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Speed Control of BLDC Machine Using Different Control Strategies

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Abstract - Brushless DC motors Controlled through electronic commutation whose motor position is sensed using Hall Sensors. In this paper, initially the responses of BLDC motor are observed by using PI and SMC Controllers. The Sensitivity of PI towards the constraint variations and unexpected torque disturbances, PI Controller replaced with Sliding Mode Controller (SMC). SMC is an effective synthesis technique for Non-Linear uncertain systems with fast and robust transient responses. This paper deals with a new control technique based on PWM control of brushless DC motor (BLDC). PWM technique is broadly used in motors which are controlled using power converters. Also, it controls analog systems with digital processing outputs.

Key Words: BLDC: Sliding Mode Control (SMC): PWM.

1. INTRODUCTION:

A brushless DC motor (BLDC) is a PMSM motor with trapezoidal back emf and electronically commutated system [1]. The permanent magnet synchronous motors (PMSM) have the advantage of high efficiency, high torque density, less volume and less maintenance which are satisfied with EV accurate necessities [2-3]. BLDC motors have less noise and large durability. The main advantage of this motor is that it can be controlled by using feedback mechanisms for faster speed responses and less ripples in torque. In conventional PI controller, the motor performance may result disturbances in torque due to variations in parameters and its sensitivity towards the uncertainty nature of the system. In order to conquer this disadvantage, sliding mode control (SMC) is adopted. Generally, the practical BLDC motor is nonlinear and there are number of disturbances, to overcome these disadvantages and to improve the performance of motor SMC is adopted. Even though SMC is vigorous to changes that occur in motor, the increment of gains which is used for controlling purpose causes chattering effect which is not desirable and causes ripples in the responses and also results high frequency switching in converters. To overcome these disadvantages PWM techniques with SMC controllers is implemented in this paper. PWM technique encodes the analog value to digital values by controlling duty cycle the method of implementing SMC controller: 1. Initially observing the convergence and setting of the control law. 2. Later establish the sliding mode at the initial time to give the robust behaviour of the implemented control law all over the system response. 3. The making of the path enabling the convergence in finite time [5], [6]. In this work overview of control of BLDC motor using PI controller and sliding mode control is observed. Later the control of motor with SMC PWM technique is observed. The results obtained in simulation and a conclusion where we emphasize the interest of this method of control.

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2. CONTROL OF BLDC MOTOR:

The control methods of DC motor are divided into two categories. One of them is scalar control which the required speed of motor is obtained by controlling the stator voltage amplitude and frequency. This method is suitable for the constant loads but it is not applicable for the motors with the dynamical varying loads. And the other is vector control which has the best dynamic responses. Controlling the motor simply by varying the supply voltage is the open loop control of the motor. In order to overcome the external disturbances and deviation from the required results and the torque ripples closed loop control is implemented. This is obtained by using the sensors which senses the output of the motor, controller and PWM circuit to generate the pulses to the inverter for proper flow of current to each phase windings.

