TEST Engineering & Management

January - February 2020
ISSN: 0193 - 4120 Page No. 14688 - 14694

Vector Control of Induction Motor with Variable Sampling Frequency Random PWM Techniques for Reduced Harmonic Distortion

S. Nithya Lavanya[1], T. Bramhananda Reddy[2], M. Vijay Kumar[3]

[1]Lecturer in Electrical Engineering Government Polytechnic College Tadipatri, Anantapur, AP, India
[2]Department of EEE, G.Pulla Reddy Engineering College,Kurnool, AP, India
[3]Department of EEE, JNTUA, Anantapur, AP, India
[1] snlmvs@gmail.com, [2]tbnr@rediffmail.com

Article Info
Volume 82
Page Number: 14688 - 14694
Publication Issue:
January-February 2020

Article History
Article Received: *18 May 2019*
Revised: *14 July 2019*
Accepted: *22 December 2019*
Publication: *28 February 2020*

Abstract

This paper presents random PWM (RPWM) methods for vector controlled induction motor at variable sampling rate. to improve the steady state performance, space vector PWM (SVPWM method was used for vector controlled drives. this method requires more calculations and produces higher amplitude harmonics at around switching frequency. This results in increased harmonic distortion, electromagnetic interference and acoustic noise. Hence, this paper proposes different RPWM techniques that are able to reduce the harmonics at multiples of switching frequency. to simplify the PWM approach, the proposed approach generates the modulating signals in a simple scalar method and pulses will be generated in carrier comparison approach. Moreover, in the proposed methods the carrier frequency is varied in a limited range (±500 Hz), which simplifies the filter design. The effectiveness of the proposed methods is proved with both simulation and experimental studies.

***Keywords*;** *Induction Motor, Random PWM, SVWPM, Vector control*

I. INTRODUCTION

The dynamics of induction motor are complex than that of a DC motor and hence the torque and flux cannot be controlled independently. The introdcution of vector control, which is also known as field oriented control (FOC) gave the solution for independent control of flux and torque [1]. In FOC, by regulating the stator current vector both torque and flux controlled similar to that of a separately excited DC motor. Hence, the DC motors are replaced with induction motors in many applications. The detailed review is presented by various authors on vector controlled drives. however, it requires speed sensor for the calcularion of rotor position, which increases the complexity. This leads to the introduction of sensorless vector control, in which the required parameters are pre-estimated by using the voltages and currents. In these control methods by using the concept of field orientation, torque and flux are controlled indirectly. To control flux and torque in a direct manner, later direct torque control (DTC) is presented. The comparison between FOC and DTC has been studied, which concludes that FOC gives superior steady state performance.

Though, the above said methods give good dynamic response, those result in increased harmonic distortion due to the hysteresis controllers. To reduce the harmonic distortion, various PWM techniques have been analyzed in [2] and came to conclusion that the SVPWM gives good performance with increased DC bus utilization. But, the classical approach requires angle and reference vector estimations, which increases the

January - February 2020
ISSN: 0193 - 4120 Page No. 14688 - 14694

complication. This complication can be decreased by implementing the SVPWM by using carrier comparison approach in a simple manner.

The SVPWM results increased harmonic amplitudes around multiples of switching frequency. it causes increased harmonic distoriton along with acoustic noise and electromagnetic interference. the reduction in these can be achieved by randomizing the pulse pattern, which results in spread spectra. The pulse positions can be randomized by using the RPWM techniques and the detailed survey on RPWM techniques is given in literature. Further, the performance of a RPWM based FOC is presented with a fixed sampling frequency in [3]. To achieve further reduction in harmonic amplitudes, a variable delay RPWM method is proposed for AC drives with a low computational burden. To distribute the energy associated with harmonics around switching freqeuncy, randomized carrier signals are used.

A variable switching frequency RPWM technique is proposed in [3], in which the sampligfreqency is randomized to achieve the spread spectra. based on the instanteneous current ripple two different variable swithcing frequency based RPWM techniques are presented, which gives wide spread spectra. Also, performance of different RPWM techniques is explained in detailed in [4]. This paper presents different RPWM methods for vector controlled induction motor drive at variable sampling frequency for reduced harmonic spectra and acoustic noise.

