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Failure Analysis of BLDC Motor

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ABSTRACT

This paper present a numerical analysis model by which one can analyze and predict the effect of failure of subsystem and components on the performance of a brushless DC motors several failure modes have been studied using this simulation techniques modeling the motor during flux weakening bring failure armature winding open circuiting and armature winding short circuiting along with the operation of the machine under normal conditions is presented. This simulation model will facility future study of BLDCM and its a beneficial in the electro- mechanical actuation and control application.

Keywords:

I. INTRODUCTION

The brushless DC (BLDC) motor is suited for low power industrial application today. They are more reliable. More efficient and with current electronic technology.

With the recent introduction of neodymium based permanent magnet materials for motor together with cost power electronics component and the simply implemented control strategies[1],[2],[3], has resulted in the development of brushless DC motors that are now being considered for a wide range of potential applications.

BLDCM offers many inherent advantages in this application and numerous journals articles [4],[5],[6],[7],[8],[9],[10] describing the operating principal and characteristic of motor.

Research efforts have been underway to study the BLDCM in the electromechanically actuation application for the space program. Particularly with regard to trust vector control .these efforts include studying the health monitoring of BLDCM in combination with a roller screw and gearing transmission system in a controlled laboratory set up designed to simulated the trust vector control Environment.

These simulation model need to predict the nature of measurable parameters. Such us current and the resulting performance, such us torque and speed. Confidence in this process will be obtained by practical verification of some non–catastrophic, readily produced, irregular operating conditions.

II. THE SIMULATION MODEL

The modeling of brushless dc involves solving many simultaneous differential equations, each depending upon the inputs to the motor and the Simulation constants.

Simulation constants are values like the phase inductance that do not change during simulation. Therefore these parameters can be treated as constants during a Simulation. However, the model provides for dialogue boxes that can be used vary the values of these constants.

Detailed of state space modeling:

The coupled circuit equations of the stator windings in terms of motor electrical constants are

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

Where:
R_s: Stator resistance per phase
I_a, I_b, I_c: Stator phase currents
p: d/dt is the time derivative operator
E_a, E_b, E_c represents the back emfs in the respective phases
V: is the neutral point node voltage given by

$$V_n = 1/3[V_{as} + V_{bs} + V_{cs}] - \Sigma BEMFs \quad \ldots..(2)$$

ΣBEMFs means summing up the individual phase emfs on an instant to instant basic. The induced emfs are all assumed to be trapezoidal, whose peak value is given by-

$$E_p = (BLv)N = N(Blr\omega) = N\Phi\omega = \lambda\omega \quad \ldots\ldots(3)$$

Where:

B: flux density of the field in webers
L: rotor length
N: number of turns per phase
ω: electrical angular speed in rad/sec
Φ: represents flux linkage= BLr
λ: represents the total flux linkage given as the product number of conductors and flux/conductor.

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

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

Simplifying (3) further we get equation (4)

$$\begin{bmatrix} V_{as} \\ V_{bs} \\ V_{cs} \end{bmatrix} = R_s \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} + p \begin{bmatrix} L-M & 0 & 0 \\ 0 & L-M & M \quad -M \\ 0 & 0 & L-M \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} + \begin{bmatrix} E_a \\ E_b \\ E_c \end{bmatrix} \quad \ldots..(5)$$

The generated electromagnetic torque is given by

$T_e = [\,E a\, I_a + E b\, I_b + E c\, I_c\,]/\omega$ (in N.m) ….(6)

The induced emfs can be written as
$E\,a = fa(\theta)\lambda\,\omega$.

$E_b = f_b(\theta)\lambda\omega$.

$E_c = f_c(\theta)\lambda\omega$. …. (7)

Where:

$f_a(\theta)$, $f_b(\theta)$ and $f_c(\theta)$ are functions having same shapes as back emfs with maximum magnitude of ± 1.

