A FUZZY SMC CONTROLLED BLDC MOTOR

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Abstract- Brushless DC (BLDC) motors are popularly in use because of their efficiency, and torque characteristics, besides having the benefit of being a direct current (DC) supplied which discards the disadvantages of using Brushes. As BLDC motors have a very wide range of speed, controlling the speed is a challenging criterion for it. Sliding mode control (SMC) is one of the well known techniques to deal with non linear control systems. The Fuzzy Sliding Mode Controller (FSMC) puts together the intelligence of a fuzzy inference system with the sliding mode control. In this paper, an intelligent Fuzzy Sliding Mode controller for the speed control of BLDC motor is proposed. Firstly, the BLDC motor's mathematical model is developed and this is used for monitoring the performance of the controller. Typically, the speed control of the BLDC motor is controlled using PI controllers. When comparing the performance, on using the Fuzzy SMC speed control for the BLDC motor, the peak overshoot is entirely eliminated whereas on using PI control a 3% peak overshoot occurs.

Keywords: *BLDC Motor, PI Controller, Fuzzy Logic and MATLAB*

I. INTRODUCTION

Brushless DC Motors (BLDC) are commonly used in many applications such as automotive, computer, industrial, aerospace etc. BLDC Motors have several advantages overbrushed DC Motor. They have lower maintenance due to the elimination of the mechanical commutator and they have ahigh-power density which makes them ideal for high torque to weight ratio applications [2]. Also, they are more efficientdue to the permanent magnets which results in virtually zerorotor losses.Modelling of BLDC Motor by using any particular controlscheme is beneficial in carrying out the comprehensivesimulation studies and further practical implementation. SIMULINK/ MATLAB environment provides accuratebehaviour of the system in reality. Sliding mode control (SMC) is one of the popularstrategies to deal with uncertain control systems. The mainfeature of SMC is the robustness against parameter variationsand external disturbances. SMC has been success fullyimplemented to control drive systems like DC motor and BLDC motor.

Over the past few years, fuzzy set theory has been successfully applied to implementing fuzzy logic controllers (FLC) that express feedback control laws using heuristicknowledge, without knowing parameters of the control plants, for many practical industrial control systems. Controller and SMC are independently applied and theresults are evaluated for the performance of BLDC motor inmany literatures. But no attempt has ever been carried out bycombining the intelligence of fuzzy logic with the slidingmode controller for this purpose. This work presents acomparative study on the speed control of brushless DC motorusing a Fuzzy Sliding Mode controller and conventional PI controller[4]. The mathematical model of the BLDC Motor is developed and it is used to examine the performance of thecontrollers. A PI controller is developed for the speed controlthe BLDC Motor, and then a Fuzzy Sliding ModeController is designed for the same.The control aim of BLDC motors (which have uncertain parameters that affect performance) is to force speed and/or current into following the reference trajectories. The problem can be alleviated through a Proportional Integral (PI) controller, which is simple to implement and common in BLDC motor control.

II. LITERATURE SURVEY

Neethu U. and Jisha V. R. in 2012 made a comparative study on speed control of Brushless DC Motor is presented. The mathematical model of the BLDC motor is developed and it is used to examine the performance of the controllers [1]. Through extensive simulations it is observed that the performance of fuzzy logic controller is better than all other controllers. Tony Mathew and Caroline Ann Sam in 2013 presented a fuzzy logic controller for the closed loop control of BLDC motor in MATLAB. The fuzzy logic controller is developed using a fuzzy logic toolbox. Here an algorithm is presented to obtain the phase current values from the DC link current [3]. M.A. Jabbar et al. in 2004 [5] presents a method of modelling and numerical simulation of a brushless permanent-magnet dc motor using time-stepping finite-element technique. In this model, the dynamic conditions of the motor at starting, step voltage variation, and load torque changes are investigated using the proposed dynamic model. V.I.Utkin in 1993 demonstrated the potential of sliding mode control methodology for the versatility of electric drives and functional goals of control [8]. E. H. Mamdani in 1974 used fuzzy logic to synthesise linguistic control protocol of a skilled operator. The method has been applied to pilot scale plants as well as in a practical industrial situation [11]. H. S. Choi et al. in 2001 demonstrated an improved global sliding-mode control (GSMC) for controlling second-order time-varying systems with bounded uncertain parameters and disturbances. The controller drove the system states along the minimum time trajectory within the input torque limit and therefore was applied to the brushless DC motor with uncertain loads [9].

