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Performance Analysis of BLDC Motor Drive using ANFIS Controller

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Abstract: In this paper a comparative analysis of speed control of brushless DC motor (BLDC) drive fed with Voltage source inverter is achieved. The performance of the drive system is successfully evaluated using ANFIS based speed controller. Then the speed and torque characteristic of conventional two-level inverter is compared with the various operating conditions. The inverters are simulated using IGBT's and the simulation results show that the ANFIS based speed controller eliminate torque ripples and provides fast speed response. The developed ANFIS model has the ability to learn both neural network and fuzzy control parameters based on disturbances with minimum steady state error, overshoot and rise time of the output voltage. The power factor correction of BLDC motor drive is done by using interleaved CSC converter and also it results shows the power factor is improved.
Keyword: ANFIS controller, Brushless DC motor, Power factor correction, interleaved CSC converter, speed controller.

I. INTRODUCTION

A Brushless DC motor drives have gained importance in the last decade due to power quality improvements that have also resulted in exceptional performance compared with other conventional drives. The advantages of including high torque to weight ratio, more torque per watt (increased efficiency), increased reliability, reduced noise, longer lifetime, elimination of ionizing sparks from the commutator, and overall reduction of electromagnetic interference (EMI). The applications of BLDC motor are many low and medium power applications ranging from household appliance, medical equipment, heating, ventilation and air conditioning. Two key performance parameters of brushless DC motors are the motor constants Kv and Km. Environments and requirements in which manufacturers use brushless type DC motors include maintenance free operation, high speeds, and operation where sparking is hazardous or could affect electronically sensitive equipment. However there are three main problems are considered in BLDC motor: they are 1) providing fast speed response, 2) improving the power factor near to unity in ac mains and 3) the reduction of torque repulsion.

For the first problems although having various controller to improve the speed response but in proposed system ANFIS controller is used. These controller have combination neural network and fuzzy logic inference system so it is called as Adaptive Neuro And fuzzy Inference System (ANFIS) controller. The CSC

converter fed BLDC motor drive consists of the front end CSC converter. It is operated at low switching frequency, so that the near unity power factor is achieved at ac mains. The speed of the BLDC motor is controlled by controlling the DC link voltage of the CSC converter. Moreover low frequency operation of VSI reduces the switching losses. This converter claims the major advantages of using one sensor, low THD high PF at AC mains, low switching losses due to low frequency operation. The supply current THD was obtained below 7% under the wide range of the motor speed and the supply voltage where those values are recommended by the PQ standard IEC 61000-3-2, hence it is well suited for low power applications [1].

The switching losses are reduced by using a concept of variable dc link voltage for speed control of BLDC motor [2]. Recently, fuzzy inference system (FIS) is widely used because of its good performance, in cases when the system or process is complicated and classical method cannot work well. Additionally, fuzzy system formulates human knowledge in systematic manner and puts them into engineering systems. But there is a problem associated with FIS, which is the time consuming process to tune the parameters of FIS relying on human knowledge by trial and error. So, there has been recently a surge of interest to combine neural network and FIS because of its both advantages of fuzzy inference systems and artificial neural networks [3]. The selection of the membership functions and the development of fuzzy control rules is difficult task without the information from the skilled operator. More over the fuzzy control rules could not be defined properly if the skilled operator is unable to give the exact instructions about the process operation. The artificial neural networks have the learning capability which gains the knowledge of a process automatically from the sample input and output relationship of the process [10-11]. In conventional Power factor correction based CSC converter has a combination of a switch(S), a capacitor (C), and a diode (D) is called as CSC converter. With proper design and selection of parameters, this combination is used to achieve PFC operation when fed by a single phase supply via a DBR and a DC filter[5].

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II.BLOCK DIAGRAM DESCRIPTION OF

A. Bldc Motor Drive

Brushless DC motor has become the fastest growing and most promising industrial application of a new motor. It contains simple structure, reliable, easy maintenance, long life and a series of advantages that AC motor. It has also contains good mechanical properties and speed performance that DC motor and also having small size, speed, reliability, currently it has been used more widely in high demand in the electric drive system. The drive system consists of BLDC motor, rotor position sensor combined fuzzy logic controller and neural network known as ANFIS controller and three phase voltage source inverter. A block diagram of speed and power factor correction of BLDC motor is shown in figure 1.

