ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

IJIREEICE

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

nCORETech 2017

LBS College of Engineering, Kasaragod

Vol. 5, Special Issue 1, March 2017

Bidirectional Quasi Z-Source Inverter Fed Induction Motor Drive

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Abstract: A novel direct control of high performance bidirectional quasi-Z-source inverter (BQZSI), with optimized controllable shoot-through insertion, to improve the voltage gain, efficiency and to reduce total harmonic distortion is investigated. The most traditional power converters used for adjustable speed drives (ASD) is the voltage source inverter. The VSI usually requires an additional boost converter. This additional converter stage increases cost and complexity and lowers overall efficiency of the power conversion system. Also, the voltage sags can interrupt traditional ASD systems, thus shutting down critical loads and processes. Theoretically, the original Z-source, Quasi-Z-source, and embedded Z-source all have unlimited voltage gain. Practically, however, a high voltage gain (>2 or 3), will result in a high voltage stress imposed on the switches. Every additional shoot-through state increases the commutation time of the semiconductor switches, thereby increasing the switching losses in the system. Hence, minimization of the commutation time by optimal placing of the shoot- through state in the switching time period is necessary to reduce the switching loss. To overcome this problem, a combination of bidirectional quasi-Z-source inverter with a maximum constant boost control with third harmonic injection is proposed. This is achieved by voltage-fed quasi-Zsource inverter with continuous input current, implemented at the converter input side which can boost the input voltage by utilizing the extra switching state with the help of shoot-through state insertion technique. The power flow can be bidirectional by connecting an active switch anti-parellel with the diode in BQ-ZSI. So it can also be used for electrical vehicle applications, since it requires both bidirectional power flow. By using a BQ-ZSI, it is possible to handle the energy in both sides. This bidirectional converter can improve the efficiency of the induction motor. So that the proposed converter have a great future in Electric Vehicle systems.

Keywords: Bidirectional quasi-Z-source inverter (BQ-ZSI), adjustable speed drive system application, reverse power flow.

I. INTRODUCTION

The ever increasing application of automation in industrial motion control requires efficient operation, low maintenance, and high reliability of the ac motor drives and their power converters. Today’s power converters for such applications consist of voltage source inverters (VSI’s), current source inverters (CSI’s) and Z-source inverters (ZSI’s). As we know, traditional voltage source inverter and current source inverter have intrinsic drawbacks. The input voltage of the traditional voltage source inverter must be greater than the peak ac output voltage. The input voltage of the traditional current source inverter must be lower than the peak ac output voltage. And they are buck or boost converter, and could not provide buck-boost function, the shoot-through or open-circuit due to the electromagnetic interference(EMI) often cause the damage of the power semiconductor devices or the power supply.

II. LITERATURE REVIEW

The traditional general-purpose motor drive (or adjustable speed drive-ASD) system is based on the voltage-source inverter (VSI), which consists of a diode rectifier front end, capacitor, and inverter bridge, as shown in Fig.1. The Z-source inverter system employs a unique LC network in the dc link and a small capacitor on the acside of the diode front end. By controlling the shoot-through duty cycle, the Z-source can produce any desired output ac voltage, even greater than the line voltage. As a result, the new Z-source inverter system provides ride-through capability under voltage sags, reduces line harmonics, improves power factor and reliability, and extends output voltage range [1]-[3].
In order to improve power factor, either an ac inductor or dc inductor is normally used. The dc link voltage is roughly equal to 1.35 times the line voltage, and the V-source inverter a buck (or step-down) converter that can only produce an ac voltage limited the dc link voltage. Obtainable output voltage is limited quite below the input line voltage. Fig.1 illustrates voltages of a 3- phase 230 V drive system. The diode rectifier fed by the 230 V_{ac} line produces about 310 V dc, under which the inverter can only produce a maximum 190 V ac in the linear modulation range.

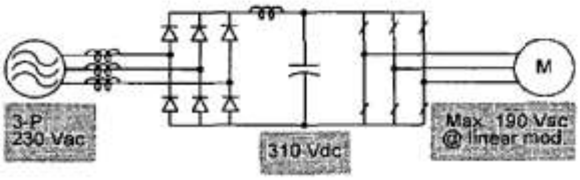

Fig.1. Traditional Adjustable Speed Drive System.

For a 230 V motor, the low obtainable output voltage significantly limits output power that is proportional to the square of the voltage. This is a very undesirable situation for many applications because the motor and drive system has to be oversized for a required power.

The Z-source inverter (ZSI) and its derivative circuit could overcome the drawbacks mentioned above.Z-Source topology was introduced by prof. Peng F.Z. in 2002 [1] which can be adopted in either current source inverters or voltage source inverters. The ZSI is shown in fig.3, it is a special L-C impedance network and usually connects the power source and conversion topologies. With the existence the Z-source topology, it can provide voltage boost/buck properties and solve the shoot-through problem of inverter's bridges, which can't be achieved by traditional inverters because the two switches in one bridge can't be turned on simultaneously without the unique L-C impedance network. In electric power conversion applications such as (DC–DC Converter, DC–AC Inverter, AC–DC Rectifier, AC– AC Converter), impedance network deliver an effective meaning of power conversionamong source and load [1].General circuit configuration of impedance-source network for power conversion with different switching cells is shown in fig.2.

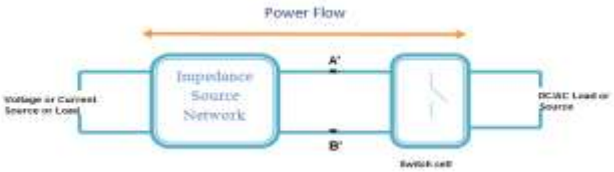

Fig.2.General Circuit Configuration of Impedance-Source Network.