III. EXISTING SYSTEM

3.1 FUZZY LOGIC CONTROLLER

Intelligent fuzzy logic (FL) has been used often in controller design. The advantage of fuzzy control methods is their non-requirement for precision, unattainable in a dynamic model. The control aim of BLDC motors (which have uncertain parameters that affect performance) is to force speed and/or current into following the reference trajectories. The problem can be alleviated through a Proportional Integral (PI) controller, which is simple to implement and common in BLDC motor control. Robust PID/PI controllers for minimum overshoot response of BLDC drives have been introduced into various applications.A fuzzy control system is a control system based on fuzzy logic—a mathematical system that analyzes analog input values in terms of logical variables that take on continuous values between 0 and 1, in contrast to classical or digital logic, which operates on discrete values of either 1 or 0 (true or false, respectively ...

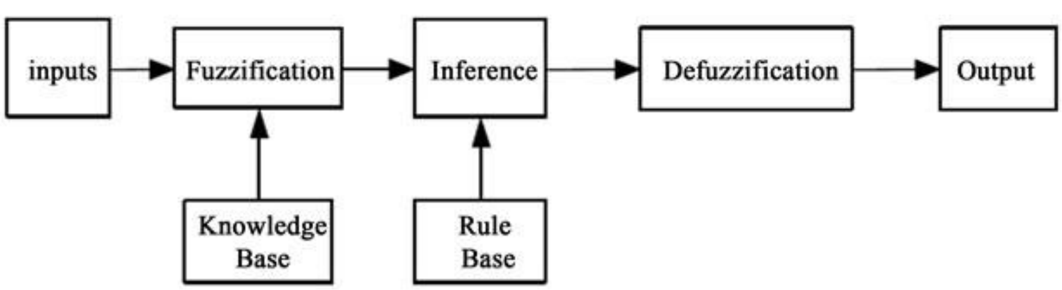

Figure.3.1 Basic block diagram of Fuzzy logic controller

IV. PROPOSED SYSTEM
FUZZY LOGIC CONTROLLER FED BLDC MOTOR DRIVE
4.1 CIRCUIT DIAGRAM

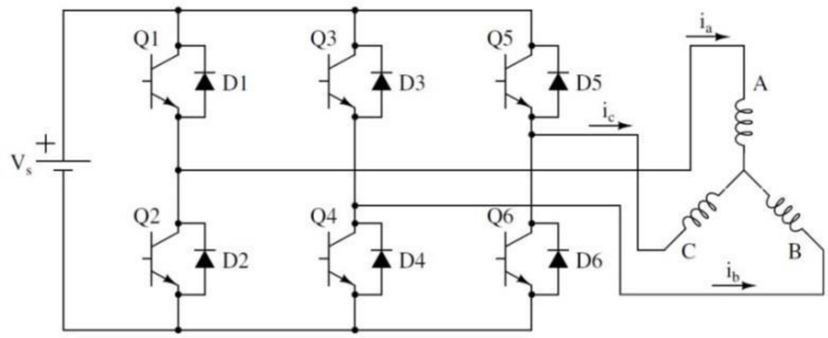

Figure 4.1Circuit Diagram of simplified BLDC Motor Drive

4.2 BLOCKDIAGRAM:

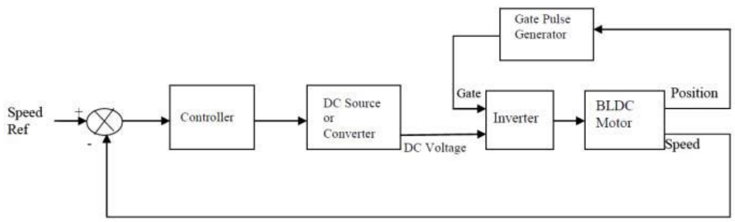

Figure 4.2 Block Diagram of BLDC speed control.

4.2.1Working Principles and Operation

The underlying principles for the working of a BLDC motor are the same as for a brushed DC motor; i.e., internal shaft position feedback. In case of a brushed DC motor, feedback is implemented using a mechanical commutator and brushes. With a in BLDC motor, it is achieved using multiple feedback sensors. The most commonly used sensors are hall sensors and optical encoders. If the direction of the magnetic field is reversed, the voltage developed will reverse as well. For Hall-effect sensors used in BLDC motors, whenever rotor magnetic poles (N or S) pass near the hall sensor, they generate a HIGH or LOW level signal, which can be used to determine the position of the shaft.

