Under Voltage SAG Conditions, Improved ASD Performance

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ABSTRACT: *Process control and energy conservation are the two primary reasons for using an adjustable speed drive (ASD). However, voltage sags are the most important power quality problem facing many commercial and industrial customers. Voltage sag problem arise because of transients in supply voltage by the usage of heavy inductive loads. Adjustable Speed Drives (ASD) is the emerging trend in the induction motor research to improve the performance during voltage sag conditions. The ride through capability of the induction motor during voltage sag is taken into account that duration of the ride-through operation depends on the initial motor flux, speed level, rotor time constant, load torque and inertia. Also Inverter design mainly affects the motor performance. A new combination technique has been proposed for the mitigation of voltage sag on adjustable speed drive. Simulation results are illustrated for the proposed techniques. It is highlighted that the waveform generated by the new technique is efficient with the reduction of the effect of voltage sag.*
Keywords: *Adjustable speed drive, Voltage sag, Z-source inverter, Neutral linked Vienna rectifier.*

I. INTRODUCTION

AC Adjustable Speed Drives (ASDs) become very popular variable speed control drives used in industrial, commercial and residential applications. These systems are fairly expensive but provide a higher degree of control over the operation and in many cases reduces the energy. ASD allow precise speed control of a standard induction motor and can result in significant energy savings and improved process control in many applications. Voltage sag is the most important PQ problem affecting industrial and large commercial customers and some cases it leads the shutdown problems in industry. This event is usually associated with a fault at some location in the supplying power system. Reduction in RMS supply voltage between 0.1 and 0.9 per unit with duration of 0.5 cycles to 1min is called voltage sag. This voltage sag affects the operation of motor drive system. Different types of voltage sag and their effect over the induction motor drive has been explained in previous research [2]. Sudden and sharp variation of current may cause triggering of protection system. Diverse torque peaks during motor's life can weaken motor's shaft and variation of speed damage the final product in different applications. A critical evaluation method over ASDs results that ASDs are very sensitive to voltage sags and swell [6] and the behavior of three phase AC ASDs during balanced and unbalanced sags also analyzed [7].

The Z-source inverter system employs a unique LC network in the DC link and small capacitors on the AC side of the diode rectifier in the front end. By controlling the shoot through duty cycle, the Z-source can produce any desired output AC voltage, even greater than line voltage. It able to provide ride-through during voltage sags without any additional energy storage elements. Improves power factor, reliability reduces harmonic current and extends output voltage range [3] [4] [5]. The improved Z-source inverter with reduced Z-source capacitor voltage stress also provides the better ride through capability to the drive systems used in industry [9] and the design calculation of Z-source network also detailed in earlier research [11]. Vienna rectifier is a combination of a single phase AC/DC boost converter with a neutral link provides a new topology [12]. Technical and economical advantageous of this type of rectifier can briefly be noted as, low harmonic injection to the main, controlled output voltage, high efficiency, high reliability, low voltage stress on power semiconductors [8]. The energy transmitted from the power station indeed involves voltage droop that often does not match the requirements of various electrical equipment. Voltage sag problem will also occur in the DC link and hence it will affect inverter which is present in the back end of the ASD. Because of the voltage sag in the inverter, switching pattern problem will occur due to that it will affect the motor resulting in reduction of speed of the motor. Voltage sag problem of power quality is improvised by a Z-source inverter rather than traditional inverter and also switching pattern problem will be reduced and improves the ride through capability of the system. In order to reduce the voltage sag problem in DC link, it should be controlled in the front end itself [13]. It is expected that the efficiency of the system can be improved by using Vienna rectifier in the front end with neutral link connection and Z-source inverter as the back end.

II. DESIGN METHODOLOGY

ZSI and Vienna Rectifier for ASD

Vienna rectifier is a combination of a single phase AC/DC boost converter provides a new topology. The DC output is obtained across DC link capacitor. This capacitor is used to filter out the AC ripple components present in the output of the rectifier. It is also used to prevent the rapid voltage change because of its split capacitor arrangements with the value double than normal rectifier. The neutral link connection in between the split capacitor of the Dc link provides suitable voltage to the inverter and provides the nominal and ride through voltage to the inverter. The Z-source network is a combination of two inductors and two capacitors. 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 Z-source inverter system provides ride through capability during voltage sag, reduces line harmonics, improves power factor and reliability and extends output voltage range.

