Sliding Mode based D.C.Motor Position Control using Multirate Output Feed back Approach

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Abstract

The paper presents discrete time sliding mode Position control of d.c.motor using MROF. Discrete state space model is obtained from continuous time system of d.c.motor. Discrete state variables and control inputs are used for sliding mode controller design using Multirate Output Feed back approach(MROF) with fast output sampling. In this system output is sampled at a faster rate as compared to control input. This approach does not use present output or input. In this paper simulations are carried out for separately excited d.c.motor position control.

Keywords : D.C.Motor, Sliding Mode Control (SMC), Multirate Output Feedback (MROF), Discrete time.

1 Introduction

Drives are used in Electro mechanical plant in modern Industrial applications. Direct current motors are very commonly used as variable speed drives and in applications where severe torque variations occur. In the applications like actuators for motion control ,robot arms, conveyor belts, dc switching converters , Process control systems, electrolytic process, welding processes, D.C.motor is the key component. Small d.c.machines are used primarily as control devices such as techo-generators for speed sensing and servomotors for positioning and tracking. Separately excited D.C.motors are

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used in applications like paper machines, diesel-electric propulsion of ships and in steel rolling mills. Classical controller design techniques such as Nyquist, Bode plots are normally used for linear control system design with fixed plant parameters. For Non linear control system with plant parameter variation, adaptive control system design techniques are more effective. Adaptive control Techniques can be classified as self tuning control ,MRAS ,Sliding mode or variable structure control, Expert System control, Fuzzy Control ,Neural Control.[1].A sliding mode control (SMC) with a variable control structure is basically an adaptive control that gives robust performance of a drive with parameter variation and load torque disturbance.SMC is non linear and can be applied to a linear or non linear plant . The variable structure system with sliding modes is the recent research domain in control of electric drives, robotics and position control applications.SMC is used for power converter control and also for drive regulation[2, 3, 4]. D.C. motor Controller can be designed using the control variable as speed, position, torque, armature current .Conventional Proportional Integral type controller are sensitive to parameter variations, load variations , system uncertainty, external disturbance [5]. Sliding mode control technique is more popular in variable speed drive because of its insensitivity to parameter variations and load variations and external disturbance. Sliding mode controller can be designed for different purpose such as current control, speed control, torque control and position control. Integral SMC is designed in for D.C.Motor Position control system.[6]Chattering is the main drawback and it is reduced by incorporating switched gains in the design of Integral SMC or by appropriate design of control law. In sliding surface is designed using intelligent approach like fuzzy logic to reduce chattering. [7] Finite speed of switching devices involved in SMC cause the phenomenon of chattering and it affects the performance of the system. It causes high frequency oscillations in the output, heating up of electrical circuits and wear in actuators. This controller offers good tracking performance and robustness property [6, 8, 9]. Continuous time SMC is designed in [9] for D.C.Motor position control system using equivalent control approach for lightweight single-link flexible arm with high varying payload. Discrete time sliding mode was introduce for implementing SMC in real time sampled data systems.[10, 11, 12, 13, 14].With the latest development in Digital Signal Processing Technology and increasing use of computers in control applications ,discrete sliding mode control systems are more popular. In the case of discrete time sliding mode control, the measurement and control signal application are performed only at after regular intervals of time and the control signal is held constants in between these instants.Multi rate Output Feedback (MROF) is the concept of sampling the control input and sensor output of a system at different rates. It provides time delay required for control law implementation. It has advantages of both state feedback and output feedback control approaches [15, 16, 17, 18].In this paper Discrete-time Sliding Mode Control Algorithm based on Multi rate Output Feed back approach for D.C.Motor Position Control is presented. The paper is organized as follows. Section II presents the system model of D.C.motor with MROF, in section III discrete-time sliding mode controller design, in section IV Simulation results and we conclude in section V.

