SIMULATION OF DC SERVO MOTOR POSITION CONTROL USING SLIDING MODE TECHNIQUE

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ABSTRACT
Generally, the DC servo motor systems have uncertain and nonlinear characteristics which degrade performance of controllers. Based on these reasons, Sliding Mode Control (SMC) is one of the popular control strategies and powerful control technology to deal with the nonlinear uncertain system. In this work, a controller based on the Integral Sliding Mode Controller (ISMC) is proposed and designed for controlling DC motor in a servo drive. The modeling and analysis of the servo DC motor are obtained. To improve the controller performance in steady state (zero error), ISMC is designed and evaluated. Since the main drawback of SMC is a phenomenon, that called chattering resulting from discontinuous controllers. An ISMC with switched gains is used for chattering reduction and controller robustness. For comparison, the proposed ISMC with switched gains is compared with that of a PID controller. The proposed controller offers very good tracking, also it is highly robust and controlled plant reached very fast to the final position. Furthermore the application of the SM ensures reduction of the system order by one. Also, quick recovery from matched disturbance in addition to good tracking. Moreover, this scheme is robust against the parameters variations.

KEYWORDS: *Servo DC motor, Proportional, Integral, Derivative, Sliding Mode Controller (SMC), Integral Sliding Mode Controller (ISMC), Simulation.*

I. INTRODUCTION

There are some special types of application of electrical motor where rotation of the motor is required for just a certain angle not continuously for long period of time. For these applications some special types of motor are required with some special arrangement which makes the motor to rotate a certain angle for a given electrical input (signal). For this purpose servo motor comes into picture. This is normally a simple DC motor which is controlled for specific angular rotation with help of additional servomechanism (a typical closed loop feedback control system). Now a days servo system has huge industrial applications. Servo motor applications are also commonly seen in remote controlled toy cars for controlling direction of motion and it is also very commonly used as the motor which moves the tray of a CD or DVD player. Beside these there are other hundreds of servo motor applications we see in our daily life. The main reason behind using a servo is that it provides angular precision, i.e. it will only rotate as much we want and then stop and wait for next signal to take further action. This is unlike a normal electrical motor which starts rotating as and when power is applied to it and the rotation continues until we switch off the power.

The most interesting fact is that robustness has becomes a major requirement in modern control application [1] The sliding mode control has gained the wide acceptance due to the use of straightforward fixed non-linear feedback control functions which operate effectively over a specified magnitude range of system parameter variations and disturbances. The sliding control requires the knowledge of mathematical model of the system with bounded uncertainties [2]. The first application of SMC method to the DC motor for control of torque, speed and position was given by Sabanovic and Izosimov [3]. SMC is only used to produce the torque command, while the inner loop is just the traditional IFOC. Some general guidelines to design SM controllers for electric drives are given in Utkin [4], including DC motors, IMs and synchronous motors. In Benchaib et al. [5] the boundary layer method is used for chattering reduction. The term chattering describes the phenomenon of finite frequency, finite amplitude oscillations appearing in many SM implementations. Yan et al. [6] are proposed an asymptotic current observer in the control loop to eliminate chattering. The parameters inaccuracy does not play any role in the chattering issue if we know their ranges. The only possible reason for the chattering are the unmodelled dynamics in the system [7]. For chattering prevention by observers, the key idea is to generate ideal SM in an auxiliary observer loop rather than in the main control loop.

II. PLANT DESCRIPTION

The plant consists of a DC motor with an inertial load. The DC motor is separately excited and armature controlled, whose schematic diagram is shown in Fig.1. In this section design of controller to control the motor-load angle speed is proposed. The system parameters are [2].

