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Performance Analysis of Different Control Methods of Z-Source Inverter Feeding Industrial Drives

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Abstract — ***Industrial drives are simultaneously the major causers and the major victims of power quality problems. This paper basically deals with the problems caused by these industrial drives such as Field Orientation Control (FOC) induction motor drive and Direct Torque Control (DTC) induction motor drive. Further, the performance of different control methods or strategies of Z- source inverter feeding these industrial drives has been investigated. The results obtained are then compared with those obtained for the conventional inverter feeding the same loads. The test systems have been modeled and simulated in MATLAB/SIMULINK. The results obtained after carrying out these simulations have been used to draw the conclusions.***

Keywords- Direct torque control (DTC), Field orientation control (FOC), Total harmonic distortion (THD), Z-source inverter (ZSI)

I. INTRODUCTION

Power Quality (PQ) related issues are of most concern nowadays. The widespread use of electronic equipment, such as information technology equipment, power electronics based devices [1], [5-6], [9] such as adjustable speed drives (ASD), induction motor drives, programmable logic controllers (PLC), energy-efficient lighting, led to a complete change of electric loads nature. These loads are simultaneously the major causers and the major victims of power quality problems. Industrial environments depend on electronic equipment to succeed in today's highly competitive, efficiency-driven business world. Computers, drives, motion controllers and sensors have become essential for optimal productivity, consistency and quality. However, these sensitive components require clean and stable electrical quality to perform properly. Power quality issues, such as voltage fluctuations, harmonic distortion, noise and power outages, disrupt production and damage equipments. Induction machines have been widely used in industries because of their advantages: simple construction, ruggedness, low cost, reliability, and a minimum of maintenance. However due to their highly coupled non linear high performance control of Induction Motor is a problem. With the new technological developments in the field of power electronics a variable induction motor drives have evolved as a new technology in the last decades. These drives in which dc to ac inverters have used to drive induction motors as variable frequency three- phase voltage or current source has been used in wide industrial applications.

Nomenclature—

i_{ds}, i_{qs} - direct and quadrature axis components of stator current, (A)

V_{ds}, V_{qs} - direct and quadrature axis components of stator voltage, (V)

φ_s, φ_r - stator and rotor flux, (Wb)

R_S,R_S - stator and rotor resistance, (Ohm)

L_S,L_r - stator and rotor leakage reactance, (H)

M - mutual inductance

T_s,T_r- stator and rotor time constant

p - pole pair numbers

σ - leakage factor

ω_r - slip frequency, (rad./s)

T - electromagnetic torque, (Nm)

II. INDUSTRIAL DRIVES

Industrial drives are causes as well as victims of power quality problem. But this paper presents the problem caused by these industrial drives [4] such as Field Orientation Control (FOC) induction motor drive and Direct Torque Control (DTC) induction motor drive.These induction motor drives are commonly used in modern day industry as loads. These loads being non-linear in nature are responsible for the increased total harmonic distortion levels in voltages and currents, noises which ultimately affect the power quality. The mathematical models of the above-mentioned industrial drives have been presented in the subsequent sub-sections.

A. Field Orientation Control

The block diagram field oriented control (FOC) induction motor drive is shown in Figure 1. The FOC drive seems to have similar performance as of DC machine over a wide range of speed and load conditions, but the performance of a FOC implementation depends critically on a very accurate coordinate transformations and flux angle estimation, which are complicated and depends on the variation of machine parameters. Various efforts have been made to improve the control of induction motor so that it could have fast response and its complexity could be reduced.

The concept of field oriented control was proposed by Blaschke in 1972. Since then, it has been the widely popular control method for induction motor drives. This technique has allowed independent control of the torque and flux of the dynamic machine. This could be done by direct or indirect flux orientation. In the direct field oriented control (DFOC), both the instantaneous magnitude and position of the rotor flux are supposed to be directly measured [2]. The condition for flux orientation is $\varphi_{qr} = 0$. So, the FOC performance equations become

$$\varphi_r = \varphi_{dr} \tag{1}$$

$$\mathrm{T} = p\frac{M}{L_r}\varphi_r \tag{2}$$

$$\varphi_r = \frac{M}{1+sT_r} i_{ds} \tag{3}$$

(4)

$$\omega_r = \omega_{s-}\omega = \frac{M}{T_r}\frac{i_{qs}}{\varphi_r} \tag{5}$$

$$V_{ds}{}^{*} = \sigma L_{S}\frac{di_{ds}}{dt} + R_s i_{ds} - \sigma L_S \omega_s i_{qs} + \frac{M}{L_r}\frac{d\varphi_r}{dt}$$

$$V_{qs}{}^{*} = \sigma L_{S}\frac{di_{qs}}{dt} + R_s i_{qs} - \sigma L_S \omega_s i_{ds} + \frac{M}{L_r}\omega_s\varphi_r \tag{6}$$

Where

$$T_r = \frac{L_r}{R_r} \text{and} \sigma = 1 - \frac{M^2}{L_r L_s} \tag{7}$$

B. Direct Torque Control

Direct Torque Control [4], [10] is one of the methods for controlling the induction motor torque and its speed also it is a standard industrial method used by industries nowadays.Its block diagram is shown in Figure 2. The main feature of DTC is that position of inverter switches are determined directly thus refrained from using any modulation techniques like pulse width modulation (PWM), space vector modulation (SVM). The control objective is to keep motor's torque and stator flux within pre specified limits. The inverter is triggered by hysteresis controllers to switch whenever these bounds are violated. The choice of the new switch has made using a pre designed look up table that has been designed using a geometric insight in the problem and additional heuristics.

The other main features of DTC induction motor drive are:

1. Decoupled control of torque and flux
2. Absence of mechanical transducers
3. Current regulator, PWM pulse generation, PI control of flux and torque co-ordinate are not required
4. Very simple control scheme and low computational time
5. Reduced parameter sensitivity

The direct torque control (DTC) has the advantage of fast dynamic torque response and has good robustness to the changes of rotor parameters etc. But the torque ripple is an inadequacy of the system. The pulsation becomes more apparent especially in the low-speed operating conditions.

