ORIGINAL RESEARCH PAPER

Engineering

LOW VOLTAGE START UP OF UNIPOLAR PMBLDC MOTOR USING BUCK CONVERTER

KEY WORDS: PMBLDC, EMF, Buck Converter, Hall Effect, Inverter. Ziglar-Nichols.

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ABSTRACT

In this paper the buck converter fed brushless dc motor controlled by using a ziglar-nichols method for tuning the parameter of PI controller. The system contains a buck converter, a resonant circuit, a conventional 3θ inverter and PMBLDC and control circuitry. The LC filter is used for controlling ripple output voltage of the buck converter. That is commonly used to supply three phase load for AC motor drive and other drive application. This drive scheme is normally referred to as six step drive for motor control application. PMBLDC motor offer several advantage including more torque per weight(increased efficiency), increased reliability, reduced noise, longer lifetime, elimination of ionizing spark from commutation. The PMBLDC motor is 3 phases, 4 poles, Y connected; trapezoidal back-EMF type of BLDC motor for automotive industry application is modeled and simulated in MATLAB / SIMULINK. A ziglar-nichols method PI controller is used to control the speed. The closed loop system of the PMBLDC motor is adopted in this paper.

I. INTRODUCTION

BLDC have been used in different applications such as industrial automation, automotive, aerospace, instrumentation and appliances since 1970's. BLDC motor is a novel type of DC motor which commutation is done electronically instead of using brushes. Therefore it needs less maintenance. Also its noise susceptibility is less, looking forward to have integral motor. These types are further divided into motors with sinusoidal and non-sinusoidal back emf's (BEMF). Machines with non-sinusoidal BEMF waveforms offer several advantages over their sinusoidal counterparts including greater power density, ease of construction and smaller inverter size. For these reasons, this type of brushless DC drive is common in industrial applications and is being considered for use in high power applications. The most commonly used switching converter is the Buck, which is used to down-convert a DC voltage to a lower DC voltage of the same polarity. The buck converter circuit converts a higher dc input voltage to lower dc output voltage. This is essential in systems that use distributed. The coupled circuit equations of the stator windings in terms of motor electrical constants are power rails (like 24V to 48V), which must be locally converted to 15V, 12V or 5V with very little power loss. The Buck converter uses a transistor as a switch that alternately connects and disconnects the input voltage to an inductor.

A. PMBLDC MOTOR

Permanent magnet brushless motors can be divided into two subcategories. The first category uses continuous rotor-position feedback for supplying sinusoidal voltages and currents to the motor. The ideal motional EMF is sinusoidal, so that the interaction with sinusoidal currents produces constant torque with very low torque ripple. The second category of PMBL motor drives is known as the brushless DC (BLDC) motor drive and it is also called a trapezoidal brushless DC drive, or rectangular fed drive. It is supplied by three-phase rectangular current blocks of 120° duration, in which the ideal motional EMF is trapezoidal, with the constant part of the waveform timed to coincide with the intervals of constant phase current. These machines need rotor-position information only at the commutation points, e.g., every 60°electrical in three-phase motors. The PMBLDC motor has its losses mainly in the stator due to its construction; hence the heat can easily be dissipated into the atmosphere. As the back EMF is directly proportional to the motor speed and the developed torque is almost directly proportional to the phase current, the torque can be maintained constant by a stable stator current in a PMBLDC motor.

$$\begin{bmatrix} V_{as}-v_n \\ V_{bs}-v_n \\ V_{cs}-v_n \end{bmatrix} = \begin{bmatrix} R_s & 0 & 0 \\ 0 & R_s & 0 \\ 0 & 0 & R_s \end{bmatrix}\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} + p\begin{bmatrix} L_{aa} & L_{ab} & L_{ac} \\ L_{ba} & L_{bb} & L_{bc} \\ L_{ca} & L_{cb} & L_{cc} \end{bmatrix}\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} + \begin{bmatrix} E_a \\ E_b \\ E_c \end{bmatrix} \text{ ------------------------ (1)}$$

$$v_n = \frac{1}{3}[V_{as}+V_{bs}+V_{cs}] - \sum BEMFs \text{ -------------------------- (2)}$$

$\sum$ *BEMFs* means summing up the individual phase emfs on an instant to instant basis. The induced emfs are all assumed to be trapezoidal, whose peak value is given by:

Ep= (BLv) N = N (Blr ω) = NΦ ω= λ ω. ---------------------------------- (3)

Φ represents flux linkage=BLr

If there is no change in rotor reluctance with angle because of no salient rotor and assuming three symmetric phases, inductances and mutual inductances are assumed to be symmetric for all phases, i.e. (1) becomes:

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = R_s * \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} + p\begin{bmatrix} L & M & M \\ M & L & M \\ M & M & L \end{bmatrix}\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} + \begin{bmatrix} E_a \\ E_b \\ E_c \end{bmatrix} \text{ ------------------------ (4)}$$