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

Also,
$J(d\omega/dt) + B\omega = T_e - T_l$ …..(8)

Where:
T1: load torque
J: moment of inertia
B: friction coefficient.
Electrical rotor speed and position are related by
$d\theta/dt = (P/2)^*\omega$ …..(9)

Where P is the number of poles in the motor.
Combining all the equations, the system space form becomes

$X' = Ax + Bu$ ……10)

Where $x = [I_{a+}I_b I + I_c]^T$ ….(11)

Thus the state space matrix becomes:

$$A = \begin{bmatrix} -R_1/L_1 & 0 & 0 & (\lambda p^* f_a(\theta))/L_1 & 0 \\ 0 & -R_1/L_1 & 0 & (\lambda p^* f_b(\theta))/L_1 & 0 \\ 0 & 0 & -R_1/L_1 & (\lambda p^* f_c(\theta))/L_1 & 0 \\ (\lambda p^* f_a(\theta))/J & (\lambda p^* f_b(\theta))/J & (\lambda p^* f_c(\theta))/J & -B/J & 0 \\ 0 & 0 & 0 & P/2 & 0 \end{bmatrix}$$

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

And

$U = [V_a \;\; V_b \;\; V_c \;\; T_l]$ …. (14)

Where:
L1 : L-M
L: self inductance of the winding per phase
M: The mutual inductance per phase
V_a, V_b, V_c are the per phase impressed voltages on the motor windings.
All the equations form the entire state space model for the BLDC.

III. MOTOR FAILURES

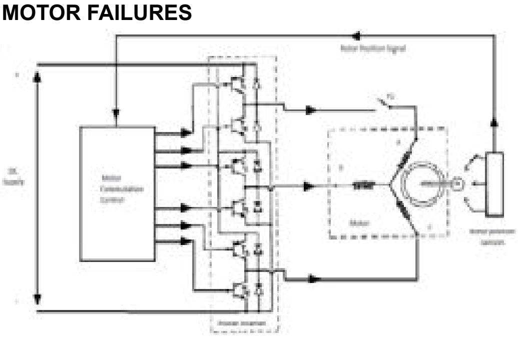

Fig 1. Complete Drive System

Several types of motor winding failure can occur. The most likely of these, the short circuited due to insulation failure, has been investigated in a reference [17] but without inclusion of PWM excitation effects. Another possibility is the open-circuited phase winding, as shown by the failure simulation switch F1 in Fig. 1. This may prevent starting but, if it occurs while the drive is running it results in unbalanced two-phase operation. The large pulsations resulting from unmodified unbalanced two-phase operation may cause problems for low inertia loads such as fans.

IV. SIMULATION & RESULTS

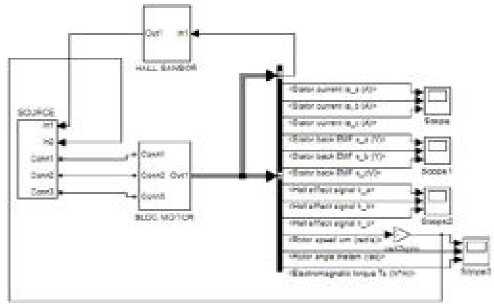

Fig 2. Simulink model of BLDC drive

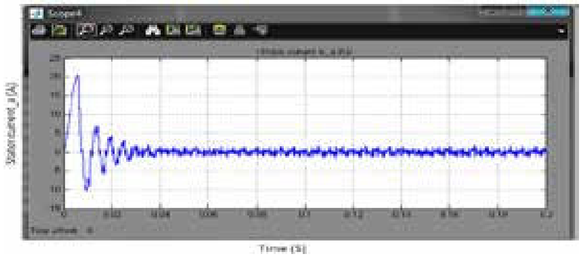

Fig 3. Stator current_a (A) waveform for motor failure

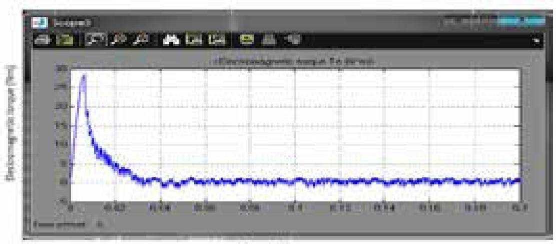

Fig 4. Electromagnetic torque (Nm) waveform for motor failure

Figure 3 & 4 shown stator current and Electromag-netic torque waveform when the motor failure. In figure 3 as we can see that the current are larger but flow for shorter period. And figure 4 as we can see that the large pulsations resulting from unmodified unbalanced two Phase operation may causes problem for low inertia load such as fan.

V.CONCLUSION
The conclusions are arrived at based on the performance.

1. The potential of computer simulation tool which does not depend on assumption of symmetry, balance or sinusoidal variation of voltage , current and inductance, and which has the demonstrate capability to conveniently model PWM excitation has been used to investigate the failure of a brushless dc drive.
2. The correlation between prediction and test data give confidence that certion types of failure may be diagnosed by this technique which can be used to develop certain fault-tolerant drives.

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