International Journal of Scientific & Engineering Research, Volume 5, Issue 5, May-2014
ISSN 2229-5518

Space Vector Pulse Width Modulation (SVPWM) Using Two Leg Inverter for Split-Phase Induction Motor

VADDI RAMESH, P.ANJAPPA, K. REDDY SWATHI, R.LOKESWAR REDDY, B.SAMBASIVARAO

Abstract-In this paper the space-vector pulse width modulation (SVPWM) technique for two-phase inverters is proposed. The pro-posed SVPWM technique is applicable to the two-phase induction motor drives. A reference voltage vector located in the square locus is realized by adjusting the four space vectors. The switching sequence for the is proposed SVPWM technique in order to minimize the ripple content of the output current. The two phase inverter using the proposed SVPWM technique can generate only four space voltage vectors, but cannot generate zero vectors.. The circuit has been simulated in MATLAB Simulink with two phase Induction Motor load. The voltage for two phase induction motor and Rotor currents, Stator currents and Electromagnetic torque and induction motor speed are obtained

Index Terms : Space-vector pulse width modulation (SVPWM) technique, split-induction motor drives, two-phase inverter

1 INTRODUCTION

Since digital ac drives are becoming an industrial standard, the traditional sinusoidal pulse width modulation (PWM) technique has been overcome by the space-vector PWM (SVPWM) technique more suitable for digital implementation. Recently, the SVPWM technique has mostly been used in the vector control of three-phase ac motors or in servo systems due to its superior performance in spite of complexity, and it will be further accepted in the future. However, the SVPWM techniques for the single-phase induction motor drives have not been proposed in spite of several advantages The single-phase induction motors have been widely employed in low or middle power level fields, especially in households where a three-phase supply is not available. The single-phase induction motor requires the auxiliary winding to produce the starting torque. For example, the capacitor-starting motor produces the starting torque with the aid of the auxiliary winding and series-connected capacitor. Accordingly, it operates as the asymmetrical two-phase induction motor at starting, but operates as a pure single-phase induction motor while running after a centrifugal switch is opened The single-phase induction motor is unsuitable for ad-just able-speed control because of poor speed characteristic. Traditionally, speed operation of the single-phase induction motors has been obtained through voltage control using a triac or back-to-back thyristors. Accordingly, the harmonic content of the output voltage becomes larger, and the frequency range is narrow. Therefore, low-cost static converters which can improve the quality are required in single-phase induction motor drives .[1]-[4]

In this paper, the SVPWM technique for the two-phase inverter-fed symmetrical two-phase induction motors is proposed. There are four space vectors and no zero vectors in the two-phase inverters, while the three-phase inverter has six space vectors and two zero vectors. It is difficult for the two-phase inverters to realize the SVPWM technique because it has no zero vectors. In this paper, the SVPWM technique for the two-phase inverter is proposed without zero space vectors. Also, the switching sequence for the proposed SVPWM is proposed to minimize the ripple content of the output current

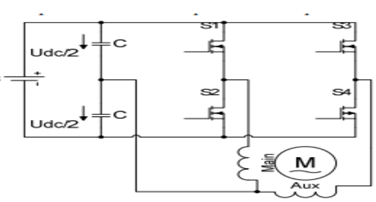

Fig. 1.Power converter for an TPIM drive.

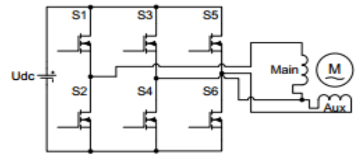

Fig 2. Rectifier and inverter composed of six switches

ISSN 2229-5518

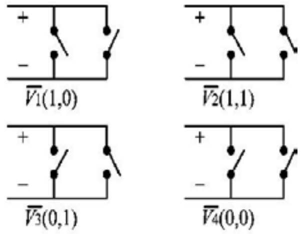

Fig 3.Switching states in the two phase inverter

2 SVPWM Techniques for Two-Phase Induction Motor Drives

In this paper, the two-phase induction motors are selected as the model motor instead of the single-phase induction motors. Supplying the balanced voltage source without harmonics to the symmetrical two-phase induction motor, the motor operates without negative torque and then maintains high efficiency. A balanced set of output voltages V_a, V_b without harmonics

$$V_a = V_{dc}/2mSinwt$$
$$= V_o Sinwt$$
$$V_b = V_0 Sin(wt-90) \text{ where } 0 \leq m \leq 1$$

