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Analysis and Simulation of PI and Fuzzy controlled five level inverters fed BLDCM with position feedback

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***Abstract*— BLDC motors, also known as electronically commutated motors are found to be more advantageous because of their high efficiency, absence of mechanical commutator, compact construction, and reliabity. Since these motors are commutated by various power electronic switches in an inverter the problem of harmonic distortions can occur. The use of multilevel inverter can be a solution to the above problem. This paper presents the THD analysis and simulation of PI and fuzzy controlled cascaded H bridge five level inverter fed BLDCM with position feedback. To make simulations power electronic simulator (PSIM) and Matlab are being used. The results of fuzzy controlled MLI fed BLDCM was compared with the conventional PI controlled MLI fed BLDCM and it was concluded that the performance of the FLC was found to be superior.**

***Index Terms*— Multilevel inverter (MLI), Brushless DC (BLDC), Total Harmonic Distortion (THD), Fuzzy logic controller (FLC).**

I. Introduction

A BLDC motor finds a lot of applications in robotics, medicine, automation, aviation and industries compared to brushed DC motor. The main drawback of conventional DC motor is the need for periodic maintenance because of the wear out which occur in the brushes of the mechanical commutator. Unlike the brushed motor brushless dc motors are commutated electronically by power electronic switches of an inverter [1] .Various position sensors can be used to sense the rotor position and this determines when to turn on and off the switches of the inverter[2].

Nowadays multilevel inverters are widely used in areas where medium voltage and high power are required due to various advantages such as common mode voltage, low voltage stress in switches. The efficiency of these inverters at lower switching frequency is high when compared to conventional PWM inverters [1]. As the number of voltage level increases the output voltage waveform will approach desired waveform with decreased harmonic distortions [8].

Different control strategies are employed in BLDC drive of which the most popular and simple are the PI controllers. Now industrial processes include different parameters with Non-linearity and variability and it became difficult to model the process mathematically and tune the PI controller parameters [7]. Here instead of conventional PI controller a fuzzy logic controller is used. Fuzzy logic which is based on fuzzy set theory was first developed by Zadeh in 1965.This type of controllers are well suited for the complex, nonlinear or inaccurate dynamics [4].

Nowadays lot of research works are being done in order to reduce the harmonics in the BLDC motor. Harmonic and torque ripple reduction using cascaded H bridge multilevel inverter is discussed in [1].In [2] BLDC motor which is used in electric vehicles which requires high power is fed by cascaded multilevel inverter and the results are evaluated. A comparative study of fuzzy logic based speed control of multilevel inverter fed Brushless DC motor drive is discussed in [3]. A Design of Fuzzy Logic Controller for Speed Regulation of BLDC motor using MATLAB is discussed in [4].A current control of BLDC motor based on a common dc signal was simulated and implemented in [5].In [6] the simulation results of three level and five level inverter was compared. The paper proposes a current control technique which works by comparing the actual current with the reference current and the error is compared with a triangular carrier wave of fixed amplitude and frequency to generate the gating signals for the various switches of the three and five level inverter.

II. BLOCK DIAGRAM

Fig 1 shows the block diagram of the proposed BLDC motor drive. These motors are electronically commutated so it requires a power electronics drive circuit which is the cascaded H bridge multilevel inverter [1]. The position of rotor is sensed by the Hall Effect position sensor. The hall sensor signals are three square wave signals which are in 120 degree phase shift with each other [5]. Since the method works by current controlling it is necessary to sense current so current sensors are placed in two of the three phases since there is no neutral connection and also because the third phase current can be obtained from the difference of other two and also the current sensing is done only to calculate the magnitude, the phase shift and sequence of switching are given by the Hall sensor signals. The dc signal may be obtained by the signal rectification of the phase currents [1]. The controller section includes various analog and digital sub blocks such as comparator, adder etc. The speed reference is compared with the actual speed of the motor which is sensed

