International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Vol-05, Issue-05, Aug 2019

Speed Variation Techniques of Three Phase Brush-Less DC Motor

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Abstract: BLDC motors are becoming most common motors nowadays in small HP requirements like in wheel chairs, automotive etc. due to its special features viz. noiseless operation, high efficiency, high dynamic response, better operating characteristics and life and higher speed ranges . Speed control of these motors can be a limitation which is to be encountered. This paper illustrates the BLDC motor along with the difference between conventional technique for speed control using Hall sensors and new sensor less technique for the same which reduces the maintenance of sensors which required for accurate detection of rotor position. This sensor less technique is also advantageous for making compact sized control circuitry.

Keywords* — *BLDC Motor,Fuzzy Logic,Hall Sensors, Speed Control,Stator,Rotor Position,Sensor Less.

I. Introduction

Conventional DC motors are getting replaced by Brushless DC motors as they are small in size, have high operating speed, efficiency, requires less maintenance and excellent torque speed characteristic, higher power-weight ratio. Due to all these advantages PMBLDC motors are extensively used in wide range of applications including information technology equipment such as, computers, printers & scanners, household appliances, aerospace, electric vehicles, robotics etc. BLDC motor can be considered as a permanent magnet synchronous motor with a trapezoidal back Electro Motive Force (EMF) waveform shape.

Speed control of PMBLDC motors can be done by using two techniques which are sensor control and sensor less control. Out of these two techniques the sensor less is more effective as it reduces cost, increases reliability, and provides easy maintenance compared to sensor control. In sensor control techniques sensors are required to detect the rotor position so the requirement of sensor maintenance is mandatory if we need accurate detection of rotor position. Due to this where the access to motor is difficult it is preferable to use sensor less speed control technique as it has many advantages as listed above. Sensor less control technique has limitations as they have low performance in transient state or low speed range or sometimes additional circuits may require achieving required performance.

Precise control is required in many applications to get desired performance of motor. I classical sensor speed control technique requires accurate mathematical model of system and gives accurate output only under linear conditions of operation. Due to the non-linear applications of PMBLDC motors like washing machines, automotive, wheel chairs or any other heavy duty application, it is very difficult to obtain mathematical model. Hence it is necessary to develop some advanced controller. For this reason here we will try a attempt by developing Fuzzy logic based controller for controlling PMBLDC motor. Specialty of Fuzzy logic is its simplicity; accurate controlling and it does not require any accurate mathematical model.

II. BLDC Motor

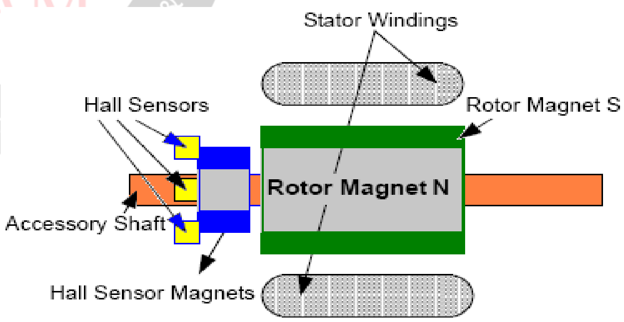

Figure 1. Transverse section structure of a brushless dc motor

Fig.1 shows the transverse section of BLDC motor. Main parts of BLDC motor are Stator, Rotor and hall sensors. Stator is similar to that of polyphase alternating current motors and it is fixed whereas rotor comprises one or more powerful permanent magnet. BLDC motors can be 1-phase,2-phase or 3-phase connections, out of which 3-phase BLDC motors are popular than others. Stationary stator windings are fed with separate three phase voltages.

 DOI : 10.35291/2454-9150.2019.0397

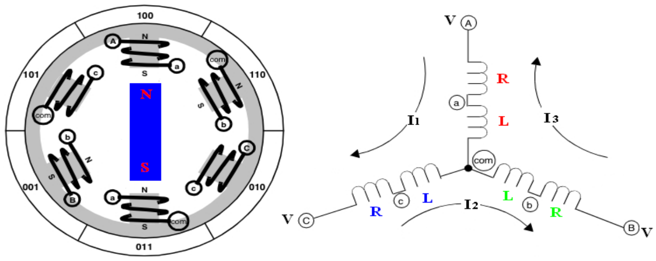

Figure 2. Electrical diagram of BLDC motor

Fig.2 elaborates the electrical wiring diagram of PMBLDC motor consisting a phase resistance (R) and an inductance (L) respectively. Though BLDC motor comes in fixed voltages type viz. 5V,6V,12V,24V etc , 12V type is commonly used. Voltage-speed characteristics follower linear relationship i.e. when voltage increases speed increases. As per this we get highest speed at rated voltage. The polarity reversal in BLDC motor is achieved by power electronic device like power MOSFET or IGBT etc. Hall sensors are used to match the rotor position.