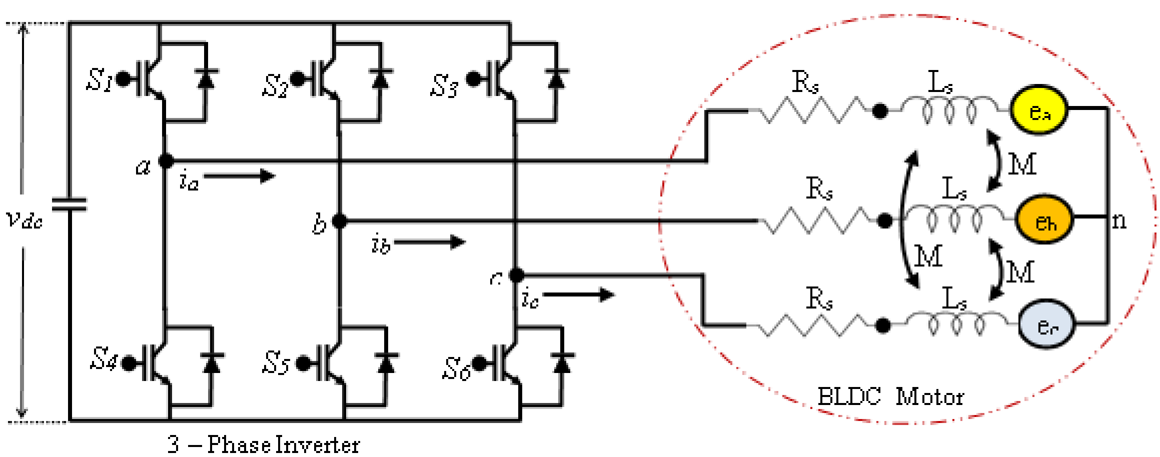

Figure.4.7 BLDC motor drive

Here v_a, v_b, and v_c denote the phase voltages, R_s the stator resistance, i_a, i_b, and i_c the phase currents, L_s the stator inductance, M the mutual inductance, and $L=L_s–M$. The back-EMFs of the phase are e_a, e_b, and e_c. The mechanical angular velocity is w_m. Fig. 3 shows that injecting a square-wave phase current into the part that has the magnitude of the back-EMFs fixed will reduce the torque ripple and stabilise control. The work presented in this paper substituted an MIFT2 controller for the current and speed controllers of a BLDC motor to obtain the deadbeat response desired in high-performance applications.