Simplifying (3) further we get equation (4)

$$\begin{bmatrix} Vas \\ Vbs \\ Vcs \end{bmatrix} = R_s * \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} + p\begin{bmatrix} L-M & 0 & 0 \\ 0 & L-M & 0 \\ 0 & 0 & L-M \end{bmatrix}\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} + \begin{bmatrix} E_a \\ E_b \\ E_c \end{bmatrix} \text{ ------------------------ (5)}$$

The generated electromagnetic torque is given by

$$T_e = [E_a I_a + E_b I_b + E_c I_c]/\omega \text{ (in N.m) ---------------------------------- (6)}$$

The induced emfs can be written as

$$E_a = \text{fa}(\theta)\lambda\ \omega.$$
$$E_b = \text{fb}(\theta)\lambda\ \omega.$$
$$E_c = \text{fc}(\theta)\lambda\ \omega. \text{ ---------------------------------- (7)}$$

These values from (6) can be substituted in (5) to obtain the value of torque

$$J(d\omega/dt) + B\omega = T_e - T_l \text{ ---------------------------------- (8)}$$

Electrical rotor speed and position are related by

d θ/dt = (P/2)* ω ---(9)

Combining all the equations, the system space form becomes

X' = Ax + Bu - -------------------------- ---------(10)

$$\text{Where } x = [I_a \quad I_b \quad I_c \quad \omega \quad \theta]^T \text{ --(11)}$$

Thus the state space matrix becomes:

$$A = \begin{bmatrix} -R_S/L_1 & 0 & 0 & (\lambda p^* f_a(\theta))/L_1 & 0 \\ 0 & -R_s/L_1 & 0 & (\lambda p^* f_b(\theta))/L_1 & 0 \\ 0 & 0 & -R_s/L_1 & (\lambda p^* f_c(\theta))/L_1 & 0 \\ (\lambda p^* f_a(\theta))/J & (\lambda p^* f_b(\theta))/J & (\lambda p^* f_c(\theta))/J & -B/J & 0 \\ 0 & 0 & 0 & P/2 & 0 \end{bmatrix} \text{ ------------------------------ (12)}$$

$$B = \begin{bmatrix} 1/L_1 & 0 & 0 & 0 \\ 0 & 1/L_1 & 0 & 0 \\ 0 & 0 & 1/L_1 & 0 \\ 0 & 0 & 0 & -1/J \\ 0 & 0 & 0 & 0 \end{bmatrix} \text{ ------------------------------------ (13)}$$

$$U = [V_a \quad V_b \quad V_c \quad T_l]^T \text{ -- (14)}$$

All the equations form the entire state space model for the BLDC. Consistent system of units must be used.

B. BUCK CONVERTER

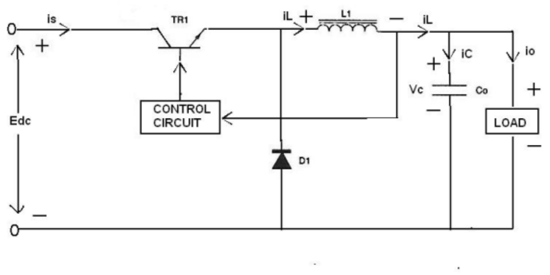

Fig: -1.1 BUCK Converter

In general, the voltage across the inductor L is given by

di eL =L dt			
Control Type	**Kp**	**Ki**	**Kd**
P	0.50 Ku	-	
PI	0.45 Ku	1.2Kp/Ku	
PID	0.60 Ku	2 Kp/Ku	KpKu/8

In time Ton , assuming that the inductor current rises linearly form I 1tol2 ,

$$E_{dc} - E_o = L\left(\frac{I_2 - I_1}{T_{on}}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Let us define, duty ratio= $\frac{T_{on}}{T} = a$.

$E_o = a.E_{dc}$ ....(2)

Now the capacitor voltage is expressed as

$Vc = C^{1} \int I_c\, dt + V_c (t = 0)$

C. ZIEGLER NICHOLS METHOD

The method is based on the characterization of process dynamics by a few parameter and simple equation for the controller parameter. One tuning method presented by Ziegler and Nichols is based on process information in the form of the closed loop step response. This method can be viewed as a traditional method based on modeling and control where a very simple process model is used. The step response is characterized by only two parameters T and *L*, as shown in:-

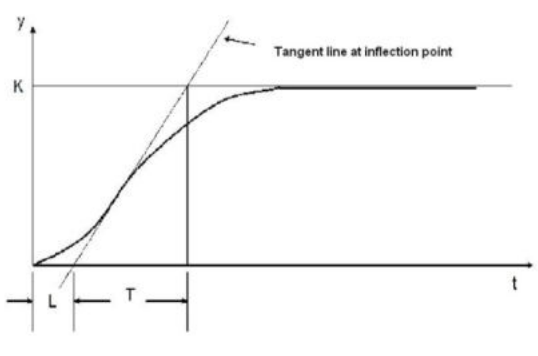

Fig: -1.2 Characterization of a step response in the

Ziegler Nichols step response method.

