Study Comparison on "Locus Comparison of Space Vector PWM and PWM Inverter using a Simulink Model"

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***Abstract*— This paper comprehensively analyzes the locus comparison of SVPWM and PWM. The comparison involved,. In PWM methods such as sine-triangle PWM, three phase reference modulating signals are compared against a common triangular carrier to generate the PWM signals for the three phases. In SVPWM methods, a revolving reference voltage vector is provided as voltage reference instead of three phase modulating waves. The magnitude and frequency of the fundamental component in the line side are controlled by the magnitude and frequency, respectively, of the reference vector. The highest possible peak phase fundamental is very less in sine triangle PWM when compared with space vector PWM. Space Vector Modulation (SVM) Technique has become the important PWM technique for three phase Voltage Source Inverters for the control of AC Induction, Brushless DC, Switched Reluctance and Permanent Magnet Synchronous Motors.**

Keywords: - PWM, SVPWM, SVM, THD, FFT

I. INTRODUCTION

PWM technique has been used to achieve variable voltage and variable frequency in ac-dc and dc-ac converters. PWM techniques are mainly used in many different types of applications like variable speed drives (VSD), static frequency changers (SFC), un-interruptible power supplies (UPS) etc. Many problems are occurring in reduction of harmonic contents in an inverter circuit. The classical square wave inverter used in low or medium power applications suffers from a serious disadvantage such as lower order harmonics in the output voltage. There is a method to reduce harmonic contents in high power converters is to use PWM control techniques. The main aim of PWM techniques is to design a sinusoidal AC output whose magnitude and frequency could both be restricted. PWM switching strategies not only help in solving the problems like less THD, effective dc bus utilization etc but also take care of secondary issues like EMI reduction , switching loss, better spreading of Harmonics over the spectrum. Real-time method of PWM generation can be broadly classified into Triangle comparison based PWM (TCPWM) and Space Vector based PWM (SVPWM).

Fig. 1 shows two types of PWM signals, symmetric and asymmetric. The pulses of a symmetric PWM signal are always symmetric with respect to the center of each PWM period. The pulses of an asymmetric PWM signal always have the same side aligned with one end of each PWM period.

It has been shown that symmetric PWM signals generate fewer harmonic in the output currents and voltages.

In a three-phase induction motor with variable frequency and variable voltage for variable speed applications a voltage source inverter is generally used. A suitable pulse width modulation (PWM) technique is employed to obtain the required output voltage in the line side of the inverter.

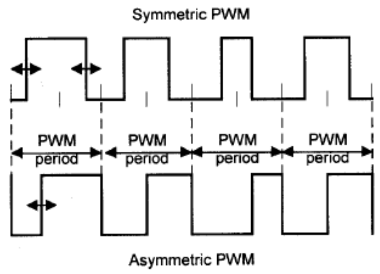

Fig.1 Symmetric and asymmetric PWM signals

The different methods for PWM generation can be broadly classified into Triangle comparison based PWM (TCPWM) and Space Vector based PWM (SVPWM).In TCPWM methods such as sine-triangle PWM, three phase reference modulating signals are compared against a common triangular carrier to generate the PWM signals for the three phases. Applying space vector technique in pwm, a revolving reference voltage vector is provided as voltage reference instead of three phase modulating waves. The study of space vector modulation technique reveals that space vector modulation technique utilizes DC bus voltage more efficiently and generates less harmonic distortion when compared with Sinusoidal PWM (SPWM) technique. In this paper first a model for Space vector PWM is made and simulated using MATLAB/SIMULINK software and its performance is compared with Sinusoidal PWM. The simulation study reveals that Space vector PWM utilizes dc bus voltage more effectively and generates less THD when compared with sine PWM.

II. LOCUS COMPARISON OF SVPWM AND PWM

A. Basics Of SVPWM And PWM

Vector Modulation (SVM) was originally developed as vector approach to Pulse Width Modulation (PWM) for three phase inverters. It is a more sophisticated technique for generating sine wave that provides a higher voltage to the motor with lower total harmonic distortion. The main aim of any modulation technique is to obtain variable output having a maximum fundamental component with minimum harmonics. Space Vector PWM (SVPWM) method is an advanced; computation intensive PWM method and possibly the best techniques for variable frequency drive application. The output voltage of the inverter contains harmonics. However, the harmonics are pushed to the range around the carrier frequency and its multiples.This technique improve the distortion factor as compare to other method where sine wave is compare with the triangular wave. It eliminates all harmonics less than or equal to 2p-1, where "p" is defined as the number of pulses per half cycle of the sine wave. The output voltage of the inverter contains harmonics. However, the harmonics are pushed to the range around the carrier frequency and its multiples.In order to implement Sinusoidal PWM using analog circuits, one has to use the following building blocks - (1) High frequency triangular wave generator; (2) Sine wave generator; (3) Comparator; and (4) The peak output voltage of an inverter using SPWM depends on the modulation index. If the modulation index value will be 1 then higher output voltage can be obtained because the width of the pulse equal to the peak of sine wave which will not vary in accordance with the modulation index. By applying carrier wave during the first and the last 60 degree interval of each half cycle sinusoidal pulse width modulation technique can be modified as shown in figure 4.