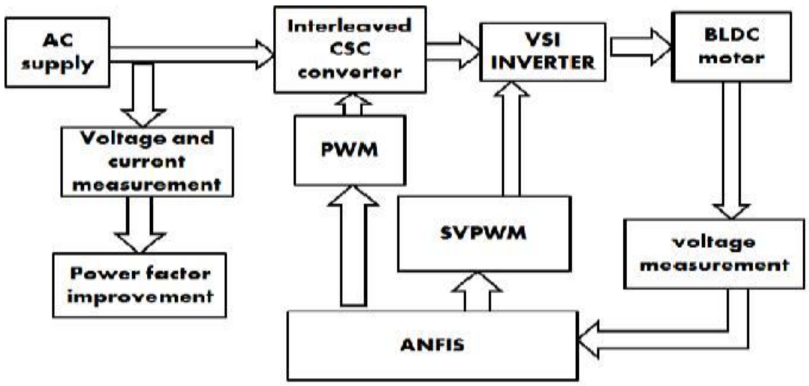

Fig.1.Block Diagram for BLDC motor drive speed control

Fig.1 shows the proposed BL Interleaved CSC converter based VSI fed BLDC motor drive. The input supply is given to the converter and its converts AC into DC power. These dc input fed into voltage source inverter again its converts DC power into three phase AC power. The three phase AC input is given to the BLDC motor because the BLDC motor only runs at three phase supply. Then the voltage and the speed of BLDC motor is given to the ANFIS controller which is used to control the speed of the motor. From input side the voltage and current measurement is used to power factor correction is improved by using this converter.

B. BLDC motor Drive

Brushless DC electric motor (BLDC motors) also known as electronically commutated motors (ECMs, EC motors) are synchronous motors that are powered by a DC electric source via an integrated inverter/switching power supply, which produces an AC electric signal to drive the motor. In this context, AC, alternating current, does not imply a sinusoidal waveform, but rather a bi-directional current with no restriction on waveform. Additional sensors and electronics control the inverter output amplitude and waveform (and therefore percent of DC bus usage/efficiency) and frequency (i.e. rotor speed).The rotor part of a brushless motor is often a permanent magnet synchronous motor, but can also be a switched reluctance motor, or induction motor.

These motors are a type of synchronous motor. This means the magnetic field generated by the stator and the magnetic field generated by the rotor at the same frequency. BLDC motors do not experience the "slip" that is normally seen in induction motors. BLDC motors come in single-phase, 2-phase and 3-phase configurations. Corresponding to its type, the stator has the same number of windings. Out of these, 3-phase motors are the most popular and widely used.

A BLDC motor depends on a mechanical system to transfer current, while AC and brushless DC motors use an electronic mechanism to control current. The stator of a BLDC motor consists of stacked steel laminations with windings placed in the slots that are axially cut along the inner periphery. The rotor is made up of permanent magnet and can vary from two to eight pole pairs with alternate North(N) and South(S) poles. Based on the required magnetic field density in the rotor, the proper magnetic material is chosen to make the rotor. A position of rotor is sensed using hall effect sensors embedded into the stator. Most BLDC motors have three Hall sensors embedded into the stator on the non-driving end of the motor.

Whenever the rotor magnetic poles pass near the hall sensors, they give a high or low signal, indicating the N or S pole is passing near the sensors. Based on the combination of these three hall sensor signals, the exact sequence of commutation can be determined. Each commutation sequence has one of the windings energized to positive power, the second winding is negative and the third is in a non-energized condition. Torque is produced because of interaction between magnetic field generated by the stator coils and the permanent magnets.

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C. Interleaved CSC Converter

Two different topologies are called buck-boost converter. Both of them can produce an output voltage much larger than the input voltage. It can produce a wide range of output voltage from the maximum output voltage to almost zero. This is also called as interleaved CSC converter. The inverting topology output voltage is of the opposite polarity as the input buck (step down) converter followed by a boost (step up) converter. The output voltage is of the same polarity as the input, and can be lower or higher than the input. Such a non-inverting buck-boost converter may use a single inductor that is used as both the buck inductor and the boost inductor. voltage and current is given as an input then the input supply is given to the bridgeless interleaved canonical switching cell it performs rectifier operation that is converts AC into DC. Also reduce switching stress of the converters then improving the power factor of the system. The output of the converter is given to the voltage source inverter. A inverter is converted DC into an three phase AC supply because the BLDC motor drive is works only in three phase AC voltage.

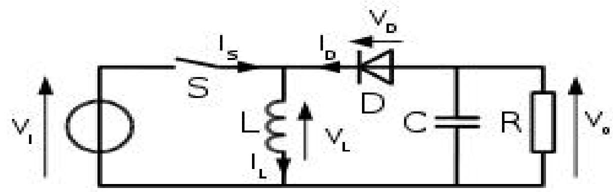

Fig.2.operational diagram for buck-boost converter

A operational diagram for buck boost converter is shown in fig.2. The two operating states of a buck-boost converter: when the switch is turned on, the input voltage source supplies current to the inductor, and the capacitor supplies the current to the resistor. When the switch is opened, then inductor supplies current to the load through the diode. The basic principle of this converter is fairly simple, while in the on state, the input voltage is directly connected to the inductor (L). This results in accumulating energy in L. In this stage, the capacitor supplies energy to the output load. While in the off state, the inductor is connected to the output load and the capacitor, so energy is transferred from L to C and R.