Design Calculation of ZSI and DC link capacitor

From the circuit of Z network we found that, shoot through (To) and non shoot through (T1) state timings are the important factor to find the voltage across inductor and capacitor of the Z network. It gives the equation to find the maximum DC link voltage across the Dc link capacitor [11],

Vi =Vc-V L = 2Vc-Vo= T / (T1-To) X (B X Vo)

Where B is the Boost factor resulting from shoot through state. The output peak phase voltage can be expressed as

V AC= M X B X (Vo/2)

And BB= M X B= (0 to 8) where BB is the appropriate buck-boost factor. The value of the inductor and capacitor are greatly depends up on the rating of the motor whose speed is to be regulated. Therefore the motor ratings are, 3-phase induction motor, star connected. Power-0.75KW, Speed - 1390 rpm Voltage - 415V, Current - 1.80 A Frequency - 50Hz, Efficiency - 75% The average current through the inductor equals to that trough the diode, which is

I L=P/Vin

I L= 0.75 X 10^3/230 = 3.26 A.

The maximum current through the inductor occurs when the maximum shoot-through happens, which causes maximum ripple current. In this design, 30% (60% peak to peak) current ripple through the inductors during maximum power operation was chosen. Therefore, the allowed ripple current is 30% and the maximum current through the inductor is 3.26 A. the maximum operating voltage applied is 400V.

1/ (1-2Do) = 400/230, Do=0.2125

For a switching frequency of 10 kHz, the shoot-through time per cycle is 21.25μs. The capacitor voltage during that condition is
Vc = 230 X (1-Do)/ (1-2Do) = 315V.

I L= ToVc/L => L= ToVc/IL
To keep the current ripple less than 30 % (0.978˜1A),
 L = (21.25 X 10^-6 X 315) / (0.978) = 6.8 mH
The purpose of the capacitor in the Z-source network is to absorb the current ripple and to maintain a fairly constant voltage so as to keep the output voltage sinusoidal. During shoot through, the capacitor charges the inductors, and the current through the capacitor equals to the current through the inductor. Therefore, the voltage ripple across the capacitors can be roughly calculated by
Vc = (Iav x T0) / C
To limit the capacitor voltage ripple to 0.015 %at peak power, the required capacitance is C = (3.26 X 21.25 X 10^-6)/ (315 X 0.015 %) = 1026.29μF ˜ 1000 μF. The DC link capacitor value is calculated by using Millman's equation assuming the ripple factor value as 0.2 and resistance of load 1000 ,
ro= 1 / (4v3FCR)

C is approximately 1000 µF but for Vienna rectifier that value should be two times of the normal Dc link capacitor when it is used as split capacitor. So here we consider the split capacitor value as 2000 µF.

