COMPARITIVE STUDY ON VOLTAGE SAG COMPENSATION UTILIZING PWM SWITCHED AUTOTRANSFORMER BY HVC

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ABSTRACT

Custom Power devices like Dynamic voltage restorer and STATCOM are normally employed as a solution for mitigation of power quality problems like voltage sag and swell. In this paper new voltage sag compensators based on an autotransformer and an IGBT switched by PWM technique and Hysteresis Voltage Control (HVC) method are compared. These two schemes are able to recognize the voltage sag condition quickly, and it can correct the correct the voltage by boosting the input voltage during voltage sag events. Different voltage sag events have been simulated by MATLAB/Simulink software. The results of simulations verify the ability of both methods to mitigate voltage sag events.

Keywords: *DVR, STATCOM, PWM Switching, Hysterisis Voltage Control, Voltage Sag*

1. INTRODUCTION

Power quality issues have become an increasing concern with an increase in the use of sensitive loads. Many crucial production processes face huge economical losses with improper quality in distribution of power. Different power quality surveys done by researchers identify voltage sags as the most serious power quality problem for industrial customers.

Voltage sag is a momentary decrease of the voltage RMS value with the duration of half a cycle up to many cycles. Voltage sag can cause serious problem to sensitive loads that use voltage sensitive components such as adjustable speed drives, process control equipment, and computers and voltage sags last until network faults are cleared. In order to increase the reliability of a power distribution system, many methods of solving power quality problems, have been suggested.

The D-STATCOM has emerged as a promising device to provide not only for voltage sag mitigation but a host of other power quality solutions such as voltage stabilization, flicker suppression, power factor correction and harmonic control. The dynamic voltage restorer (DVR) employs series voltage boost technology using solid state switches to correct the load voltage amplitude as needed [4],[6]. The basic concept is that during sag period, the DVR operates in boost mode and injects voltage of sufficient magnitude to maintain constant voltage throughout the sag period.

PWM switched autotransformer a new mitigating device for mitigating voltage *sag*, control circuit based on *rms* voltage reference could identify the disturbance and capable of mitigating the disturbance by maintaining the load voltage at desired magnitude within limits.

The PWM switched autotransformer is simple and only one IGBT switch per phase is used is more simple and economical compared to commonly used DVR or D-STATCOM[1].

A hysteresis voltage control technique is simple and only one power switch with no energy storage device. It is a closed loop system where an error signal, $e(t)$, is used to determine the switching states and to control the load voltage. $e(t)$ is the difference between the reference voltage, V_{Ref}, and the actual voltage, V_{actual}. As shown in the figure, there are bands above and under the reference voltage. When the error reaches to the upper limit, the voltage gets forced to decrease and when the error reaches to the lower limit, the voltage gets forced to increase.[2]

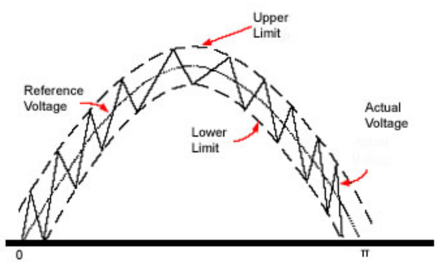


Figure 1: A Typical Hysterisis Voltage Control

2. PWM CONTROL VS HV CONTROL

Many voltage sag mitigation schemes are based on inverter systems with energy storage and power switches, but the new methods of Voltage sag compensation using autotransformer switched by PWM Control and HV Control uses only one power switch with no energy storage device per phase. Since fewer components are required in these schemes, the systems are more reliable and less expensive. The design and simulation results are presented for both the schemes. Analysis at normal conditions of the controls is essential to bring out performance efficiency of above control techniques. The intervening IGBT and autotransformer supports compensation through relays and by pass switches. In normal conditions the IGBT switch is off and the control system transfers the power to the load through thyristor by pass switch**.** In HVC scheme, when the error reaches to the upper limit, the voltage gets forced to decrease and when the error reaches to the lower limit, the voltage gets forced to increase to maintain the output voltage contant.When voltage sag occurs, the control system compensator makes the thyristor turn off and commands the IGBT to turn on, and power flows through IGBT and auto transformer. Utilizing the autotransformer and the IGBT improves the output voltage maintains constant in both PWM and HVC controls.