ZSI can implement the boost function and dc–ac conversion in one stage and decrease the total number of switching device over the dc–dc converter with the VSI topology, which reduces the total cost and further improves the efficiency of the system [1]. The voltage-fed ZSI treats the leg straight as a normal operating mode, and achieves single-stage boost/buck conversion by controlling the shoot-through duty cycle. However, the voltage-fed ZSI has discontinuous input current, which will shorten the lifetime and deteriorate the motor performance, large voltage stress on the capacitor of the impedance networks and no common ground point between the DC source and the inverter bridge. So that new voltage-fed QZSI topologies are developed [5-6].

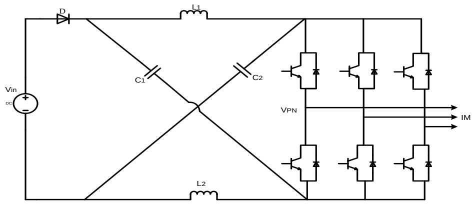

Fig.3: ZSI

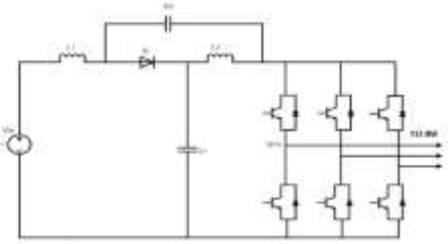

Fig.4. QZSI

DOI 10.17148/IJIREEICE

To overcome the defects of the ZSI, reducing the capacitor voltage and inductor current, reducing the size and cost of system [1], by rearranging the components in the Z-source network, a new topology called the QZSI (quasi-Z-source inverter) was introduced [7], shown in fig.4.The input current of the QZSI is continuous, at the same time retaining all the merits of the ZSI, which makes it a good candidate for adjustable speed drive applications. However, the traditional QZSI allows only unidirectional power flow from the dc to the ac side.

A. Classification of QZSI

QZSI can be classified into two categories based on whether it has extension circuits: 1) single impedance-source QZSI topologies; 2) the extended-boost quasi-Z-source networks. Each topology has distinct features and advantages, and will be discussed as following.

1. Single Impedance-Source QZSI Topology

In order to get a greater boost capacity, the switched inductor QZSI (SL-QZSI) [8] and the switched-coupled-inductor QZSI (SCL-QZSI) [9] are introduced, shown in Fig.5 and Fig.6.Extra inductors and capacitors have been added in the Z-source and quasi-Z-source impedance network, aim of improving the boost capability of the circuit. Many topologies are presented in the literature to reduce the stress on the passive components and also to eliminate the start-up inrush current. A switched inductor/capacitor ZSI/QZSI provides continuous input current and reduced voltage stress on the capacitor. Small shoot-through timeperiod is needed to generate large output voltage.

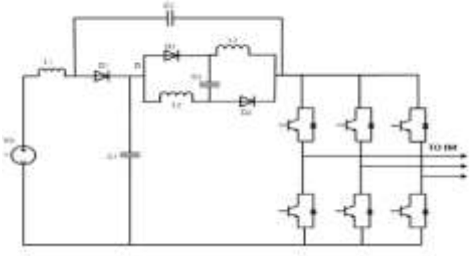

Fig.5. Switched Inductor QZSI

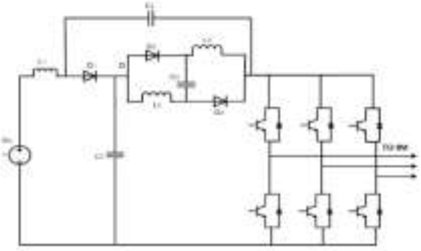

Fig.6. Switched-Coupled-Inductor QZSI

To reduce additional components, [10] put forwarded a transformer based quasi-Z source inverter (trans-QZSI) shown in Fig.7. Trans-Z-source network is implemented with the aim of achieving higher boost at a lower shoot-through time period of the switch. Proper implementation could reduce the turn’s ratio of the transformer as compared to other QZSI-based topologies. This advantage is utilized to design the converter to operate in parallel to achieve higher power level and premium power quality along with improved system efficiency. But it has the magnetic saturation problem.

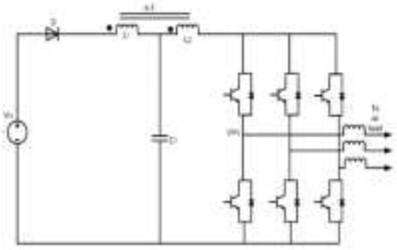

Fig.7. Voltage-Fed Trans-QZSI

A LCCT (Inductor-Capacitor-Capacitor-Transformer)-QZSI is introduced to prevent magnetic saturation by the built-in capacitor [11], as shown in Fig.8. The LCCT Z-source with the inductor and a transformer integrated into a common core, achieves higher voltage gain and modulation index. This topology maintains a continuous input current even at a light load, and also filters out high-frequency ripples from the input current.

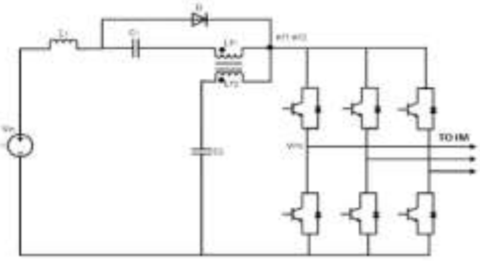

Fig.8. LCCT-QZSI

In order to reduce the turns ratio, size and weight of the transformer in trans-QZSI[12] introduced the transformer-based quasi-TZ-source inverter shown in Fig.9.The T-shaped inverter using a capacitor along with coupled inductors. The network with few reactive components has substantial advantages in utilizing common voltage source of the passive arrangement, which makes a suitable topology for neutral point clamped converters. The gain of the T-shaped source inverter can be set high, compared with conventional QZ/Z-source inverters.

