Assessment of Position Control of DC Servomotors with PID and Sliding Mode control approach

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Abstract: ***A position control of a class of DC servomotors is addressed in this article via a novel adaptive PD with sliding mode control approach. This paper contracts with the specific type of robust control i.e., sliding mode control for position and speed controlling of a DC servo motor. The paper contributes synthesis and investigation of DC servo motor with sliding mode controller and a conventional PID controller. This process has done through the modeling and simulations are carried out and their performing is assessed in steady as well as in transient state. In this way, the DC servo motor position drive is tricky to parameter assortment and load agitating impact, a generous control approach in light of sliding mode is comprehended. The proposed approach has the extra favored outlook that, for outside disturbance, it only requires a bound to exist, without needing to know the magnitude of this bound. The proposed controller is applied to control a model of uncertain induction servomotor subject to significant disturbances and a model of DC servomotor with unknown parameters and uncertainty in load condition.in this article, the usefulness of the projected Procedure is validated by performing simulations using MATLAB tool. The simulation results demonstrate that the role of sliding mode based arrangement is supplementary robust than fixed gain PID controller.***

Keywords: DC servomotors, Sliding Mode Control, PID controller.

I. INTRODUCTION

Following is every now and again connected with servomechanism applications demanding high accuracy in rotor situating [1]. Automation plays a very vital role in our everyday life, it can be establish in practically any robotic manipulator and electronic appliance we use in daily life, starting from air conditioning systems, automatic doors, and automotive battery operated vehicle control systems to extra innovative machinery system such as robotic arms, and thousands of industrial, scientific and research applications. DC servo motors are one of the main modules of automatic control systems used in nowadays [2]. The position control of the DC servo motor necessary to study because DC servo motors are broadly used in servomechanism [3]. DC servo motor has shortcomings of undefined and nonlinear characteristics which slow down the working of controllers. On the other side based on these observations, Sliding Mode Control (SMC) is one of the widespread control methodologies to a pact with the nonlinear uncertain system [4]. The main reason behind using a servo is that it provides angular precision, i.e. it will just pivot as much we need and after that stop and sit tight for next flag to make additionally move. This is dissimilar to an ordinary electrical motor which begins pivoting as and when control is connected to it and the revolution proceeds to the point when we turn off the power. These attributes of the sliding-mode control may be engaged in controlling of a DC servo motor. There are two essential steps in the design of SMC, firstly to decide a sliding surface that models the required closed loop performance and secondly to design a control law such that the phase plane trajectories of the system are forced towards the sliding surface. The system dynamics under the reaching phase is affected by uncertainties which consequences in the undesired effect called chattering. The unforeseen instability can arise due to unwanted chattering effect because it excites unmolded high-frequency plant dynamics [5].

The paper presents a position and speed control of a DC servo motor drive system with sliding mode control approach. The purpose of the designed controller is to force the motor speed and position to follow the desired tracks without excessive overshoots undershoots and zero steady state error. The system responses compared with fixed gain PID controller [6]. The PID controller is selected because the implementation cost of the PID controller is inexpensive and it is used in industries on a large scale. A MATLAB simulation is done to show the validity of the proposed controller.

II. DESCRIPTION OF DC SERVO MOTOR MODELLING

The transfer function of the DC servomotor can be imitative consuming Kirchhoff's voltage law and Laplace transform as resulting: This section shows the design of a controller to control the position and speed of the DC servo motor. The block diagram of the DC servo motor is shown in Fig1. The dynamic equations below describe the behavior of the motor [7]. A DC motor is an actuator that converts electrical energy to mechanical rotation using the principles of electromagnetism. Three equations of motion are fundamental to the derivation of the transfer function. Relationships between torque and current, voltage and angular displacement, and torque and system inertias are used.

