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Implementation of Scalar Control Technique in SVPWM Switched Three –Level Inverter Fed Induction Motor Using DSP Controller

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Abstract

The main objective of the paper is to control the speed of an induction machine with scalar control technique. The scalar control technique (V/F) is used because of simplicity of control algorithm implementation and the response is better and accurate with closed loop slip compensation. An IGBT based three level diode clamped inverter (DCI) topology has been used instead of conventional two level inverter in order to reduce the harmonic content and to increase the device capability to handle the double the voltage of its rating.

Keywords: *Multi-level inverter, SVPWM, modulation-index, induction motor.*

1. Introduction

Multi-level diode clamped voltage fed inverters are recently becoming very popular for multi-megawatt power applications The main objective of the project is to control the speed of an induction machine with scalar control technique. The scalar control technique (V/F) is used because of simplicity of control algorithm implementation and the response is better and accurate with closed loop slip compensation. An IGBT based three level diode clamped inverter (DCI) topology has been used instead of conventional two level inverter in order to reduce the harmonic content and to increase the device capability to handle the double the voltage of its rating. The switching of the IGBT is done with space vector PWM technique (SVPWM) instead of sine PWM technique (SPWM) in order to increase the utilization of DC link voltage by 15%. The DC link voltage is obtained from a two six pulse uncontrolled diode bridge rectifier fed form a three winding transformer. The control algorithm and SVPWM technique is implemented in a DSP controller. The PWM signal generated from the DSP controller is of 5V which is pulled up to 15V signal and fed to semikron gate driver (protects IGBT) which in turns generates +/- 15V signal to drive the IGBT. In SVPWM we have more freedom to choice the sequences of the states of the inverter devices. The free choice can be used in order to minimize switching losses to reduce output ripple or to obtain Neutral-Point balancing.

1.1 Three-Level Diode Clamped Inverter

The diode-clamped multilevel inverter employs clamping diodes and cascaded dc capacitors to produce ac voltage waveforms with multiple levels. The inverter can be generally configured as a three-, four-, or five-level topology, but only the three-level inverter, often known as neutral-point clamped (NPC) inverter, has found. The main features of the NPC inverter include reduced *dv*/*dt* and THD in its ac output voltages a certain voltage level without switching devices in series. The circuit of a three-level inverter is shown below

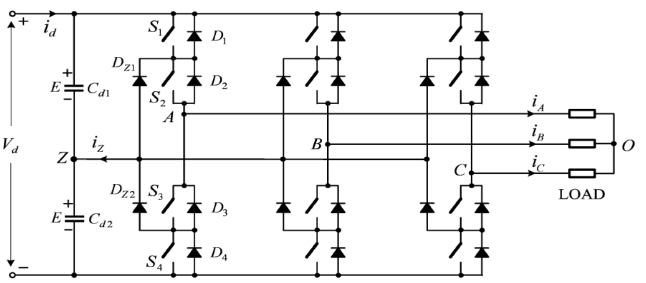

Fig 1. Three-level NPC inverter

On the dc side of the inverter, the dc bus capacitor is split into two, providing a neutral point *Z*. The diodes connected to the neutral point, D_{z1} and D_{z2}, are the clamping diodes. When switches S_2 and S_3 are turned on, the

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inverter output terminal *A* is connected to the neutral point through one of the clamping diodes. The voltage across each of the dc capacitors is *E*, which is normally equal to half of the total dc voltage V_d. With a finite value for C_{d1} and C_{d2}, the capacitors can be charged or discharged by neutral current I_z, causing neutral-point voltage deviation.

1.2 Switching States

The operating status of the switches in the NPC inverter can be represented by switching states shown in Table. Switching state ‘P’ denotes that the upper two switches in leg A are on and the inverter terminal voltage vAZ, which is the voltage at terminal A with respect to the neutral point Z, is +E, whereas ‘N’ indicates that the lower two switches conduct, leading to v_{AZ} = –E. Switching state ‘O’ signifies that the inner two switches S_2 and S_3 are on and v_{AZ} is clamped to zero through the clamping diodes. Depending on the direction of load

Table 1 Definitions of switching states

Switching state	Device Switching Status (Phase A)				Inverter Terminal Voltage
	S_1	S_2	S_3	S_4	V_{AZ}
P	On	On	Off	Off	E
O	Off	On	On	Off	0
N	Off	Off	On	On	-E

Current i_A, one of the two clamping diodes is turned on. For instance, a positive load current ($i_A > 0$) forces D_{Z1} to turn on, and the terminal *A* is connected to the neutral point *Z* through the conduction of D_{Z1} and S_2. It can be observed from Table.[1] that switches S_1 and S_3 operate in a complementary manner. With one switched on, the other must be off. Similarly, S_2 and S_4 is a complementary pair as well

2. Features of Three Level NPC Inverter

The three-level NPC inverter offers the following features:

- No dynamic voltage sharing problem. Each of the switches in the NPC inverter with stands only half of the total dc voltage during commutation.
- Static voltage equalization without using additional components. The static voltage equalization can be achieved when the leakage current of the top and bottom switches in an inverter leg is selected to be lower than that of the inner switches.
- Low THD and *dv*/*dt*. The waveform of the line-to-line voltages is composed of five voltage levels, which leads to lower THD and *dv*/*dt* in comparison to the two-level inverter operating at the same voltage rating and device switching frequency.

