International Journal of Scientific Research in Science, Engineering and Technology (www.ijsrset.com)
© 2020 IJSRSET | Volume 7 | Issue 2 | Print ISSN: 2395-1990 | Online ISSN : 2394-4099
DOI : 10.32628/IJSRSET207232

Modelling and Analysis of BLDC Motor Using Sliding Mode Control and comparing it with PI Controller

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ABSTRACT

The sliding mode control technique for brushless DC motor is used to improve its dynamic performance with high accuracy. The proposed novel sliding mode (SM) controller method is used drive at all speed levels. The SM controller is the most attractive and simple in modelling for its insensitivity to parameter variations and external disturbances. The validity of the proposed method is verified through simulation. The BLDC motor is inherently electronically controlled and requires rotor position information for proper commutation of current. An equation based model for closed loop operation of BLDC motor drive is simulated in MATLAB/Simulink. Simulation results show the proposed SM Controller has the advantage of fast response and less steady-state error when compared to that of the conventional PI controller. In this paper the responses of current, speed and torque using SM controller is compared with that of PI controller.

Keywords : Brushless DC Motor, Sliding mode controller, PI controller.

I. INTRODUCTION

The BLDC is essentially configured as a permanent magnet rotating part, a set of current carrying conductors. In this respect, it is equivalent to an inverted DC commutator motor, in that the magnet rotates while the conductors remain stationary. In both cases, the current must reverse polarity every time a magnet pole passes by, in order that the torque is unidirectional. In the DC commutator motor, the commutator and brushes perform the polarity reversal. In the brushless DC motor, the polarity reversal is performed by power MOSFETS, which must be switched in synchronism with the rotor position. The stator is normally 3-phase star connected. Each commutation sequence has one of the windings energized to positive power current entering into the winding and the second winding energized to negative power current exits the winding and third winding non-energized. Torque is produced by the interaction of the magnetic field produced by the permanent magnets and the stator windings.

II. PI CONTROLLER

PI controller operates the BLDC motor at the set point corresponding to a reference speed. It is important to incorporate a controller in the feedback path. The PI controller contains an outer speed controller and an inner current controller. Accordingly a PI speed controller has been chosen with gain parameters K_p and K_i. The speed of the BLDC motor compared with the reference value and the error in speed is processed by the speed controller. The output of the PI controller at any instant is the reference torque given by

$$T_{ref} = \left(Kp + \frac{K_i}{s}\right).(\omega_{ref} - \omega_r) \quad (1)$$

III. SLIDING MODE CONTROLLER

The sliding mode controller modelling approach involves two distinct stages. The first stage considers the modelling of a switching function which provides desirable system performance in the sliding mode as shown in Fig. 1. The second stage consists of modelling a control law which will ensure the sliding mode, and thus the desired performance, is attained and maintained. With sliding mode controller, the system is controlled in such a way that the speed error in the BLDC motor always moves towards a sliding surface. The sliding surface is defined with the tracking speed error of the motor and its rate of change of variables. The distance of the error trajectory from the sliding surface and its rate of convergence are used to decide the control input to the motor. The sign of the control input must change at the intersection of the tracking error trajectory with the sliding surface. In this way the error trajectory is always forced to move towards the sliding surface.

The rotor speed ω_r is given as

$$\omega_r = \int (Te - TL).dt \quad (2)$$

The equation (2) can be written as

$\dot{\omega} = (\alpha + \Delta\alpha)\omega + (b + \Delta b)I_a + (c + \Delta c)T_L$ (3)

Where $\alpha = -\frac{B}{J}$, $b = K_t/J$, $c = -\frac{1}{J}$

$\Delta\alpha, \Delta b, \Delta c$ Represents the transient or disturbance values of the machine parameters J, B, Kt respectively

The state variable is defined as

$$y = \omega - \omega_{ref} \quad (4)$$

For step changes in speed reference

$$y = ay + b\dot{I_a} + a\omega_{ref} + \delta \quad (5)$$

Where the total disturbance δ is defined as

$$\delta = \Delta a\omega + \Delta bI_a + (c + \Delta c)T_L \quad (6)$$

The design of the sliding mode controller includes the selection of sliding surface and the control law. Once the system states enter the sliding mode, the system dynamics is determined by the chosen sliding surface and is robust to the disturbances as well as parameters variations. The control law must satisfy the reaching condition and guarantees the existence of the sliding mode.53Since SMC is applicable to the first-order system, the SMC employs the acceleration signal, which is sensitive to the noises.

