International Journal of Engineering &Technology, *7 (4.24) (2018) 42-45*

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Power Spectral Density Estimation and THD of Motor Line Currents of AZSPWM Based DTC of Induction Motor Drive

V. Anantha Lakshmi[1], Satheesh.G[1*], T. Bramhananda Reddy[1]
irst Author[1]*, Second Author[2], Third Author[3]

[1]Department of EEE, G.Pulla Reddy Engineering college, Kurnool
**Corresponding author E-mail:gsatish.eee@gmail.com*

Abstract

Estimating the power distribution over a given frequency range and the total harmonic distortion of the line currents of the AZSPWM based induction motor drive is discussed in this paper. Applying a spectrum analysis on the motor line currents and inspecting the spectrum amplitudes at different switching frequencies for abnormality is a well-known procedure for acoustic noise detection and diagnosis. Among the spectrum analysis techniques for acoustic noise detection, the Fast Fourier Transform (FFT) is the most widely used technique. There are other spectrum techniques, which are based on the power spectral density (PSD) estimates. AZSPWM based DTC of induction motor currents are estimated for the power spectral densities. The harmonic spectra and the power spectral density estimates of all AZSPWM family are validated through the MATLAB/ simulink environment.

Keywords: *AZSPWM, DTC, FFT, Harmonic spectra, Induction motor drives, PSD*

1. Introduction

With the increment of the usage of the fast switching semiconductor devices like IGBT, result in the form of unexpected problems like bearing currents and acoustic noise increment etc.,[1]. Many techniques were presented in [2-4] for the reduction of bearing current acoustic noise and various active filters. But these were resulted in increasing the size and cost of the system. The Conventional DTC is affected with the large amount of ripple in motor current, flux and torque of the induction motor [5-7]. To reduce these affects a space vector PWM technique has been proposed but again it is resulted in the increment of the common mode voltage (CMV) [8-9]. Further Active Zero State PWM (AZSPWM) techniques are proposed for the compensation of the CMV [10]. These CMV leads to different problems in the induction motor drives. These effects are analyzed by using the power spectra and harmonic spectra of the current waveform.

In this paper, three AZSPWM sequences [11-12] 6213, 2215 and 3216 are used for the analysis of the power spectra and harmonic spectra of the DTC of the induction motor drive. In power spectra analysis the magnitudes of the power accumulated at different frequencies and in the harmonic spectra the side band magnitudes at different switching frequencies are considered for the analysis.

2. AZSPWM Sequences

In this approach, different AZPWM sequences [11-12] are considered in which the actual times are calculated using imaginary switching times concept, hence the complexity involved in SVPWM can be eliminated. From Table-I in sector-I, consider AZPWM1, AZPWM3 sequence, two active opposite voltage vectorsV3 - V6 are used with the two adjacent voltage vectorsV1- V2 to compose the reference voltage vector. Similarly in case of AZPWM2 two active opposite voltage vectorsV2 - V5 are used with the two adjacent voltage vectors V1 - V2 to compose the reference voltage vector. From the table it can be observed that in sector-I, AZPWM1 method involves 600 jump in the output voltage vectors during commutation from adjacent active voltage vectors (V1, V2) to the active opposite voltage vectors (V3.V6), whereas AZPWM3 method involves 1200 jumps in the output voltage vectors during commutation from adjacent active vectors to the active opposite voltage vectorsV3 and V6 acting as zero vectors. With the usage of active voltage vectors CMV changes which result in the power and harmonic spectra of the drive.

3. DTC of Induction Motor Drive

The block diagram of AZSPWM based DTC is shown in Fig.1. As in the conventional DTC drive the reference angle and magnitude of the flux linkage value are derived from the values of d-axis and q-axis stator fluxes are compared with actual values of fluxes which are obtained from adaptive motor model and an error in flux is obtained which when divided by the sampling Time period gives a reference voltage vector used for direct control of torque and flux. The errors are given as follows:

$$\Delta\lambda_{ds} = \lambda_{ds}^{*} - \lambda_{ds} \tag{1}$$

and $$\Delta\lambda_{qs} = \lambda_{qs}^{*} - \lambda_{qs} \tag{2}$$

The reference voltage vectors can be obtained as follows

$$V^*_{ds} = R_s i_{ds} + \frac{\Delta\lambda_{ds}}{T_s} \quad (3)$$

and

$$V^*_{qs} = R_s i_{qs} + \frac{\Delta\lambda_{qs}}{T_s} \quad (4)$$

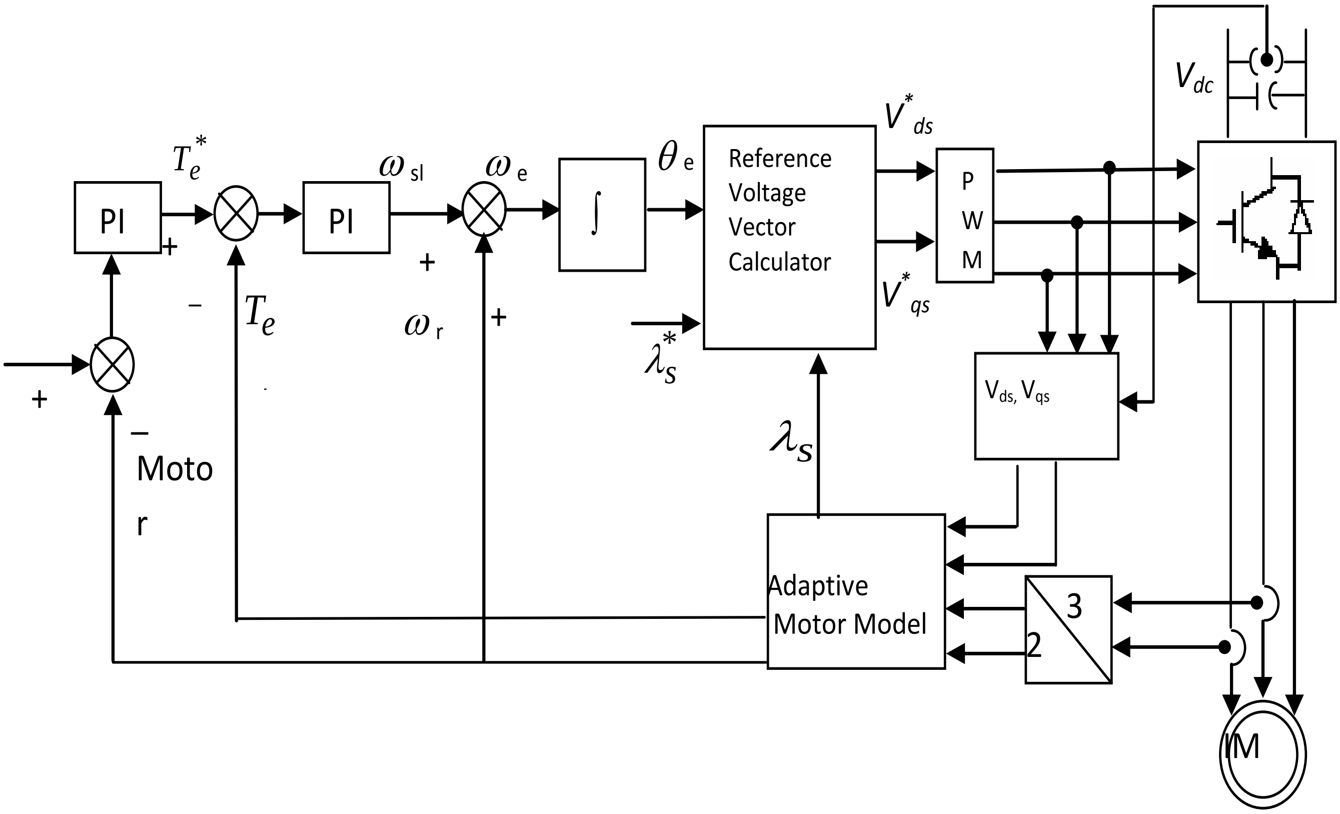

Fig. 1: Block diagram of AZSPWM based DTC of IM drive.

