

# Induction Motor Speed Control Using Space Vector Pulse Width Modulation

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**ABSTRACT:** This paper presents generalized space vector pulse width modulation (SVPWM) scheme for multilevel inverter. The SVPWM scheme generates all the available switching states and switching sequences based on two simple and general mappings, thus independent of the level number of the inverter. The generalized method of generating the switching states (first mapping), calculating duty cycles, and determining the switching sequence (second mapping) is described in this paper. The scheme is suitable for every reference vector with any modulation index, and can be conveniently extended to meet specific requirements, such as symmetric switching sequences. Comparing with previous methods, the SVPWM scheme proposed in this paper provides two more degrees of freedom, i.e., the adjustable switching sequences and duty cycles, thus offering significant flexibility for optimizing the performance of multilevel inverters. In this paper, open loop speed control of three phase induction motor using space vector pulse width modulation is presented by using MATLAB/SIMULINK model.

**KEYWORDS:** SVPWM, 3 $\phi$ -Induction motor, adjustable duty cycles, redundant switching states

## I. INTRODUCTION

Induction motors have been used in applications requiring constant speed because conventional methods of their speed control have been expensive and highly inefficient. The speed control of three phase induction motor is essential because the motor control industry is a dominant sector. Multilevel power conversion has become more popular in recent years due to advantages of high power quality waveforms, and low switching losses. The research on the multilevel converter has been receiving wide attention mainly due to its capability of high voltage operation without switching devices connected in series. In addition, with the increase of voltage levels, the inverter output contain fewer harmonic and will ultimately approach a desired sinusoidal waveform. For high voltage and high power applications the multilevel inverters have selected as a preferred power converter topology. Modular multilevel converters have become more emerging technology for multilevel Inverters. Among various modulation strategies for multilevel inverters, space vector pulse width modulation (SVPWM), also called space vector modulation, attracts more attention because it provides significant flexibility to optimize switching waveforms, and is suitable for implementation in digital signal processors. A block diagram of an SVPWM – based n- level inverter is shown in Fig 1. The space vector modulation for more than three- level inverters is very complex due to the high number of space vectors and redundant switching states and switching sequences that accompany the higher number of levels. For an N- level inverter, there are  $N^3$  switching states and  $6(N-1)^2$  triangles in the space vector diagram.

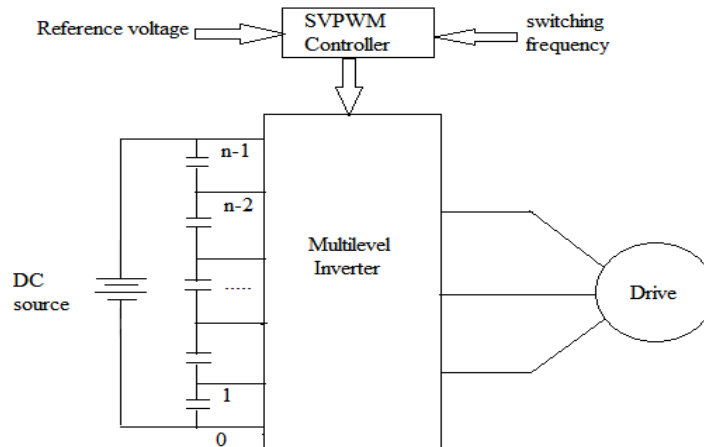


Fig 1: Block diagram of a multilevel inverter

A Euclidean vector system based SVPWM algorithm is presented in [1]. However, several matrix transformations are needed, and do not provide either systematic approach for determining the switching sequences or real time implementation. A coordinate transformation and switching sequence mapping based SVPWM scheme is proposed in [2], in which a coordinate transformation is needed to determine the location of the reference vector and to calculate the duty cycles, and a pre stored switching sequence mapping table is needed to determine the switching sequence. The three level space vector diagram can be partitioned into six two level space vector diagrams [9]. However, for the calculation of on – time, the origin is shifted to one of the six centres and the axes are rotated by 60 .

This new SVPWM scheme has the following salient features:

1. Switching states, duty cycles and switching sequences are all obtained by simple calculation; less memory is needed and it is computationally fast.
2. The SVPWM scheme proposed in this provides two more degrees of freedom i.e. adjustable switching states and switching sequences.
3. The scheme works good for any reference vector with any modulation index.

## II. BASIC PRINCIPLE OF THE SVPWM SCHEME

For an N level inverter shown in Fig 1: the output voltage vector is defined as

$$V_{out} = V_{dc}(S_a + S_b e^{j2\pi/3} + S_c e^{j4\pi/3}) \tag{1}$$

Where  $V_{dc}$  is voltage of the dc source, and  $S_a, S_b,$  and  $S_c$  are the switching states of Phase A, B and C respectively. If the values of  $S_a, S_b,$  and  $S_c$  are defined as  $S_a, S_b, S_c = 0,1, 2, \dots, N-1$ , then the output voltages of phases A, B and C relative to the negative terminal of the dc source are  $S_a \cdot V_{dc}/(n-1), S_b \cdot V_{dc}/(n-1), S_c \cdot V_{dc}/(n-1)$ , respectively. The definition in equation (1) is still suitable, when the N – level inverter is a cascaded inverter and in this condition  $V_{dc}/(n-1)$  represents the smallest voltage among the separate dc sources.

