ANFIS Based Speed Control for Sensor Less BLDC Motor

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Abstract - Owing to its good torque to inertia ratio, less electromagnetic interference problems (EMI), good efficiency and ruggedness, the Brushless Direct Current (BLDC) motor finds broader applications. It is ideally suited to super fans, electric and hybrid cars, such as industrial robot actuators, extruder drive motors, and machine tools and home appliances for computer numerical control (CNC) drive. Various speed control strategies were implemented. Existing system uses fuzzy controller logic to control the speed. The proposed system aims in regulating the speed of sensor less BLDC fed with 4 switches 3 phase inverter. The proposed controller is ANFIS. The proposed system is estimated with less cost as it is working with no sensor and a smaller number of solid-state switches. Here, we are estimating back emf difference zero cross approximation technique and hence filter design is made easier. The MATLAB simulation was done and the prototype is developed in the laboratory. A comparison has been done between conventional fuzzy controller and ANFIS controller for the speed response characteristics. The experimental results were specified to bear out the uniqueness of the circuit and regulation of speed using ANFIS is better when compared with fuzzy.

Keywords - PMBLDC motor, ANFIS controller, Back emf, four switch three phase.

1. Introduction

There are several methods available to regulate the speed of BLDC motor. The speed can be controlled by controlling the dc input voltage or current. So many algorithms are available to govern the speed of BLDC motor with certain advantages and disadvantages. Here the specialty is with sensor less BLDC in which the detection of back emf (BEMF) zero crossing is done with the help of ANFIS controller. This ANFIS controller helps the BLDC drive to run in sensor less mode.

Generally, the permanent magnet motors are classified as Permanent magnet synchronous motor and Permanent magnet BLDC motor.

Brushless Direct Current (BLDC) machine is an AC machine with rotor as permanent magnet and stator with usual windings. As the stator gets enough dc supply, the switching process converts the dc into ac signal with specified waveform. There exist an interrelation between the electromagnetic stator and permanent magnet rotor. Flux created in the rotor permanent magnet energizes the stator windings which creates electromagnetic poles (North Pole and South Pole). The stator creates the rotating field by sequential stator phase supply. The energized stator attracted the rotor. In this situation, the rotor gets chased by the respective poles of the windings on the stator and rotor. The switching process chosen here is the SSTPI. This SSTPI is a 3ϕ VSI with six switches in three legs are commonly referred to as Six Switch Three Phase Inverter (SSTPI). Our proposed model reduces the number of switches from six to four. This 4 Switch 3ϕ VSI (FSTPI) is assigned with only 3 legs with two capacitors and four solid state switches. The problems with conventional dc machines are commutation and need for added sensors. Even though they are highly effective, they had the problem of sparking of brushes for changing loads and during speed reversal. In BLDC motors the commutators and brushes are replaced with solid state switches. Not only are the BLDC engines distinguished by their high performance, but also by their low maintenance. The function of mechanical commutator is performed by the six-switch commutation circuit.

A brushless DC motor is actually a usual DC motor with little modification. It is facilitating with the coil is wounded in the static part and permanent magnetic core fixed on the rotor. The stator and rotor have no physical connection. The several methods which are available to detect the rotor position can measure it only on every 60-degree electrical. But our method helps in determining the speed of the drive and rotor position exactly and continuously with measured motor parameters.

The requirement of low-cost high-performance drive for low and medium power applications has put the choice of sensor less technology in the present scenario of research and technology. This 4-switch inverter fed sensor less BLDC for speed control is not only the cost-effective sensor less approach but also the proposed drive. Using the back EMF difference technique, the rotor position is established. The benefit of using this three-phase inverter with four switches is that it eliminates the loss of conduction and switching. The speed control of the closed loop is accomplished by the ANFIS controller. This accomplishes least mean square algorithm. It tries to avoid the error in the feedback signal. Sensor less technique improves accuracy and MATLAB was used to simulate. The proposed inverter only has less phase voltage. In lieu of sensor applications, this suggested method is highly stable, competent and better to implement.

