gerard Ledwich, 2002). The proposed DVR control system consists of a open loop load voltage using phase locked loop (PLL). The PLL circuit is used to generate a unit sinusoidal wave in phase with mains voltage. From

into $\alpha\beta$ using $\alpha\beta o$ transform

$$\begin{bmatrix} V_\alpha \\ V_\beta \\ V_0 \end{bmatrix} = \frac{2}{3} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \\ 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \end{bmatrix} \begin{bmatrix} V_A \\ V_B \\ V_C \end{bmatrix}$$

$\alpha\beta$ Co-ordinate system can be transformed into the dq plane

$$\begin{bmatrix} V_d \\ V_q \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} V_\alpha \\ V_\beta \end{bmatrix}$$

figure 4(b) the three phase voltages can be converted. The Space Vector Pulse Width Modulation (SVPWM) method computation-intensive PWM method and possibly the best among all the PWM techniques. The circuit model of a typical three-phase voltage source PWM is shown in figure 2(a). There are eight switch states, the output voltages of the inverter are composed by eight switch states.

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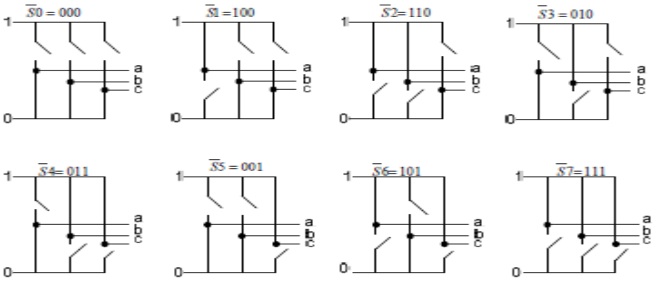

Figure.2a.Space vector eight switching states

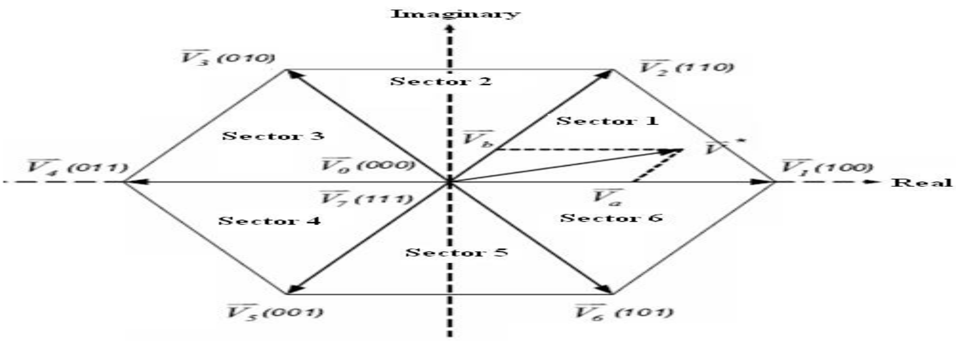

Figure 2(b): Voltage space vector

Define eight voltage vectors *o V* =[000],……. 7 *V* =[111] corresponding to the switch states 0 *S* ……., 7 *S* , respectively. The lengths of vectors 1 *V* ,………, 6 *V* are unity and the lengths of 0 *V* and 7 *V* are zero, and these eight vectors form the voltage vector space as shown in figure 2 (b). The voltage vector space is divided up into six sectors .