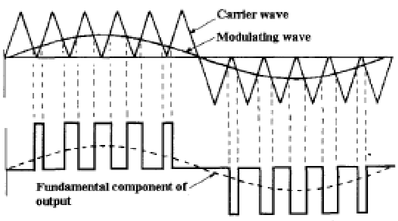

Fig.2 Sinusoidal pulse width modulation

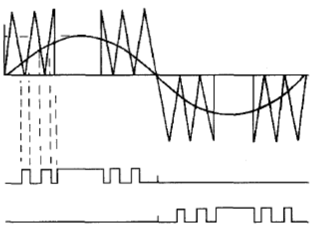

Fig. 4 Modified sinusoidal PWM technique

The SVPWM generates minimum harmonic distortion of the currents in the winding of 3- phase AC motor. SV Modulation also provides a more efficient use of the supply voltage in comparison with sinusoidal modulation methods.Comparison of sinusoidal wave with a a triangular wave is done. The locus of the reference vector is the inside of a circle with a radius of 1/2Vdc.In the SV modulation it can be shown that the length of each of the six vectors is 2/3Vdc .In steady state the reference vector magnitude might be constant. This fact makes the SV modulation reference vector locus smaller than the hexagon described above. This locus narrows itself to the circle inscribed within the hexagon, thus having a radius of 1/√3 Vdc. In figure below the different reference vector loci are presented**.**

Therefore, the maximum output voltage based on the Space Vector theory 2/√3 (=OM/ON) times as large as that of the conventional sinusoidal modulation. This explains why, with SVPWM, we have a more efficient use of the supply voltage than with the sinusoidal PWM method. Space Vector Modulation techniques have been increased in last decade, because they allow reducing commutation losses and/or the harmonic content of output voltage, and to obtain higher amplitude modulation indexes if compared with convectional SPWM techniques.

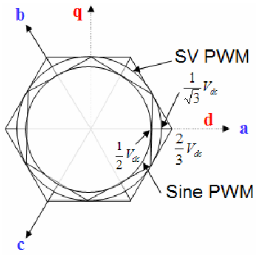

Fig. 5 Locus comparisons SVPWM with sinusoidal-PWM

Generalization of the Space Vector Modulation:

Five steps can be identified to implemented the space vector modulation,

1) Definition of the possible switching vectors in the output voltage space.
2) Identification of the separation planes between the sectors in the output voltage space.
3) Identification of the boundary planes in the output voltage space.
4) Obtaining decomposition matrices.
5) Definition of the switching sequences

III. COMPUTER MODEL

Fig.6 shows Simulink model of the whole system.

In the first step coordinate transformation called d-q transformation is obtained by multiplication of vector X_{abc} by matrix T.

$X_{dq} = T\, X_{abc}$.

Where T is the transformation matrix. From the block diagram the voltage vector U_{out} is obtained after transformation. When desired output voltages are 3-phase sinusoidal voltages with 120°, U_{out} becomes a vector rotating around the origin of d-q plane with a frequency corresponding to that of the desired 3-phase voltages the envelope of hexagon formed by the basic space vector is the locus of maximum U_{out}. Therefore the magnitude of U_{out} must be limited to the shortest radius of this envelope when U_{out} is a rotating vector. This gives a maximum magnitude of $\sqrt{3}/2\ V_{dc}$ for U_{out} and correspondingly the maximum rms value of the fundamental line-line and line-neutral output voltage are $V_{dc}/\sqrt{3}$ and $V_{dc}/\sqrt{6}$.

For sector selection a subsystem is prepared as shown in fig. important task is to set 60 ° for each sector selection which is accomplished through this subsystem. Finally the output is compared with triangular wave and triangular wave decides switching frequency of SVPWM to obtain the require pulse train**.** Similarly as shown in computer model SPWM is generated after comparison with triangular wave.

