Mitigation of Voltage Sag Using Dynamic Voltage Restorer Based on Space Vector Pulse Width Modulation

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***Abstract*— This paper presents the operation of DVR ,which is custom power device used to mitigate voltage sag by injecting appropriate voltage as well power into system and the control technique applied for three phase voltage source inverter is space vector PWM. It is standard PWM technique to utilize the DC-AC power conversion, SVPWM technique can apply amend DC voltage and generated less harmonic in inverter output. This work describes the DVR with space vector PWM and PI controller is used. In this paper presented control technique is able to compensate voltage sag.**

Keywords— Voltage source converter, voltage sag, SVPWM , DVR.

I. Introduction

A Power quality problem is occurrence manifested as a nonstandard voltage, current or frequency that result in failure or mis-operation of end use equipments. Power quality is very serious issue recently due to affect on electricity suppliers, disturbance, faults at either transmission or distribution level. Power quality is define as the variation of voltage magnitude, waveform, current, and frequency in power system. Power quality problem such as sag ,swell, transient, flickers, unbalance. Disturbance may have affect on customer devices cause mis-function. The concept of custom power was introduced to distribution system for improving the system performance.

DVR is effective custom power device for enhancement of power quality due to its quick response, high reliability and nominal cost. A DVR is used to inject three phase voltage in series and in synchronism with distribution feeder voltage in order to voltage sag at protect sensitive load from point of common coupling (pcc).DVR are a class of custom power devices for providing reliable distribution power quality. They employ a series of voltage boost technology using solid state switches for compensating voltage sags/swells. The DVR application are mainly for sensitive loads that may be drastically affected by fluctuations in system .

II. Basic structure and principle of DVR

DVR is basically consists of power circuit and control circuit. The power circuit of DVR is consists of voltage, injection transformer, DC energy storage and harmonic filter.

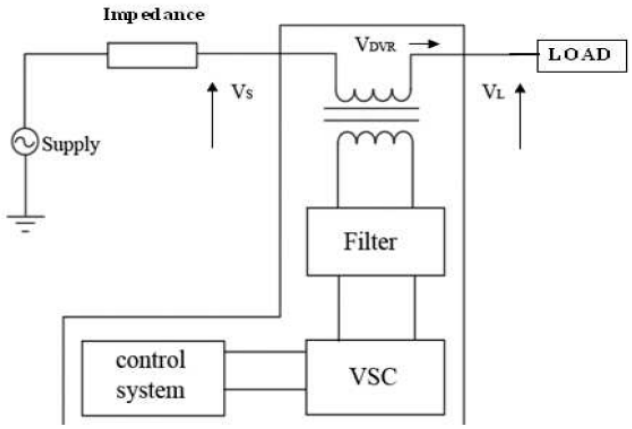

Fig. 1 Basic diagram of DVR

A. Injection transformer

The injection transformer is designed transformer that attempts to limit the coupling of noise and transient energy from primary side to secondary side. Its basic function is to step up the low voltage to required voltage. In a three phase system, either three single phase transformer units or one three phase transformer unit can be used for voltage injection purpose.

B. Harmonic filter

The main task of harmonic filter is to keep harmonic voltage content generated by inverter within tolerable limits. Harmonic filter consists of inductor and a capacitor. It is used to filter out the switching harmonic components from the inverter side, the

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higher order harmonics are prevented from penetrating into transformer.

C. Voltage source converter

A VSC is power electronic system consisting of storage device and switching device, which can generate a sinusoidal voltage at any required frequency, magnitude and phase angle. It is used to convert the DC voltage supplied from energy storage device to AC voltage.

D. Storage Device

The purpose is to supply the necessary energy to the VSC via DC link for generation of injected voltages. It provides the real power requirement of the during compensation. Lead acid batteries, flywheels, super conducting magnetic energy storage (SMES) can be used as the storage device. In fact the capacity of stored energy determines directly the duration of sag which can be mitigated by the DVR.

Principle of operation

The DVR is custom power device that is connected in series with distribution system shown in figure 1, The DVR is capable of generating or absorbing independently controllable real and reactive power at its ac output terminal. Basic principle of DVR is to transfer the voltage sag compensation value from DC side of inverter to injected transformer after filter, The compensation capability and real power that can be supplied by DVR. DVR is power electronic device that injects a set of three phase AC voltage in series and synchronism with distribution feeder voltage. The maximum injection capability of DVR is limited by the rating of DC storage and voltage injection transformer ratio.

III. SPACE VECTOR PULSE WIDTH MODULATION

Space vector PWM technique is advanced PWM method and it is the best among all PWM techniques. The circuit model of three phase voltage source PWM inverter is shown in figure 2.