However, the NPC inverter has some drawbacks such as additional clamping diodes, complicated PWM switching pattern design, and possible deviation of neutral point voltage.

2.1 Causes of Neutral-Point Voltage Deviation

In addition to the influence of small- and medium-voltage vectors, the neutral-point voltage may also be affected by a number of other factors, including

- Unbalanced dc capacitors due to manufacturing tolerances.
- Inconsistency in switching device characteristics.
- Unbalanced three-phase operation.

To minimize the neutral-point voltage shift, a feedback control scheme can be implemented, where the neutral-point voltage is detected and then controlled.

3. SVPWM Technique

3.1. Introduction

Space Vector Modulation (SVM) Technique has become the most popular and important PWM technique for three level voltage source inverters for the control of AC Induction , Brushless DC,Switched Reluctance and Permanent Manget Synchronous Motors. This work proposes a new soft ware implementation for the three level inverter using Space Vector Modulation technique.Space Vector modulation (SVM) technique was originally developed as a 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.

4. Space Vector Concept

The concept of space vector is derived from the rotating field of AC machine which is used for modulating the inverter output voltage. In this modulation technique the three phase quantities can be transformed to their equivalent 2-phase quantity either in synchronously rotating frame (or) stationary frame. From this 2-phase component the reference vector magnitude can be found and used for modulating the inverter output. The process of obtaining the rotating space vector is explained in the following section, considering the stationary reference frame. Each leg of the DCI can solely take three different switching states. Consequently the DCI has twenty seven valid switching states. Each switching state is denoted with a three letter code (e.g. pnn, pop) which corresponds to the three nodes (a, b, c), respectively, then being connected to the positive (p), zero (o) or negative (n) dc rail. The principle of the SVM is that we use these switching states to compose the desired output voltage. Every switching state corresponds to specific output voltages which are equivalent to a vector on an α-β plane, using

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = \begin{bmatrix} \frac{3}{2} & 0 & 0 \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} \tag{1}$$

Some switching states are equivalent to the same vector as they match up to the same output voltages. Therefore the switching vectors are only nineteen, as shown in fig. and can be divided into four types: zero vectors (V_0), short vectors (V_1, V2, V_3, V_4, V_5, V_6), medium vectors (V_7, V_6, V_9, V_{10}, V_{11}, V_{12}) and large vectors (V_{13}, V_{14}, V_{15}, V_{16}, V_{17}, V_{18}). The voltages that we want to generate at the output of the inverter can also be matched to a reference vector Vref on an α-β plane using the transformation from equation above.

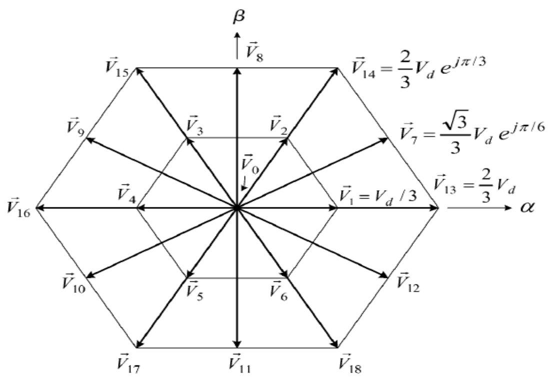


Fig.2. Switching vectors of three level DCI

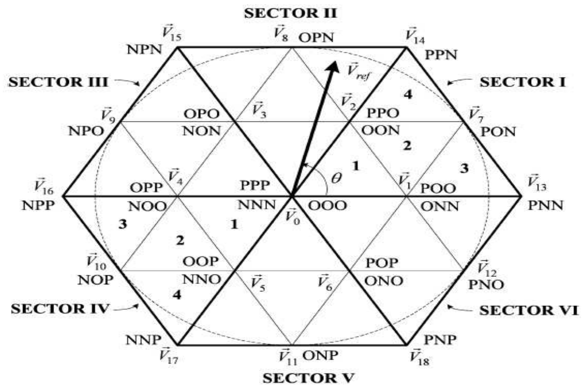


Fig 3. Division of sectors and Regions

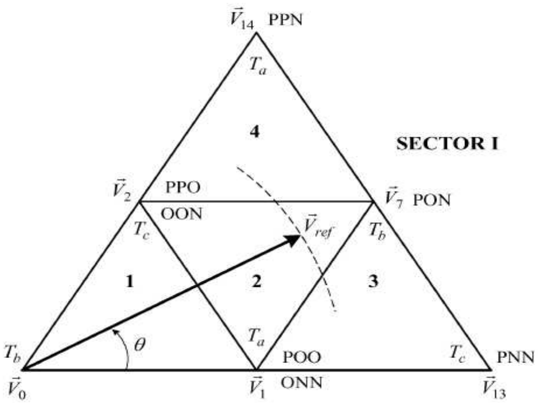


Fig 4 Voltage vectors and their Dwell Times

In general the SVM can be divided into the following three steps:
a) Switching vectors selection.
b) Computation of the duty cycles of the selected switching vectors.
c) Switching states selection

Based on their magnitude (length), the voltage vectors can be divided into four groups.
Zero vector (V_0), representing three switching states [PPP], [OOO], and [NNN]. The magnitude of (V_0) is zero.