Based on equation (1) a space vector diagram contains all the output vectors and the corresponding switching states of the inverter can be generated. For example Fig 2 shows the space vector diagram of a 7 level inverter calculated in this way. In the space vector diagram, the number at each vertex represents the switching state  $S_a S_b S_c$  of the inverter, where  $S_a, S_b$  and  $S_c$  are respectively the switching states of phases A, B and C as in (1). For example, the number 061 at vertex  $P_1$  means that for the vector  $OP_1$ , the corresponding switching states of phases A, B and C are  $S_a = 0, S_b = 6,$  and  $S_c = 1$ . Some vectors can be equivalently produced by more than one switching state of the inverter, and those switching states at the vertex of the vector are listed decreasingly from top to bottom corresponding to the switching states of phase A in the space vector diagram[5]. For example, the numbers 566, 455, 344, 233, 122 and 011 are all valid switching states

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for generating the vector with tip  $P_4$ , and they are listed decreasingly from top to bottom corresponding to the switching states of phase A.

A reference vector  $V_{ref}$  and the corresponding “nearest three vectors”  $OP_1$ ,  $OP_2$ , and  $OP_3$  are also shown in Fig 2. The vertices of the nearest three vectors to create called as “modulation triangle”, which encloses the reference vector. In order to synthesize or equate the reference vector, it is the task of the SVPWM scheme to detect the nearest three vectors (i.e., the switching states of the vertices  $P_1$ ,  $P_2$ , and  $P_3$ ), to determine the sequence of the nearest three vectors during a switching cycle (i.e., the switching sequence), and to calculate the needed on- time (i.e., duty cycle) of each nearest vector based on the following equation.

$$T_s \cdot V_{ref} = d_1 \cdot OP_1 + d_2 \cdot OP_2 + d_3 \cdot OP_3 \quad (2)$$

Where  $T_s$  is the command switching cycle, and  $d_1$ ,  $d_2$ , and  $d_3$  are the duty cycle periods of  $OP_1$ ,  $OP_2$ , and  $OP_3$  respectively.

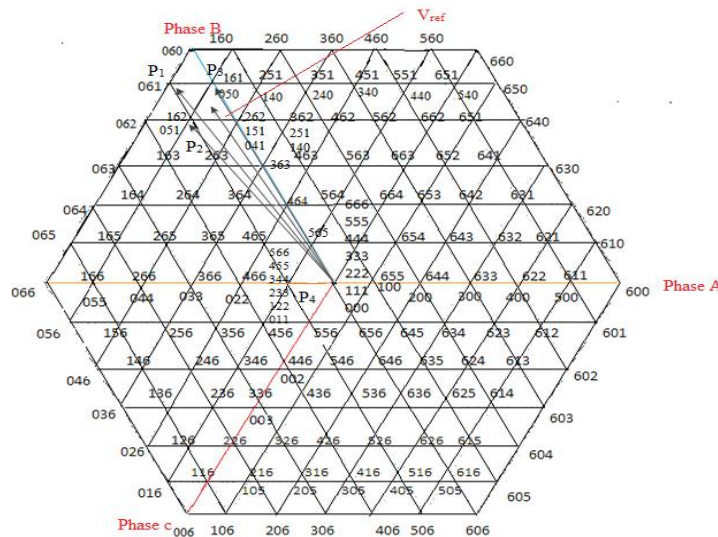


Fig 2: Space vector diagram of seven level inverter

The SVPWM scheme proposed in this paper is illustrated in Fig 3. Fig3(a): shows how to locate the reference vector (i.e., to detect the modulation triangle  $\Delta P_1P_2P_3$ ); Fig. 3(b) and (c) shows how to locate the duty cycles and to generate the switching sequence in two modes, i.e., counter clockwise (mode =1) and clockwise (mode =2 ), as if it were an equivalent two level SVPWM. In Fig. 3(b) and (c),  $V_0$ ,  $V_1$ , and  $V_2$  are, respectively, equivalent to the nearest three vectors  $OP_2$ ,  $OP_3$ , and  $OP_1$ . Fig 3 is described in more detail. The proposed SVPWM illustrated is based on the space – vector diagram of a seven level inverter is shown in Fig 2.

### III. LOCATING THE REFERENCE VECTOR

First, the reference vector  $V_{ref}$  is represented as the sum of a set of “vertex vectors” ( $OO_1$ ,  $O_1O_2$ ,  $O_2O_3$ ,  $O_3O_4$  and  $O_4P_2$ ) and a “remainder vector”  $V_{ref}$ , as shown in Fig 3(a). A vertex vector is a vector containing two adjacent vertices. The vertex vectors connect the centre vertex of the  $N$  - level space vector diagram  $H_0$  with a first vertex ( $P_2$ ) of the modulation triangle ( $\Delta P_1P_2P_3$ ) enclosing the reference vector. The remainder vector is enclosed by the modulation triangle and connecting the first vertex of the modulation triangle with the reference vector.

One way to determine the set of vertex vectors is based on determining a set of nested hexagons  $H_1$ ,  $H_2$ , and  $H_3$  enclosing the reference vector, as shown in Fig 3(a).