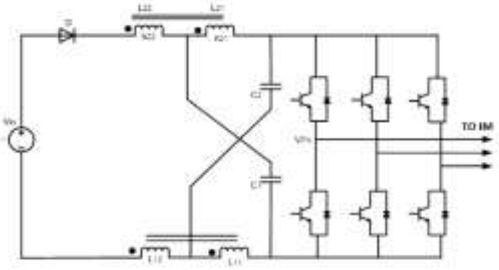

Fig.9. TZ-Source Inverter

To increase the safety, voltage-fed isolated QZSI [13] is introduced using coupled inductors as shown in Fig.10. According to this topology, with the small shoot-through time period, high voltage gain is achievable and one of the advantages of this topology is the minimum possible device stress.

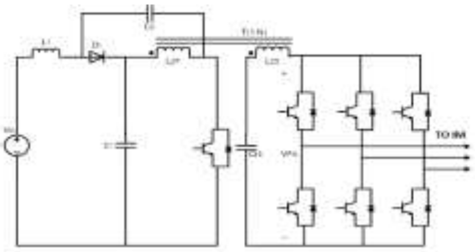

Fig.10. Voltage-Fed Isolated QZSI

2. The Extended-boost Quasi-Z-source Network (QZSN)

In order to meet the needs of applications requiring very high voltage boost, the cascaded QZSNs are introduced [15-16].In Fig.11 and Fig.12 higher stage QZS-networks can be designed by just multiple repeating of the partsD$_3$–D$_2$–L$_3$–C$_3$ or D$_2$–C$_3$–L$_3$–C$_4$ respectively. The cascaded QZSI inFig.14with more capacitors can produce highest boost ratio, and have lowest voltage stress on switching devices with the same voltage gain. Though, the cost will increase because of added passive elements.

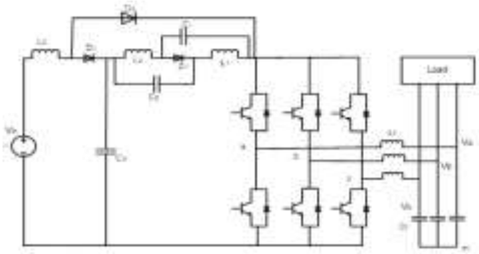

Fig.11. Extended QZSI

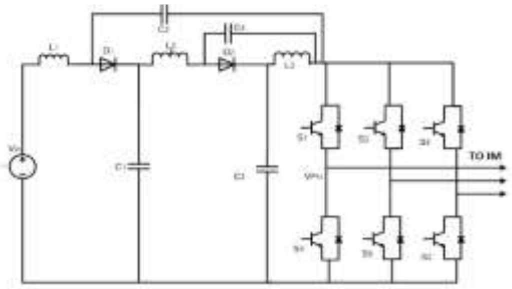

Fig.12. Cascaded QZS-Network

Several studies about bidirectional ZSI applications have been reported in [17]–[20]. However, the operation mode analysis was based on the topology of the ZSI and mainly focused on the power flow from the dc to the ac side. To achieve the bidirectional power flow capability, the same approach as in [17]–[19] is utilized here and the diode in the quasi-Z-source network(QZSN) is replaced by an active switch in BQ-ZSI.

This paper gives a detailed circuit analysis of the BQ-ZSI during the regenerative braking mode, when the power flows from the ac to the dc side. Furthermore, with the additional switch, the discontinuous conduction mode (DCM) can be avoided and theBQ-ZSI can have a better performance with small inductance or under low power factorcondition. Theanalysis shows that with the active switch, theinductorcurrents in the BQ-ZSI can be reversed and the energy from the ac side can be delivered to the dc source. The performance of the inverter under load variation can be improved by inserting an inner current control loop in the dc side. Therefore, a dedicated voltage controller with inductor current controller is designed to reject the disturbance and stabilize the dc-link voltage during a non-shoot through state. Fig.13 shows the circuit diagram of BQ-ZSI.

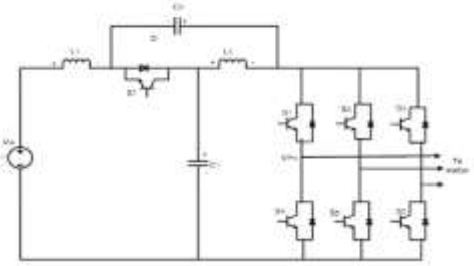

Fig.13. BQ-ZSI

B. Operation Principle

Bidirectional quasi-Z-source overcomes the limitations of conventional QZSIs. This new design simplifies the controller design and has an advantage of operating in wide-range of load even no load with the smaller inductors which eliminates the probability of voltage drop in DC-link. The topology of the BQ-ZSI is shown in Fig.13. It has two functional parts: 1) the QZSN, which is composed of C_1, C_2, L_1, L_2andS_7, and 2) the three-phase bridge. Compared to the traditional QZSI, the diode in the QZSN is replaced by an active switch S_7 with a parallel diode. Through proper control of this switch, the bidirectional power flow can be realized. The BQZSI has three general operation states: the active state, the zero state, and the shoot-through state [17]. In the shoot- through state, theupper and lower switches in the same arm of the three-phase bridge conduct at the same time, which is utilized to boost the dc-link voltage.

