

Fuzzy Logic Controller Based Speed Control Of BLDC Motor in Cooling System

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Abstract: Nowadays in all industries almost all the machines are run by the motor. To control the machine quickly and easily motor should be electronically controlled. In this paper the proposed system is to control the speed of BLDC motor without DC link Capacitor using Fuzzy logic controller. A simple BUCK Converter model has been proposed to predict the behavior of BLDC motor at constant speed. If DC link capacitor is not used, then the motor drive is operated directly from the rectified mains supply. The BLDC motor is controlled by a MOSFET inverter. In this system embedded plays a major role. Speed sensor senses the speed of motor and the data is given to the embedded system. It compares the set speed and actual speed to control the MOSFET driver. Mean time embedded system displays the speed of motor in a Liquid Crystal display. Using keypad operator set the required speed. Embedded system is programmed with Fuzzy logic controller to control the MOSFET inverter which is used to run the motor in a speed. Rotor position is obtained by the Hall Sensor signal. This control signal is given to the MOSFET inverter through isolating circuit. This isolating circuit is used to isolate the supply from the motor and to the embedded system. Without using DC link capacitor torque ripple is fully eliminated and speed can be controlled. For experimental results 60W prototype BLDC motor drive has been proposed to validate the theoretical analysis. To reduce the cost of components, minimize the size and to increase reliability, BLDC motor without DC link capacitor has been proposed. Therefore by using this project accurate and wide range of speed control can be achieved. The system consist of PIC controller, Isolating circuit, Fuzzy logic controller, MOSFET inverter, Brushless DC motor (BLDC), Hall sensor.

Keywords: BrushLess DC motor (BLDC), Fuzzy Logic Controller, MOSFET inverter, Hall Effect sensor signal, Gating signal, Torque ripple control.

1. Introduction

The proposed technique uses a small capacitor on the DC link to energize the motor on demand. The small compensation capacitor is more efficient than the original DC link capacitance. When compared to other motor types such as induction motor, brushed DC motors, BLDC motors has many advantage such as high reliability, low maintenance, high efficiency and long operating life. Permanent Magnet Synchronous (PMS) motors require either rotor position or angular position but three-phase BLDC motors only require rotor position for every 60 electrical degrees. The cost of the motor is reduced and performance is achieved due to the absence of DC link capacitor. In BLDC motor the position of the coil are sensed and current switched electronically to the corresponding phases. Hall Effect sensors are typically used to sense the rotor position. In this project the speed control and torque ripple is eliminated by means of a three phase with the star connection permanent magnet BLDC motor with the use of buck converter model. The speed control of BrushLess DC motor mainly useful in cooling systems to limit the heat flow. The proposed system for speed control performs the following tasks.

- Switching operations
- Back EMF sensing technique
- To control MOSFET inverter by means of gating signals

2. Brushless Dc Motor

Brushless DC (BLDC) motors are designed for tiny H.P. management motors which have high potential, salient operation, compact, dependable, and low maintenance. However, the management complexity for variable speed and also have high price for the electrical drive twiddling my thumbs the various use of Brushless DC motor. Over the past years, continuous technology development are made in semiconductors, microprocessors, logic ICs, adjustable speed drivers (ASDs) for management schemes and permanent-magnet brushless motor productions are combined as efficient resolution for a broad variety of adjustable speed applications. Appliance are historically proven on classical motor technologies like single AC induction motor, as split section, capacitor-starter, capacitor-run sort, and universal motor. These classic motors usually measured on the basis of operation at constant-speed directly from main AC power supply which considers about the potential. BLDC motors do not expertise on the slip that is not seen in induction motors. BLDC motors operate in single-phase, 2-phase and 3-phase configurations. By admiring its kind, the mechanical device has a similar type of windings. Out of these phases, 3-phase motors measure almost all styles and are widely used. This application mainly focuses on 3-phase motors. Every commutation sequence has one of those windings energized to provide positive power which means current enters into the winding and the second winding is negative which means current exits the winding and also the third is in almost non-energized condition. Torsion is obtained due to the

interaction between the magnetic flux generated by the mechanical device and the permanent magnets. Ideally, the height torsion happens when these 2 fields measure at 90° to every phase and falls off because the fields are moved. The rotor is mainly made up of permanent magnet and can vary from two to eight pole pairs such as North (N), South (S) poles. Based on the density in the rotor magnetic field, the proper material is chosen to make the rotor winding. Ferrite magnets are used to make permanent magnets. As the technology becomes advanced, rare earth alloy magnets are gaining popularity nowadays as shown in the Figure 1.



