THE DYNAMIC BEHAVIOR OF DC LINK CURRENT WITH CONSTANT LOAD TORQUE USING MATLAB/SIMULINK

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ABSTRACT

In this paper we have studied open loop modelling and analysis of separately excited dc motor drive. First, we have done its steady state analysis or non- linear analysis. A set of non-linear differential equations has been made and perturbation technique has been applied in it and its linear model has been developed using dc equivalent circuit model. These set of non-linear equations, analog model in terms of transfer function are developed. Variation in the performance of DC motor is studied how the firing angle changes while changing the speed and armature current. The dynamic model of separately excited dc motor drive has been developed with constant load torque used for loading purpose of dc motor. The non-linear differential equations describing the dynamics of the drive are linearized around steady state operating point using small perturbation technique, open-loop transfer function in s-domain are determined and further results are shown with the help of MATLAB.

Keywords: Armature Current, Angular Frequency, Dc Motor, Firing Angle, Load Torque.

I. INTRODUCTION

At steady state operation of dc drives all electrical transients, such as, instantaneous variations/disturbances in voltage/ current, stator frequency and load torque are neglected. But such variation/disturbances arise in industrial application. Hence, there is a need to evaluate the dynamic performance of the drive system for small perturbation in the input variables around the steady state operating point. The dynamic model of the drive system should consider the effect of these instantaneous variations/disturbances in the system. A set of non-linear differential equations of the Separately Excited DC motor drive at steady state is obtained using DC equivalent circuit model. These set of non-linear equation are then linearized considering small perturbation around the steady state operating point. From the sets of linearized equations, analog model in terms of transfer function are developed.

II. DEVELOPMENT OF DYNAMIC MODEL

The dynamic model of the drive in open loop is developed as the steady state performance drive of the drive is nearest to the experimental investigation.

2.1 Performance Equation

A set of nonlinear differential equations describing behaviour of separately excited DC motor is obtained with the help of the dc equivalent circuit is written as:

A voltage equation of the motor armature circuit is written as:

$$\frac{2V_m}{\pi}\sin\alpha = R_a i_a + L_a \frac{di_a}{dt} + E_b$$

(2.1.1)

Or

$$\frac{2V_m \sin\alpha}{\pi} - E_b = R_a i_a + L_a \frac{di_a}{dt}$$

(2.1.2)

Where,

$$E_b = K_b \omega$$

(2.1.3)

$$\frac{2V_m \sin\alpha}{\pi} - K_b \omega = R_a i_a + L_a \frac{di_a}{dt}$$

(2.1.4)

The expression for electromagnetic torque developed is given as:

$$T_e = K i_a$$

(2.1.5)

The torque balance equation of load is expressed as:

$$T_e = J\frac{d\omega}{dt} + B\omega + T_l$$

(2.1.6)

Substituting the expression of electromagnetic torque from (2.1.5), the above equation is modified as:

$$K i_a = J\frac{d\omega}{dt} + B\omega + T_l$$

(2.1.7)

The (2.1.4) and (2.1.7) are non-linear differential equations. The transient response for small and large perturbation can be obtained by solving the above equations. But it involves considerable computation effort and time.

III. LINEARIZED CONTINOUS DYNAMIC MODEL OF THE CONSTANT TORQUE LOAD

The transfer function model of a system is applicable for linear and time invariant system. The (2.1.4) and (2.1.7) are non-6 linear , hence, they are linearized around the steady-state operating point using small signal perturbation technique. The steady state values of supply voltage, back emf, armature current, angular velocity, electromagnetic torque, load torque α_0, E_{b0}, i_{a0}, ω_0, T_{e0} and T_{L0} respectively. Making small perturbations in variables around the steady state operating point, one gets:

$$\alpha = \alpha_0 + \Delta\alpha$$

(3.1)

$$E_b = E_{b0} + \Delta E_b$$

(3.2)

$i_a = i_{a0} + \Delta i_a$

(3.3)

$\omega = \omega_0 + \Delta\omega$

(3.4)

$T_e = T_{e0} + \Delta T_e$

(3.5)

$T_l = T_{l0} + \Delta T_l$

(3.6)

Substituting new values from (3.1) – (3.6) into (2.1.4)

$\frac{2V_m \cos(\alpha_0+\Delta\alpha)}{\pi} - K_b(\omega_0 + \Delta\omega) = (i_{a0} + \Delta i_a)R_a + L_a \frac{d(i_{a0}+\Delta i_a)}{dt}$

(3.7)

Further solving above equation we get:

$2V_m \left[\frac{\cos\alpha_0 \cos(\Delta\alpha) + \sin\alpha_0 \sin(\Delta\alpha)}{\pi}\right] - [K_b(\omega_0) + K_b(\Delta\omega)] = (i_{a0})R_a + (\Delta i_a)R_a + L_a \frac{d(i_{a0})}{dt} + L_a \frac{d(\Delta i_a)}{dt}$

(3.8)

As $\Delta\alpha \to 0$

Cos $\Delta\alpha = 1$

(3.9) $\sin\Delta\alpha = \Delta\alpha$

(3.10)

Substituting these (3.7) and (3.8) and neglecting the smaller value terms, the (2.1.4) is modified as below:

$L_a \frac{d(\Delta i_a)}{dt} = (\Delta i_a)R_a + 2V_m \left[\Delta\alpha \frac{\sin\alpha_0}{\pi}\right] - [(K_b(\Delta\omega)]$

(3.11)

Similarly, the (2.1.7) is also linearized around the steady state operating point using small signal erturbation technique. Substituting the perturbed values from (3.1) – (3.5), the (2.1.7) is written as :