IV. STIMULATION RESULT

Comparative model of SVPWM and SPWM was designed & simulated successfully using MATLAB (SIMULINK) & following results were generated.

Fig depicts the locus of SVPWM and can be clearly seen that length of each of the six vectors is 2/3Vdc. In steady state the reference vector magnitude might be constant. This fact makes the SV modulation reference vector locus smaller than the hexagon described above. This locus narrows itself to the circle inscribed within the hexagon, thus having a radius of $1/\sqrt{3}$ Vdc.

From the fig. below we see that in sinusoidal modulation in which the sinusoidal signals are compared with a triangular carrier, the locus of the reference vector is the inside of a circle with a radius of 1/2Vdc. Fig 6.4 shows the pole voltages waveforms of the spacevector PWM output, i.e.Va0, Vb0 and Vc0.These continuous output voltage waveform pattern is obtained .

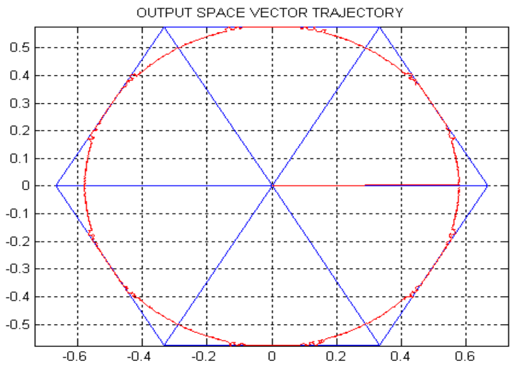

Fig. 7 Locus output of SVPWM

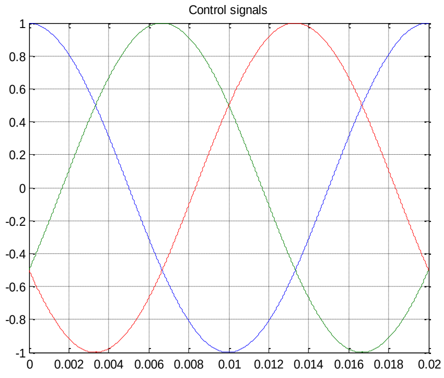

Fig 8. The 2-phase output voltage of PWM

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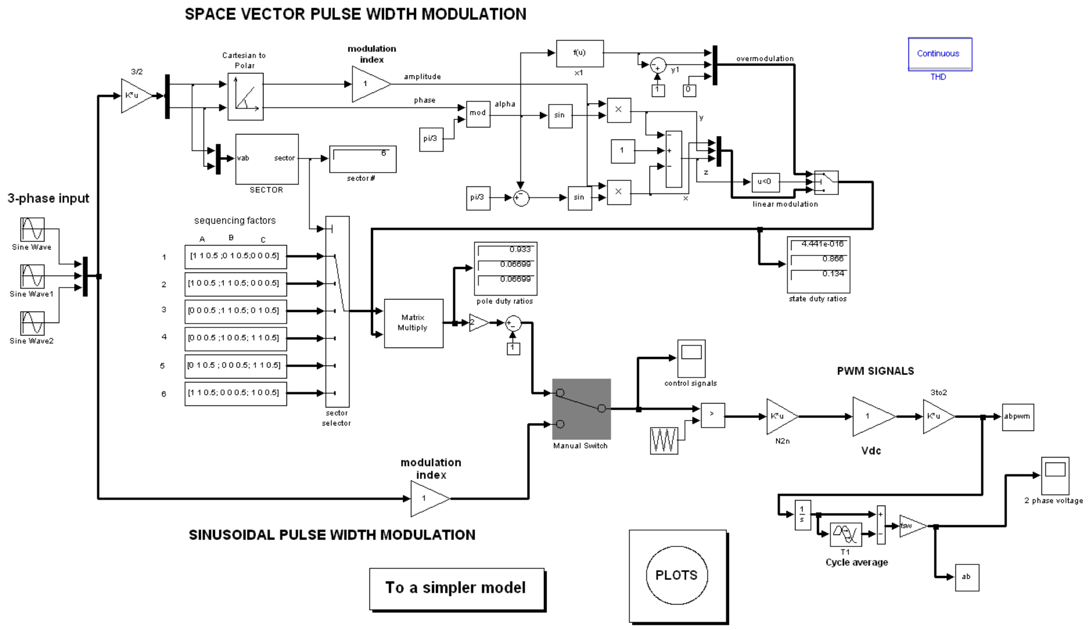

Fig.6 Comparative Simulink model of SVPWM and PW