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Implementation of Space Vector PWM for Hybrid DSTATCOM

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Abstract - *The inverters are used to converts dc power into ac power at desired output voltage and frequency. The waveform of the output voltage depends on the switching states of the switches used in the inverter. The most commonly used techniques are Sine PWM and Space vector plus width modulation (SVPWM). SVPWM is considered to be superior performance than other PWM technics for Distribution static compensator (DSTATCOM) with better DC bus utilization. This paper focuses on a three-phase VSI using Space vector modulation for Hybrid DSTATCOM. Finally the simulation results of SVPWM are compared with un-compensated system.*

***Key Words*: Distribution static compensator (D-STATCOM), Pulse-width modulation (PWM), space-vector PWM (SVPWM), space-vector PWM (SVPWM), Voltage source inverter (VSI).**

1. INTRODUCTION

The increased use of power electronics based converters causes harmonics and unbalanced in distribution system; which results in poor power quality [1, 2]. In order to improve waveforms of voltage and current; active power filters have been proposed in literature [7]. The shunt active power filter is also known as Distribution static compensator (DSTATCOM); which injects equivalent compensating currents into the grid to compensate phase current harmonics; reactive power and load balancing. Space-vector modulation has become one of the most important PWM methods for three-phase converters [3]. There is various pulse-width modulation (PWM) techniques have been developed for DSTATCOM. The most popularly used PWM schemes for three-phase voltage source inverters are sinusoidal PWM and space vector PWM (SVPWM) [4]. The output voltage per phase for a sinusoidal PWM based three phase converter is restricted to $0.5V_{dc}$ (pinnacle esteem) and the line-to-line RMS voltage is $0.612V_{dc}$. SVPWM is another direct advanced PWM procedure proposed in 1982. SVPWM based converter can have a higher output voltage at $0.707V_{dc}$ (Line-to-line, RMS).Reviewing the literature it can be concluded that SVPWM has certain advantages over SPWM [3]. The performance of the proposed topology is validated through the MATLAB 2013a simulation results.

2. PROPOSED DSTATCOM TOPOLOGY

The hybrid three Phase four Wire DSTATCOM is shown in Fig. 1. It is acknowledged utilizing a three phase, four wire, two level, and neutral point clamped VSI. Proposed scheme connects an LCL filter at the front end of VSI, which is followed by a series capacitor C_{se}. In traditional DSTATCOM topology considered in this paper, the same VSI is connected to the PCC through an inductor Lf. In LCL filter based DSTATCOM topology, an LCL filter is connected between the VSI and the PCC. The Proposed DSTATCOM compensates the current harmonics and reactive power required by the nonlinear load [7].

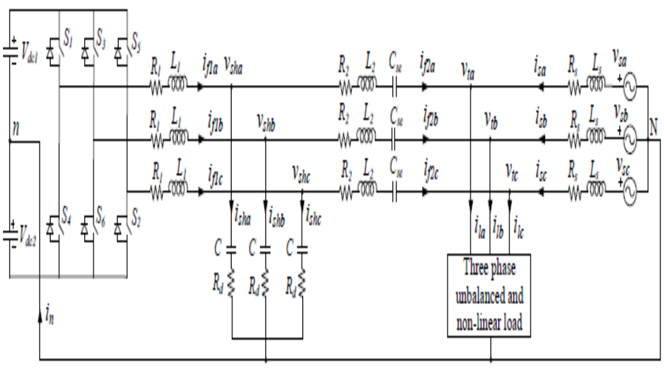

Fig.1. Proposed DSTATCOM topology

3. SPACE VECTOR PWM (SV-PWM) TECHNIQUE

The circuit model of a typical three-phase voltage source PWM inverter is shown in Fig. 2. The space-vector PWM technique aims to realize this slowly rotating voltage space vector (corresponding to fundamental component of output voltage) from the six active state voltage vectors and two null state vectors. The active state voltage vectors have a magnitude Vdc and they point along fixed directions whereas null state vectors have zero magnitude [2].

