

Study and Implementation of Space Vector Close Loop Control for Induction Motor

Mr. E VijayKumar, Mr.Ganesh D.Khadsane, Mr Mahesh Singh

Abstract— This paper represents the design and implementation of a voltage source inverter for closed loop control of Induction Motor. The space-vector pulse-width-modulation was used in the development of firing pulses for the three-wire IGBT inverter. The objective was to improve the output waveform of the inverters by Space Vector Pulse Width Modulation (SVPWM) which can be used for control of ac/dc drive, alternate energy resources and Flexible ac transmission application controller. This can be achieved by maintaining the synchronization and half wave symmetry, quarter wave symmetry, three phase symmetry in the PWM waveforms. For verification simulation of closed loop control of induction motor is presented in MATLAB simulink with the results showing that even if load on motor is varied speed is maintained constant.

Index Terms—IGBT, SVPWM, MATLAB, Inverter

I. INTRODUCTION

Advances in the last decade in power electronics and high performance digital processors have lead a better electric power control in electrical machines. In industry controlling of induction motor required for better output.. These types of controls can be achieved with the help of a variable speed drive (VSD). An electrical VSD system consists of the power converter, the electrical machine and the control system. The electrical machine is connected to the load and the power converter controls the power flow from AC mains to the electrical machine by means of a high speed power semiconductor switches and the different types of controller which generates the control signal needed to get the desired speed or torque reference. Voltage source inverters used in VSD, can also be found in railway propulsion systems applications, uninterruptible power supplies, induction heating, alternative power generation and active filters [1][6].

The VSDs are also useful in current investigation on multiphase electrical machines and sensorless control of induction motors. Variable speed drive uses Pulse width modulation techniques specially Sinusoidal Pulse Width Modulation (SPWM) techniques to control the output voltage and frequency of inverter. But SPWM produces harmonics in the output voltage which leads to a pulsating torque of Induction motor. The foregoing problem can be solved by Space Vector Pulse Width Modulation (SVPWM) control which gives best solution in terms of output voltage, harmonic losses and switching frequency per cycle. SVPWM is more

suitable for digital implementation and can increase obtainable maximum output voltage with maximum line voltage approaching 70.6% of the DC link voltage in the linear modulation range [2][7].

This paper represents implementation of space vector pulse width modulation for the closed loop control of Induction motor with impact of Matlab Simulation . Software implementation of SVPWM in Matlab Simulink is presented with results.

II. SPACE VECTOR MODULATION

Variable speed drives system based on AC induction motors are usually fed from the three phase voltage source inverter (VSI). The structure of typical three-phase VSI is shown in fig- 1. Because of topological restrictions a path must exist for the flow of main inductor current and no short circuit must be created to the dc side due to which only eight combinations of the switches could be possible as shown in fig- 2. Each low side switch is complementary to the positive-side switch means that when an upper switch is ON, the corresponding lower switch has to be OFF and vice versa [3].