3. SYSTEM CONFIGURATION

An autotransformer is used as a boosting transformer instead of a two-winding transformer. A transformer with N_1:N_2 = 1:1 ratio is used as an autotransformer to boost the voltage on the load side upto 50% voltage sag. As the turns ratio equals 1:2 in autotransformer mode, the magnitude of the load current I_L (high voltage side) is the same as that of the primary current I_1 (low voltage side).
An IGBT is used as power electronic device to inject the error voltage into the line so as to maintain the load voltage constant. Four power diodes (D1 to D4) connected to IGBT switch (SW) controls the direction of power flow and connected in ac voltage controller configuration as shown in figure 2. This combination with a suitable control circuit maintains constant *rms* load voltage. In this scheme sinusoidal PWM pulse technique is used. RMS value of the load voltage V_L is calculated and compared with the reference *rms* voltage $V_{ref.}$
When sag is detected by the voltage controller, IGBT switched ON and is regulated by the PWM pulses. The primary voltage V_P is such that the load voltage on the secondary of autotransformer is the desired rms voltage. Under normal condition, the power flow is through the anti-parallel SCRs and the gate pulses are inhibited to IGBT.

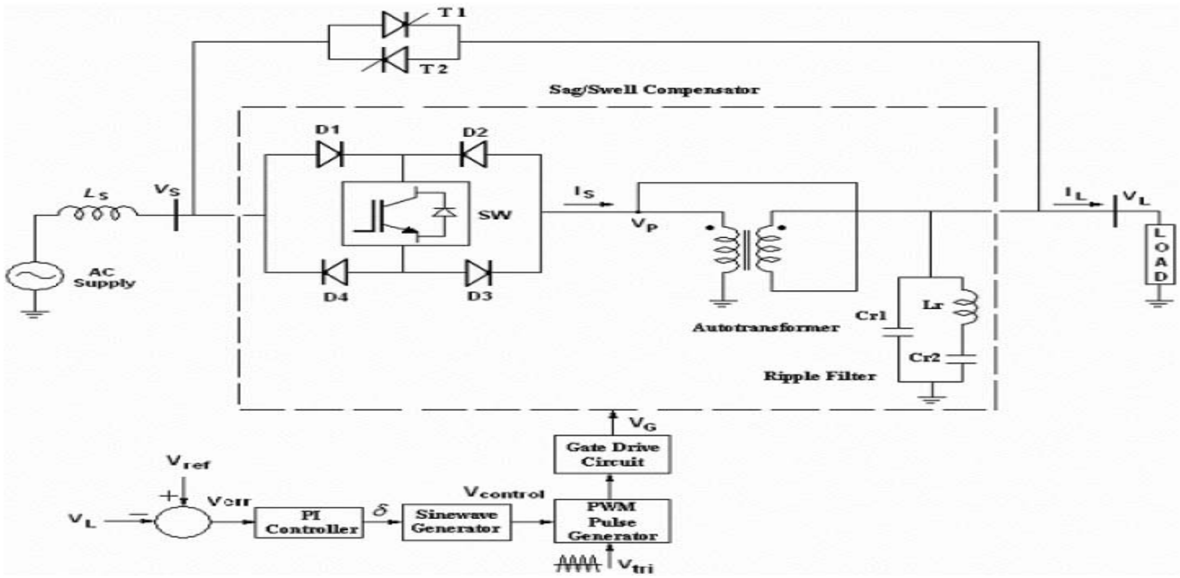


Figure 2: Block Diagram of Voltage Sag Mitigation using IGBT Switching - PWM control

