Quasi-Z Source Inverter fed Induction Motor Drive Control Using Fuzzy Logic Controller

U. Himalini[1] P. Vimala[2]
[1]UG Student [2]Associate Professor
[1,2]Department of Electrical & Electronics Engineering
[1,2]IFET College of Engineering, Villupuram, India

Abstract— This paper refer to about the control of the induction motor drive with the Quasi-Z Source inverter and the fuzzy logic controller, for the industrial application. The quasi-z source inverter (qzs-I), provides more advantages over the conventional inverter. It provides a balanced dc-link voltage and voltage boost ability, saves one-third modules, etc. However, the Quasi-Z source inverter still cannot overcome the recurrent & stochastic fluctuation. The obtained AC voltage must be pure sinusoidal. But it can't be obtained due to the presence of increased harmonic content in the existing system. In the proposed module, with the combination of Quasi-Z Source inverter and the Fuzzy Logic controller, controls the speed & torque characteristics through ATMEGA microcontroller 328. The impedance network used here, act as the filter and completely eliminates the harmonic content for the flexible operation of the drive.

Key words: Quasi-Z Source Inverter, Fuzzy Logic Controller, ATMEGA Microcontroller- 328, Voltage Sag, Speed-Torque Characteristics, Harmonic Elimination, L-C Network

I. INTRODUCTION

The variable speed induction drives finds more applications in transportation systems, home appliances, paper and textile mills, conveyors, elevators, etc. The use of variable speed motor drives is a growing trend in automotive and industrial applications, due to its guaranteeing increased efficiency, increased energy saving and higher versatility and flexibility. The Electric Power Research Institute in USA, reports that almost 60% to 65% of power generation is consumed by electric motor drives. In this 75% of electrical motor drives are pump, fan and compressor – type drives. The back-back converter, which is formed by two voltage – source inverter (VSI) bridges together at their dc – link, is commonly applied in many motor drive applications. One of the convertors operates in the rectifying mode, whereas the other convertor operates in the inverting mode. The voltage in the dc – link must be higher than the peak line to line voltage to achieve full control of the motor drive speed – torque characteristics. Even though the back to back convertor is a well-proven topology, still it has more limitations.[1] Further it has a inadequate provision lifespan and is well – known to be a primary source of failure in most convertors. Additionally the back – back topology is sensitive towards electromagnetic interference and other sources of noises that can unintentionally turn ON two switches from the same phase leg, causing a short circuit fault in the turns. In the conventional control method, the motor runs at the constant speed. This method causes large energy wastage.[3] Thus the drawbacks in the existing system is increased harmonic content, high cost, large size, heavy weight, relatively high energy loss and sensitive to electromagnetic interference. The speed control of the motor drive according to the load variations, can save more than around 20% at the varying light load conditions.

The regularly used AC-AC convertor topology in the industry is a traditional DC link voltage source convertor. The quasi-Z source invertor is an attractive substitute to the back-back convertor, because it can convert an AC voltage directly into an AC output voltage of variable amplitude and frequency without the need for an intermediate dc-link.[2] The most notable alternative to MC is the B2BC, due to its high power density, bidirectional flow of power, reduced harmonics with sinusoidal waveforms, lower volume and weight, unity power factor, extendable lifetime and reliable in inimical conditions. Dual topologies of MC are Direct matrix convertors (DMC) and Indirect matrix convertors (IMC). The DMC performs single stage of conversion (AC-AC), while the IMC performs dual stages of conversion process (AC-DC-AC) without DC link capacitor. Although both the convertors possess same characteristics, the DMC operates with complex commutation, while IMC has easy commutation, which similar to the B2BC.[4] Many researchers have made significant process, penetration of MC in industry is less because of its limitations. Similar to the B2BC, MC has limited voltage transfer ratio as 0.87 and they cannot have short circuit the source and open circuit the load.