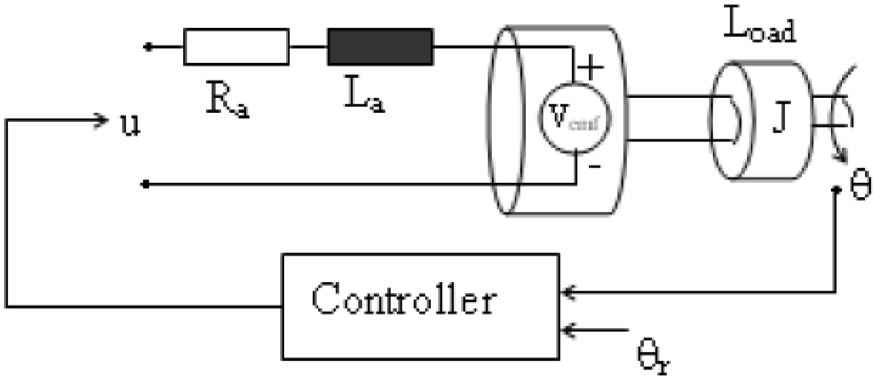

Figure 1: Equivalent circuit of DC servo motor.

The differential equation governing electrical part of the model can be written,

$$V = iR + \frac{L\,di}{dt} + E \tag{1}$$

where, V=DC voltage applied in Volts.
L=Inductance of the windings in Henry.
R=Resistance of the windings in Ohms.
E = Kbω=Back emf of the motor.
ω=Speed in rad .sec.
The above equation can be written as

$$\frac{di}{dt} = 1/L(-E - iR + V) \tag{2}$$

The relation between torque and speed can be obtained by the following differential equation as

$$T = \frac{Jdw}{dt} + Bw + TL \tag{3}$$

T=Torque in Newton = meter.
J=Moment of inertia in Kg/ms.
TL= Disturbance input.
B=Coefficient of friction in Kg/ms.

2.1 PID Controller

The proportional integral derivative controller is about the most common and useful algorithm in control system engineering. The feedback loops are controlled using PI algorithm [3]. Feedback is very important in systems in order to attain a set point irrespective of disturbances or any variation in characteristics of any form. PI controller is designed to correct error between the measured process value and a particular desired set point in a system.
PID controllers are dominant and popular and has been widely used because one can obtain the desired system responses and it can control a wide class of systems. This may lead to the thought that the PID controllers give solutions to all requirements. PID controllers have a simple control structure, inexpensive cost. However, when the system is nonlinear and when bounded uncertainties present in

the system, PID controllers are not perfectly able to stabilize the system, particularly, when the nonlinearity is very high or the bound of uncertainty is large [7]. The transfer function of a PID controller is given by

$$Gc(s) = Kp(1 + \frac{Kp}{TiS} + TdS) \quad (4)$$

Where, Kp, $\frac{Kp}{TiS}$, $KpTd$ represent the proportional, integral &derivative gains respectively

$$\omega n = 1/\sqrt{TiTd} \quad (5)$$

$$\zeta = 1/2\sqrt{Ti/Td} \quad (6)$$

Then the PID transfer function can be written as

$$Gc(s) = Kp\ \omega n^2 + 2\zeta\omega ns + s^2/2\zeta\omega ns \quad (7)$$

2.2 Sliding Mode Controller

The first and important step in SMC is to define a sliding surface along which the process can slide to its desired final value Figure 2.shows the SMC objective. first step in SMC is to define the sliding surface s(t) [4] . s(t) is chosen to represent a desired global behavior, for instance stability and tracking performance. The objective of control is to ensure that the controlled variable be equal to its reference value at all times, meaning that error e(t) and its derivatives must be zero. Once the reference value is reached, it indicates that sliding surface s(t) reaches a constant value. To maintain s(t) at this constant value, meaning that error e(t) is zero at all times; it is desired to make

$$\dot{s} = \frac{d(constant)}{dt} = 0 \quad (8)$$

The SMC control law, u, consists of two additive parts; a continuous part, u_{eq}, and a discontinuous part, u_{sw}.