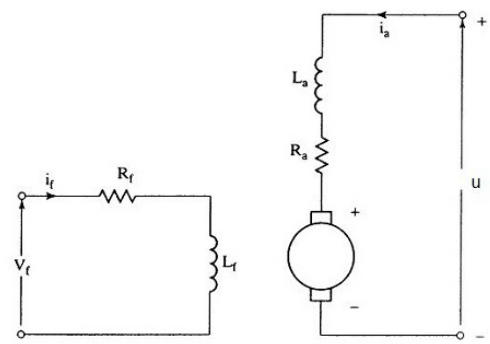

Figure 1: Separately excited d.c.motor [2]

2 SYSTEM MODELLING USING MROF

Separately excited dc motor with armature voltage control shown in Fig-1[2],the State space model for d.c.motor position control [19, 20, 21]obtained as follows for State variables

$$\dot{x_1}(t) = \theta(t), x_2(t) = \omega(t), x_3(t) = i_a(t), y(t) = \theta(t)$$

Continues time State space model is obtained as,

$$\begin{aligned} \dot{x}(t) &= Ax(t) + bu(t) \\ y(t) &= cx(t) \end{aligned} \tag{1}$$

where

$$A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & -\frac{B}{J} & \frac{K_T}{J} \\ 0 & -\frac{K_b}{L_a} & -\frac{R_a}{L_a} \end{bmatrix}; b = \begin{bmatrix} 0 \\ 0 \\ \frac{1}{L_a} \end{bmatrix} \tag{2}$$

$$c = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} \tag{3}$$

The parameters defined for above state space model as La= Inductance of armature winding(H), Ra= Resistance of armature winding(ohm), e(b)= back emf(volts) , TM= torque developed by the motor (N-m), J= equivalent moment of inertia of motor (kg-m2) , u= applied armature voltage. B= equivalent viscous friction coefficient of motor (N-m/(rad/sec)) KT= motor torque constant(N-m/amp), Kb= back emf constant(volts/(rad/sec)).[22] Discrete state space model of d.c.motor is obtained by discretizing the above system sampled at a sampling interval τ sec be represented as

$$\begin{aligned} x((k+1)\tau) &= \phi_\tau x(k\tau) + \Gamma u(k\tau) \\ y(k\tau) &= Cx(k\tau) \end{aligned} \tag{4}$$

Consider the previous output samples for discrete system as

$$y_k = \begin{bmatrix} y(k\tau - \tau) \\ y(k\tau - \tau + \eta) \\ \vdots \\ y(k\tau - \eta) \end{bmatrix} \tag{5}$$

To design the controller it is necessary to measure input and output states of the system. In practise it is not always possible to measure all the input and output states of the system.Multirate output feed back (MROF) sampled system does not need the system state for feedback and uses output samples for the controller design.[23, 24]In this control input and output is sampled at different sampling rate. Multirate output feed back (MROF) sampled system [15, 16, 17, 18]can be represented as

$$\begin{aligned} x((k+1)) &= \phi x(k) + \Gamma u(k) \\ y_{k+1} &= C_0 x(k) + D_0 u(k) \end{aligned} \tag{6}$$

where

$$C_0 = \begin{bmatrix} C \\ C\ \phi \\ \vdots \\ C\ \phi^{N-1} \end{bmatrix} \tag{7}$$

$$D_0 = \begin{bmatrix} 0 \\ C\ \Gamma \\ \vdots \\ C\ \sum_{j=0}^{N-2} \phi^j\ \Gamma \end{bmatrix} \tag{8}$$

3 DISCRETE SLIDING MODE CONTROL DESIGN USING MROF

Discrete controllers are more popular due to rapid developments in digital computer technology. Discrete time sliding mode control has been applied here for separately excited d.c.motor position control using multi rate output feed back(MROF).Sliding Mode controller design consist of two stages hyper plane or switching surface design and control law design.[6, 15, 16, 11]. Following Reaching Law applied here for the design

$$s(k+1) - s(k) = -q\tau s(k) - \epsilon\tau sgn(s(k)) \tag{9}$$

$$\epsilon > 0, q > 0, 1 - q\tau > 0$$

The switching surface taken as follows

$$s(k) = c^T x(k) \tag{10}$$

Multirate output [25, 26] to state relationship,the state x(k) can be expressed in terms of system outputs y(k+1) and control input u(k) as

$$x(k) = (C_0^T C_0)^{-1}[C_0]^T(y_{k+1} - D_0 u(k)) \tag{11}$$

Substitue the value of x(k) from equation (16) into (11) ,x(k+1) can be obtained as

$$x(k+1) = L_y y_{k+1} + L_u u(k) \tag{12}$$

where

$$L_y = \phi\tau((C_0)^T C_0)^{-1}(C_0)^T$$

$$L_u = \Gamma_\tau - \phi_\tau((C_0)^T C_0)^{-1}(C_0)^T D_0 \tag{13}$$

Using the above relations control input function for MROF obtained as ,

$$u(k) = Fx(k) + \gamma sgn(s(k)) \tag{14}$$

where

$$\begin{aligned} F &= -(c^T\Gamma_\tau)^{-1}[c^T\phi_\tau - c^T I + q\tau c^T] \\ \gamma &= -(c^T\Gamma_\tau)^{-1}\epsilon\tau \end{aligned}$$

4 SIMULATION RESULTS

Simulations are obtained for d.c.motor position control using Multi rate output Feed back approach (MROF) [18, 27, 28, 29]. System model for MROF based controller as shown in Fig-2.

