INVESTIGATION OF VARIOUS SPACE VECTOR PWM TECHNIQUES FOR INVERTER

R.Madhavi, C.Harinath Reddy

***Abstract*— In this paper , the investigation of the various space vector pulse width modulation techniques for inverter is presented. This paper uses the SVPWM techniques such as conventional SVPWM, digital SVPWM, simplified SVPWM and discontinuous PWM. In this the conventional SVPWM and discontinuous PWM requires the angle and sector information but the simplified SVPWM uses the imaginary switching times which can be obtained from the reference voltages. The influence of SVPWM techniques are analyzed for higher modulation and lower modulation indices based on the harmonic distortion in the current ripple by using MATLAB/Simulink.**

***Index Terms*— conventional SVPWM, discontinuous PWM, digital SVPWM, simplified SVPWM**

I. INTRODUCTION

The PWM techniques are mainly employed for applications such as inverter fed AC drives and high power factor rectifiers. In order to generate the inverter output voltage, various PWM methods have been developed. we are having several approaches. In that mainly we are implementing triangular comparison approach and space vector approach. The conventional space vector PWM is widely used in the PWM strategy. It has the advantages of lower current harmonics and having the higher modulation index when compared with sine triangle PWM method.

In space vector based PWM algorithm , the reference voltage vector is approximated by the time averaging over a subcycle of the two adjacent active states and the two zero states[1-3]. The equal division of zero voltage vector are considered in the conventional SVPWM algorithm. In the conventional SVPWM algorithm it requires the angle and sector information. To reduce the burden in that we can use the imaginary switching times for the modulation techniques[4-5].

II. SVPWM TECHNIQUES

Space vector pulse width modulation(SVPWM) techniques are having better performance compare to sine PWM. So this SVPWM techniques are widely used and this SVPWM techniques are categorized depending upon the complexity of the system. From this we are having the SVPWM algorithms as

A. Conventional SVPWM algorithm
B. Digital SVPWM algorithm
C. Simplified SVPWM algorithm

These three SVPWM algorithms are explained as follows.

A. *Conventional SVPWM algorithm*

Figure 1 shows the voltage vectors produced by a three-phase, two-level inverter. With the six active voltage vectors dividing the space vector plane into six sectors. In CSVPWM algorithm, the desired reference voltage vector is generated by time averaging the suitable discrete voltage vectors in every subcycle or sampling time period Ts. For example, the reference vector in sector I, as shown in figure 1, is generated by applying the active state 1, active state 2 and the zero states 0 and 7 for durations T1, T2 and TZ respectively [1-3]. For a given reference voltage vector and Ts, the duration T1, T2 and TZ are unique. The expressions for the various active state time durations and zero states time duration in the first sector can be given as in formulae(1)-(3).

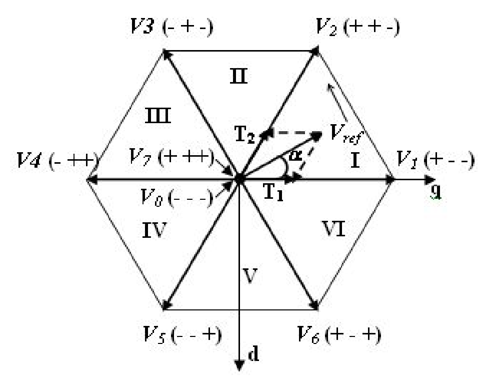

Fig 1: Voltage space vectors for SVPWM

$$T_1 = \frac{2\sqrt{3}}{\pi} M_i \left(\sin(60^o - \alpha)\right) T_s \quad (1)$$

$$T_2 = \frac{2\sqrt{3}}{\pi} M_i \left(\sin\alpha\right) T_s \quad (2)$$

$$T_Z = T_s - T_1 - T_2 \quad (3)$$

$$where\ M_i = \frac{\pi V_{ref}}{2V_{dc}}$$

$T_0 = K_0 T_z$

$T_7 = (1-K_0) T_z$

The active states for the inverter can be represented as follows.