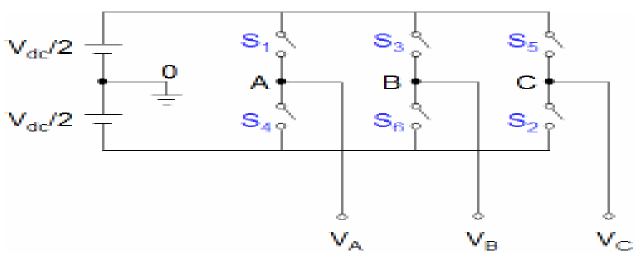

Fig. 2 Three-phase PWM Inverter

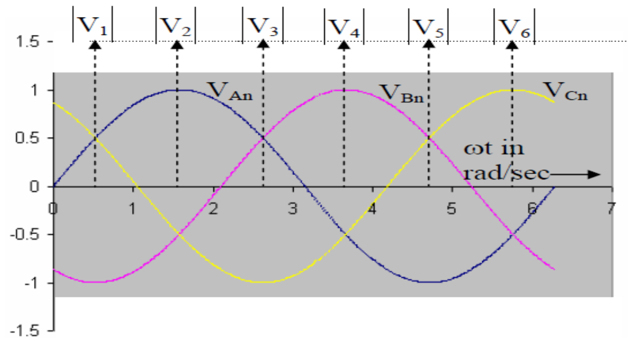

Fig.3: The concept of voltage space-vectors

Fig.3. shows the voltage space-vector plane formed by the active state and null state voltage vectors. The null state voltage vectors V_0 and V_7 are each represented by a dot at the origin of the voltage space plane. The switching word for V_0 is 000, meaning all lower side switches are ON and for V_7 is 111, corresponding to all upper side switches ON. A regular hexagon is formed after joining the tips of the six active voltage vectors. The space-plane can be divided in six identical vectors (I to VI) [3]. The output voltage vector from the inverter (barring high frequency disturbances) should be rotating with fixed magnitude and speed in the voltage plane. Now it is possible to achieve the resultant voltage space-vector along any direction in the space vector using the six active vectors of the inverter. Suppose one needs to realize a space voltage vector along a direction that lies exactly in the center of sector-I of the space-plane shown in Fig. 4 [5].

For this the inverter may be continuously switched (at high frequency) between V_1 and V_2 active states, with identical dwell time along these two states. The resultant vector so realized will occupy the mean angular position of V_1 and V_2 and the magnitude of the resultant vector can be found to be 0.866 times the magnitude of V_1 or V_2 (being the vector sum of 0.5 V_1 and 0.5 V_2). Further, the magnitude of the resultant voltage vector can be controlled by injecting suitable durations of null state. The circuit model of a typical three-phase voltage source PWM inverter is shown in Fig. 2. S_1 to S_6 are the six power switches that shape the output, which are controlled by the switching variables S_1, S_4, S_3, S_6 and S_5, S_2. When an upper transistor is switched on, i.e., when S_1, S_3 or S_5 is 1, the corresponding lower transistor is switched off, i.e., the corresponding S_4, S_6 or S_2 is 0. Therefore, the on and off states can be determine using switch S_1, S_3 and S_5 [6].

The relationship between the switching variable vector $[A, B, C]^T$ and the line-to-line voltage vector $[V_{AB}\ V_{BC}\ V_{CA}]^T$ is given as follows;

$$\begin{bmatrix} V_{AB} \\ V_{BC} \\ V_{CA} \end{bmatrix} = V_{dc} \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} A \\ B \\ C \end{bmatrix} \qquad (1)$$

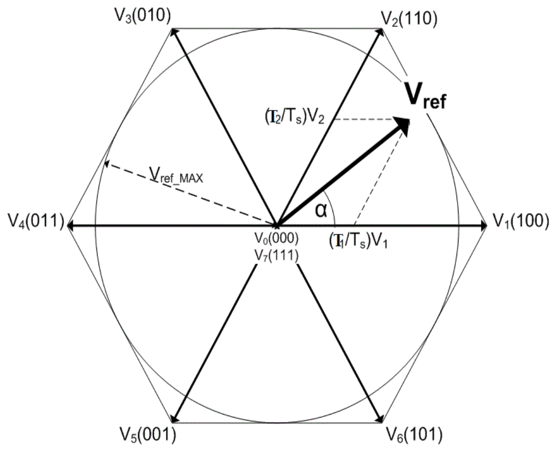

Fig.4. Basic switching vectors and sectors

Also, the relationship between the switching variable vector $[A, B, C]^T$ and the phase voltage vector $[V_{AN}\ V_{BN}\ V_{CN}]^T$ can be expressed below.

$$\begin{bmatrix} V_{AN} \\ V_{BN} \\ V_{CN} \end{bmatrix} = \frac{V_{dc}}{3} \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix} \begin{bmatrix} A \\ B \\ C \end{bmatrix} \qquad (2)$$

From (1) and (2), calculates total eight possible switching vectors in the form of output line-to-neutral voltage (phase voltages), and output line-to-line voltages in terms of DC bus voltage (V_{dc}) are given in Table.1 and Fig.4 shows the eight inverter voltage vectors (V_0 to V_7).