$v_{PN}=V_{in}\frac{1}{1-2D}$ (1)The maximum ac output voltage under a certain shoot-through duty ratio can be calculated as,

$$V_{acrms} = V_{in}\frac{1}{1-2D} * \frac{1}{2} * \frac{\sqrt{3}}{\sqrt{2}} * (1-D) * \frac{2}{\sqrt{3}} (2)$$

C. Control of S_7

During the regeneration mode, the switching pattern S_7 of is complementary with the shoot-through pattern of the three- phase bridge. When the three-phase bridge is in the shoot- through state, S_7 is open. The body diode is reversely blocked and the voltage boost function can be realized. When the three- phase bridge is in the non-shoot-through state, S_7 is closed. The reverse current goes through S_7 and feeds the energy back to the dc source. For safety purposes, a suitable dead time needs to be inserted between the control signals of the shoot-through state and S_7. Otherwise, the two capacitors in the QZSN may be short-connected throughS_7, which will cause damage of the devices. The modes of operation is described below,

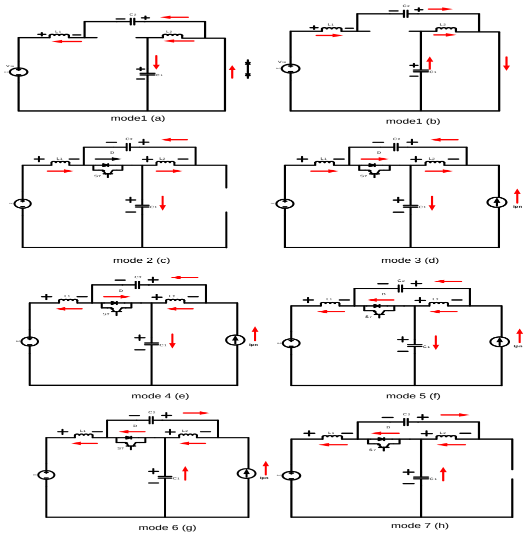
mode1 (a)
mode1 (b)
mode 2 (c)
mode 3 (d)
mode 4 (e)
mode 5 (f)
mode 6 (g)
mode 7 (h)

Fig.14. Modes of Operation of BQZSI

Mode 1:The BQZSI is operating in the shoot-through state. $S_7$is open, and the diode is reversely blocked because $v_{c1} + v_{c2} > v_{in}$. The currents in the inductors decrease sharply and charge up the capacitors, as shown in Fig.14 (a). If the shoot-through state is long enough, there is possibility that the currents in the inductors change thedirection and the capacitors begin to charge energy back to the inductors, as shown in fig. 14(b).

Mode 2:If at the end of Mode 1, the inductor currents have a positive direction, the BQ-ZSI will go to Mode 2. Otherwise, it will go to Mode 7, which is described later. In Mode 2, the BQ-ZSI is in the zero state and S_7 is closed. There is current flowing through the parallel-connected diode of S_7 . The inductor currents are in the positive direction and start to decrease, while the capacitor voltages are charged up.

Mode 3: The BQZSI is switched to the active state. The currents in the inductors are still in the positive direction and continue to decrease. The voltages of the capacitors are continuously charged up.

Mode 4: The BQ-ZSI will remain in Mode 3 until the currents in the inductors decrease to zero and change the direction. Then, the circuit will be operating in mode 4, where the following condition holds:

$$i_L < 0, |i_L| < \frac{|I_{PN}|}{2} \quad (3)$$

In this mode, the inductor currents increase reversely, and the capacitor voltages are charged up by the ac side active power.

Mode 5: The BQZSI begins to operate in Mode 5 when,

$$i_L < 0, \frac{|I_{PN}|}{2} < |i_L| < |I_{PN}| \quad (4)$$

In this mode, the inductor currents and capacitor voltages follow the same pattern as in Mode 4, but the current in S_7 changes the direction.

Mode 6: The BQZSI is in Mode 6 when,

$$i_L < 0, |i_L| > |I_{PN}| \quad (5)$$

In this mode, the capacitor voltages begin to drop, and the inductor currents continue to increase.

Mode 7:The BQ-ZSI is again in the zero state. The capacitors continue to discharge and the currents in the inductors increase. One possible waveform of the inductor current and capacitor voltage in one switching cycle is shown in Fig.15, where T_{st} stands for the shoot-through state,$T_o$stands for the zero state, and T_a stands for the active state. Depending on the real operation condition, the BQ-ZSI may work with different combinations and sequences of the current modes described above.

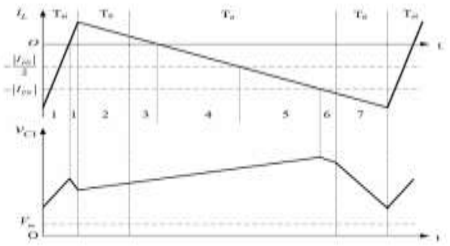

Fig.15. Change of Inductor Current and Capacitor Voltage In One Switching Cycle

D. PWM signal generation of the active switch

The main purpose of modulation method is to achieve and improve the voltage gain and decrease the total-harmonic-distortion (THD) as much as possible. There is a difference between BQZS inverter and conventional voltage source inverter; the method of inserting shoot-through time period is influencing the design and efficiency of the inverter. One of the unique characteristics of BQZSI is the variation of AC-voltage between 0 to ∞ without considering the input DC-voltage. A controllable shoot-through modulation technique for voltage-fed BQZS DC-AC inverter is described. Unique feature of new control strategy is reducing commutation time and decreasing losses in the switches. Active state period and shoot-through zero state can be controlled separately which allows the shoot-through time period get to the maximum limit. Hence, achieving a desire voltage gain for the application that sources is renewable energy such as photovoltaic, fuel cell, etc.