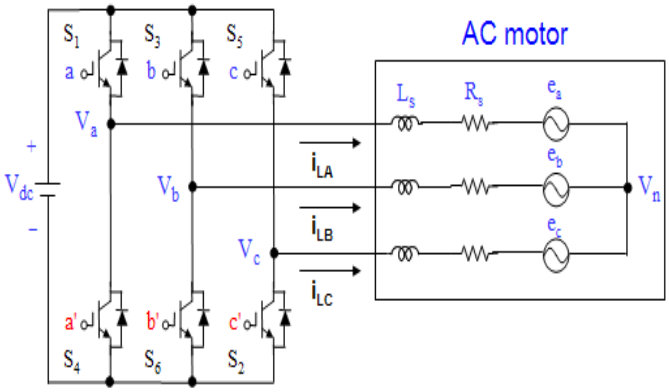

Fig. 2 three phase voltage source PWM inverter

The There are eight switch states, the output voltage of inverter are composed by eight switch states. Treats the sinusoidal voltage as a constant amplitude vector rotating at constant frequency . This PWM technique approximates the reference voltage Vref by combination of eight switching patterns (V0 to V7). The vector (V1 to V6) divide the plan into six sectors (each sector : 60 degrees) Vref is generated by two adjacent non zero vectors and two zero vectors, the objective of control scheme is to maintain constant voltage magnitude at point where a sensitive load is connected, under system disturbances. The aim of space vector PWM technique is to approximate reference voltage vector Vref using the eight switching pattern..

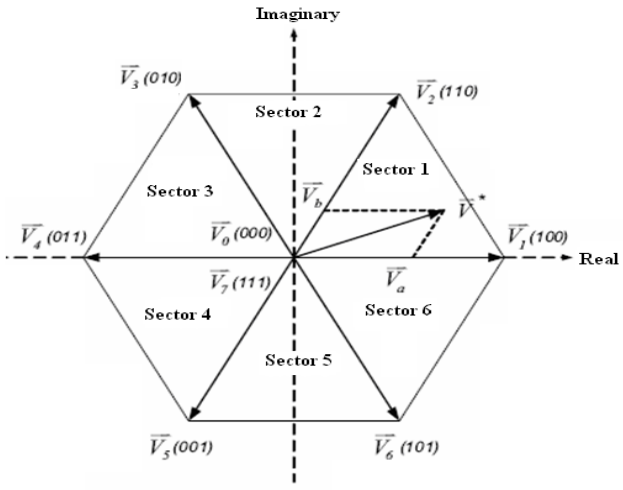

Fig. 3 Voltage space vector

In single and three phase dc/ac power converters, generally it is use pulse width modulation (PWM) technique, but using technique such as SPWM gives some problems such as large noise peaks at the multiple numbers of carrier frequencies. Space Vector PWM generates less harmonic distortion in the output voltage or currents in comparison with sine PWM. Space Vector PWM provides more efficient use of supply voltage in comparison with sine PWM.

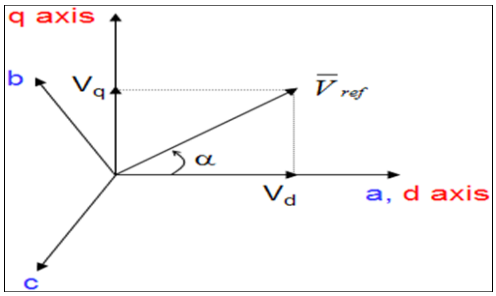

Fig 4 Voltage space vector and its component in (d,q)

$$Vd = Van - Vbn \cos 60 - Vcn \cos 60$$

$$Vq = 0 + Vbn \cos 30 - Vcn \cos 30$$

$$\begin{bmatrix} V_d \\ V_q \end{bmatrix} = \frac{2}{3} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_{an} \\ V_{bn} \\ V_{cn} \end{bmatrix}$$

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$$\left|\overline{V}_{ref}\right| = \sqrt{V_d^{\,2} + V_q^{\,2}}$$

