

COMPARISON OF TRADITIONAL PWM INVERTER AND A COMPONENT MINIMIZED Z-SOURCE INVERTER FOR AC DRIVES

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Abstract: In this paper, two different inverters: Traditional PWM inverter and component minimized [four switch three phase (FSTP)] Z-source inverter for Induction Motor Drive were investigated. Total switching device power of each of these inverters was calculated. For purposes of comparison, an example of the total switching device power, requirement of passive components, efficiency, and the constant power speed ratio of the different inverters powered by the same source and loaded by the same motor were conducted. This comparison shows that the Z-source inverter is very promising for Induction Motor Drive.

Key words: Harmonic distortion, Four-Switch Three-phase Inverter, motor drives, voltage sags and Z-source inverter

1. Introduction.

With the recent progress in power semiconductor device technology followed by advancements in power electronics control methods, variable frequency inverter fed ac drives are being adopted for wide variety of applications. Recently there has been growing interest in low cost ac drives to meet the need for reducing cost. Improvements in power semiconductor switch technology have significantly reduced the cost and size of such devices and improved wave form quality. In a traditional voltage source inverter, the two switches of the same phase leg can never be gated on at the same time because doing so would cause a short circuit (shoot-through) to occur that would destroy the inverter. In addition, the maximum output voltage obtainable can never exceed the dc bus voltage. These limitations can be overcome by the new Z-source inverter [1], shown in Fig. 1, that uses an impedance network (Z-network) to replace the traditional dc link. The Z-source inverter advantageously utilizes the shoot-through states to boost the dc bus voltage by gating on both the upper and lower switches of a phase leg. Therefore, the Z-source inverter can buck and boost voltage to a desired output voltage that is greater than the available dc bus voltage [2].

Currently, there are two existing inverter

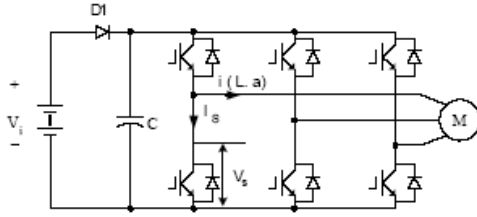
topologies used for Induction Motor Drive, the conventional 3- phase Pulse Width Modulation (PWM) inverter and a 3-phase PWM inverter with a dc-dc boost converter, which is also very popular in other applications. The conventional PWM inverter topology imposes high stresses to the switching devices and motor, and limits the motor's constant power speed ratio. The dc/dc boosted PWM inverter topology can alleviate the stresses and limitations, however, suffers problems such as high cost and complexity associated with the two-stage power conversion.

The newly proposed component minimized [four switch three phase (FSTP)] Z-source inverter has the unique feature that it can boost the output voltage by introducing shoot through operation mode, which is forbidden in traditional voltage source inverters. With this unique feature, the Z-source inverter provides a cheaper, simpler, single stage approach for applications. Moreover, it highly enhances the reliability of the inverter because the shoot through can no longer destroy the inverter. This paper provides analysis and comparisons of the two inverters for Induction Motor drive using total Switching Device Power (SDP), passive components requirement as benchmarks.

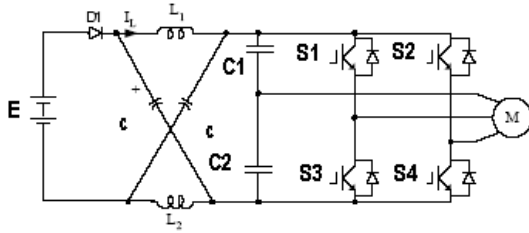
2. System Configurations.

As previously mentioned, two different inverter system configurations are to be investigated: the conventional PWM inverter and the component minimized [four switch three phase (FSTP)] Z-source inverter. Their system configurations for Induction Motor drives are shown in Fig. 1 (a), and (b), respectively. In the traditional PWM inverter, the dc bus voltage, which is also the output voltage of dc source varies with the load. The Z-source inverter outputs a required voltage by adjusting the shoot

through duty cycle with the restriction to keep the voltage across the switches not to exceed its limit.