Small vectors (V_1 to V_6), all having a magnitude of $V_{d/3}$. Each small vector has two switching states, one containing [P] and the other containing [N], and therefore can be further classified into a P- or N-type small vector.
Medium vectors (V_7 to V_{12}), whose magnitude is $\sqrt{3}Vd/3$.
Large vectors (V_{13} to V_{18}), all having a magnitude of $2Vd/3$.

5. Dwell Time Calculations

To facilitate the dwell time calculation, the space vector diagram of Fig. 2 can be divided into six triangular sectors (I to VI), each of which can be further divided into four triangular regions (1 to 4) as illustrated in Fig. 3. The switching states of all the vectors are also shown in the figure. Similar to the SVM algorithm for the two-level inverter, the space vector modulation for the NPC inverter is also based on "volt-second balancing" principle; that is, the product of the reference voltage V_{ref} and sampling period Ts equals the sum of the voltage multiplied by the time interval of chosen space vectors. In the NPC inverter, the reference vector V_{ref} can be synthesized by three nearest stationary vectors. For instance, when V_{ref} falls into region 2 of sector I as shown in Fig. 3.4.3, the three nearest vectors are V_1, V_2, and V_7, from which

$$V_1\, T_a + V7\, T_b + V_2\, T_c = V_{ref}\, Ts \qquad (2)$$
$$T_a + T_b + T_c = T_s$$

where T_a, T_b, and T_c are the dwell times for V_1, V_7, and V_2, respectively. Note that V_{ref} can also be synthesized by other space vectors instead of the "nearest three." However, it will cause higher harmonic distortion in the inverter output voltage, which is undesirable in most cases is shown in Table.2.

Table 2.Voltage vectors & switching states

Space Vector		Switching State		Vector Classification	Vector Magnitude
$\vec{V_0}$		[PPP] [NNN]	[OOO]	Zero Vector	**0**
$\vec{V1}$		P-type	N-type		
	$\vec{V}_{1P}$	[POO]			
	$\vec{V}_{1N}$		[ONN]		
	$\vec{V}_{2P}$	[PPO]			
$\vec{V2}$	$\vec{V}_{2N}$		[OON]		
	$\vec{V}_{3P}$	[OPO]			
$\vec{V3}$	$\vec{V}_{3N}$		[NON]	Small Vector	$\frac{1}{3}V_d$
	$\vec{V}_{4P}$	[OPP]			
$\vec{V4}$	$\vec{V}_{4N}$		[NOO]		
	$\vec{V}_{5P}$	[OOP]			
$\vec{V5}$	$\vec{V}_{5N}$		[NNO]		
	$\vec{V}_{6P}$	[POP]			
$\vec{V6}$	$\vec{V}_{6N}$		[ONO]		
$\vec{V7}$		[PON]			
$\vec{V8}$		[OPN]			
$\vec{V9}$		[NPO]		Medium Vector	
$\vec{V10}$		[NOP]			$\frac{\sqrt{3}}{3}V_d$
$\vec{V11}$		[ONP]			
$\vec{V12}$		[PNO]			
$\vec{V13}$		[PNN]			
$\vec{V14}$		[PPN]			
$\vec{V15}$		[NPN]		Large Vector	$\frac{\sqrt{3}}{3}V_d$
$\vec{V16}$		[NPP]			
$\vec{V17}$		[NNP]			
$\vec{V18}$		[PNP]			

The voltage vectors V_1, V_2, V_7, and V_{ref} in Fig. 3.4.1 (c) can be expressed as

$$V_1 = 1/3Vd,\ V_2 = 1/3\ Vd\ e^{j\ \pi/3},\ V_7 = \sqrt{3}/3Vd\ e^{\ j\pi/6}\ \text{and}\ \ V_{ref} = V_{ref}\ e\ j\theta \qquad (3)$$

Substituting (3.4-2) into (3.4-1) yields

$$Vd*Ta+\sqrt{3}/3*Vde^{j\pi/6}*Tb+Vde^{j\pi/3}*Tc=V_{ref*}e^{j\theta*}Ts \quad (4)$$

From which

$$1/3Vd*Ta + \sqrt{3}/3Vd\,(\cos\pi/6+ j\sin\pi/6)Tb +1/3\,Vd\,(\cos\pi/3+ j\sin\pi/3)Tc = Vref\,(\cos\theta + j\sin\theta)Ts \quad (5)$$

Splitting (4) into the real and imaginary parts, we have

$$\text{Re: } Ta+3/2* Tb +1/2* Tc=3\,Vref/Vd* (\cos\theta)* Ts$$
$$\text{Im: } 3/2*Tb+\sqrt{3}/2\,Tc=3\,Vref/Vd* (\sin\theta)* Ts \quad (6)$$