$K(i_{a0} + \Delta i_a) = J \frac{d(\omega_0+\Delta\omega)}{dt} + B(\omega_0 + \Delta\omega) + (T_{l0} + \Delta T_l)$

(3.12)

Neglecting the lower value, the (3.11) is modified as the below:

$K(\Delta i_a) = J \frac{d(\Delta\omega)}{dt} + B(\Delta\omega) + (\Delta T_l)$

(3.13)

Take Laplace transform of (3.11) we get:

$sL_a I_a = \Delta I_a R_a + 2V_m \Delta\alpha \frac{\sin\alpha}{\pi}$

(3.14)

After re-arranging the terms, the above equation is written as:

$\Delta I_a(s) = -\frac{K_b}{R_a+sL_a}\Delta\omega + \frac{K_1}{R_a+sL_a}\Delta\alpha$

(3.15)

Where $K_1 = 2V_m \frac{\sin\alpha}{\pi}$

(3.16)

Further simplifying the above equation one get:

$$\Delta I_a(s) = -\frac{K_b/L_a}{(s+R_a/L_a)}\Delta\omega + \frac{K_1/L_a}{(s+R_a/L_a)}\Delta\alpha$$

(3.17)

Take Laplace transform of (3.13) we get:

$$K\Delta i_a(s) = sJ\Delta\omega(s) + B\Delta\omega(s) + \Delta T_l(s)$$

(3.18)

"Equation 3.18" is further simplified as:

$$\Delta\omega(s) = \frac{K}{(Js+B)}\Delta I_a(s) - \frac{\Delta T_l(s)}{(Js+B)}$$

(3.19)

The "equation 3.19" is further simplified as:

$$\Delta\omega(s) = \frac{K_j}{(s+B/J)}\Delta I_a(s) - \frac{1/J}{(s+B/J)}\Delta T_l(s)$$

(3.20)

Where,

$$K_j = K/J$$

(3.21)

3.1 Transfer Function Block Diagram of the Drive Considering Perturbation in Firing Angle ($\Delta T_l = 0$).

Using above derived equations, the transfer functions

$\frac{\Delta I_a(s)}{\Delta\alpha(s)}, \frac{\Delta\omega(s)}{\Delta\alpha(s)}$

are also obtained by considering small perturbation only in one input variable at a time. Considering small perturbation only in the firing angle, $\Delta T_l = 0$, The (3.20) is modified as:

$$\Delta\omega(s) = \frac{K_j}{(s+B/J)}\Delta I_a(s)$$

(3.1.1)

Substituting from (3.1.1), the (3.17) is modified as:

$$\frac{\Delta I_a}{\Delta\alpha} = \frac{a(s+\frac{B}{J})}{\left[s^2+s\left(\frac{R_a}{L_a}+\frac{B}{J}\right)+(R_aB+KK_b)/JL_a)\right]}$$

(3.1.2)

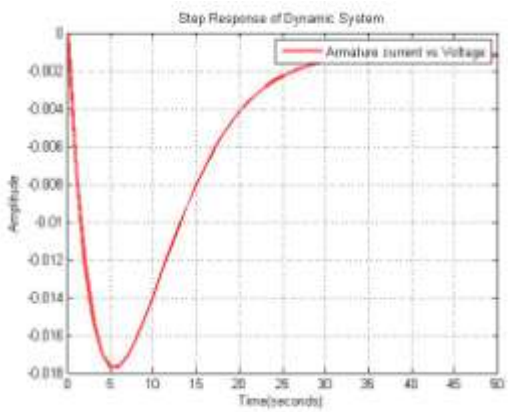

Fig.(3.1.1)

the matlab simulink model between armature current and amplitude.

Where,

$$a = \frac{K_1}{L_a}$$

(3.1.3)

From (2.22) and (2.23), the transfer function $\frac{\Delta\omega(s)}{\Delta\alpha(s)}$ is given as below:

$$\frac{\Delta\omega(s)}{\Delta\alpha(s)} = \frac{aK_j}{\left[s^2 + s\left(\frac{R_a}{L_a} + \frac{B}{J}\right) + (R_a B + K K_b)/J L_a\right]}$$

(3.1.4)

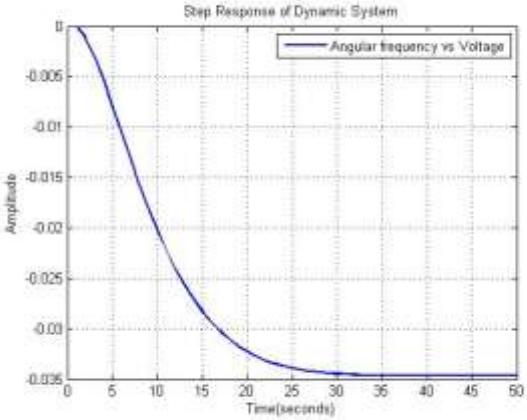

Fig.(3.1.2)

the matlab simulink model between angular frequency and amplitude

IV. CONCLUSION

The dynamic responses of dc link current and the speed of the separately excited dc motor drive for small perturbation in the delay angle are obtained using MATLAB.

V. APPENDIX

The motor used in the experiment is an 110V D.C. motor with constant load at 1025 rpm.

Parameter value

J, Moment of inertia = 0.01;

B , Viscous friction co-efficient= 0.1;

Ra, Armature resistance = 1;

La, Armature inductance = 0.5;

Kb, back emf contant= 0.01;

Tl, Load torque=0;

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