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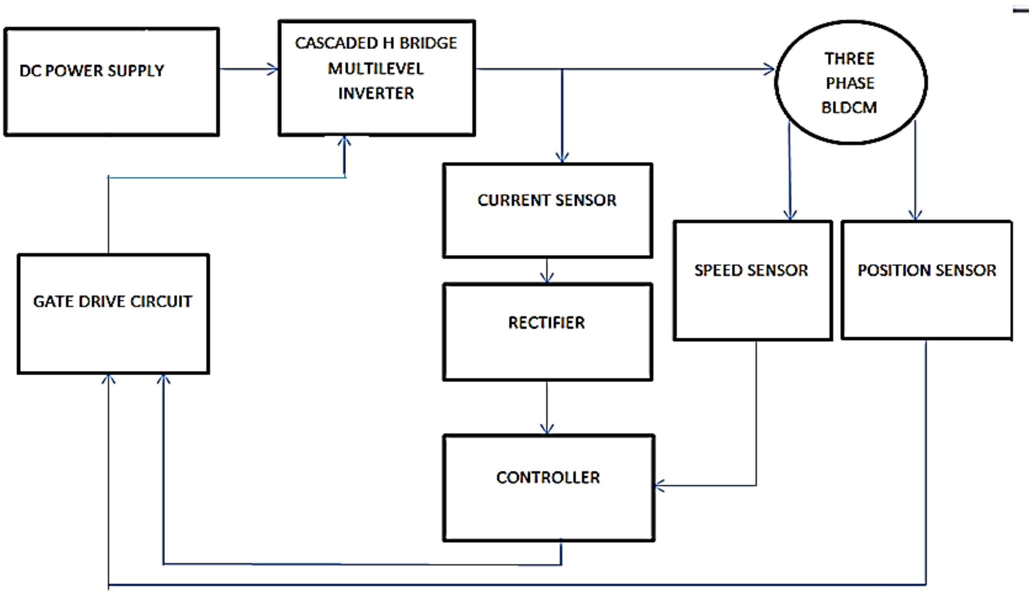

Figure 1: Block Diagram

by the speed sensor and the error is passed through a PI controller to generate the reference value of current.

The reference current is then compared with the dc signal and the error is again passed through a controller (fuzzy/PI).[5] The output of fuzzy/PI is again compared with a triangular wave of fixed amplitude and frequency to generate the PWM for all switches which are sequentially activated according to the shaft position sensors. The pwm signals controls the magnitude whereas the position sensor signals controls the turn on and off of the switches of the multilevel inverter. The hall sensor signals are decoded by a combinational digital logic to provide the firing signals which are also at 120 degree phase shift. PWM pulses and the hall sensor output are given as two inputs of an AND gate whose output produces the firing pulses.

III. CONTROLLERS

Different control strategies are employed for the current control of BLDC drive of which the most popular and simple are the PI controllers. Now industrial processes include different parameters with nonlinearity and variability and it became difficult to model the process mathematically and tune the PI controller parameters [6]. Here instead of conventional PI a fuzzy logic controller is used. This controller is able to improve the performance without having to identify the model of the plant [3]. Nowadays fuzzy logic system plays a vital role in controlling the linear systems and mainly in industries. Fuzzy controller takes input values from the real input and it is mapped by various membership functions in the fuzzification step. Various decision making process are done and output is again mapped to control actions in the defuzzification step. The collections of rules are the rule base which are in the 'if and then' format [4].

This controller is designed using the fuzzy inference system which is the FIS editor which is shown in Fig 2 along with the input and output membership functions [3] shown in Fig 3.