3 Four Space Vectors of Two-Phase Inverter

Fig.1 shows a typical two-phase half-bridge inverter for the two-phase induction motors, which consists of four switches, four diodes and a center-tapped dc voltage source. The dc link can be supplied from a single-phase ac source by inserting a diode rectifier, which needs two electrolytic capacitors to maintain the ground and to reduce the dc-link ripple.Fig.3 shows four switching states formed in a two-phase inverter when four switches are adjusted. Based on the four possible combinations of the four individual switches signified by switching states labeled as [s_1, s_2] the four space voltage vectors are originated. Whereas '0' denotes connection to the negative dc link. Fig.4 shows four space vectors in two-phase inverters, but zero vectors are not involved. [6]Four space vectors are evenly distributed at 90^0 intervals with the length of $V_{dc}/\sqrt{2}$ and form an exact square. In the figure, each '1' represents an output line attached to the positive dc-link. Fig.2 shows the advanced two-phase inverter drive, which utilizes six switches or one IGBT intelligent power module (IPM). Two switches and two diodes are used for a boost rectifier for power-factor correction, and the other four switches and four diodes are used for the two-phase inverters. Such circuit has originally been used for the single-phase to three-phase conversion with a view to offering low cost, and has been applied to compact single-phase induction motor drives to improve the input power factor and to reduce the harmonics of output voltages. Four space voltage vectors are represented by the following complex vector expression:

$$V_k = 0.707\, V_{dc}\, e^{j(k-1)\pi/2};\ k=1,2,3,4,\ldots\ldots$$

3.1 Proposition of the Two Phase SVPWM Techniques:

Researchers studying two leg inverter have been presented several space vectors PWM (SVPWM) method for two leg inverters. However, SVPWM methods for two leg inverters are complex because zero vectors do not exist. In presented implementation method for SVPWM with a triangular carrier wave form was applied to a three phase inverter using the offset voltage concept. In this article the offset voltage concept is applied for an implementation carried based PWM method for a two leg inverter[7]. An offset voltage specified by V_{sn}^* exists between the phase voltage (V_{as}^*, V_{bs}^*) across loads and the output voltages (V_{an}^*, V_{bn}^*) in the two phase inverter. The determined output voltages can be expressed as

$$V_{an}^* = V_{as}^* + V_{sn}^* \quad (1)$$
$$V_{bn}^* = V_{bs}^* + V_{sn}^* \quad (2)$$

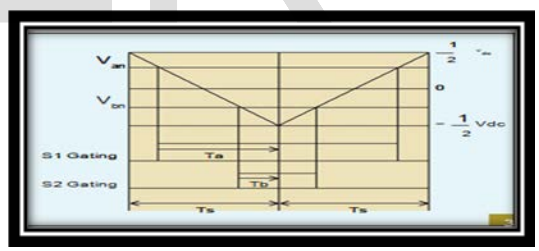

Fig.4 Determination of switching times in two leg inverter

The determined output voltage (V_{as}^*, V_{bs}^*) are equal to the phase voltage (V_{as}^*, V_{bs}^*) because the voltage V_{sn}^* is zero in the two leg inverter of Fig.1 this mean that the SVPWM method for a two leg inverter is the same **SPWM** method from the view point of the offset voltage concept. The switching times of each leg are determined by a comparison between the determined output voltage (V_{an}^*, V_{bn}^*) (1) and (2) and the triangular carrier wave. From obtained as shown in Fig.4 the on time T_a, T_b of the upper switches to realize the output voltages V_{an}, V_{bn} can be expressed as

$$T_a = Ts/2 + V_{an}/V_{dc}\ Ts \quad (3)$$

$T_b = Ts/2 + V_{bn}/V_{dc}\ Ts$ (4)

As shown in Fig.4 It is to be noted that V_{as} and V_{bs} can be exchanged with V_{an} and V_{bn} in (3) and (4) because the offset voltage V_{sn} is zero.

3.2Determination of the Switching Sequence:

When the reference vector $\boldsymbol{V}*$ stays at any sector, the switching sequence is considered in order to make the optimal PWM voltage waveform in the two-phase inverter. Proper switching sequence minimizes the torque ripple and reduces the average switching frequency. In this section, the switching sequence in the two-phase SVPWM is proposed, which is derived from the "three-phase symmetrical modulation" in the three-phase SVPWM. Let it be named the "two-phase symmetrical modulation." In order to realize the reference vector $\boldsymbol{V}*$ [1]-[2] the four space vectors and four time durations must be adjusted by four switches during the sampling time T_s , and the switching sequence should also be determined suitably. Fig.4 shows four sets of output voltages V_a, V_b realized by the two-phase symmetrical modulation of the two-phase SVPWM when the main sector changes. From the figure, the output voltages of the two-level PWM waveform appear in the two-phase inverter. The reference vector $\boldsymbol{V}*$ begins at V_1 with time duration t_{10} in the main sector, and finishes at V_4 with t_{21}. in the diagonal sector, and begins again at $\boldsymbol{V}_4$ and returns to $\boldsymbol{V}_1$ in order to minimize the ripple content of line current. This rule applies normally to the two-phase inverter as the switching sequence, for example, " ....$\_\boldsymbol{V}_1\_\boldsymbol{V}_2\_\boldsymbol{V}_3\_\boldsymbol{V}_4\_\boldsymbol{V}_4\_\boldsymbol{V}_3\_\boldsymbol{V}_2\_\boldsymbol{V}_1\_$.... -------However, the reference vector $\mathbf{V}$

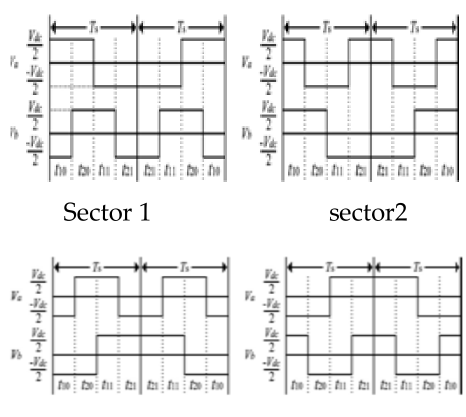

Fig.5 Output voltage of the two-phase inverter by the two-phase symmetrical modulation of the two-phase SVPWM. (a) At the main sector 1. (b) At the main sector 2. (c) At the main sector 3. (d) At the main sector 4.

Hardware because the switching operations during T_s are changed irregularly according to the sector number, while three output voltages v_a, v_b, and v_c are easily realized in the three-phase SVPWM because only one switching per phase is carried out regularly during T_s,[7]Also, the significant surge is involved in the output current, and the switching loss increases because the output voltage is discontinuous at the boundary between sectors. Therefore, the two-phase symmetrical modulation of Fig. 9 is not desirable to reduce the ripple content of output current. Then, a new switching sequence, which makes the output voltage continuous at the boundary between sectors, should also be required. Fig. 10 shows the advanced two-phase symmetrical modulation to eliminate the previously mentioned disadvantages of the two-phase symmetrical modulation.[3]-[6] When the advanced two-phase symmetrical modulation is used in switching operation, the output voltage becomes continuous at the boundary between sectors, of course. The inverter leg of phase A carries out one switching at t=ta and the inverter leg of phase B carries out two switching at t=tb1 and t=tb2 during T_b therefore , two output voltage waveforms are realized easily by the proper design of erasable programmable logic device (EPLD) because the advanced two-phase symmetrical modulation has

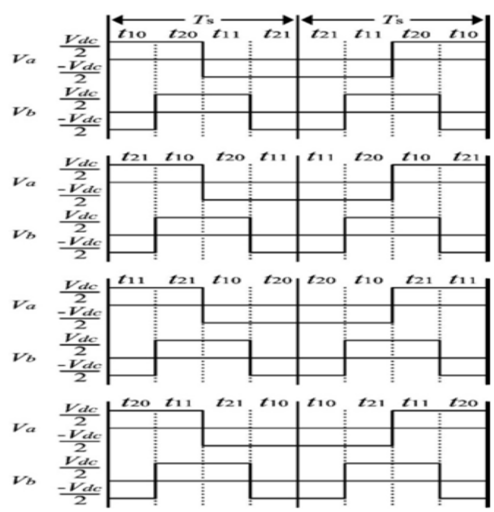

Fig6. Output voltage of the two-phase inverter by the advanced two-phase symmetrical modulation of the two-phase SVPWM

Table: switching arrangement to realize the advanced two-phase symmetrical modulation

Sec	Time	First T_S					Second T_S				
		t_1	t_2	t_1	t_2	T	t_1	t_2	t_1	t_2	T
I	t_a	1	1	0	0	↓	0	0	1	1	↑
	t_{b1}	1	0	0	0	↑	0	0	0	1	↑
	t_{b2}	1	1	1	0	↓	0	1	1	1	↓
II	t_a	1	0	0	1	↓	0	1	1	0	↑
	t_{b1}	0	0	0	1	↑	0	0	1	0	↑
	t_{b2}	1	1	0	1	↓	1	1	1	0	↓
III	t_a	0	0	1	1	↓	1	1	0	0	↑
	t_{b1}	0	0	1	0	↑	0	1	0	0	↑
	t_{b2}	1	0	1	1	↓	1	1	0	1	↓
IV	t_a	0	1	1	0	↓	1	0	0	1	↑
	t_{b1}	0	1	0	0	↑	1	0	0	0	↑
	t_{b2}	0	1	1	1	↓	1	0	1	1	↓