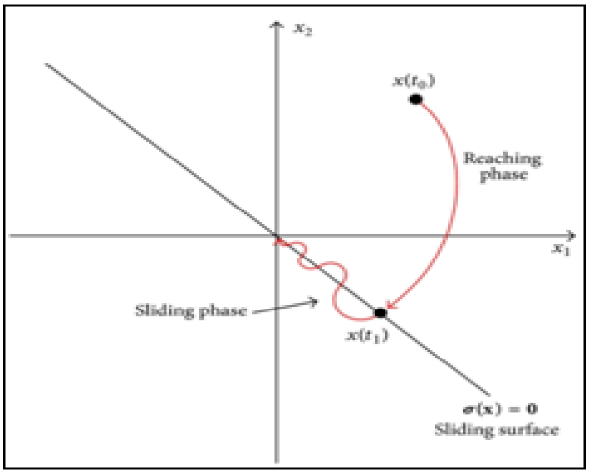


Fig. 1 The behaviour of system states in sliding mode control.

IV. BLDC MOTOR DRIVE WITH SM CONTROLLER

The general block diagram of the SM controller drive of the brushless DC motor is shown in Fig. 2.the complete drive system of a BLDC motor consists of a permanent magnet motor fed by a three-phase PWM inverter, rotorpositionestimation and SM controller. The inverter which is connected to the dc supply feeds controlled power to the motor. The magnitude and frequency of the inverter output voltage depends on the switching signals generated by the hysteresis controller. The state of these switching signals at any instant is determined by the rotor position, speed error and winding currents. The controller synchronizes the winding currents with the rotor position.it also facilitates the variable speed operation of the drive and maintains the motor speed reference value even during load variation and supply fluctuations. The Simulink model of the PI controller and SM controller is shown in Fig. 3.

V. SIMULATION RESULTS AND ANALYSIS

The motor is started at no-load and reference speed is set at 150 rad/sec at no load. Load torque of 1 Nm is applied after 1 sec. The motor is rated at 100 V, 2 Nm and 136 rad/sec as shown in Table 1. The results of BLDC motor with PI and SM controllers are compared. The variation of current, speed, and torque are shown in Fig. 4 and Fig. 5