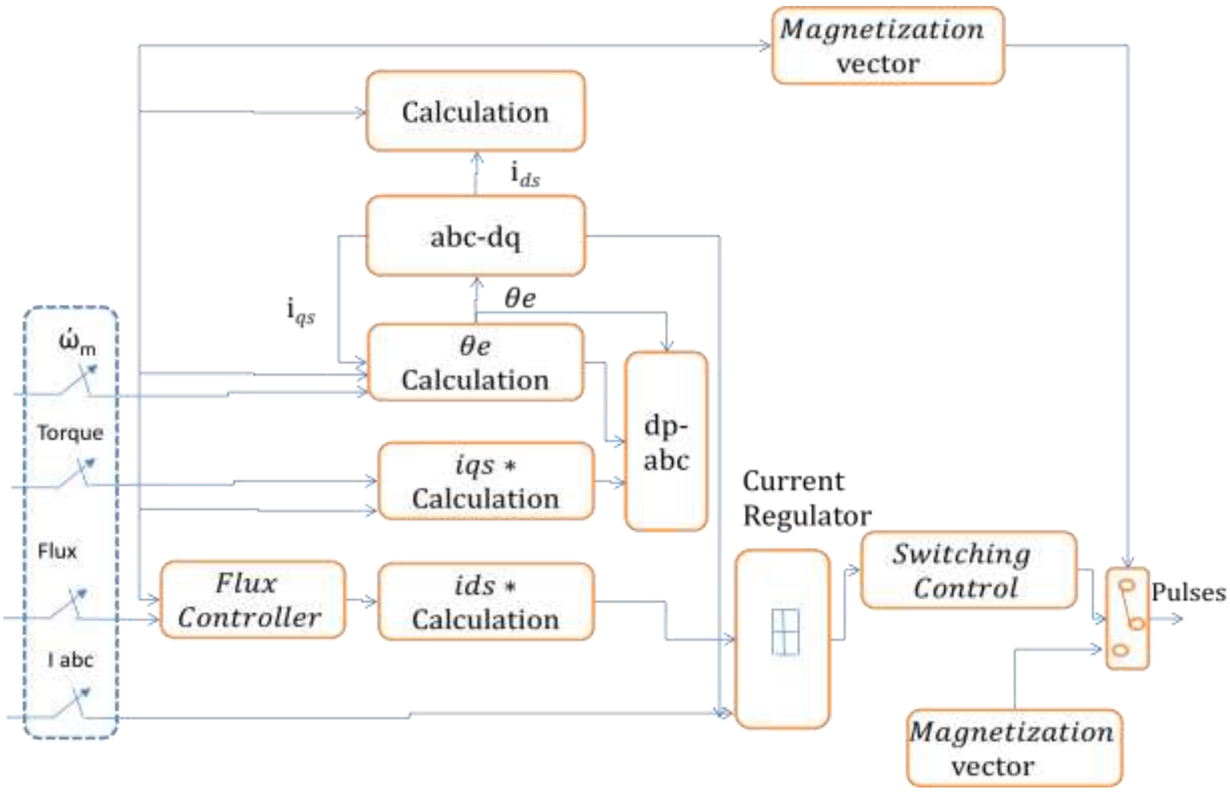

Figure 1 Block Diagram of FOC Scheme

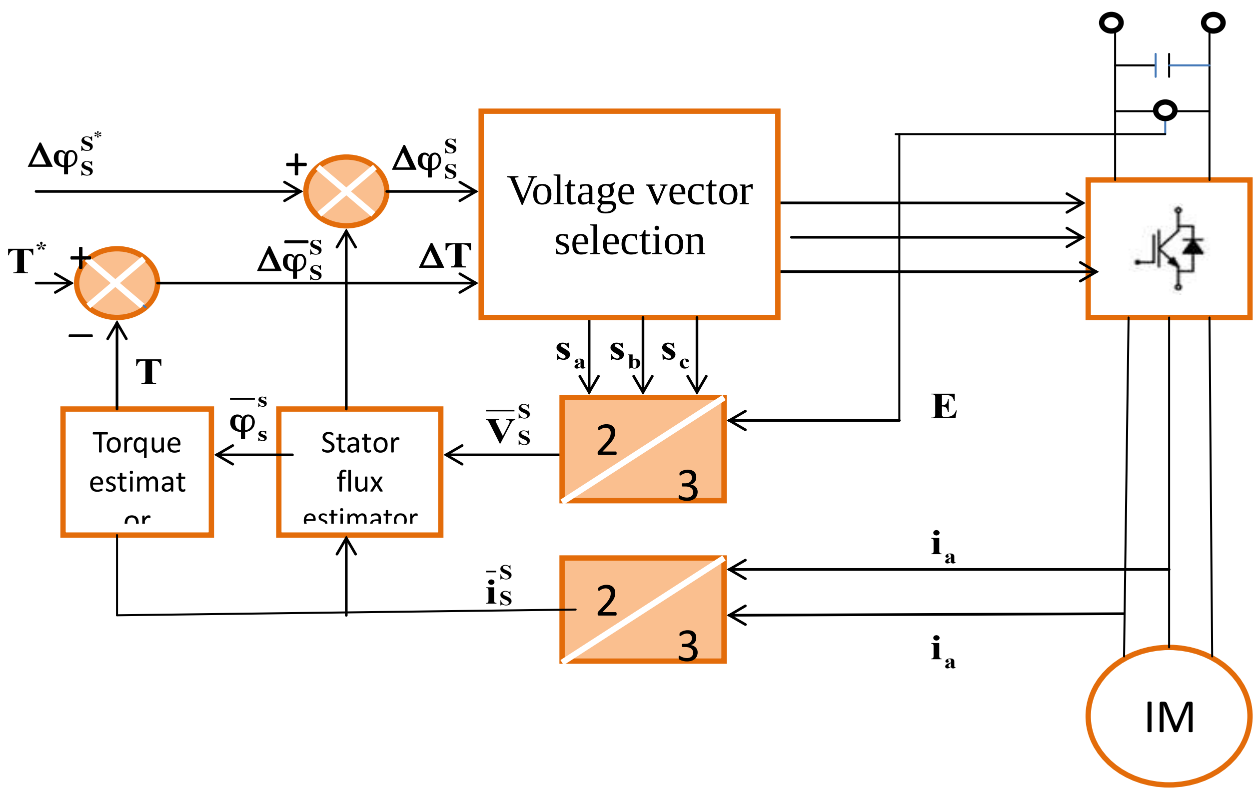

Figure 2 Block diagram of DTC Scheme

The basic idea of DTC for induction motor is to control the voltage space vectors properly, which is based on the relationship between the slip frequency and torque by using a α-β stationary stator reference frame [2], the stator flux linkage and electromagnetic torque T are calculated by using:

$$\varphi = \sqrt{(\varphi_{\alpha s})^2 + (\varphi_{\beta s})^2}$$

Where

$$\varphi_{\alpha s} = \int_0^t (V_{\alpha s} - R_S i_{\alpha s}$$

The error between the estimated torque T and the reference torque T* is the input of a three level hysteresis comparator, whereas the error between the estimated stator flux magnitude $\varphi_s$and the reference stator flux magnitude φ_s*is the input of a two level hysteresis comparator [2]. The selection of the appropriate voltage vector is based on the switching table given in Table 1. The input quantities are the flux sector and the outputs of the two hysteresis comparators.

Table 1 Switching Table [2]

Output of hysteresis comparator		**Sector**					
		1	2	3	4	5	6
C_φ = -1	C_T =-1	V_2	V_3	V_4	V_5	V_6	V_1
	C_T =0	V_7	V_0	V_7	V_0	V_7	V_0
	C_T =+1	V_6	V_1	V_2	V_3	V_4	V_5
C_φ = +1	C_T =-1	V_3	V_4	V_5	V_6	V_1	V_2
	C_T =0	V_0	V_7	V_0	V_7	V_0	V_7
	C_T =+1	V_5	V_6	V_1	V_2	V_3	V_4

In present scenario, operating conditions have changed dramatically because of rapid growth of advanced power conversion devices, electronic equipments, computers, office automations, air conditioning systems, adjustable speed heating ventilations which have drastically increased the level of harmonics and made the current distorted. All these devices are non- linear loads and hence become source of harmonics. The amount of harmonics distortion depends on input supply like the performance of inverters in case of induction motor drives. Thus, directly or indirectly the performance of industrial loads depend on the efficiency of inverter. In this paper,the performance comparison of Z-source inverter [3], [7-8], [11-14]with different control strategies i.e. simple boost control [3], maximum boost control [13], and constant maximum boost control [3] feeding FOC induction motor drive and DTC induction motor drive, has been done with the help of simulated models in MATLAB/SIMULINK.

III. SIMULATION RESULTS