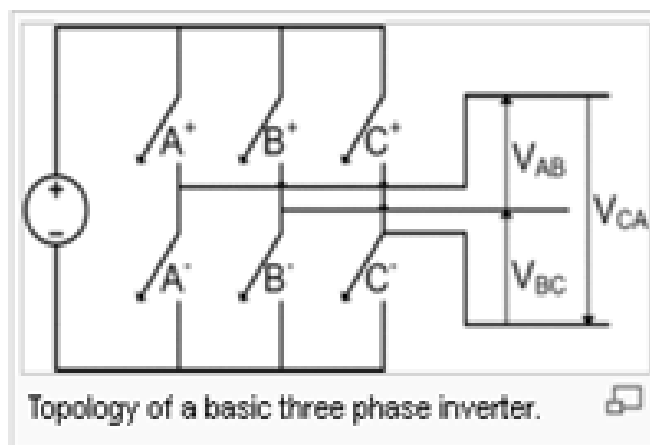


Figure.1 Topology of three phase inverter

Vector	A ⁺	B ⁺	C ⁺	A ⁻	B ⁻	C ⁻	V _{AB}	V _{BC}	V _{CA}	
V ₀ = [000]	OFF	OFF	OFF	ON	ON	ON	0	0	0	zero vector
V ₁ = [100]	ON	OFF	OFF	OFF	ON	ON	+V _{dc}	0	-V _{dc}	active vector
V ₂ = [110]	ON	ON	OFF	OFF	OFF	ON	0	+V _{dc}	-V _{dc}	active vector
V ₃ = [010]	OFF	ON	OFF	ON	OFF	ON	-V _{dc}	+V _{dc}	0	active vector
V ₄ = [011]	OFF	ON	ON	ON	OFF	OFF	-V _{dc}	0	+V _{dc}	active vector
V ₅ = [001]	OFF	OFF	ON	ON	ON	OFF	0	-V _{dc}	+V _{dc}	active vector
V ₆ = [101]	ON	OFF	ON	OFF	ON	OFF	+V _{dc}	-V _{dc}	0	active vector
V ₇ = [111]	ON	ON	ON	OFF	OFF	OFF	0	0	0	zero vector

Figure. Figure 2 Combination of switches

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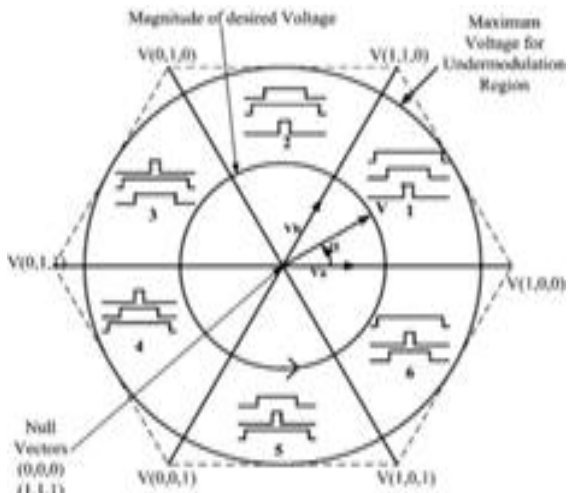


Figure.3 Generation of reference vector from base vector

Accordingly three-phase inverters have eight possible switching states were possible out of which two of them represent a null value because all of the inverter terminals are connected to the same potential point (V_{cc} or GND). The remaining six switching states deliver a non-zero voltage and are represented as vectors in a plane as it is shown in Figure-3.

Each of the active states is represented by a three number coordinate system, these numbers represent the state of each of the inverter leg, where 1 corresponds to conduction 'ON' the upper switch and 0 represents conduction on the lower switch. There is a reference vector which rotates at the same angular speed of the desired frequency and the position of this vector determines the instantaneous voltage output of the inverter.

Whenever the reference vector lies between two state vectors, a vector sum is made in order to obtain the desired voltage, this sum is given by (1)

$$V = V_a + V_b + V_0 \quad (1)$$

The components of the adjacent vectors constitute the reference vector are obtained as

$$V_a = \frac{2}{\sqrt{3}} V \sin\left(\frac{\pi}{3} - \alpha\right) \quad (2)$$

$$V_b = \frac{2}{\sqrt{3}} V \sin \alpha \quad (3)$$

Once the voltage components were calculated, they must be transformed into time which represents conduction time of various phases. Transformation from voltages to commutation times was calculated by a simple comparison of the voltages with the maximum voltage available on three phase inverter, this comparison yields equation

$$T_a = \frac{V_a}{\frac{2}{3} V_{cc}} T_c$$

$$T_b = \frac{V_b}{\frac{2}{3} V_{cc}} T_c$$

$$T_o = T_c - T_a - T_b$$

Where T_c is the commutation period divided by 2 and V_{cc} is DC voltage fed to the inverter. T_o is the time at which the null vector is applied to the load, with objective of completing the turn Off time of various switches .