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2. Literature Review

The possibility of low-cost commercial applications four-switch three-phase BLDC motor drives: topology and control

This paper's key motivation is to facilitate low-cost four-switch brushless DC (BLDC) motor drives for industrial applications [1]. Using the direct current regulated PWM scheme, the desired static and dynamic speed torque features were extracted. This method is applied to two phases six switch bldc drive to do power factor correction and for speed control [2]. With its control system, this suggested drive was developed and theoretically analyzed and the output was shown. Along with DSP, TI TMS320C F243, the MATLAB simulation and experimental results were obtained [3].

Modeling-simulation-analysis of permanent-magnet motor drives

A phase variable form of the BLDCM (brushless DC motor) was developed by the authors. It evaluates the efficiency of a BLDCM speed servo fed by hysteresis current controller and pulse width-modulated inverter (PWM) [4]. The dynamic analysis has been made in motor by studying its pulse. The state space model has been done for its inverter switches and speed controller. The simulation was completed. For every switching sequence of the power system, the torque pulsation and current oscillations generated were simulated and measured [5]. The findings indicate that the outputs of the small and large signals were more or less identical [6]. Regardless of the technique used, PWM or hysteresis current controllers can be used; the large-signal and small-signal speed response will be the same [7]. While, due to the use of various current controllers, the torque pulses used can be different, the average value that defines the overall speed response is the same [8].

Four-switch BLDC motor drive focused on switching functions for modeling-simulation - implementation

In this paper, the proposed model replaced the actual circuits with functions for inverter switching and demonstrated the drive's entire steady state and transient efficiency [9]. With the power conversion unit, current and speed control system, an entire BLDC motor drive is investigated and the suggested model is implemented with the help of MATLAB-Simulink software [10]. Due to the problem arises by the elimination of two power switches, the direct phase current method is used. Both the simulation and the experiment illustrate the proposed model [11].

New configuration of a 4 switch BLDC motor drive without phase-shifter

This paper also applies the same inverter as above paper. The detection of 3 voltage variables derived from terminal voltages is centred on the Zero Crossing Point (ZCP) and six switching instants are given that correlate with voltage functions from ZCPs [12]. Thus, in conventional sensor less techniques, there was no need for a 30 or 90 phase delay that is common.

3. Existing System

In the existing system, the uncontrollable phase current produces the torque ripples and discontinuities in region 2. The reason for the uncontrollable phase current is due to the lack of capacitor for dc connection. The drawbacks to achieving a constant torque in some applications are those ripples and discontinuities. The reason for the uncontrollable phase current is due to the lack of capacitor for dc connection. The drawbacks to achieving a constant torque in some applications are those ripples and discontinuities [13].

The block diagram representation of the existing system is shown below. It is modelled with spider rotor 3 phase six pulse inverter in which the generated pulse from the fuzzy controller is fed to the machine for its control on error parameters. This method is having own disadvantages and advantages. The persistence of torque ripples for varying loads and hence problem in achieving desired performance.

4. Proposed System

A low-cost sensor less BLDC drive fed with four switch inverters was developed in the proposed system. The rotor position is sensed by back emf zero cross detecting method. This method helps in reducing the switching and conduction losses as there are only a smaller number of switches. This adaptive neuro fuzzy inference system with sensor less technique is proposed to control the motor performance characteristics.

The speed control of the closed loop is accomplished by the ANFIS controller. This accomplishes least mean square algorithm in the feed forward and back propagation algorithm. It tries to avoid the error in the feedback signal. Sensor less technique improves accuracy and MATLAB was used to simulate. The proposed inverter only has less phase voltage. In lieu of sensor applications, this suggested speed control scheme is highly stable, competent and easy to implement [14].

The suggested inverter has only a smaller phase voltage. In place of sensor applications, this suggested control method is highly accurate and competent. The block-diagram for the proposed system is shown below. The electronically commutated switch includes the switching logic of the FSTPI.
The speed error controlled by the ANFIS algorithm will be received as control signal to the FSTPI. From there it would be given to the BLDC machine [15].