3. BLOCK DIAGRAM:

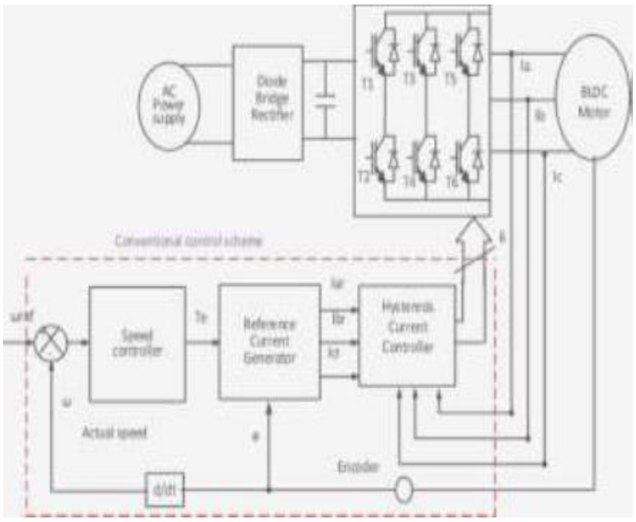

Fig.1. Overall control structure of BLDC motor

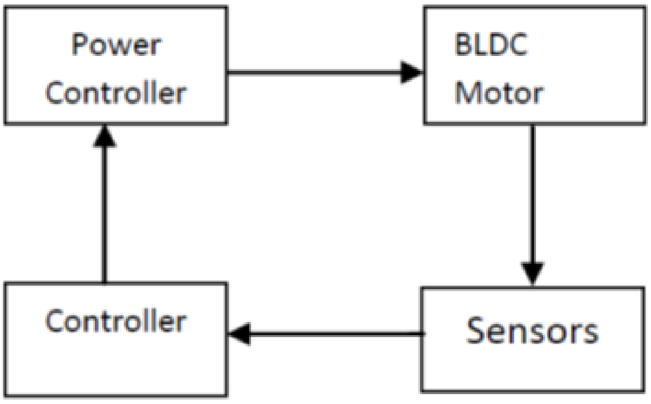

Fig.2. Block Diagram of BLDC motor with Hall Sensors

The BLDC motor is powered by DC supply via inverters whose gate pulses are given based on the rotor position sensed by the sensors and by using PWM technique. There exists an error between the measured value and the desired value. So, to correct that error controllers are implemented in controlling of BLDC motors.

3.1 Design of PI controller:

There are two separate modes i.e., Proportional mode & integral mode present in PI controller. The proportional mode rectifies the current error that is caused in system and the integral mode calculates the recent error.

PI controller can be implemented as:

$$\text{output}, u(t) = K_P e(t) + K_I \int_0^t e(t)\, d\tau$$

$$U(s) = K_P E(s) + \frac{K_I}{s} E(s)$$

$$\Rightarrow \quad U(s) = E(s)\left(K_P + \frac{K_I}{s}\right)$$

The transfer function of PI controller is given by,

$$D(s) = \frac{U(s)}{E(s)}$$

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$$\therefore D(s) = \frac{K_P s + K_I}{s}$$

Where, $e(t)$ = set reference value-actual calculated

K_P and K_I are the gains of PI speed controller.

3.2 Design of SMC controller:

PI controller is simple but sensitive to the variations caused in parameters due to temperature variations etc and external disturbances and nonlinear nature of the motor. SMC is well suited for tracking the performance of the system against the uncertainties and disturbances in practical motors.

Sliding Mode Design involves two tasks:

1. Selection of state sliding surface.

2. Designing control law.

Origin of co-ordinate axes considered as the stable equilibrium, the control law is designed in such a way to force the trajectory into the sliding surface, S and to travel towards the stable equilibrium (where origin is considered).

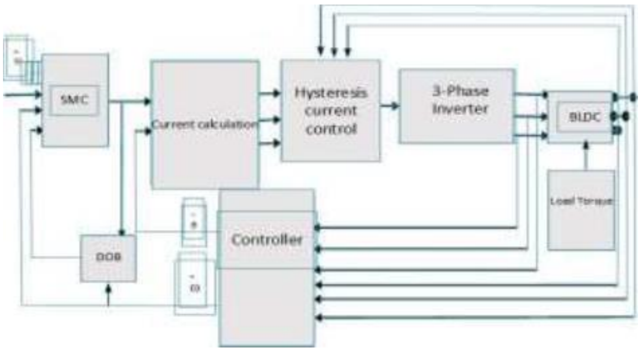

Fig.3. Overall block diagram of SMC with BLDC motor

Any point on Sliding surface,
$S = 0 \Rightarrow \dot{s} = 0$

After striking of point on sliding surface the way it move towards the origin by switching, S called Sliding Mode.

Above Sliding Surface, $S > 0$ then $\lim_{S \to 0^+} \dot{S} < 0$

Below Sliding Surface, $S < 0$ then $\lim_{S \to 0^-} \dot{S} > 0$

$\therefore S\dot{S} < 0$ (This is Reaching Condition)

Consider the two sliding surfaces S_1 and S_2. S_1 is for the current control which is assumed as the current error and S_2 is for the speed control which is assumed as the speed error.

The electrical part of motor from equation (2.1) is given by

$$V = iR + L\frac{di}{dt} + E$$

$$\frac{di}{dt} = (-E - iR + V)\frac{1}{L}$$

And mechanical part from equation,

$$T = J\frac{d\omega}{dt} + B\omega + T_L$$

$$\frac{d\omega}{dt} = \frac{1}{J}(-B\omega + T + T_L)$$

The speed error is controlled by designing S_2 Sliding Surface.