(a) System configuration using conventional PWM inverter



(b) System configuration using the component minimized Z-source inverter

Fig. 1. Three phase inverter system configurations for comparison

3. Modeling of the Drive System

The complete drive system modeling involves the modeling of the inverter, Induction motor, and Z-source inverter, which are discussed in the following subsections.

3.1 Four Switch Three Phase Inverter Model

In the analysis, the inverter switches are considered as ideal power switches and it is assumed that the conduction state of the power switches is associated with binary variables S_1 to S_4 . Therefore, a binary “1” will indicate a closed switch, while “0” will indicate the open state. Pairs S_1 to S_3 and S_2 to S_4 are complementary and as a sequence.

$$S_3 = 1 - S_1 \quad (1)$$

$$S_4 = 1 - S_2 \quad (2)$$

Also, it will be assumed that a stiff voltage is available across the two dc-link capacitors and

$$V_{C1} = V_{C2} = \bar{E}/2 \quad (3)$$

Where \bar{E} corresponds to a stiff dc-link voltage, i.e. the actual value of the dc-link voltage is equal to \bar{E} . The phase voltage equations of the motor can be written as a function of the switching logic of the switches and the dc-link voltage and given by -

$$V_a = V_{dc} (4S_a - 2S_b - 1) / 3 \quad (4)$$

$$V_b = V_{dc} (-2S_a + 4S_b - 1) / 3 \quad (5)$$

$$V_c = V_{dc} (-2S_a - 2S_b + 2) / 3 \quad (6)$$

Where, V_a, V_b, V_c are inverter output voltages, V_{dc} be the voltage across the dc-link capacitors, S_a, S_b the switching functions for each phase leg.

In matrix form, the above equations can be written as:

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \frac{V_{dc}}{3} \begin{bmatrix} 4 & -2 \\ -2 & 4 \\ -2 & -2 \end{bmatrix} \begin{bmatrix} S_a \\ S_b \end{bmatrix} + \frac{V_{dc}}{3} \begin{bmatrix} -1 \\ -1 \\ 2 \end{bmatrix}$$

For a balanced capacitor voltages, the four switching combinations lead to four voltage vectors. Table shows the different mode of operation and the corresponding output voltage vector of the inverter.

Table I. The four combinations of the states of the power switches and the corresponding terminal voltages V_{as}, V_{bs} and V_{cs}

K_1	K_2	V_{as}	V_{bs}	V_{cs}
0	0	$-U_c/6$	$-U_c/6$	$-U_c/3$
1	0	$U_c/2$	$-U_c/2$	0
1	1	$U_c/6$	$U_c/6$	$-U_c/3$
0	1	$-U_c/2$	$U_c/2$	0

3.2 Induction motor model

The mathematical model of a three phase y connected induction motor and the load is given by the following equations in the d-q synchronously rotating reference frames as [6]

$$\begin{pmatrix} V_{qs} \\ V_{ds} \\ 0 \\ 0 \end{pmatrix} = \begin{pmatrix} R_s + pL_s & \omega_e L_s & pL_m & \omega_e L_m \\ -\omega_e L_s & R_s + pL_s & -\omega_e L_m & pL_m \\ pL_m & (\omega_e - \omega_r)L_m & R_r + pL_r & (\omega_e - \omega_r)L_r \\ -(\omega_e - \omega_r)L_m & pL_m & (\omega_e - \omega_r)L_r & R_r + pL_r \end{pmatrix} \begin{pmatrix} i_{qs} \\ i_{ds} \\ i_{qr} \\ i_{dr} \end{pmatrix}$$

$$T_e = (3P/4) L_m [i_{qs} i_{dr} - i_{ds} i_{qr}] \quad (7)$$

$$T_e = J_m (d\omega_r/dt) + B_m \omega_r + T_L \quad (8)$$

$$d\theta_r / dt = \omega_r \quad (9)$$

where, V_{qs} , V_{ds} are q,d-axis stator voltages, i'_{qs} , i_{ds} are q,& d axis stator current, i_{qs} , i_{ds} are q,d axis rotor current R_s , R_r are the stator and rotor resistances per phase, L_s , L_r are the self inductances of the stator respectively. L_m is the mutual inductance, ω_r is the rotor speed, P is the number of poles. p is the differential operator, T_e is the electromagnetic developed torque, T_L is the load torque, J_m is the rotor inertia, B_m is the rotor damping co-efficient and θ is the rotor position.