Simulations were conducted for different Z-Source Inverter configurations feeding FOC and DTC Induction Motor drive as well as for conventional SPWM inverter and output voltage waveform for simple boost control,constant boost control and maximum boost control using Field Orientation Control technique (FOC) are depicted in Figure 3, Figure 5, Figure 7 and Figure 9, respectively.Output current waveform for simple boost control, constant boost control and maximum boost control using Field Orientation Control technique (FOC) are depicted in Figure 4, Figure 6, Figure 8 and Figure 10, respectively. Similarly, output voltage waveform for simple boost control, constant boost control and maximum boost control using Direct Torque Control technique (DTC) are shown in Figure 11, Figure 13, Figure 15 and Figure 17, respectively. Output current waveform for simple boost control, constant boost control and maximum boost control using Direct Torque Control technique (DTC) are depicted in Figure 12, Figure 14, Figure 16 and Figure 18 respectively. Also, results of Z-source inverter have been compared with conventional inverter and have been shown in Table 2.The Table 2 shows the variations of fundamental output voltage, currentand their THD level for the various inverter configurations feeding FOC induction motor drive.Similarly,Table 3 shows the variations of fundamental output voltage, current and their THD level for the various inverter configurations feeding DTC induction motor drive. Following parameters have been considered:

L1 = L2 = 1.0mH
C1 = C2 = 1.3mF
Input Voltage = 260V
Cut off frequency = 1kHz
DTC Drive 2238VA, 11KV, 50Hz
Stator Resistance R_S= 0.435Ohm
Leakage Reactance X_S= 2mH
Rotor Resistance R_r = 0.816Ohm
Leakage Reactance X_r= 2mH
Mutual Inductance = 69.31mH
FOC Drive 2238VA, 11KV, 50Hz
Stator Resistance R_S= 0.435Ohm
Leakage Reactance X_S= 2mH

Rotor Resistance R_r = 0.816Ohm
Leakage Reactance X_r= 2mH
Mutual Inductance = 69.31mH

Table 2 Variations of fundamental output voltage, current and their THD level for FOC induction motor drive

Inverter	Output voltage (V)	THD (%)	Output current(A)	THD (%)
Simple boost control ZSI	285.1	89.94	39.1	105.58
Maximum boost control ZSI	341	68.45	34.44	82.80
Constant boost control ZSI	452.3	91.53	76.18	120.69
Conventional SPWM inverter	12.06	239.41	1.09	90.39

Table 3 Variations of fundamental output voltage, current and their THD level for DTC induction motor drive

Inverter	Output voltage (V)	THD (%)	Output current(A)	THD (%)
Simple boost control ZSI	285.1	89.94	39.1	105.58
Maximum boost control ZSI	341	68.45	34.44	82.80
Constant boost control ZSI	452.3	91.53	76.18	120.69
Conventional SPWM inverter	12.06	239.41	1.09	390.39