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$$V_k = \frac{2}{3} V_{dc} e^{j(k-1)\frac{\pi}{3}} \qquad \text{where } k = 1,2,...,6$$

B. digital SVPWM algorithm

A rough alternative which does not require troublesome calculations, is to reduce the smaller vector component enough to put the vector on the hexagon border. This digital SVPWM reduces the complexity compare to the conventional SVPWM . This digital SVPWM can be implemented in digital circuits for the better performance. This digital SVPWM can be done in steps as follows. Steps:

1. Intialize the values f, t, and Vdc
2. Calculation of Ta and Tb
3. Sector identification and sequence settings
4. define the time variable for the sectors
5. pulse generation

C. Simplified SVPWM algorithm

Different switching sequences can be obtained by using conventional space vector approaches given in (1)-(3), which uses the reference voltage vector and angle information and increases the complexity of the control algorithm. In order to reduce the complexity, the proposed PWM algorithms use the concept of imaginary switching times. The imaginary switching times are proportional to the instantaneous three phase reference voltages V_{an},V_{bn} and V_{cn} and are defined as

$$T_{an} \equiv \left(\frac{T_s}{V_{dc}}\right) V_{an} \; ;$$

$$T_{bn} \equiv \left(\frac{T_s}{V_{dc}}\right) V_{bn} \; ;$$

$$T_{cn} \equiv \left(\frac{T_s}{V_{dc}}\right) V_{cn}$$

Where T_s is the sampling time period and V_{dc} is dc link voltage.

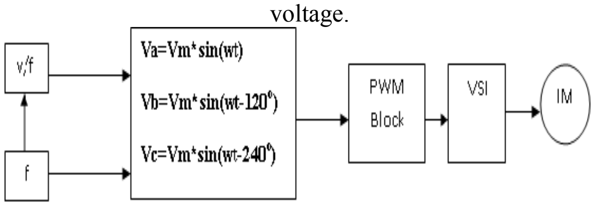

Fig 2: v/f control of induction motor

If the instantaneous reference voltages are negative, the corresponding switching times will also be negative. Hence these times are called as imaginary switching times. In every sampling time, the maximum, minimum and medium values of imaginary switching times are calculated as [7-8].

$$T_{\max} = Max(T_{an}, T_{bn}, T_{cn})$$

$$T_{\min} = Min(T_{an}, T_{bn}, T_{cn})$$

$$T_{mid} = Mid(T_{an}, T_{bn}, T_{cn})$$

Where max, min and mid are thee nominal values used during the sampling interval.

The function Max(T_{an} ,T_{bn} ,T_{cn}), Min(T_{an} ,T_{bn} ,T_{cn}) and mid(T_{an} ,T_{bn} ,T_{cn}) select the maximum, minimum and middle values respectively among T_{an} ,T_{bn} and T_{cn} . Finally the active state times T_1 and T_2 maybe expressed as

$T_1 = T_{max} - T_{mid}$

$T_2 = T_{mid} - T_{max}$

III. DISCONTINUOUS PWM

In the DPWM methods, the zero sequence signal is a discontinuous one and the modulation wave of a phase has at least one segment which is clamped to the positive or negative dc bus for at most a total of 120^o.In discontinuous PWM techniques we are having the different types depending upon the K_0 value in the zero state. Some of the DPWM methods are DPWMMIN, DPWMMAX, DPWM0, DPWM1, DPWM2, DPWM3. Depending upon the k_0 value the clamped section will be different. Moreover with in a sampling interval three switchings occurred while DPWM has two switchings only. So the frequency is reduced by 33% compared to conventional SVPWM[6]. Based on the K_o value the PWM techniques are performed.when K_o=0.5Then SVPWM algorithm will be developed. When K_o=0,1 then the discontinuous PWM algorithms are developed.

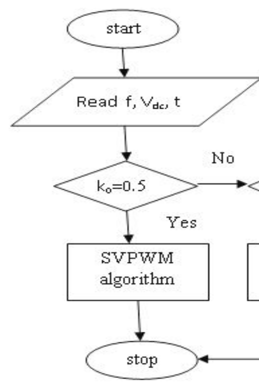

Fig 3: flowchart for different PWM techniques

IV. RESULTS

The 3-phase induction motor have the following parameters. Rr= 1.57, Rs=1.21, Lm=0.165, Lr=0.17, Ls=0.17.