3.3 Z-Source Model

This Z-source inverter is used to overcome the problems in the traditional source inverters. This Z-source inverter employs a unique impedance network coupled with the inverter main circuit to the power source. This inverter has unique features compared with the traditional sources [3]. It consists of voltage source from the rectifier supply, Impedance network, three phase inverter and with A.C. motor load. AC voltage is rectified to DC voltage by the rectifier. This rectified output DC voltage fed to the Impedance network. Which consist of two equal inductors (L_1 , L_2) and two equal capacitors (C_1 , C_2). The network inductors are connected in series arms and capacitors are connected in diagonal arms. The impedance network used buck or boost the input voltage depends upon the boosting factor. This network also act as a

second order filter. This network should required less inductance and smaller in size. Similarly capacitors required less capacitance and smaller in size [2]. This impedance network, constant impedance output voltage fed to the three phase inverter main circuit. The inverter main circuit consists of four switches. Gating signals are generated from the DPWM. Which to generate by digital signal processor. The discontinuous pulse with modulation (DPWM) will minimize the harmonic content, this signals fed to the MOSFET Gate terminals. Depends upon the Gating signal inverter operates, this output fed to the AC load or motor.

3.4 Analysis of The Z-Source Network

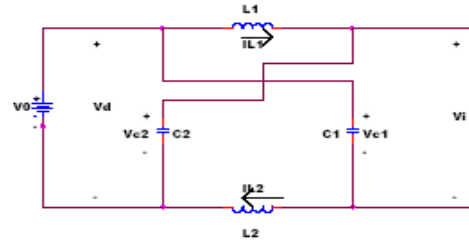


Fig 2 Equivalent circuit of the impedance-source inverter.

Assume the inductors (L_1 and L_2) and capacitors (C_1 and C_2) have the same inductance and capacitance values respectively. From the above equivalent circuit

$$V_{c1} = V_{c2} = V_c \quad (10)$$

$$V_{L1} = V_{L2} = V_L \quad (11)$$

$$V_L = V_c, V_d = 2V_c$$

$$V_i = 0;$$

During the switching cycle T

$$V_L = V_o - V_c \quad (12)$$

$$V_d = V_o$$

$$V_i = V_c - V_L = V_c - (V_o - V_c)$$

$$V_i = 2V_c - V_o \quad (13)$$

Where, V_o is the dc source voltage and

$$T = T_o + T_1 \quad (14)$$

The average voltage of the inductors over one switching period (T) should be zero in steady state

$$\begin{aligned} V_L &= V_L = T_o \cdot V_c + T_1(V_o - V_c) / T = 0 \\ V_L &= (T_o \cdot V_c + V_o \cdot T_1 - V_c \cdot T_1) / T = 0 \\ V_L &= (T_o - T_c)V_c/T + (T_1 \cdot V_o)/T \\ V_c/V_o &= T_1/T_1 - T_o \end{aligned} \quad (15)$$

Similarly the average dc link voltage across the inverter bridge can be found as follows.

From equation 13:

$$\begin{aligned} V_i &= V_i = (T_o \cdot 0 + T_1 \cdot (2V_c - V_o)) / T \\ V_i &= (2V_c \cdot T_1/T) - (T_1 V_o/T) \\ 2V_c &= V_o \end{aligned} \quad (16)$$

From equation 15:

$$\begin{aligned} T_1 \cdot V_o / (T_1 - T_o) &= 2V_c \cdot T_1 / (T_1 - T_o) \\ V_c &= V_o \cdot T_1 / (T_1 - T_o) \end{aligned}$$