Table I: Switching sequences of PWM algorithms

PWM METHOD	S-I	S-II	S-III	S-IV	S-V	S-VI
AZPWM3	6213-3126	4231-1324	2435-5342	6453-3546	4651-1564	2615-5162
AZPWM2	2215-5122	6233-3326	4431-1344	2455-5542	6653-3566	4611-1164
AZPWM1	3216-6123	1234-4321	5432-2345	3456-6543	1654-561	5612-2165

These Vds and Vqs are further fed to the PWM generation block to generate the individual phase switching pulses. At first these Vds and Vqs are converted in to Vas, Vbs and Vcs larter from these instantaneous references the individual phase switching pulses are obtained. These individual phase switching pulses are then fed to the inverter which drives motor.

4. Results and discussion

The parameters of the given induction motor are as follows: R_s=1.57ohm, R_r=1.21ohm, L_m= 0.165H, L_s= 0.17H, L_r= 0.17 H and J= 0.089 Kg - m^2. To validate the proposed PWM algorithms, numerical simulation studies have been carried out by using Matlab /Simulink. For the simulation, the reference flux is taken as 1wb and starting torque is limited to 45 N-m. For the simulation studies, a 3-phase, 400V, 4 kW, 4-pole, 50 Hz, 1470 rpm induction motor has considered. The performance of the induction motor drive with three different sequences of the AZSPWM is shown in Fig.2 to 11. In the Fig.2 to 4 the current ripple for the three sequences are shown. These ripple are obtained during the steady state operation of the drive. For the sequence 6213 the current ripple is having the magnitude about ±1A, but the variation in the current ripple is less than ±0.8A for the sequence 2215 and it is quite less for the sequence 3216. Also from the results it is observed that ripple in the current waveform for the sequence 6213 is low.