Pulse width Modulation (PWM) control for the introduced inverter is needed to be altered to include the shoot through states for voltage boost. All the existing PWM techniques can be applied for this topology. A modified PWM method called simple boost control method was introduced in [27], uses two straight lines to control the shoot-through states. But in this control method, the voltage stress across the switches will be quite high. Due to the limitation of device voltage rating, the obtainable voltage gain is restricted. A maximum boost control was presented in [29]. By using this method, theBQZSI can provide a boosted output voltage that is greater than the input voltage. This method is also capable of reducing the voltage stress across the switches. But it produces low frequency current ripple. In order to get an optimum design of BQZSI, the current ripple should be eliminated by maintaining a constant shoot through duty ratio. Also, the voltage boost should be high in order to reduce the voltage stress across the switches. This is achieved by maximum constant boost control method [30]. The above said maximum constant boost control can be implemented alternatively by using third harmonic injection. A sketch map of the third- harmonic injection control method is shown in Fig.21. Third harmonic injection is commonly used in a three-phase inverter system to increase the modulation index range and to increase system voltage gain range. There are five modulation curves in this control method: three reference signalsV_a,V_b, and V_c, and two shoot-through envelope signals V_p and V_n. When the carrier triangle wave is higher than the upper shoot-through envelope V_p or lower than the bottom shoot-through envelopeV_n, the inverter is turned to a shoot-through zero state. In between, the inverter switches in the same way as in the traditional carrier based PWM control. Here the BQZSI with third harmonic injected maximum constant boost control is introduced.

A third-harmonic component with 1/6 of the fundamental component is injected to the three phase-voltage references. Only two straight lines, $V_p$and V_n, are needed to control the shoot-through time with the 1/6 (16%) third harmonic injection.

The duty ratio can be calculated by using the following expression,

$$\frac{T_o}{T}=\frac{2-\sqrt{3}M}{2}=1-\frac{\sqrt{3}M}{2} \qquad (6)$$

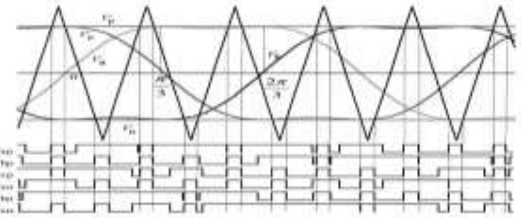

Fig.16. Gate Signal Generation

The boost factor and voltage gain can be calculated as follows,

$$B=\frac{1}{1-2\frac{To}{T}}=\frac{1}{\sqrt{3}M-1}(7)$$

$$G=MB=\frac{M}{\sqrt{3}M-1}(8)$$

The duty ratio, boost factor and the voltage gain of the third harmonic injected constant boost control method are similar to the maximum constant boost control method. The only difference is that the introduced control method has a larger modulation index M, which is increased from 1 to 2/√3. The third harmonic PWM utilizes the dc supply voltage better than the sinusoidal PWM.

III.SIMULATION RESULTS

Simulation study is a powerful tool to check the circuit design and to analyse the circuit under various operating conditions. This may include varying supply, load conditions, component values etc.For analysis BQZSI operating in CCM is simulated. Circuit is designed for input supply of 225 V with a switching frequency of 10 kHz and a carrier frequency of 5 kHz is used. The simulation of BQZSI with induction motor load are carried out. The simulation diagram and waveforms are given below.

For the analysis of BQZSI 3-phase 4 pole squirrel cage induction motor of 415 V, 1.6 A, 1400 rpm is used. The induction motor parameters used for the simulation are tabulated as following.