The peak dc-link voltage across the inverter bridge is

$$\begin{aligned} V_i &= V_c - V_i = 2V_c - V_o \\ &= T / (T_1 - T_o) \cdot V_o = B \cdot V_o \end{aligned} \quad (17)$$

Where $B = T / (T_1 - T_o)$ i.e ≥ 1

B is a boost factor. The output peak phase voltage from the inverter $V_{ac} = M \cdot V_i / 2$

$$(18)$$

Where M is the modulation index

$$\text{In this source } V_{ac} = M \cdot B \cdot V_o / 2 \quad (19)$$

In the traditional sources

$$V_{ac} = M \cdot V_o / 2$$

For Z-Source

$$V_{ac} = M \cdot B \cdot V_o / 2$$

The output voltage can be stepped up and down by choosing an appropriate buck - boost factor (BB)

$$BB = B \cdot M \text{ (it varies from 0 to } \alpha \text{)} \quad (20)$$

The capacitor voltage can be expressed as

$$V_{c1} = V_{c2} = V_c = (1 - T_o/T) \cdot V_o / (1 - 2T_o/T) \quad (21)$$

The buck - boost factor BB is determined by the modulation index m and the boost factor B. The boost factor B can be controlled by duty cycle of the shoot through zero state over the non-shoot through states of the PWM inverter. The shoot through zero state does not affect PWM control of the inverter. Because it equivalently produce the same zero voltage to the load terminal. The available shoot through period is limited by the zero state periods that is determined by the modulation index.

4. Z-Source Inverter Fed Induction Motor

The induction motor drive system suffers the following common limitations. The diode rectifier fed by the 230V ac line produces about 310V dc on the dc link, which is roughly 1.35 times the line to line input voltage under the assumption of heavy load. For small drives with no significant inductance, the line current becomes discontinuous and the dc voltage is closer to 1.41 times the line to line input voltage, the low output voltage significantly limits output power that is proportional to the square of the voltage. It is a very undesirable situation for many applications because the motor and drive system has to be oversized for a required power. The voltage sags can interrupt an induction motor drive system and shut down critical loads and processes. The dc capacitor in induction motor drives is a relatively small energy storage element, which cannot hold dc voltage above the operating level under such voltage sags. Lack or ride through capacity is a serious problem for sensitive loads driven by drives [8]. Details the vulnerability of induction motor drives and the dc voltage under three phase and two phase voltage sag. Solutions have been sought to boost ride-through [2]. The industrial drives provide options using fly back converter or boost converter with energy storage to achieve ride-through; however, these options come with penalties of cost, size and complexity. Inrush and harmonic current from the diode rectifier can pollute the line. Low power factor is another issue of the traditional induction motor drives. Performance and reliability are compromised by the voltage source inverter structure, because miss witching from EMI can cause shoot-

through that leads to destruction of the inverter, the dead time that is needed to avoid shoot-through creates distortion and unstable operation at low speeds, and common-mode voltage causes shaft current and premature failures of the motor. A recently developed new inverter, the Z source inverter, has a niche for drives systems to overcome the aforementioned problems [1].

The Z- source inverter system can produce an output voltage greater than the ac input voltage by controlling the boost factor, which is impossible for the traditional induction motor drive systems. A Z- source inverter based induction motor drives can produce any desired output voltage, even greater than the line voltage, regardless of the input voltage, thus reducing motor ratings. Provide ride-through during voltage sags without any additional circuits. Improve power factor, reduce harmonic current and common-mode voltage. In this paper the implementation of the four switch three phase (FSTP) Z- Source inverter fed induction motor using Atmel (AT89C2051) Microcontroller is presented.

5.Comparison Items, Conditions, Equations and Results

5.1. Total Switching Device Power Comparison.

In an inverter system, each switching device has to be selected according to the maximum voltage impressed and the peak and average current going through it. To quantify the voltage and current stress (or requirement) of an inverter system, switching device power is introduced. The SDP of a switching device/cell is expressed as the product of voltage stress and current stress. The total SDP of an inverter system is defined as the aggregate of SDP of all the switching devices used in the circuit [8]. Total SDP is a measure of the total semiconductor device requirement, thus an important cost indicator of an inverter system. The definitions are summarized as follows:

Total Average SDP

$$(SDP)_{av} = \sum_{i=1}^N V_i I_{i_average} \quad (22)$$

where N is the number of devices used, and V_i is the

peak voltage induced on the devices.