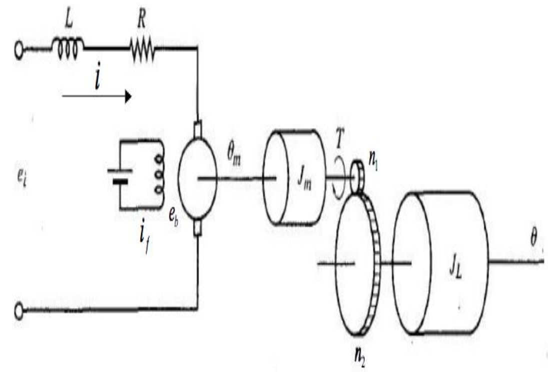

Fig.1. DC Servo Motor

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

$$V=IR+L\frac{di}{dt}+E \qquad (1)$$

We can say that Back-electromotive force (emf) Eb can be found by

Using the equation shown below.

$$E_b = K_a \frac{d\theta}{dt} = K_a \omega_r \qquad (2)$$

Where E_b is the induced voltage, K_a is the motor torque Constant, and ω_r is the angular rotating speed. It can be seen that ω_r can be calculated by the equation shown below

$$\omega_r = \Theta_r \qquad (3)$$

Using Laplace Transform,

$$\omega_s = s\theta_s \qquad (4)$$

Our motto in this phase is to control the angular rotating Speed, by controlling the input voltage V_a.

Where:

J = Rotor moment of inertia

B_m = Damping ratio

T_L = Motor Load Torque

i_a = Armature Current

E_b = Back emf

θ_r= Angular position of rotor

K_a = Electromotive force constant

ω_r= Measured angular Speed

R_a = Motor Armature Resistance

L_a = Inductance
V_a = Armature Voltage
The resulting transfer function:

$$\frac{\omega_r}{V_a} = \frac{K_a}{(J_s+B_m)(L_a s+R_a)+{K_a}^2} \quad (5)$$

Our real concern in this exploration is the correct control of the angular speed of the motor; since angular speed is the part that experiences most the non-linearity. Figure 1 demonstrates the Block graph which expresses to the servomotor system utilizing MATLAB SIMULINK.

Permanent magnet DC motor actuated servo system with all its modeling is represented by the following differential equations. The power converter dynamics is represented by the differential equation, and the applied armature voltage to the motor is controlled by varying the amplifier duty ratio'd'.The following differential equations are taken to mock-up the transient behavior of DC servo motor,

$$\frac{dV_a}{dt} = \frac{1}{T_i}V_a + \frac{K_i}{T_i}d \quad (6)$$

$$\frac{dV_a}{dt} = \frac{1}{L_a}V_a - \frac{R_a}{L_a}i_a - \frac{K_a}{L_a}\omega_r \quad (7)$$

$$\frac{d\omega_r}{dt} = \frac{K_a}{J}i_a - \frac{B_m}{J}\omega_r - \frac{1}{J}T_L \quad (8)$$

$$\frac{d\theta_r}{dt} = \omega_r \quad (9)$$

From the exceeding equation, we can write as according to space-state model,

$$X\dot{(t)} = Ax + Bu \quad (10)$$

$$\begin{bmatrix} \frac{dV_a}{dt} \\ \frac{di_a}{dt} \\ \frac{d\omega_r}{dt} \\ \frac{d\theta_r}{dt} \end{bmatrix} = \begin{bmatrix} -\frac{1}{T_i} & 0 & 0 & 0 \\ \frac{1}{L_a} & -\frac{R_a}{L_a} & -\frac{K_a}{L_a} & 0 \\ 0 & \frac{K_a}{J} & -\frac{B_m}{J} & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} V_a \\ i_a \\ \omega_r \\ \theta_r \end{bmatrix} + \begin{bmatrix} \frac{K_i}{T_i} \\ 0 \\ 0 \\ 0 \end{bmatrix} d + \begin{bmatrix} 0 \\ 0 \\ -\frac{1}{J} \\ 0 \end{bmatrix} T_L \quad (11)$$

Table 1. Parameters of DC Servo Motor

Parameters	**Values**
Armature resistance R_a	2.7Ω
Armature inductance L_a	0.004H
Motor inertia J_m	0.0001
Viscous friction constant B_m	0.00008
Back emf constant K_e	0.11 V-sec/rad
Torque constant K_t	0.11N-m/A
Gear constant K_{gear}	0.1
T_i	0.0001
D	±1
K_p(proportional constant)	0.5
K_i(integral constant)	0.034
K_d (derivative constant)	31