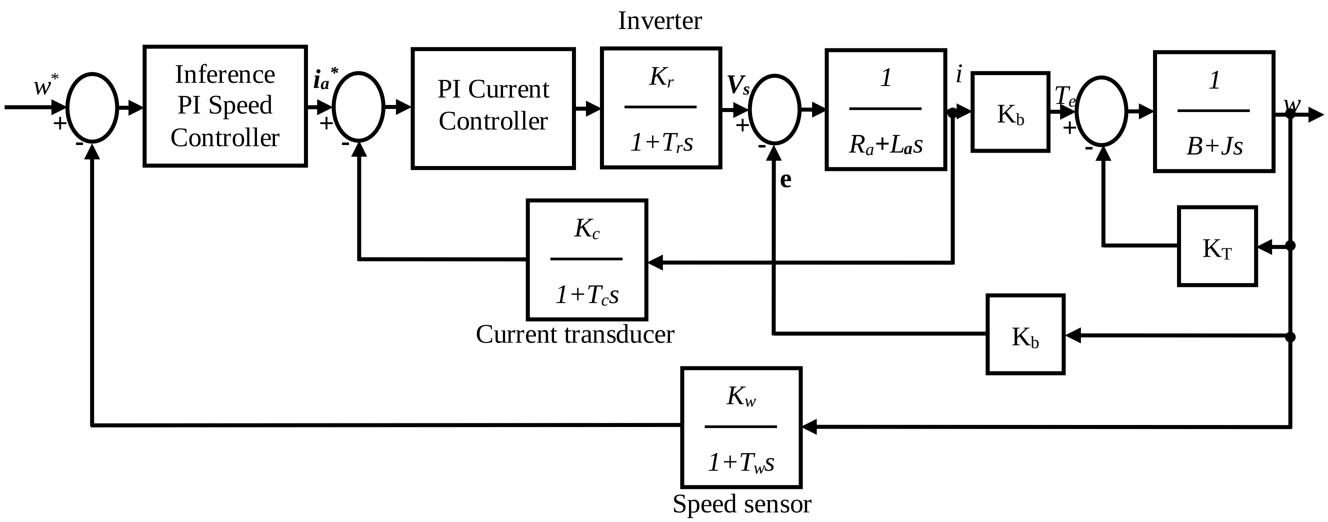

Figure. 4.8: classical controller diagram for BLDC motor

4.2.2 FUZZY LOGIC CONTROLLER

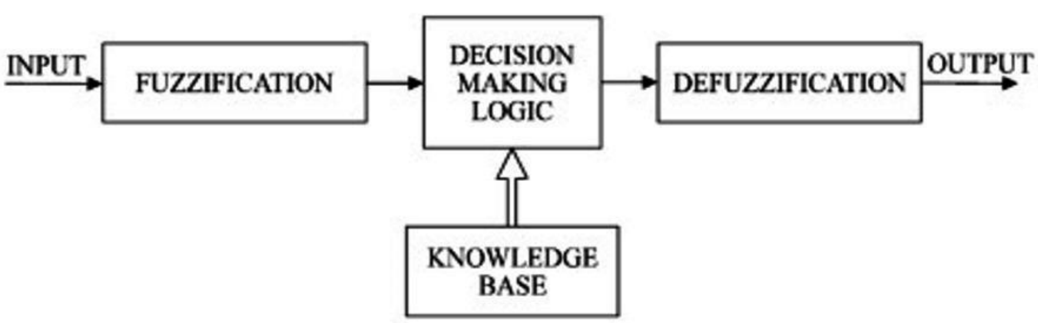

Figure.4.9 Block diagram of a Fuzzy Logic Controller

Fuzzy logic controllers (FLC), which are based on the fuzzy set theory, are verysimple and easy to design. An FLC consist of a fuzzification unit, a decision-making unit, and a de-fuzzification unit as shown in fig.3. The fuzzification unit converts the real inputsto corresponding fuzzy values by using appropriate input membership functions. The decision-making unit performs the inference operation and generate the fuzzy output and it isbased on a number of logic statements called fuzzy rules, in the form of IF-THEN statements. The number of fuzzy rules depends on the number of input membership functions. Thende-fuzzification unit converts the fuzzy output back into the crisp or real control output values using the output membership functions [10]. There are several methods for de-fuzzification and the centroid method is most popular method, which is used in this paper [12]. The commonly usedshape of membership functions is triangular, although Gaussian (or bell shaped) and trapezoidal membership functions are also used [6],[7].

4.2.3Applications of BLDC motor:

Single-speed

For single-speed applications, induction motors are more suitable, but if the speed has to be maintained with the variation in load, then because of the flat speed-torque curve of BLDC motor, BLDC motors are a good fit for such applications.

Adjustable speed

BLDC motors become a more suitable fit for such applications because variable speed induction motors will also need an additional controller, adding to system cost.

Position control

Precise control is not required applications like an induction cooker and because of low maintenance; BLDC motors are a winner here too. However, for such applications, BLDC motors use optical encoders, and complex controllers are required to monitor torque, speed, and position.

Low-noise applications

Brushed DC motors are known for generating more EMI noise, so BLDC is a better fit but controlling requirements for BLDC motors also generate EMI and audible noise. This can, however, be addressed using Field-Oriented Control (FOC) sinusoidal BLDC motor control [12],[13].

V. HARDWARE IMPLEMENTATION

5.1 POWER SUPPLY UNIT

5.1.1 BLOCK DIAGRAM

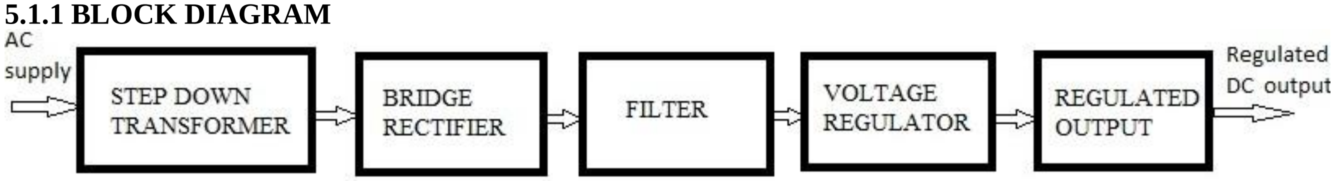

Figure 5.1 Block diagram of power supply unit

As we all know any invention of latest technology cannot be activated without the source of power. So it this fast moving world we deliberately need a proper power source which will be apt for a particular requirement. All the electronic components starting from diode to Intel IC's only work with a DC supply ranging from +5v to 0-+12v. We are utilizing for the same, the cheapest and commonly available energy source of 230v-50Hz and stepping down, rectifying, filtering and regulating the voltage. This will be dealt briefly in the forth-coming sections.