Error, $e_2 = \omega_{ref} - \omega$

($\because$ consider $S_2 = e_2$)

$$\Rightarrow S_2 = \omega_{ref} - \omega$$

$$\Rightarrow \dot{S_2} = \dot{\omega_{ref}} - \dot{\omega}$$

The switching law is to reach the sliding surface in finite time. This is obtained by adding two switching functions with gains Υ and ζ along with the sliding surface S_2 i.e., $\mathrm{sgn}(S_2)$ and S_2.

i.e., $U_{sw} = \Upsilon \mathrm{sgn}(S_2) + \zeta S_2$

By considering constant plus proportional rate switching,

$$\dot{S} = \Upsilon \mathrm{sgn}(S_2) + \zeta S_2$$

$$\Rightarrow \dot{\omega} = \dot{\omega}ref + \Upsilon \mathrm{sgn}(S_2) + \zeta S_2$$

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Consider equation (3.3)

$$\Rightarrow \frac{1}{J}(-B\omega + T + T_L) = \dot{\omega}ref + \Upsilon sgn(S_2) + \zeta S_2$$

$$\Rightarrow T = J(\dot{\omega}ref + \Upsilon sgn(S_2) + \zeta S_2) + B\omega - T_L$$

∴ The control law for regulating speed of motor is

$$T = J(\dot{\omega}ref + \Upsilon sgn(S_2) + \zeta S_2) + B\omega - T_L$$

The current error is controlled by designing S_1 sliding surface.

$S_1 = I_{ref} - I$

$\dot{S}_1 = \dot{I}_{ref} - \dot{I}$

The relation between Torque and current is

$$T = K_t I$$

$$I = \frac{1}{Kt}(J(\dot{\omega}ref + \Upsilon sgn(S_2) + \zeta S_2) + B\omega - T_L)$$

The switching law for S_1 is given by,

$$U_{sw} = \alpha sgn(S_2) + \beta S_2$$

By repeating the method of designing the control law for speed error and using equation (3.2) we get the control law for current error as

$$\therefore \quad V = L(\dot{I}_{ref} + \alpha\, sgn(S_1) + \beta S_1) + E + IR$$

4. Results and Discussions:

By considering gains Kp=5.09 and Ki=2.255. The reference speed of BLDC is taken as 1000rpm. So the speed response settles at reference speed 1000 rpm in 0.1seconds with ripples up to 0.08 seconds.

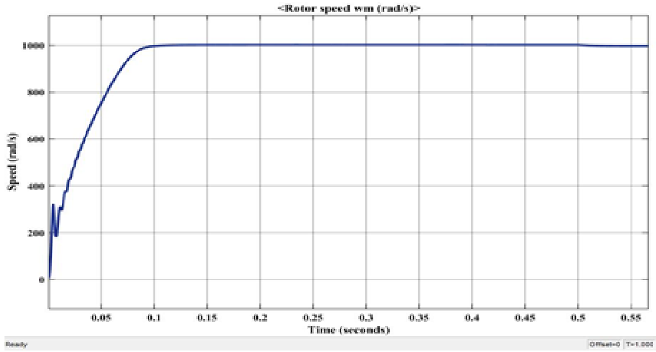

Figure. 5 Speed response of BLDC motor with PI controller

Torque ripples are present continuosly without setteling to a fixed point. Torque has highest value at 0.0038seconds, later decayed to 0 at 0.082 seconds and further torque oscillates about 0 value, but never settetles to a fixed point.