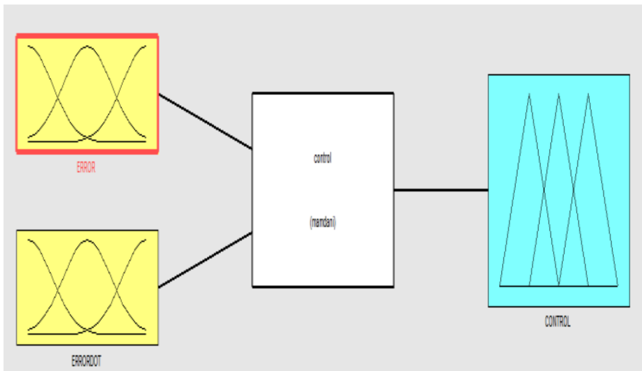

Figure 2: FIS editor

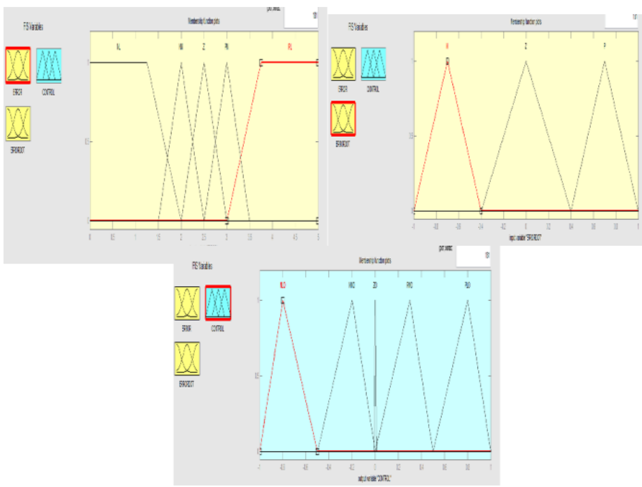

Figure 3: .Input and output membership function plots

IV. MULTILEVEL INVERTERS

As the number of voltage levels increases the waveform become smoother but the system complexity increases with the increased number of components and better control strategies are to be employed for the control of the inverter [8]. The multilevel inverter is used to synthesize near sinusoidal voltage and as the number of levels increases the staircase waveform will approach the desired waveform. The multilevel inverters are mainly of three types diode clamped MLI, flying capacitor type MLI and cascaded H bridge MLI [2]. The advantages of the cascaded H Bridge MLI when compared to the other two are that it has a series structure that has a scalable and modularized circuit layout. It does not require extra clamping diodes or voltage balancing capacitors. In this topology the number of phase voltage levels at the converter terminals is 2N+1, where N is the number of cells or dc link voltages. Each H-bridge cell may have positive, negative or zero voltage [6]. Final output voltage is the sum of all H-bridge cell voltages and is symmetric with respect to neutral point, so the number of voltage levels is odd.

V. FILTER DESIGN

The BLDC motor is energized by three phase inverter through an Inductor – Capacitor filter for reducing the high frequency component. The LC filter in this system acts as a low pass filtering circuit which offer high impedance to high frequency component of the voltage and very minimum impedance to the power frequency voltage components and thereby minimizes harmonics in the supply voltage to the motor and the series inductance opposes the sudden changes in the current due to electronic commutation and thereby reduces the torque ripple. The value of filter capacitor C can be calculated by

$$C = \frac{10}{2\omega\sqrt{(R^2 + (2\omega L_l)^2}} \qquad (1)$$

R is the load resistance and L_l is the load inductance. The value of inductor L obtained by R is the load resistance and L_l is the load inductance. The value of inductor L obtained by

$$\mathrm{VRF} = \frac{\sqrt{2}}{3}\left\{\frac{1}{(2\omega)^2 LC - 1}\right\} \qquad (2)$$

VRF is voltage ripple factor. According to IEEE standard maximum allowable range to ripples is up to 10%.So by taking VRF as 0.01 and L value is calculated using known value of C.

VI. SIMULATION MODELS AND RESULTS

A. PI controlled five level inverter fed BLDCM

The simulation model of PI controlled five level inverter fed BLDCM is shown in Fig 4.Here the number of cells/phase is 2.

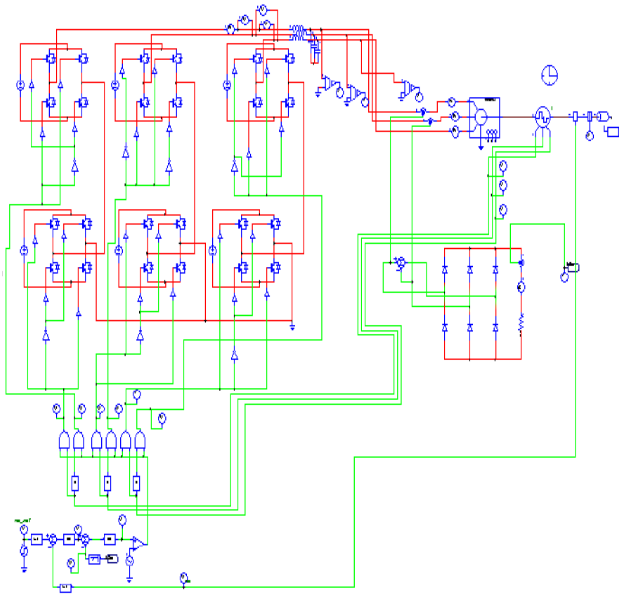

Figure 4: PI controlled five level inverter fed BLDCM

Therefore the number of levels will be five. Fig 5 shows with and without filter three phase to phase voltages and phase currents waveforms of a PI controlled five level inverter fed bldcm.