5.1.2 TRANSFORMER UNIT

When AC is applied to the primary winding of the power transformer it can either be stepped down or up depending on the value of DC needed. In our circuit the transformer of 230v/0-12v is used to perform the step down operation where a 230V AC appears as 12V AC across the secondary winding. One alteration of input causes the top of the transformer to be positive and the bottom negative. The next alteration will temporarily cause the reverse. The current rating of the transformer used in our project is 1A. Apart from stepping down AC voltages, it gives isolation between the power source and power supplycircuitries.

5.2 RECTIFIER UNIT

5.2.1 RECIFIER

The diodes are used to convert AC into DC these are used as half wave rectifier or full wave rectifier. Three points must he kept in mind while using any type of diode. The ac input from the main supply is stepped down using a 230 /30V step down transformer. The stepped down AC voltage is converted into dc voltage using a diode bridge rectifier. The diode bridge rectifier consists of four diodes arranged in two legs. The diodes are connected to the stepped down AC voltage. For positive half cycle of the ac voltage, the diodes D1 and D4 are forward biased (ref fig). For negative half cycles diodes D2 and D3 are forward biased. Thus dc voltage is produced to provide input supply to the DC-DC Converter. When the positive half cycle is applied to the diode bridge rectifier, the diodes D1 and D4 are forward biased. The diodes start conducting and the load current flows through the positive of the supply, diodeD1, the load, the diode D4 and the negative of the supply.The diode D2 and D3 are reverse biased and do not conduct.

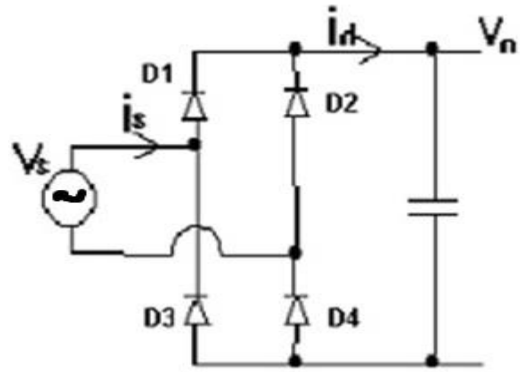

Figure 5.2 Circuit of Diode Bridge Rectifier

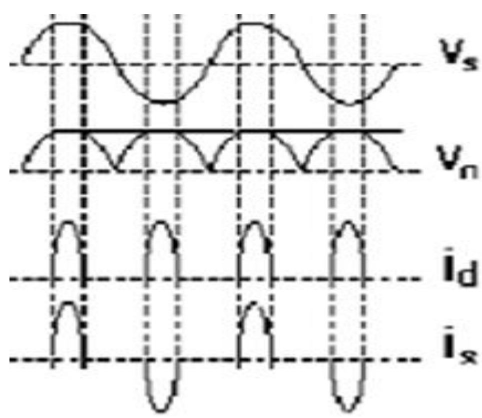

Figure 5.3 Waveform of Diode Bridge Rectifier

During the negative half cycle, the diodes D1 and D4 are reverse biased and they stop conducting. The diodes D2 & D3 are forward biased and they start conducting. The load current flows in the same direction for both the half cycles. Thus the ac supply given to diode bridge rectifier is converted into pulsating dc.

5.3 FILTER UNIT

Filter circuits which are usually capacitors acting as a surge arrester always follow the rectifier unit. This capacitor is also called as a decoupling capacitor or a bypassing capacitor, is used not only to ‘short’ the ripple with frequency of 120Hz to ground but also to leave the frequency of the DC to appear at the output.

A load resistor R1 is connected so that a reference to the ground is maintained. C1R1 is for bypassing ripples. C2R2 is used as a low pass filter, i.e. it passes only low frequency signals and bypasses high frequency signals. The load resistor should be 1% to 2.5% of the load.

1000•f/25v : for the reduction of ripples from the pulsating.
10•f/25v : for maintaining the stability of the voltage at the load side.
O, 1•f : for bypassing the high frequency disturbances.

5.4 VOLTAGE REGULATOR

The voltage regulators play an important role in any power supply unit. The primary purpose of a regulator is to aid the rectifier and filter circuit in providing a constant DC voltage to the device. Power supplies without regulators have an inherent problem of changing DC voltage values due to variations in the load or due to fluctuations in the AC liner voltage. With a regulator connected to the DC output, the voltage can be maintained within a close tolerant region of the desired output IC7805 is used in this project for providing +12v and –12v DC supply.

