VOLTAGE CONTROL SCHEME FOR THREE PHASE SVM INVERTER FED INDUCTION MOTOR DRIVE SYSTEMS

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Abstract:This paper presents an efficient implementation scheme for the closed-loop voltage control of an induction motor incorporating 'Space Vector Pulse Width Modulation (SVPWM)'. Voltage control is required to meet the variation in the input voltage and to regulate the output of the inverter. Space Vector Modulation (SVM) is an algorithm for the control of Pulse Width Modulation (PWM). Comparative study has been made between SVM and PWM techniques. From the simulation results, SVM has reduced THD compared to pulse width modulation techniques. Thus, SVM gives better harmonic response and higher efficiency.

Keywords*:* Closed loop voltage control of Induction Motor, Pulse Width Modulation, Space Vector Modulation, Three Phase Inverter

1. INTRODUCTION

Motor drives are popularly applied in air-conditioning, fans, pumps, compressors, chillers, escalators, elevators and industrial drives. One of the common and most popular drives with real applications is the induction motor drive.

Three phase induction machine is most widely used in industry because of its simple construction, reliable operation, lightness and cheapness. The AC induction motor drive is the fastest growing segment of the motor control market.

Voltage controllers are increasingly applied as motor soft starters and sometimes as energy savers, reducing the flux level in the connected induction motor in accordance with the load. When practical SCR voltage controllers are used, they result in considerable harmonic distortion and substantial additional losses. The use of Space Vector Modulation (SVM) inverter eliminates this drawback partially.

SVM has the advantage of lower harmonics in addition to the features of complete digital implementation by a single chip microprocessor. Thus, SVM is advantageous over phase control and PWM. With the increasing availability and power capability of MOSFET's and IGBT's switches, SVM converters can efficiently and economically be used in low and medium power applications.

In an inverter, a variable voltage can be obtained by varying the gain of the inverter. This could be done by PWM control within inverter. The gating signals are generated by comparing a reference signal with a triangular carrier wave. The number of pulses per half-cycle depends on the carrier frequency. But, this PWM involves relatively high harmonic distortion in the supply.

The various formulae and the methodology involved in SVM is explained (Jin-Woo-Jung,2005).The simulation of ANN for the energy saving of a single phase Induction Motor is focused. In this various parameters from the motor are taken and are trained

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to meet the goal(Jamuna V et al.,2009).Induction motor model that is developed based on Krause's model in a step by step approach is explained. Indirect vector control is implemented. In this scheme, Space Vector Modulation is used(Leon M Tolbert and Burak Ozpineci, 2005).SVM implementation for speed control is explained(Linga Swamy R et al.,2008).

An efficient implementation scheme for the closed loop speed control of an induction motor with constant v/f control, slip regulation and SVM technique is discussed(Muhammed Safian et al.,).The neural network controlled Space Vector Modulator is discussed. The vector control was implemented and the strategy is explained (Rajesh Kumar et al.,2008).

The generalized model of three phase induction motor is explained (Shi k l et al.,1999).An overview of all PWM techniques and the comparison of various SVM techniques is focused(Trznadlowski M, Wei- Feng Zhang et al.,1996,2007). A control scheme to implement the energy-savings of three-phase induction motors when they operate under long-term light load or small duty ratio load is discussed. The proposed scheme is based on the principle of variable voltage control (VVC) at constant speed (Xue et al.,2006).

In the above literature, the voltage control scheme for three phase induction motor drive is not implemented using SVM. In this paper, the simulink model for the voltage control scheme of SVM fed induction motor is developed and the results are presented.

2. SVM INVERTER FED INDUCTION MOTOR DRIVE

SVM is quite different from PWM methods. SVM treats the inverter as a single unit; the inverter can be driven to eight unique states. The block diagram of voltage control of SVM inverter fed induction motor drive is shown in Fig.1.