To derive the SDP of the different inverters, we define some parameters that are necessary for derivation. P_o is the maximum output power; V_{max} is the maximum output voltage of the dc supply; $\cos\phi$ is the power factor of the motor at maximum power; V_i is the dc source output voltage at maximum power; M is the modulation index;

a. Traditional PWM inverter

For the traditional PWM inverter, the output phase RMS voltage at peak power is

$$V_p = \frac{V_i}{2\sqrt{2}} M \quad (23)$$

With motor power factor of $\cos\phi$, the output line RMS current is

$$I_p = P_o / 3 \cos\phi V_p \quad (24)$$

Because the line current is evenly shared by two switches in a line cycle, the average current through each switch is:

$$I_{av} = \frac{P_o}{3\cos\phi V_i/(2\sqrt{2})M} \sqrt{2} * \frac{2}{2\pi} = \frac{4P_o}{3\cos\phi V_i \pi M} \quad (25)$$

The maximum voltage stress of the switches occurs when the output power is zero, and the fuel cell voltage reaches its maximum value, which is

$$V_s = V_{max} \quad (26)$$

The total average switching device power of the circuit is

$$(SDP)_{av} = 6 * V_s * I_{av} = \frac{8V_{max}P_o}{\cos\phi V_i \pi M} \quad (27)$$

The peak current through the switches is the peak line current

$$I_{pk} = \sqrt{2} I_p = \frac{4P_o}{3 \cos\phi V_i M} \quad (28)$$

The total peak switching device power of the traditional PWM inverter is

$$(SDP)_{pk} = 6 * V_s * I_{pk} = \frac{8V_{max}P_o}{\cos\phi V_i M} \quad (29)$$

b. Z-source inverter

For the Z source inverter, the current through the inverter switches consists of two elements, one is the current to the load and the other is the current through them during the shoot through state. Because of the symmetrical structure of the inverter, the current during shoot through in terms of average is evenly distributed in three parallel paths. The current through the inverter during shoot through is twice of the inductor current. Therefore, the average current value in shoot through period through each switch is

$$I_{avss} = 2 / 3(I_L) \quad (30)$$

where I_L is the inductor current. From the input end, the average current through the diode equals to the sum of the average current through inductor L_1 and capacitor C_1 . In steady state, the average current through the capacitor is zero, the average current through the inductor equals to that of the diode. The output power of the dc source under maximum power is P_o , therefore, the average current through the diode as well as the inductor is:

$$T_d = I_L = P_o / V_i \quad (31)$$

While in active states, the average current is the same as a conventional PWM inverter, therefore the overall average current through inverter switches is

$$\begin{aligned} I_{avs} &= \frac{2}{3} I_L * \frac{T_0}{T_s} + \frac{\sqrt{2}P_o}{3V_o \cos\phi\pi} (1 - \frac{T_0}{T_s}) \\ &= \frac{2}{3} I_L * \frac{T_0}{T_s} + \frac{4(\sqrt{3}M-1)P_o}{3V_i \cos\phi\pi M} (1 - \frac{T_0}{T_s}) \end{aligned} \quad (32)$$

where T_0 is the shoot through period in a switching cycle T_s , V_o is the RMS output phase voltage. With the control method presented in [8], T_0 and V_o can be expressed as

$$T_0 = \left[1 - \frac{\sqrt{3}}{2} M \right] T_s \quad (33)$$

$$V_o = \frac{M V_i}{(\sqrt{3}M - 1) (2\sqrt{2})} \quad (34)$$

Voltage stress of the inverter switches is

$$V_s = BV_i = \frac{V_i}{\sqrt{3}M - 1} \quad (35)$$

The average switching device power of the six switch inverter is

$$\begin{aligned} (SDP)_{av} &= 6I_{av}V_s \\ &= 4I_L V_i \frac{T_0}{T_s(\sqrt{3}M - 1)} + 8 \frac{P_o}{\cos\phi\pi M} \left[1 - \frac{T_0}{T_s} \right] \end{aligned} \quad (36)$$