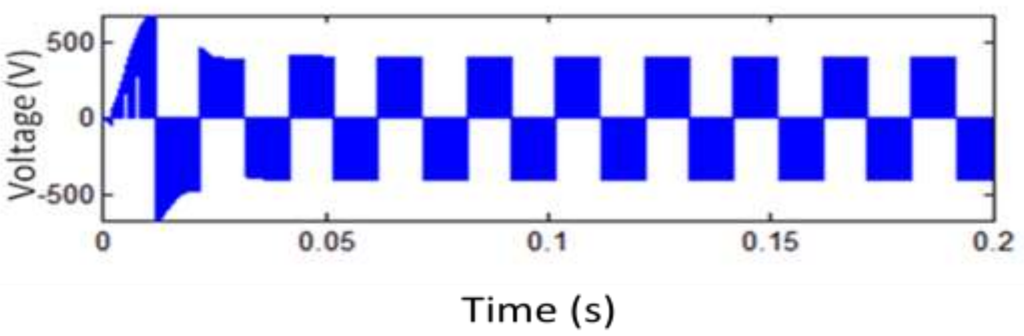

Figure 3 Waveform of output voltage for simple boost control strategy of ZSI feeding FOC induction motor drive

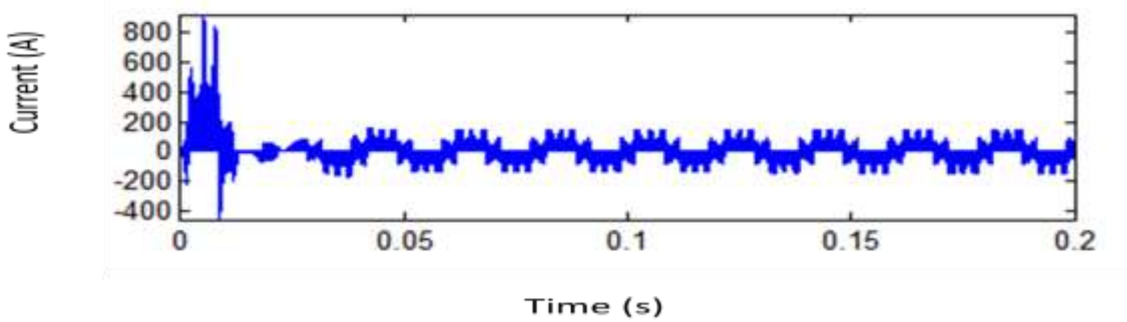

Figure 4 Waveform of output current for simple boost control strategy of ZSI feeding FOC induction motor drive

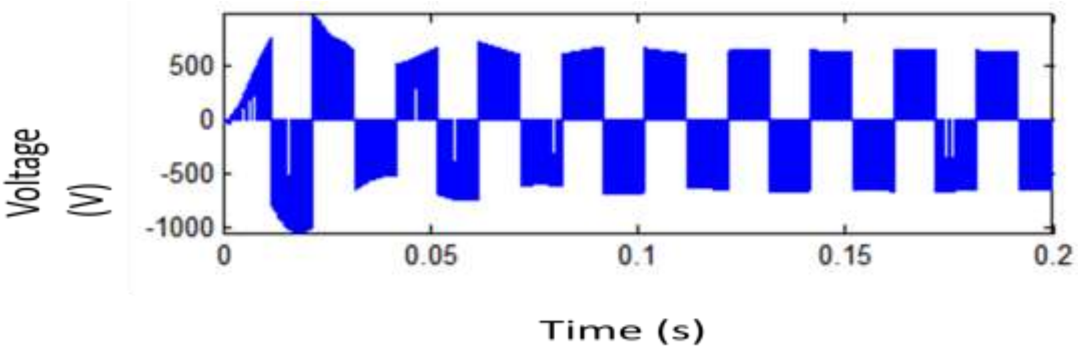

Figure 5 Waveform of output voltage for constant boost control strategy of ZSI feeding FOC induction motor drive

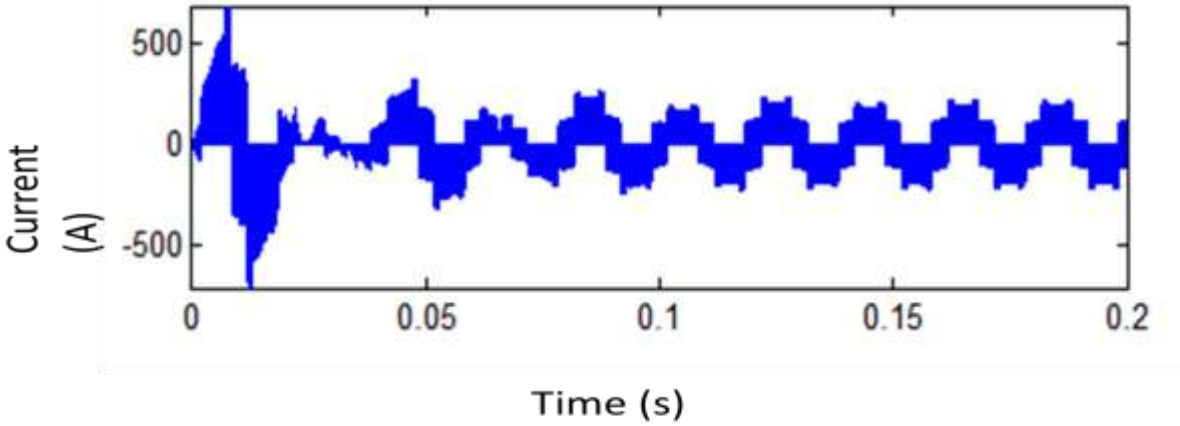

Figure 6 Waveform of output current for constant boost control strategy of ZSI feeding FOC induction motor drive