Solve (5) together with $Ta + Tb + Tc = Ts$ for dwell times

$$Ta = Ts\,[1 – 2ma\sin\theta]$$
$$Tb=Ts*[2ma*\sin(\pi/3+\theta)-1] \text{ for } 0<\theta<\pi/3 \quad (7)$$
$$Tc = Ts\,[1 – 2ma\sin(\pi/3-\theta)]$$

Where ma is the modulation index, defined by

$$ma= \sqrt{3}*Vref/Vd \quad (8)$$

The maximum length of the reference vector V_{ref} corresponds to the radius of the largest circle that can be inscribed within the hexagon of Fig. 3, which happens to be the length of the medium voltage vectors

$$V_{ref}, \max = \sqrt{3}\,V_d/3 \quad (9)$$

Substituting *Vref*, max into (8) yields the maximum modulation index

$$Max = \sqrt{3}Vref,max/Vd = 1 \quad (10)$$

from which the range of *ma* is

$$0 \leq ma \leq 1$$

The above equations can also be used to calculate the dwell times when *Vref* which is provided that a multiple of π/3 is subtracted from the actual angular displacement 'θ' such that the modified angle falls into the range between zero and π/3 for use in the equations

6. Features of Space Vector

The main aim of any modulation technique is to obtain variable output having a maximum fundamental component with minimum harmonics. During the past years many PWM techniques have been developed for letting the inverters to posses various desired output characteristics to achieve the following aim:

- Wide linear modulation range.
- Less switching loss.
- Lower total harmonic distortion.

The space vector modulation (SVM) technique is more popular than conventional technique because of the following excellent features:

- It achieves the wide linear modulation range associated with PWM third-harmonic injection automatically.
- It has lower base band harmonics than regular PWM or other sine based modulation methods, or otherwise optimizes harmonics.
- 15% more output voltage then conventional modulation, i.e. better DC-link utilization.
- More efficient use of DC supply voltage.
- SVM increases the output capability of SPWM without distorting line-line output voltage waveform.
- Advanced and computation intensive PWM technique.
- Higher efficiency.
- Prevent un-necessary switching hence less commutation losses.
- A different approach to PWM modulation based on space vector representation of the voltages in the α/β plane.
- The switching sequence is determined without a look-up table .so, the memory of the controller can be saved.
- In the SVPWM, we have more freedom to choice the sequences of the inverter devices, this choice can be used in order to minimize switching losses, to reduce the out- put ripple or to obtain the input neutral point balancing.

Apart from SVPWM the triangular-sinusoidal & hysteresis PWM technique do not deal with the dc-link capacitor voltage balancing.

7. Scalar Control Technique

In this type of control, the motor is fed with variable frequency signals generated by the PWM control from an inverter using TMS320F2810 DSP controller. Here, the V/f ratio is maintained constant in order to get constant torque over the entire operating range. Since only magnitudes of the input variables – frequency and voltage – are controlled, this is known as “scalar control”. Generally, the drives with such a control are without any feedback devices (open loop control). Hence, a control of this type offers low cost and is an easy to implement solution. In such controls, very little knowledge of the motor is required for frequency control. Thus, this control is widely used. A drawback of such a control is that the torque developed is load dependent as it is not controlled directly. Also, the transient response of such a control is not fast due to the predefined switching pattern of the inverter. However, if there is a continuous block to the rotor rotation, it will lead to heating of the motor regardless of implementation of the over current control loop. By adding a speed/position sensor, the problem relating to the blocked rotor and the load dependent speed can be overcome There are a number of ways to implement scalar control.

7.1 Scalar Controlled Techniques

1.Open loop Volts/Hertz Control.
2 .Closed loop Volts/Hertz Control with slip regulation.
3. Speed control with torque and flux control.

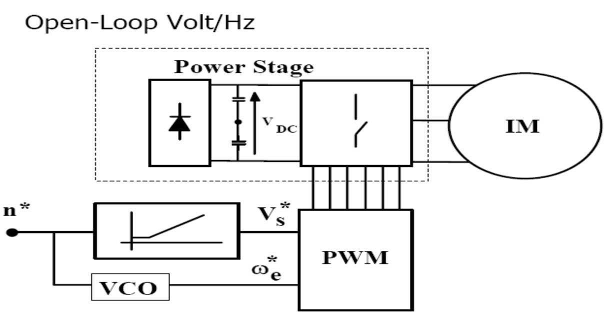


Fig 5 Open –Loop Volt/Hz

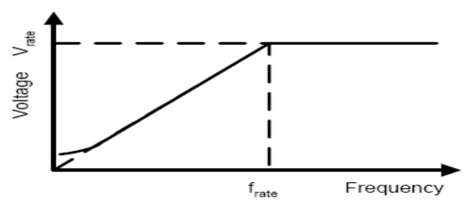


Fig. 6 Voltage versus frequency under the constant V/Hz principle

The ratio V/ f remains constant for any change in f , then flux remains constant and the torque becomes independent of the supply frequency. In actual implementation, the ratio of the magnitude to frequency is usually based on the rated values of these parameters, i.e., the motor rated parameters. However, when the frequency, and hence the voltage, is low, the voltage drop across the stator resistor cannot be neglected and must be compensated for. At frequencies higher than the rated value, maintaining constant V/Hz means exceeding rated stator voltage and thereby causing the possibility of insulation break down. To avoid this, constant V/Hz principle is also violated at such frequencies. This principle is illustrated in Figure 5. Since the stator flux is maintained constant (independent of the change in supply frequency), the torque developed depends only on the slip speed. This is shown in Fig. 7. So by regulating the slip speed, the torque and speed of an AC Induction motor can be controlled with the constant V/Hz principle.