III. PROPOSED NEUTRAL LINKED VIENNA RECTIFIER COMBINED ZSI FED ASD

Vienna rectifier is a combination of a boost DC/DC converter series with a single phase rectifier provides a new topology. It's a single-phase, single-switch rectifier. It can be seen as a diode bridge rectifier with an integrated boost converter. The Vienna rectifier is useful wherever six switch converters are used for achieving sinusoidal mains current and controlled output voltage, when no energy feedback from load into the mains is required. The Vienna rectifier comprises a semiconductor switch in each phase leg of 1- phase Diode Bridge. By using Pulse Width Modulation (PWM) technique that turns on the semiconductor switch, the corresponding line current is forced to be sinusoidal and in phase with the voltage. The great advantageous of this type of rectifiers are, low harmonic injection to the main, controlled output voltage, high efficiency, high reliability, low voltage stress on power semiconductors. The harmonic distortion is also very less when Vienna rectifier is used. It is a highly efficient method of high current, single-phase AC/DC conversion and is very useful for achieving unity power factor correction. The circuit diagram of adjustable speed drive in combination of Neutral linked Vienna rectifier and Z-source inverter under sag condition (approximated sag produced in the input supply side) which was shown in the Fig.1. Single phase AC voltage is the source for the Vienna rectifier and the output of the Vienna rectifier is the input for the Z-source inverter. The input for the Z-source inverter is taken from the two split capacitors of Vienna rectifier. The three phases induction motor which was connected to the Z-source inverter without LC filter.
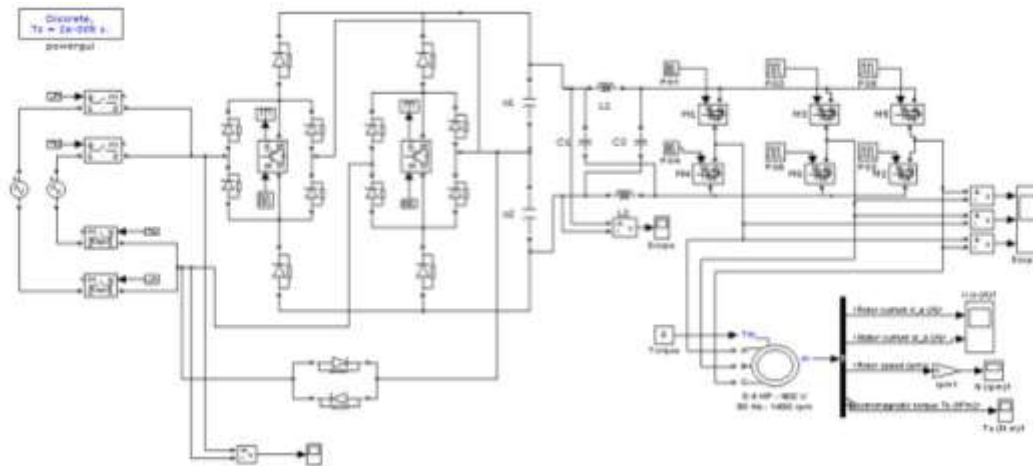

Fig.1 Circuit diagram of Neutral linked Vienna Rectifier combined Z-Source inverter fed IM drive

IV. EXPERIMENTAL RESULTS

The results are compared, shows Fig.2, which explains the DC link output voltage for normal rectifier under sag condition. It depicts voltage level during both normal and sag. Under sag the voltage lying at less than 50. In Fig.3, shows the DC link voltage, which proves that the neutral link provides the voltage doublers than the normal rectifier. Therefore during sag period the DC link voltage is considerably nominal to 280V which would not affect the performance of the motor and only minimum variation in the speed of the motor. Waveforms comparisons are shown in Table.1
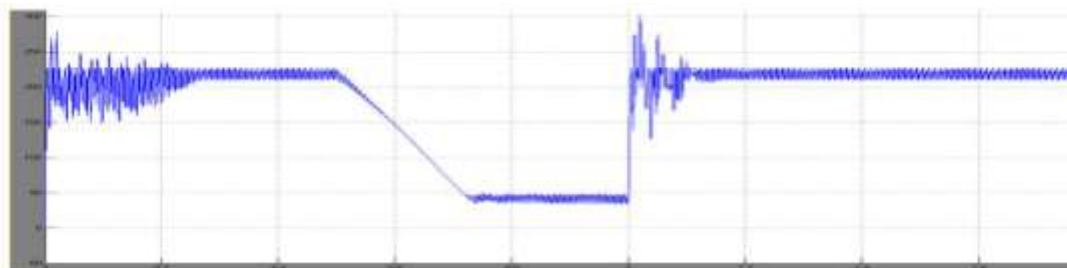

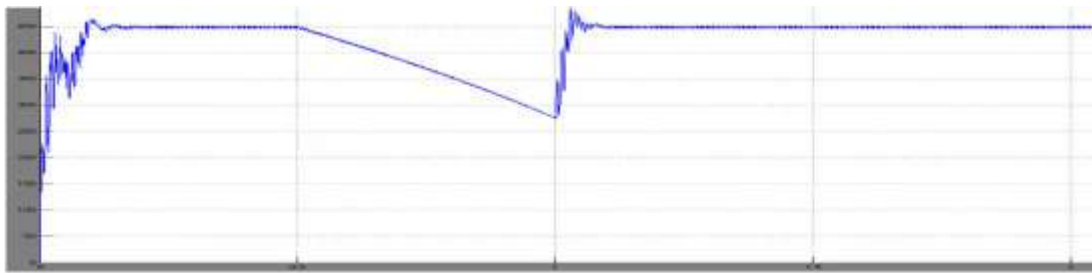
Fig.2 DC link capacitor voltage of normal rectifier