II. PROPOSED VARIABLE SWITCHING FREQUENCY RPWM TECHNIQUES

Among different PWM technqiues sinusoidal PWM (SPWM) is popular due its simpler implementation. Later, SVPWM is becoimng popular due to its advantages such as low harmonic distoriton with increased DC bus utilization. These two methods can be implemented in a simple manner using carrier comparisionappraoch. The modulating signals of SVPWM method can be derived easily by adding the suitable value of zero sequence signal to the three-phase sinusoidal signals as given in (1). The zero sequence signal can be expressed as given in (2), which is a function of V_{max} and V_{min}. Here, V_{max} and V_{min} are maximum and minimum values of instanteneous three-phase voltages. The obtained modulating signals are compared with a common triangular carrier for the generation of pulses as shown in Fig.1.

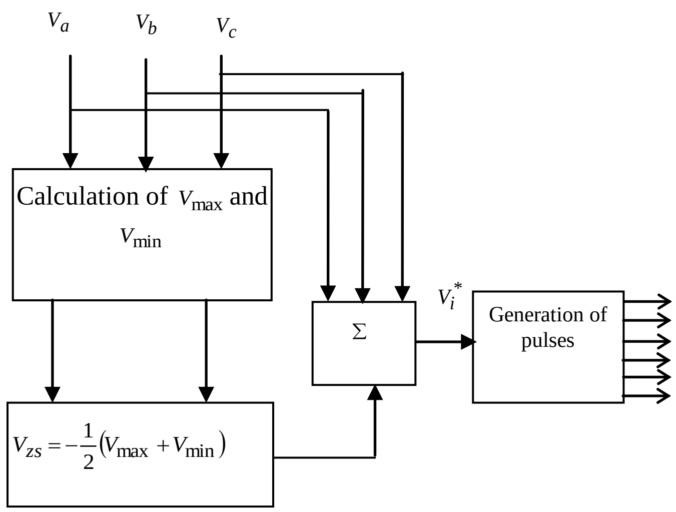


Figure 1. Block diagram of the proposed modulator

2.1 Variable Switching Frequency RPWM (VSFRPWM) Technique

This method generates a triangular carrier, whose frequency is varied over a wide range of fs±500 Hz. Here fsis switching frequency of the inverter. The block diagram of VSFRPWM is shown in Fig.2, in which random frequency generator produces a frequency of ±500 of base switching frequency (5kHz). Based on this, carrier signal generator is able to produce a triangular signal at a variable sampling rate as per random frequency generator. thus, in this approach, the modulating signals are compared with a variable frequency triangular signal for the generation of pulses to the inverter [19].

Published by: The Mattingley Publishing Co., Inc.

January - February 2020
ISSN: 0193 - 4120 Page No. 14688 - 14694

2.2 Random Carrier and Random Variable Switching Frequency PWM (RCVSFPWM) Technique

The block diagram of RCVSFPWM is shown in Fig.3. This method uses two sets of (positive and negative) variable swithcing frequency (VSF) triangular signals instead of a single VSF triangular signal. based on the output of random frequency generator, the carrier signal generator produces positive (lower in Fig.3) and negative (upper in Fig.3) triangular signals at a variable sampling rate. Then, the carrier selector selects suitable triangular signal based on the random generator. If the output of random generator is 1, then positive carrier signal will be selected and if the output of random generator is 0, then negative carrier signal will be selected. The final blended common triangular signal will be compared with three modulating signals for the generation of pulses [19].