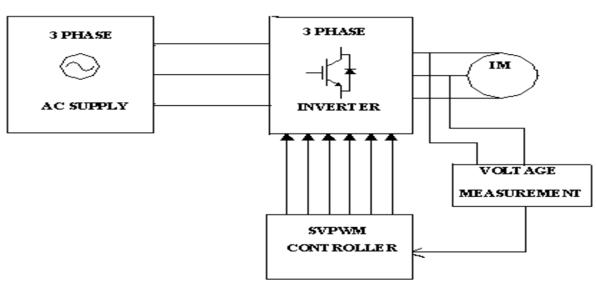


Fig.1. Block diagram of Voltage Control of SVM Inverter fed Induction Motor Drive

The three phase inverter has six power switches S_1 to S_6 and are controlled by switching variables aa', bb', cc'. When an upper transistor is switched on, i.e., when a, b or c is 1, the corresponding lower transistor is switched off, i.e., the corresponding a′, b′ or c′ is 0.Therefore, the on and off states of the upper transistors S1, S3 and S5 can be used to determine the output voltage.

The output voltage is measured and is given to the SVM controller. The control circuit regulates the output voltage.

The SVM treats the sinusoidal voltage as a constant amplitude vector rotating at constant frequency. SVPWM technique approximates the reference voltage V_{ref} by a combination of the eight switching patterns (V_0 to V_7).Three-phase voltage vector is transformed into a vector in the stationary d-q coordinate frame. The vectors (V_1 to V_6) divide the plane into six sectors (each sector: 60 degrees). V_{ref} is generated by two adjacent non-zero vectors and two zero vectors.

3. REALIZATION OF SVM

Realization of SVM involves

Step 1: Determination of V_d, V_q, V_{ref} and angle (α)

Step 2: Determination of time duration T_0, T_1 and T_2

Step 3: Determination of the switching time of each transistor

Three phase (abc) system to two phase (dq) system is obtained using Park's transformation.

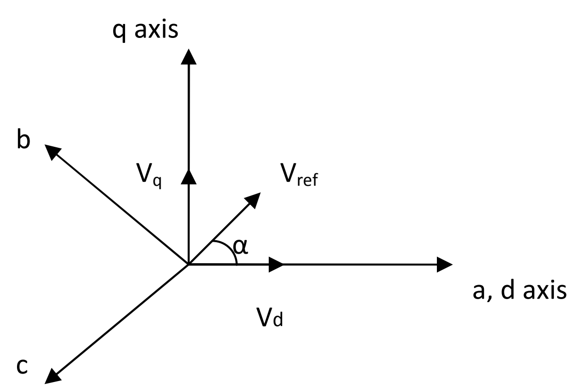


Fig.2. Voltage space vectors and its components in (d, q)

From the Fig.2,

$$V_d = V_{an} - V_{bn}.\cos60 - V_{cn}.\cos60 \quad (1)$$

$$V_q = 0 + V_{bn}.\cos30 - V_{cn}.\cos30 \quad (2)$$

The angle between V_d and V_{ref} is calculated as

$$\alpha = \tan^{-1}(v_q/v_d) \quad (3)$$

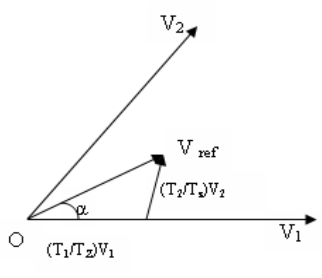


Fig.3. Reference vector as a combination of adjacent vectors at sector 1

The switching time duration at any sector can be calculated as

$$T1 = \sqrt{3}.Ts.\frac{|Vref|}{Vdc}\left(\sin\frac{n\pi}{3}\cos\alpha - \cos\frac{n\pi}{3}\sin\alpha\right) \quad (4)$$

$$T2 = \sqrt{3}.Ts.\frac{|Vref|}{Vdc}\left(-\cos\alpha\sin\frac{(n-1)\pi}{3} + \sin\alpha\cos\frac{(n-1)\pi}{3}\right) \quad (5)$$

$$T0 = Tz - (T1 + T2) \quad (6)$$

$$(where, n = 1 \; through \; 6 (that \; is, Sector \; 1 \; to \; 6)$$

$$0 \leq \alpha \leq 60^\circ)$$

The switching time calculator shown in Fig.4. is used to calculate the timing of the voltage vector applied to the motor. The block input is the sector in which the voltage vector lies, voltage magnitude and alpha. The gate logic receives the timing sequence from the switching time calculator. This block compares the triangle and the gate timing signals to generate the driving pulses to activate the inverter switches at the proper time.