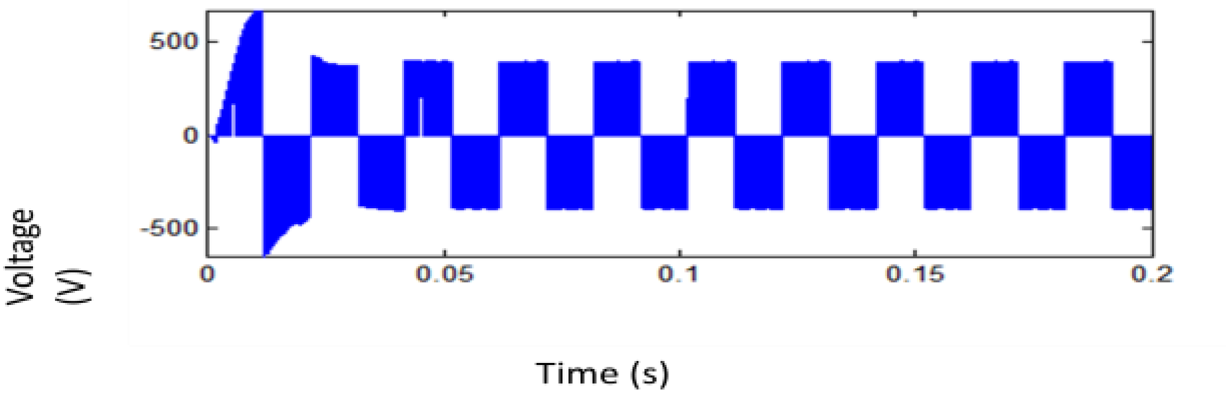

Figure 7 Waveform of output voltage for maximum boost control strategy of ZSI feeding FOC induction drive

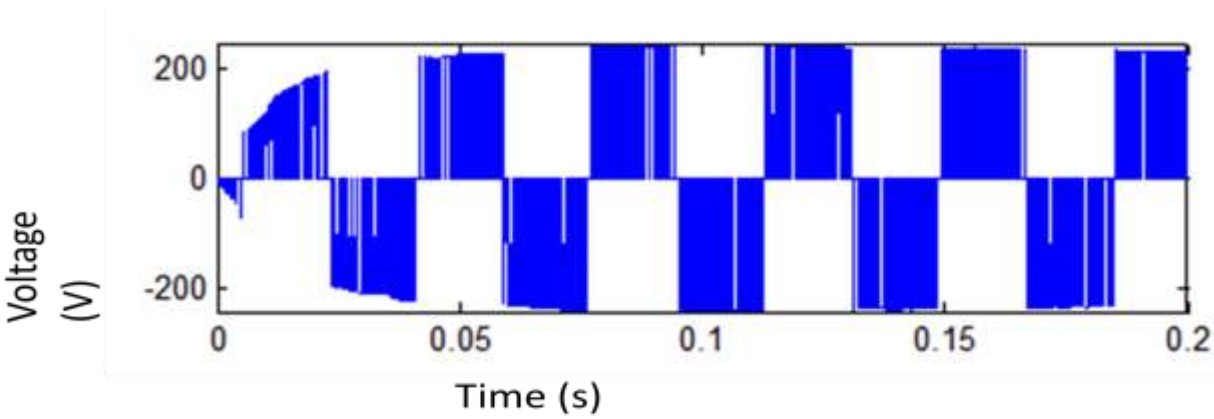

Figure 8 Waveform of output current for maximum boost control strategy of ZSI feeding FOC induction motor drive

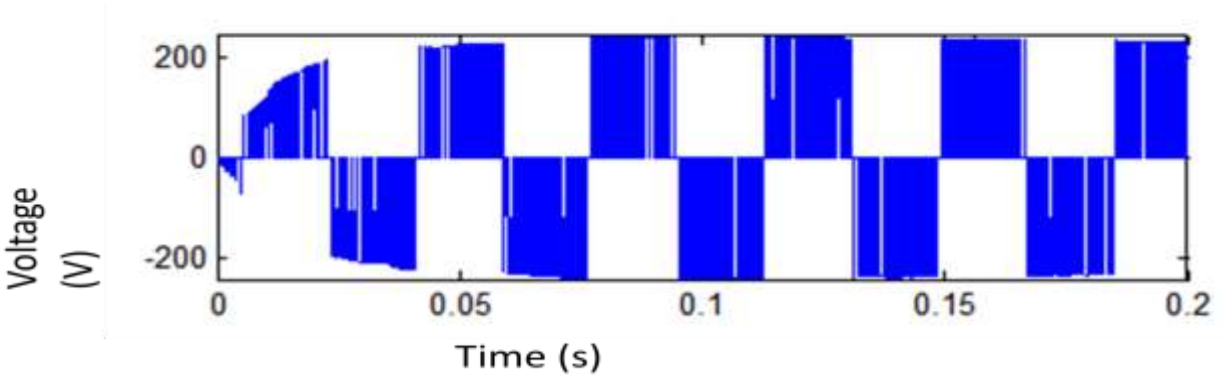

Figure 9 Waveform of output voltage for conventional SPWM converter feeding FOC induction motor drive