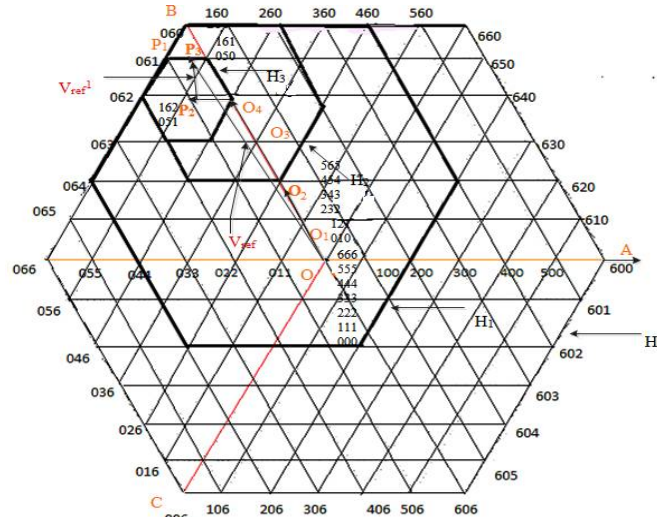


Fig 3(a): locating the reference vector

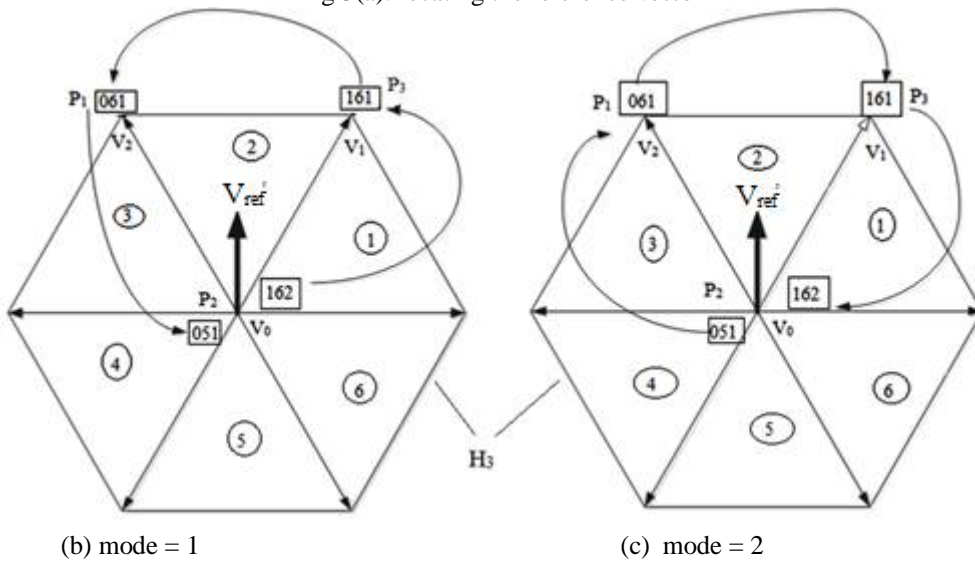


Fig 3 SVPWM:(b) and (c) two switching modes

Each nested hexagon corresponds to a specific level ranging from (N -1) to a second level, and centres at the vertex of a vertex vector. For instance, the method of selecting the nested (N -1) level hexagon  $H_1$  is shown in Fig 4. In this way the other nested hexagons can be selected.

As shown in Fig 4(a), the N- level space – vector diagram  $H_0$  is partitioned into six sectors by six dashed lines. The six dashed lines pass through the centre of the N- level space – vector diagram and their angles are from  $\pi/6$  to  $11\pi/6$ , and the angle between any two adjacent dashed lines is  $\pi/3$ . Consider the N- level space vector diagram as being composed of six hexagons that are the space – vector diagrams of (N-1) level inverters, and whose centre vertices ( $O_1$ , and  $Q_1 - Q_5$ ) compose a two level hexagon enclosing the centre of  $H_0$ . For clarity, only three hexagons  $SH_1, SH_2,$  and  $SH_3$  of the six (N-1) level space – vector hexagons are shown in Fig 4(a), and the other three (N-1) level hexagons can be reached by shifting the centre of  $SH_1$  to the corresponding centres of the (N-1) level hexagons.

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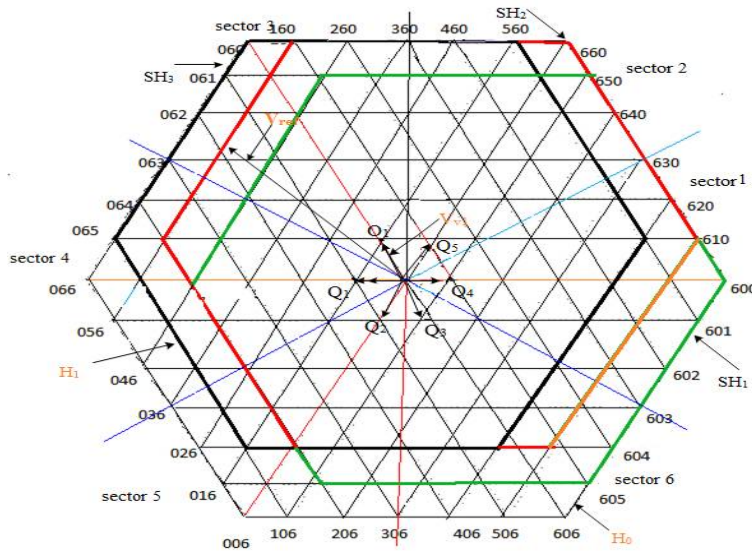


Fig 4(a): division of the space vector diagram

Consequently, the nested (N-1) level hexagon  $H_1$  is selected as the one whose centre locates in the same vector as the reference vector does (i.e.,  $SH_3$ ), which in Fig 4(a) means that the angle  $\theta_0$  of the reference vector has values within the following range:

$$\pi/2 \leq \theta_0 \leq 5\pi/6 \tag{3}$$

The first vertex vector  $V_{v1}$  is the vector that connects the centre vertices of  $H_0$  and  $H_1$ , as shown in Fig 4(a). Another equivalent way to determine the vertex vector is shown in Fig 4(b). There are six vectors available for the nested (N-1) level hexagon  $H_1$ , which indicates black solid arrows ( $OO_1$ ) and ( $OQ_1 - OQ_5$ ) are shown in Fig 4(b). The actual vertex vector, among the six available vertex vectors, for the nested (N-1) level hexagon  $H_1$ , is the one for which the angle between this vertex vector and the reference vector is the smallest. In this way, the first vertex vector  $V_{v1}$  can also be selected, as shown in Fig 4(b).

