SENSORLESS CONTROL OF BLDC MOTOR WITH PI AND FUZZY CONTROLLERS

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Abstract—**In the present days the BLDC motor has increased the demand for the various advantages like the obtaining high efficiency by reducing the losses in the motor, low maintenance , low rotor inertia etc., that are been used in the various application fields in the BLDC for the robotic applications ,servo drives but further reduction of losses can increase the application range which has been obtained by the sensorless operation of the BLDC motor in which the motor does not need the sensors and the decoders which reduces the construction cost of the motor which can be used in the various application fields. The paper includes the operation of the BLDC motor in sensorless operation with the standard PI and fuzzy logic controller and the obtained results are compared and tabulated for the various speed ranges and the different loading conditions as given below are obtained with the help of MATLAB/SIMULINK and the results are graphically compared.**

Index Terms— BLDC motor, fuzzy, sensorless control, modeling.

I. INTRODUCTION

In recent day improvements in devices using the , power electronics, permanent magnet and modern controlling technologies have been prompting the high scale usage of Permanent magnet brushless (PMBL) DC motor to reach the industrial requirement of recent day to day worldwide market in need of developed goods, products, and devices. large, medium, small and as well as mini PMBLDC motors are more needed for the all recent day applications in most types of controlling motion devices and their respective models. The speedy increase in the recognition of the PMBLDC motor which is highly needed to its business usefulness in the types of motor in terms of size and high performance and operation.

The Brushless dc motor has physical appearance resemblance same as the 3-ph Permeant Magnet Synchronous Motor which is normally operated using a six step inverter which changes a continuous voltage to 3-phase voltages with frequency equivalent to the real-time rotor speed. This paper is the implementation of PI and fuzzy logic controllers to a simulation of BLDC motor for achieving of better performance in terms of robustness, speed, variations in the parameters and control during the loading conditions.

II. BRUSHLESS DC MOTOR

The BLDC motor system consists of a permanent magnet motor runs by the pulses fed from the 3-ph PWM inverter, position sensor for the rotor, current controller and speed controller for the controlling purposes. Coming to the working here the inverter is connected to the dc source will feeds power to the motor. Here the switching pulses are generated for the control of hysterics of the motor and the magnitude and frequency of the inverter .the rotor position will be decided by the switching pulses that are generated by the inventor and also depended on the speed error and winding currents. Here the controller matches the currents of winding with the rotor position. It also controls the variable speed operation of the drive and preserves the motor speed reference value even during load variations and supply fluctuations. Figure 1 shows the block diagram of the PMBLDC motor.

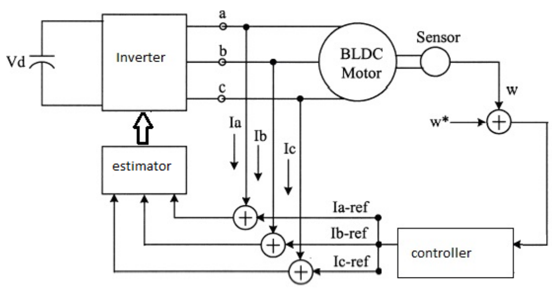

Figure-1: block diagram of BLDC motor

III. SENSORLESS CONTEOL

For the sensorless control of the PMSM motor, include in trapezoidal and sinusoidal machines. .the estimation of the speed and position (absolute) is not difficult if the machine is running above the certain minimum speed, it becomes extremely difficult at low speeds, particularly from stand still condition. Here we have 2 types as explained above

1. Trapezoidal machine drive or (BLDM)
2. Sinusoidal PM drive (PMSM)

1. Sinusoidal PM drive

As the trapezoidal method, the sinusoidal method is some difficult since 3 devices conduct in an instant and continues position signal of rotor to be controlled. For this there are 3 methods

1. Terminal voltage and current sensing
2. Inductance variation method
3. Extended kalman filter

1. Terminal voltage and current sensing

This is one of the simplest method, where the unit vectors are derived directly from machine terminal voltages and currents to implement stator flux- oriented vector control figure 2 shows that the vector controlled drive based in estimation from terminal voltages and the estimated equations are given as below

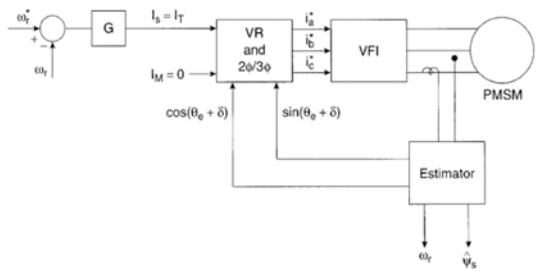

Figure-2: block diagram of sensorless control of sinusoidal drive based on the terminal voltages and currents

$$\psi_{ds}^{s} = \int (v_{ds}^{s} - R_s i_{ds}^{s}) dt$$

$$\psi_{qs}^{s} = \int (v_{qs}^{s} - R_s i_{qs}^{s}) dt$$

$$\psi_s = \sqrt{(\psi_{ds}^{s2} - (\psi_{qs}^{s2})}$$

$$\cos(\theta_e + \delta) = \frac{\psi_{ds}^{s}}{\psi_s}$$

$$\mathrm{Sin}(\theta_e + \delta) = \frac{\psi_{qs}^{s}}{\psi_s}$$

$$w_e = \frac{d\theta_e}{dt} = \frac{(v_{qs}^{s} - R_s i_{qs}^{s})\psi_{ds}^{s} - (v_{ds}^{s} - R_s i_{ds}^{s})\psi_{qs}^{s}}{\psi_s^2}$$