After these times are calculated, they are arranged on symmetrical pattern that corresponds to a sector where the voltage vector is located .This symmetrical pattern has the objective of reducing the harmonic distortion from the

generated wave The arrangement of commutation times of Sector -1 is shown in figure-4.

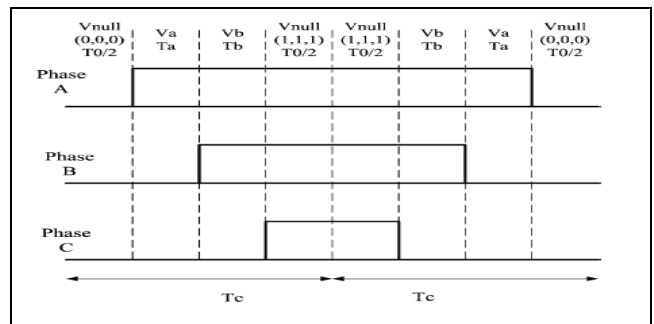


Figure.4 symmetrically arranged switching patterns

Whenever the reference vector V remains within the hexagon, the inverter is said to be operating in the under modulation region, any excursion outside the hexagon makes the inverter to operate in the over modulation region. In order to determine the inverter working region, it is necessary to know the modulation factor which is obtained by (4):

$$m = \frac{2V_{cc}}{\pi} \quad (4)$$

Where V is the magnitude of the reference vector . If this equation is evaluated for the maximum vector magnitude available for linear operation, the modulation factor will give a value of 0.907.

This means that 90.7% of the fundamental is available at the square wave, compared to a 78.55% in the sinusoidal PWM. The over modulation starts when the reference vector exceeds the hexagon boundary; as a result there is a loss of fundamental voltage in that region. In order to minimize the loss in fundamental voltage, under modulation voltages are kept for every region where the reference voltage does not exceed the hexagon [1].

III. GENERALIZATION OF SPACE VECTOR MODULATION

Five steps can be used to implement the space vector modulation of voltage-source inverters

1. switching vector technique in the output voltage space.
2. Determination of a separation plane in between output voltage space vector
3. Identification of boundary plane in the output voltage space
- 4 Forming the decomposition matrices.
5. Selecting the switching sequence.

In first step it is possible to include a coordinate conversion in output voltage space, to simplify its representation. On the other hand, the separation planes of the second step is required in the algorithm that represent sector where desired output voltage vector was located. If it is possible to apply the voltage vector a decomposition matrices (fourth step) allow computing the time period that each switching vector should be applied in a sampling period. Finally, the switching sequence are selected to minimize an additional losses, which can include commutation losses, THD and in some inverter the unbalance of the dc bus neutral point.

IV. HARDWARE IMPLEMENTATION

As stated above the elements of a VSD system are power converter, control system and an electrical machine. There are intelligent power IGBT's modules for converters and there are also discrete IGBT devices.

In this paper, three-phase 3-wire converter used by using a set of six IGBT IRG4PC40U with high speed diodes RHRP1560. In order to guide all switching signals generated in the DSPIC an IGBT driver is needed. The IR2130 circuit is used because it operates at high voltage and it can handle high speed power MOSFET's and IGBT. Additionally, it has floating channels, preventing cross-conduction logic, an over current protection with other useful features. To avoid a damage to the power bridge, it is necessary to use a R-C snubber circuit to minimise high voltage transients which may damage the IGBT switches. These voltage transients are caused by the stored energy in the inductive load during the switching time especially in OFF time. It is also important to note, that during the switching of the device for some time a large on current is present which leads voltage drop in it. This causes the device to suffer from commutation power losses, and it is worse when higher switching frequencies are used in IGBT's or MOSFET's. The usage of snubbers becomes necessary to guarantee a safe operation at high switching frequencies; and they are connected directly to the switching devices. There are variety of snubber circuits, from simple bypass capacitors to complex RCD networks which may also return energy to the source. An RC snubber circuit was selected because of its low cost, implementation advantages and good performance. It is extremely important to select the particular snubber elements otherwise the transient may be worse as a result consequent IGBT damage. The snubber was constructed using carbon resistors (because of its low stray inductance) and a high voltage capacitor.

