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Control of DC Motor by Cascaded Control Method

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Abstract - *Speed of a DC Motor can be controlled indirectly by controlling the armature current. This paper describes the designed cascade control system which has two control loops: the first loop determine the set point of armature current according to the comparison between actual speed and the reference speed while the purpose of second control loop secure the armature current set point and so on secure the target speed. The controller used in both the case is PI Controller in a closed loop. The main objective of this is to demonstrate how the armature current of the DC motor and the speed of the DC motor can be controlled using the Cascade Control system.*

Key Words: *Speed control, PI controller, DC Motor, Current Controller, Closed Loop*

1. INTRODUCTION

DC Motors are considered as one of the important machine in the control systems such as electrical systems in homes, vehicles and process control. It is well known that the mathematical model is very crucial for a control system design. For a DC motor, there are several models to represent the machine behavior with a good accuracy and the parameters of the model are important because the mathematical model cannot provide a correct behavior without correct parameters in the model. DC Machines are characterized by their versatility. By means of various combinations of shunt, series and separately- excited field windings they can be designed to display a wide range of volt ampere or speed-torque characteristics for both dynamic and steady state operation.

The DC motor here is chosen according to the good electrical and mechanical performances. The DC motor here is chosen according to electrical and mechanical performances. The DC motor is driven by applied voltage. Figure below shown is the equivalent circuit of dc motor.

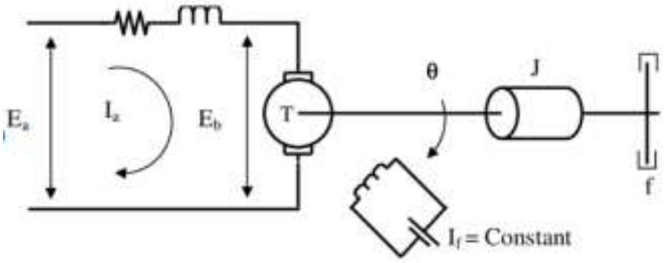

Fig 1: Circuit diagram of DC Motor

The equations for the DC motor can be written as:

$$V_a = R_a i_a + L_a \frac{di_a}{dt} + E_a \text{ .... (1)}$$

$$T_e = J\frac{dw_m}{dt} + T_L \operatorname{sign}(w_m) + B_m w_m \text{ ... (2)}$$

Equations (1) and (2) can also be written as

$$I_a(s) = \frac{V_a(s) - E_a(s)}{R_a + sL_a} \text{ and } E_a(s) = k_E w_m(s) \text{ ... (3)}$$

$$w_m(s) = \frac{T_{em}(s) - T_L(s)}{sJ_{eq}} \text{ and } T_{em}(s) = k_T I_a(s) \text{ ...(4)}$$

1.1 Block Diagram

The basic block diagram of a cascaded control of dc motor is shown below.

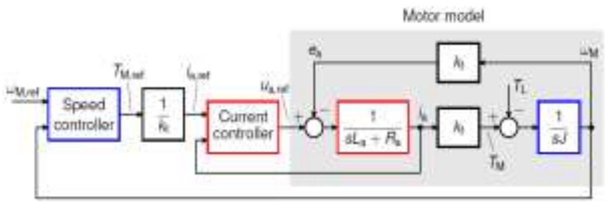

Fig 2: Cascaded control of dc motor block diagram

The main elements that can be included in a system of cascaded control of dc motor are speed controller, DC motor and current controller.

1.2 PI Controller

The most common controlling method used in the Cascade control is PI controller. It is a feedback control loop that calculates the error signal by taking the difference between the output of a system and the set point. The PI Controller is both used in case of Speed and current control method. The block diagram of a PI Controller is show below:

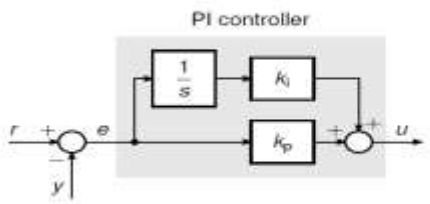

Fig 3: PI controller

In time-domain, the output u = $K_p e + K_i \int edt$

Transfer function $\frac{u(s)}{e(s)} = K(s) = K_p + \frac{K_i}{s}$

1.3 Current Controller

The block diagram for controlling the current is shown below. Current control is basically done to limit the current and to provide precise and fast torque control.

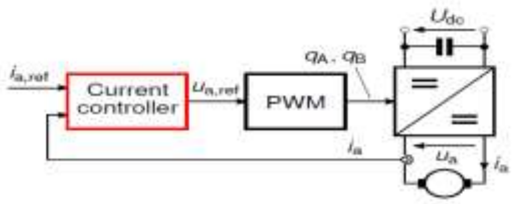

Fig 4: Current control method

2. Methodology

The overall MATLAB simulation of the above system is shown in figure below. Two PI controllers are used in cascaded system. The speed controller is the outer loop and is slow in nature. The current controller is the inner loop and is fast in nature.

