International Journal of Power Electronics and Drive System (IJPEDS)
Vol. 7, No. 4, December 2016, pp. 1228~1232
ISSN: 2088-8694, DOI: 10.11591/ijpeds.v7i4.pp1228-1232

A DC Inrush Current Minimisation Method using Modified Z-source Inverter in Adjustable Speed Drives

S. Renukadevi, M. Rathinakumar
Department of Electrical and Electronics Engineering, SCSVMV University, India

Article Info

Article history:

Received Apr 6, 2016
Revised Nov 11, 2016
Accepted Nov 23, 2016

Keyword:

ASD
DC inrush current
Modified ZSI
Z-source inverter

ABSTRACT

The adjustable speed drives employ PWM converter-inverter system in order to obtain unity power factor. The DC inrush current in DC link capacitors of the rectifier limits the operation of power devices. Hence, this paper proposes a new approach to reduce the DC inrush current by employing modified Z-source inverter in a Adjustable Speed Drive system. The operating principles, design procedure and simulation results are shown and compared with the conventional Z-Source inverter.

Corresponding Author:

S. Renukadevi,
Departement of Electrical and Computer Engineering,
SCSVMV University, Nether, Kanchipuram- 62102, Tamilnadu, India.
Email: renukaeee15@gmail.com

1. INTRODUCTION

The adjustable speed drives are now adays widely spread in industrial applications. This system draws harmonic current by the front-end rectifiers which affect the utility grid.ASD's are more sensitive to voltage sags, one of the most prominenet power quality problem the ASD's experiences [15]. Also, the rectifiers in front-end employ bulk capacitors which draws large amount of current to charge due to which large inrush current flows. The inrush current affects the power devices and leads to large voltage and current surge. The inherent inrush current in the DC link capacitors makes the back-end inverter not to achieve the soft-start capability [4]. Z-source inverter is a topology to achieve both buck and boost operation in converting power [1]. This topology does not requires dead time and hence distortion in the output is reduced. But this traditional Z-source inverter requires bulk capacitors as the voltage across the capacitance is greater than the input voltage. And also, it has high inrush current which damages the power devices. A boost converter between the rectifier and the Dc-link capacitors can be used to maintain the Dc bus voltage during voltage sag [8]. Even though this method provides ride through with lower cost, it fails during outages [1]. The diode rectifier can be replaced with an PWM rectifier in order to provide ride through up to 50% sag but it also fails during outages [1]. Vienna rectifier is a boost type three level converter [10]. Single phase neutral linked Vienna rectifier is a combination of a single phase AC/DC boost converter and a neutral link [11]. The neutral in the Dc bus doubles the voltage and acts as a voltage doubler [12]. This modified topology of Vienna rectifier has n advantage of low harmonic injection, controlled output voltage and power factor improvement [10]. The Dc link also gets affected by the voltage sag and hence the back end inverter Due to the above mentioned demerits many research area focuses on other derived topologies [2]-[7]. The drawbacks in Z-source inverter can be reduced by replacing traditional Z-Source inverter with modified Z-source inverter. This modified topology has reduced voltage stress across the capacitirs and provides limitation in inherent inrush current during startup. Some of have concentrated on inducing PWM strategies into ZSI topologies, applicatios, modelling and control [8]-[4].

2. CONVENTIONAL ZSI TOPOLOGY

The Conventional Z-Source inverter shown in Figure 1 in which the unique impedence network couples the DC supply source with the main circuit of the inverter. The impedence network contains two similar inductors L1 and L2 and two similar capacitors C1 and C2 which are connected in X model. This ZSI is a single stage power conversion topology which can buck and boost the input voltages. It also contains a shoot through zero state in addition which is responsible to boost the input dc voltage. Circuit diagram of Adjustable Speed Drive with ZSI as shown in Figure 2.

