# Fuzzy-PI Controlled Cascade H-Bridge Inverter Fed Single Phase Induction Motor Drive

**Sushma J Patil, M S. Aspalli, P.Ramesh, V Agalya, D Kodandapani**

**Abstract:** Now a day's multilevel inverters (MLI) are emerging in ac drive oriented applications. MLI topological structure that allows output voltage is to be integrated from isolated voltage sources. Various MLI topologies have been developed. The operation of the MLI is used to make a output ac voltage from variation in the dc source. This paper presents the detailed experimental study and effect of Proportional Integral controller (PI) and Fuzzy Logic Controller (FLC) for closed loop speed control of the 1-phase asymmetric cascade H Bridge (CHB) MLI fed induction motor drives. The FLC design and rule based implementation procedures are clarified. The FPGA based simulation and experimental results are tested and discussed.

**Index Terms**: MLI, speed-control, induction motor, FPGA, cascade H-Bridge, PI Controller

## 1 INTRODUCTION

Deviations and options of the two-level voltage source inverter topology have been dynamic for in excess of a portion of current century. The MLI was researched in the multi-level approach which generates lower dv/dt output voltages in the calculation of output voltage levels. By using isolated power supplies, the individual inverters are synthesized [1]. Few researchers are experimentally verified the SPWM modulation technique for ac drive in pumping application [2]. Rekha Agrawal [3] explained a cross associated source based MLI with less number of switches and triggering circuits, however the circuit are progressively implemented .Drive torque control is analyzed by ANN controller [4]. Performance reduction of MLI on induction motor drive is estimated [5]-[12]. The single phase induction motors are the most frequently usable motors for many applications. They are used especially in fans, blowers, centrifugal pumps, air conditioning equipment, stokers, conveyers, small desk fans, hair dryers etc. They are used in huge number of low power industries and applications. The speed control of Induction Motor (IM) is a pre-requisite for these applications. The speed control is normally in open loop. However, this open loop drive does not give good performance. The closed controller plays a major performance in the designing of any closed loop controller. PI controller is the best conventional controller [6] - [8]. The fuzzy and neural based controller is better than PI controller for many applications. Consequently, FLC based closed loop system is observed the speed control of a motor. The suggested FLC is tested with all motor load conditions and the predominance of the FLC is contrasted with PI controller. With the assistance of FPGA based FLC, the speed control execution of a drive attributes are executed and


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## 2 METHODOLOGY

To understand the dynamic process of CHB-MLI, the design of fuzzy logic control system involves obtaining better performances. Fig.1 shows the typical fuzzy logic systems. The four major components fuzzy logic rules of knowledge base, Fuzzifier, Inference engine and Defuzzifier. The advantages of fuzzy logic include quicker development cycles and superior performance. Fig.2 represents the process outline of FLC for IM control.