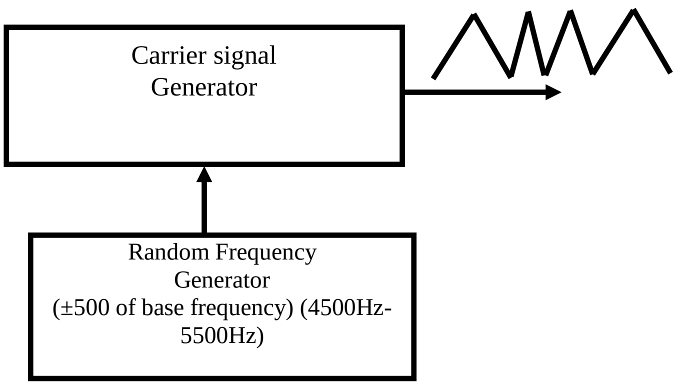


Figure 2. Block diagram of VSFRPWM scheme

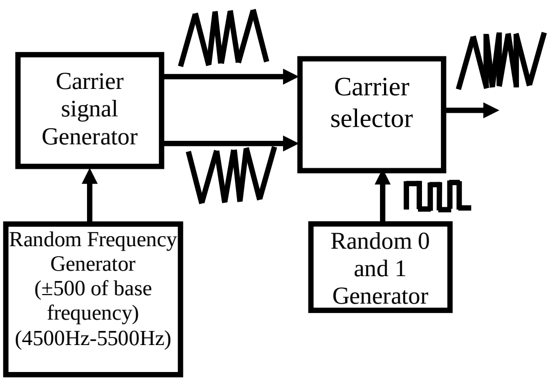


Figure 3. Block diagram of RCVSFPWM technique

RPWM Methods Based Vector Controlled Drive

The schematic diagram of proposed variable switching frequency RPWM algorithms fed vector controlled drive is shown Fig. 4. By using PI controllers, the reference d- and q-axes current signals are generated, which controls the flux and torque indirectly. These reference signals are compared with actual current signals and errors will fed to the PI controllers, which generate the two-phase voltages at synchronously rotating reference frame. Then these d-q voltages will be converted into three phase voltage signals and send to the RPWM block. This RPWM block generates thepulse pattern as explained in section.2.

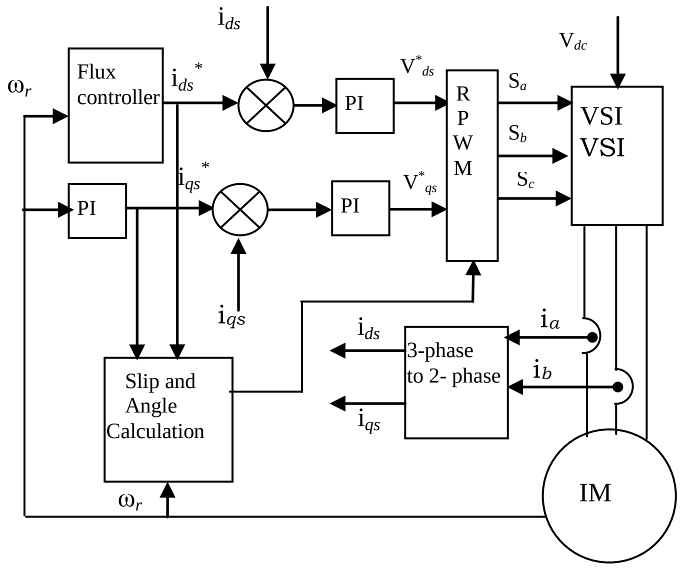


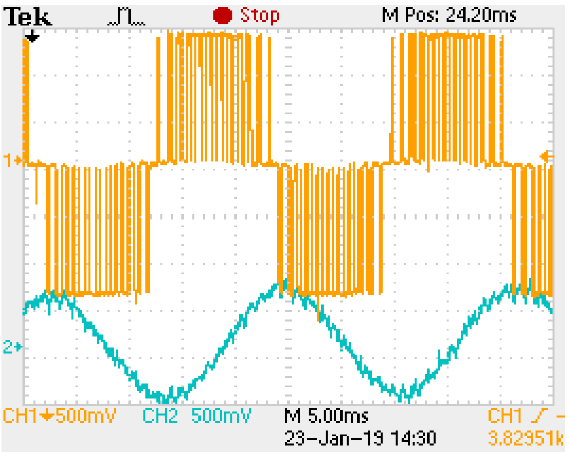
Figure 4. Block diagram of RPWM based vector controlled induction

III. RESULTS AND DISCUSSION

To test the performance of variable switching frequency random PWM techniques open loop v/f controlled experimental and closed loop vector control studies are carried. In experimental studies 9.2 kVA inverter module is connected to indction motor drive. An input voltage of 200V is applied the variable switching frequency PWM signals are generated using dSPACE control board. The frequency is varies in band of ±100Hz of 1kHz.