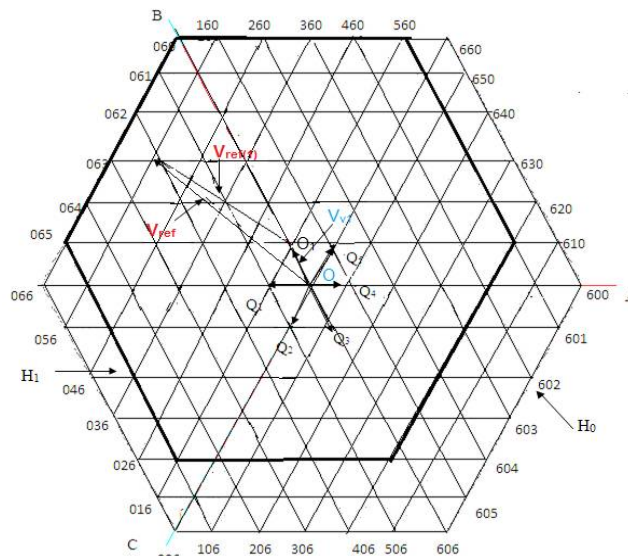


Fig 4(b): selection of nested hexagons: first centre vertex

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Generally, the angle ( $\phi_1$ ) of the first vertex vector are determined by the angle  $\theta_0(0 \leq \theta_0 < 2\pi)$  of the reference vector as

$$\phi_1 = \text{int}\{\text{mod}(\theta_0 + \pi/6, 2\pi) \cdot 3/\pi\} \cdot \pi/3 \tag{4}$$

Where the function  $\text{int}(x)$  means the integer part of  $x$ , and the function  $\text{mod}(x, y)$  represents the remainder of  $x$  divided by  $y$ . After the first vector is determined, the origin of the reference vector  $V_{\text{ref}}$  is shifted to the centre vertex of  $H_1$ , which yields a new reference vector  $V_{\text{ref}(1)}$  as

$$V_{\text{ref}(1)} = V_{\text{ref}} - V_{\text{dc}} \cdot e^{j\phi_1} \tag{5}$$

Based on  $V_{\text{ref}(1)}$ , all the other nested hexagons and vertex vectors can be determined by repeating the process shown in Fig 4 and the calculation by using equations (4) and (5). After the set of vertex vectors is obtained, determine iteratively the switching states at the vertices (i.e., centres of the nested hexagons) for each vertex vector in the set of vertex vectors, starting from the present switching states of the inverter at the origin vertex, by modifying (increase or decrease by 1) a corresponding phase of the present switching states to produce the switching states of the inverter at the first vertex ( $P_2$  in Fig 3) of the modulation triangle. The type of the modification for the switching states and the corresponding phases are shown in Table I, which is called the “first mapping” in this paper and will be explained later. For each iteration, the type of the modification and the corresponding phase are determined based on a function  $s$  [represents the order number of the sector containing the reference vector as in Fig 4(a)] of the angle  $\phi$  of the corresponding vertex vector relative to axis A, and the function  $s$  of the angle  $\phi$  ( $0 \leq \phi < 2\pi$ ) of the corresponding vertex vector can be described as

$$S = 3\phi/\pi + 1 \tag{6}$$

The rule of the modification for the switching states (first mapping) according to the function  $s$  is shown in Table I, in which the letters A, B, or C mean the switching state of phase A, B or C respectively, that needs to be modified. The up arrow “ $\uparrow$ ” means that the switching state of the phase needs to increased by 1, and the down arrow “ $\downarrow$ ” means that the switching state of the phase needs to decreased by 1. For example, if a switching state is  $S_a S_b S_c$  and the modification rule is “ $A\uparrow$ ” ( $S = 1$ ), then the switching state after the modification is  $(S_a + 1) S_b S_c$ . The switching states after the modification for other values of  $S$  are also abridged in Table I

Table I: Rule of the modification of Switching States (First Mapping)

S	1	2	3	4	5	6
Modification	A	C	B	A	C	B
Switching state $S_a S_b S_c$ after modification	$(S_a + 1) S_b S_c$	$S_a S_b (S_c - 1)$	$S_a (S_b + 1) S_c$	$(S_a - 1) S_b S_c$	$S_a S_b (S_c + 1)$	$S_a (S_b - 1) S_c$

Since the switching state for each phase of an  $N$  – level inverter can only have a value from 0 to  $(N-1)$  by definition in this paper, a switching state needs to be excluded when the corresponding switching state of phase A, B or C is larger than  $(N-1)$  or less than 0.

Based on the first mapping in Table I, the switching states at the vertices of the vertex vectors (the centres of the nested hexagons) and the first vertex of the modification triangle are shown in Fig 3 and Fig 5, which can be verified by comparing it with the space – vector diagram of the seven level inverter shown in Fig 2. The invalid switching states 676, 575, and -120 are excluded sequentially, as shown in Fig 5.