$$u = u_{eq} + u_{sw} \quad (9)$$

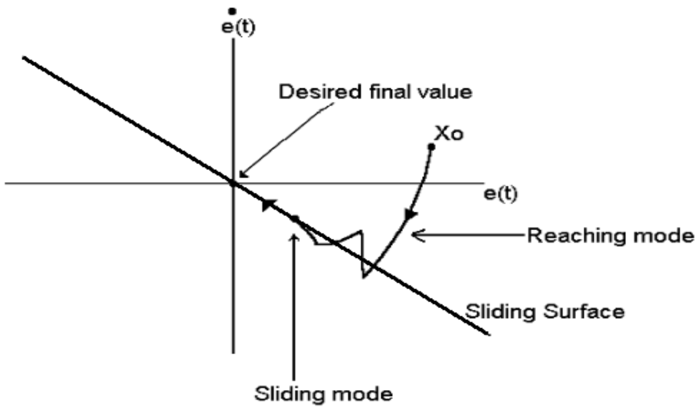

Figure 2: Graphical interpretation of SMC.

The integral sliding mode (ISM) controller is introduced. To improve the controller performance in steady state (zero error), the integral sliding mode controller (ISMC) is designed and evaluated. Since the main drawback of SMC is a phenomenon, that called chattering resulting from discontinuous controllers [5] . An ISMC with switched gains is used for chattering reduction and controller robustness. For comparison, the proposed ISMC with switched gains is compared with that of a PID controller.

The sliding surface σ is defined as

$$\sigma = \dot{e} + C * e = (\theta_r - \theta) * C + \dot{\theta}_r - \boldsymbol{\omega} \quad (10)$$

where θ_r=Reference rotor position.

C=Constant.

e(t)=Error signal=Reference position- actual position.

In addition to above, the integral mode with sliding surface given is also used to check the performance of the servo DC motor

$$s(t) = \lambda 1e + \lambda 2 \int e + de/dt \quad (11)$$

III. DIGITAL SIMULATION RESULTS

The result shown in below figure 6. and Figure 7.gives the clear difference between the traditional PID controller SMC and ISMC.

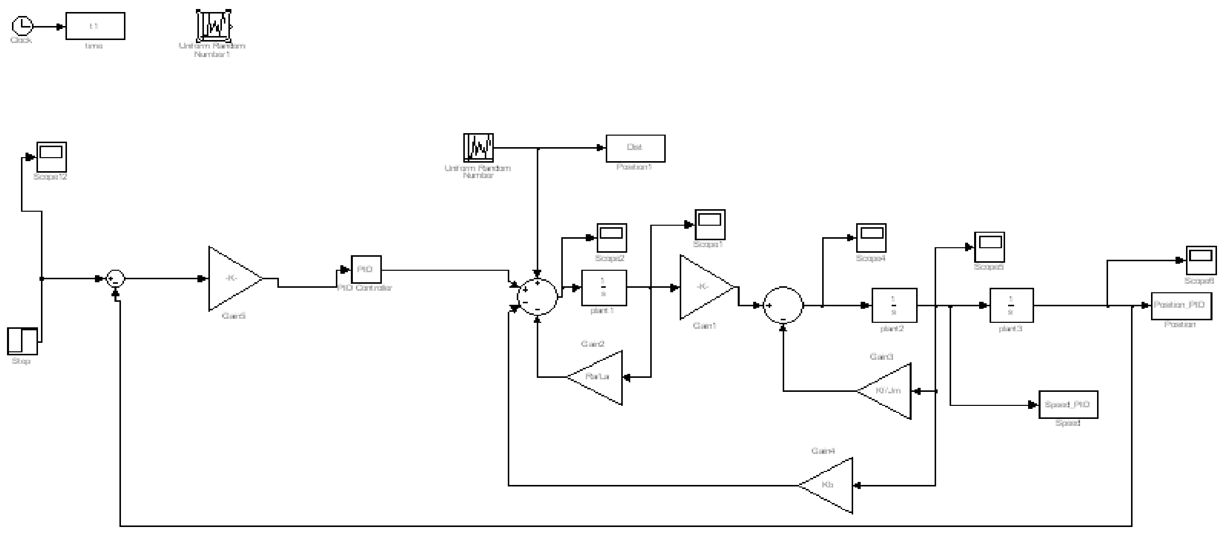

Figure 3: PID controller for DC servo motor.