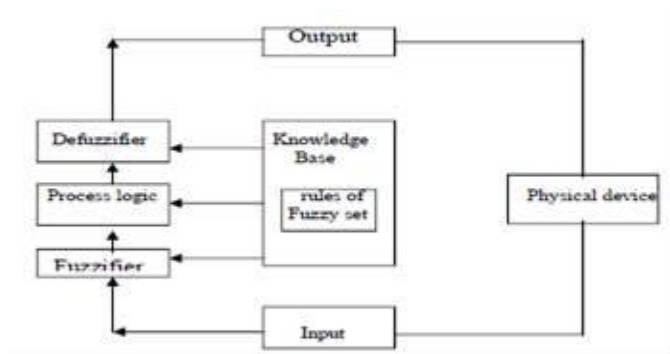


***Fig.1*** *Typical Fuzzy systems*

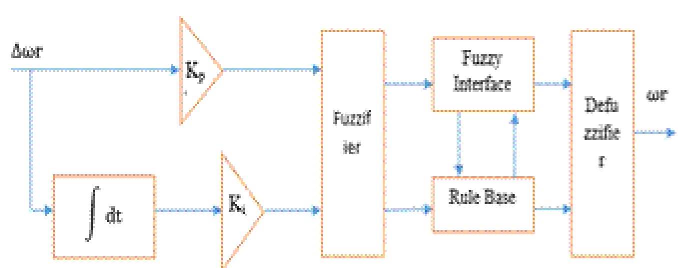


***Fig.2*** *Fuzzy Controller Block diagram*

The motor execution measurements are regulated by setting the expansion estimate of PI and PID controllers. Model Reference Adaptive Control (MRAC), Sliding Mode Control (SMC), Variable Structure Control (VSC), and self tuning PI controllers, and so on, are many control procedures widely used in science.The structure of all the previously mentioned controllers depends upon the distinct system scientific model. In any case, it is frequently hard to build up a precise framework scientific model because of variation in load, parameter variation because of saturation, variation in temperature, and disturbances present in the systems. In order to beat the above issues, starting late, the FLC is being used. The error, Δωr, between the set point and shaft speed, is utilized to create the accompanying contributions to the controller:

u1=kpΔωr (1)
u1=kp (2)

The controller realizes a nonlinear PI control algorithm by accurately changing the membership functions and the gains Kp and Ki. The performance is based on reference torque, T*em, to fulfill the drive's desired speed tracking function.The information participation elements of the fluffy framework are triangular, with expanding widths from the starting point, so as to gain better power action near the set point. In the fuzzification procedure, the enrolment capacities fresh information sources, u1and u2, into fluffy subsets with the accompanying etymological factors: Positive High (PH), Positive Average (PA), Positive Low (PL), Null (NU), Negative Low (NS), Negative Average (NA) and Negative High (NH). The knowledge base consists of 49 rules for determining the result of the fuzzy implication process, as appeared in Table 1. For example, the main passage in the standard base peruses. The principles are appeared in Table 1 by utilizing the fluffy tool kit. The info yield mapping of the fluffy controller is appeared in Fig.3. The controller surface is practically direct for little aggravations around zero error. An induction motors recreate the human examination by building fuzzy inference on the sources of inputs and IF-THEN standards. Defuzzification is the way toward delivering contributions to one output. In this two inputs are used. They are,

Error (e) i.e., speed error
2. Changes of error (Δe) i.e., change of speed error.

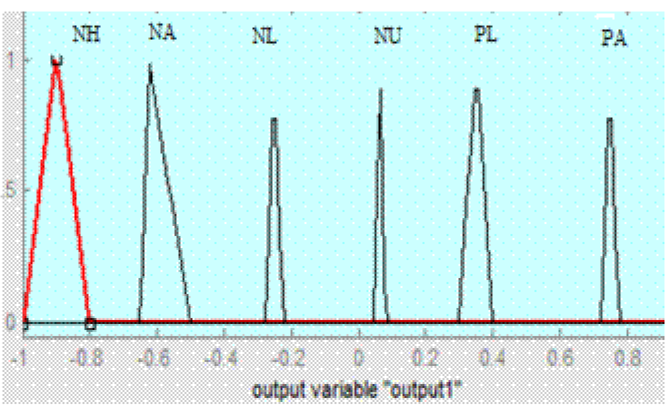


***Fig.3*** *Output Member Functions*

Seven triangular member functions are used as shown in Fig.3 for both inputs and output membership functions. In Knowledge base 49 IF-THEN rules are utilized. They are shown in Table 1

***Table 1*** *Rules of Fuzzy Logic*

| CE | NH | NA | NL | NU | PL | PA | PH |
|---|---|---|---|---|---|---|---|
| NH | NH | NH | NH | NH | NL | NU | PL |
| NA | NA | NA | NH | NA | NL | NU | PL |
| NL | NH | NH | NM | NL | NU | PL | PA |
| NU | NH | NA | NL | NU | PL | PA | PH |
| PL | NA | NL | NU | PL | PA | PH | PH |
| PA | NL | NU | PL | PA | PH | PH | PH |
| PH | NU | PL | PA | PH | PH | PH | PH |