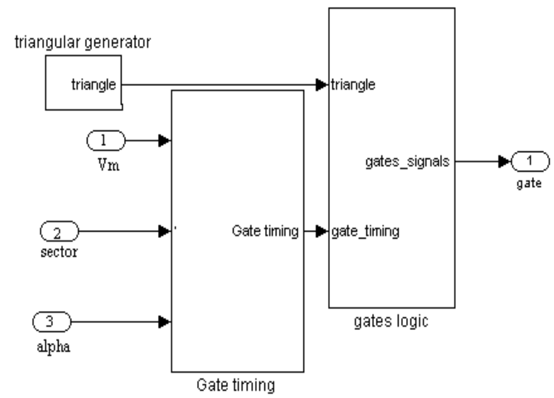


Fig.4. Switching time calculator

4. VOLTAGE CONTROL OF 3 PHASE INDUCTION MOTOR USING SVM

4.1 Open Loop

The open loop voltage control of an induction motor is shown in Fig.5. For each variation in the input voltage, the respective output voltage is measured.

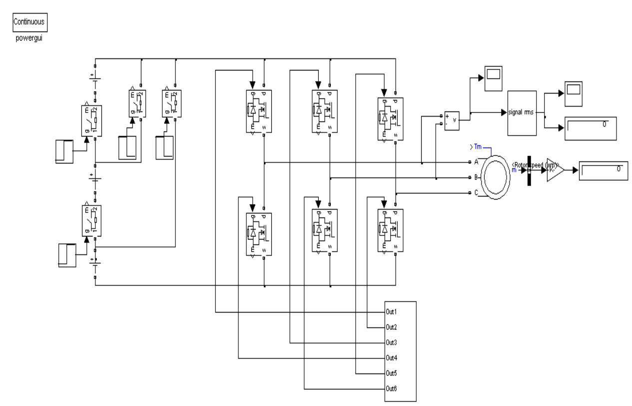


Fig.5. Open Loop Voltage Control of an Induction Motor

The performance parameters of inverters are determined using PWM and SVM techniques. The corresponding harmonic spectrums are given in Fig.6 and Fig.7.

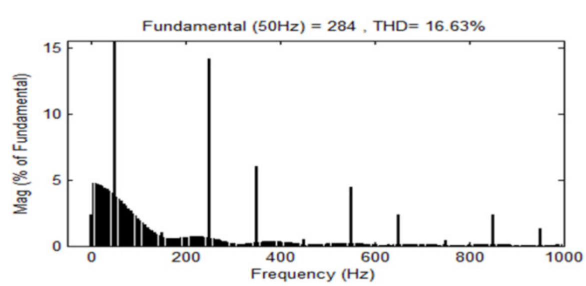


Fig.6. Harmonic Spectrum of PWM Output Voltage using Fast Fourier Technique

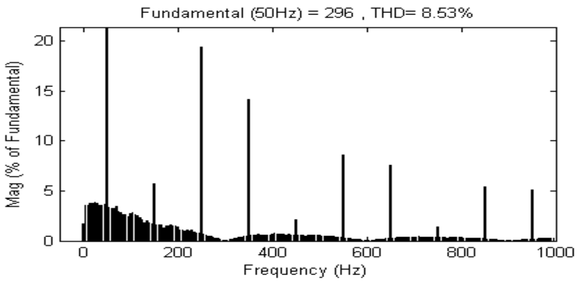


Fig.7. Harmonic Spectrum of SVM Output Voltage using Fast Fourier Technique

The comparison is made between PWM and SVM fed induction motor drive systems and is presented in Table-1.

Table 1 Comparison between PWM and SVM fed induction motor drive systems

PARAMETERS	PWM	SVM
V_{01}	284 V	296 V
THD	16.63%	8.53%

From the Table-1, it is observed that, SVM has improved fundamental voltage, lower THD.

In open loop voltage control, the voltage fluctuations are introduced through the circuit breaker as shown in Fig.5. In open loop control, the output voltage varies with the fluctuations in the input voltage and the results are shown in Fig.8.The voltage can be regulated by closed loop control.

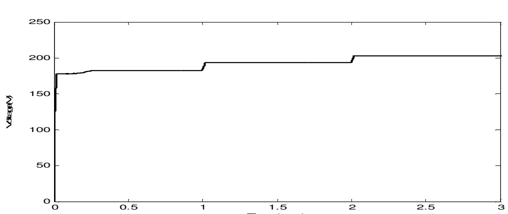


Fig.8. RMS Output Voltage of the open loop control of an Induction Motor

4.2 Closed Loop

In order to meet the requirement of constant voltage control, closed loop operation is performed for the desired value of the voltage according to the need. The closed loop voltage control of the induction motor drive system is shown in Fig.9. Here, the RMS voltage is compared with the reference voltage.