Adequate exploration was carried out for the proliferation of the voltage transfer ratio[5]. The effortless method is to connect a transformer between the supply and the load. But then again the bulky transformer affects the compactness of the MC. The other way is to make the MC operate over the modulation region. Through this process, the voltage transformer ratio can be increased up to unity. The ZSN has an additional advantage, which allows short circuit of the source as a consequence commutation becomes straight forward and effortless. The Quasi-Z source network improves the voltage transfer ratio to 4 – 5 times and allows the short circuit of the source. The ZSN is sandwiched between the source and the MC to improve the voltage transfer ratio. Input source disturbances in the QZSN, have an immediate reflection on the load[6]. The unbalanced input voltages and sag conditions can result in unwanted output harmonic current and voltage sag on the load. Thus a fuzzy logic based compensation method is used, during the unbalanced input voltage conditions and improves the output performance. In section II, the proposed topology has been explained. In section III, the working principle of QZS, inverter fed induction motor drive is explained. Section IV explicates, the proposal of a fuzzy logic controller for variable speed drive control. In section V, the simulation results of the quasi-z source inverter fed induction motor drive control using the logic controller is explained in detail.[7] Section VI presents the experimental implementation and the results of the QZSI fed induction motor drive with the ATMEGA microcontroller

– 328. In Section VII, the conclusion of the proposed topology has been presented.

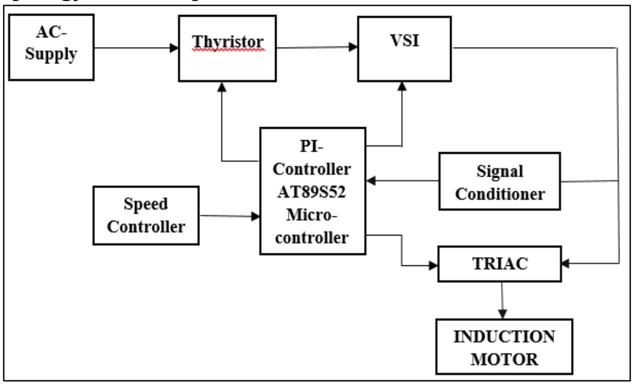


Fig. 1: Block Diagram

II. PROPOSED QZSI-HARMONIC REDUCTION

The speed of the induction motor drive depends the supply voltage provided to it.[8] The unbalanced supply voltage and the harmonic distortion in it, which is fed to the drive will produce a diverse effect on the load. To control the induction drive even under the voltage sag conditions, the variable boost QZSI with the fuzzy logic controller has been proposed. In this paper, the capability of the QZSI has been tested for different load conditions. Figure 1 shows the , QZSI fed induction motor drive control scheme. The topology has six parts, which includes, thyristor, VSI, speed controller, signal conditioner, TRIAC and ATMEGA microcontroller-328. The fuzzy logic controller determines the shoot through duty ratio D of QZSI and maintains the constant load conditions even under the voltage sag and harmonic distortion conditions.

III. QUASI-Z SOURCE INVERTER FED INDUCTION MOTOR DRIVE

A. *Topology of QZSI*

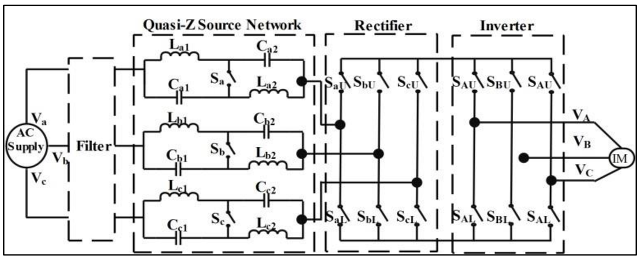


Fig. 2: Topology of QZSI fed Induction motor drive

The topology of the QZSI fed induction motor drive is shown in figure 2. Two capacitors (Cx1, Cx2), two inductors (Lx1, Lx2) and one bidirectional switch (Sx) has been connected to form QZSN for any of the phase x; x= a,b,c. Similarly, three QSZI has been connected to each of the phase.