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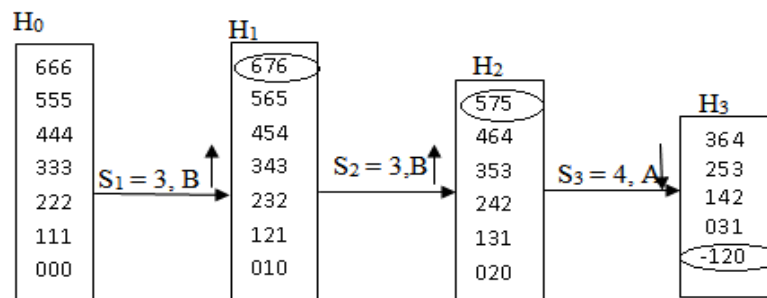


Fig 5: Switching states at the first vertex of the modulation triangle and the vertex vectors

For example, for the vertex vector from the centre of  $H_2$  to the centre of  $H_3$ , the value of  $S$  in equation (6) is  $S_3 = 4$ ; thus, the modification rule according to Table I is “A↓”. Because the switching states at the centre of hexagon  $H_2$  are 262, 151, and 020, the switching states at the centre of hexagon  $H_3$  (the first vertex  $P_2$  of the modulation triangle) can be calculated as 162 and 051 (the invalid switching state -120 is removed)

The rationale for the first mapping (see Table I) is based on equation (1). For a vertex vector, the shift of the origin of the reference vector is  $V_{dc} \cdot e^{j(s-1)\pi/3}$  ( $S$  is calculated in equation (6)), which can be substituted into equation (1) to determine the required modification for the present switching states of phase A, B or C. The first mapping is suitable for any level inverter and any reference vectors with any modulation indexes.

## IV. CALCULATING DUTY CYCLES

Based on the remainder vector  $V_{ref}^1$ , as shown in Fig. 3(b) and (c), the duty cycles of the “nearest three vectors” are determined as for a two – level SVPWM, thus independent of the level number of the inverter.  $V_0$ ,  $V_1$ , and  $V_2$  are respectively, equivalent to the nearest three vectors  $OP_2$ ,  $OP_3$ , and  $OP_1$ . Equation (2) is now expressed as

$$T_s \cdot V_{ref}^1 = V_{dc} \cdot (T_1 \cdot e^{j(\text{reg}-1)\pi/3} + T_2 \cdot e^{j\text{reg}\pi/3}) \quad (7)$$

Where  $T_s$  is the commanded switching cycle;  $T_1$  and  $T_2$  are, respectively, the duty cycle periods of  $V_1$  and  $V_2$ ;  $\text{reg}$  is the region number (1 – 6) of the modulation triangle in the nested two – level hexagon  $H_3$  as shown in Fig 3(b) and (c), and can be calculated as

$$\text{reg} = \text{int}(3\theta_{\text{rem}}/\pi) + 1 \quad (8)$$

Where  $\theta_{\text{rem}}$  ( $0 \leq \theta_{\text{rem}} < 2\pi$ ) is the angle of the remainder vector, and  $\text{int}(3\theta_{\text{rem}}/\pi)$  means the integer part of  $3\theta_{\text{rem}}/\pi$ . For example,  $\text{reg} = 2$  in Fig. 3 (b) and 3(c).

Finally the duty cycles are

$$T_1 = \frac{2}{\sqrt{3}} [V_{rx} \sin(\frac{\text{reg}\pi}{3}) - V_{ry} \cos(\frac{\text{reg}\pi}{3})] \cdot T_s \quad (9)$$

$$T_2 = -\frac{2}{\sqrt{3}} [V_{rx} \sin(\frac{\text{reg}-1}{3}\pi) - V_{ry} \cos(\frac{\text{reg}-1}{3}\pi)] \cdot T_s \quad (10)$$

$$T_0 = T_s - T_1 - T_2 \quad (11)$$

Where  $V_{rx}$  and  $V_{ry}$  represents the real and imaginary part of  $V_{ref}^1/V_{dc}$ , respectively;  $T_0$  is the total duty cycle period for the vectors from the centre vertex of the  $N$  – level hexagon  $H_0$  to the centre vertex of the nested two level hexagon  $H_3$ , or called the “zero vectors” in this paper.

In the SVPWM scheme, two switching states (e.g., 162 and 051 in Fig 3) at the centre vertex of the nested two level hexagon are used, and each switching state represents a “zero vector”. The duty cycle periods  $T_{01}$  and  $T_{02}$  of the two zero vectors can be freely adjusted as long as the following equation is met:

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$$T_{02} = T_0 - T_{01}, 0 \leq T_{01} \leq T_0 \tag{12}$$

Since different zero vectors have different influences on the voltage across the dc – link capacitors of a multilevel inverter and on the harmonic distortion of the flux trajectories, the SVPWM scheme provides more flexibility for balancing the dc – link capacitor voltages and approaching the ideal flux trajectories.

## V. GENERATING THE SWITCHING SEQUENCES

The switching states at first vertex ( $P_2$ ) of the modulation triangle are obtained, based on this the switching sequences are determined along with the switching mode and the region number of the nested two level hexagon  $H_3$ . There are two switching sequence modes are described. The first switching sequence mode is mode = 1 when the switching sequence is counter clockwise selected as in Fig 3(b), and the second is mode =2 when the sequence is clockwise selected as in Fig 3(c). To determine the switching sequences, are also called as “second mapping” is shown in below Table II.

TABLE II: Rule of the determination of switching sequences (second mapping).