In the vector space, following operation rules are obeyed:

$$\overline{V_1} = -\overline{V_4}$$
$$\overline{V_2} = -\overline{V_5}$$
$$\overline{V_3} = -\overline{V_6}$$
$$\overline{V_0} = \overline{V_7} = 0$$
$$\overline{V_1} + \overline{V_3} + \overline{V_5} = 0 \quad (1)$$

In one sampling interval, the output voltage vector

$$\overline{V}(t) = \frac{t_0}{T_s}\overline{V_0} + \frac{t_1}{T_s}\overline{V_1} + \ldots + \frac{t_7}{T_s}\overline{V_7} \quad (2)$$

Where t0, t1,…….,t7 are the turn –on time of the vectors

Figure 3 showing the case of Sector I, where Ts is half of the PWM period, T 1 is the duration of Vector 1 and T2 is the duration of Vector 2 in a half PWM period. The remaining time Ts --- T1 --- T2 is the duration for the zero vectors. The values of T1 and T2 are calculated based on the values of Vref .One sampling interval, vector *V* can be expressed as

$$\overline{V} = \frac{T_1}{T_s}\overline{V_1} + \frac{T_2}{T_s}\overline{V_2} + \frac{T_7}{T_s}\overline{V_7} + \frac{T_0}{T_s}\overline{V_0} \quad (3)$$

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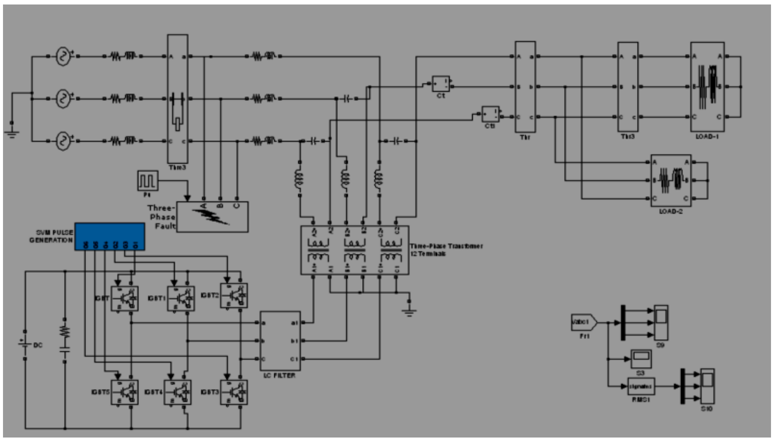

Figure 4(a): Simulation of DVR Control

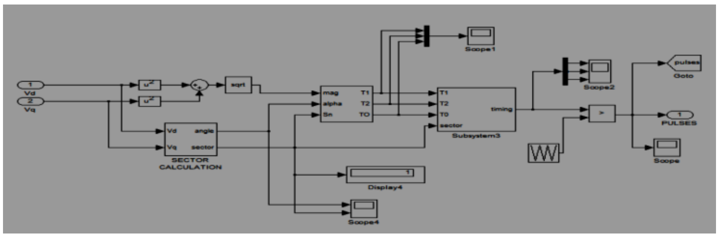

Figure 4(b): Control Block Diagram of SVM implemented

SIMULATION ANDEXPERIMENTAL RESULTS

Parameters	Constant Values
Main supply per phase	200v
Line Impedance	L_s =0.5mH. R_s =0.1Ω
Series Transformer Ratio	1:1
DC Bus Voltage	100v
Filter Inductance	1mH
Filter Capacitance	1μF
Load Resistance	40Ω
Load Inductance	60Mh
Line frequency	50Hz

A detailed system as shown in Figure 4(a) has been modeled by MATLAB to study the efficiency of suggested method. The system parameters and constant value are listed in Table I. The results of the most important simulations are represented in Figures 5(a) and 5(b).In order to understand the performance of the DVR, a simple distribution network as shown in figure 4(a), is implemented. Voltage sags are simulated using MATLAB software. First a case of three phase balanced sag is simulated by connecting a three phase reactance to the busbar. As a result balanced voltage sag is created immediately after a fault as shown in figure 5 (a). The load voltages restoration are shown in figure 5 (b) through the compensation by DVR.