B. *Operating Principle of the QZSIMC*

QZSIMC operates in two states namely Non-ShootThrough (NST) and Shoot-Through (ST) state. One switching period T_s has NST and ST state. T_{nst} and T_{st} are the time period of NST and ST state. Shoot through duty ratio is well-defined as $D=T_{st}/T_s$. In NST state the switches (S_x) is closed. Fig. 4 represents the equivalent circuit of QZSIMC in NST state. The input voltage of each phase is the sum of the output voltage and the voltage across the two capacitors in each of the individual phase. During this state, the inductor is parallel to the capacitor.[9] Hence, the inductor discharges to the capacitor.

In ST state the switches (S_x) opens and the upper three switches of the rectifier (S_{aU}, S_{bU} and S_{cU}) are shorted. As the switches (S_{aU}, S_{bU} and S_{cU}) closed the output voltage becomes null in the ST state a. As the switches (S_x) opened, the inductor charges. Due to the symmetry the voltage across the inductor and the capacitor are same.

In steady state, the average voltage across the inductor and the average current across the capacitor for one switching period should be equal to zero.

IV. QUASI-Z SOURCE INVERTER FED INDUCTION MOTOR DRIVE

In QZSIMC boost factor B and the gain G depend on the modulation index (m) and shoot through duty ratio D. The constant modulation index (m) and shoot through duty ratio D is appropriate for the balanced source, constant load and constant speed operation. Modulation index $m=m_r.m_i$.

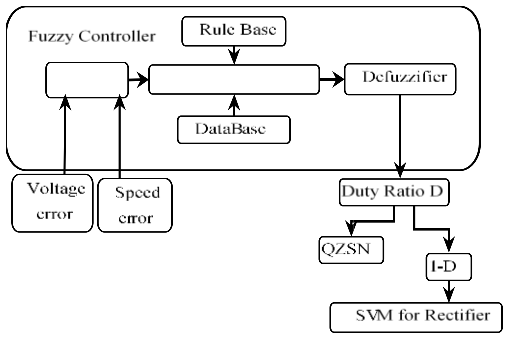
A. *Control Scheme for Inverter*

The vector controller provides control action over the outer speed loop and inner current loop over with its q-axis component and d-axis component thereby providing error free speed tracking. The vector controller fixes the modulation index (m_i) of the load side inverter. When there is a drop in input voltage, the DC link voltage is being affected which thereby affects the performance of the vector controlledinverter fed induction motor drive. Therefore, DC link voltage plays a major role in the performance of the QZSIMC. Quasi-Z-Source Network (QZSN) and source side rectifier decide the DC link voltage. Further, PI and fuzzy logic controllers are implemented to optimize shoot through duty ratio D and source side rectifier modulation index (m_r), thereby deciding the gain (G) of the QZSN.

B. *PI Controller for Rectifier*

Simple proposal and integral controller has been implemented to decide the shoot through duty ratio D and source side rectifier modulation index (m_r) based on the input voltage sag conditions. Error in the input voltage and change in error in the input voltage are fed as input variable to the PI controller[10]. Shoot through duty ratio D is the output variable of the PI controller. Using PI tuner in the Matlab Simulink software the gain of the controller was tuned with Ziegler Nichols which robustly stabilize the system.

C. *Fuzzy Logic Controller for Rectifier*



The design steps are as follows,

1) Step 1: Initial step is to set the inputs and outputs variables. The input variables that are considered are the Input voltage error and Speed error. The output variable, shoot through duty ratio D is being considered.
2) Step 2: Fuzzification forms the process of converting the input from numerical or crisp value into fuzzy values and the outputs from fuzzy value to crisp value. For the conversion process of crisp values to linguistic terms, fuzzy membership functions are used. A fuzzy variable contains many fuzzy subsets which depend on the number of linguistic terms used. Each of the fuzzy subsets represents one linguistic term which allows its members to have different grade of membership, whereby the membership value lies in the interval [0, 1]. Linguistic values chosen for input and output variable are represented in Table.
3) Step 3: This step defines the fuzzy membership functions. Based on the designer's preference and experience, the shape of the fuzzy membership function is defined. The triangular shape has been chosen as it provides easy representation, less computation time and damping of oscillation. Triangular input and output membership function are selected from the defined range.