January - February 2020
ISSN: 0193 - 4120 Page No. 14688 - 14694

For the experimental results of line voltage and line current with PWM techniques are shown in Fig. 5 to Fig. 7. For the results it observed that the two level VSI had generated three different levels of voltage – Vdc,0,Vdc for an input voltage of Vdc with all the PWM techniques. Only change in voltage width is observed maintaining same voltage step. With the chage in frequency in a band of ±100Hz pulse position is varied hence the magnitude of harmonics at and around harmonics of switching frequencies are reduced. The magnitude of harmonics at multiples of switching frequencies are reduced by changing (increase or decrease) magnitude of harmonics around switching frequencies is observed in harmonic spectrum shown in Fig. 5 to Fig.7. As the magnitude of harmonics are reduced acoustic noice can also be reduced.



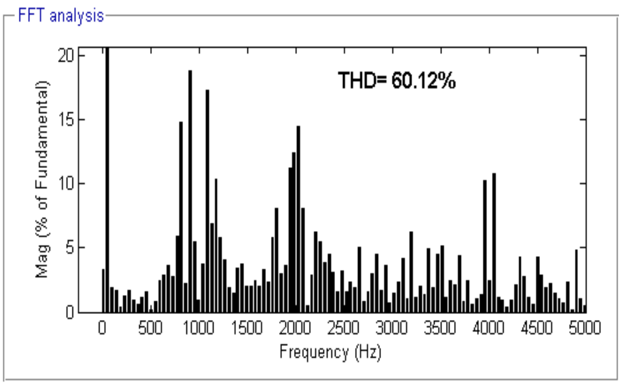
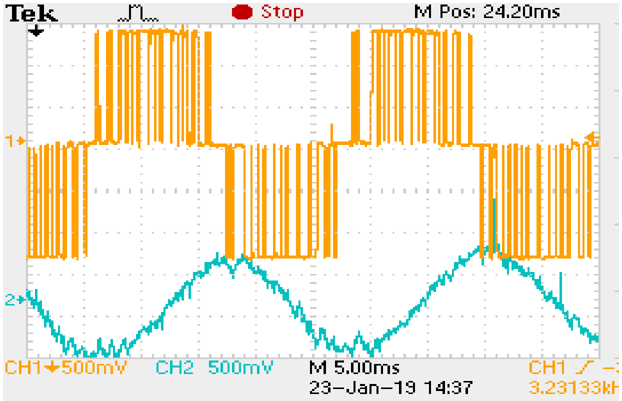


Figure 5. (a) Line voltage and line current plots (b) Harmonic spectrum of line voltage with SVPWM



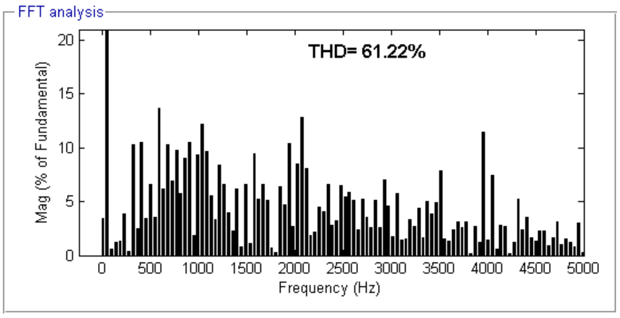
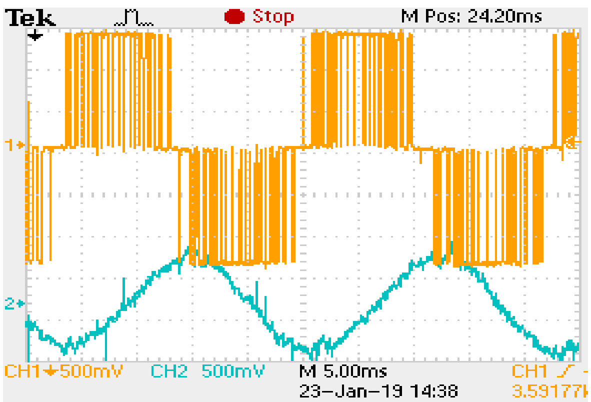


Figure 6. (a) Line voltage and line current plots (b) Harmonic spectrum of line voltage with VSFRPWM