	Region(reg)					
	1	2	3	4	5	6
Mode = 1	ABC ↑(L)	CAB ↓(U)	BCA ↑(L)	ABC ↓(U)	CAB ↑(L)	BCA ↓(U)
Mode =2	CBA ↓(U)	BAC ↑(L)	ACB ↓(U)	CBA ↑(L)	BAC ↓(U)	ACB ↑(L)

The variable reg is the region of the modulation triangle calculated in equation (8). Here the letter A, B, or C indicates switching states of phase A, B or C is to be modified sequentially. And the symbol “↑” or “↓” indicates that the state of the corresponding phase is increased or decreased by 1, respectively. For example, if the first switching state of a switching sequence is  $S_a S_b S_c$  and the switching sequence rule is “ABC↑(L)” (i.e., reg = 1 and mode = 1) according to Table II, then the switching sequence is generated as  $S_a S_b S_c \rightarrow (S_a + 1) S_b S_c \rightarrow (S_a + 1)(S_b + 1) S_c \rightarrow (S_a + 1)(S_b + 1)(S_c + 1)$ . The redundant switching states at each vertex are listed decreasingly from top to bottom corresponding to the switching states of phase A, of the space vector diagram, as shown in Fig 2[5]. For example, the switching states 566, 455, 344, 233, 122 and 011 at vertex  $P_4$  are listed decreasingly from top to bottom corresponding to the switching states of phase A. The letter “L” in the parentheses represents the word “lower” and means the first switching state at the first vertex of the modulation triangle should not be the top one [5], e.g., not 566 for vertex  $P_4$ ; and the letter “U” in the parenthesis represents the word “Upper” and means the first switching state at the first vertex of the modulation triangle should not be the bottom one, e.g., not 011 for vertex  $P_4$ . Based on the second mapping, the switching sequences for the reference vector in Fig. 2 according to different switching sequence modes are summarized in Table III and shown in Fig 3(b) and (c), and the accuracy of the switching sequences can be verified by comparison with the space – vector diagram is shown in Fig 2.

Table III: switching sequences for different modes

Mode = 1	162→161→061→051
Mode = 2	051→061→161→162

Consider “CAB↓(U)” when reg = 2 and mode = 1 [shown in Fig 3(b)] as an example to explain the switching sequence selection method in this paper. As mode = 1, reg = 2, the switching sequence is  $V_0 \rightarrow V_1 \rightarrow V_2 \rightarrow V_0$ . From  $V_0$  to  $V_1$ , the change of the vector is  $V_{dc} \cdot e^{j\pi/3}$ , which can be substituted into equation (1) and means that the switching state of phase C is decreased by 1. Similarly From  $V_1$  to  $V_2$ , the change of the vector is  $V_{dc} \cdot e^{j\pi}$ , and from  $V_2$  to  $V_0$  the change of the vector is  $V_{dc} \cdot e^{j5\pi/3}$  which can be substituted into equation (1) and means that the switching states of phase A, B are decreased by 1 respectively. In this way based on second mapping all the available switching sequences for other values of region and mode can be analyzed.



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For any level and reference vector with any modulation indexes, the second mapping is suitable and it can be extended to meet other requirement that is symmetric switching sequences. Based on the second mapping when the modulation index is low, the SVPWM scheme can generate more than one switching sequence [5].

Based on second mapping all the redundant switching sequences and optimal switching sequences for different applications can be easily generated. The optimized switching sequences, for example, achieving minimum number of switching transitions in a fundamental cycle as described in [4] can be obtained by simply choosing the first switching state of a switching sequence as that closest to the last switching state of the previous switching sequence. Moreover, because different switching sequences have dissimilar effects on the voltage across the DC link capacitors of a multilevel inverter [3], [6], [7], the SVPWM scheme provides more flexibility for balancing the dc – link capacitor voltages.

It should be noted that the second mapping in Table II is for generating the continuous switching sequences (i.e., no switching state is eliminated). The second mapping can also be conveniently modified to produce discontinuous SVPWM patterns (i.e., eliminating either the first or last switching state in each switching sequence), since discontinuous SVPWM can potentially increase the switching frequency and thus provide harmonic benefits for certain modulation ranges. For example, if the discontinuous pattern DPWMMAX is desired for the reference vector  $V_{ref}$  shown in Fig 2, the modulation rule for  $reg = 2$  and  $mode = 1$  is adjusted to “CA↓(U)”, and the corresponding discontinuous switching sequence is  $162 \rightarrow 161 \rightarrow 061$ , which means phase B is un modulated. The rules for other discontinuous patterns can be summarized in a similar way.

## VI. SIMULATION MODEL OF SVPWM WITH INDUCTION MOTOR CONTROL

The simulation results are given for the induction motor as shown below. The specifications of the induction motor are: Number of poles (P) = 4, Frequency (f) = 50Hz, number of phases = 3, stator resistance ( $R_s$ ) =  $4.67\Omega$ , Rotor resistance ( $R_r$ ) =  $8\Omega$ , stator inductance ( $L_s$ ) =  $347mH$ , mutual inductance ( $L_m$ ) =  $366mH$ , moment of inertia(J) =  $0.061kg\cdot m/sec$ .