5.5 THREE PHASE INVERTER

The 3-phase bridge type VSI with square wave pole voltages has been considered. The output from this inverter is to be fed to a 3-phase balanced load. Figure below shows the power circuit of the three-phase inverter. This circuit may be identified as three single-phase half-bridge inverter circuits put across the same dc bus. The individual pole voltages of the 3-phase bridge circuit are identical to the square pole voltages output by single-phase half bridge or full bridge circuits. The three pole voltages of the 3-phase square wave inverter are shifted in time by one third of the output time period.

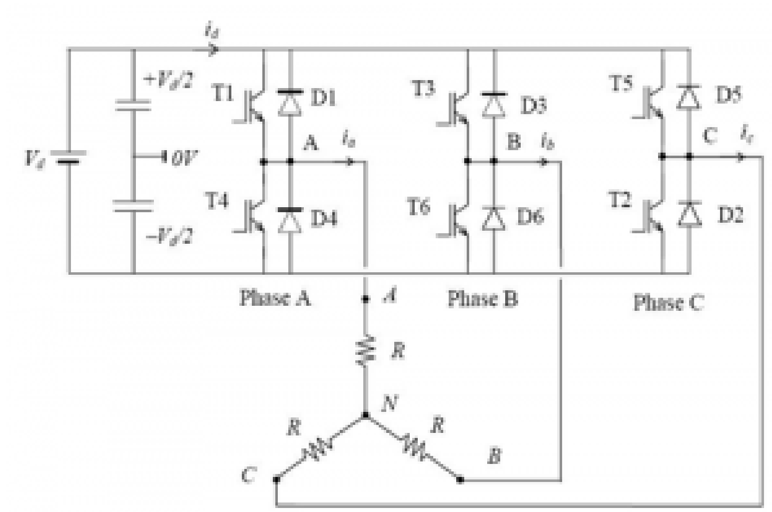

Figure 5.4 Circuit diagram of three phase inverter

Inputs and Outputs

g- The gate input for the controlled switch devices. Pulses are sent to upper and lower switches of inverter legs A, B, and C. This input is visible only when the Model detail level parameter is set to Detailed.

Ctrl-Control signals from the appropriate controller. In average mode, the Inverter (Three-Phase) block no longer receives pulses, but receives various types of other signals that are drive-type specific. This input is visible only when the Model detail level parameter is set to Average and the Drive type parameter is set to Field-oriented control, WFSM vector control, or PMSM vector control.

Duty-The PWM duty cycles (or phase-voltage-to-DC-bus-voltage ratio) of the inverter legs A, B, and C. This input is visible only when the Model detail levelparameter is set to Average and the Drive type parameter is set to Space vector modulation.

+ -The positive terminal on the DC side.

- - The negative terminal on the DC side.

A, B, C - The three-phase terminals on the AC side

IV. SIMULATION RESULTS

6.1 SIMULATION

In a Modified Cascaded Multilevel Inverter based Topology is used to obtain the fifteen level and reducing the Total Harmonic Distortion (THD).Total Harmonic Distortion of the fifteen level inverter is analyzed its result is shown in the MATLAB/SIMULINK. The embedded-based Switching pulses is given to the gate of the Semiconductor Switches (S1, S2, S3, S4, S5, S6, S7).The positive polarity of dc voltage sources is connected in Drain and the negative polarity of the dc voltage
Source is connected in source of the next semiconductor switch.