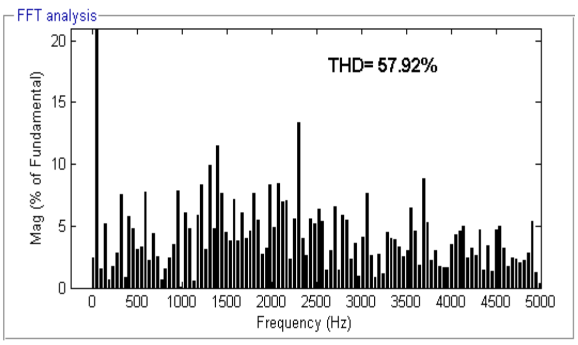
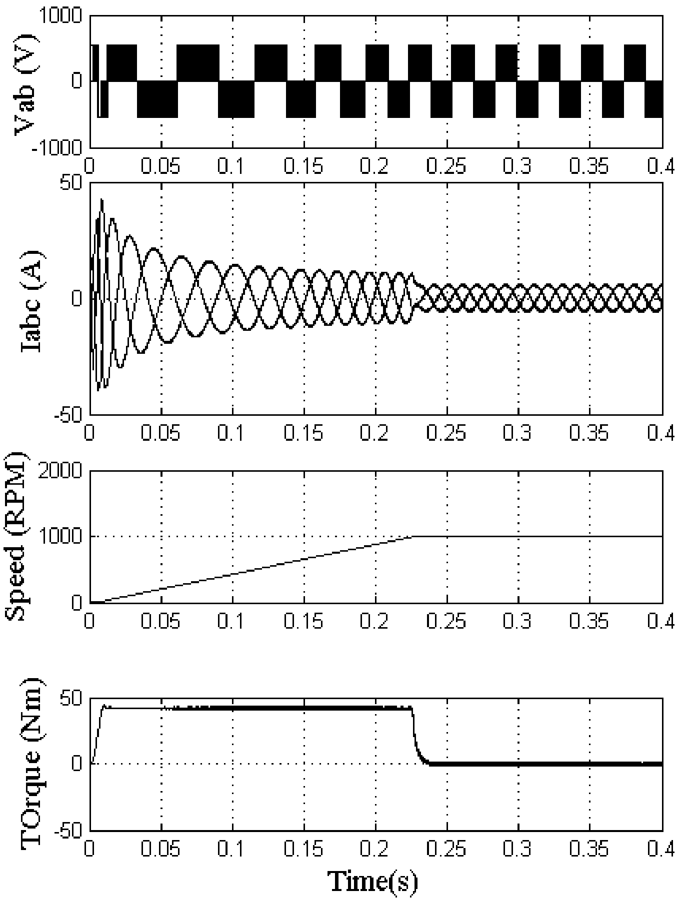


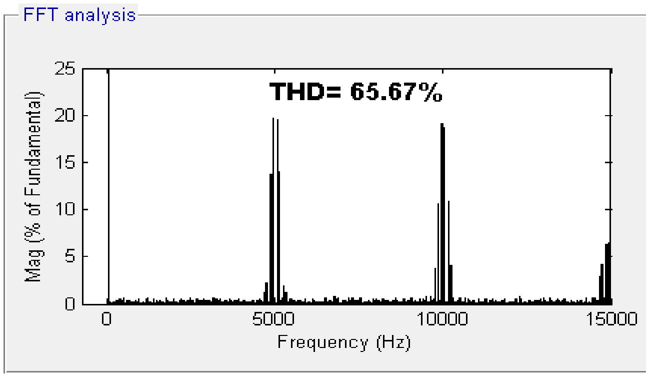
Figure 7. (a) Line voltage and line current plots (b) Harmonic spectrum of line voltage with RCVSFPWM

Published by: The Mattingley Publishing Co., Inc.