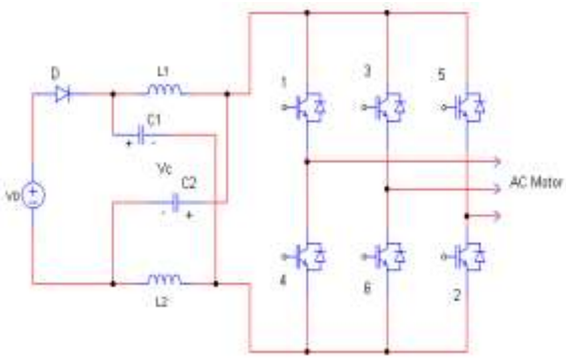

Figure 1. Z-Source inverter

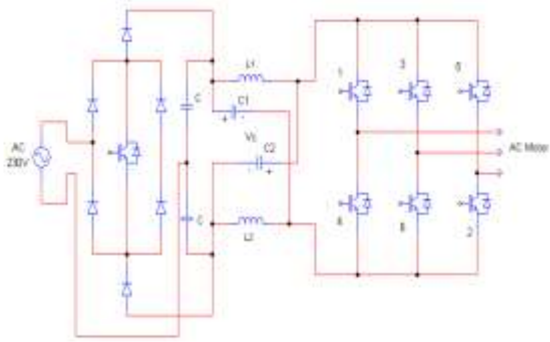

Figure 2. Circuit diagram of Adjustable Speed Drive with ZSI

3. MODIFIED Z-SOURCE INVERTER

The Figure 3 shows the model of adjustable speed drive with modified Z-source inverter. The components used in this modified Z-source inverter are same as the conventional Z-source inverter. The variation between the two topologies is the inverter bridge and diode positions are interchanged and directions of their connections are reversed. This modified Z-source inverter topology has reduced inrush current when compared with the conventional topology. This feature is due to no current path at start up.

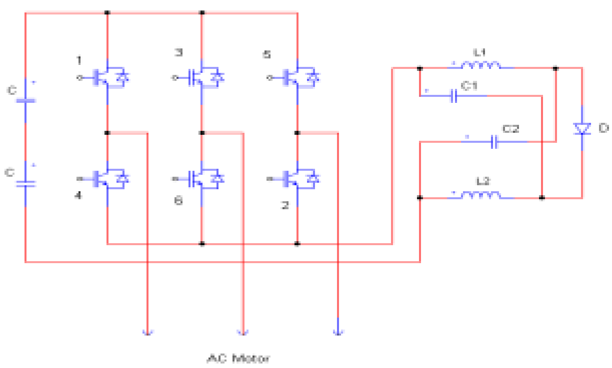

Figure 3. Circuit diagram of Modified Z-Source inverter

4. OPERATION AND PRINCIPLE

Considering the inductors and capacitor values in the impedance network we have,

$$L1=L2,\ C1=C2,\ V_{L1}=V_{L2}=V_L \text{ and } Vc_1=Vc_2=Vc \quad (1)$$

During the shoot through state, we get

$$V_L = V_{dc} + V_C \tag{2}$$

The inverter side is shorted during this state.
During non-shoot through state, we get

$$V_L = -V_C \tag{3}$$

If the duty ratio in the shoot through state is D_o and the average value of V_L is zero, we get

$$V_c = \frac{D_o}{1-2D_o} \tag{4}$$

The above equation prove that in the modified topology, when D_o is zero, the capacitor voltage of the impedance network V_C becomes zero. So, if D_o is gradually increased and thus sof start can be achieved. The maximum DC link voltage across the inverter input can be given as,

$$V_{mn} = \frac{1}{1-2D_o} V_{dc} \;=\; BV_{dc} \tag{5}$$

Where B is boost factor.
The maximum utput phase voltage can be given as

$$V_m = MB\frac{V_{dc}}{2} \tag{6}$$

Where M is modulation ratio.

4.1. Inrush Current

From the equation (4) the capacitor voltage during start up is zero as the shoot through duty ratio D_o is zero. Thus, this modified topology hase inherent limitation ability to the inrush current.

4.2. Z-Source Capacitor Voltage Stress

The peak value of dc-link voltage in both the topologies are same and the capacitor voltage can be decreased by V_o whereas the voltage boost is maintained constant. In the conventional topology, the capacitor voltage stress is decided by minimum input voltage to obtain maximum boost in the output voltage. Thus, modified topology has reduced voltage stress across the capacitor andhence low value capacitors can be utilised.

