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Comparative Study of Interline Dynamic Voltage Restorer (IDVR) using Space Vector Pulse Width Modulation (SVPWM) and Sinusoidal Pulse width Modulation (SPWM) Technique

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Abstract: *This paper describes the performance and efficiency of interline dynamic voltage restorer (IDVR) depends upon the control technique. Control technique plays a very important role in DVR. Space vector pulse width modulation (SVPWM) and sinusoidal pulse width modulation are two distinct control technique have been presented in this paper depending upon the performance and characteristics. Among these two techniques SVPWM finds the most effective technique because of easier digital realization and reduction of total harmonic distortion (THD) created by rapid switching inherent to these algorithm. The approach of this paper to the implementation of SVPWM and SPWM in IDVR and these methods investigated through the computer simulation by using MATLAB software. Experimental results obtain showed the efficiency of the proposed controller based on SVPWM and SPWM works on both normal and disturbance condition of voltage.*

1. INTRODUCTION

Now a day's increasing in use of the voltage sensitive equipment concerns a wide range of disturbance, such as voltage sag and swell, harmonic distortion, flickers. Such kind of disturbances not expected in system so high power quality in distribution system is required otherwise it affects voltage sensitive equipment which results in damage of equipment and causes loss of production in automated process since voltage disturbances can trip a motor or cause its controller to malfunction. The dynamic voltage restorer is the most effective and economical way to mitigate above mentioned issues. The dynamic voltage restorer mainly divided mainly four common parts such as series transformer, three phase voltage source inverter, control system and energy storage unit as shown in fig. 1.

Dynamic voltage restorer is a new approach in compensating voltage sag in low voltage distribution system by series injection of voltage to maintain the desired level [1]. The basic concern of this new approach is the quality and reliability of power supplies at sensitive load centers where they are located. Distribution systems basically should provide the smooth sinusoidal and uninterrupted power to the industries where the sensitive load installed with desired magnitude and frequency. In addition, DVR can also act against other issues like harmonic compensation and power factor correction [2].There are many ways to compensate voltage sag, swells and interruptions in distribution systems. Now a day's, broad range of flexible controllers, power electronics components are coming out for custom power applications. Among those DVR is the most efficient devices [3]. Dynamic voltage restorer only compensates the sag depending upon the amount energy stored in energy storage unit if somehow increase the competence of energy storage unit it directly affects on coast of DVR. Hence DVR cannot compensate long duration voltage.

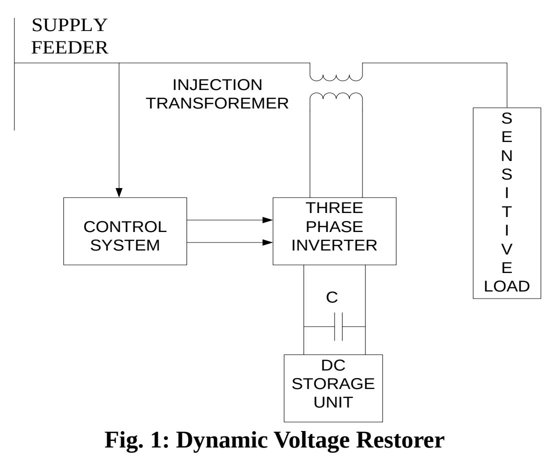


Fig. 1: Dynamic Voltage Restorer

Interline dynamic voltage restorer is the cost effective solution to overcome the problem of long duration voltage sag and to increase the competence of energy storage unit by only means of required amount of power obtained from neighboring feeder. Interline dynamic voltage restorer technique is similar to concept of interline power flow controller (IPFC) but IDVR concerns to the lower voltage distribution system [4].

The main purpose of this paper is to present the new approach of interline dynamic voltage restore (IDVR) control solution. IDVR normally installed in between two feeders where to regulate the load side voltage of both feeders.

Two distinct approaches are presented, space vector pulse width modulation and sinusoidal pulse width modulation. The comparative study of the total harmonic distortion (THD) varies with the voltage sag and swell and simulation is carried out with the help of MATLAB.