D. Power Inverter

A power inverter, or inverter, is an electronic device or circuitry that changes direct current to alternating current. The input voltage, output voltage and frequency, and overall power handling are dependent on the design of the specific device. The inverter can be entirely electronic or may be a combination of mechanical effects and electronic circuitry. Static inverters do not use moving parts in the conversion process.

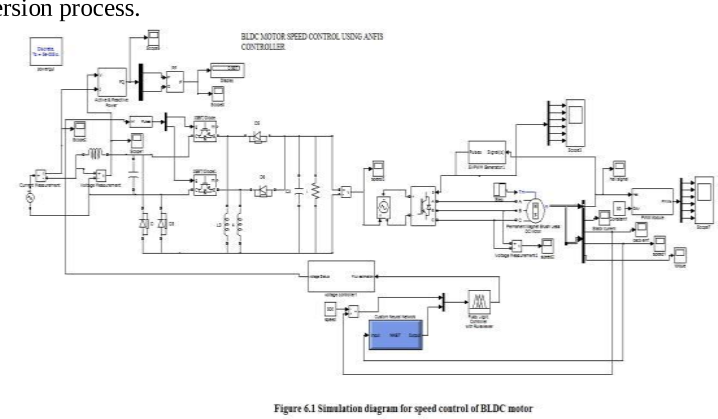

Fig.3.Simulation diagram

The parameters of the BLDC motor drive like speed, voltage, current, torque and back EMF is measured through scope. Then the speed of the motor drive is taken as input for the neuro control and the back EMF is compared with constant value. After that the output from two blocks is given to the input for fuzzy controller.

A fuzzy controller is change the frequency through pulse width modulation technique due to this the speed of the motor drive is controlled. The output of this controller is PWM signal which is given to the converter IGBT's through voltage controller. A space vector PWM signal is given to the inverter to control the speed and torque repulsion by changing the frequency of PWM signal.

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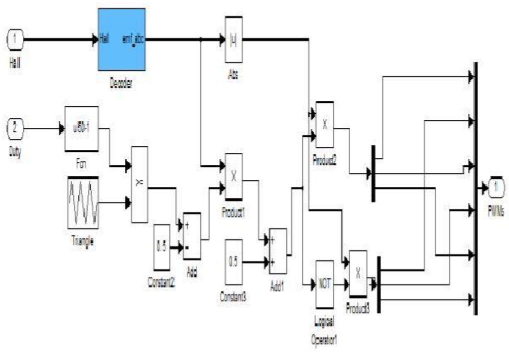
III.SIMULINK DIAGRAM

Fig.3.shows the simulation diagram for a speed control BLDC motor drive using ANFIS controller. The



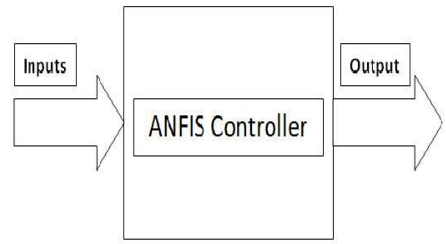


Fig.4.pulse width modulation   Fig.5. Block Diagram For ANFIS controller

Fig.4.shows the hall decoder subsystem consists of two IGBT switching connections. The IGBT block implements the controllable by the gate signal. A switch is simulated as a PWM module the PWM signals will be generator. The hall signal to the decoder and the output of the decoder is to give the PWM gate signal. This is the PWM gate signal operation of subsystem.

IV. ANFIS CONTROLLER

The combination of fuzzy logic and neural network is called as ANFIS (Adaptive Neuro Fuzzy Inference System). Neural system has many inputs and also has multiple outputs but the fuzzy logic has multiple inputs and single output, so the combination of this two is known as ANFIS which is used for nonlinear applications. The combination between the two methods (Neuro-fuzzy control systems) is a powerful identification and control technique. In recent years, Fuzzy Inference Systems (FISs) and Artificial Neural Networks (ANNs) have attracted considerable attention as candidates for novel computational systems because of the variety of the advantages that they offer over conventional computational systems. Unlike other classical control methods, Fuzzy Logic Control (FLC) and ANNs are more model free controllers, i.e. they do not require exact mathematical model of the system. For non-linear modelling, neural networks and neuro-fuzzy modelling approaches have received a great deal of attention.