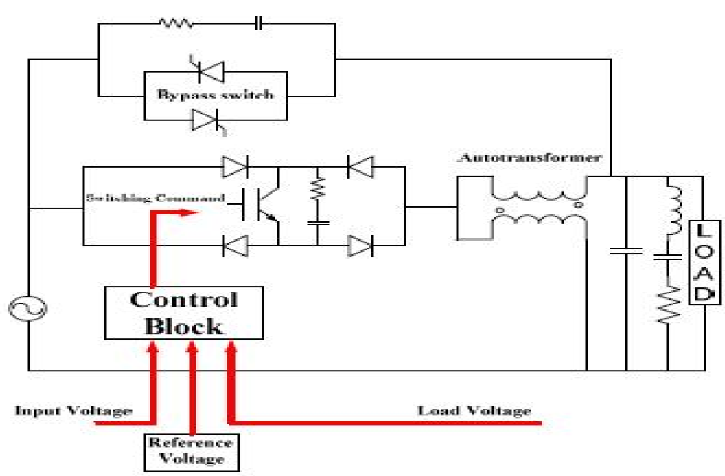


Figure 3: Block Diagram of Voltage Sag Mitigation using IGBT Switching –for HVC control

The load voltage and current are same as supply voltage and current. When a disturbance occurs, an error voltage which is the difference between the reference *rms* voltage and the load *rms* voltage is generated. Voltage V_{err} applied to the PI controller gives the phase angle δ. The

Control voltage at fundamental frequency (50 Hz) is generated and compared with the carrier frequency triangular wave of carrier frequency 1 kHz. The PWM pulses now drive the IGBT switch. The autotransformer rating in each phase is 6.35/6.35 kV (as line voltage is 11 kV) with 1:1 turns ratio. The effective voltage available at the primary of autotransformer is such that the load voltage is maintained at desired *rms* value (6.35 kV or 1 pu).

A hysteresis voltage control technique is implemented with a closed loop system as shown in fig (3). Where an error signal, e(t), is used to determine the switching states and to control the load voltage. e(t) is the difference between the reference voltage, V_{Ref}, and the actual voltage, V_{actual}. The block diagram of the HVC method is as shown in figure 4.The actual signal (V_{actual}) acts as the input of decision block. If V_{actual} is positive, the upper path of decision block produces IGBT switching pulses, and if V_{actual} is negative, the lower path of decision block produces IGBT switching pulses. The control method described above is simulated in MATLAB. The simulink block of hysteresis voltage controller is shown in Figure 5. The switching pulses produced by Relay1 and Relay2 are given to the IGBT. Whereas, in PWM Switching an IGBT is used as power electronic device to inject the error voltage into the line so as to maintain the load voltage constant. In this scheme sinusoidal PWM pulse technique is used. RMS value of the load voltage V_L is calculated and compared with the reference *rms* voltage V_{ref}.

Control voltage given in (1) is constructed at power frequency f= 50 Hz.