5. SIMULATION RESULTS

The simulation results of conventional ZSI is shown in the Figure 4. It depicts the dc link current of the DC link capacitors in a adjustable drive system with conventional ZSI at its back end. The Figure 5 shows the simulation results of modified ZSI. The ASD system in both the cases is considered with single phase Vienna rectifier with neutral linked at its fron end. The smulaton results are compared and tabulated in the Table 1. The Dc lnk voltage durng normal and sag condition is mentoned in the Table 1. For the continous operation of ASD Dc link voltage of 315V s sufficient. So, from the Table1 it is clear that both the confguratons of ASD are suitable for mitgating voltage sag but the ASD with modified z-source inverter at the back end proves to be with reduced dc inrush current and hence it can reduce the stress over the power devices.

Table 1. Dc Link Voltage & DC Inrush Current

Topology	DC inrush current	DC link voltage	DC link voltage during sag
Conventional ZSI	10A	455V	315
Modified ZSI	2.6A	455V	325

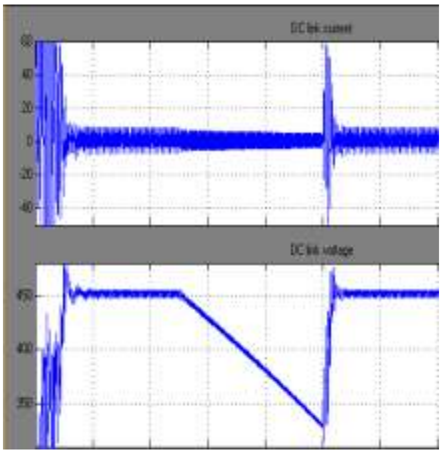

Figure 4. Dc link voltage and current of conventional Z-Source inverter in ASD

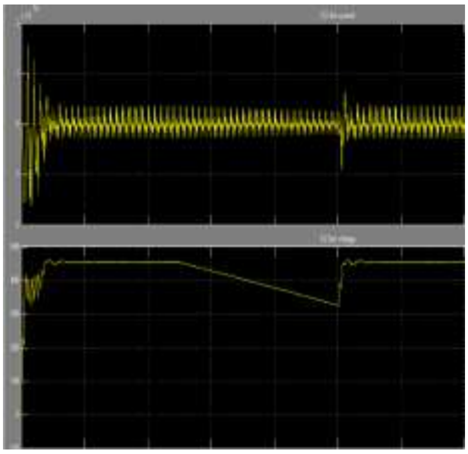

Figure 5. Dc link voltage an current of modified Z-Source inverter in ASD

6. CONCLUSION

This paper has discussed about modified Z-sourec inverter for adjustable speed drives. The simulation results are compared with the conventional Z-source inverter topology and it has the following merits.

a. Inorder to obtain similar boost ability the capacitor voltage stress is extremely reduced.
b. The reduced capacitor voltage stress leads to use low-voltage capacitors which also decreases the cost and volume of the system.
c. The soft start strategy suppreses dc inrush current to the inverter system.

REFERENCES

[1] F.Z. Peng, "Z-source inverter", *IEEE Trans, Ind. Appli*., vol. 39, no. 2, pp. 504-510, Mar/Apr. 2003.

[2] J.C. Rosas-Caro, F.Z. Peng, H. Cha and C. Rogers, "Z-source-converter-based energy-recycling zero voltage electronic load", *IEEE Trans. Ind. Electron*., vol, 56, no. 12, pp. 4894-4902. Dec. 2009.

[3] D. Vinnikov, I. Roasto, "Quasi-Z-source-based isolated DC/DC converters for distributed power generation", *IEEE Trans. Ind Electron*. vol. 58. no. 1, pp. 192-201, Jan. 2011.

[4] D. Vinnikov, I. Roasto, R. Strzelecki, and M. Adamowiez, "Step-up DC/DC converters with cascaded quasi-Z-source network", *IEEE Trans. Ind Electron.* vol. 59. no. 10 pp. 3727-3736, Oct. 2012.

[5] B Zhao, Q. Yu. Z. Leng, and X. Chen, "Switched Z-source isolated bidirectional DC-DC converter and its phase-shifting shoot through bivariate coordinated control strategy", *IEEE Trans. Ind. Electron* vol. 59. no. 12, pp. 4657-4670, Dec. 2012.