The snubber resistor values are determined by using (10)

$$i.e. R \leq V_0/I \quad (10)$$

where V_0 is the off voltage and I is the on current. The capacitance is then calculated with eq. (11).

$$C_s = 1/ V_0^2 f_s \quad (11)$$

Where f_s is the switching frequency

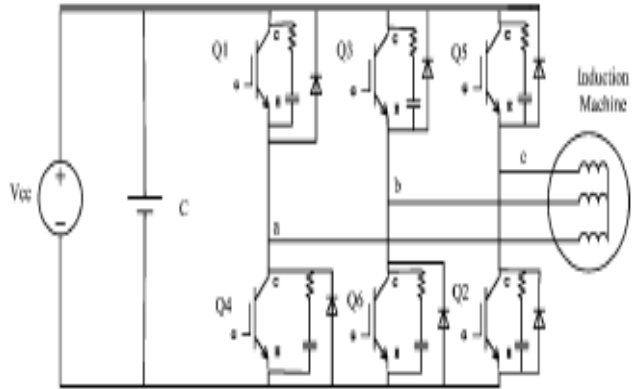


Fig.5 Inverter circuit

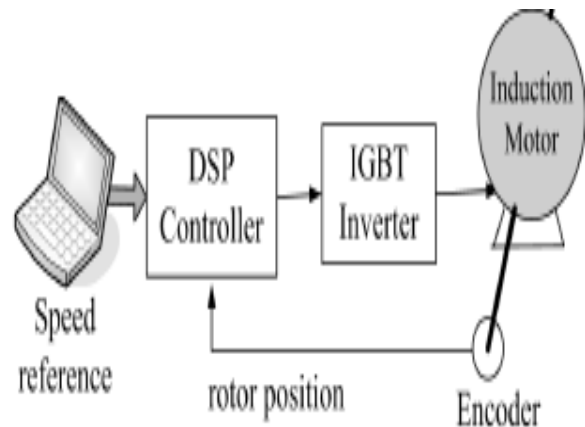


Figure.6 Closed loop scalar control of Induction motor

In this paper, the scalar control in closed loop was selected to show the performance validity of the designed inverter (Figure.6). In the scalar closed-loop control, there is an improvement with respect to the open-loop control in the sense that slip regulation is taken into account. The speed error (difference between the set point and rotor speed) is fed to a proportional- integral (PI) regulator and then, the resulting signal is limited. Afterwards, the signal is added to the feedback speed signal to produce the new frequency control signal. The voltage command is obtained through a second priority is given to the speed measurement that helps to maintain a correct speed control on the motor. Finally, lowest priority is given to a new speed command that comes from the user.

V. SOFTWARE IMPLEMENTATION

Figure.7 is the illustration of implementation of a closedloop control of Induction Motor using space vector pulse width modulation in Simulink /Matlab Program