4 Advantages and Disadvantages of Split-Induction Motor Drive System

In comparison with the six-switch inverter, the four switches inverter has several advantages. First, a power switch reduction of 1/3 is obtained, and two drive circuits can be omitted because only two inverter legs are used. Accordingly, manufacturing cost will be reduced despite the higher switch voltage rating in the four-switch inverter. Second, the conduction losses can be reduced by 1/3 because only two inverter legs will conduct compared with the six-switch inverter, where three inverter legs will conduct. However, the following disadvantages should be mentioned. The stress on the motor insulation and the switching losses are increased due to the higher dc-link voltage. Several advantages are predicted when the proposed SVPWM is applied to the two-phase motor. First, speed of the two-phase motor can be controlled exactly for a wide frequency range. Second, compared to the three-phase SVPWM, 2Φ/3Φ or 3Φ/2Φ transformation is not required in the vector control, while it is required in the vector control of the three-phase ac motor drive. Therefore, the two-phase induction motor drive system for the vector control is simpler and cheaper compared to the three-phase induction motor

5 Simulation Results

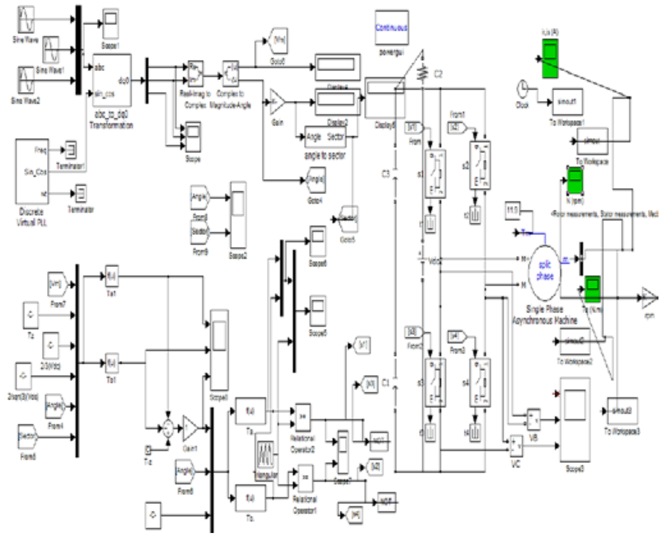

Fig.7 Two leg inverter using SVPWM techniques fed split-induction motor

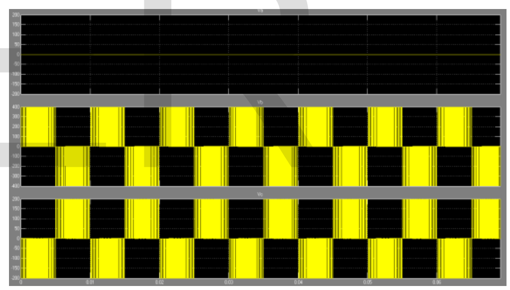

Fig 8. Three Phase Voltage V_A,V_B,V_C

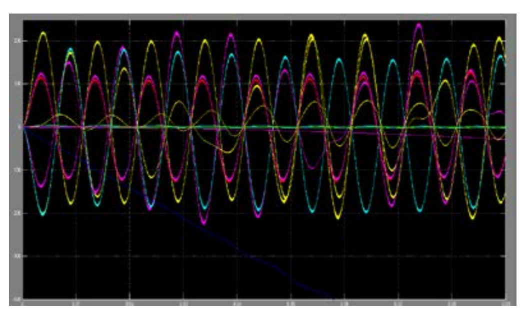

Fig 9.Simulation of Induction Motor Speed In RPM

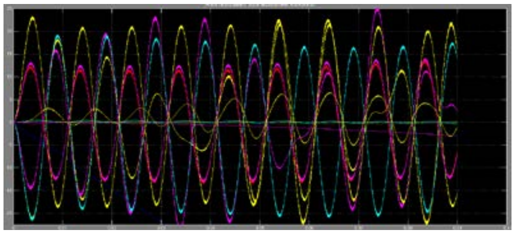

Fig 10.Simulation of Electromagnetic Torque

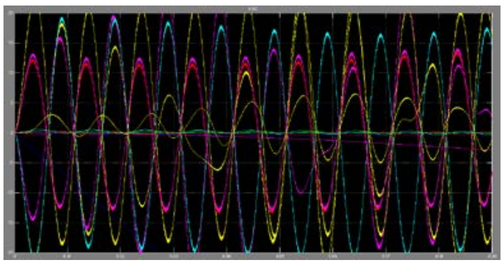

Fig11.Simulation of Rotor and stator Current

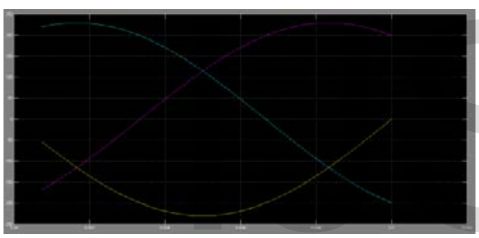

Fig12: Three phase to Two phase Transformation voltage

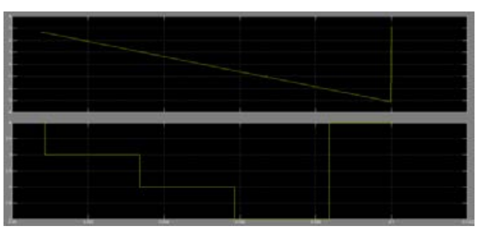

Fig13: simulation of angle &sector current

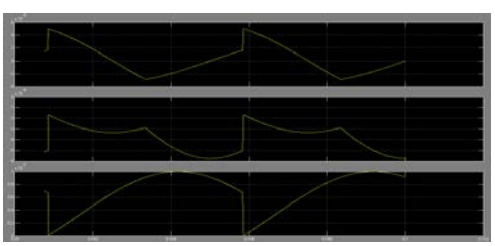

Fig14: simulation of angle &sector voltage

6 Conclusions

In this paper, the SVPWM technique is proposed for the two-phase inverter-fed two-phase induction motor. There are four space voltage vectors and no zero vectors in two-phase inverters. A reference voltage vector is realized by adjusting four space vectors without zero space vectors. Also, the two-phase sym-metrical modulation to carry out the switching sequence is pro-posed in order to minimize the ripple content of the output cur-rent.