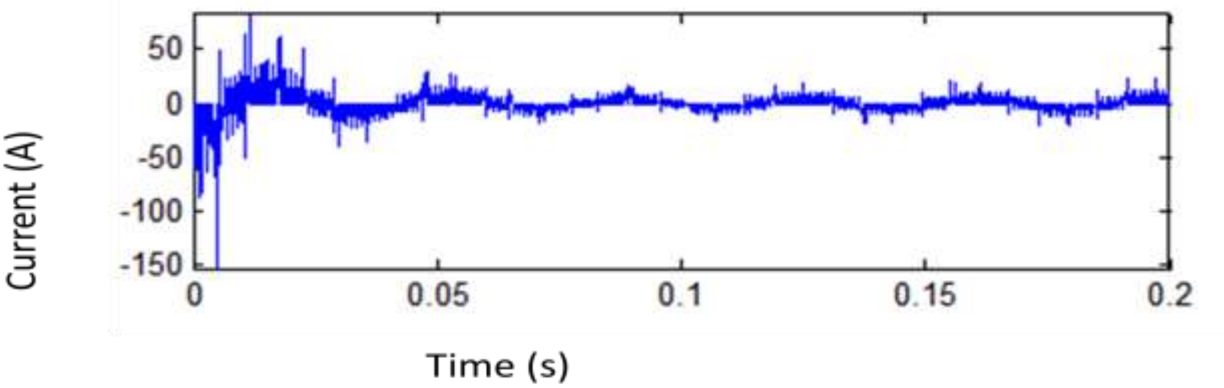

Figure 10 Waveform of output current for conventional SPWM converter feeding FOC induction motor drive

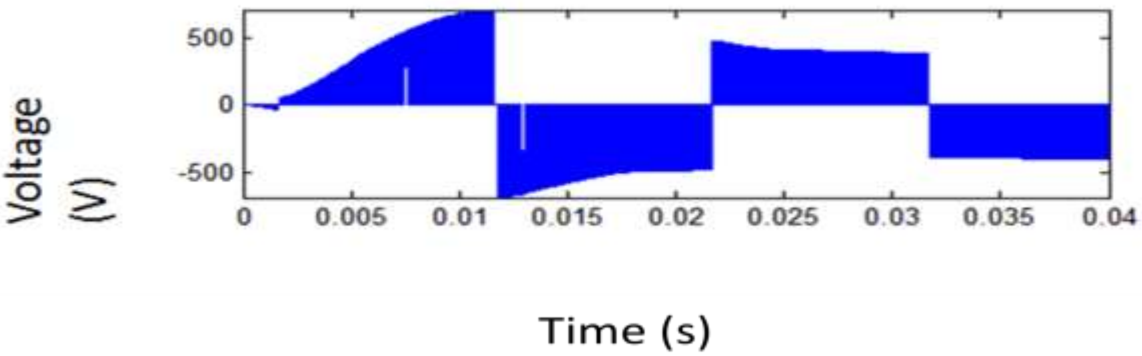

Figure 11 Waveform of output voltage for simple boost control strategy of ZSI feeding DTC induction motor drive

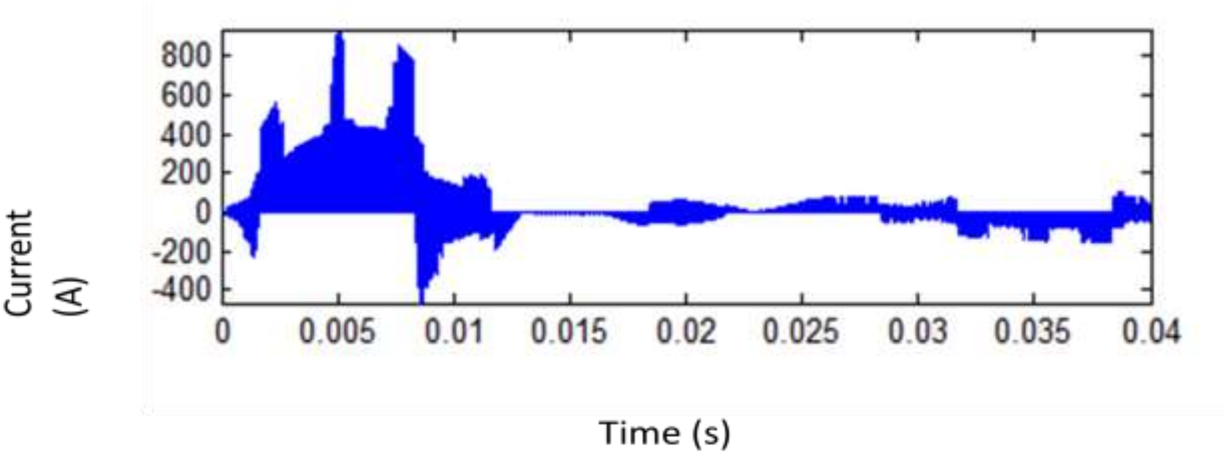

Figure 12 Waveform of output current for simple boost control strategy of ZSI feeding DTC induction motor drive

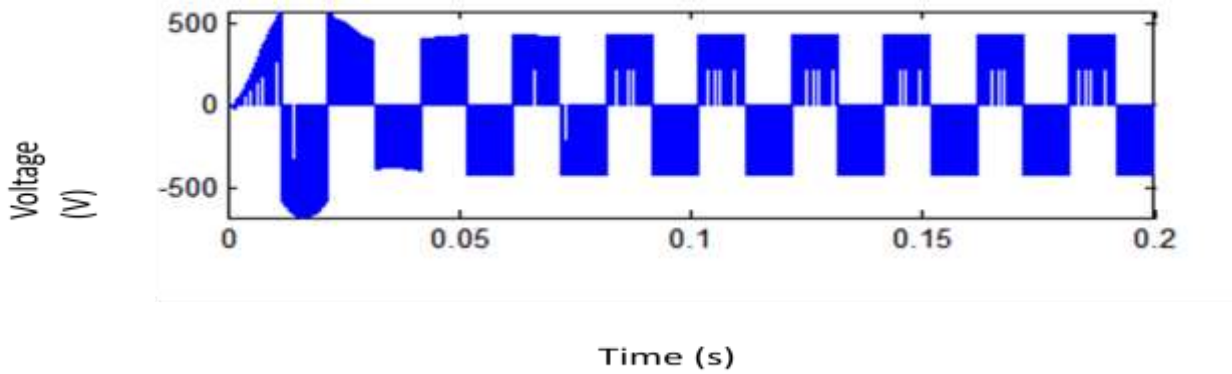

Figure 13 Waveform of output voltage for constant boost control strategy of ZSI feeding DTC induction motor drive