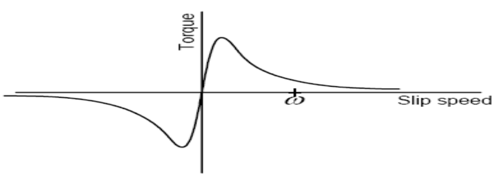


Fig.7 Torque versus slip speed of an induction motor with constant stator flux

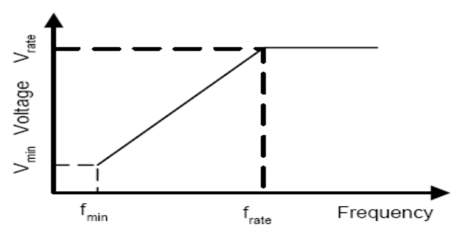


Fig 8 Modified V/Hz profile

Both open and closed-loop control of the speed of an AC induction motor can be implemented based on the constant V/Hz principle. Open-loop speed control is used when accuracy in speed response is not a concern such as in HVAC (heating, ventilation and air conditioning), fan or blower applications. In this case, the supply frequency is determined based on the desired speed and the assumption that the motor will roughly follow its synchronous speed. The error in speed resulted from slip of the motor is considered acceptable. In this implementation, the profile in Figure 6 is modified by imposing a lower limit on frequency. This is shown in Figure 7. This approach is acceptable to applications such as fan and blower drives where the speed response at low end is not critical. Since the rated voltage, which is also the maximum voltage, is applied to the motor at rated frequency, only the rated minimum and maximum frequency information is needed to implement the profile.

8. Simulation Results for Three-Level Inverter

(a) For Acceleration (5Hz -50Hz frequency)

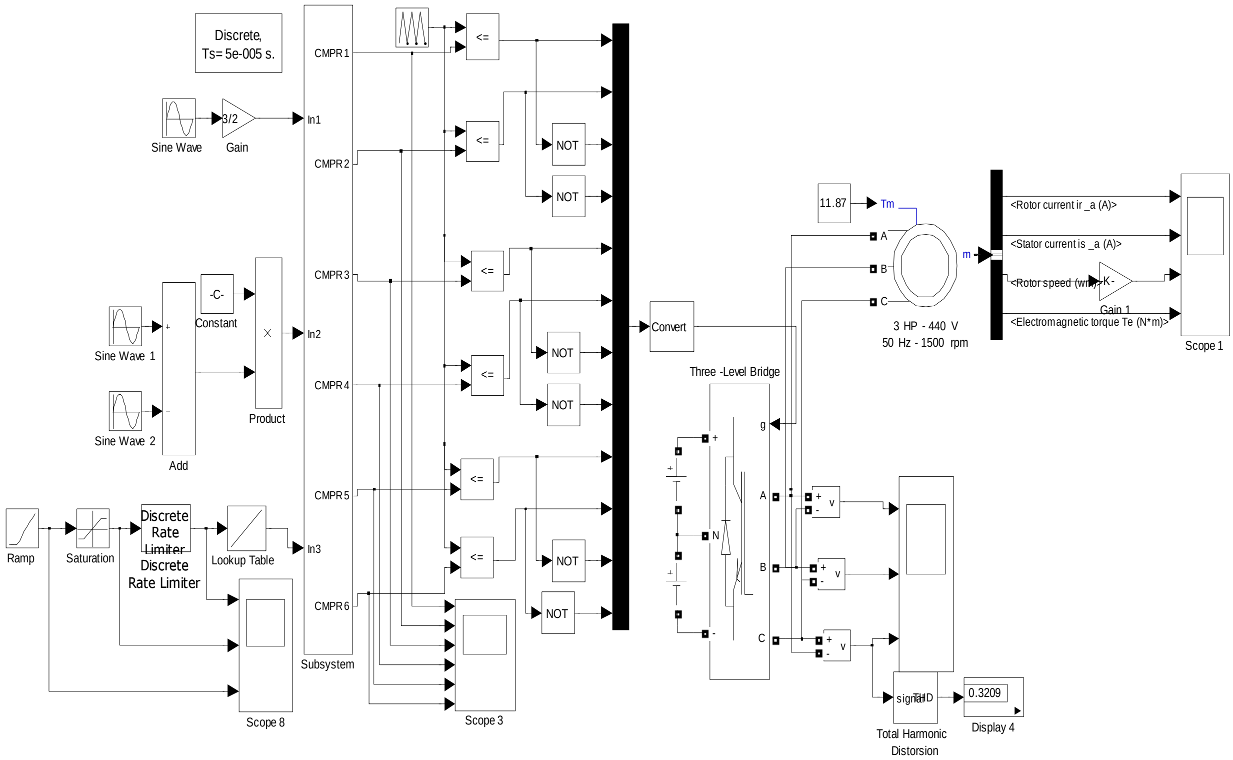


Fig.9. Simulink block of Scalar Control

In this Simulink, the input command frequency is varied from 5 to 50 hertz and mean while our modulation index value also varies according to the changes in frequency in such a way that the flux command remains constant. And we observed that the total harmonic distortion is 32.09% and speed is achieved near to synchronous speed.