The point where the slope of the step response has its maximum is first determined, and the tangent at this point is drawn. The intersections between the tangent and the coordinate axes give the parameters T and *L*. The controller parameters are then obtained from Table1. An estimate of the period *Tp* of the closed loop system is also given in the table.

II. MATLAB SINULATION AND RESULT

Closed loop system is simulated using MATLAB Simulink. The Simulink model buck converter fed brushless dc motor drive which shown in Fig.1.3. Here 48V DC is stepped down to 24V DC using a buck converter. The output of buck converter is filtered using pi-filter. The output of the pi-filter is applied to the three phase inverter, the inverter produces three phase voltage required by the PMBLDC motor. The comparator circuit is used to controls the pulse width applied signal for conducting the buck MOSFET. In this circuit the two signals are enter. One signal are come for the pi controller and other signal are come for the repeating signal, both the signals are to difference and the signal are gave to the relay. The relay is used as a sensing device and the relay is sense the signal. If the signal is zero the relay is off and if the signal is one the relay is on the MOSFET is conduct.

Ha'* Hb	Hb'* Hc	Hc'* Ha	Emf a	Emf b	Emf c
0	0	0	0	0	0
0	1	0	0	-1	+1
1	0	0	-1	+1	0
1	0	0	-1	0	+1
0	0	1	+1	0	-1
0	1	0	+1	-1	0
0	0	1	0	+1	-1
0	0	0	0	0	0

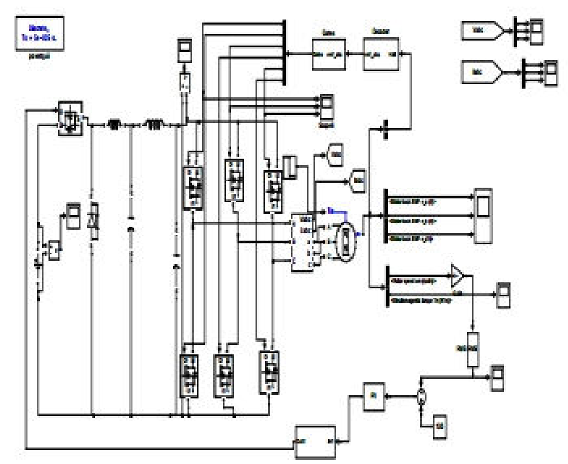

Fig.1.3. MAT Lab circuit for PMBLDC Motor with buck converter

Ha	Hb	Hc	Ha'	Hb'	Hc'	Ha* Hc'	Hb* Hc'	Hc* Ha'
0	0	0	1	1	1	0	0	0
0	0	1	1	1	0	0	0	1
0	1	0	1	0	1	0	1	0
0	1	1	1	0	0	0	0	1
1	0	0	0	1	1	1	0	0
1	0	1	0	1	0	1	0	0
1	1	0	0	0	1	0	1	0
1	1	1	0	0	0	0	0	0

A decoder is a circuit that changes a code into a set of signals. It is called a decoder because it does the reverse of encoding, but we will begin our study of encoders and decoders with decoders because they are simpler to design. A common type of decoder is the line decoder which takes an n-digit binary number and decodes it into 2n data lines. The simplest is the 1-to-2 line decoder. The truth table is A is the address and D is the data line. The gate circuit is used to triggering gate pulse for commutation in to the inverter. The above truth table shown the EMFs signal are enter in the gate circuit and the signal are compared to the grater then to zero or less then to zero. This signal is throwing to the inverter and inverter is conducting. If the signal is zero the inverter is not conducting and if the signal is one the inverter is conducting.

2.1 SIMULATION RESULT

The result is show the drive system with the buck converter topology that is reduced the switching losses. The system is work at low voltage that the power losses are low. The switching are through into the inverter at 120 degree mode and the output voltage of the inverter is displayed by 120 degree each other. Same the output current of the inverter is very 0.5 to -0.5. The output of the rotor speed is 1360 rpm or 160red/sec. the electromagnetic torque is 1 N-m.

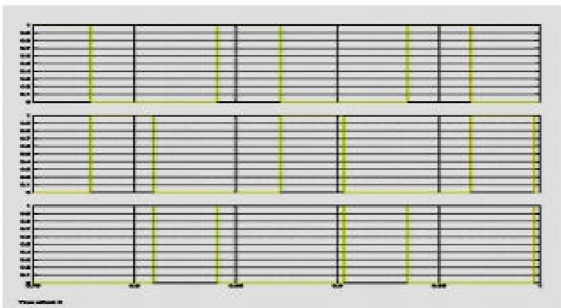

Fig1.4:-The triggering pulse.