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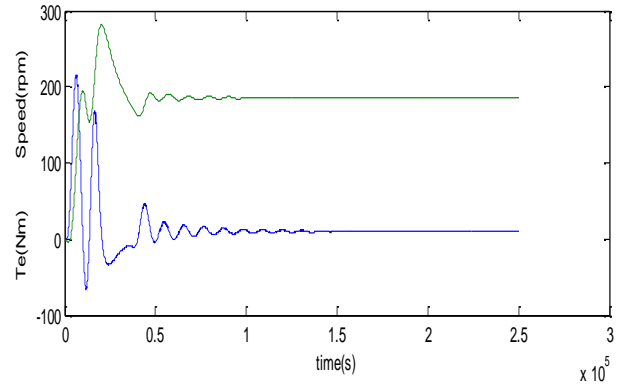
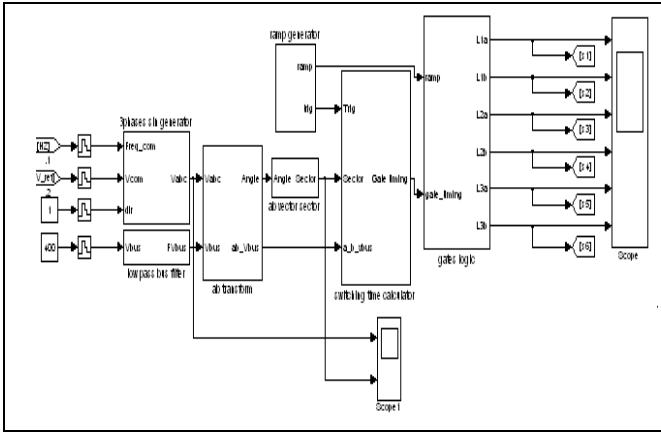


Fig.8 Speed 200 rpm with Torque 10 Nm

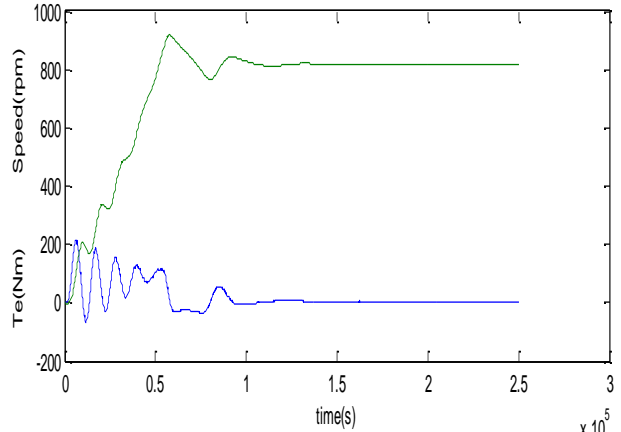
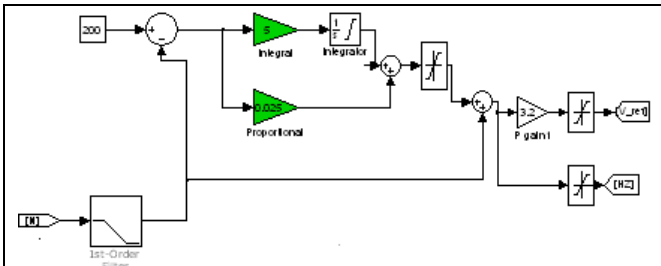