This is the block diagram of ANFIS Controller, ANFIS controller is the combination of neural network and Fuzzy Logic. Many inputs are applied to the neural network depending upon the inputs the neural network has some standard output, so depending upon the input and the output the neural network is trained, after training the neural network the output is applied to the fuzzy logic which generates the IF THEN rules and membership functions, This is done in MATLAB Below is the block diagram of ANFIS controller.

V. SIMULATION RESULTS

The fig.6.shows a speed response BLDC motor drive system. The steady state is achieved at 0.1sec with less oscillation. For controlling the speed the system efficiency is improved. When compared to the existing system the speed oscillation is reduced so that the BLDC motor stability is not affected.

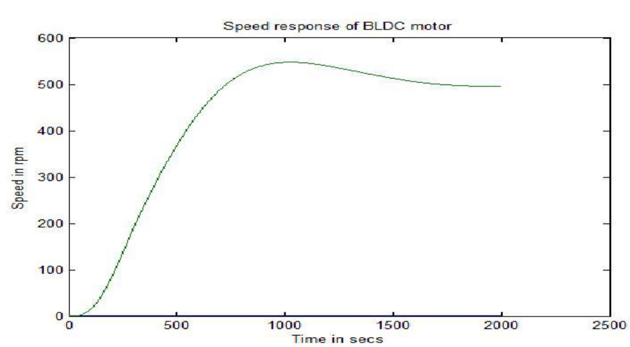


Fig.6.Speed response of BLDC motor drive

Fig.7. shows the power factor correction proposed system. From this the power factor is improved upto 0.987. When compared to the existing system the power factor is improving so the system efficiency is also increased.

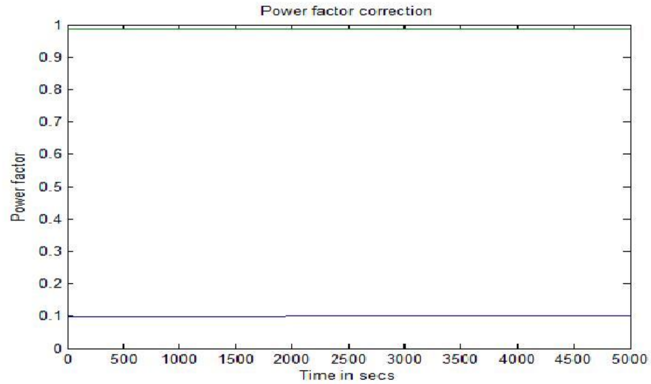


Fig.7.Power factor correction

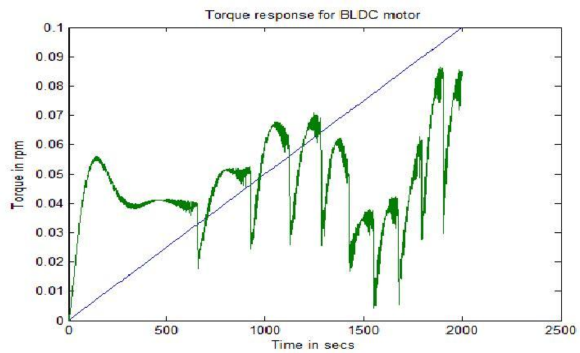


Fig.8. Torque response

Fig.8 shows the torque response for BLDC motor with low repulsion. Due to this less repulsion the system stability is improved. When compared to the existing system the torque repulsion is less and also is not affected the efficiency of the system.

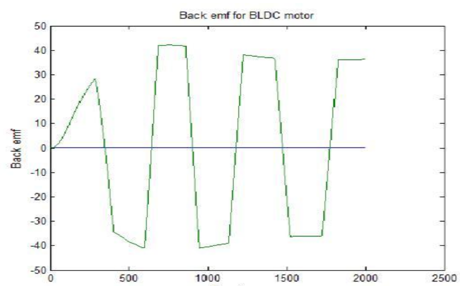


Fig.9. Back EMF of BLDC motor

Fig.9. shows the result of back EMF for BLDC motor drive system.

VI. CONCLUSION

A PFC brushless Interleaved CSC converter based voltage source inverter fed BLDC motor drive has been proposed targeting low power applications. A new method of speed control has been utilized by controlling the voltage at dc bus and operating the VSI at fundamental frequency for the electronic commutation of the BLDC motor for reducing the switching losses in voltage source inverter. The front end brushless interleaved canonical switching cell (CSC) converter has been operated for achieving an inherent power factor correction at ac mains. A satisfactory performance has been achieved for speed control and supply voltage variation with power quality indices within the acceptable limits of IEC 61000-3-2. Moreover, voltage and current stresses on the PFC switch have been evaluated for determining the practical application of the proposed system. A speed control is achieved by using ANFIS controller.

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