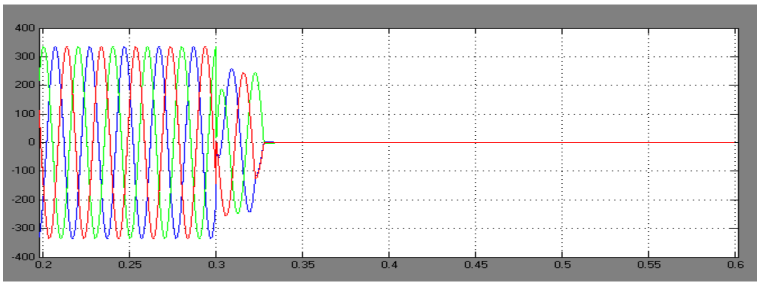

Figure 5(a): Three phase fault (Load voltage with fault conditions)

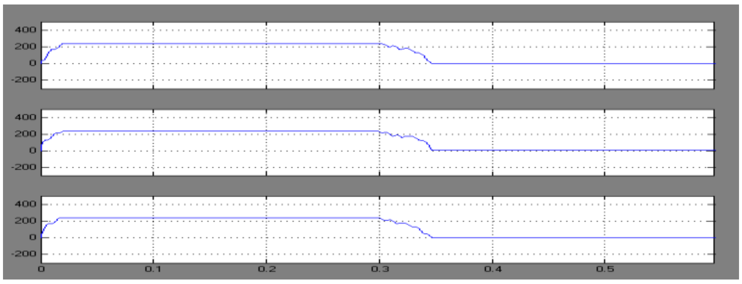

Figure 5.1: Three phase load voltage (RMS)

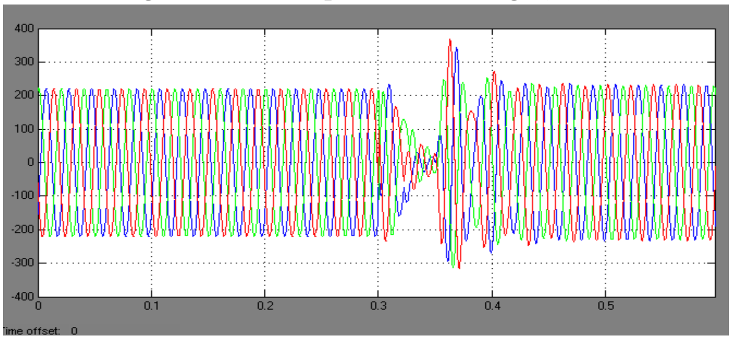

Figure 5(b): Three phase load voltage

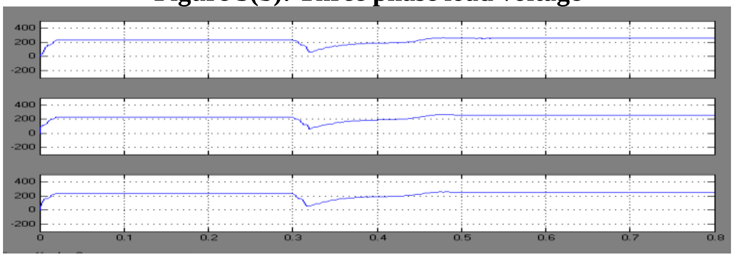

Figure 5.2: Three phase load voltage (RMS)

Tabular Analysis for SVM Technique

FFT ANALYSIS CHART

Parameter	Without DVR	SVM
voltage peak	0	230
Voltage RMS	0	165
% THD	0	1.98

CONCLUSION

The modeling and simulation of a DVR using MATLAB has been presented. The simulation results showed clearly the performance of the DVR in mitigating voltage sags. In this paper, the DVR has shown the ability to compensate for voltage sags at the grid side; this can be proved through simulation and experimental results. The efficiency and the effectiveness in voltage sags compensation showed by the DVR makes it an interesting power quality device compared to other custom power devices. The results verify MATLAB simulation of the proposed control algorithm based on Space Vector Pulse Width Modulation (SVPWM) technique to generate the pulses for mitigating voltage sags.

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