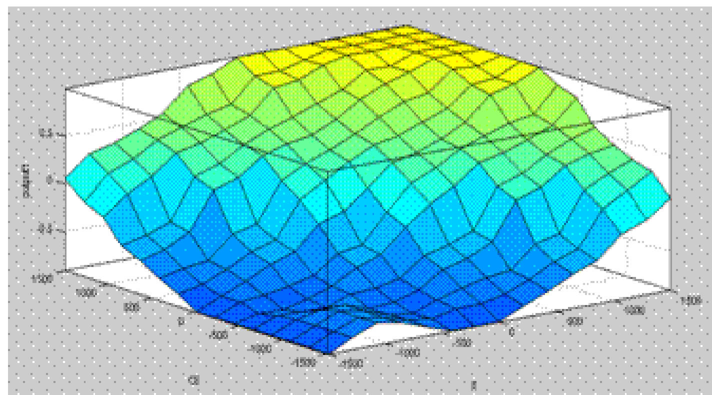

***Fig.4*** *Surface view of Non-Linear Mapping*

The speed regulation of IM drive is determined by equation 3. The 1-phase IM are mainly utilized for several applications like actuators, crushers, AC Compressor etc. Whenever the load fluctuates, induction motor is difficult to maintain constant speed. A motor's speed control expresses how much its speed varies with regard to the full load speed between no-load and full load.The motor attains good speed regulation from no load to below the rated full load. So the squirrel cage induction motor has good speed regulation. Similarly, percentage (%) speed regulation is given as,

Speed Regulation % = X 100% (3)

Where

ωnl - Speed of induction motor at No load

ωfl- Speed of induction motor at full load

So the desired induction motor is almost run at nearly constant speed for various load conditions ranging from no load to below the rated full load.

## 3 RESULTS AND DISCUSSIONS

### A. SIMULATION RESULTS

Speed control performance of CHB MLI fed is explored with FLC controller. The results were examined for the entire drive load. Both PI and FLC based 7- level CHB-MLI for IM drive was simulated through MATLAB/Simulink and the outcome results were compared. In addition to maintaining the MLI output voltage THD profile, the proposed FLC technique regulated the speed as well as being able to eliminate the low frequency DClink oscillations, which helped improve drive efficiency over the entire speed range.

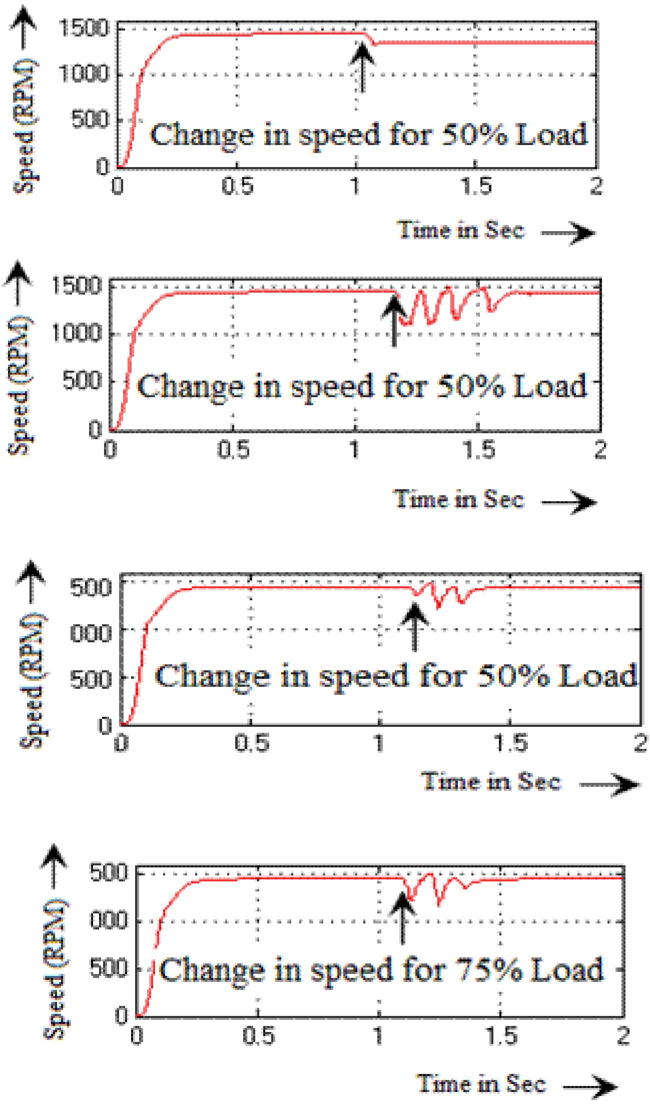


Fig.5 Speed response of single phase IM, before and after load change (a) Half load without any controller (b) Half- load with PI controller (c) Half-load with FLC controller (d) 3/4th load with FLC controllerIn Fig.5 the FLC obviously demonstrates the response of induction motor speed control drive with changing load. Here the FLC is capable of maintaining its set speed for the entire load duty (0% load to 100%load), though in the PI controller it isn't up to the level as appeared in Fig.5 (b). It is obvious from the results that the proposed FLC scheme regulates the speed with error of 3 percent. Table.2 indicates the performance analysis of closed loop control of induction motor. The performance of the proposed FLC is better than that of normal PI controller.