Through the simulations and experiments, it is confirmed that the proposed SVPWM technique can make the balanced two-phase output voltage where the Rms values of voltage of phase A are equal to those of phase B, and the phase difference between the two voltages is also fixed at 90_{o} . Therefore, the proposed SVPWM will apply in practical use in the vector control of two-phase induction motor drives. However, the proposed two-phase SVPWM technique has several unsolved problems, such as the current distortion due to dead-time effect, and over modulation. The proposed technique will build the optimal PWM output voltage without harmonics after solving several problems. It is expected that good results will be obtained if the pro-posed two-phase SVPWM technique is applied to the field of small servo systems

REFERENCES

[1]E.r. Collins, Jr., A. B. Puttgen, and W. E. Sayle, II, "*Single-phase in-duction motor adjustable speed drive: Drive phase angle control of the auxiliary winding supply,*" *in Conf. Rec. IEEE-IAS Annu. Meeting*, 1988, pp. 246–252.

[2] D. G. Holmes and A. Kotsopoulos, "*Variable- speed control of single and two phase induction motors using a three voltage source inverter*," in *Conf. Rec. IEEE-IAS Annu.Meeting*, 1993, pp. 613–620.

[3]M. F. Rahman and L. Zhong, "*A current-forced reversible rectifier fed single-phase variable speed induction motor drive,*" in *Proc. IEEE PESC'96* , 1996, pp. 114–119.

[4]M. B. R. Correa, C. B. Jacobina, A. M. N. Lima, and E. R. C. da Silva, "*Field oriented control of a single-phase induction motor drive*," in *Proc. IEEE PESC'97* , 1997, pp. 990–996.

[5]D.-H. Jang and J.-S. Won, "Voltage, frequency, and phase-difference angle con trol of PWM inverters-fed two-phase induction motors," *IEEE Trans. Power Electron.*, vol. 9, pp. 377–383, July 1994.

[6]H. W. van der Broeck, H. C. Skudelny, and G.Stanke, "*Analysis and realizationof a pulsewidth modulator based on voltage space vectors*," *IEEE Trans. Ind. Applicat.*, vol. 24, pp. 142–150, Jan./Feb. 1988.

[7]P. N. Enjeti, H. W. van der Broeck, and H. C.Skudelny, "*Analytical anal-ysis of the harmonic effects of a PWM AC drive*," *IEEE Trans. Power Electron.*, vol. 3, pp. 216–223, Apr. 1988