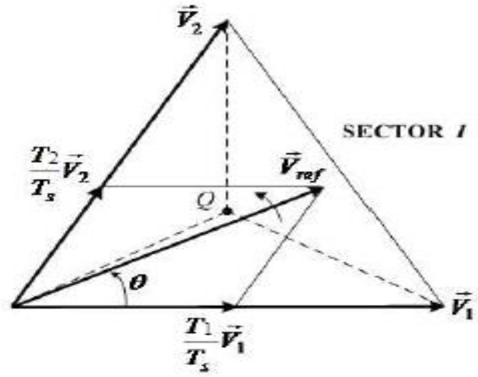

Fig.5.Vref falls into Sector 1

Therefore, from fig. 5 switching time duration for sector 1 is given as;

$$\therefore T_0 = T_S - (T_1 + T_2), \left(\begin{matrix} where, n = 1-6\ (i.e., sector\ 1\ to\ 6) \\ 0 \le \theta \le 60^0 \end{matrix} \right) \qquad (3)$$

$$\therefore T_1 = \frac{\sqrt{3}\, T_S\, |\bar{V}_{ref}|}{V_{dc}} \left(Sin \left(\frac{\pi}{3} - \theta + \frac{n+1}{3} \pi \right) \right) \qquad (4)$$

$$\therefore T_2 = \frac{\sqrt{3}\, T_S\, |\bar{V}_{ref}|}{V_{dc}} \left(Sin \left(\theta - \frac{n-1}{3} \pi \right) \right) \qquad (5)$$

Table 1: Vectors, Switching Vectors, Phase Voltages

Voltage Vectors	Switching Vectors			Line-to-Neutral Voltages			Line-to-Line Voltages		
	A	B	C	V_{AN}	V_{BN}	V_{CN}	V_{AB}	V_{BC}	V_{CA}
V_0	0	0	0	0	0	0	0	0	0
V_1	1	0	0	$\frac{2V_{dc}}{3}$	$-\frac{V_{dc}}{3}$	$-\frac{V_{dc}}{3}$	V_{dc}	0	$-V_{dc}$
V_2	1	1	0	$\frac{V_{dc}}{3}$	$\frac{V_{dc}}{3}$	$-\frac{2V_{dc}}{3}$	0	V_{dc}	$-V_{dc}$
V_3	0	1	0	$-\frac{V_{dc}}{3}$	$\frac{2V_{dc}}{3}$	$-\frac{V_{dc}}{3}$	$-V_{dc}$	V_{dc}	0
V_4	0	1	1	$-\frac{2V_{dc}}{3}$	$\frac{V_{dc}}{3}$	$\frac{V_{dc}}{3}$	$-V_{dc}$	0	V_{dc}
V_5	0	0	1	$-\frac{V_{dc}}{3}$	$-\frac{V_{dc}}{3}$	$\frac{2V_{dc}}{3}$	0	$-V_{dc}$	V_{dc}
V_6	1	0	1	$\frac{V_{dc}}{3}$	$-\frac{2V_{dc}}{3}$	$\frac{V_{dc}}{3}$	V_{dc}	$-V_{dc}$	0
V_7	1	1	1	0	0	0	0	0	0

4. SIMULATION RESULTS

The SIMULINK representation of a space vector modulated inverter with Hybrid D-STATCOM shown in Fig. 6 below. Advantages of proposed topology are that it uses lower rating of the VSI, smaller value of filter inductor, reduces damping power loss, and provides improved current compensation. All these advantages are verified through MATLAB/Simulink (R2013a) software.