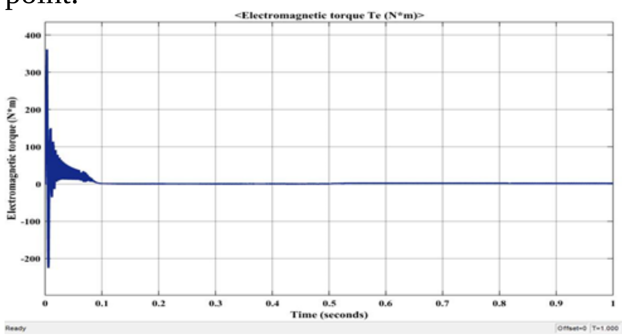

Figure. 6 Torque ripple response of BLDC motor with PI controller

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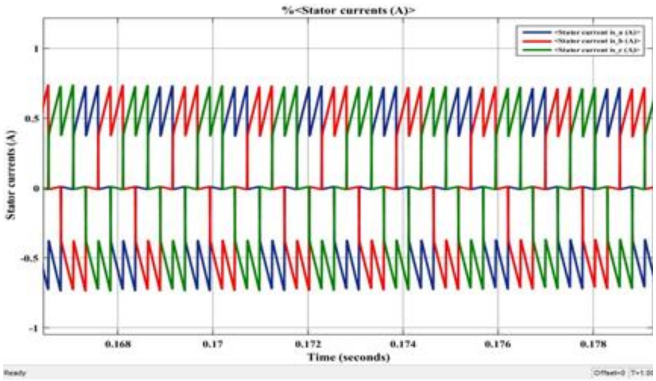

Figure. 7 Stator currents of BLDC motor with PI controller

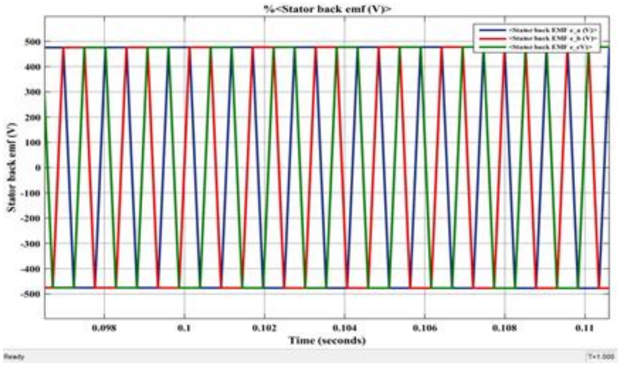

Figure. 8 Stator back emf of BLDC motor with PI controller

BLDC motor control with sliding mode controller: By considering gains α=10, β=5000, ϒ=10 and ζ=8000, also the reference speed of BLDC is taken as 1000rpm. So the speed response settles at reference speed 1000 rpm in 0.044 seconds with distortions up to 0.016 seconds.

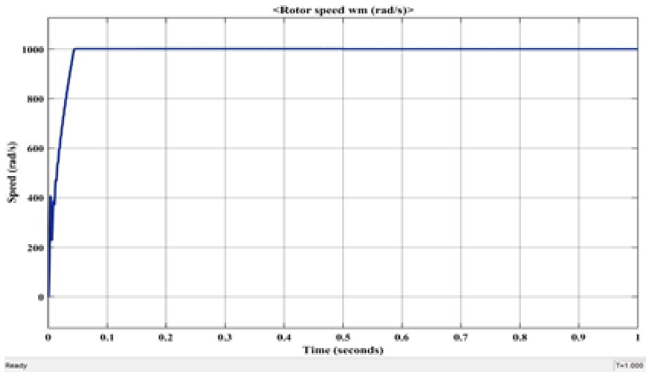

Figure. 9 Speed response of BLDC motor with SMC controller

Torque ripples are present continuosly without setteling to a fixed point. Torque has highest value at 0.002678 seconds, later decayed to 0 at 0.045 seconds with small distortions and from 0.5 seconds the torque oscillates about 0 value, but never settetles to a fixed point.