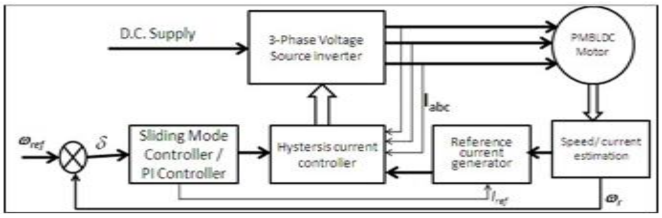


Fig. 2 Block diagram of BLDC drive with sliding mode controller

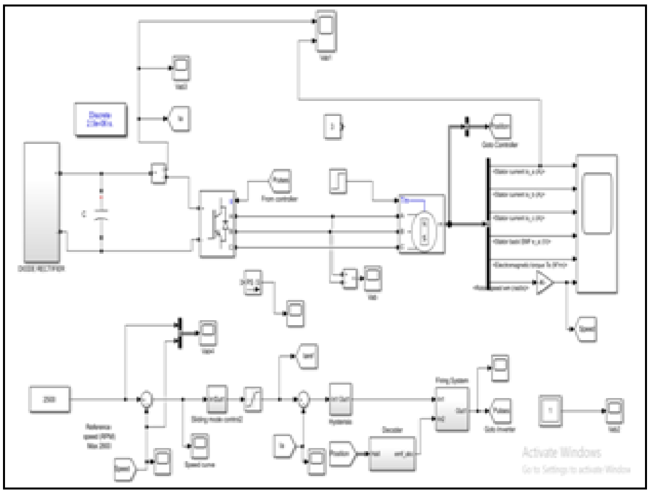
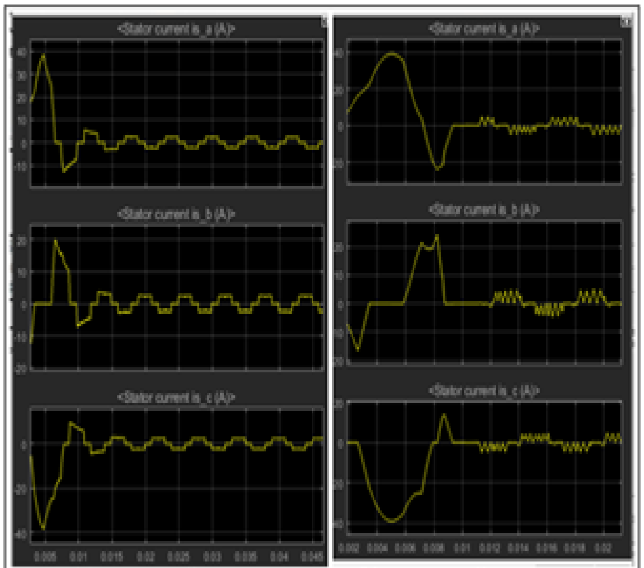


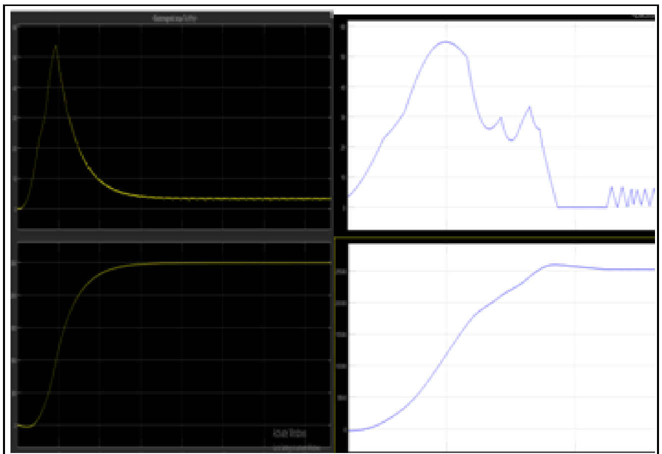
Fig. 3 Simulation model of PI controller and SM controller

A. Current, speed and torque in SM controller and PI controller.



(a)SM controller (b)PID controller

Fig. 4 Three phase current of a BLDC motor.



(a)SM controller (b)PI controller

Fig. 5 speed and torque of bldc motor in

VI. CONCLUSION

In this paper the sliding mode controller is modelled, for BLDC motor are organized so as to apply the SM control technique. Consider the case such as starting time and at application of load. It also gives good trajectory tracking performance. The response of current speed and torque with SM controller is superior then with PI controller. The SM controller is simulated under transient conditions and a comparative study of the results with that of PI controller has been presented and proved that SM controller has better performance in all aspects.

VII. ACKNOWLEDGMENT

We express our sincere thanks to the support given by the management in completing our project. We express our sincere gratitude & deep sense of respect to my project guide Mr.T.Santosh Kumar, Dr. G. Joga Rao, HOD of EEE department and Project coordinator Mr.G.S.N.M Venkatesh. We thankful to Dr.DVN Ananth and other staff members of Electrical department for their support to complete of this project.

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Cite this article as :

T. Santosh Kumar, B. Ramsankar, K. Raviteja, P. Ravi, B. Rambabu,V. Jagadeesh, "Modelling and Analysis of BLDC Motor Using Sliding Mode Control and comparing it with PI Controller", International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET), Online ISSN : 2394-4099, Print ISSN : 2395-1990, Volume 7 Issue 2, pp. 98-101, March-April 2020.
Journal URL : http://ijsrset.com/IJSRSET207232