$$\alpha = \tan^{-1}\left(\frac{V_q}{V_d}\right) = \omega_s t = 2\pi\pi_s t$$

$$(\text{where, } f_s = \text{fundamental} \quad \text{frequency})$$

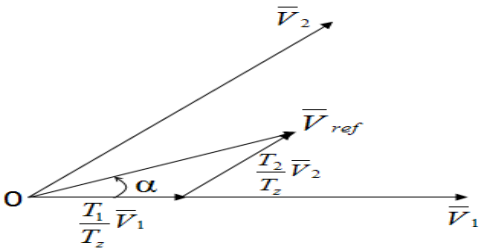


Fig. 4 Reference vector as combination of adjust vectors at sector 1

$$T_Z\, Vref = [\, T_1 V_1 + T_2 V_2]$$

$$T_1 = T_z \cdot a \cdot \frac{\sin(\pi/3 - \alpha)}{\sin(\pi/3)}$$

$$\therefore T_2 = T_z \cdot a \cdot \frac{\sin(\alpha)}{\sin(\pi/3)}$$

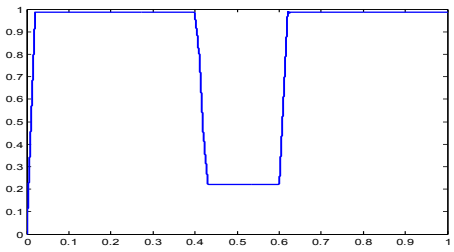
$$\therefore T_0 = T_z - (T_1 + T_2), \quad \left(\text{where,} \quad T_z = \frac{1}{f_s} \quad \text{and} \quad a = \frac{\left|\overline{V}_{ref}\right|}{\frac{2}{3} V_{dc}} \right)$$

$$T_0 = T_Z - (T_1 + T_2)$$

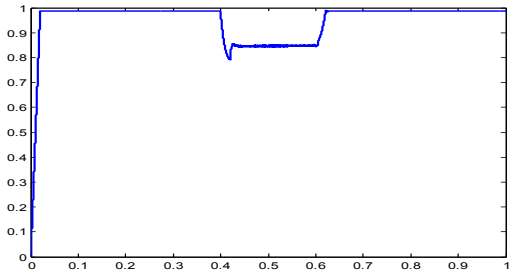
$$T_0 = T_Z - T_1 - T_2$$

The proposed DVR control system consists of open loop load voltage using PI controller. The three winding transformer connected in star/delta/delta, 13/120/120 KV. such transmission line feed two distribution networks through two transformer connected in delta/star, 120/13 KV.

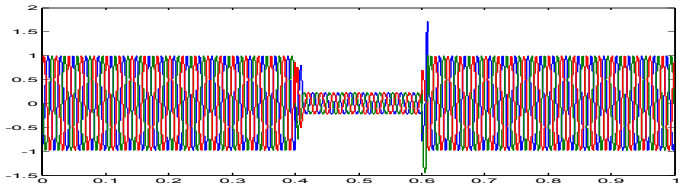
Simulation Result



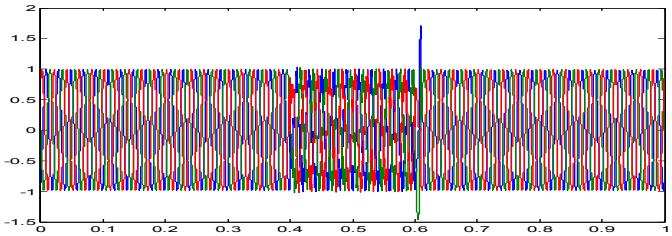
FIGURE(5) P.U. VOLTAGE AT LOAD POINT, WITH THREE PHASE FAULT, WITHOUT DVR



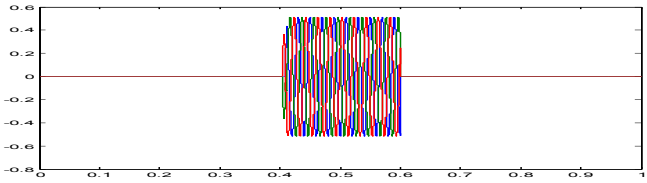
FIGURE(6) P.U. VOLTAGE AT LOAD POINT, WITH THREE PHASE FAULT, WITH DVR



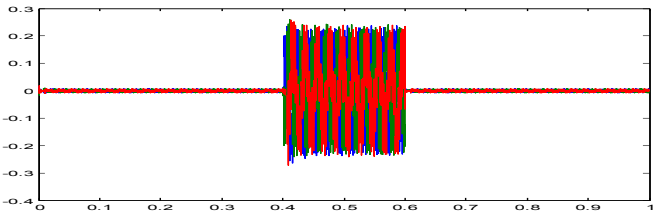
FIGURE(7) THREE PHASE VOLTAGE AT LOAD POINT, WITH THREE PHASE FAULT, WITHOUT DVR



FIGURE(8) THREE PHASE VOLTAGE AT LOAD POINT, WITH THREE PHASE FAULT, WITH DVR



FIGURE(9) INPUT VOLTAGE AT INJECTION TRANSFORMER, WITHOUT DVR



FIG(10) INPUT VOLTAGE AT INJECTION TRANSFORMER, WITH DVR

a.

IV. CONCLUSION AND RESULT

This paper presents the power quality problems and mitigation techniques of DVR. The simulation results show the performance of DVR in mitigating different faulty conditions, the DVR handles faulty situation easily and injects the appropriate voltage component to correct rapidly any anomaly

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in supply voltage to keep the voltage constant at nominal value. The DVR protects the sensitive load from effect of voltage sag using SVPWM. The modeling and simulation of DVR using matlab/simulink is presented..

The result of matlab / simulink also verify 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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