Discrete system modelling with MROF obtained in section III represented by the equations (6-8) and for Sliding mode approach, Sliding surface was given by equation (10),reaching law was given by equation (9) and control input obtained as shown in equation (14) used for the simulations study. The parameters of separately excited d.c.motor are same as used in [30] as R=7.5ohm, J=0.006kgm^2,L=5mH B=0.005Nms, Kb=KT=0.809. The parameters for the discrete sliding mode control were $\tau = 0.3$;$q = 1$;$\epsilon = 0.05$

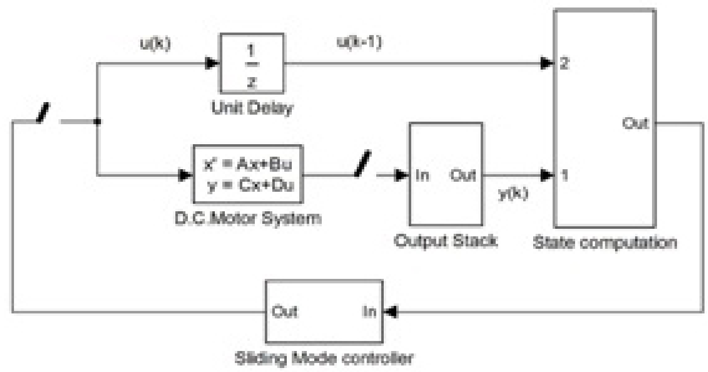

Figure 2: Multirate output Feedback(MROF) based SMC [15]