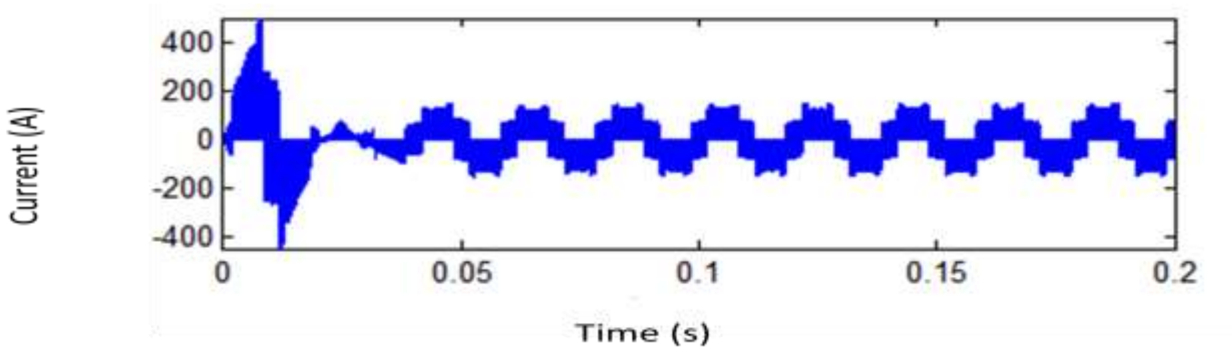

Figure 14 Waveform of output current for constant boost control strategy of ZSI feeding DTC induction motor drive

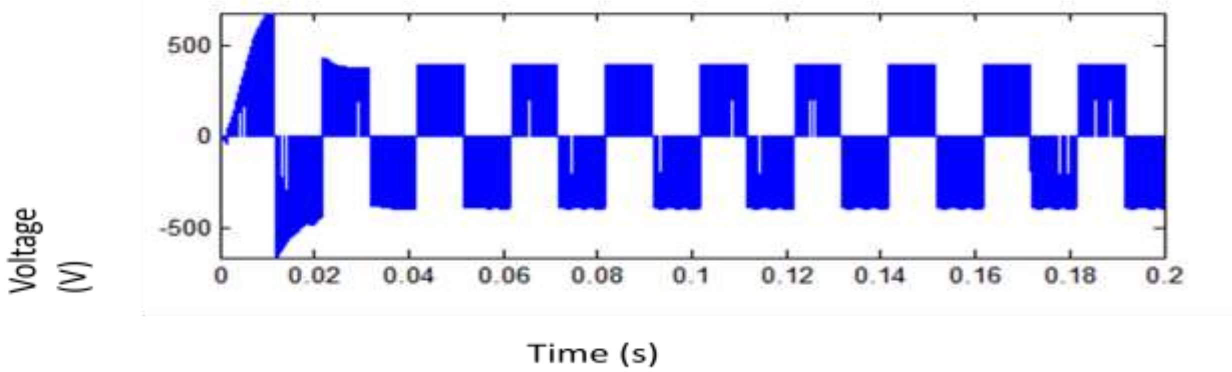

Figure 15 Waveform of output voltage for maximum boost control strategy of ZSI feeding FOC induction drive

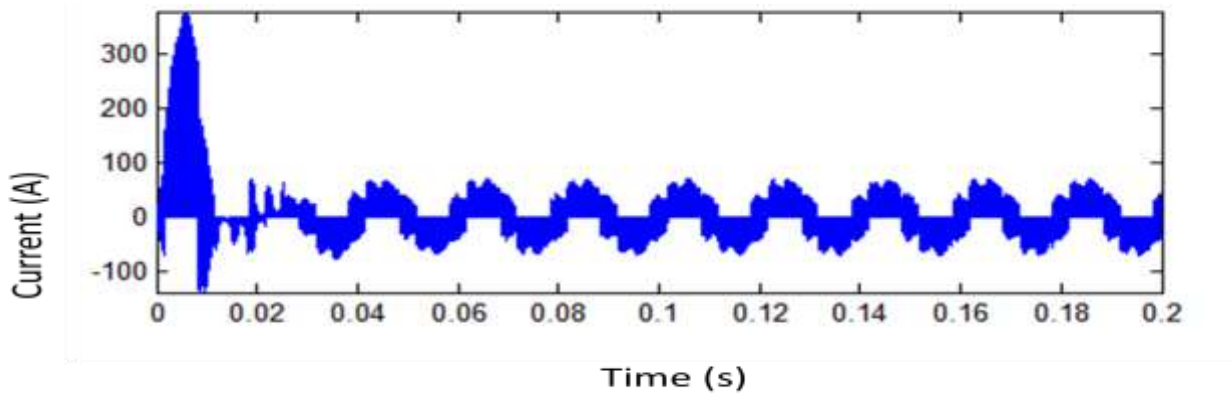

Figure16 Waveform of output current for maximum boost control strategy of ZSI feeding FOC induction drive

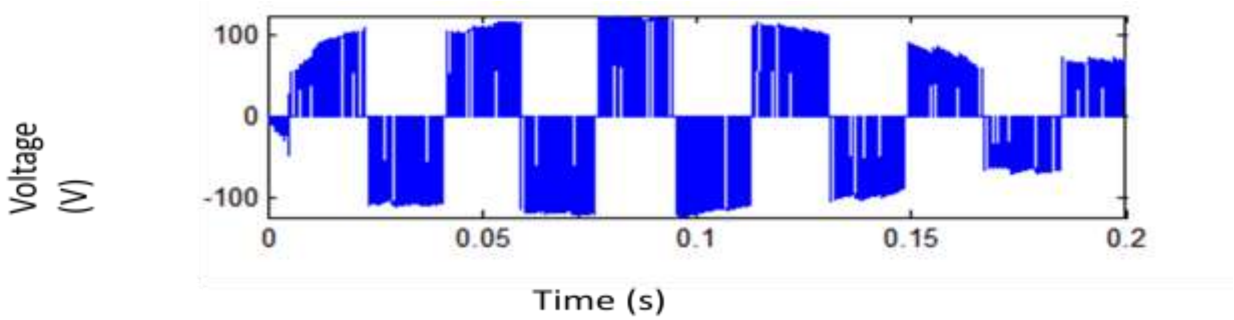

Figure 17 Waveform of output voltage for conventional SPWM converter feeding DTC induction motor drive

