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Analysis And Simulation Of Speed Control Of PMBLDC MOTOR by PI Controller

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Abstract: This paper deals with analysis and design of a speed controller for PMBLDC motor. The brushless DC motor has permanent-magnets on rotor and the stator windings are wound such that the back electromotive force is trapezoidal in nature. The control unit used is a PI controller, which governs the duty cycle of the PWM pulses applied to the switches of the inverter to run the motor at desired speed. The simulation of the proposed scheme was done using MATLAB software package in SIMULINK environment.

Keywords: PMBLDC motor, PWM technique, PI controller, MATLAB.

I. INTRODUCTION

In recent years the development in signal processors, controllers and power electronics devices have significantly influenced the wide spread use of Permanent Magnet Brushless DC motors also known as electronically commutated motors in home appliances, automobiles and industries. These motors have salient features such as high efficiency, long life, noise immunity, small size and less maintenance due to absence of brush and commutator arrangement. A voltage source inverter replaces the brush and commutator arrangement and hence commutation control of inverter becomes very essential to the BLDC motor drive. Proper commutation control provides smooth rotation of the stator magnetic field and hence the interaction between the stator and rotor magnetic field produces smooth torque[5]. One key factor of PMBLDC motor is the presence of permanent magnet rotor which replaces the wound rotor to reduce the copper loss.

II. DESIGN OF SPEED CONTROLLER

The BLDC motor is fed by a voltage source inverter that operates in 120^o conduction mode. In this mode at any instant two switches of the inverter will be conducting, one from upper leg and other from lower leg. Thus, at any instant two windings of the motor will be energized with the third one off. The sequence at which the switches of the voltage source inverter should be commutated is shown in the Table.1. The block diagram of the closed loop speed control scheme of the BLDC motor is shown in the Fig.1. The position of the motor is sensed and hence the instantaneous speed of the motor is obtained. The actual speed of the motor ω is compared with a reference speed ωr and the error signal ωe is generated. The error signal is given as input to the controller. The controller designed is of PI type. The value of proportional and integral constants is derived from the Ziegler Nichols graphical method. The controller will generate the PWM signals that are to be given to the switches of the inverter.

By varying the voltage of the pulsed supply from the inverter the current through the stator winding changes and thus the force on the rotor poles and speed of the rotor is varied [4]. The trapezoidal back-emf induced in the windings and the phase currents are shown in the Fig.1

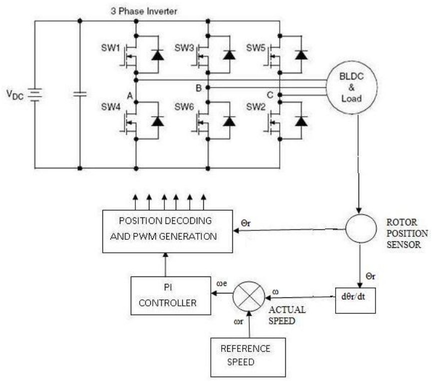

Fig.1. Block diagram for closed loop speed control scheme for BLDC motor.

III. MODELLING OF PERMANENT MAGNET BRUSHLESS DC MOTOR

The equivalent circuit of brushless dc motor is shown in Fig.3. It consists of three phase star connected stator winding With phase resistance, inductance and induced back emf. The modelling is based on the following assumptions [6].

(1) Induced currents in the rotor due to stator harmonic fields are neglected.
(2) Iron and stray losses are also neglected.
(3) Damping is provided by the inverter control.

Table.1. Switching sequence for 120^o conduction mode.

Hall sensor position			Conducting Phases			Conducting switches					
A	B	C	A	B	C	S1	S2	S3	S4	S5	S6
1	0	0	+1	0	-1	1	1	0	0	0	0
1	1	0	0	+1	-1	0	1	1	0	0	0
0	1	0	-1	+1	0	0	0	1	1	0	0
0	1	1	-1	0	+1	0	0	0	1	1	0
0	0	1	0	-1	+1	0	0	0	0	1	1
1	0	1	+1	-1	0	1	0	0	0	0	1

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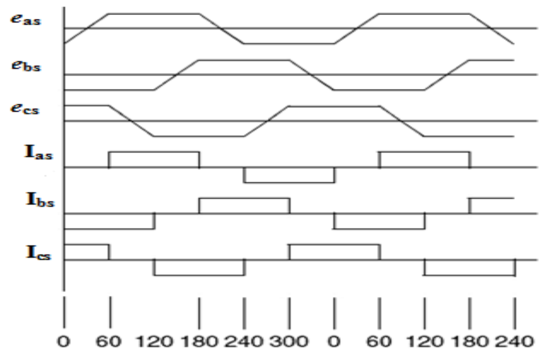

Fig.2 Trapezoidal back emf and current waveform.