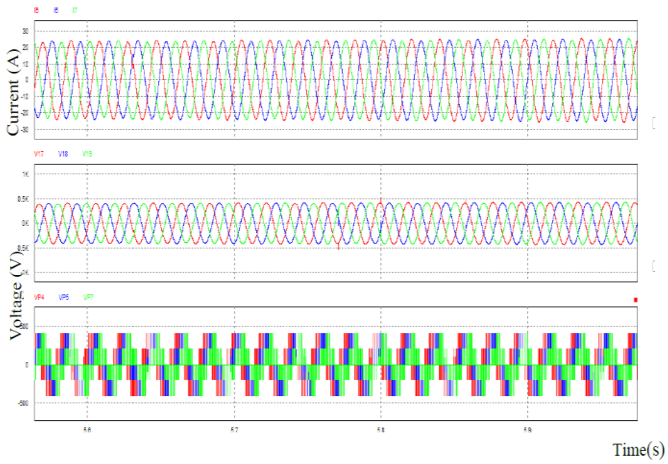

Figure 5: Waveforms of PI five level inverter fed BLDCM (a) Three phase currents (b) Three phase to phase voltages with filter(c) Three phase to phase voltages without filter

Fig.6 shows the FFT analysis of the Phase A current of the Brushless DC motor. The THD was measured as 6.380837%.

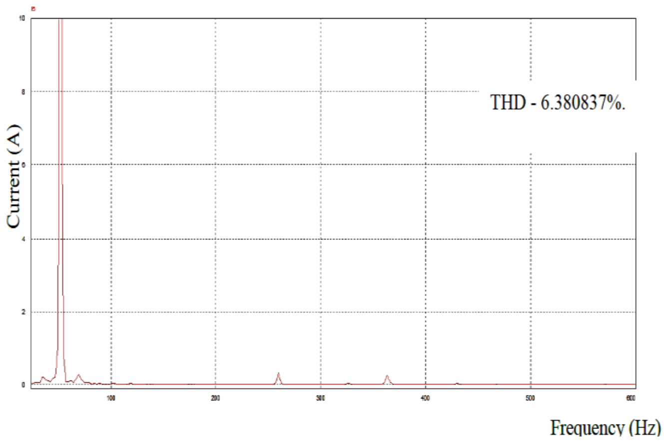

Figure 6: FFT analysis of the Phase A current

B. *Fuzzy controlled five level inverter fed BLDCM*

The fuzzy controller has been simulated in Matlab and the simcoupler element is used to couple the Matlab and psim. Both the softwares were coupled in such a way so that the two models are simulated for the same period of time so that they run simultaneously. The model of fuzzy controller in Matlab is shown in Fig 7.

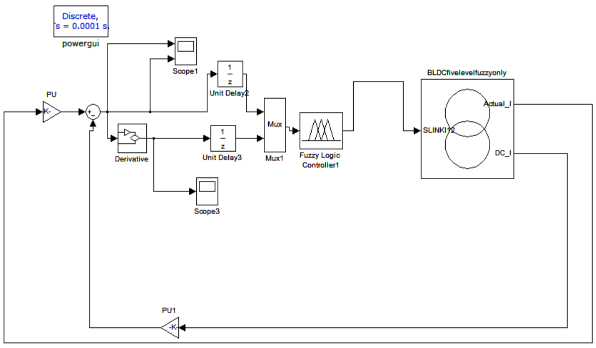

Figure 7: Model of Fuzzy controller

The simulation model in psim of fuzzy controlled five level inverter fed BLDCM is shown in Fig 8. Here the number of cells/phase is 2.Therefore the number of levels will be five.