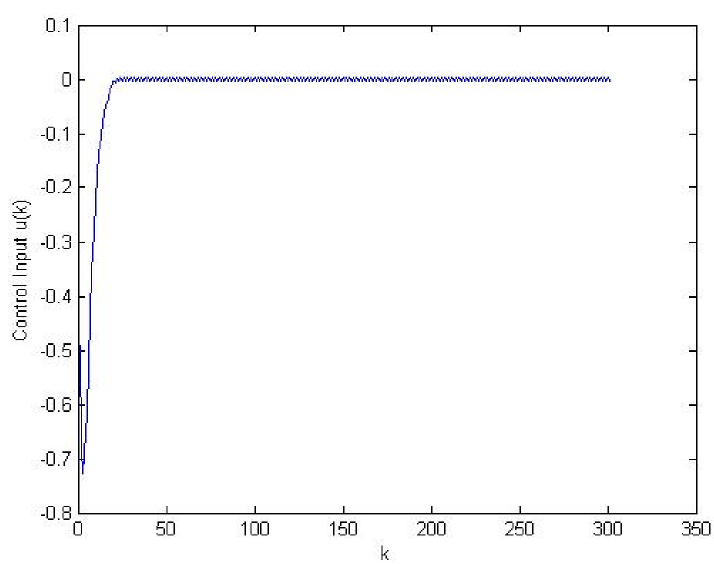

Figure 3: Control Input u

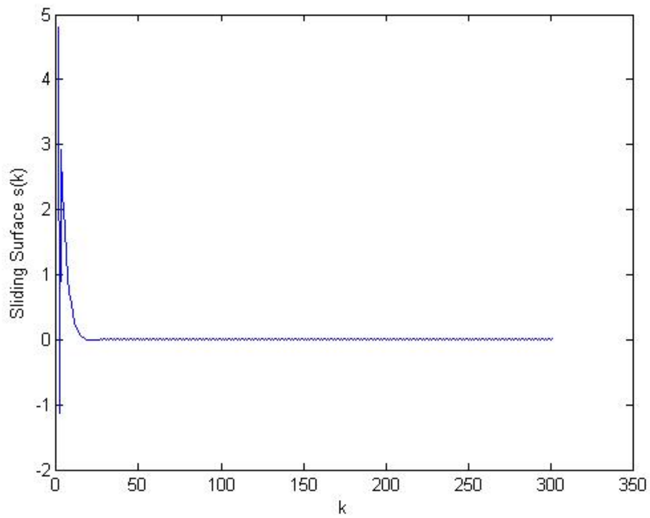

Figure 4: Sliding Surface S

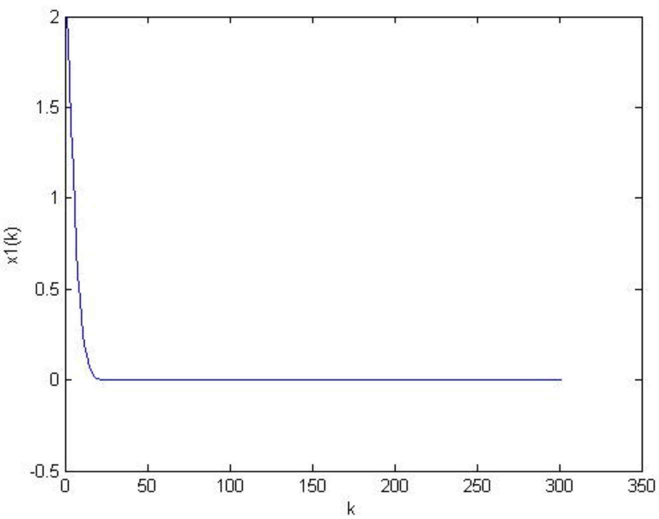

Figure 5: Position state x_1

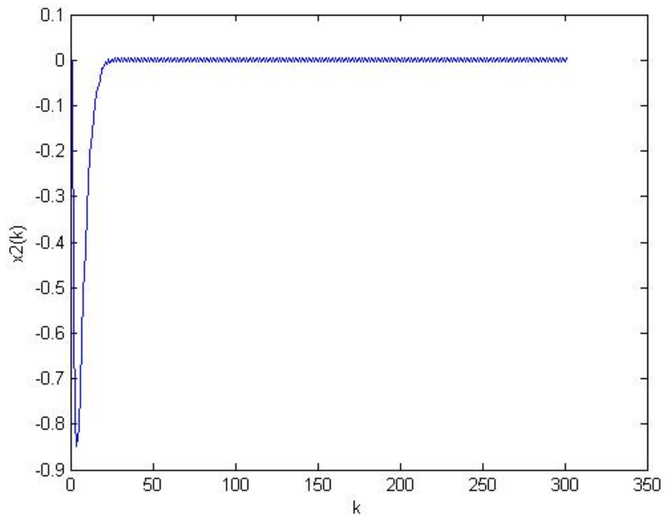

Figure 6: Angular velocity state x_2

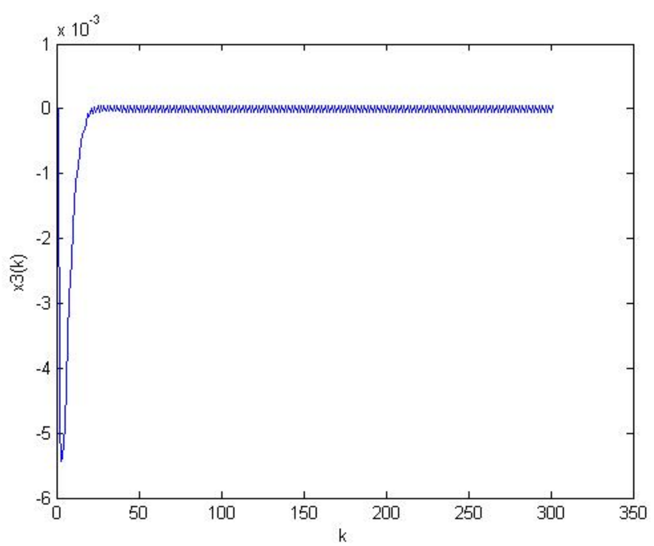

Figure 7: Armature current state x_3

5 CONCLUSIONS

The controller design for D.C.Motor Position control system using discrete sliding mode has been presented in this paper. Continuous time mathematical model has been used for obtaining discrete state space model and Multirate output feed back sampled system. Simulation results shows that Discrete sliding mode controller using Multirate output feed back (MROF) approach brings position control system error states of d.c.motor to zero from the initial conditions and also reduces Chattering.

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