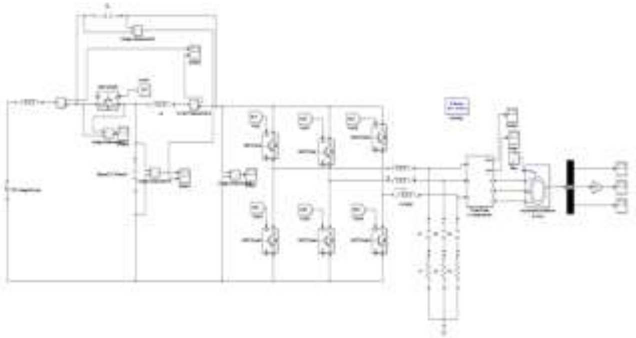

Fig.17. BQZSI With Induction Motor

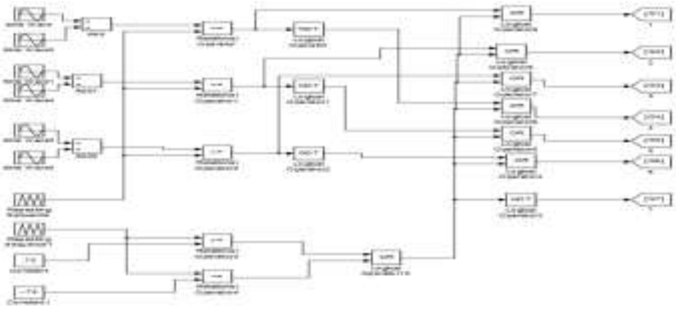

Fig.18. Gate Signal Generation Control Circuit

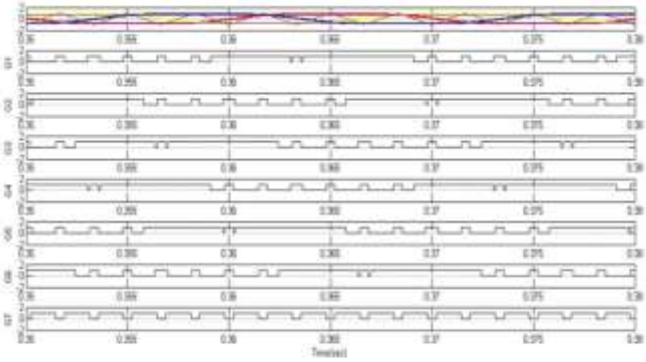

Fig.19. Gate Signal Generation

The gate signal for BQZSI generated by using third harmonic injected maximum constant boost control. The third harmonic injected sine wave is compared with triangular wave for PWM generation and for shoot through insertion the triangular wave is compared with two straight lines V_p and V_n. Gate signal for switch S_7 iscomplimentary of shoot through gate signal.

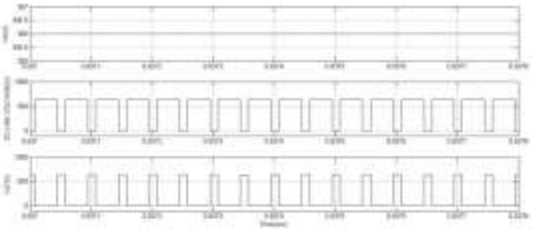

Fig.20. DC-Link Voltage and Voltage Across The Switch

When input dc voltage of 306 is applied the dc link voltage is boosted to two times the input dc supply voltage. And corresponding ac voltage and current are obtained across the load terminal. The result shows that there is no distortion on the DC-link voltage and the voltage across the switchS_7, which indicates that there is no discontinuous current in the inductors and the switch. Therefore, the system is working in the continuous conduction mode (CCM).

Fig.21. Output Voltage

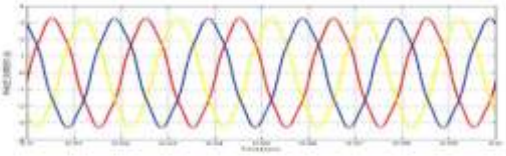

Fig.22. Output Current

Fig. 21 and 22 shows the output three phase load voltage and current respectively.

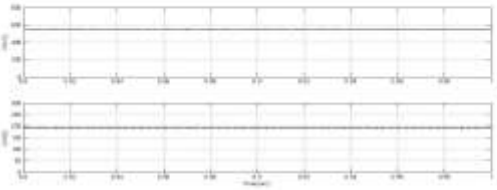

Fig.23. Capacitor Voltages

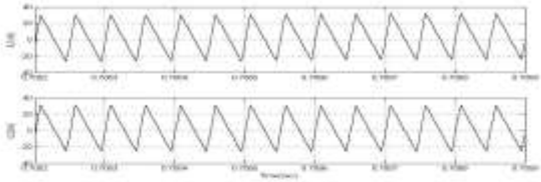

Fig.24. Inductor Current

Fig. 24 shows the current through the inductors which are same. It can flow in both directions and is always continuous. Therefore, the DCM operation can be avoided.

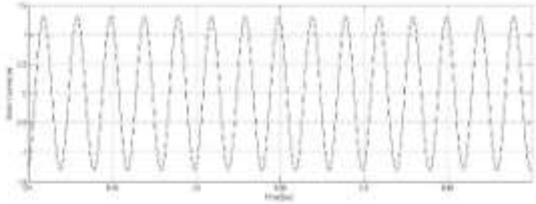

Fig.25. Stator Current

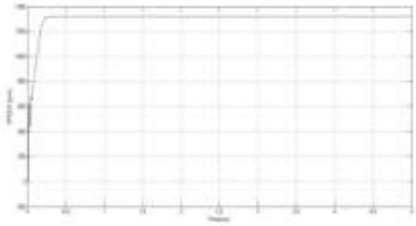

Fig.26. IM Speed Curve

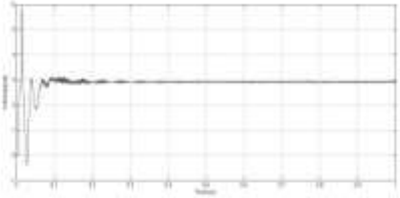

Fig.27. IM Torque Curve

Fig.25, 26, and 27 respectively shows the induction motor stator current, speed and torque, which are obtained around the rated value.

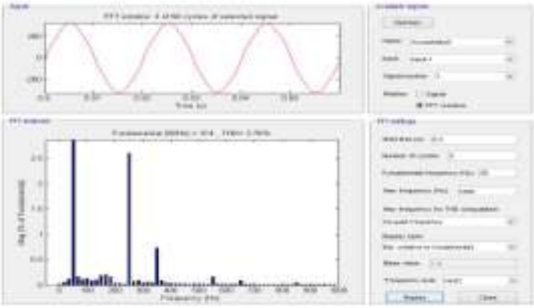

Fig.28. Voltage THD

From the simulation results in fig (28), it is observed that the fundamental value of filtered voltage for Induction machine of 0.5 HP is 314 V with THD 2.76 %. This is within the limits of IEEE519.