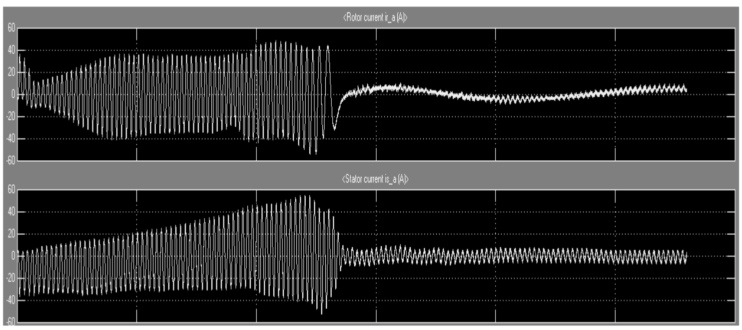


Fig 10. Rotor & Stator currents waveforms

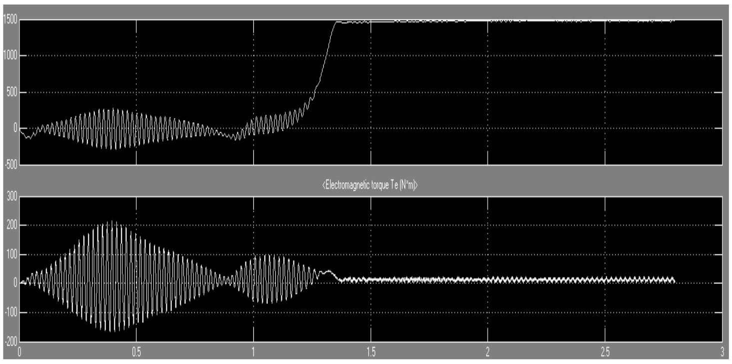


Fig.11. Speed & Torque Waveforms

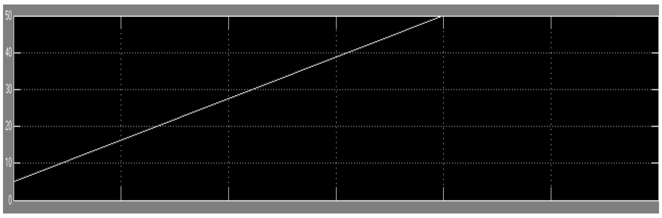


Fig 12. V/f profile (frequency from 5-50Hz)

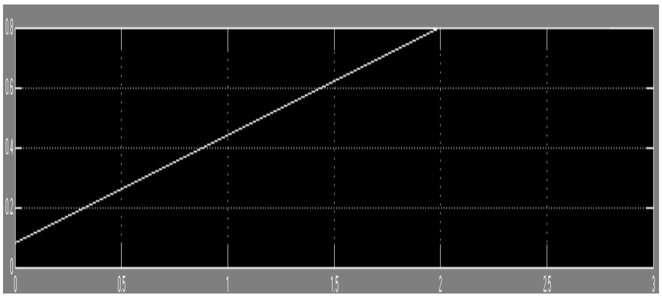


Fig 13. Modulation index (0.08-0.8)

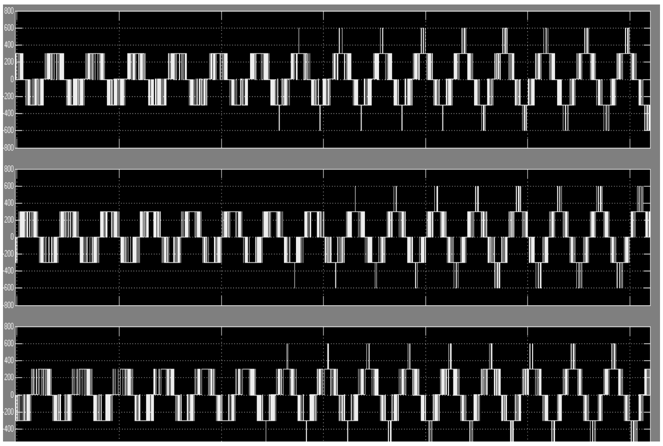
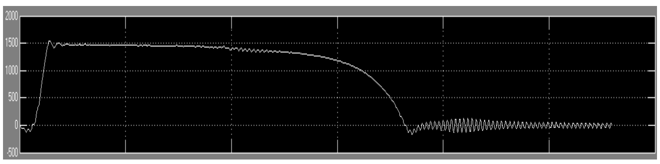


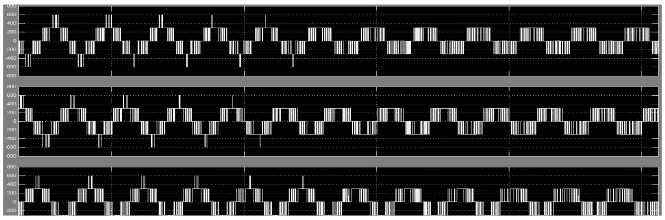
Fig 14. output line-line voltages (V_{ab}.V_{bc},V_{ca})

From this waveform, we observe that it is clearly seen that the wave form changes from two level voltage level to three level as frequency increases from 5 to 50 hertz

(b) For Deceleration (50Hz -5Hz frequency)



From deceleration we observe that speed decreases from rated to zero value.