[6] M.K. Nguyen. Y.C. Lim, and Y.J. Kim, "A modified single phase quasi-Z-source AC-AC converter", *IEEE Trans. Power Electron*. vol. 27, no. 1, pp. 201-210, Jan. 2012.

[7] J. Anderson and F.Z. Peng, "*Four quasi-Z-source inverters",* in Proc. IEEE PESC, 2008, pp. 2743-2749.

[8] F.Z. Peng, M. Shen nd Z. Qian, "Maximum boost control of the Z-source inverter", *IEEE Trans.Power Electron*. vol. 20, no. 4, pp. 833-838, Jul. 2005.

[9] M. Shen, J. Wang, A. Joseph, F.Z. Peng, L.M. Tolbert and D.J. Adams, "Constant boost control of the Z-source inverter to minimise current ripple and voltage stress", *IEEE Trans. Ind. Appl*, vol. 42, no. 3, pp. 770-778, May-Jun. 2006.

[10] C.J. Gajanayake, D.M. Vilathgamuwa, and P.C.Loh, "Development of a comprehensive model and a multiloop controller for Z-source inverter DG systems", *IEEE Trans. Ind. Electron*. vol. 54, no. 4, pp. 2352-2359, Aug. 2007.

[11] M.K. Nguyen.Y.C. Lim, and Y.J. Kim, "A modified single phase quasi-Z-source AC-AC converter", *IEEE Trans. Power Electron*. vol. 27, no. 1, pp. 201-210, Jan. 2012.

[12] M. Shen, F.Z. Peng, "Operation modes and characteristics of the Z-source inverter with small inductance or low power factor", *IEEE Trans. Ind. Electron.* vol. 55, no. 1, pp. 89-96, Jan. 2008.

[13] Arasakumar sangari and R. Umamaheswari, "Analysis of impedance source inverter topologies for grid integration of pv inverter", *Internatonal Journal of Power Electronics and Drive Systems (IJPEDS),* vol. 6, no. 4, pp. 797-807, Dec. 2015.

[14] Hamid Reza Mohammadi, Ali Akhavan, "A new control method for grid conneceted PV system based onquasi-z-source cascaded multilevel inverter using evolutionary algorithm", *Internatonal Journal of Power Electronics and Drive Systems (IJPEDS),* vol. 6, no. 1, pp. 109-120, March. 2015.

[15] S. Dahiya, D.K. Jain, Ashokkumar, R. Dahiya and S.S. Deswal, *et al.*, *"Improvement of Adjustable Speed Drives (ASD's) Performance During Sag Conditions Using Ultracapacitors"*, IEEE conference, pp.1-4, 2008.

BIOGRAPHIES OF AUTHORS

Mrs. S. Renukadevi, born in Kalpakkam, Tamilnadu, India, on July 04, 1979. She graduated from JJ College of Engineering and Technology, affiliated to Bharadhidhasan University under Electrical and Electronics Engineering in the year 2000. She obtained her post graduation in Power Electronics and Industrial Drives from Sathyabama University in the year 2009. She has put around 9 years of experience in teaching Electrical Engineering. Her areas of interest are Power Electronics and Industrial Drives. Presently she is working as Assistant Professor in the Department of Electrical and Electronics Engineering SCSVMV University, Enathur, Kanchipuram, Tamilnadu, India.

Dr. M. Rathinakumar, born in Madurai, Tamilnadu, India, on July 19, 1969. He graduated from Thiyagarajar College of Engineering, affiliated to Madurai Kamaraj University under Electrical and Electronics Engineering in the year 1994. He obtained his post graduation in Power Systems from the same University in the year 1995. He obtained his Ph.D from SCSVMV University, Enathur, Kanchipuram, Tamilnadu, India in the year 2010. He has put around 16 years of experience in teaching Electrical Engineering. His areas of interest are Power systems, Power Quality, Power System Operation and Control. Presently he is working as Professor and Head in the Department of Electrical and Electronics Engineering SCSVMV University, Enathur, Kanchipuram, Tamilnadu, India.