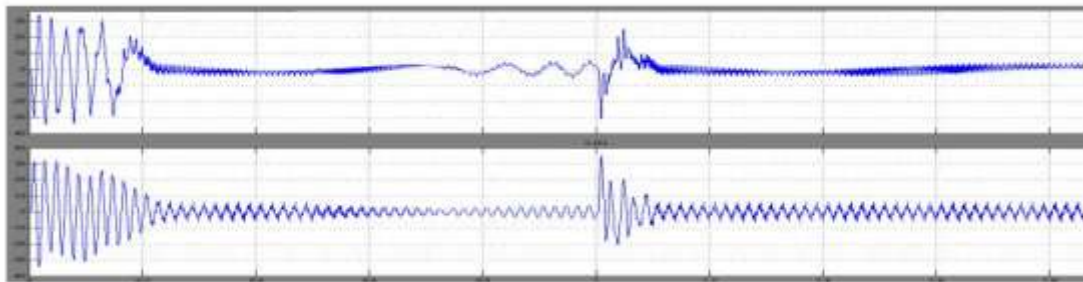**Fig.3** DC link capacitor voltage of Vienna rectifier

Fig.4 Rotor and Stator current waveforms of normal rectifier and inverter fed IM
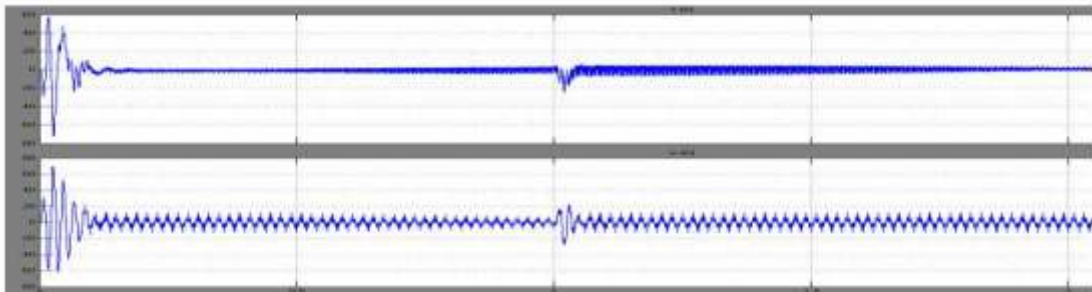

Fig.5 Rotor and Stator currents of Neural linked Vienna rectifier and ZSI fed IM

Table 1. Result analysis of the waveform

	During voltage sag condition for normal system	During voltage sag condition for normal system with Z source inverter	During voltage sag condition neural linked Vienna system with Z source inverter
Stator and rotor currents	Ir oscillating in between zero & it disturbs the speed of the motor	Ir oscillating in between zero & it disturbs the speed of the motor	Is varies from 12A – 6A during sag, but provides stable condition
Rotor Speed	1490 – 980 rpm	1490 – 990 rpm	1490 – 1470 rpm
DC link voltage	227 V – 47V	228.5 V – 48.5 V	450V–150V
DC link voltage variation	Reduced less than 50V at 0.6 seconds and stays up to 0.4 seconds. That gives reduction in motor speed	Reduced less than 50V at 0.74 seconds and stays up to 0.36 seconds. That gives reduction in motor speed	Provides series connection of Vienna and a half-wave rectifier which doe DC link voltage than normal configuration

V. CONCLUSIONS

The simulation results are analyzed for the combination of neutral linked Vienna rectifier with Z-source inverter. These outputs which are compared with the circuit in the combination of diode rectifier and Z source inverter, without Vienna rectifier combination the motor speed reduced rapidly during sag. This affects the drive

and in turn, the process stops, but this power quality problem can be resolved by the new combination of Neutral linked Vienna rectifier with Z-source inverter provides double the voltage than normal system across DC link capacitor and proves the better performance of the motor even at sag conditions.