The average switching device power of the four switch inverter is

$$\begin{aligned} (SDP)_{av} &= 4I_{av}V_s \\ &= 2.66I_L V_i \frac{T_0}{T_s(\sqrt{3}M - 1)} + 5.33 \frac{P_o}{\cos\phi\pi M} \left[1 - \frac{T_0}{T_s} \right] \end{aligned} \quad (37)$$

The four switch three phase (FSTP) Z-source inverter's average SDP is the smaller compare to the six switch three phase (SSTP) Z- Source inverter. The average SDP also indicates thermal requirements and conversion efficiency.

5.2. Requirement of Passive Components Comparison

In this comparison, we are going to compare the inductors and capacitors requirement in the systems. The inductors are designed based on the current ripple limit, and the capacitors are designed based on the current ripple capacity requirement and capacitance requirement due to voltage ripple range. In a Traditional PWM inverter the peak voltage ripple of

the capacitor in traditional PWM inverter occurs at maximum power, when the power factor of the motor is pretty high and there is no current fed back to the capacitor from the inverter. The voltage across the capacitor increases when the inverter is in zero state when capacitor current equals to dc supply. In a line cycle, the maximum voltage ripple across the capacitor occurs when the longest zero state happens. For the Z-source inverter, during the shoot through interval, the capacitor charges the inductor and gives out current. When the inverter is in a shoot through state, the voltage across the inductor is the voltage across the capacitor. We can design inductors with requirement of current ripple level. The capacitors are designed to take the ripple current through them based on the ripple current level. The required L and C of the traditional PWM inverter, Z-source Six switch three phase and Z-source Four switch three phase inverter is shown in Table 2 based on the same system specification as above and requirement to limit the value, and capacitor voltage ripple less than 5% of its average value at switching frequency of 10kHz.

Inverter Systems	Number of inductors	Number of capacitors
conventional PWM inverter	0	1
Z - source inverter (FSTPI)	2	4

Table 2. Required Passive Components

5.3.Cost Comparison

The commercially available integrated power modules (IPMs) [or insulated gate bipolar transistors (IGBTs)] are limited in terms of voltage and current ratings. Assuming that the voltage rating is limited to 600 V, and the current rating is chosen to be two times the average current stress of each inverter topology. Again, the four switch three phase (FSTP) Z-source inverter has the lowest price among the two inverters. In addition, because it has fewer components (only four switches), a higher mean time between failures can be expected, which leads to better reliability.

6.Simulation Results

In order to verify the effectiveness of the inverter configuration and its control strategy, a computer simulation model is developed using the Matlab / Simulink software. Induction motor current waveforms and voltage waveforms of the Four Switch three phase Z-Source inverter are identical conditions with six switch three phase inverter. It is evident that starting phase current is in the acceptable range. The steady state three phase current shown in fig 4 (d). indicates almost balanced conditions of the four switch three phase inverter which is also verified by six switch three phase inverter response. The harmonic spectrum of a phase current I_a , for the inverter is shown in fig 4 (f).The Total harmonic distortion (THD) of I_a is found 4.30 % where as the THD of I_a for six switch three phase PWM inverter is found 8.70 % as shown in fig.5 (d).The effectiveness of the Z-Source Inverters is proven by no overshoot, no undershoot, and zero steady-state error of the speed response. It is also seen in Figs. 4 (e). and 4 (f). that the speed response and the harmonic distortion of the FSTP- Z-Source inverter- based IM drive are also comparable to those of the conventional PWM inverter-based drive in Figs 5(a). and 5 (b). It is found that the performance of the four switch three phase inverter based drive is much close to that of the traditional six switches three phase inverter. The analysis and simulation results show that this inverter can dramatically reduce the complexity of the control algorithms and cost.