From this above waveform, we observe that it is clearly seen that the wave form changes from two level voltage level to three level as frequency decreases from 50 to 5 Hertz.

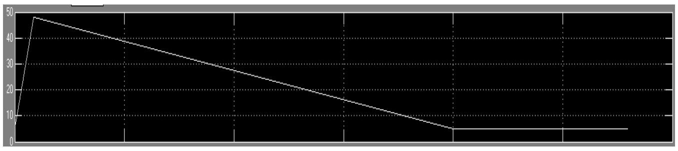


Fig.15. Frequency changes from 50 -5 Hertz

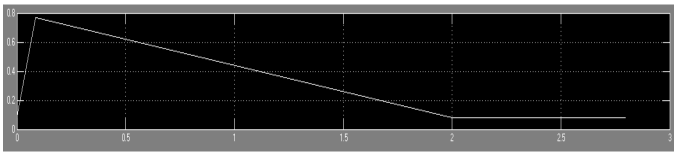


Fig. 16. Modulation index changes from 0.8 to 0.08

PULSES FROM DSP CONTROLLER
R-phase (R_3,R_1,R_4,R_2)

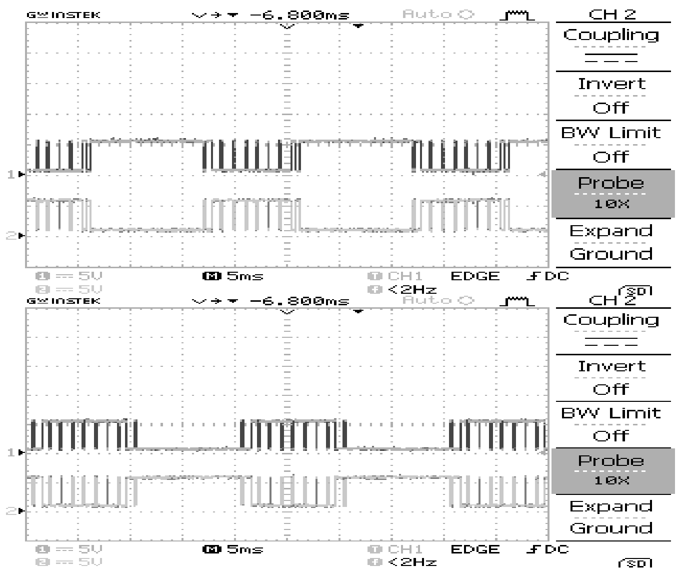


Fig.17. Phase R pulses from DSP Controller.

9. Level Shifter

It is used for increases the amplitude of signal from (0-5V) to (0-15V).The ULN2004 is a high-voltage, high-current Darlington transistor arrays. Each consists of seven npn Darlington pairs that feature high-voltage outputs with common-cathode clamp diodes for switching inductive loads. The collector-current rating of a single Darlington pair is 500 mA. The Darlington pairs can be paralleled for higher current capability. The Circuit diagram of Level shifter is shown in below.

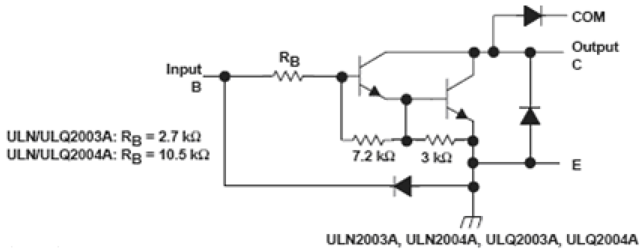


Fig.18. Circuit diagram of Level shifter

9.1. Buffered Waveforms

R-phase(R_1,R_3,R_2,R_4) buffered waveforms is shown in figure.19.