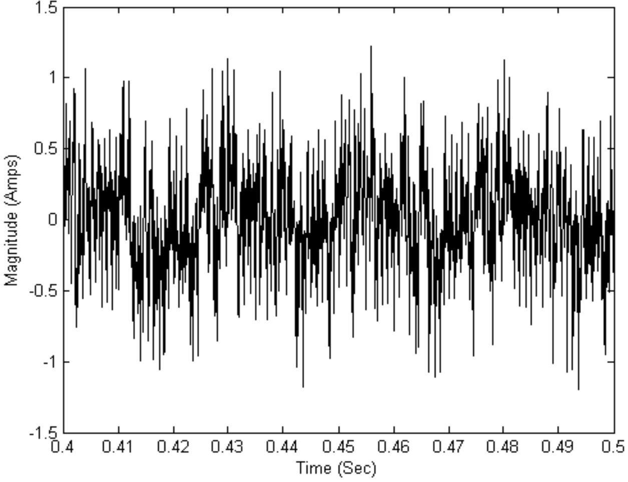

Fig. 2: Motor line current ripple for AZSPWM 6213 sequence

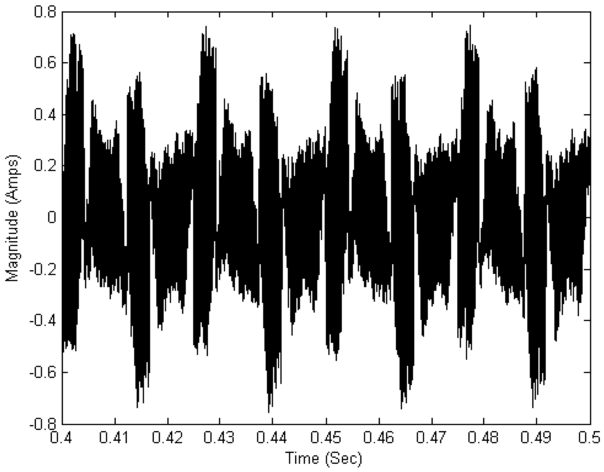

Fig. 3: Motor line current ripple for AZSPWM 2215 sequence

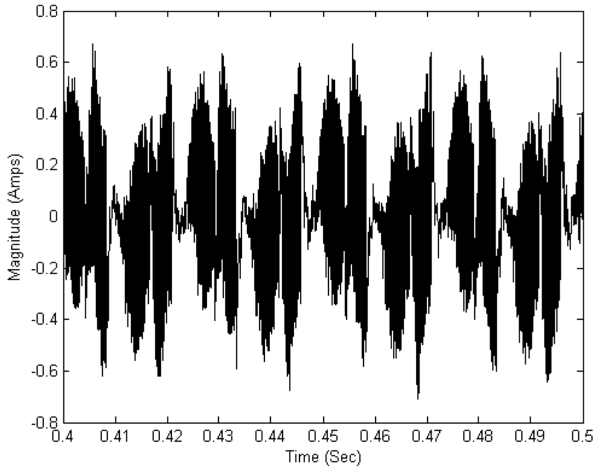

Fig. 4: Motor line current ripple for AZSPWM 3216 sequence

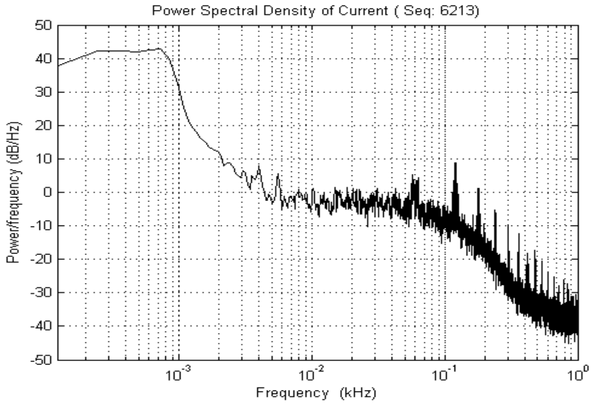

Fig. 5: Motor line current Power spectra for AZSPWM 6213 sequence

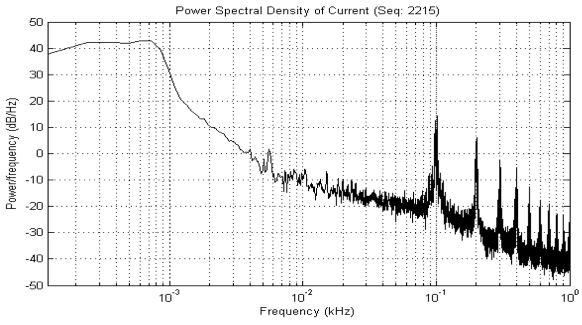

Fig.6: Motor line current Power spectra for AZSPWM 2215 sequence

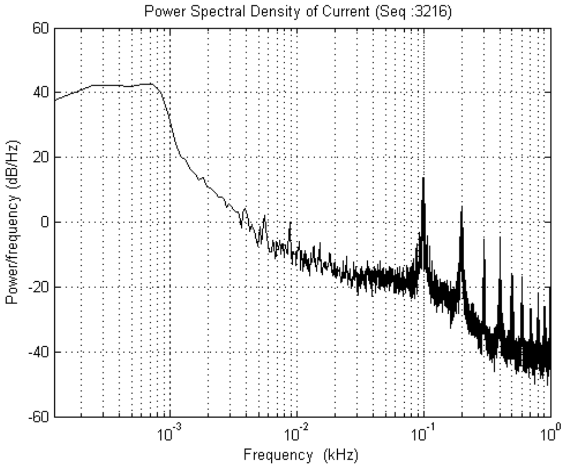

Fig.7: Motor line current Power spectra for AZSPWM 3216 sequence

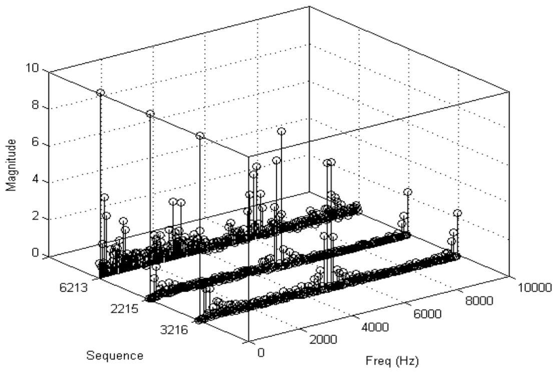

Fig.8: Total Harmonic spectra of the three AZSPWM sequences.