***Table 2**. Controller Comparative analysis*

| Controller | Rise time (sec) | Peak time (sec) | Setting time (sec) | Steady state error ( %) |
|---|---|---|---|---|
| PI | 0.2 | 0.4 | 0.51 | 15 |
| FLC | 0.15 | 0.2 | 0.23 | 3 |

**B. IMPLEMENTATION OF HARDWARE CIRCUIT**

FPGA based FLC for 300W, 1 -phase 7-level CHB-MLI fed IM exploratory set-up was done and researched. The standard based codes were held in MATLAB/Simulink are done through file exchanger; then the FLC Simulink output was changed over as a piece record in the target FPGA SPARTAN – III - 3AN – XC3S400 processor. The proposed FPGA usage was brought out through Xilinx system generator apparatus, which ensured the gadget and processor time use. The induction motor rating and other motor parameters are given in Table 3. The motor was operated through single phase eight switch CHBI. The dc – link voltages of the H bridge 1 and 2 were set as 100V and 50 V individually. The motor speed was measured to IR sensor and given to the FPGA where the FLC getting the input speed. The reference speed of the motor was set using FPGA board key by using counter. There were two keys in the FPGA board, in which one switch was used for increasing the desired speed and the other one for decreasing the speed. Based on the set speed (reference speed) the FLC found the error and added or reduced the speed gain. The corresponding speed gain was converted to the gate pulse of the MOSFET and the inverter giving the desired output voltage of the motor. The FLC rules were framed and stored in the FPGA LUT. Based on the error, the FPGA FLC was turning the duty cycle of the inverter pulses and running the motor at the reference The proposed FLC strategy controlled the speed as well as was fit for taking out the low recurrence DC-link oscillations other than guaranteeing the MLI output voltage THD profile, which helped for the headway of drive execution over the total range of speed. Fig.6 shows the trial set-up of FPGA based FLC for single phase IM drive. The support of the system performance was accomplished for output voltage, percentage voltage THD, and motor speed responses.

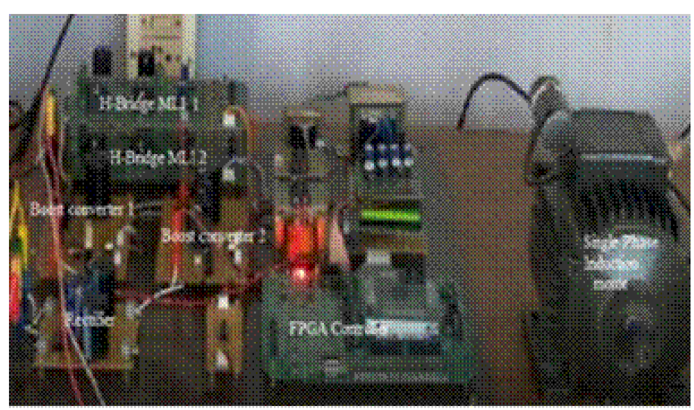


***Fig.6**. Experimental set-up of the proposed FLC based MLI fed IM Drive*

In order to validate the FLC-PI performance against motor speed, initially the speed and the load were set as 1100 rpm and zero loads (zero load torque). In this stage, the motor's set speed and the actual were maintained as the same. Next, the motor speed performance was tested with load conditions. The motor was loaded from 0 to 4 Nm and the corresponding results were measured. While loading the motor, the stator current was raised from 1.2 Amps to 2.2 Amps.

***Table 3*** *Motor Specification*

| Description | Rating |
|---|---|
| Power | 1KW |
| Voltage | 230V |
| Current<br><br>Class of Insulation | 5.43A<br><br>A |
| RPM | 1440 |

The DC -link voltage and the output voltage of the inverter are appeared in Fig. 7 (a) and 7 (b) individually.