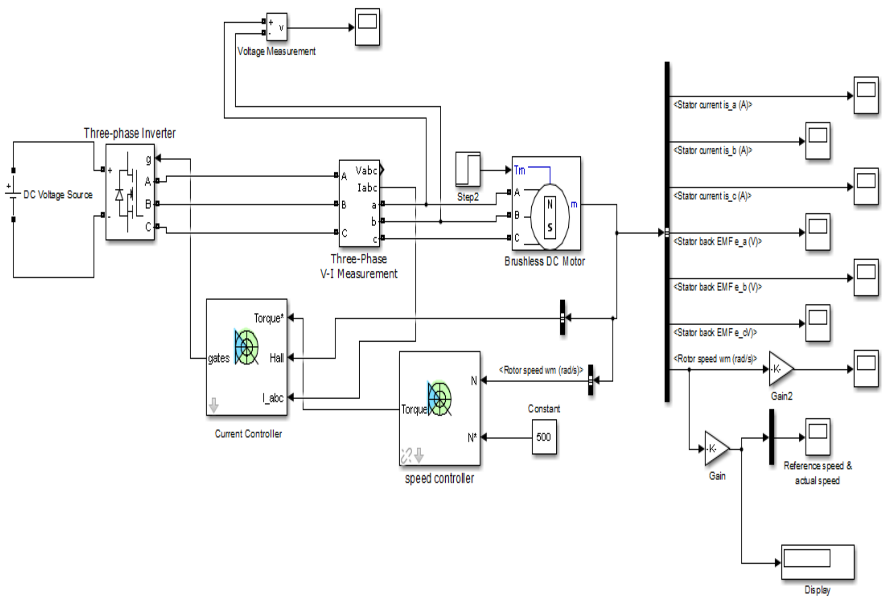

Figure 6.1 Simulation Circuit

6.2SIMULATION OUTPUTS:

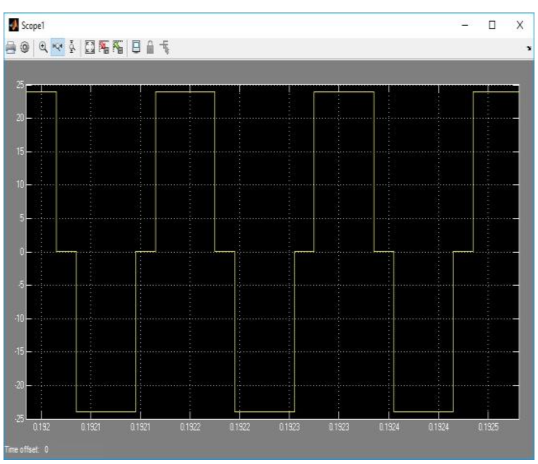

Figure 6.2: Inverter Output voltage in volts

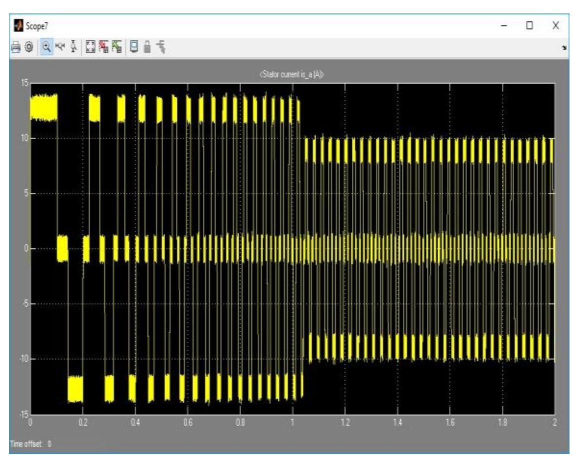

Figure 6.3: Stator current (A) R Phase in Amps

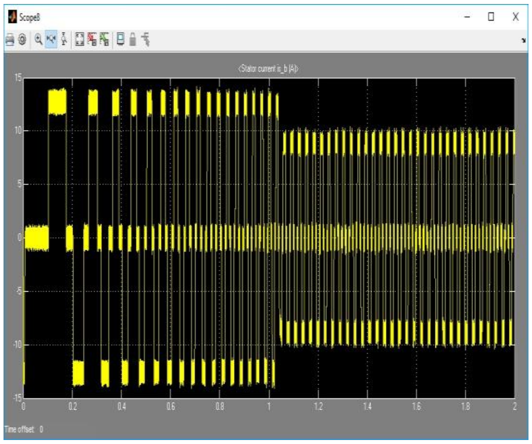

Figure 6.4: Stator current (B) Y Phase in Amps

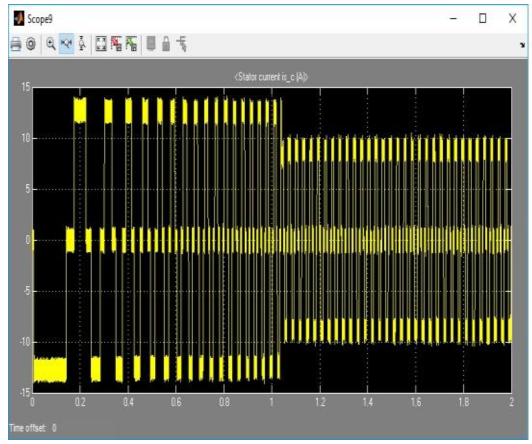

Figure 6.5: Stator Current (C) B Phase in Amps

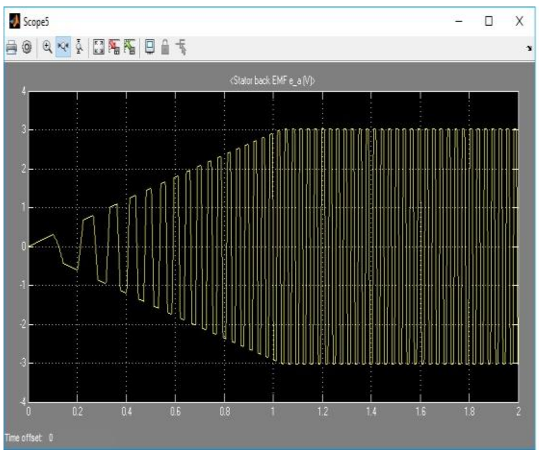

Figure 6.6: Back EMF (A) R Phase in volts

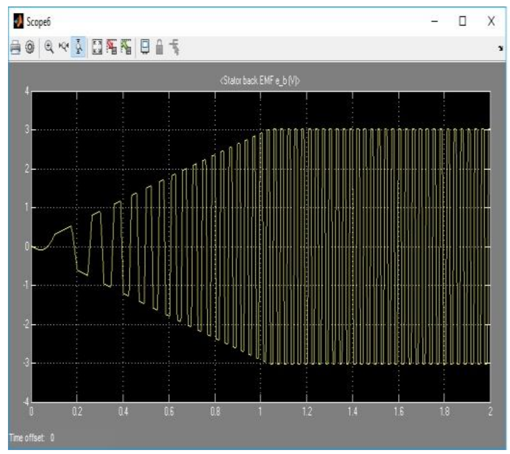

Figure 6.7: Back EMF (B) Y Phase in volts

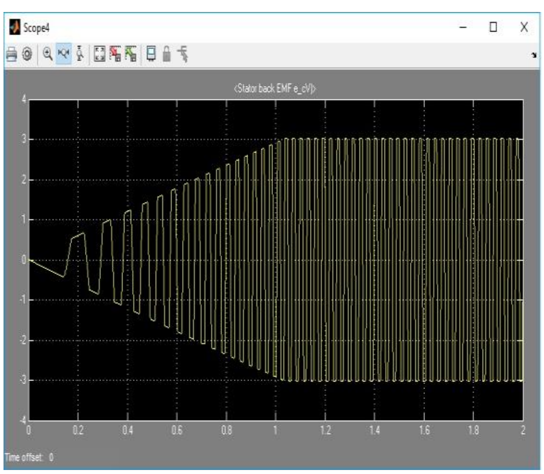

Figure 6.8: Back EMF (C) B Phase

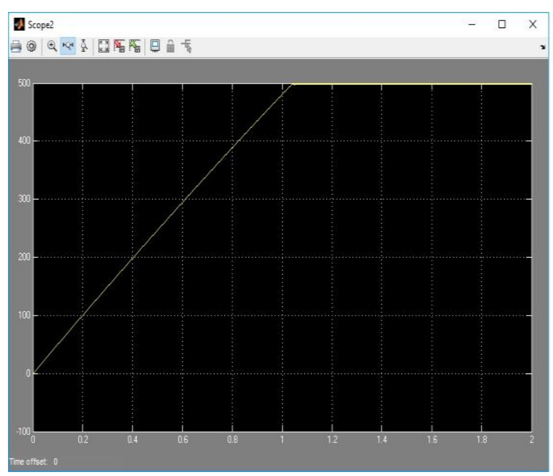

Figure 6.9: Rotor speed in RPM

CONCLUSION

Fuzzy mode controller for the speed control ofBLDC motor is designed and its performance comparison withPI controller is carried out in this paper. Conventionally PIcontrollers are used for the speed control of BLDC motor andthey give moderate performance under undisturbed conditionseven though they are very simple to design and easy toimplement. But their performance is poor under disturbedcondition like sudden changes in reference speed and suddenchange in load. The BLDC motor with PI controller showslarge overshoot, high settling time and comparatively largespeed variation under loaded condition.AFuzzy logic controller fed BLDC motor drive has beendesigned for achieving a unity PF at ac mains for the developmentof the low-cost PFC motor for numerous low-powerequipment's such fans, blowers, water pumps, etc. The speedof the BLDC motor drive has been controlled by varying thedc-link voltage of VSI, which allows the VSI to operate in thefundamental frequency switching mode for reduced switchinglosses.

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