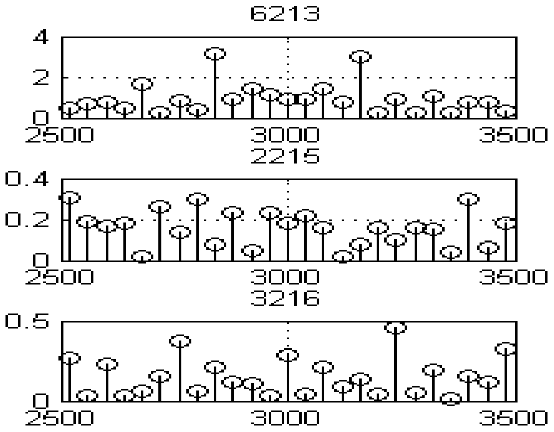

Fig.9. Harmonic spectra of the three AZSPWM methods with switching frequency 3 kHz

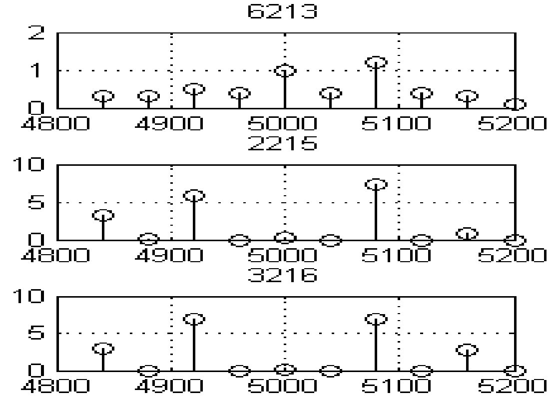

Fig.10: Harmonic spectra of the three AZSPWM methods with switching frequency 5 kHz

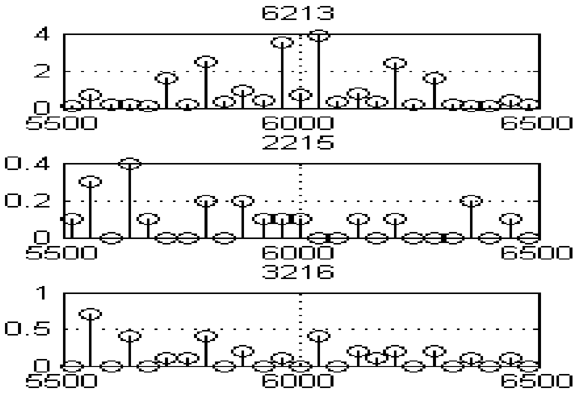

Fig.11: Harmonic spectra of the three AZSPWM methods with switching frequency 6 kHz

The power spectral density for three sequences is shown in fig. 5 to 6. The magnitudes of the power accumulated at the switching frequency 0.1kHz is positive but in 6213 sequence this values is less than +10 dB/Hz. Where as in other two sequences the magnitudes are more than +10 dB/Hz. Also it can seen that the remaining peaks at different switching frequencies are quite high when compare with the 6213 sequence.

The total harmonic distortion of the motor line currents for the three sequences is shown in Fig.8. The THD is plotted for the three sequences from 0 Hz to 10000 Hz switching operations. The magnitudes of the harmonic content at different frequencies are shown. It is observed that the magnitudes of the harmonics are very less comparatively from the fundamental component. Later, at the inverter switching frequency that is around 6 kHz the magnitudes of the harmonic component is considerably high.

Further, to analyze the harmonic magnitudes at different frequencies the harmonic spectra of the motor line currents of three switching sequences is shown in Fig.9 to 11. In fig.9 the harmonic spectra of the line currents at 3kHz switching frequency is depicted. The top trace shows the harmonic spectra of the line current of the induction motor for the sequence 6213, middle trace shows the harmonic spectra of the line current of the induction motor for the sequence 2215 and bottom trace shows the harmonic spectra of the line current of the induction motor for the sequence 3216 respectively. The magnitude of the harmonic at 3kHz is considerably low in the sequences 2215 and 3216. But with the switching frequency of 5kHz the magnitudes are almost zero for the sequences 2215 and 3216, but it is quite high in case of 6213. In Fig. 11 the harmonic spectra of the line current of the induction motor is depicted for 6 kHz switching operation. At this switching operation the magnitude is quite low in all the sequences and it is noticed that the side bands of the frequency($fs\pm 1$) for the 6213 sequence is quite high.