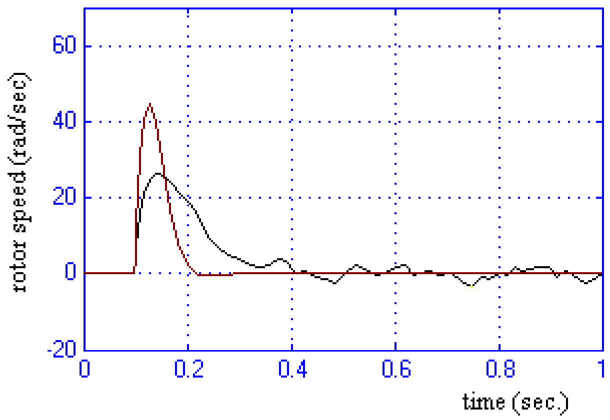

Figure 4: Speed control output of DC motor using PID and SMC.

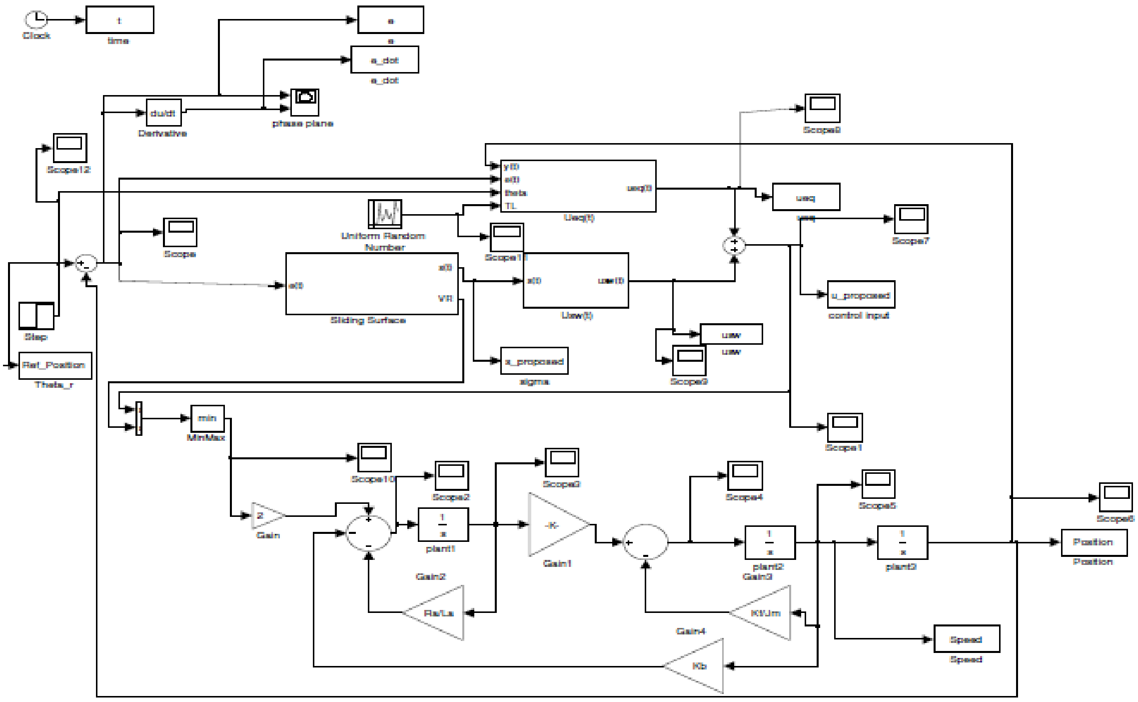

Figure 5: Simulink model of DC servo motor using SMC and ISMC.