Figure1. Circular core with rectangular magnets embedded in the core.

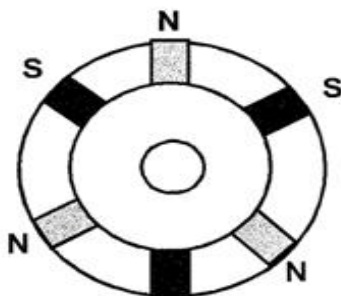


Figure2. Circular core with rectangular inserted into the rotor core

In contrast, three-phase BLDC motors only require rotor position information for every 60 electrical degrees, which can be derived from three inexpensive Hall Effect sensors or a back EMF sensing technique. Circular core for rotor winding with rectangular part is shown in the Figure 2. BLDC motors have become the preferred choice for industry applications where efficient, compact and cost effective motor drives are required. The motor drive comprises a diode rectifier, a large electrolytic capacitor and a converter fed with rotor position information. The electrolytic capacitor is bulkier in size and weight, and its lifetime is severely affected by the operating temperature. Thus, the inclusion of the capacitor reduces the reliability of the motor drive, particularly in hot or cold environments such as heating, ventilation and air conditioning applications. Moreover, electrolytic capacitor technology is relatively stable, and the price is governed only by the cost of materials. Therefore, the cost of an electrolytic capacitor is more or less static compared to costs associated with processors, power electronic switches and driver circuits. For example, the cost of the DC link capacitor is approximately 5% – 15% of the overall cost of BLDC motor drives made by Wellington Drive Technologies Ltd. In addition, the absence of the DC

link capacitor yields a reduction of 4% – 15% in the area of the printed circuit board and the volume of the enclosure. Thus, to reduce the cost of components, minimize the size of the enclosure and to increase the reliability, a BLDC motor drive without a DC link capacitor is proposed in this system. For more detailed information on this subject, the applications of the BLDC motor includes the following

- Computer hard drives
- Cooling fans
- Cordless power tools
- Electric vehicles and hybrid vehicles
- HVAC and refrigeration industries

3. Proposed System

Switching Operation of BLDC Motor

The switching operations for BLDC Motor are shown in the Figure 3. Various techniques have been proposed and successfully implemented to compensate for the torque ripples in BLDC motor drives that are caused by current commutation between phases and cogging. These compensation techniques can be broadly classified into two mainstreams. The first mainstream is physical modifications of the motor to reduce the torque ripple. The second mainstream is modifications of the controller to compensate for the torque ripple. The cost of the overall motor drive is significantly reduced due to the absence of the DC link capacitor but at the expense of torque ripples, which are inevitable and expected to be around zero crossings of the mains supply. The operation of the motor drive during all other steps of the switching algorithm can be represented by the same buck converter model. Since two phases are lumped together, $e(t)$ represents the line-to-line back EMF (V), and S and D in represent the controlled switch and freewheeling diode, respectively.

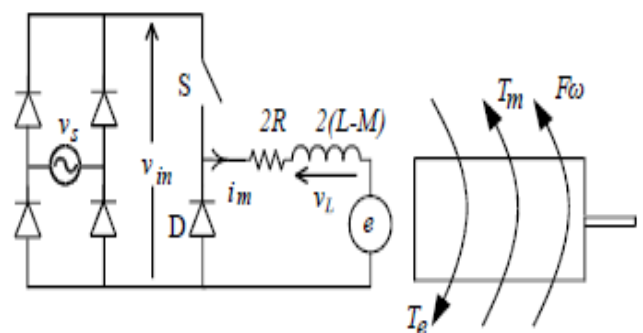


Figure 3: Switching Operation of BLDC motor

To reduce the cost of components, minimize the size of the enclosure and to increase the reliability, a BLDC motor drive without a DC link capacitor is proposed and illustrated in Figure4. Without the DC link capacitor, the motor drive is operated directly from a rectified mains supply. The cost of the overall motor drive is significantly reduced due to the absence of the DC link capacitor but at the expense of torque ripples, which are inevitable and expected to be around zero crossings of the mains supply. Various

techniques have been proposed and successfully implemented to compensate for the torque ripples in BLDC motor drives that are caused by current commutation between phases and cogging.