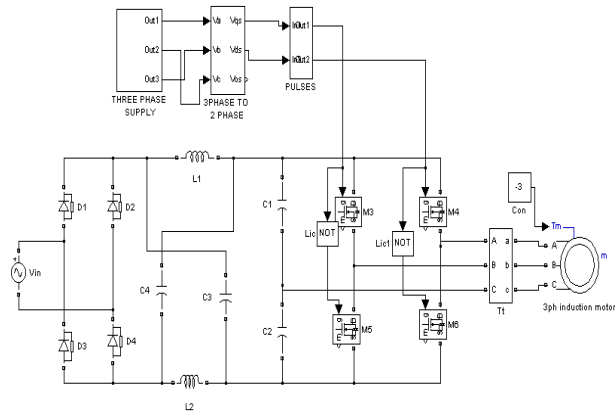


Fig 3.. FSTP Z- Source Inverters

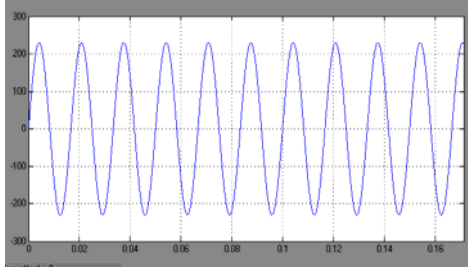


Fig.4(a) Input Line voltage

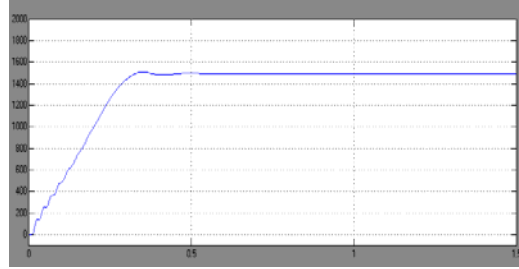


Fig.4(e) Speed response

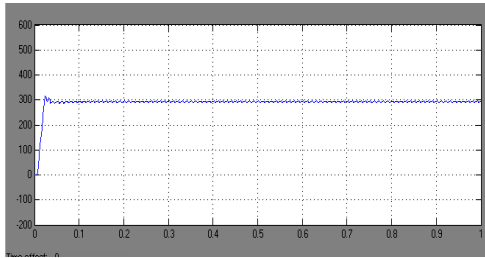


Fig.4(b) Rectifier output

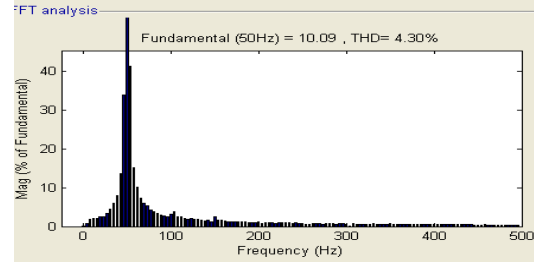


Fig.4(f) Harmonic spectrum

Fig.4. Simulation response of the FSTP Z-source inverter fed induction motor drive.