5. Performance Analysis
MATLAB simulations are used to conduct performance analysis of the speed regulation of the BLDC motor. It was first developed for the Fuzzy controller and later on and the results were compared with the ANFIS controller.

*Performance analysis & results using FUZZY controller*

The simulated model for speed regulation of BLDC motor with the Fuzzy Logic Controller is shown in Figure 1 and Figure 2. Simulation results provide the required waveforms for the study of speed-time characteristics of BLDC motor drives. The back emf (B-EMF) estimation is done by means of zero crossing detectors. Thereby, the terminal voltage corresponding to the neutral point is measured because the velocity at which the machine is running is purely based on system voltage. So, by receiving the error signal, the fuzzy controller generates the pulse as per the requirement and is fed to the FSTPI. The time of rise, settling time and peak overshoot of the characteristics of speed have been studied. This fuzzy controller produces the output with certain improvement in the performance and in control of parameters for both speed and load changes. Its response shows high overshoot compared to ANFIS with significant disturbances and disadvantages. They are high cost, usage of additional capacitors, size and increased weight and less efficiency in spider web. Hence, the same speed control of BLDC is studied for ANFIS controller shown in the Figure 3.

*Performance- analysis & results using ANFIS controller*

ANFIS (Adaptive Neuro Fuzzy Inference System) is a dominant method which can be extremely used for all complex and non-linear systems. Fuzzy consists of only input layer, output layer and knowledge base rules. The advance neuro fuzzy has additionally ANN in between rules and defuzzification output layer. The architecture of ANFIS is shown in Figure 4. Using this advance technique, we can attain optimum output by keep on changing the parameters. The process of ANFIS includes a) fuzzification, b) knowledge base rules, c) neural network and d) defuzzification. [2] Input layer to ANFIS comprises the three phase currents flowing through the stator winding $i_a$, $i_b$, and $i_c$. The input i.e.; current and
speed error fed to fuzzy layer as the crisp data will be converted into linguistic variables. After that the linguistic variables are given to the predefined algorithm in the rule base block. The rule base block is linked to the neural network block where the back propagation and feed forward algorithm are used to eliminate the error and also to develop the control signal is shown in the Figure 5.

After the neural network block the signal is fed to the defuzzification block, there the linguistic variable is converted back to numeric variables. This is how the ANFIS estimator determines the parameter. The simulink for the proposed four switch inverter fed sensor less BLDC is shown below in Figure 6. This closed loop bdic drive had given good performance and speed characteristics.

The rotor position is sensed by back emf difference method. The current is controlled by current controller. The response settled smoothly compared with normal fuzzy controller with less disturbances. The simulation results are shown in Figure 7. Speed-Time Characteristics is shown in Table 1.

![Fig. 5: Architecture of ANFIS](image)

![Fig. 6: Speed control using ANFIS controller – MATLAB Simulink model](image)

![Fig. 7: Speed - time characteristics of BLDC motor using ANFIS controller](image)

### Table 1: Speed-Time Characteristics

| QUANTITY         | FUZZY controller | ANFIS controller |
|------------------|------------------|------------------|
| Rise Time (Rt) (milliseconds) | 299.5835         | 296.5678         |
| Settling Time Ts (Sec)          | 1.9794           | 1.1156           |
| overshoot         | 3.0116           | 2.2345           |

### 6. Conclusion

ANFIS controller is modelled and its output is checked at this point to attain speed control of sensor less BLDC machine. The BRUSHLESS DIRECT CURRENT motor drive increases the performance of the ANFIS controller. The results (Table I) were obtained from the open model indicating the implementation of the ANFIS controller. This paper presents a 4-switch converter topology that is considered more economical where cost savings are achieved by showing changes in the number of switches. The suggested procedure is confirmed by the simulation and hardware outcome.

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