2. Inference Engine - combine membership functions with the rules to derive the fuzzy outputs
3. Defuzzification – use different methods to calculate the output and form them as lookup table. Select the output from lookup table based on the current input during the application.

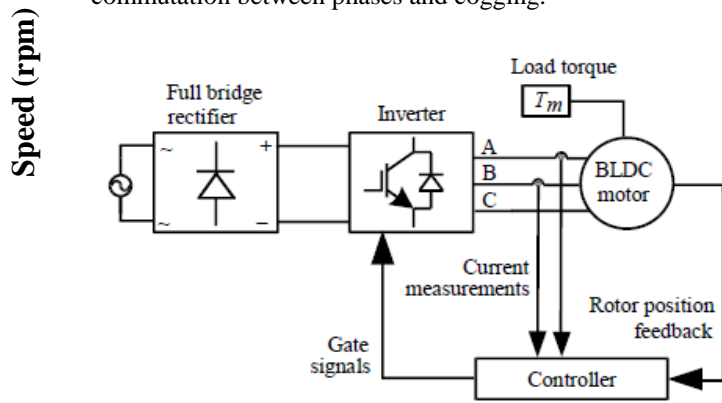


Figure :4. BLDC motor drive without a DC link capacitor.

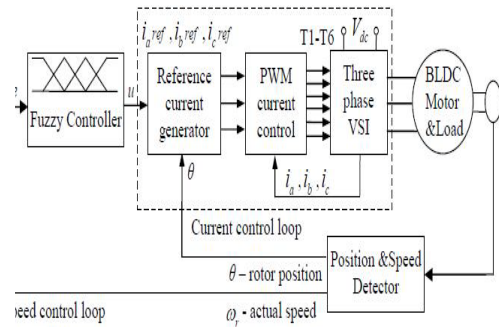


Figure6. Fuzzy Logic Controller

The equivalent circuit operation has been obtained in the Figure 5. CDC is charged through the antiparallel freewheeling diode associated with SDC. However, there is no natural discharging path for the capacitor, and the discharge can be controlled by the gate signal applied to SDC. The energy stored in CDC should be sufficient to keep $i_m(t)$ at I_{ref} during region 2 to eliminate the torque ripple. The controller is developed in such a way that the gate signal applied to SDC is derived based on E and $V_{em}(t)$, while controlling the other switches in the inverter. Line-to-Line back EMF E can be calculated by the speed of the motor, which can be obtained using the rotary part of the motor. Since CDC only supplies energy to the motor during region 2 when $E > V_{em}(t)$, the size of CDC is smaller compared to a DC link capacitor used in a conventional BLDC motor drive. Thus, an inexpensive capacitor and a switch can be used to compensate for the torque ripple.

4. Simulation Results And Analysis

Proposed fuzzy logic controller based output has reduced the torque ripple and maintains the constant speed as shown in Figure 7. Hence the motor can be operated with sufficient speed and ripples are eliminated.

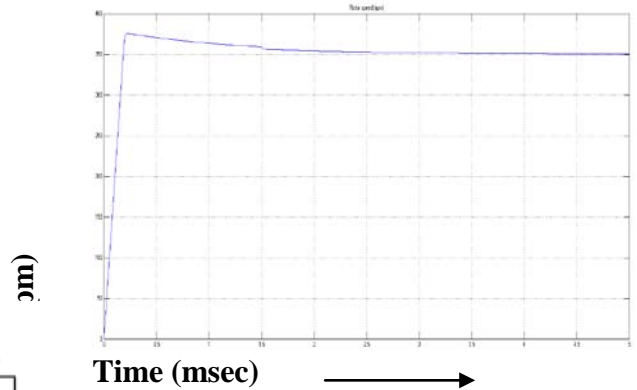
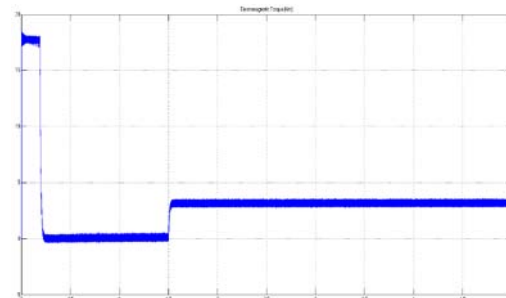


Figure7. Proposed Fuzzy controller based BLDC motor of output waveform for Rotor Speed

The maximum torque that can be delivered from the motor drive is lower without the DC link capacitor for a given value of peak current limit. Ideally, with the proposed compensation, the torque ripple due to the absence of the DC link capacitor is fully eliminated.