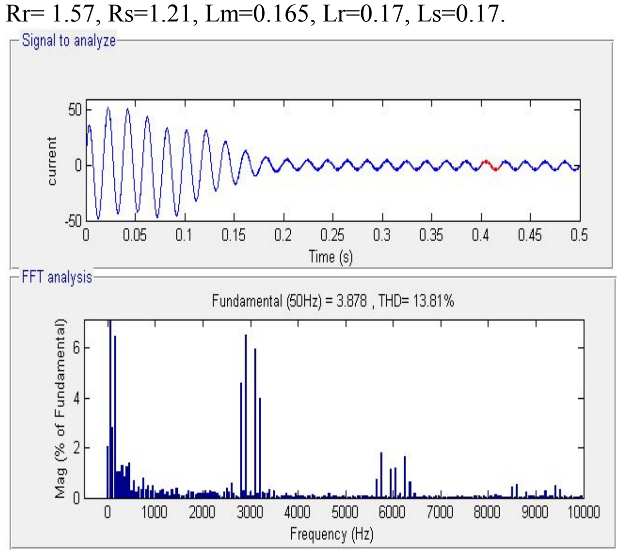

Fig 4: Harmonic spectra of current of SVPWM algorithm at higher modulation

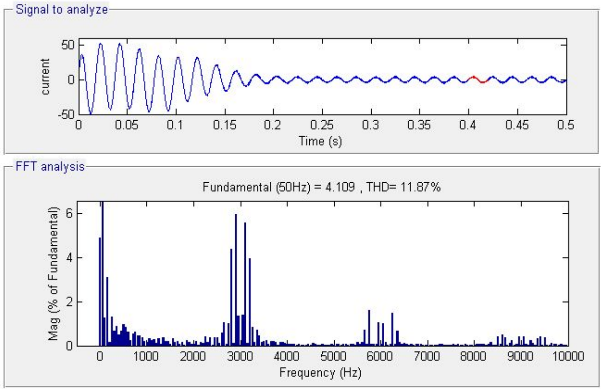

Fig 5: Harmonic spectra of current of DPWMmax algorithm at higher modulation

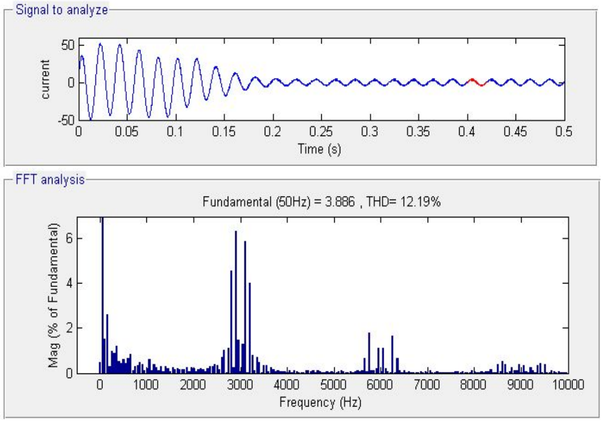

Fig 6: Harmonic spectra of current of DPWMmin algorithm at higher modulation

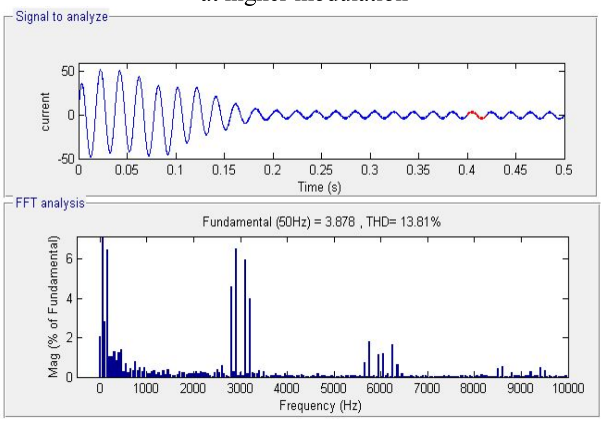

Fig 7: Harmonic spectra of current of simplified SVPWM algorithm at higher modulation

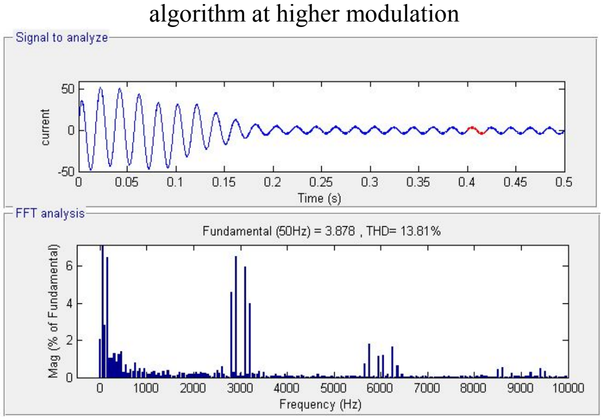

Fig 8: Harmonic spectra of current of digital SVPWM algorithm at higher modulation