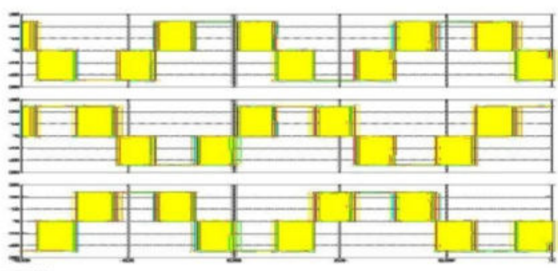

Fig1.5:-phase voltage of inverter.

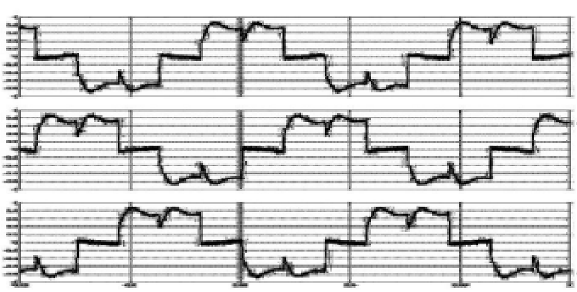

Fig1.6:-output current of inverter.

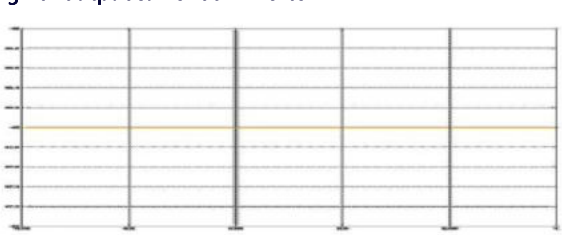

Fig1.7:-input DC voltage.

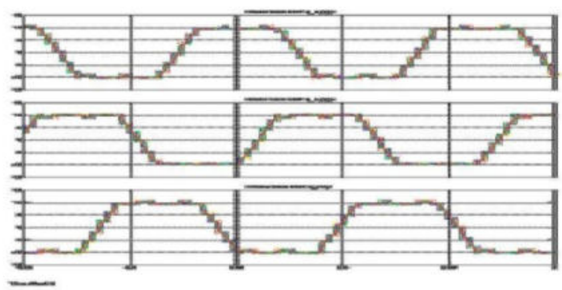

Fig:-1.8:-Back EMF waveform

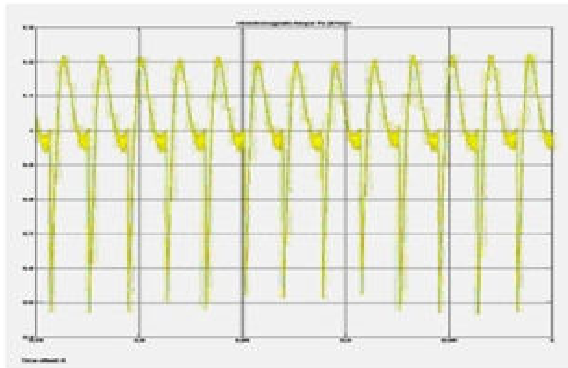

Fig:-1.9:-Electromagnetic torque waveform.

Fig.1.10. Rotor Speed Waveform

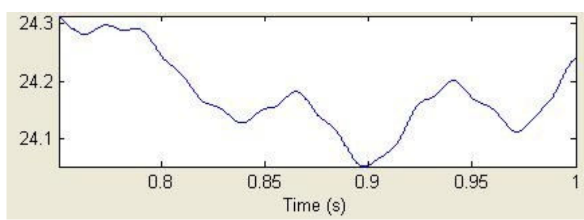

Fig1.11:-output of the buck converter

The calculated gain of PI controller is Kp = 9

III. CONCLUSION

In this paper presented the simulation model of the BLDC motor drive system with ziglar-nichols method for tuning the parameter of PI controller based speed control and four switch three phase inverter on MATLAB/Simulink platform is presented .modeling. Simulation and analysis of a low voltage Closed Loop Controlled Buck Converter Fed Pmbldc Drive System. The torque control algorithm is based on a variable structure strategy and the switching patterns for the inverter are generated directly by the digital controller. The maximum torque load of 1.2 N-m, the torque feedback information is derived from knowledge of machine parameters, instantaneous currents and the rotor angle. Buck converter is reduce the input voltage to the required value. Pi-filter is reduce the ripple. The speed range between the 0 to 2500 rpm according to our application requirement. The stator current and the motor back EMFs are discussed under rated condition. All switches work under soft-switching condition, so their power losses are small. Experimental results derived from BLDCM drives without using any current and Hall sensors fully confirm the theoretical analysis.

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