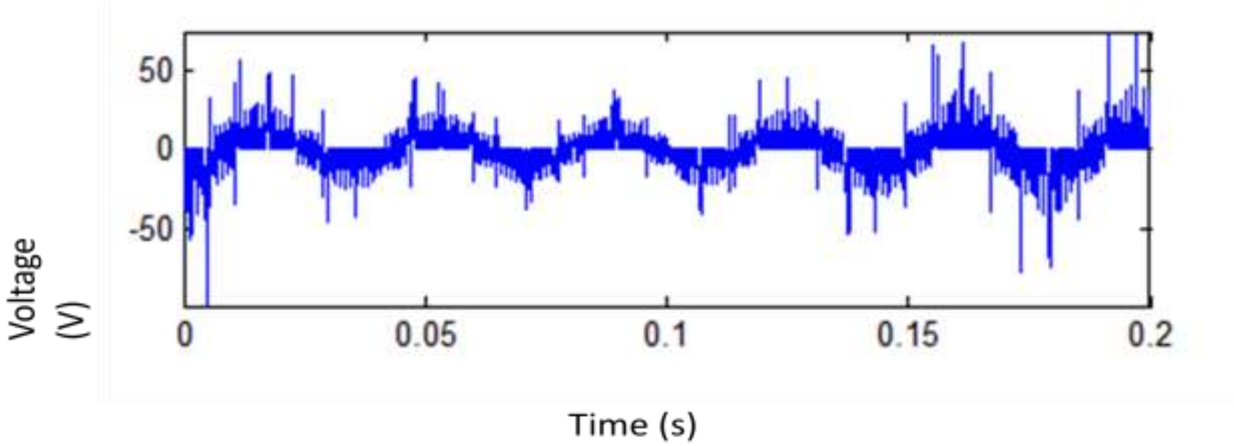

Figure18 Waveform of output current for conventional SPWM converter feeding DTC induction motor drive

IV. CONCLUSIONS

In this work, simulation of Z-source inverter configurations schemes and conventional SPWM inverter feeding industrial drives has been done in MATLAB/SIMULINK. From the results obtained, following conclusions have been drawn:

➢ In case of constant maximum boost control, it has been observed that fundamental output voltage is highest. Output voltage has increased to almost 1.5 times that of input supply voltage.

➢ In case of maximum boost control, the fundamental output voltage is more whereas its THD level is observed to be lower than any other method.

➢ In case of conventional SPWM inverter, fundamental output voltage is very less and its THD level is very high as compared to any control strategy of Z-source inverter. So, Z-source inverter definitely proves to be a better equipment/device than conventional inverter.

V. REFERENCES

[1] A.M. Trzynadlowski, “Introduction to Modern Power Electronics”,New York, Wiley, 1998.
[2] Hamid Chaikhy; Mohamed Khafallah; AbdallahSaad, “Evaluation of two control strategies for induction machine”, International Journal of Computer Application, vol.35, issue:5 December 2011.
[3] H.Rostami; D.K., Khaburi, “Voltage Gain Comparison of Different Control Methods of the Z-source inverter”, Iran University of Science and Technology, Tehran, Iran.
[4] I. Takahashi; T. Noguchi, “A new quick-response and high-efficient control strategy of an induction motor”,IEEE Transaction on Industrial Application, vol. 22, issue:5, pp. 820-827, September / October 1986.
[5] K. Thorobog, “Power Electronics”,Prentice Hall International, 1998.
[6] M.H. Rashid, “Power Electronics”, 2nd ed. Englewood Cliffs, NJ, Prentice Hall, 1993.
[7] Miao Zhu; Kun Yu; Fang Lin Luo, " Switched Inductor Z-Source Inverter", IEEE Transaction on Power Electronics, vol.25, issue:8, pp. 2150-2158, August 2008.
[8] MiaosenShen; Z. FangPeng, "Operation Modes and Characteristics of Z- Source Inverter with Small Inductance or Low Power Factor",IEEE Transaction on Industrial Electronics, vol.55, issue:1, pp. 89-96, January 2008.
[9] P.T. Krein, “Elements of Power Electronics”, Oxford University Press, 1998.
[10] VanjaAmbrozic; ManueleBertoluzzo; S. Giuseppe Buja; Roberto Menis, “An assessment of the inverter switching characteristics in DTC induction motor drive”,IEEE Transaction on Power Electronics, vol.20, issue:2, pp. 457-465, March 2000.

[11] Yi Huang; MiaosenShen; Z. Fang Peng, "Z- Source Inverter for Residential Photovoltaic Systems",IEEE Transactions on Power Electronics, vol.21, issue:6, pp. 1776-1782, November 2006.
[12] F.Z. Peng, “Z-Source Inverter”, IEEE Transactions on Industry Applications, vol.39, issue:2, pp.501-510, March/April 2003.
[13] F.Z. Peng,; MiaosenShen,; ZhaomingQian, “Maximum Boost Control of the Z-Source Inverter”,IEEE Transaction on Power Electronics, vol. 20, issue:4, pp. 833-838, July 2005.
[14]ZhiqiangGao; Jianze Wang; Qichao Chen, "An Improved Control Method for Inductive Load of Z- Source Inverter",School of Electrical Engineering and Automation Harbin Institute of Technology, Harbin, China.