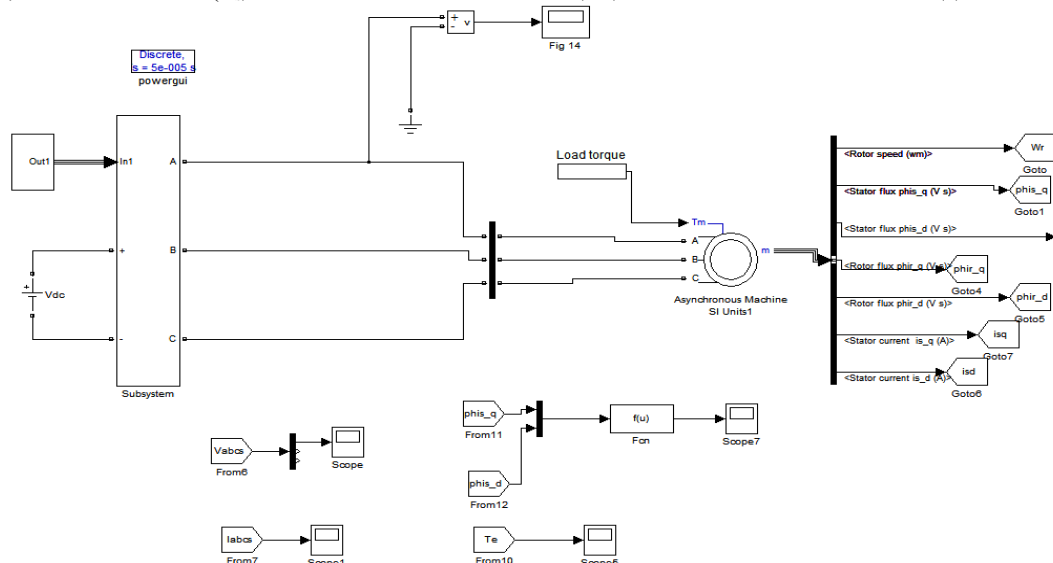


Fig 6: MATLAB Simulink model of SVPWM based induction motor

The Fig 6 shows the complete MATLAB/ SIMULINK model of the space vector pulse width modulation based induction motor. The step by step subsystem model of the SVPWM method is shown in Fig 7, Fig 8 and Fig 9.

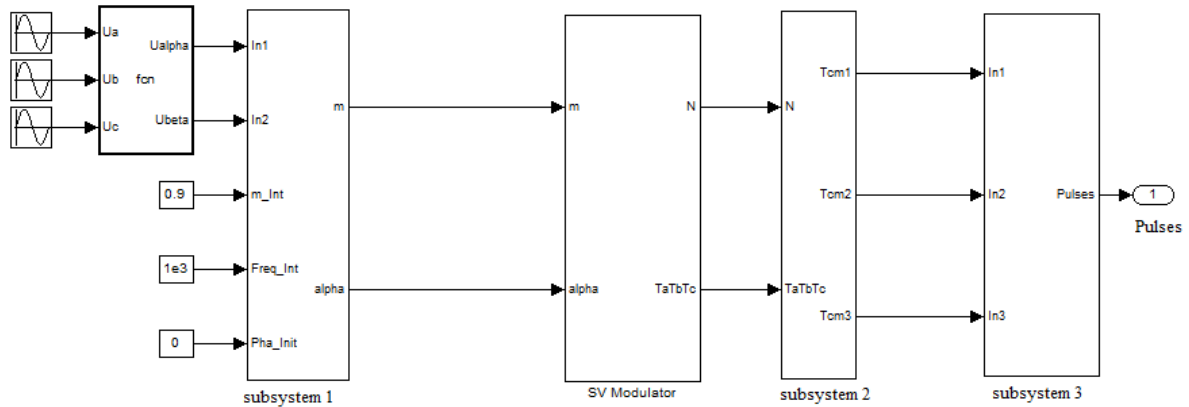


Fig 7: MATLAB SIMULINK subsystem model for generation of pulses

In this SIMULINK the step by step procedure is as follows:

- First the three phase voltages are calculated.
- $V_\alpha$  and  $V_\beta$  are calculated. For this  $3\phi$  to  $2\phi$  transformation block is used.
- Now  $V_{ref}$  and alpha are calculated, For this Cartesian to polar block is used.
- compute the time duration of switching states  $T_a$   $T_b$   $T_c$  are calculated and  $T_n$  calculated (SV Modulator is Shown)
- Multipoint switch is used for realisation of switching states (subsystem 2 is shown)
- Finally, the 6 individual gate pulses for 7 level Inverter is derived (Subsystem 3 shows).

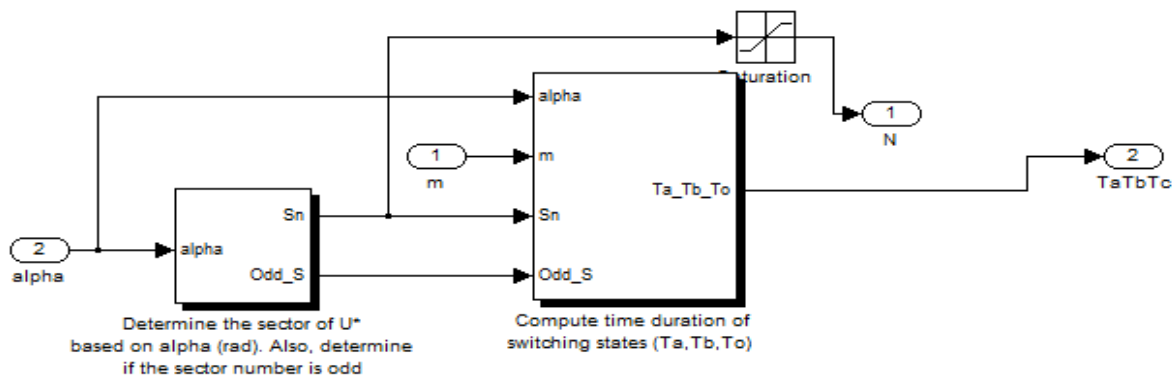


Fig 8: MATLAB SIMULINK subsystem model for computing time duration of switching states

### VII. SIMULATION RESULTS

In this simulation, the switching frequency  $f_s$  is 1 KHz and fundamental frequency is 50Hz. And the modulation index of the reference vector is 0.9. The experimental result for the output voltage of 7- level inverter is shown in Fig 9.