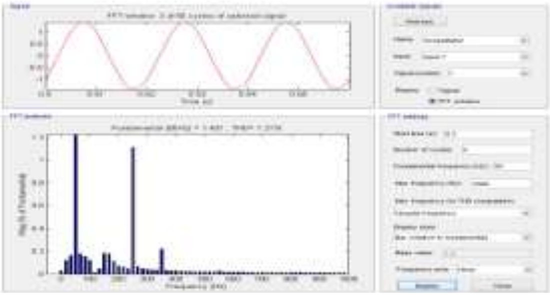

Fig.29. Current THD

From the simulation results in fig.29, it is observed that the fundamental value of filtered current for Induction machine of 0.5 HP is 1.43 A with THD 1.21 %. This is within the limits of IEEE519.The reverse power flow capability of the BQZSI is then examined. The BQZSI is connected to a three-phase adjustable voltage source through a three-phase reactor. A dc load is used at the dc input side to emulate the battery pack. The dc load is working under constant voltage mode with fixed voltage of 200 V. The shoot through duty ratio is 0.25 and the dc bus voltage is boosted to 400 V. Fig. 30 shows the input load voltage, voltage across the switch S_7 and the dc-link voltage of the BQZSI during reverse power flow mode.

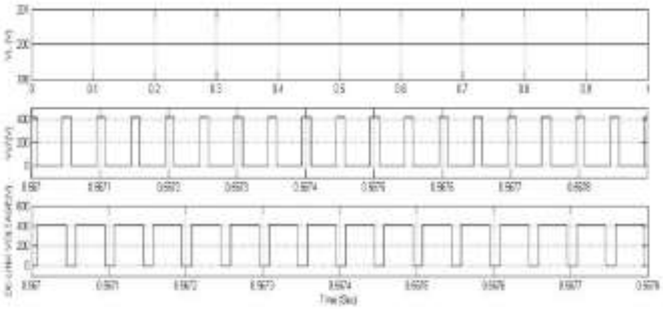

Fig.30: Load Voltage, Vs7, DC-Link Voltage During Reverse Power Flow

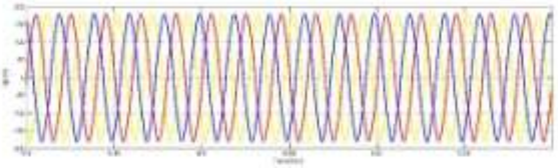

Fig.31: Phase Voltage During Reverse Power Flow

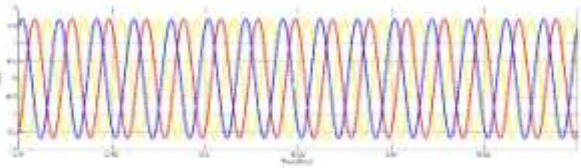

Fig.32: Phase Current During Reverse Power Flow

IV. CONCLUSION

A close study of all the relevant topologies reveals that the modifications are motivated by one or more of the following reasons:

1. Improves efficiency
2. Increase the voltage gain
3. Reduces the voltage stress across the switching devices.
4. Optimal utilization of input voltage to maximize the output voltage.

The operation mode analysis shows that by replacing the diode in the QZSN with an active switch, the reverse power flow can be realized with the QZSI and induction motor can have a better operating condition. Moreover, the current through the inductors are continuous, therefore, DCM can be avoided. By using maximum constant boost control with third harmonic injection reduces the voltage stress across the switching devices and THD is also found to be very less, which is within limits of IEEE519. So the performance of the inverter can be improved.

ACKNOWLEDGMENT

It is my proud privilege to express my sincere gratitude and deep indebtedness to the people who helped me to complete this paper successful. I give my esteemed gratitude to **Divyalal R K,** Asst. Professor, Department of Electrical and Electronics Engineering GCE Kannur, for motivating, encouraging and supporting me in completion of my theses.I am thankful to **Dr. T D. John,** Principal GCE Kannur and Dr.Shahin M, the Head of the Department of Electrical and Electronics Engineering GCE Kannur, for their valid inspiring directions for the preparation of this paper. I express my thanks to all my friends for their enthusiastic encouragement and full support. More than anybody else, I am grateful to my parents for their encouragement, support and blessing.

REFERENCES

[1] F. Z. Peng, "Z-source inverter," IEEE Transaction on Industry Applications, vol. 39, no. 2, pp. 504–510, Mar./Apr. 2003.

[2] H. G. Sarmiento and E. Estrada, "A Voltage Sag Study in an Industry with Adjustable Speed Drives," IEEE Industry Applications Magazine, vol. 2, pp. 16- 19, 1996.

[3] A. Van Zyl, R. Spee, A. Faveluke, and S. Bhowmik, "Voltage Sag Ride-Through for Adjustable-Speed Drives with Active Rectifiers," IEEE Transactions on Industry Applications, Vol. 34, No. 6, pp. 1270-1277, 1998.

[4] Y. Kim and S. SUI, "A Novel Ride-Through System for Adjustable-Speed Drives Using Common-Mode Voltage," IEEE Transactions on Industry Applications, Vol. 37, No. 5, pp. 1373-1382, 2001.

[5] J. Popovi´c-Gerber, J. Ferreira, and J. Wyk, "Quantifying the value of power electronics in sustainable electrical energy systems," IEEE Transaction on Power Electronics., vol. 26, no.12, pp. 3534–3544, Dec. 2011.

[6] J. Popovi´c-Gerber, J.Oliver, N. Cordero,T. Harder, J.A.Cobos, M.Hayes, S. O'Mathuna, and E. Prem, "Power electronics enabling efficient energy usage: Energy savings potential and technological challenges," IEEE Transaction on Power Electronics, vol. 27, no. 5, pp. 2338–2353, May 2012.

[7] J. Anderson and F. Z. Peng, "Four quasi-Z-source inverters,"in Proceedings of IEEE Power Electronics Spec. Conf., Rhodes, Greece, pp. 2743–2749,Jun. 2008.

[8] Kai Deng, Jun Mei, JianyongZheng, Wei He, and HupingBao, "An Improved switched inductor quasi-Z-source inverter," in 2013 International Future Energy Electronics Conference ,pp. 354-358,april 2013.