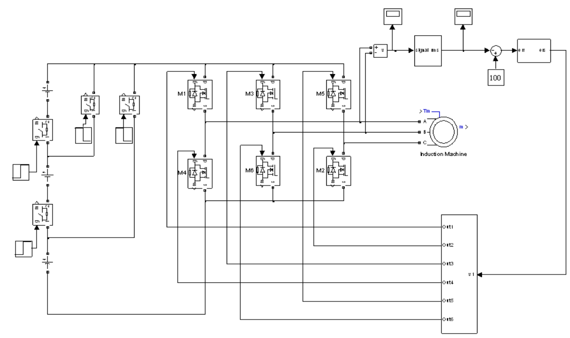


Fig.9. Closed Loop Voltage Control of an Induction Motor

The subsystem of the closed loop scheme is shown in Fig.10. The error signal is given to the PI controller. The obtained error voltage is sent to the subsystem which consists of SVM control circuit shown in Fig.10. From the error voltage signal, frequency is obtained by suitable transformation(v/f control). By using the voltage and frequency the three phase voltages are produced.

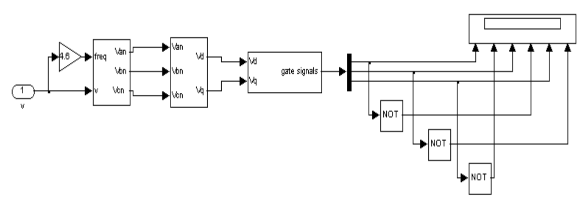
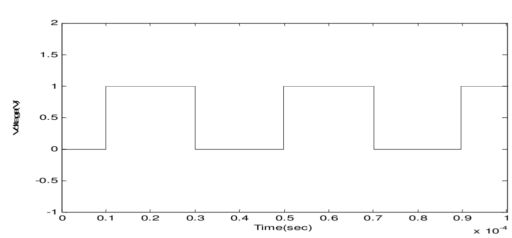


Fig.10. Subsystem of the closed loop scheme

In SVM control, three phase voltages are converted to two phase voltages. With the two phase voltages, alpha is determined. With the help of switching time calculator, the switching signals are generated for each switch and the same is shown in Fig.11, 12 and 13 and are fed to the inverter switches.

Based on the reference value, the output voltage is regulated.



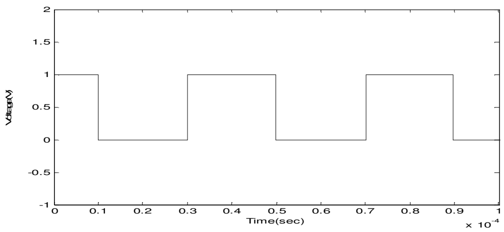


Fig.11. Gate Pulses for the first leg of Inverter (1 and 4 switch)

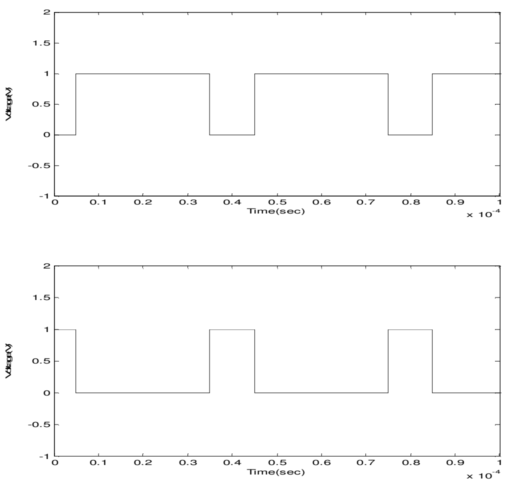


Fig.12. Gate Pulses for the second leg of Inverter (3 and 6 switch)