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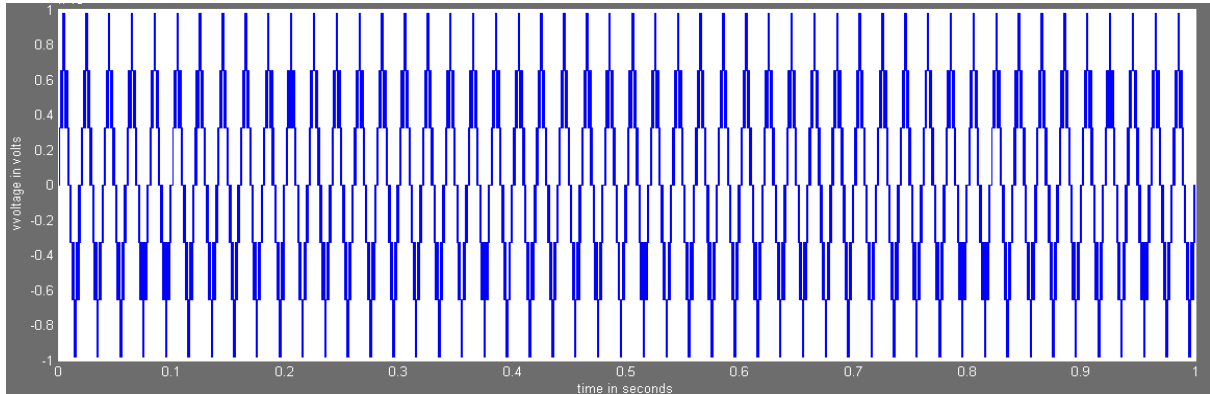


Fig 9: Normalized PWM waveform of the output voltage of 7 – level inverter

The results for the stator currents and flux are shown in figures (10) and (11) respectively.

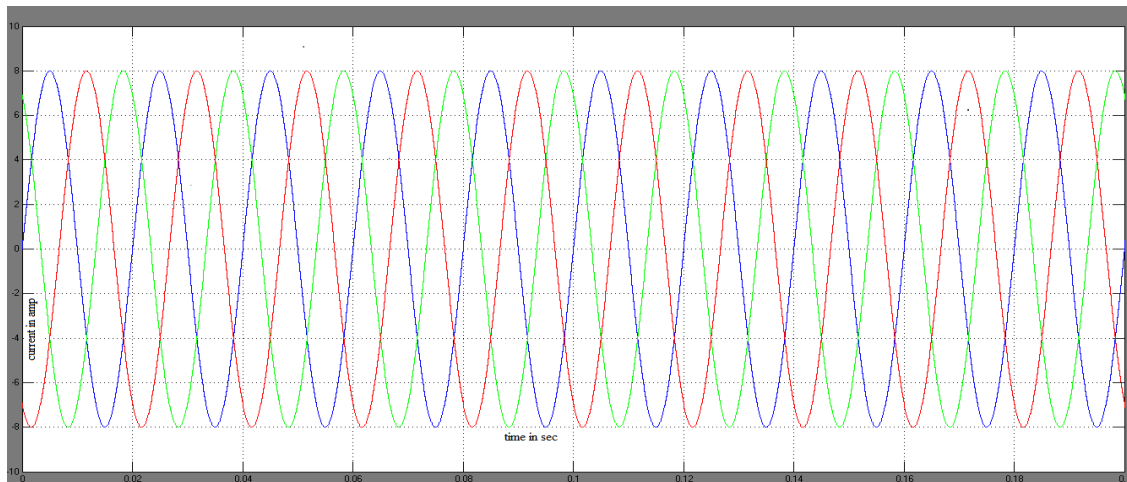


Fig 10: stator currents

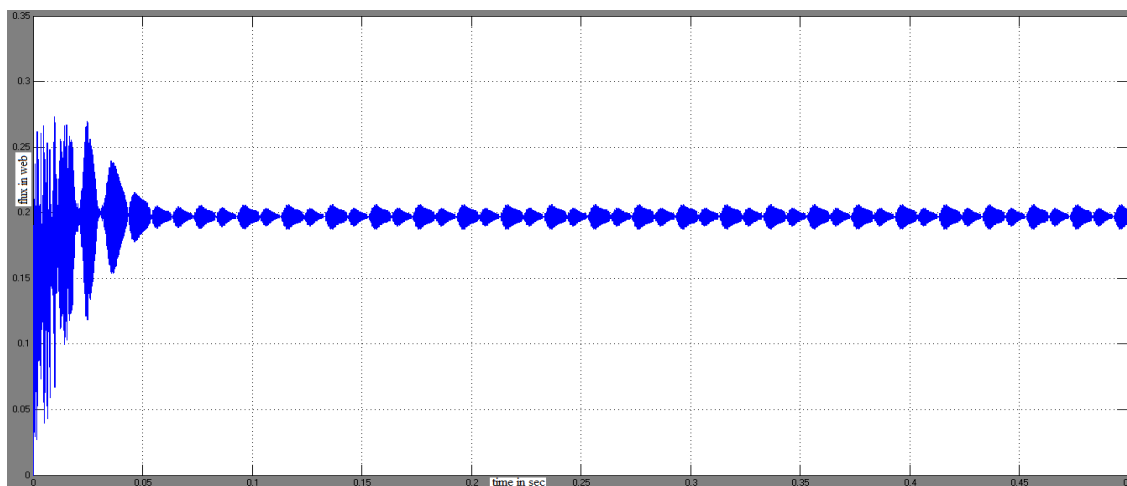


Fig 11: stator flux

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## VIII. CONCLUSION

In this research paper induction motor speed control using space vector pulse width modulation is designed through MATLAB software and also tested successfully by evaluating the parameters like voltage, stator current, and flux. It is due to its characteristics like good power factor, extremely rugged and high efficiency. This scheme provides all the available switching states and switching sequences based on two general mappings and calculates duty cycles. This scheme also leads to be able to adjust the speed of the motor by control the frequency and amplitude of the stator voltage, the ratio of stator voltage to frequency should be kept constant. Besides the design and implementation of an induction motor using by MATLAB Simulink is trouble free and uncomplicated.

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