[9] F.Ahmed, Honnyong Cha, Su-Han Kim, and Heung-Geun Kim, "A high voltage gain switched-coupled-inductor quasi-Z-source inverter," in 2014 International Power Electronics Conference (IPEC-Hiroshima 2014-ECCE-ASIA), pp. 480-484,2014.

[10] Wei Qian, Fang ZhengPeng, and Honnyong Cha, "Trans-Z –Source Inverters," IEEE Transactions on Power Electronics, vol.26, no.12, pp.3453-3463, Dec.2011.

[11] M. Adamowicz, "LCCT-Z-Source inverters," in 2011 International Conference on Environment and Electrical Engineering, pp. 1-6,2011.

[12] M.K., Nguyen, Y. C. Lim, and Y. Kim, “TZ-Source Inverters,” IEEE Transactions on Industrial Electronics, vol.60,no.12, pp. 5686-5695,Dec.2013.

[13] Shuai Jiang, Dong Cao, and Fang Z. Peng, “High frequency transformer isolated Z-source inverters, ” In IEEE 2011 Applied Power Electronics Conference and Exposition (APEC),pp.442-449,2011.

[14] M. Shen, A. Joseph, J.Wang, F. Z. Peng, and D. J. Adam,“Comparison of traditional inverters and Z-source inverter for fuel cell vehicles,” IEEE Power Electronics Transaction, Novi, MI, pp. 1453–1463, Oct. 2004.

[15] C. J.Gajanayake, Fang Lin Luo, H.B. Gooi, Ping Lam So, and Lip KianSiow, “Extended-Boost Z-Source Inverters,” IEEE Transactions on Power Electronics,vol.25,no.10,pp. 2642-2652, Oct.2010.

[16] D.Vinnikov., I. Roasto, R. Strzelecki, and M. Adamowicz, “Step-Up DC/DC Converters with Cascaded Quasi-Z-Source Network,” IEEE Transactions on Industrial Electronics, vol. 59,no.10, pp.3727-3736,Oct.2012.

[17] H. Xu, F. Z. Peng, L. Chen, and X. Wen, “Analysis and design of bidirectional Z-source inverter for electrical vehicles,” in Proc. IEEE 23rd Appl. Power Electron. Conf. Expo., Austin, TX, pp. 1252–1257, Feb. 2008.

[18] M. Yamanaka and H. Koizumi, “A bi-directional Z-source inverter for electric vehicles,” in Proceedings of International Conference on Power Electronic Drive System., pp. 574–578, Nov. 2009.

[19] S. Rajakaruna and B. Zhang, “Design and control of a bidirectional Z source inverter,” in Proceedings Power Engineering Conference, pp. 1–6, Sep. 2009.

[20] M. Yamanaka and H. Koizumi, “A bi-directional Z-source inverter for electric vehicles,” in Proc. International Conference Power Electronic Drive System, pp. 574–578, Nov. 2009.

[21] D. WNovotny and T. A. Lipo, Vector Control and Dynamics of AC Motor. London, U.K: Oxford Univ. Press, 2000

[22] Y. Liu, B. Ge, F. Z. Peng, A. R. Haitham, A. T. de Almeida, and F. J. T. E. Ferreira, “Quasi-Z-source inverter based PMSG wind power generation system,” in Proceedings of IEEE Energy Convers. Congr. Expo., pp. 291–297, Sep.2011.

[23] C. J. Gajanayake, D. M. Vilathgamuwa, and P. C. Loh, “Development of a comprehensive model and a multi loop controller for Z-source inverter DG systems,” IEEE Transaction on Industry Electronics, vol. 54, no. 4, pp. 2352–2359,Aug. 2007.

[24] O. Ellabban, J. Van Mierlo, and P. Lataire, “A DSP-Based dual-loop peak DC-link voltage control strategy of the Z-source inverter,” IEEE Transaction on Power Electronics, vol. 27, no. 9, pp. 4088–4097, Sep. 2012.

[25] X. Ding, Z. Qian, S. Yang, and F. Z. Peng, “A new feed forward compensation to reject dc-link voltage ripple in bi-directional Z-source inverter ASD system,” in Proc. IEEE 23rd Annu. Appl. Power Electron. Conf.Expo, pp. 1809–1813, Feb. 2008.

[26] Loh P. C., Vilathgamuwa D. M., Lai Y. S., “Pulse-width modulation of Z-source inverters”, IEEE Transactions on Power Electronics, vol. 20, no. 6, pp. 1346-1355, 2005.

[27] N. Muntean, L. Tutelea, and I. Boldea, "A modified carrier - based PWM modulation technique in Z - source inverters," in International Aegean Conference on Electrical Machines and Power Electronics. ACEMP '07, pp. 174-180,2007.

[28] L. Calderone, L. Pinola, and V. Varoli, “Optimal feed-forward compensation for PWM DC/DC converters with “linear” and “quadratic” conversion ratio,” IEEE Transaction on Power Electronics, vol. 7, no. 2, pp. 349–355, Apr. 1992.

[29] F. Z. Peng, M. Shen, and Z. Qian, “Maximum boost control of the Z-source inverter,” IEEE Transaction on. Power Electronics, vol. 20, no. 4, pp. 833–838, Jul. 2005.

[30] MiaosenShen, Jin Wang, Alan Joseph, Fang Zheng Pang, Leon M. Tolbert, Donald J. Adams, “Constant boost control of the Z-source inverter to minimize current ripple and voltage stress”, IEEE transactions on Industry Applications, Vol.42, No.3, May/June 2006.

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