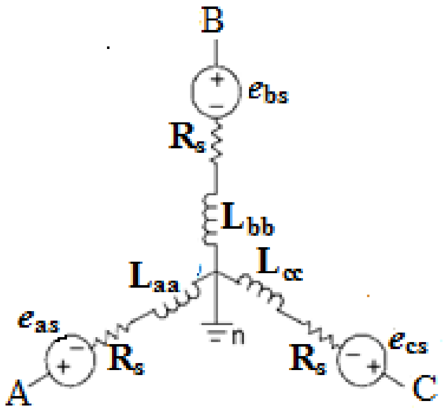

Fig.3 Equivalent Circuit.

The system equation is given by

$$\begin{bmatrix} V_{as} \\ V_{bs} \\ V_{cs} \end{bmatrix} = \begin{bmatrix} R_s & 0 & 0 \\ 0 & R_s & 0 \\ 0 & 0 & R_s \end{bmatrix} \begin{bmatrix} I_{as} \\ I_{bs} \\ I_{cs} \end{bmatrix} + p \begin{bmatrix} L_{aa} & L_{ab} & L_{ac} \\ L_{ba} & L_{bb} & L_{bc} \\ L_{ca} & L_{cb} & L_{cc} \end{bmatrix} \begin{bmatrix} I_{as} \\ I_{bs} \\ I_{cs} \end{bmatrix} + \begin{bmatrix} e_{as} \\ e_{bs} \\ e_{cs} \end{bmatrix} \quad (1)$$

Where Rs is rotor resistance per phase, p is differential operator and eas, ebs and ecs are the induced emf. The induced emf is given by

$e_{as}=kbf_{as}(\theta r)\omega r(\text{volt})$ (2)

Where fas is a unit function generator correspond to the trapezoidal induced emf as a function of rotor electrical position θr. kb is the emf constant and ωr rotor electrical speed.

f_{as} is given by

$$f_{as}(\theta r) = \begin{cases} (\theta r)\, 6/\pi, & 0<\theta r<\pi/6 \\ 1, & \pi/6<\theta r<5\pi/6 \\ (\pi-\theta r)\, 6/\pi, & 5\pi/6<\theta r<7\pi/6 \\ -1, & 7\pi/6<\theta r<11\pi/6 \\ (\theta r-2\pi)\, 6/\pi, & 11\pi/6<\theta r<2\pi \end{cases} \quad (3)$$

The electromagnetic torque (Te) is developed by the motor is given by

$T_e= k_t \{f_{as}(\theta r)\, i_{as}+f_{bs}(\theta r)\, i_{bs}+f_{cs}(\theta r)\, i_{cs}\}$ (4)

$T_e=k_t\, \phi_{as} I_{as}$ (5)

The electromechanical equation with the load is given by

$Jp\omega r+B\omega r=(T_e-T_L)$ (6)

where J is the moment of inertia, B is the friction co-efficient and TL is the load torque[1].

$\omega r=\int(T_e-T_L-B\omega r)/J dt$ (7)

$\theta r=\int\omega r dt$ (8)

IV. SIMULATION RESULT

In order to verify the feasibility of the proposed scheme, a speed controlled brushless DC motor drive is simulated using MATLAB/Simulink and the outputs are shown. Initially the speed increases beyond the set speed (3000 rpm) and then decreases due to the generation of negative error signal and then settles as 3000 rpm. Also the speed characteristics for the motor with mechanical load 1 Nm applied at 0.15 sec is shown in the Fig.4. Similarly the torque and current profile of the motor at loaded and no load conditions are shown.

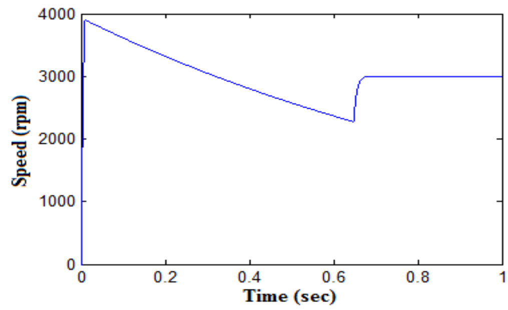

Fig.4. Simulated output of speed (rpm) versus time (sec).

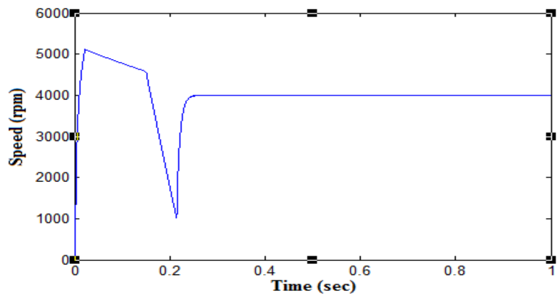

Fig.5. Simulated output of speed (rpm) with mechanical load applied at 0.15 sec.

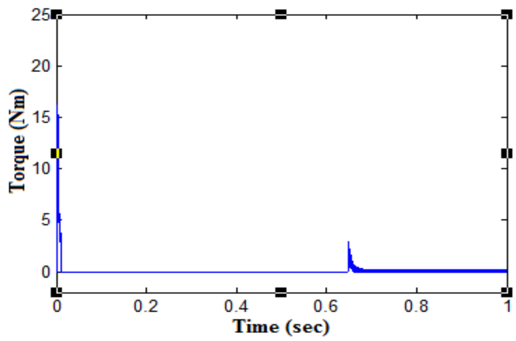

Fig.6. Electromagnetic torque (Nm) at starting and no-load operation.