Current (mA)

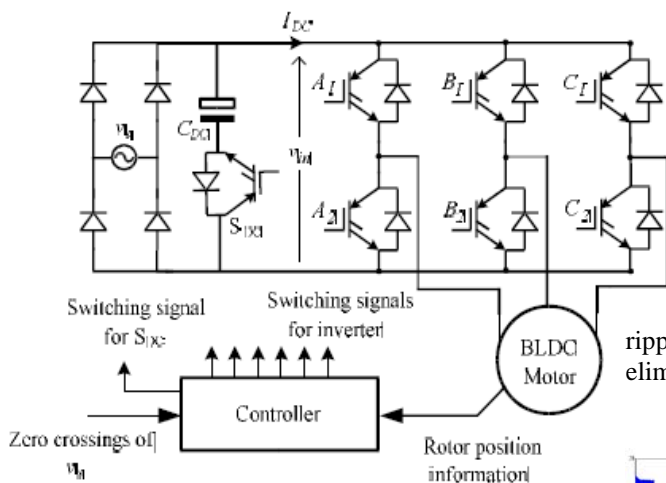


Figure5: Equivalent Circuit of BLDC motor

Fuzzy Logic Controller

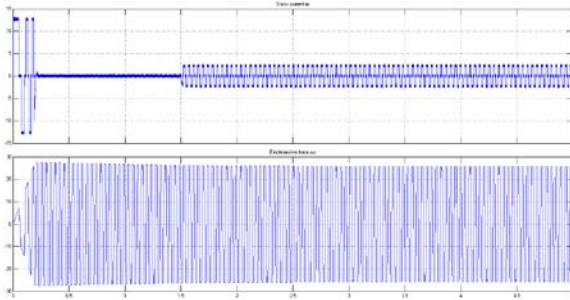
Proposed system for Fuzzy Logic Controller is shown in the Figure 6. To implement fuzzy logic technique in a real time application requires the following three steps:

1. Fuzzification – convert crisp data into Membership Functions

Time (msec) →

Figure8. Proposed Fuzzy controller based BLDC motor of output waveform for Electromagnetic Torque

In existing there is a path to discharge so that the torque ripples are partially eliminated which makes the motor to get distorted. So the application of BLDC motor speed is not compact for perfect industrial operations.



Time (msec) →

Figure9. Proposed Fuzzy controller based BLDC motor of output waveform for Stator Current and Electromotive Force

In Figure 9 the proposed fuzzy logic controller based output waveform for stator current and EMF has shown. This is almost lower than the existing system so that the ripples are fully eliminated.

Torque (Nm)

5. CONCLUSION

BLDC motor has become an effective application in industries. Brushes are not used in this system, as it leads to avoid the mechanical friction with rotor. The starting torque is comparatively high. The control of the motor is possibly done through a converter in the input. PWM signals required to feed the input. In this paper fuzzy logic controller is used for efficient outcome and ripples are fully eliminated. The accuracy in results is based on buck converter model and is effective for proposed technique. To reduce the cost of components, minimize the size and to increase reliability, BLDC motor without DC link capacitor has been proposed. The proposed compensation technique is expected to be useful for manufacturing low cost BLDC motor drives with comparable performance and speed can be controlled by using the inverter.

Advantages

- Minimized size
- High Reliability
- High Performance

Applications

- Cooling fans
- Refrigerator
- Computer Hard drives

Future Work

The paper deals with the Speed control for BLDC motor without DC link capacitor using fuzzy logic controller. Switching operations and gating signals are analyzed and torque, speed can be measured by using fuzzy logic controlling technique. In future the paper can be analyzed with genetic algorithm method and comparison results can be implemented in the hardware to achieve the comparable performance.

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