REFERENCES

[1]   Amitava Das, S.Chowdhury, S.P, Chowdhury, Prof.A.Domijan (2008) "Performance Analysis of Z-source inverter Based ASD system with reduced Harmonics" IEEE transaction on power electronics, Vol 15, No.5, Nov, pp 1 – 7

[2]   Farahbakhsh.A and Jalilian.A (2007) 'Operation of induction motor under different voltage sag conditions', IEEE transaction on power electronics, Vol 20, No. 7, April, pp 1074 - 1082

[3]   Fang Z.Peng (2002) "Z-Source inverter" IEEE transaction on power electronics, Vol 10, No.6, April, pp 775 – 781

[4]   Fang Z.Peng, Xiaoming Yuan, Xupeng Fang and Zhaoming Qian (2003) "Z-source inverter for Adjustable speed Drives", IEEE power electronics letters, Vol.1, No.2, June, pp 33 - 35

[5]   Fang Zheng Peng, Alan Joseph, Jin Wang, Miaosen Shen, Lihua Chen, Zhiguo Pan, Eduardo Ortiz-Rivera and Yi Huang (2005) 'Z-source inverter for motor drives', IEEE transaction on power electronics, Vol 20, No. 4, July, pp 857-863

[6]   Jose Luis Duran Gomez, Prasad N.Enjeti and Byeong ok woo (1999) "Effect of Voltage sags on Adjustable speed drives: A critical evaluation and an approach to improve performance" IEEE transactions on industry applications, Vol.35, No.6, Nov / Dec, pp 1440 -1449

[7]   Math H.J.Bollen and Lidong D.Zhang (2000) " Analysis of voltage tolerance of AC Adjustable speed drives for Three phase balanced and unbalanced sags" IEEE transactions on industry application, Vol.36, No.3, May / June, pp 904 - 910

[8]   Shahriyar Kaboli, Aras Sheikhi, Amir Hossein Rajaei (2009) 'Application of random PWM techniques for reducing the electromagnetic interference of Vienna rectifiers in distribution power system', IEEE transaction on power electronics, Vol 54, No. 6, (IPEMC 2009), pp 998-1003

[9]   Yu Tang, Shaojun Xie, Chaohua Zhang and Zegang Xu (2009) 'Improved Z-source inverter with reduced Z-Source capacitor voltage stress and soft-start capability', IEEE Transaction on power electronics, Vol 24, No. 2, Feb, pp 409-415

[10] Zhiqiang Gao, Ke Shen, Jianze Wang and Qichao Chen (2010) 'An improved control method for inductive load of Z-source inverter', IEEE transaction on power electronics, Vol 25, No. 4, Feb, pp 978-984

[11] Fang Z. Peng(2007)'Z-source inverter' IEEE Transaction on power electronics. pp 775-781.

[12] M.A Inayathullaah et al,' Single phase high frequency AC converter for induction heating application', International Journal of Engineering Science and Technology.Vol. 2 (12), 2010, 71917197

[13] Raju.N.R," Improving Voltage Sag Tolerance of Three-Phase ASDs Through Addition of Neutral Connection", 0-78037420-7/02, 2002 IEEE.

[14] Grzegorz RADOMSKY,"Analysis of Inverter" Electrical Power Quality and Utilization, journal vol. X1, no.1, 2005.

[15] P.H. Zope and Ajay Somkuwar, "Design and Simulation of Single Phase Z-Source Inverter for Utility Interface" International Journal of Electrical Engineering & Technology (IJEET), Volume 1, Issue 1, 2010, pp. 127 - 143, ISSN Print: 0976-6545, ISSN Online: 0976-6553

[15] Suresh Kamble, and Dr. Chandrashekhar Thorat, "Characterization of Voltage SAG Due to Balanced and Unbalanced Faults in Distribution Systems" International Journal of Electrical Engineering & Technology (IJEET), Volume 3, Issue 1, 2012, pp. 197 - 209, ISSN Print: 0976-6545, ISSN Online: 0976-6553