5. Conclusion

In this paper, AZSPWM based DTC of induction motor drive is presented. The three sequences of the AZSPWM algorithm are analyzed with PSD and THD of the motor line currents with different frequencies. The power spectra of the motor line currents for the sequences 2215 and 3216 is considerably high. But the harmonic spectra of the 6213 sequence shows low In harmonic spectra of the motor line currents the magnitude of the harmonics at the switching frequency is considerably high in case of 6213 sequence. But the remaining two sequences shows as low magnitude at the same switching frequency. All the three sequences are showing same effectiveness on the induction motor drive application. To analyze further these sequence results are to be compared with the conventional SVPWM and hybrid PWM algorithms.

References

[1] Erdman, R.J.Kerkman, D.W.Schlegel, and G. L. Skibinski,: “Effect of PWM inverters on AC motor bearing currents and shaft voltages”, In: IEEE Trans. Ind. Applicat., vol. 32,Mar/Apr. 1996,pp,250-259. M.M.Swamy, K.Yamada, and T.Kume,: “Common mode current attenuation techniques for use with PWM drives,” In: IEEE Trans. Power Electron., vol. 16, no.2,pp. 248-255,Mar. 2001.

[2] Satoshi Ogasawara, Hirofumi Akagi ,: “Suppression of Common-mode Voltage in a PWM Rectifier/Inverter System”,In: IEEE Trans, Ind. Applicat. ,vol. 3, pp. 2015-2021,Sep.-Oct 2001.

[3] Yaxiu Sun, Abdolreza Esmaeli ,: Li Sun, Erliang Kang“Investigation and Suppression of Conducted EMI and Shaft Voltage in Induction Motor Drive System”, In: IEEE Trans, on Int. Con. & Aut. , Jun 21- 23, 2006

[4] Domenico Casadei, Francesco Profumo, Giovanni Serra, and Angelo Tani,: “FOC and DTC: Two Viable Schemes for Induction Motors Torque Control”, In: IEEE Trans. Power Electron., vol. 17, no.5, Sep, 2002, pp. 779-787.

[5] Isao Takahashi and Toshihiko Noguchi,: “A new quick-response and high-efficiency control strategy of an induction motor,” In: IEEE Trans.Ind. Applicat., vol. IA-22, no.5, Sep/Oct 1986, pp. 820-827.

[6] Marcello Pucci, Gianpaolo Vitale and Giansalvo Cirrincione,: “A new direct torque control strategy for the minimization of common-mode emissions”,In: IEEE Trans. Ind. Appl.,vol.4, no.2,Mar/Apr, 2006.

[7] Thomas G. Habetler, Francesco Profumo Michele Pastorelli and Leon M. Tolbert ,: “Direct Torque Control of Induction Machines Using Space Vector Modulation”, In: IEEE Trans. Ind. Appl., Vol. 28, No.5, pp. 1045-1053, Sep/Oct, 1992.

[8] Heinz Willi Van Der Broeck, Hans-Christoph Skudelny, Member, IEEE, and Georg Viktor Stanke ,: “ Analysis and Realization of a Pulsewidth Modulator Based on Voltage Space Vectors” In: IEEE Trans. Ind. Appl.,vol.24, no.1,Jan/Feb, 1998.

[9] Ahmet M.Hava and Emre Un,: “Performance Analysis of Reduced Common-Mode Voltage PWM Methods and Comparison With Standard PWM Methods for Three-Phase Voltage-Source Inverters” In: IEEE Trans. Power Electron., vol. 24, no.1, Jan, 2009, pp. 241-252.

[10] Anantha Lakshmi, V. C. Veera Reddy, M. Suryakalvathi, “Space Vector Based Hybrid Pwm Algorithm For Direct Torque Controlled Induction Motor Drives Forreduced Common Mode Voltage”, Jee Trans, Vol. 12, Ed.3, 2012, Pp: 65-72.

[11] V. Anantha Lakshmi, Satheesh.G, T. Bramhananda Reddy, M. Nayeemuddin, “ SVPWM based algorithms for reduction of common mode voltage in induction motor drives”, IJAER, Vol. 12, No. 1, Aug 2017, pp:665-670.