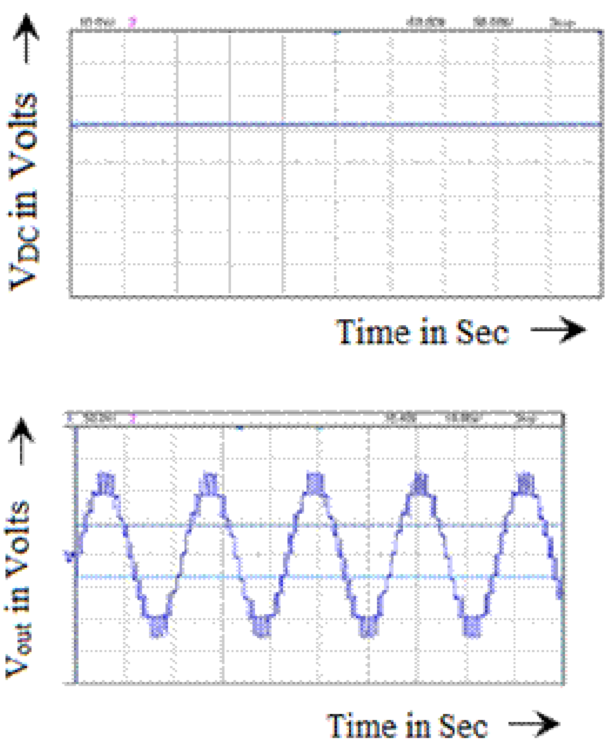


***Fig.7*** *Experimental Results (a) Input DC voltage (b) Output Voltage of CHB-MLI*

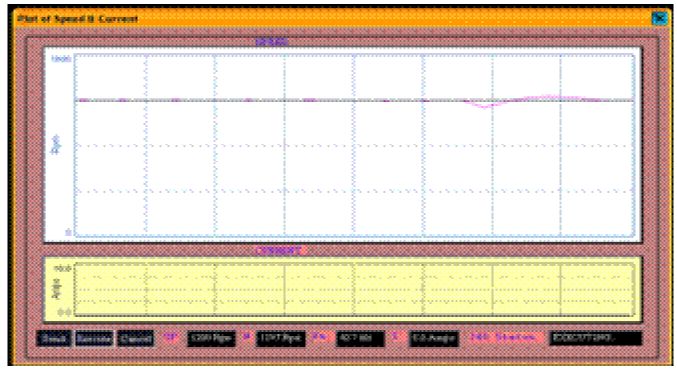

***Fig.8*** *Experimental speed response characteristics of FLC for 50% Full load*

Fig.8 shows the speed response characteristics for the FLC based MLI fed IM at 50% load. It is seen that the speed response kept up exceptionally close to the set speed with better harmonics spectra. The speed regulations of an induction motor are maintained in the range of 7% to 10%. Thus, the proposed FLC-PI based MLI drive is recommended for Industrial drives application of any kind. The comparison of simulation and hardware results are showed up in Table 4.

***Table 4*** *Comparative Analysis of Simulation and Experimental Results*

| Topology | $V_s$ Volts | $I_s$ Amps | Simulation results Parameters | | Experimental Result Parameters | |
|---|---|---|---|---|---|---|
| | | | % $THD_I$ | $\%THD_V$ | $\%THD_I$ | $\%THD_V$ |
| 7 Level PI based MLI's | 230 | 5.43 | 5.75 | 6.8 | 5.85 | 7.7 |
| 7 Level FLC based MLI's | 230 | 5.43 | 5.55 | 6.72 | 5.65 | 6.78 |

## 5 CONCLUSION

In this work, the speed of the 1-phase induction motor is controlled by FLC-PI based seven-level asymmetric cascaded multilevel inverter. The steady state speed response characteristics of a motor with PI & FLC-PI was developed and implemented .The analyzed results indicates that the FLC-PI was superior than the normal PI controlled system, since the settling time and steady state error were considerably reduced. The FPGA SPARTAN –III - 3AN –XC3S400 processor has been used for implementation of FLC-PI based seven-level CHB-MLI fed Induction motor. From the analyzed hardware results, the proposed controller has been controlled the speed with 3% of error.

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