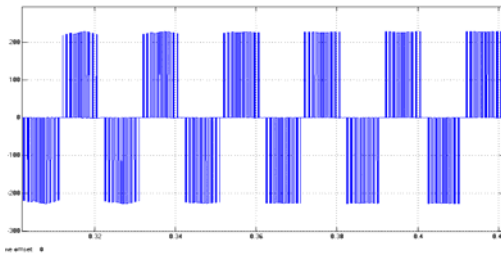


Fig.4(c) voltage wave form

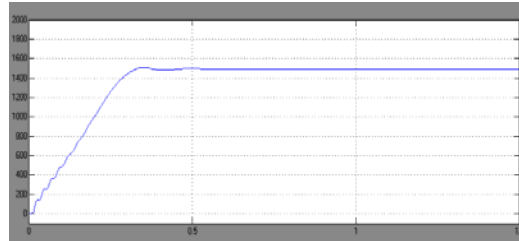


Fig.5 (a) Speed response

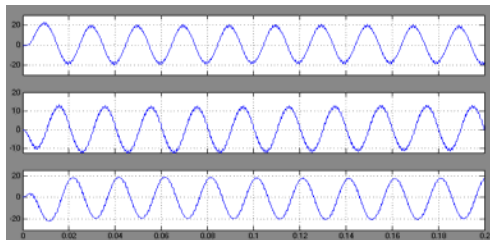


Fig.4(d) Stator currents

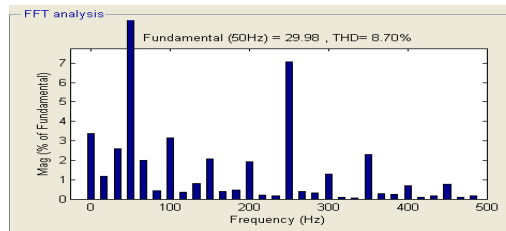


Fig.5 (b) Harmonic spectrum

Fig.6. Simulation response of the Conventional PWM Inverter fed induction motor drive.

7. Experimental Results

A laboratory model has been built to verify the Operation. The PWM control of the FSTP Z-source Inverter was tested using AT89C2051 Micro Controller and a three phase induction motor. In the experimental tests the load is a three phase induction motor (wound rotor, 0.5H.P). Figure. 6. shows experimental waveform. The dc voltage across the bridge was boosted with a boost factor of 1.21. Also, it can be seen that the line current contains much less harmonics than the traditional ASD, although the wave shape is different from the simulation. This is because the line voltage is distorted in the lab, which was not considered in the simulation. Figure 6 shows the Laboratory model and experimental voltage waveform obtained with the FSTP Z-Source Inverter. The experimental curves were obtained using a Oscilloscope.

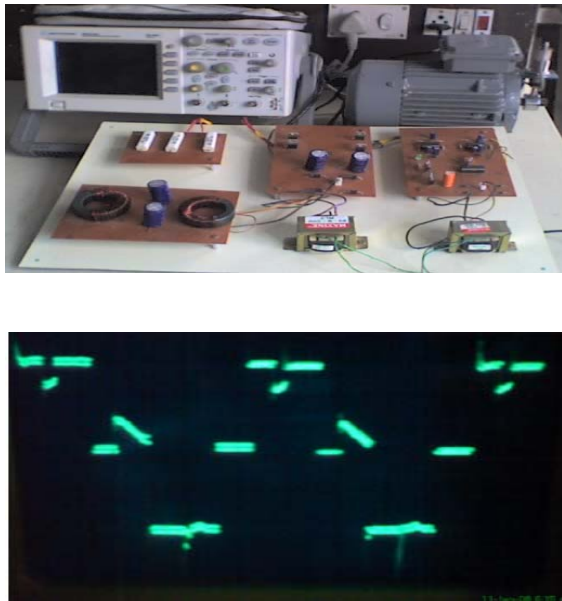


Fig 6. Laboratory model and experimental voltages of the FSTP Z-Source Inverters

8. Conclusion

A comparisons of the four switch three phase (FSTP) Z- Source inverter-fed IM drive with a

conventional six switch three phase (SSTP) inverter-fed IM drive system has been performed. The comparison results show that the four switch three phase (FSTP) Z- Source inverter can increase inverter conversion efficiency by 1% over the six switch three phase (SSTP) inverter systems and inverter motor system efficiency by 1% to 10 % over the conventional PWM inverter. The harmonic contents, Simulation and experimental results verified the operational and demonstrated the promising features. In summary, the Z-source FSTP inverter system has several unique advantages that are very desirable for many ASD applications,

- * It can produce any desired output ac voltage, even greater than the line voltage
- * Provides ride-through during voltage sags without any additional circuits and energy storage;
- * Minimizes the motor ratings to deliver a required power;
- * Reduces in-rush and harmonic current.
- * Unique drives features include buck-boost inversion by single power-conversion stage, improved reliability, strong EMI immunity, and low EMI
- * The Z-source technology can be applied to the entire spectrum of power conversion.
- * The experimental results are closely agreed with the simulation results.

This comparison shows that the four switch Z-source inverter is very promising for Induction Motor Drive.

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