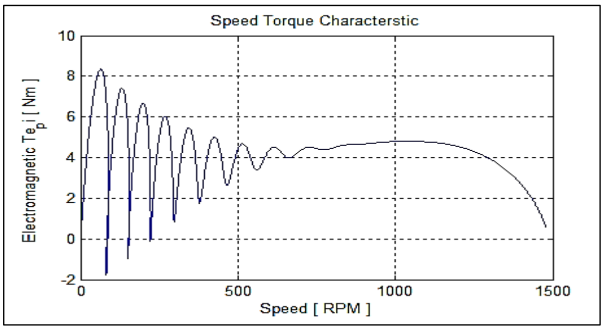
The universe of discourse for fuzzy logic controller is normalized between [-4, 4] for input and between [0, 0.5] for output. Linguistic variable NB and PB for inputs are made left open and right open to incorporate the negative infinite and positive infinite values. Thus, two input scaling factors namely VE and SE and one output scaling factor namely D has to be designed. Input supply voltage to the system is sinusoidal 230 V. Thus the possible input voltage error range is from -230 to 230 voltages. Thus voltage error range from [160,160] has been scaled down as [-4, 4] from NS to PS. The range of the NB has been chosen as -230 to -160 with left open and the range of the PB has been chosen as 160 to 230 with right open. The rated speed of the induction motor is 1500 rpm. The possible error range is from -1500 to 1500 rpm. To achieve minimum speed error the speed error from -50 to 50 has been scaled as -4 to 4 for NS to PS. The range of the NB has been chosen as -1500 to -25 with left open and the range of the PB has been chosen as 25 to 1500 with right open. The range of the shoot through duty ratio has been limited below 0.5. Thus the range of the shoot through duty ratio D has been selected from 0 to 0.5.

4) Step 4: This step defines the rules for selected membership function. In this case, FLC utilizes fuzzy rules instead of using a mathematical formula in order to make a decision and generate control action. The rules are in the form of IF-THEN statements. For example, IF the input Voltage Error (VE) is negative small (NS) and the Speed Error (SE) is positive small (PS) THEN the output is medium (M). 25 rules are framed as mentioned in Table.

V. SIMULATION RESULTS AND DISCUSSION

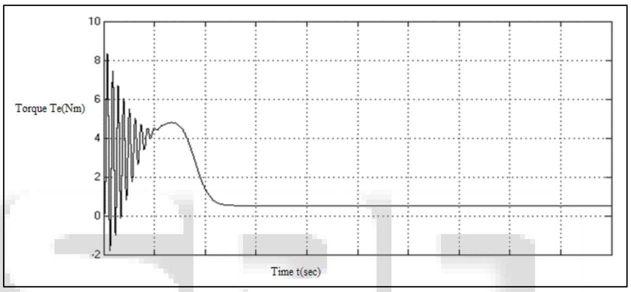
A. *Speed – Torque characteristics*

The torque of the induction motor varies in proportional to the speed at which the induction motor is operated. Initially there are some oscillations in the torque of the machine, due to simultanious variations in the speed and the load. Later the torque becomes constant, even if the speed of the machine is varied gradually. Thus the overall operation of the machine becomes constant.



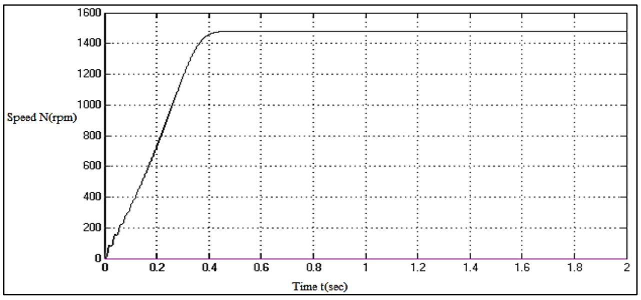
B. *Torque Characteristics*

Initially the torque of the induction motor drive has more fluctuations, due to the variations in the load. As the speed of the drive is gradually increased, the torque of the machine becomes constant, even if there is variations in the load.