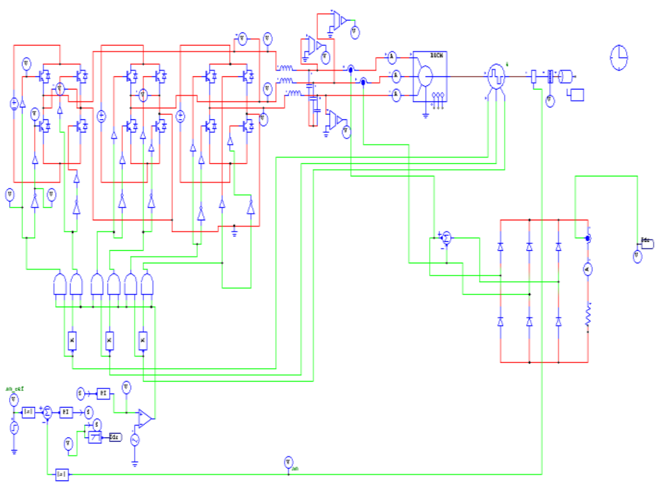

Figure 8: Fuzzy controlled five level inverter fed BLDCM

Fig 9 shows the with and without filter three phase to phase voltages and phase currents waveforms of a fuzzy controlled five level inverter fed bldcm.

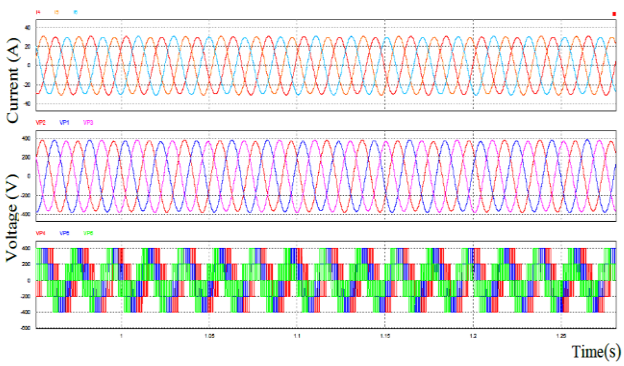

Fig 9 Waveforms of fuzzy controlled five level inverter fed BLDCM (a) Three phase currents (b) Three phase to phase voltages with filter(c) Three phase to phase voltages without filter

Fig.10 shows the FFT analysis of the Phase A current of the Brushless DC motor. The THD was measured as 1.2840805 %.

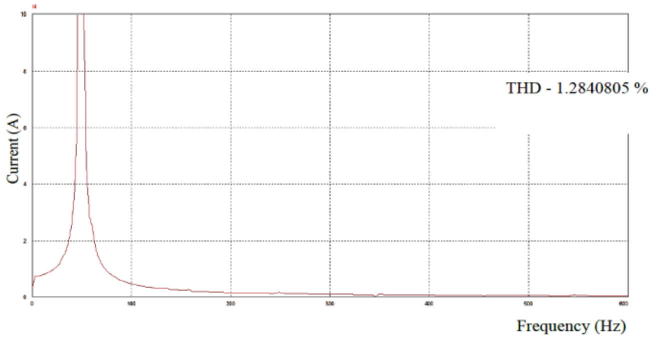

Figure 10: FFT analysis of the Phase A current

The torque and speed waveforms obtained for fuzzy controlled five level inverter fed BLDCM are shown in Fig 11.

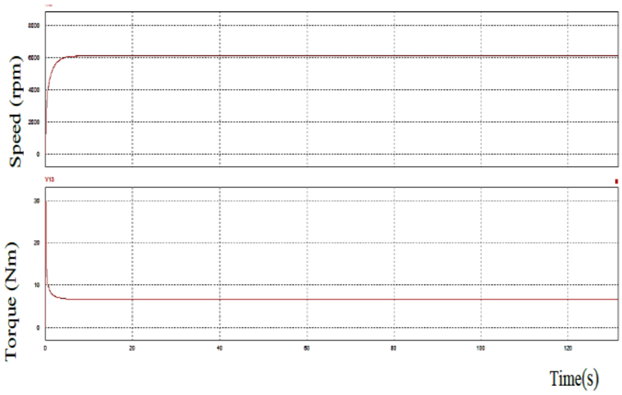

Fig 11. Torque and speed waveforms of fuzzy controlled five level inverter fed BLDCM

VII. Conclusion

In this paper a comparative study of various PI and fuzzy controlled cascaded H bridge five level inverter fed BLDCM with position feedback was done. From the simulation results and analysis we can conclude that while employing the current control technique in BLDCM the harmonic content in the phase currents are reduced when fuzzy controller was used instead of PI controller.

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BIOGRAPHY

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