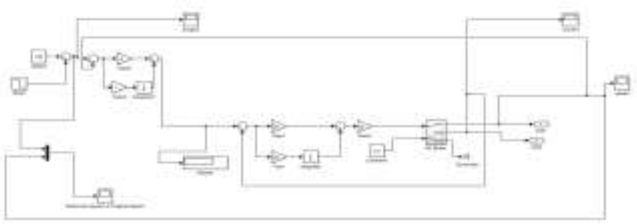

Figure 5: Matlab model of a complete system

2.1 DC Motor representation

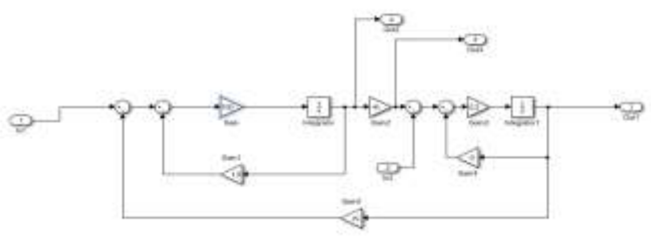

Fig 6: MATLAB simulation of DC Motor

The DC Motor shown above in the block diagram was designed using the integrators instead of transfer functions. This allowed setting the initial conditions for the current and speeding state variables. The model also includes the friction coefficient B. However, during simulations, the value of B is considered as zero.

The dc motor parameters used are:

Armature resistance (R_a)	1.5 Ω
Inductance (L)	100mH
Moment of Inertia (J)	5 Kgm^2
B (as it can be neglected)	0
K_T , K_E	K_T = 3.65 Nm/A, K_E = 3.65 Vs/

Once the response in current is considered optimal, the speed controller is designed. A similar PI Controller for the speed loop is added where the speed of the motor is compared to the reference speed. The reference speed of the motor is given 100 rpm with a step input.

3. Results and Analysis

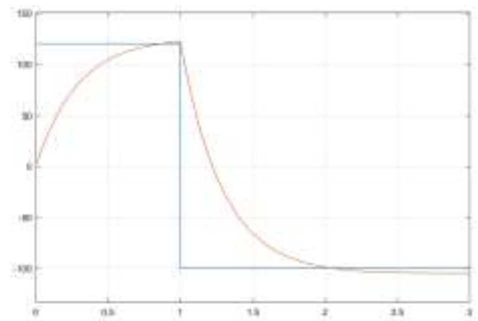

Figure7: Speed v/s time characteristics

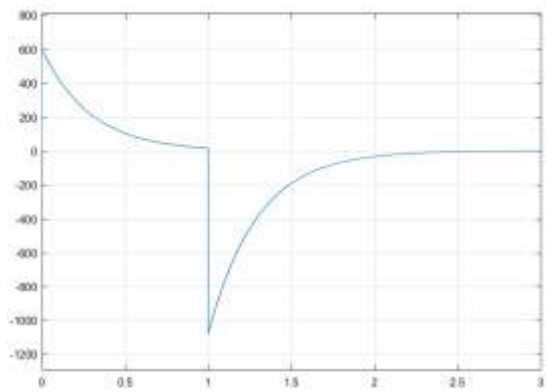

Figure8: Current v/s time characteristics

The reference speed is taken as 100 rpm step input. Load Torque (T_L) is taken as zero. The motor slowly gains speed and reached to the peak 120 rpm at time t=1 second. Due to the step input, as the speed decreases back to zero and then negative value of 100 rpm, the motor speed also reduces progressively as shown in speed/time characteristics.

The current is increased at the beginning to a maximum value of 600A and is too large. At t=1 when the speed is reduced, the current also decreases progressively and as the speed is negative value of 100 rpm, the current slowly increases from negative value and goes to zero.

In brief, typical responses of the speed and current are shown. The motor is initially at standstill and at no load when a step command in speed is applied; when steady-state conditions are reached, a reversal of speed is commanded followed by a step load application.

4. Conclusions

The proposed cascade control system is designed and implemented using a SIMULINK to track the motor speed and determine the armature current under the no load case. The simulation results show that the proposed system has excellent performance.

One of the problems in the above system is that, it is highly non-linear and to reduce so, saturation is needed to limit both the current delivered and the voltage applied to the motor. The Saturation limits on the PI controller are not included in the above system and are therefore necessary to provide antiwindup action.

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