Where

$\cos(\theta e + \delta)$, $\sin(\theta e + \delta)$ are unit vector signals

By solving the value of the above estimation the speed and the position can be estimated.

Here the voltage and the current are taken as a input of the estimator and the estimated value of the Ψs and by the value of the $\cos(\theta e + \delta)$, $\sin(\theta e + \delta)$ to the voltage regulator which is used to convert the signals of the sin, cos the output from the regulator to the motor

This mainly is the operation of the sensorless control of the BLDC motor.

IV. CONTROL TECHNIQUES

Here the study of the BLDC motor is operated in the PI and FUZZY

1. Proportional- Integral (PI) Control

The combination of proportional and integral terms is important to increase the speed of the response and also to eliminate the steady state error. The PID controller block is reduced to P and I blocks only as shown in figure 3.

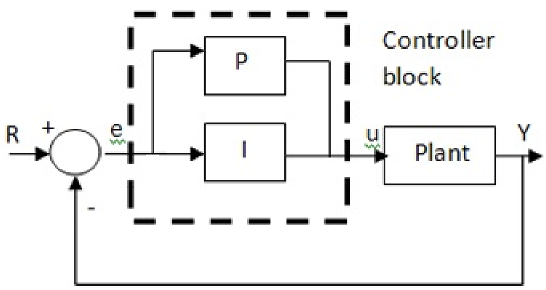

Figure 3: Proportional Integral (PI) Controller block diagram

Coming to the working of the pi controller the Kp and Ki values are the respective proportional and integral values of the controller are firstly given assumed values of Kp and Ki respectively. These values are been tuned to the desire values such that the error is minimum and this estimation is done by the error between the output and the set value (desired value).

2. FUZZY CONTROLLER

Fuzzy logic has developed from few decades. During these period of time this fuzzy had been vastly developed in many fields and has been successfully implementing till date with a large scale of industrial applications and the various applications that are required for the consumer
Mainly the logic has a capability of converting the controlling rules that are been given on the expert knowledge of automatic controlling system as a similar to the human brain which converts the signals .this fuzzy can be applied to the various applications depending on the certain and uncertain models .
This model is operated on the fuzzy logic by the some basic rules that are been implemented to the fuzzy membership function and also the pi controller is also applied for the motor The block diagram of the fuzzy is as below fig 4 The FLC has two inputs,
The error e (K) and change of error Δe(K),

Which are defined by
Error e (K) = r (K) – y (K) (1)
Change of error Δe (K) = e (K) – e (K-1) (2)
Here r and y are the set point of the input and output of the plant respectively. Similarly the K and (K-1) indicate the present and the previous state of the model, similarly. The output of the fuzzy logic is the increasing change in the signal Δu(K). And here the membership functions of the fuzzy are inputs, e and Δe, and the output, Δu which are been defined on the common domain [-10, 10].

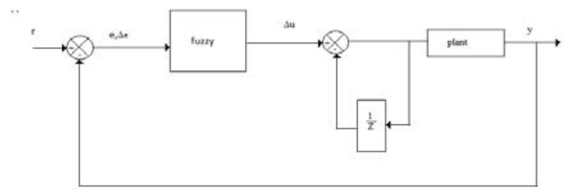

Figure 4: block diagram of fuzzy logic.

V. RESULTS

The simulation model of BLDC motor with fuzzy and pi
Using MATLAB/SIMULINK is shown in Figure 5

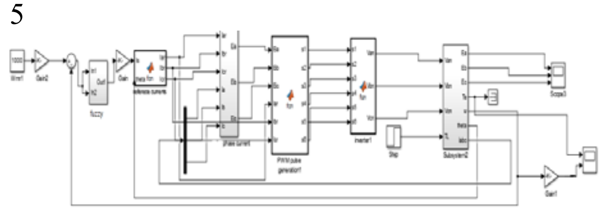

Figure: 5a model of fuzzy controlled BLDC motor

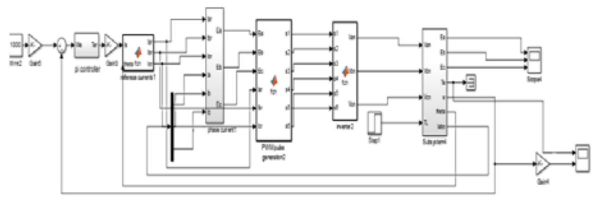

Figure: 5b model of pi controlled BLDC motor

Motor speed control is simulated using PI, FLC the results are shown in Figures 6