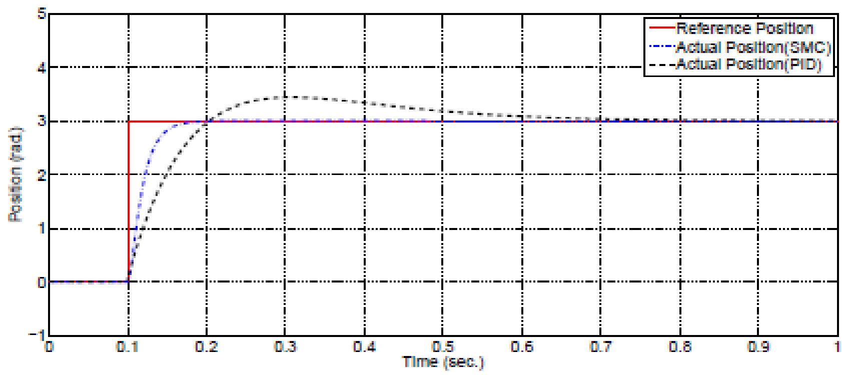

Figure 6: Position control output of DC motor using SMC& PID controller

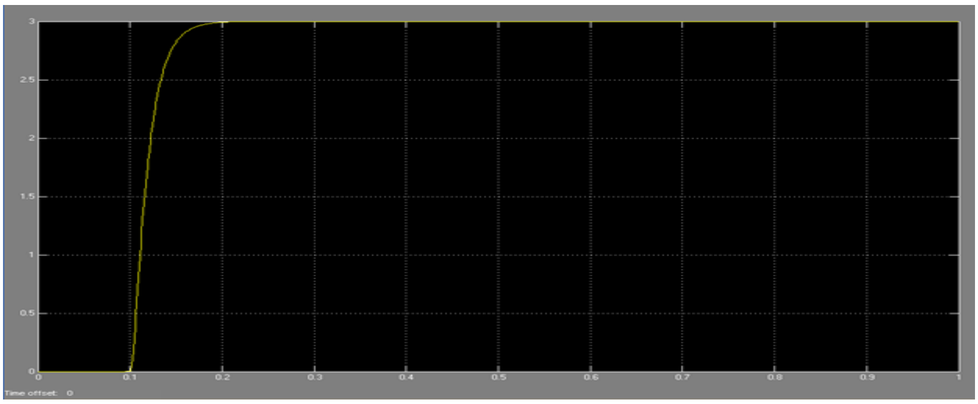

Figure 7: Position control output of DC motor using ISMC.

Table 1: Simulation Results

Parameter	Term	SMC	PID
Settling Time	Position	0.16 sec	0.54 sec
Peak Overshoot	Position	0%	14.2%
Settling Time	Speed	0.25 sec	-
Peak Overshoot	Speed	55%	268%

IV. CONCLUSION AND FUTURE WORK

This work is intended to compare the two Controllers namely, Proportional-Integral-derivative (PID) controller and sliding mode controller (SMC) for the position control of a DC motor. It is observed that

• SMC provides important advantages over the traditional PID controller like limiting the overshoot in position, thus the starting position overshoot can be reduced.

• From the simulation results, both techniques give required result. However, simulation results show that the sliding mode controller realized a good dynamic behavior of the motor with a rapid rise time and settling time, and had better performance than the PID controller related to reduction in settling time and smaller overshoot. The SMC response has much better torque load rejection capabilities as well as against parametric uncertainties or variations in parameters of DC motor. To improve the system response in steady state ISMC is developed and its output is shown in figure 10. And the comparative results with the traditional controller showed the definite difference. The control strategy used in this work is limited to SMC and PID controller, however, different control strategies such as adaptive, predictive can be implemented to compare the results with SMC. The design and tuning of the PID controller for position control of DC motor can be done by using artificial intelligence techniques.

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