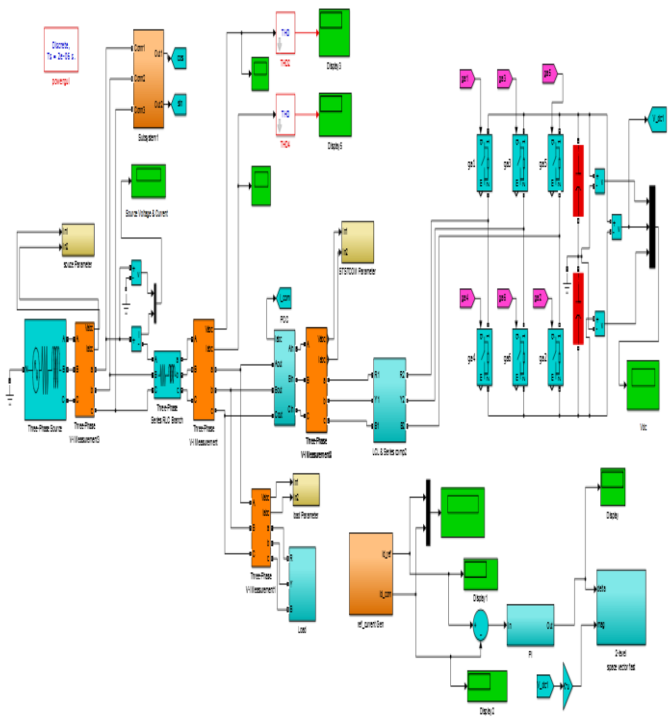

Fig. 6: Simulink Model for SVPWM based DSTATCOM

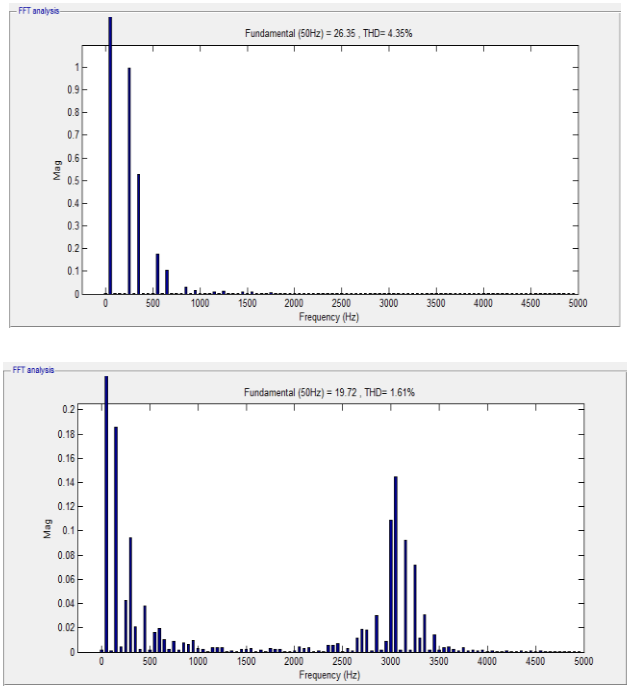

Fig. 6: THD Without & With DSTATCOM

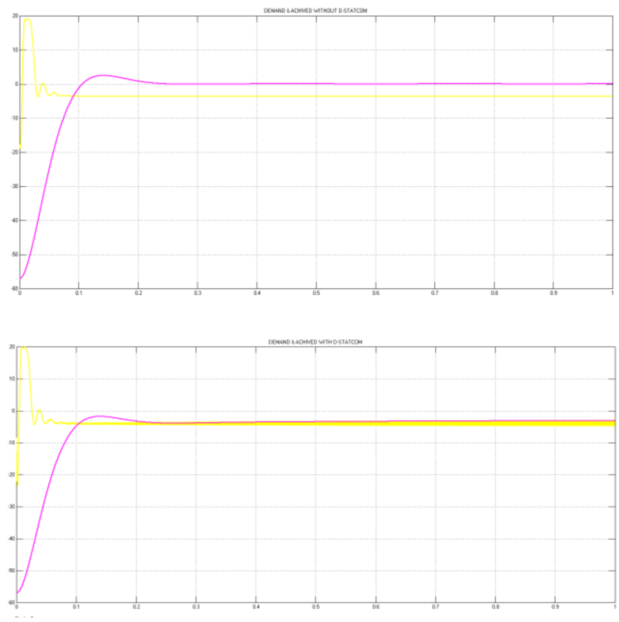

Fig. 7: Demand & achieved without & with DSTATCOM

5. CONCLUSIONS

This paper proposes a method for Hybrid Distribution static compensator (DSTATCOM) using SVPWM. In this paper the space voltage vector pulse width modulation technique is proposed to DSTATCOM. Space vector Modulation Technique has become the most popular and important PWM technique for Three Phase Voltage Source Inverters FACTS Controller application. This technique actually can utilize 100% DC source and the output voltage is about 15% more as compared to SPWM. The SVPWM technique utilizes DC bus voltage more efficiently and generates less harmonic distortion in a three-phase voltage-source inverter.

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