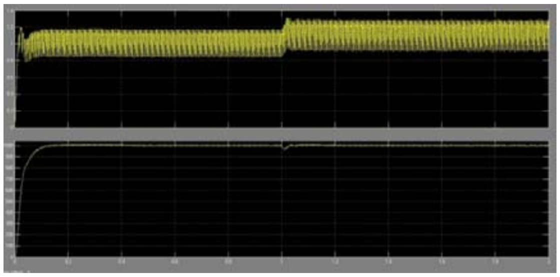

Figure 6a: output of the pi controller

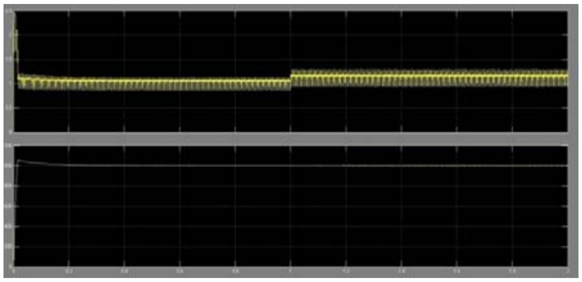

Figure 6b: output of the fuzzy controller

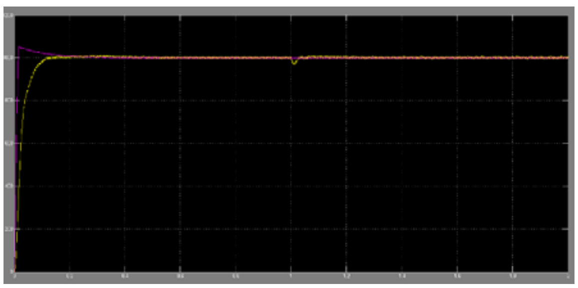

Figure 6c: output of PI and FUZZY

The fuzzy rule base that is given in the fuzzy controller is as given figure 7

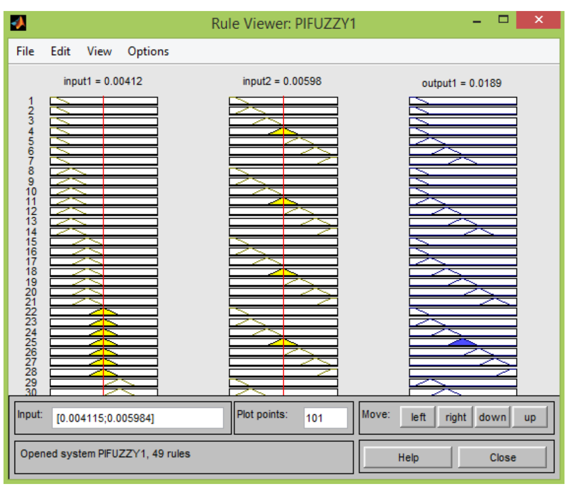

Figure 7: fuzzy rule viewer

The parameters of BLDC motor are given below.

Rating: 1 HP
Rated speed: 1000 rpm
Rated voltage: 160 V dc
Rated Torque: 0.662N-m
Number of poles: 4
Rated current: 5 A
Type of connection: star
Resistance / phase: 0.75 Ω
Self & Mutual inductance: 2.75 x 10-3 H / Phase
Moment of inertia: 0.1524x10-4 kgm2
Back emf constant: 0.10743Vsec/rad

VI. DISCUSSION OF RESULTS

The overall performance can be studied by the settling time, peak time, peak overshoot, set speed time etc. Here the motor is operated at a set speed of 1300, 1000, 500 respectively and at a time of 1 sec the load is applied and the variation of the load can be observed in the pi controller and has been reduced in the fuzzy and similar the output is observed at various loads and speeds as given tabular columns

Table 1: comparison of the pi and fuzzy controller

Reference speed in rpm	1300		1000		500	
controller	PI	FUZZY	PI	FUZZY	PI	FUZZY
Settling time	0.5	0.2	0.3	0.1	0.2	0.1
Rise time	0.3	0.1	0.1	0.02	0.1	0.01
Peak overshoot	0.60	0.15	0.50	0.12	0.45	0.11
Dip when load applied(S)	0.15	0.01	0.04	0.01	0.02	0.01

VII. CONCLUSION

From the above obtained outputs of the pi and fuzzy logic controllers the sensorless operation of the BLDC motor has been studied and the tabular column gives a clear cut view of the operation at various speeds and loads at the desired level of operation and from the tabular column and the obtained we can clearly say that the performance of the BLDC is more accurate and reliable for the fuzzy logic controller than that of the standard pi controller which helps the motor that can be used for the vast range of application on the further work can be done by combining the models as a hybrid network which can be research for the operation and study of the BLDC motor

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