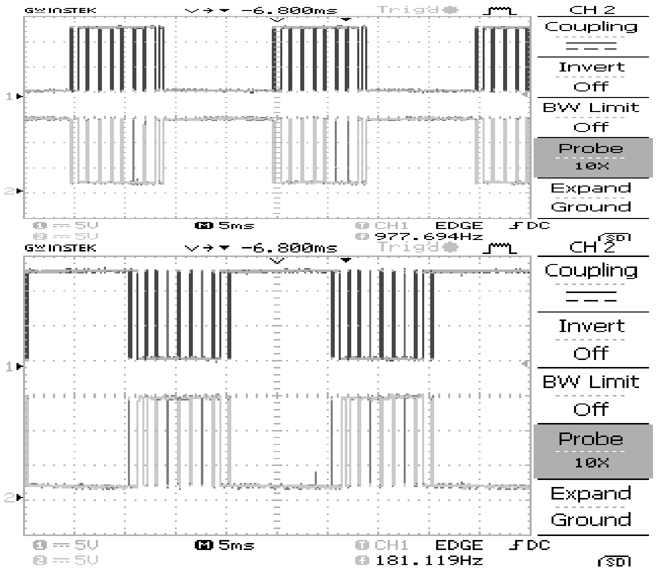


Fig.19. Buffered waveforms for R_1, R_2, R_3, R_4

10. Experimental Results

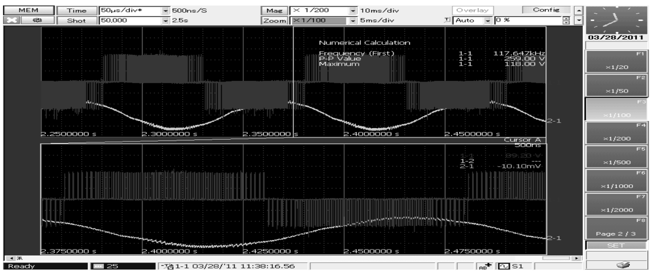


Fig 20. 250Rpm,26.09V_{L_L},10Hz

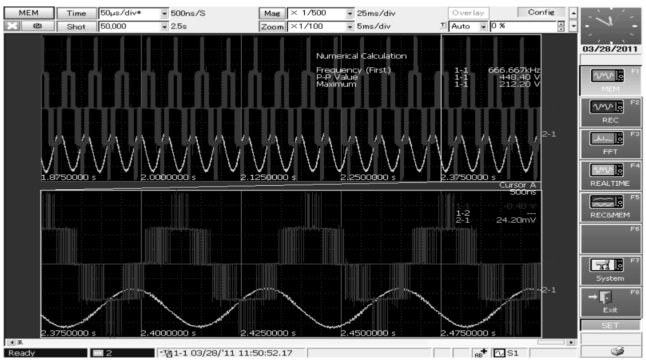


Fig 21. 866rpm,76.5V_{L-L},30Hz

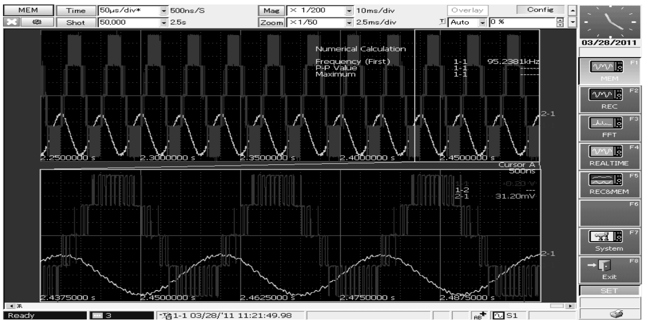


Fig 22. 1455rpm,117.7$V_{L\text{-}L,}$50Hz

11. Conclusion

In this work SVPWM technique for three level inverter fed induction machine has been presented .The rotor speed and torque waveforms are also been presented and those are satisfactorily. With SVPWM technique we can obtain 15% more output voltage then conventional modulation, i.e. better DC-link utilization. The simulation results and hardware are presented and they are same.

References

[1] Samir Kouro, Mariusz Malinowski,” Recent Advances and Industrial Applications of Multilevel Converters” IEEE *Transactions on Industrial Electronics*, Vol. 57, No. 8, August pp 2553-2580, 2010.

[2] M.Saeedifard,H.Nikkhajoei,and R.Iravani, “A Space Vector Modulated STATCOM Based on a Three-Level Neutral point clamped converter” IEEE *Transaction on Power Delivery*, Vol.22, No.2, April 2007.

[3] Amit Kumar Gupta and M.Khambadkone,“A Space Vector PWM Scheme for Multilevel Inverters Based on Two-Level Space Vector PWM.”IEEE *transaction on Industrial Electronics*, Vol.53, No.5, pp.1631-1639, October 2006.

[4] P.Satish Kumar,J Amarnath and S.V.L.Narasimham,“An Effective Space Vector PWM Method for Multilevel Inverter Based on Two –level Inverter.” *International Journal of Computer and Electrical.Engineering*, Vol.2,No.2,pp.1793-8163 April,2010.

[5] Atif iqbal,Sk Moin Ahmed,Mohammad Arif Khan,Haitham Abu-Rub,”Generalised Simulation and experimental implementation of space vector PWM technique of a three-Phase voltage source inverter”. *International.Journal.of Engineering Science and Technology*, Vol.1, No.2, pp.1-12 April 2010.

[6] P.Satish Kumar,J Amarnath and S.V.L.Narasimham,”A Fast Space-Vector Pulse with Method for Diode-Clamped Multi-Level Inverter fed Induction Motor.” *Asian Power Electronics Journal*, Vol.4, No.1, April 2010.”

[7] George A. Varsamis, Epaminontas D. Mitronikas, Athanasios N. Safacas ,”Field Oriented Control with Space Vector Modulation for Induction Machine Fed by Diode Clamped Three Level Inverter”, *Proceedings of the 2008 International Conference on Electrical Machines,* September 2008.

[8] Bin Wu,“High Power Converters &AC Drives.”*John Wiley and Sons Publications*, First Edition, October 2006.

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