2. PULSE WIDTH MODULATION AND TECHNIQUE

A Pulse Width Modulation (PWM) Signal is a method for generating an analog signal using a digital source. A PWM signal consists of two main components that define its behavior: a duty cycle and a frequency. The duty cycle describes the amount of time the signal is in a high (on) state as a percentage of the total time of it takes to complete one cycle. The frequency determines how fast the PWM completes a cycle.

Inverter is a power electronic device which converts power from DC to AC. Now a day's most of industrial application often needs a variable output power to compensate the voltage and to supply some which require variable voltage with frequency.

This paper presents the two different techniques of PWM Sinusoidal pulse width modulation (SPWM) and space vector pulse width modulation (SVPWM).

2.1 Sinusoidal Pulse Width Modulation

The switching pulses for the three phase inverter are generated by comparing a sinusoidal reference signal with the high frequency triangular carrier wave using sinusoidal PWM techniques. Modulation index is the ratio of peak magnitudes of the modulating waveform and the carrier waveform. It relates the inverter's dc-link voltage and the magnitude of pole voltage output by the inverter. By varying the modulation index value can control the output voltage [5].

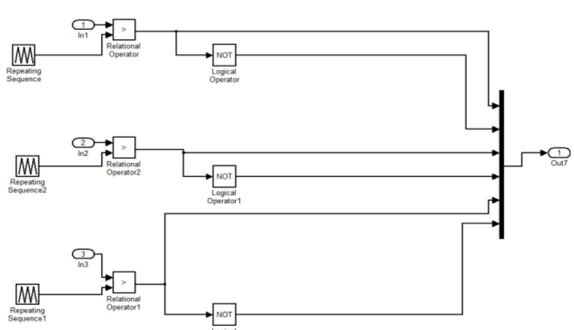


Fig. 2: SPWM generator for gating pulses

2.2 Space Vector Pulse Width Modulation

Space Vector PWM (SVPWM) refers to a special switching sequence of the upper three power transistors of a three-phase power inverter. It has been shown to generate less harmonic distortion in the output voltages and to provide more efficient use of supply voltage compared with sinusoidal PWM modulation technique [6].

Specifically the method can be driven to eight distinctive states. Modulation is accomplished by switching the state of inverter. Space vector pulse width modulation treats the sinusoidal voltage as a constant amplitude vector rotating at constant frequency.

In this work, the park's transformation is used to calculate the difference voltage.

The abc to dqo transformation is transformed the 3Φ stationary coordinate system to dqo rotating coordinate system. In abc to dq0, the following transformation is used.

$$V_d = \frac{2}{3}\left[V_a sinwt + V_b \sin\left(wt - \frac{2\pi}{3}\right) + V_c \sin\left(wt + \frac{2\pi}{3}\right)\right] \quad (1)$$

$$V_d = \frac{2}{3}\left[V_a coswt + V_b \cos\left(wt - \frac{2\pi}{3}\right) + V_c \cos(wt + \frac{2\pi}{3})\right] \quad (2)$$

$$V_0 = \frac{1}{3}\left[V_a + V_b + V_c\right] \quad (3)$$

The reference value compared with the dq coordinate, calculate the difference value in the dq coordinate and these can be transformed again to abc coordinate [7].

In a 2 level 3 phase inverter total eight vectors are possible among those six are active vectors and also two zero space vector are locate at the center of hexagon in the complex plane as shown in fig. 3. Six active vectors (V1-V6) shape the axes of a hexagonal as depicted in fig. 3, supplies power to the load. The angle difference between any adjacent two active vectors is 60 degrees. Meanwhile, two zero vectors (V0 and V7) and are at the origin and apply zero voltage to the load. The eight vectors are called and are denoted by the basic vectors are denoted (V0, V1, V2, V3, V4, V5, V6, V7) called them Basic space vectors. This transformation can be used to obtain desired output voltage to get the desired reference voltage vector Vref in the d-q plane. The purpose of SVPWM technique is to estimate the reference voltage vector Vref using the eight switching vectors.