January - February 2020
ISSN: 0193 - 4120 Page No. 14688 - 14694

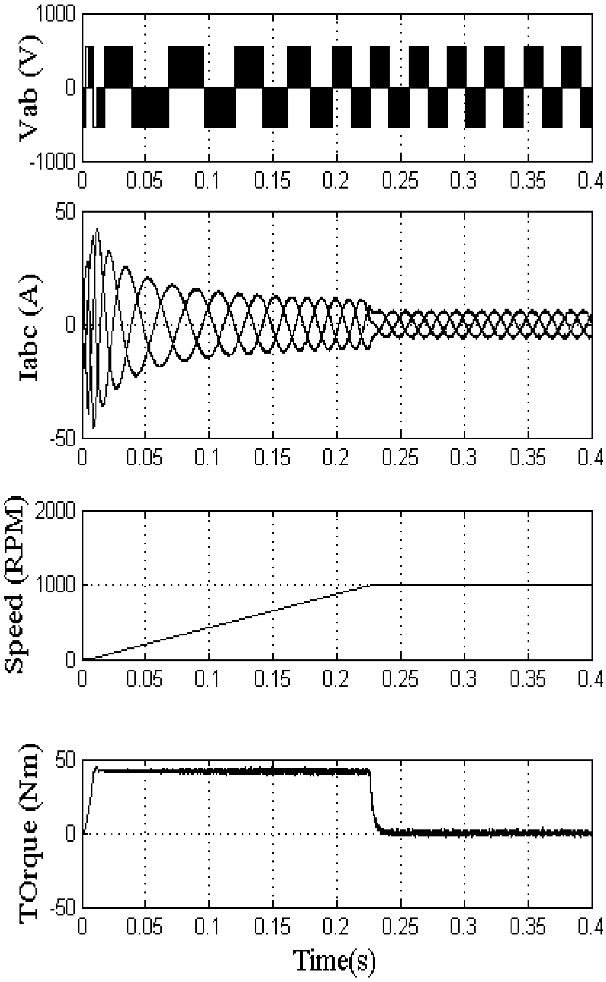


(a)

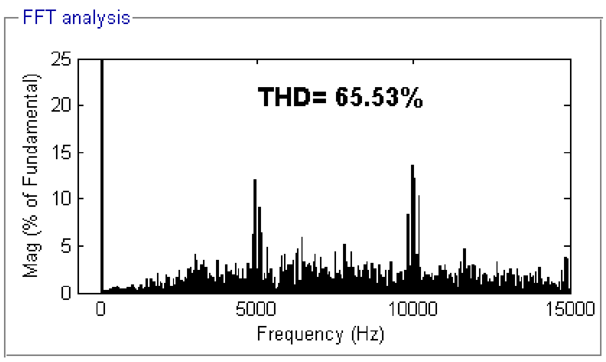


(b)

Figure 8. (a) Starting Transient and steady state results of vector controlled induction motor drive line voltage, three phase currents, speed and torque (b) Harmonic spectrum of line voltage with SVPWM



(a)

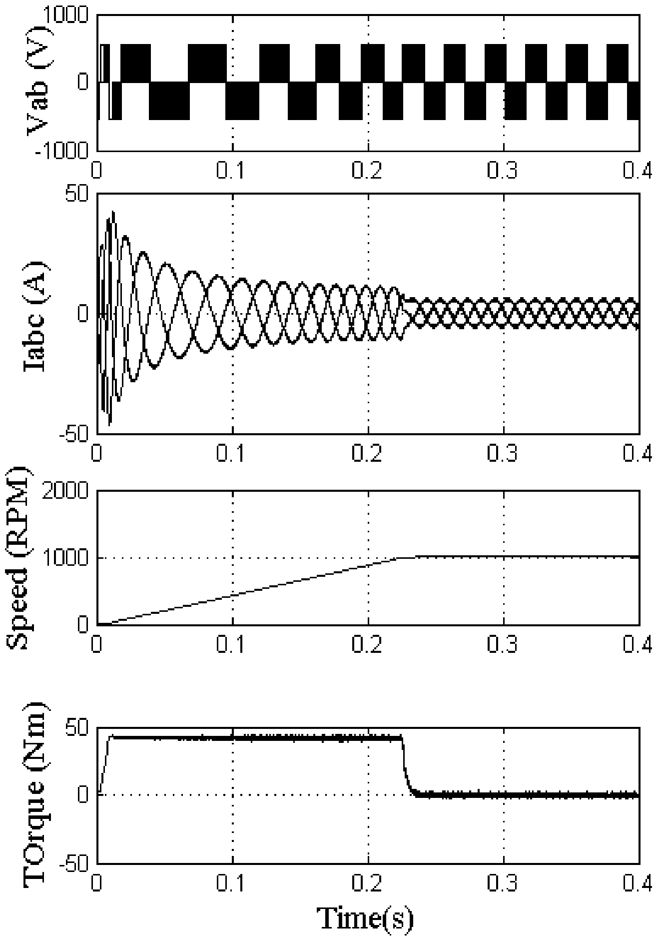


(b)