III. HALL SENSORS

Hall sensors are embedded into the stator on non-driving end of motor. It provides information to synchronize stator armature excitation with rotor position by sensing accurate position of the rotor to the stator. At a time two coils work for 3Φ current as sensors shift at 60º or 120º phase shift for each of three coils. As per the changing current direction and Fleming's left hand rule we can determine direction of force. According to this if permanent magnet on rotor moves clockwise, and rotor of the BLDC also moves clockwise.

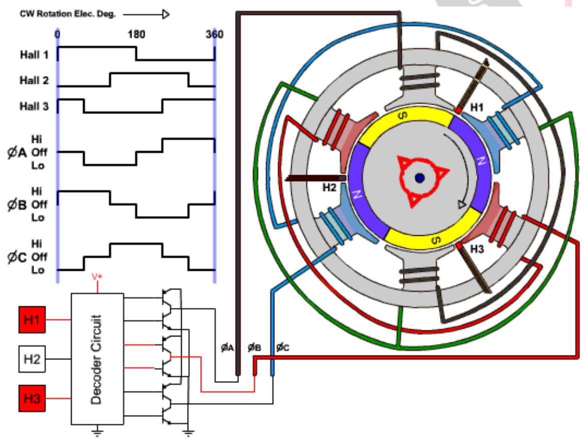

Fig.3 shows BLDC motor with Hall sensor positions and rotor position detection circuit. To control the speed PWM is required. Pulse Width Modulation of Hall sensor output can be performed to vary the speed. When the signals marked by PWM switches ON or OFF according to the sequence, the motor will run at the rated speed. The PWM frequency should be 10 times of the maximum frequency as thumb rule. The stator voltage can be increased by varying duty cycle which will result into increased speed.

IV. FUZZY LOGIC AS A CONTROL TOOL

An application of Artificial Intelligence (AI) is increasing daily. Techniques like neural network and Fuzzy like some examples of controlling under AI which applies in complex and on-linear systems like Washing Machines, subway systems, video cameras etc. Fuzzy logic enables the designer to describe the general behavior of the system in a linguistic manner by forming IF-THEN rules which are in the form of statements by understanding general behaviors of load connected. Fuzzy logic controller comprises of fuzzification, fuzzy rule-base, fuzzy inference engine and defuzzification. The structure is as shown in Fig.4

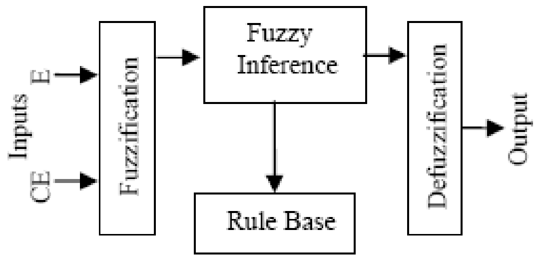

Figure.4 Structure of fuzzy logic controller

Step 1: Define inputs, outputs and universe of discourse.

The inputs are error (E) and change in error (CE) and the output is change in duty-cycle (ΔDC). The error is defined as the difference between the set speed (Nset) and actual speed (Nact) and the change in error is defined as the difference between the present error e(k) and previous error e(k-1). The output, Change in duty-cycle ΔDC is which could be either positive or negative is added with the existing duty-cycle to determine the new duty-cycle (DC new) in order to control the voltage applied across the armature windings.

Step 2: Defining fuzzy membership functions and rules

To perform fuzzy computation, the inputs must be converted from numerical or crisp value into fuzzy values and the output should be converted from fuzzy value to crisp value. The fuzzy variables error, change in error and change in duty-cycle are quantized using the following linguistic terms negative (N), zero (Z) or no-change (NC) and positive (P). Fuzzy membership functions are used as tools to convert crisp values to linguistic terms. A fuzzy variable can contain several fuzzy subsets within, depending on how many linguistic terms are used. Each fuzzy subset represents one linguistic term. Each fuzzy subset allow its members to have different grade of membership, usually the membership value lies in the interval [0, 1]. Since microcontroller can handle only integer values, the range of membership is chosen in the range of [0,10]. In order to define fuzzy membership function, the designer can choose many different shapes based on their preference and

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experience. The popular shapes are triangular and trapezoidal because these shapes are easy to represent designer's ideas and requires less computation time. In order to fine tune the controller for improving the performance, the adjacent fuzzy subsets are overlapped by about 25%. The membership functions used for inputs and output are illustrated in Fig. 5.