When Vref passes through the plane one by one different sets of switches get turned on or off. As a result when Vref complete one revolution in space the inverter output voltage changes one cycle over time. The inverter output frequency depends upon the rotating speed of reference vectors while its output voltage can be attuned by the Magnitude of Vref.

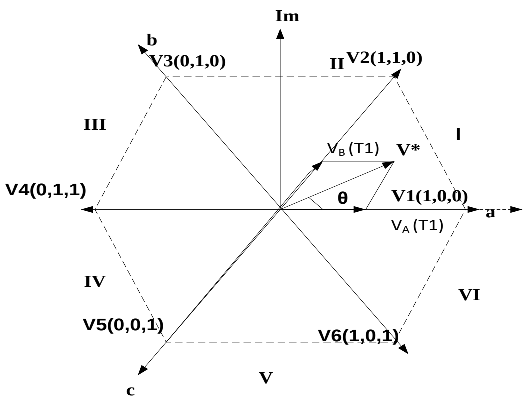


Fig. 3: Vector representation of switching gate

Table 1: Switching Time of Transistor

.Sector	Upper	Lower
1	S1=T1+T2+T0/2 S3=T2+T0/2 S5=T0/2	S4= T0/2 S6=T1+ T0/2 S2=T1+T2+T0/2
2	S1=T1+T0/2 S3=T1+T2 +T0/2 S5=T0/2	S4= T2+T0/2 S6= T0/2 S2=T1+T2+T0/2
3	S1= T0/2 S3=T1+T2+T0/2 S1= T2+T0/2	S4=T1+T2+T0/2 S6= T0/2 S2=T1 +T0/2
4	S1=T1+T2+T0/2 S3= T +T0/2 S5=T1+T2+T0/2	S4=T1+T2+T0/2 S6=T1+T2+T0/2 S2=T1+T2+T0/2
5	S1= T2+T0/2 S3=T0/2 S1=T1+T2+T0/2	S4=T1 +T0/2 S6=T1+T2+T0/2 S2= T0/2
6	S1=T1+T2+T0/2 S3=T0/2 S1=T1+T0/2	S4= T0/2 S6=T1+T2+T0/2 S2= T2+T0/2

Table 1 shows the 6 sectors and the time calculation of each switch.

3. SIMULATION RESULTS

Simulation has made for two independent feeders with two independent sources. When one of the feeder experience voltage sag controller sense it and error signal send it to the controller. The basic function of controller in IDVR is to detect a voltage difference in the system and generation trigger pulses for the both sinusoidal PWM and space vector PWM based DC-AC inverter and execution of the trigger pulses when the disturbance has overcome. The three phase DC-AC inverter can also be used as AC-DC converter to replenish the DC link in balanced normal condition.

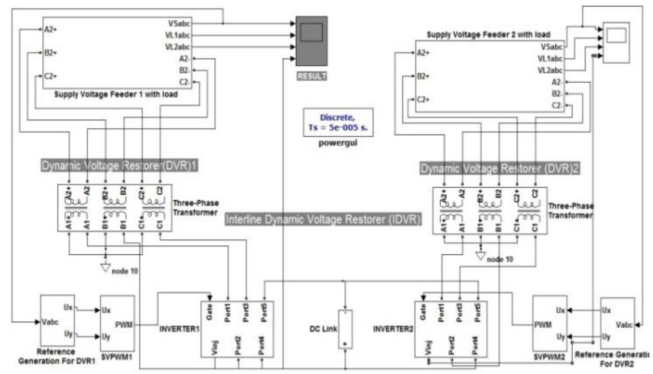


Fig. 4: Complete interline dynamic voltage restorer system

MATLAB simulation model of interline dynamic voltage restorer is shown in fig. 4 and system parameter as shown bellow in table 2.

Table 2: System parameter

Sr. No.	Parameter	Value
1	Source voltage	3.3Kv
2	Frequency	50Hz
3	Load	1Mw RL Load
4	DC source	3Kv
5	Filter inductor	10mH
6	Filter capacitor	0.0177µF
7	transformer	10MVA 1:1
8	Switching frequency	2kHz

4. SIMULATION RESULTS OF SPACE VECTOR PULSE WIDTH MODULATION

Simulation results presented in this paper work are for the 3 phase voltage sag of 30% which appears in the load bus on feeder one (3.3Kv) for a duration 0.3ms to 0.7ms. The DVR 1 is operated in active control mode and mitigates the sag above with optimum energy.