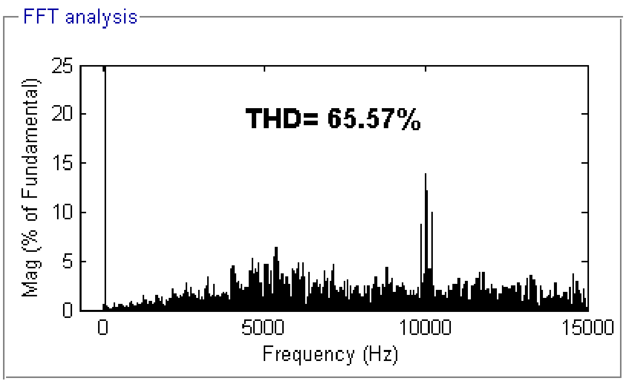
Figure 9. (a) Starting Transient and steady state results of vector controlled induction motor drive line voltage, three phase currents, speed and torque (b) Harmonic spectrum of line voltage with VSFRPWM

Published by: The Mattingley Publishing Co., Inc.

January - February 2020
ISSN: 0193 - 4120 Page No. 14688 - 14694



(a)



(b)

Figure 10. (a) Starting Transient and steady state results of vector controlled induction motor drive line voltage, three phase currents, speed and torque (b) Harmonic spectrum of line voltage with RCVSFPWM

The result analysis of variable switching frequency random PWM techniques for vector controlled induction motor drives are shown in Fig. 8 to Fig.10. For the simulation analysis an input voltage of 540V is applied. The PWM signals are applied at a switching frequency of 5kHz with variation in frequency band of ±500. The parameters used for induction motor are R_s=1.57Ω, R_r =1.21Ω, L_s=0.17H, L_r=0.17H, L_m =0.165 H and J = 0.089 Kg.m^2. Because of decoupled control the drive has high starting torque which lead to fast stating transients. The starting transients and steady analysis of drive with the variable switching frequency random PWM techniques are shown Fig. 8 to Fig.10. For the harmonic spectrum of line voltages it is observed that all the PWM techniques generate of voltage step of -540,0,+540. Hence there is only small difference in THD. But the magnitude of harmonics at and around switching frequencies are reduced with both VSPWM and RCPWM techniques when compared with SVPWM techniques. As the switching frequency is varied in a band of ±500 Hz filter design also becomes eashier. Hence the acoustic noise can be reduced.

IV. CONSLUSIONS

The anslysis and implementation of variable switching frequency random PWM techniques for open loop and closed loop drive are presend. From the results it is concluded that magntitude of harmonics at and around harmonics of switching frequencies are reduced. As the switching frequency is varied in a band of ±500 Hz the fileter design also becomes easier. Moreover the implementation of these PWM techniques are presented in an simplified manner with less number of computations.

REFERENCES

[1] F. Blaschke “The principle of field orientation as applied to the new transvector closed loop control system for rotating-field machines," Siemens Review, 1972, pp 217-223.

[2] Edison Roberto C.Da Silva, Euzeli Cipriano Dos Santos, Jr., and Cursino Brandao Jacobina,

Published by: The Mattingley Publishing Co., Inc.

"Pulse width modulation strategies" IEEE IE Magazine, pp. 37-45, 2011.

[3] Dong Jiang, and Fei (Fred) Wang, "Variable Switching Frequency PWM for Three-Phase converters based on current ripple prediction" IEEE trans. on Power Electron., vol. 28, NO. 11, Nov, 2013, pp 4951-4961.

[4] S. NithyaLavanya, T.Bramhananda Reddy, M.Vijay kumar, "Performance of Random PWM Techniques for Induction Motor Drive" International Journal of Engineering and Advanced Technology, vol. 8, issue-2S2, January 2019, pp. 133-139.