Fig.9 Speed 800 rpm with Torque 5 Nm

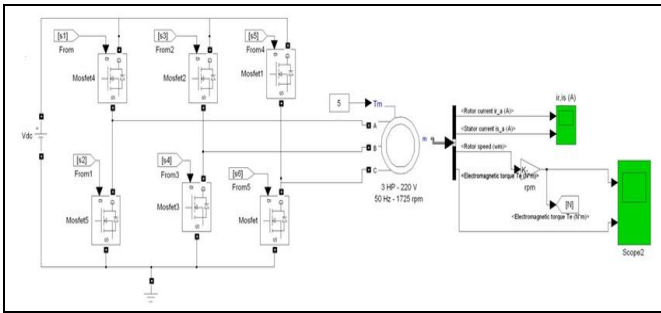


Figure.7 Simulation of closed loop control of Induction Motor

VI. SIMULATION RESULTS

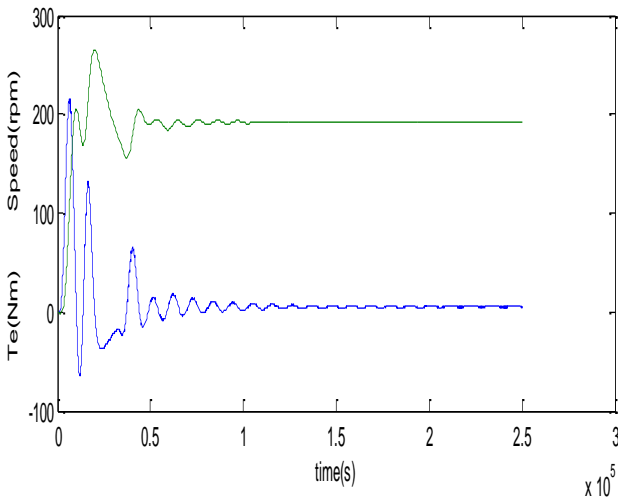


Fig.7 Speed 200 rpm with Torque 5 Nm

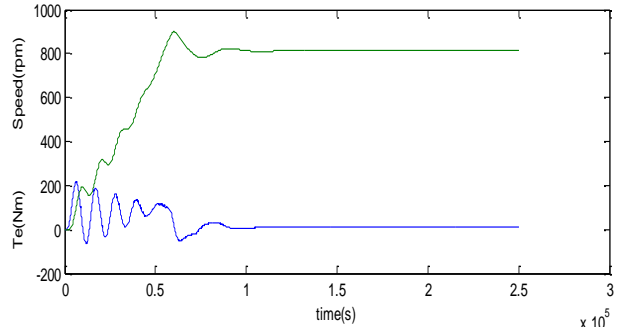


Fig.10 Speed 800 rpm with Torque 10 Nm

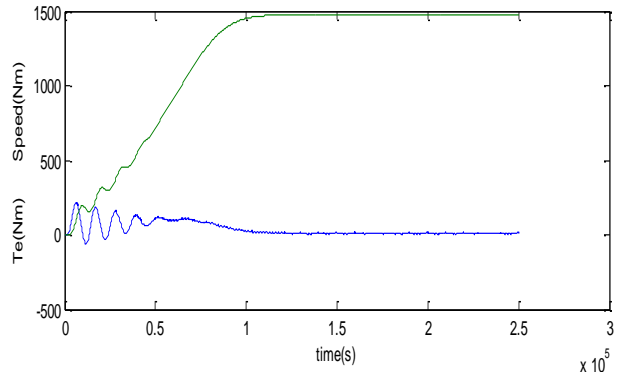


Fig.11 Speed 1500 rpm with Torque 5 Nm

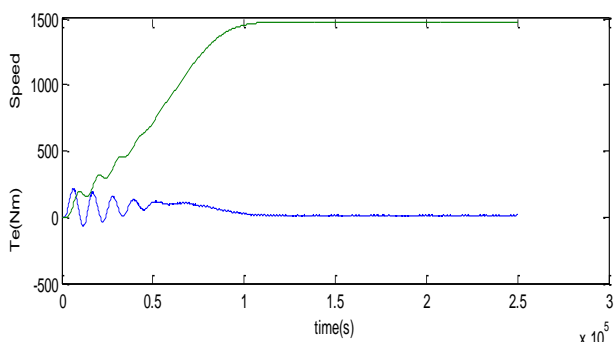


Fig.12 Speed 1500 rpm with Torque 10 Nm

Figure- 7 to Figure -12 shows the simulation results for various speed with different load conditions. Modulation Index is taken 0.15 considering constant V/f steady state operation. The result shown in figure- 7 and 8 is for the same speed of 200 rpm at different load torque of 5 Nm and 10 Nm respectively. From this, it is observed that motor speed remains almost constant even at different load condition which is actually needed for a closed loop control. Similarly Figure 9 and 10 shows results for 800 rpm and Figure 11 and 12 shows results for 1500 rpm at different load condition in this also it can be observed, speed remains almost constant at different load condition.

VII. CONCLUSION

This paper represents study and implementation of space vector closed loop control for induction motor with impact of Matlab Simulation link system. The vector control model of the induction motor uses direct vector control system with closed loop speed control. The simulation results show that the dynamic response of the motor speed is fast, steady tracking has high precision, and the torque has instantaneous response characteristics.

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