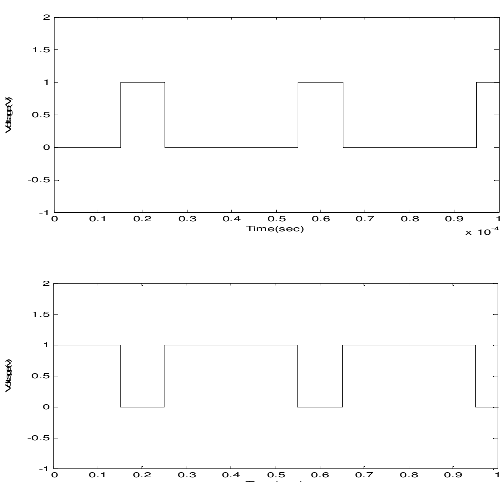


Fig.13. Gate Pulses for the third leg of Inverter (5 and 2 switch)

The RMS output voltage of the closed loop control of an induction motor is shown in Fig.14. From the figure, it is observed that the output voltage is closer to the reference value irrespective of the fluctuations in the input voltage.

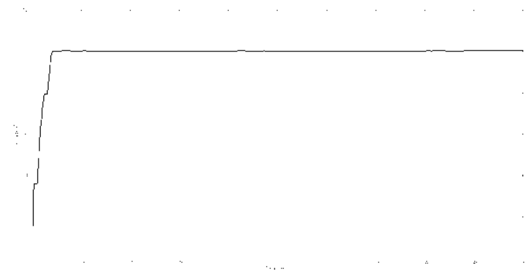


Fig.14. RMS Output Voltage of the closed loop control of an Induction Motor

A 4kW, 4 pole, three phase squirrel cage induction motor with the following parameters is used in the simulation.

R_r=0.39Ω;	R_s=0.19Ω;
L_{ls}=0.21*10^{-3}Henry;	L_{lr}=0.6*10^{-3}Henry;
L_m=4*10-3Henry;	F_b=100Hz;
J=0.4Kgm^2;	

5. RESULTS AND CONCLUSIONS

The performance parameters of PWM and SVM fed induction motor drive systems are determined. It is observed that SVM has improved fundamental component and reduced THD.

With the open loop control, the output voltage is not regulated and it varies with the fluctuations in the input voltage. By implementing the closed loop control scheme, the output voltage is regulated irrespective of the fluctuations in the input voltage.

In order to meet the constant voltage requirement, the closed loop control is proposed. With the variations in the input, the output of the inverter is regulated. With the SVM inverter fed induction motor, voltage can be effectively controlled with reduced harmonic content**.**

REFERENCES

Jin-Woo-Jung, (2005), ‘ Space Vector PWM Inverter’ Mechatronics Systems Laboratory, DECE, The Ohio State University .

Jamuna V and Rama Reddy S(2009),’ANN controlled Energy Saver for Induction Motor Drive’, Journal of Electrical Engineering, Romania, Vol 8,Edition 4, pp 70-77.

Leon M Tolbert and Burak Ozpineci(2005), 'Simulink Implementation of Induction machine model – A Modular approach'pp 728-734.

Linga Swamy.R and Satish Kumar.P (2008), 'Speed control of space vectored modulated inverter driven induction motor', proceedings of the International Multi conference of engineers and computer scientist, vol. 2.

Muhammed Safian Adeel, Tahir Izhar and Muhammed Asghar Saqib, (2009), 'An Efficient Implementation of the Space Vector Modulation based Three Phase Induction Motor Drive', 978-1-4244-4361-1-IEEE.

Rajesh Kumar, Gupta.R.A, Rajesh.S.Surjuse (2008), 'A vector controlled motor drive with neural network based space vector pulse width modulator', Journal of theoretical and applied information technology,pp 577-584.

Shi.K.L, Chan.T.F, Wong.Y.K and Ho.S.L (1999), 'Modeling and simulation of three phase induction motor using simulink', Int.J.Electrical engineering education Vol.36, pp. 163-172.

Trzynadlowski M, (1996), 'An overview of modern PWM techniques for three- phase, voltage-controlled, voltage-source inverters', in Proc. the IEEE International Symposium on Industrial Electronics, Warsaw, Poland, 1996, pp. 25-29.

Wei-Feng Zhang and Yue-Hui Yu (2007), 'Comparison of three SVPWM Strategies', Journal of electronics science and technology of China, vol.5, no.3.pp 283-287.

Xue.X.D and Cheng.K.W.E (2006), ' An Energy-saving Scheme of Variable Voltage Control for Three-Phase Induction Motor Drive Systems', 2nd International conference on power Electronics systems and applications, pp 241-243.

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