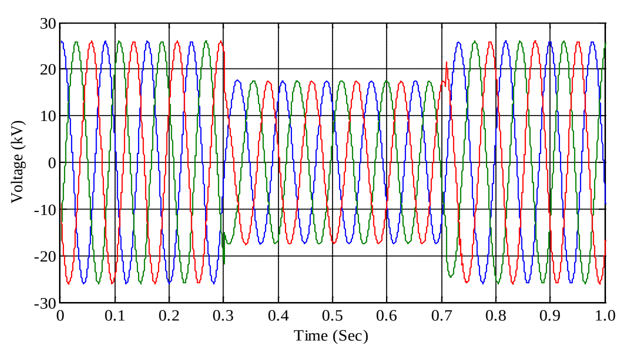


Fig. 5: Voltage sag on feeder

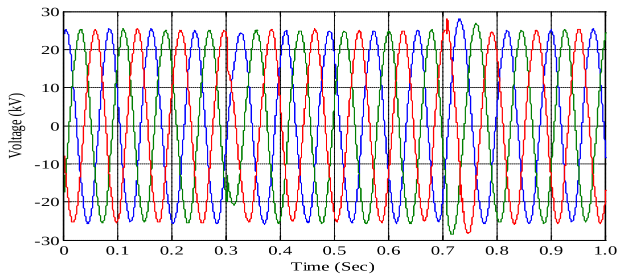


Fig. 6: Compensated voltage on feeder at the time of sag

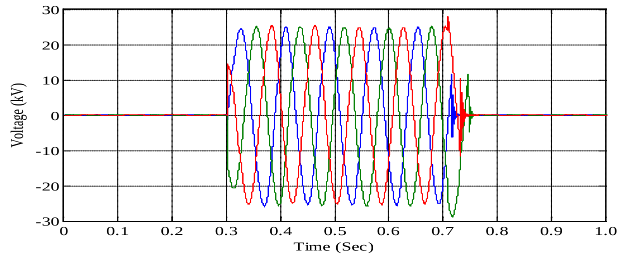


Fig. 7: Voltage across load

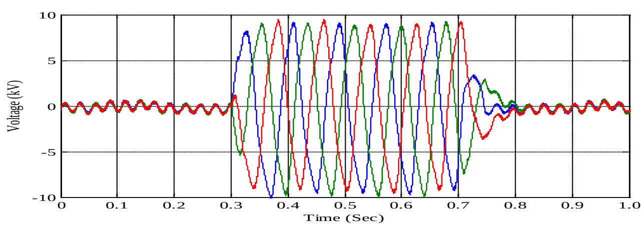


Fig. 8: Injected Voltage

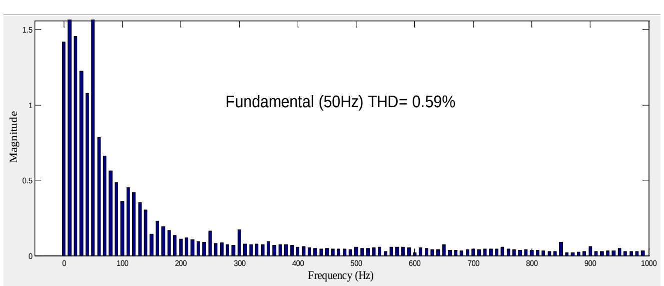
The voltage sag appeared in the feeder one is shown in fig. 3.

Compensated voltage by the DVR1 remains constant voltage during the voltage sag period. Voltage across sensitive load and injected voltage across same load respectively in fig. 5 and 6.