$$V_{control} = m_a * \sin(\omega t + \delta) \rightarrow (1)$$

Where m_a is the modulation index

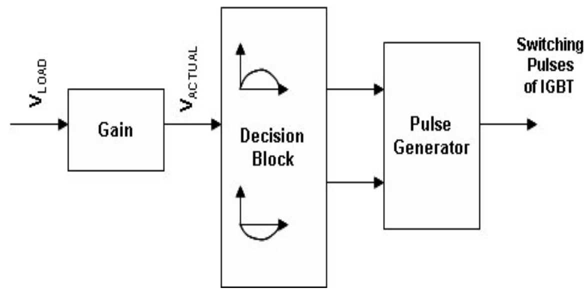


Figure 4: Block diagram of control method for HVC

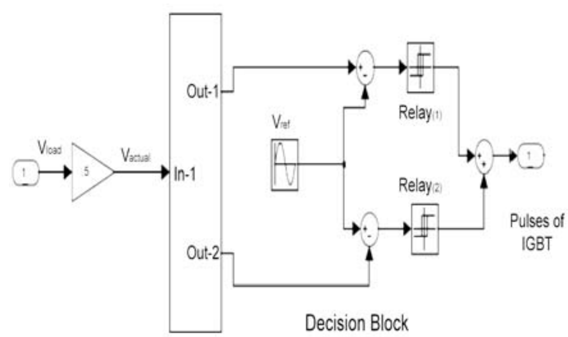
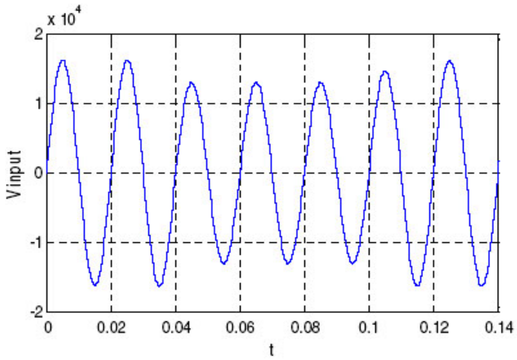


Figure 5: Simulink Model of HVC

4. SIMULATION ANALYSIS

Simulation analysis is performed on a three-phase, 115/11 kV, 100 MVA, 50 Hz system to study the performance of the switched autotransformer by PWM control and HV Control to mitigate the voltage sag disturbance. To compare the simulation results for both the techniques voltage sag of 20% is considered for verification and is simulated by MATLAB/SIMULINK software.

In these simulations, the load of system is an R-L load. In normal condition, the IGBT switch is off and the control system transfers the power to the load through thyristor (bypass switch). When voltage sag occurs, the control system of compensator makes the thyristor turn off and commands the IGBT to turn on, and power flows through IGBT and autotransformer. The input signals of control block are V_{input}, V_{load1} and V_{load2}.



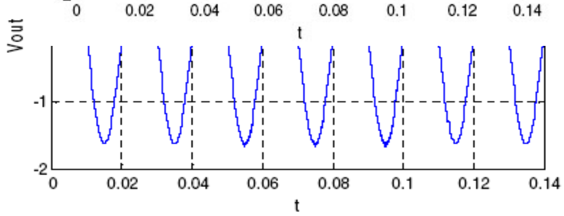


Figure 6: Input voltage having 20% sag given to both schemes

Figure 7: Compensated output voltage using HVC scheme

Considering the load voltage fed back to the control block, the hysteresis voltage controller switches the IGBT. Figure.7 and figure 8 are the compensated voltage waveforms for the 20% voltage sag. From the figures it is evident that hysterisis voltage control method gives superior results than PWM control.

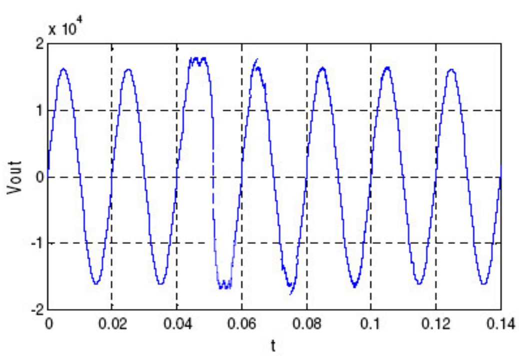


Figure 8: Compensated output voltage using Switched PWM

5. CONCLUSION

A comparison study on voltage sag compensation utilizing PWM switched autotransformer and hysteresis voltage control is presented. In HVC scheme, when the error reaches to the upper limit, the voltage gets forced to decrease and when the error reaches to the lower limit, the voltage gets forced to increase.

The phase angle δ is dependent on the percentage of disturbance and hence controls the magnitude of $V_{control}$. This control voltage is then compared with the triangular voltage V_{tri} to generate the PWM pulses V_G which are applied to the IGBT to regulate the output voltage. Hence the IGBT switch operates only during voltage sag or swells condition and regulates the output voltage according to the PWM duty-cycle. From the figures it is evident that hysterisis voltage control method gives superior results than PWM control.

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