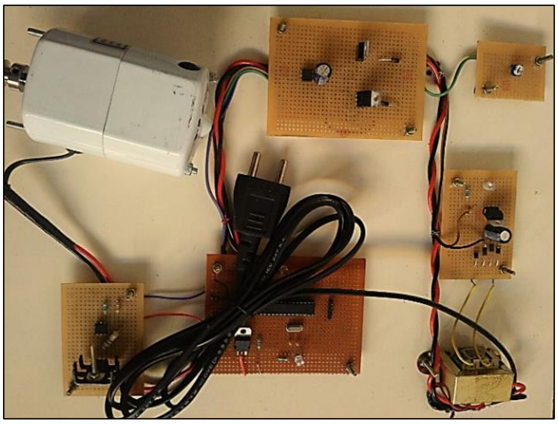


C. *Speed Characteristics*

The speed of the induction drive gradually increases with respect to time and remains constant, even if there is variations in the load.



D. *Snapshot of the Model*



VI. Conclusion

Thus the control of the Induction motor drive, for variable load industrial applications was developed using the Quasi Z-source invertor and the fuzzy logic controller. The LC network which is used along with the supply system, completely reduces the harmonic content, in the supply voltage of the induction drive. Thus stochastic fluctuations produced in the drive, under variable load conditions is avoided and flexible operation of the drive under different nature of the load is achieved.

References

[1] B. K. Bose, “Global Energy Scenario and Impact of Power Electronics in 21st Century,” IEEE Transactions on Industrial Electronics, vol. 60, no. 7, pp. 26382651, July2013.doi: 10.1109/TIE.2012.2203771.
[2] J.W. Kolar, T. Friedli, J. Rodriguez and P. W. Wheeler, “Review of ThreePhase PWM AC–AC Converter Topologies,” IEEE Transactions on Industrial Electronics, vol. 58, no. 11, pp. 4988-5006, Nov. 2011.
[3] L. Gyugi, and B. Pelly, “Static Power Frequency Changers, Theory, Performance and Application,”John Wiley & Sons, New York, USA, 1970.
[4] A. Alesina and M. G. B. Venturini, “Analysis and Design of Optimum Amplitude Nine-Switch Direct AC-AC Converters,” IEEE Transactions on Power Electronics, vol. 4, no. 1, pp. 101-112, Jan. 1989.
[5] T. Friedli, J. W. Kolar, J. Rodriguez, P. W. Wheeler, “Comparative Evaluation of Three-Phase AC–AC Matrix Converter and Voltage DC-Link Back-to-Back Converter Systems,” IEEE Transactions on Industrial Electronics, vol. 59, no.12, pp. 4487-4510, Dec. 2012.
[6] P. W. Wheeler, J. Rodriguez, J. C. Clare, L. Empringham and A.Weinstein,, “Matrix Converters: A Technology Review,” IEEE Transactions on Industrial Electronics, vol. 49, no. 2, pp. 276-288, Apr. 2002.
[7] L. Empringham, J. W. Kolar, J. Rodriguez and P.W. Wheeler, J.C. Clare, “Technological Issues and Industrial Application of Matrix Converters: A Review,” IEEE Transactions on Industrial Electronics, vol. 60, no. 10, pp. 4260-4271, Oct. 2013.
[8] J. Rodriguez, M. Rivera, J. W Kolar and P. W. Wheeler, "A Review of Control and Modulation Methods for Matrix Converters,” IEEE Transactions on Industrial Electronics, vol. 59, no. 1, pp. 58-70, Jan. 2012.
[9] Y. Tamai, H. Ohguchi, I. Sato,A. Odaka,H. Mine and J. I. Itoh, “A Novel Control Strategy for Matrix Converters in Over-modulation Range,” Power Conversion Conference, Nagoya, pp. 1049-1055, Apr. 2007.
[10] Paweł Szcześniak, "Three-phase AC-AC Power Converters Based on Matrix Converter Topology, Matrix-reactance frequency converters concept", Springer-Verlag London 2013.