5. COMPARISON OF SVPWM AND SPWM

5.1 SVPWM Total Harmonic Distortions Results

Space vector pulse width modulation technique is more superior to sinusoidal pulse width modulation in terms of total harmonic distortion (THD) and switching losses [8]



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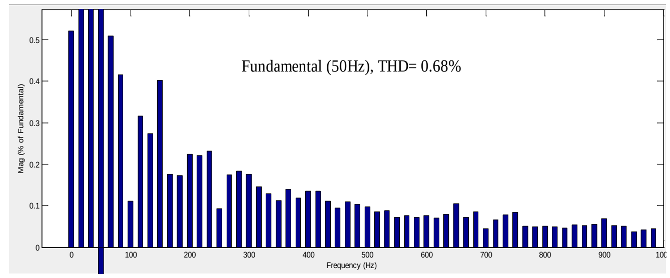

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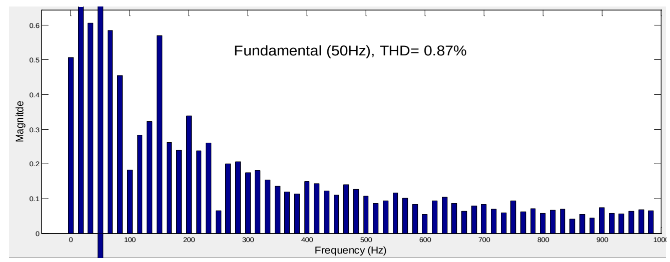
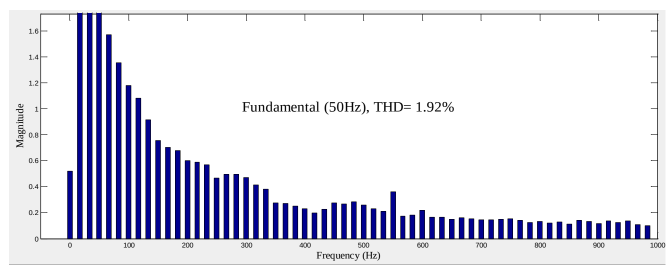


(c)

Fig. 9: total harmonic distortion by SVPWM technique (a) THD 0.59% at 20% sag. (b) THD 0.68% at 25% sag (c) THD at 0.87% at 30%

4.2 Sinusoidal Pulse Width Modulation



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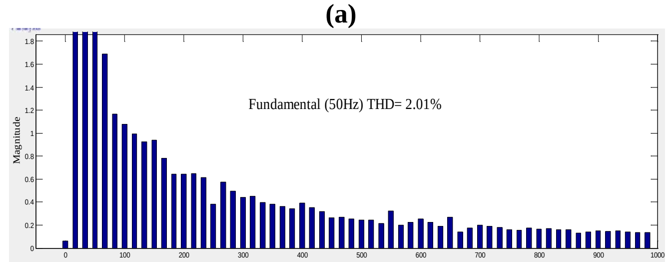

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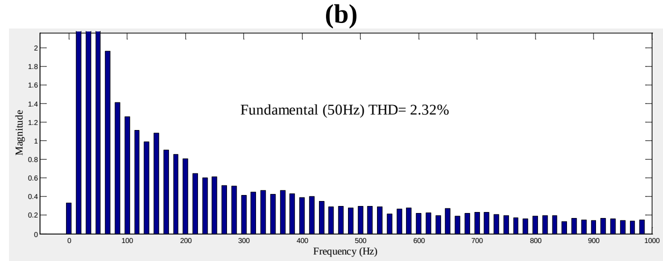

(c)

Fig. 10: Total harmonic distortion by SVPWM technique (a) THD 1.91% at 20% sag. (b) THD 2.1% at 25% sag (c) THD at 2.32% at 30%

Table 3. THD comparison of SVPWM and SPWM

Sag (%)	THD in SVPWM	THD in SPWM
20	0.59%	1.91%
25	0.68%	2.01%
30	0.87%	2.32%

6. CONCLUSION

Simulation of interline Dynamic voltage restorer by using MATLAB has been presented. This paper work proposed a new control technique space vector pulse width modulation and sinusoidal pulse width modulation shows that SVPWM technique is more superior to SPWM technique in terms of total harmonic distortion.

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