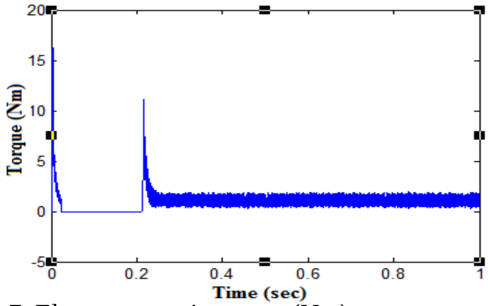

Fig.7. Electromagnetic torque (Nm) output waveform under loaded condition.

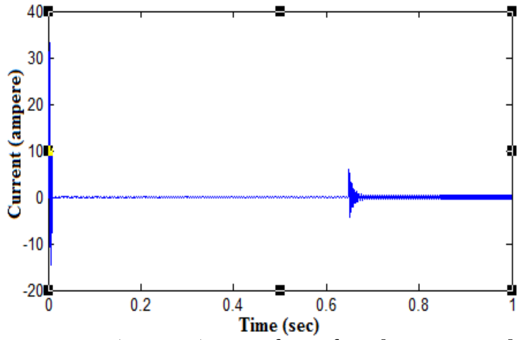

Fig.8. Current (ampere) waveform for phase A winding of stator at starting and no-load operation.

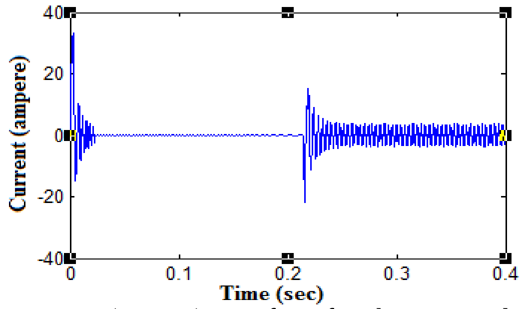

Fig.9. Current (ampere) waveform for phase A winding

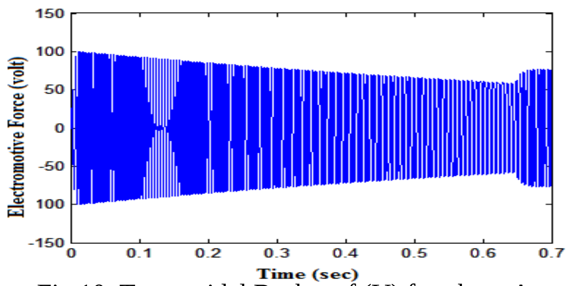

Fig.10. Trapezoidal Back emf (V) for phase A

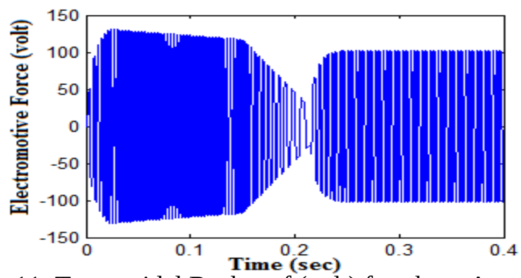

Fig.11. Trapezoidal Back emf (volt) for phase A under loaded condition.

V. CONCLUSION

Thus the mathematical model of the Permanent Magnet Brushless DC motor is developed and the speed control of the modelled machine is done using PI controller and PWM technique. From the simulation results it is clear that the speed is controlled to the reference value.

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REFERENCES

[1] M Kumar ,B Singh and B P Singh, "Single current sensor based speed control of permanent magnet brushless dc motor using digital signal processor", Electrical Engineering Department,IIT,Delhi,IE journal,vol.86,June 2005.

[2] T.J.E Miller,"Brushless permanent magnet and reluctance motor drives",Oxford University Press,1989.

[3] P Pillay and R Krishnan,"Modeling,simulation and analysis of permanent magnet motor drivesII:The brushless dc motor drive",IEEE Transactions on IA,vol.25,pp.274-279,1989.

[4] Jiaxin Chen,Youguang Guo and Jianguo Zhu,"Development of a high-speed permanent magnet brushless DCmotor for driving embroidery machines",IEEE Transactions on magnetic,vol.43,Nov.2007.

[5] Yen-ShinLai,Yong-Kai Lin,"Assesment of pulse width modulation techniques for brushless dc motor drives",Industrial Applications Conference, 2006.

[6] R Krishnan,"Electric motor drives –modeling,analysis and control",Prentice Hall of India Private Limited,2002.

[7] Ali Emadi,"Handbook of automotive power electronics and drives",CRC Press,2005

APPENDIX

Motor Specifications

No. of pole pairs = 4, Rated power = 1Kw, Vdc = 310 volt, R_s=3.07 ohm, L_{aa}=6.52 mH, Voltage constant =51.31V/Krpm, Torque constant = 0.49Nm, Rated speed = 4600 rpm.

BIOGRAPHIES

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