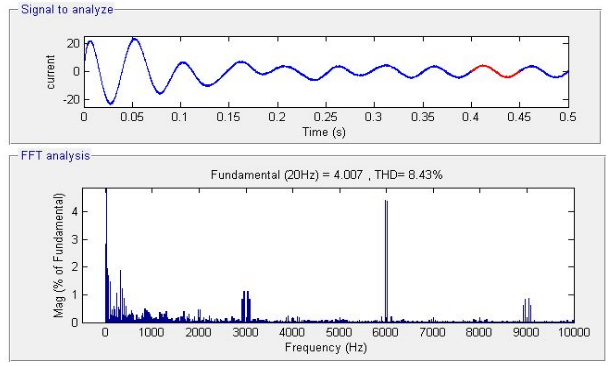

Fig 9: Harmonic spectra of current of SVPWM algorithm at lower modulation

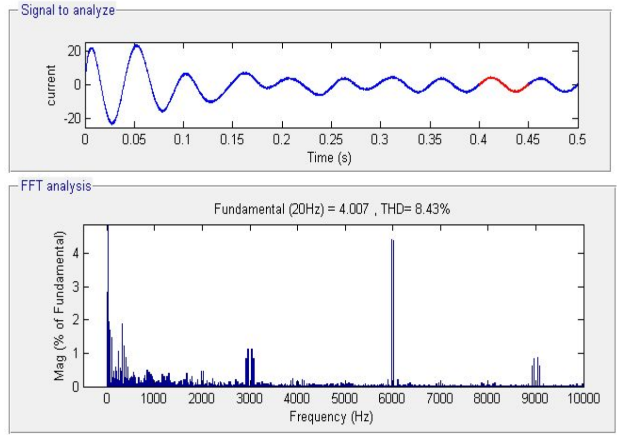

Fig 10: Harmonic spectra of current of DPWMmax algorithm at lower modulation

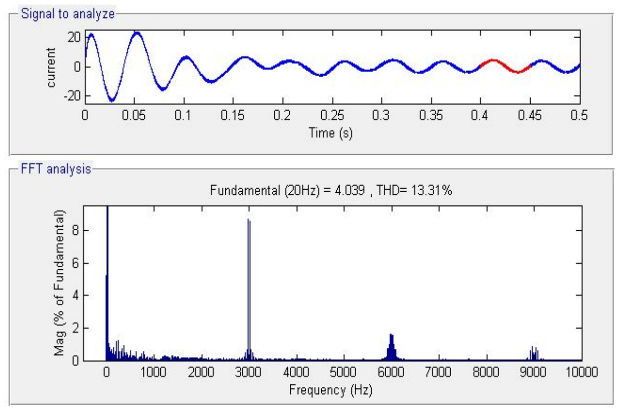

Fig 11: Harmonic spectra of current of DPWMmin algorithm at lower modulation

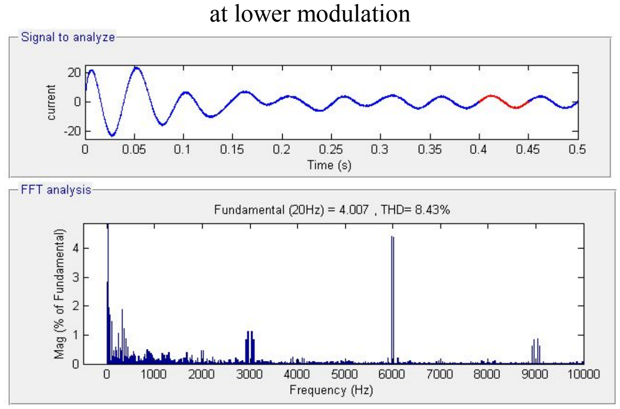

Fig 12: Harmonic spectra of current of simplified SVPWM algorithm at higher modulation

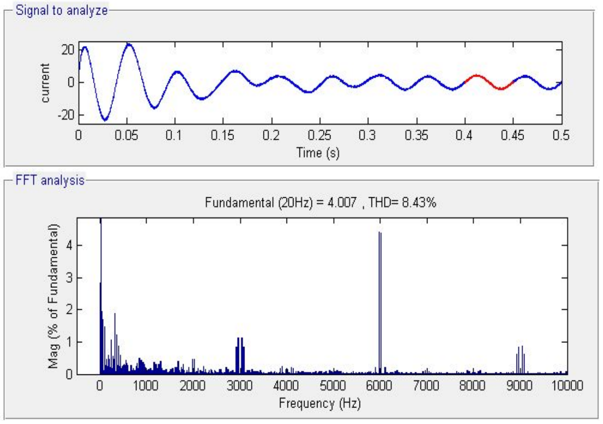

Fig 13: Harmonic spectra of current of digital SVPWM algorithm at lower modulation

CONCLUSION

From the above results the various SVPWM used obtain the same results for conventional SVPWM, digital SVPWM and simplified SVPWM. The another thing we observed here is the SVPWM algorithm gives better performance at lower modulation compared to discontinuous PWM algorithm and the discontinuous PWM algorithm gives the better performance at higher modulation compared to SVPWM algorithm.

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