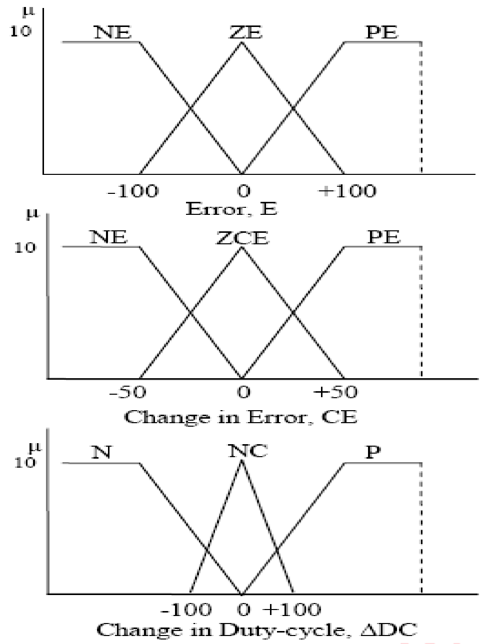

Fig5. Membership functions for Error (E), Change in Error (CE) and Change in Duty-Cycle (ΔDC).

Fuzzy Logic Controller uses Fuzzy Rules instead of accurate mathematical model of system to create control actions in the form of IF-Then statements. Rules are depend on designer's understanding and past experience. Adjustment in membership function helps to improve the performance of controller. Fuzzy associative memories (FAM) are transformations which map fuzzy sets to fuzzy sets. A FAM matrix maps antecedents to consequents and is a collection of IF-THEN rules. Each composition involves three fuzzy variables and each fuzzy variable is further quantized into three. This has resulted in nine possible two input and single output FAM rules.

Finally the fuzzy output is converted into real value output i.e. crisp output by the process called defuzzification. Even though many defuzzification methods are available, the most preferred one is centroid method because its can easily implemented and requires less computation time when implemented in digital control systems using microcontrollers or DSPs.

V. Sensor less Speed Control

There are different methods to detect the rotor position. Some of them are (i) Back EMF detection by zero-crossing detection or by phase locked loop method or emf integration approach. (ii) Stator's third harmonic voltage detection (iii) Detection of conducting interval of free-wheeling diodes connected in anti-parallel with the solid-state switches (iv) Monitoring the inductance variation in the d-q axes.

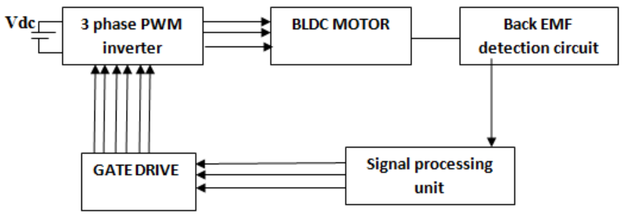

Figure 6: Block Diagram of Sensor less Speed control of PMBLDC Motor

Fig 6 shows the block diagram of Sensor less speed control using Bach EMF detection technique used for PMBLDC motor.

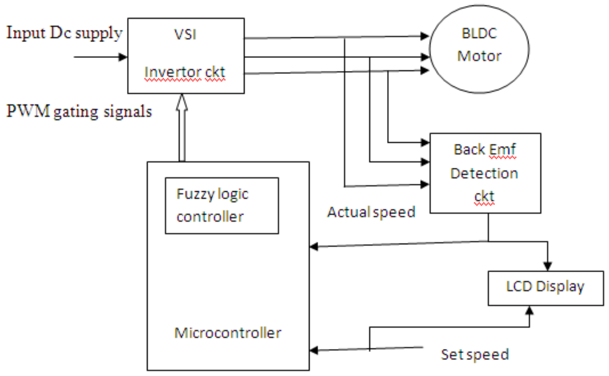

Figure 7: Block Diagram of Experimental Setup Sensor less control of BLDC motor using fuzzy logic

Fig 7 shows the proposed experimental setup of sensor less speed control of BLDC motor using Fuzzy Logic. Fuzzy logic is most suitable for BLDC motor's non-linear behavior as it is rule based control. Simple IF-THEN rule set eliminates the requirement of complex mathematical model of system.

VI. Conclusion

This Paper elaborates about different techniques of speed control of BLDC motors. Along with it we can compare conventional speed control method using Hall Sensors and new sensor less technique based on Fuzzy Logic. There are advantages and limitations of both the methods. The major advantage of conventional sensor control is it gives accurate results under low speeds also but limitations of it are high maintenance cost and bulky ness as compared to new sensor less control. Whereas sensor less control has many advantages like less cost, compact etc. but it does not give desired output under low speed conditions. Here we can conclude that sensor less control is suitable for applications where there is less space is available. And conventional method can be adapted where application is of low speed.

 DOI : 10.35291/2454-9150.2019.0397

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