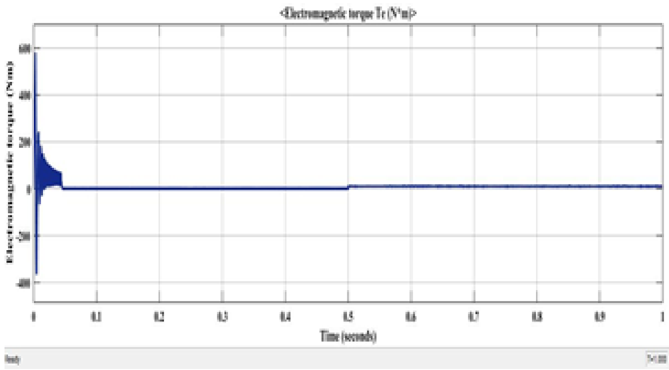

Figure.10 Torque ripple response of BLDC motor with SMC controller

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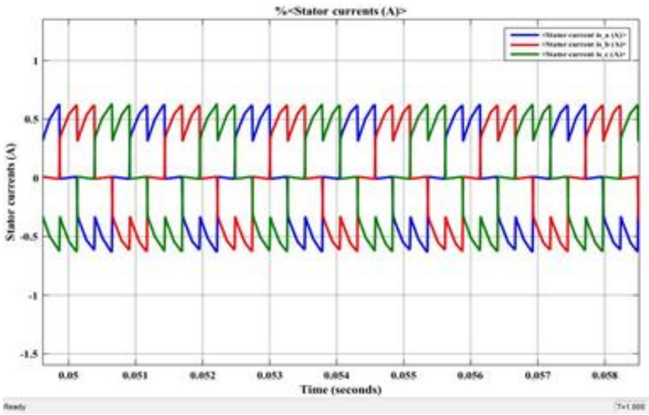

Figure. 11 Stator currents of BLDC motor with SMC controller

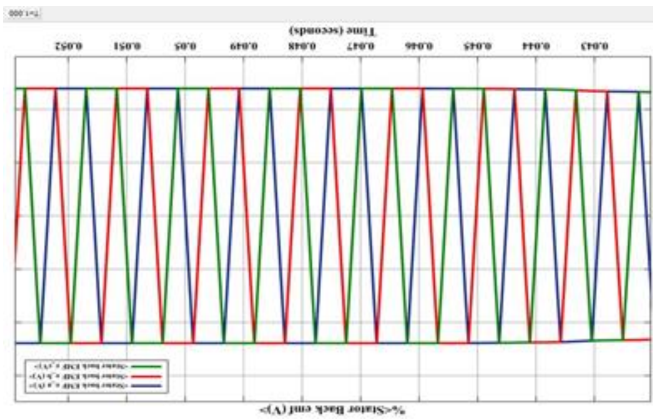

Figure. 12 Stator currents of BLDC motor with SMC controller

CONCLUSION:

SMC is designed to overcome the large overshoot and weak anti-interference ability encountered in the BLDC motor when PI controller is used. However, the gains adjusted in sliding mode controller for the better performance of the motor decreases the robustness of motor and increase the chattering effective in motor. Comparative simulation experiments are performed and simulation results are analyzed respectively. The simulation results obtained by using the traditional sliding mode controller are better than the PI controller results, but the proposed technique in this paper is better than the traditional SMC as it improves the robustness of the motor and reduces the chattering effect compared to the prior techniques. High efficiency and high performance of BLDC motor can be realized using SMC-PWM technique. The ripples in the torque for different loading condition are reduced. The proposed method reduces the torque ripples produced due to the flow of motor currents through the freewheeling diodes during the commutation intervals and obtains the faster speed responses.

REFERENCES:

[1] Brushless Permanent Magnet Motor Design Second Edition Dr. Duane Hanselman Electrical and Computer Engineering University of Maine Orono, ME 04469 USA

[2] S.Balamurali, P.Mallikarjuna Rao, “Adaptive sliding mode control of BLDC motor using Cuckoo search algorithm”, 2nd international conference on Inventive systems, 2018.

[3] Bindeshwar Singh, S. P. Singh, Ravi Chaurasia, Jaswant Singh and Sulabh Sachan“Perfomance investigation of Permanent magnet syn- chronous motor drive using vector controlled technique”, IEEE,2nd International Conference on Power, Control and Embedded Systems, 2012

[4] Munje, R.K., Road, M.R., & Kushare, B.E. (2010). Speed control of DC motor using PI and SMC. 2010 conference.

[5] J. Gao and J. Kang, “Modeling and simulation of pennanent magnet synchronous motor vector control”, Information Technology Journal,vo!. 13, no. 3, pp. 578-582, Feb., 2014.

[6] Hoang Le-Huy, Robert Perret, Rene Feuillet, “Minimization of torque ripple in Brushless DC motor drive”, IEEE Transactions on Industry Applications (Volume: IA-22, Issue: 4,July 1986)