III. PID CONTROLLER

The PID controller is very widely used in the industries. A PID controller is the simple three-term controller. The letter P, I and D stand for P- Proportional, I- Integral, D- Derivative. The main function of the PID controller is to make the plant less sensitive to changes that take place in surroundings. The basic PID controller composes of three terms proportional (P), derivative (D) and integral (I) to stabilize the response of the system. The Ziegler –Nicholas ultimate cycle or closed loop tuning has been widely used [8].

$$\mathrm{Y(t)} = e(t)Kp + Ki \int_0^t \mathrm{e(t)dt} + K_d de(t)dt \quad (12)$$

Equation (xii) shows the output of the PID controller

Where e = Error signal
K_p = Proportional Constant
K_i= Integral Constant
K_d = Derivative Constant

IV. SLIDING MODE CONTROLLER

The sliding mode controller has been produced by consolidating the idea pole placement technique and power rate achieving law [9]. Consider a system described by equation 10 and 11

Controllability is an important property of a control system, and the controllability property plays a crucial role in many control problems, such as stabilization of unstable systems by feedback, or optimal control

Controllability of the system observed by classical method,

$$X(\dot{t}) = Ax + Bu \qquad (13)$$

by testing the rank of the controllability matrix Qc, where

$$Q_c = [B \quad AB \quad A^2B \ldots\ldots A^{(n-1)}B] \qquad (14)$$

For the given system, in this calculation, we have to find the Rank = 4. Subsequently the rank of the Qc = 4.

Therefore, the system is fully controllable. Every sliding mode controller design needs two main things, firstly the designing of the sliding surface and secondly the synthesizing of control law.

Utilizing the idea of variable structure framework the plan of sliding mode controller is performed. The non- linear sliding surface is[10].

$$X = P_1V_1 + P_2i_a + P_3\omega_r + P_4\theta_r + P_5E_a \qquad (15)$$

So that

$$X\dot{X} < 0$$

The basis of Lyapunov stability theory which the control law is derived

$$V = Sgn(P_1v_1 + P_2i_a + P_3\omega_r + P_4\theta_r + P_5E_a) \qquad (16)$$

$-1 \leq V \leq 1$

With the use of Pole placement technique the feedback a resound. Fig.2 is showing the schematic block diagram of derived control law including the riding surface.

V. RESULT ANALYSIS

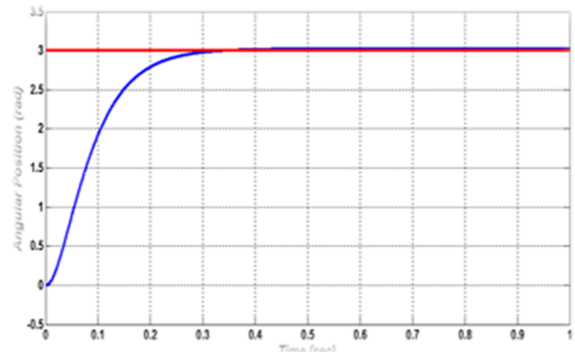

Fig.2.The position of the Servo system with PID controller

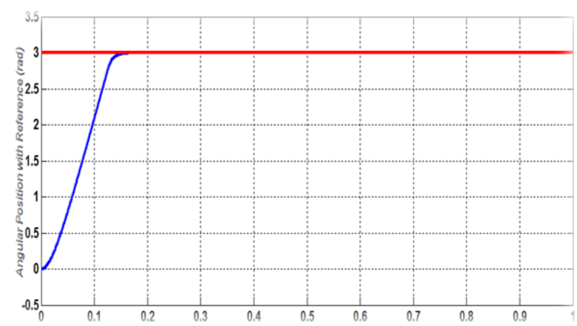

Fig.3. The position of the Servo system with SMC at No load

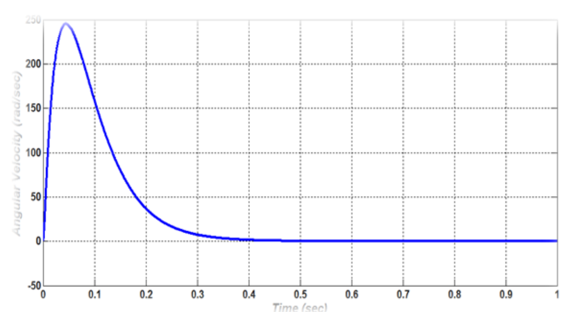

Fig.4. Angular Velocity of Servo system with PID Controller at No load

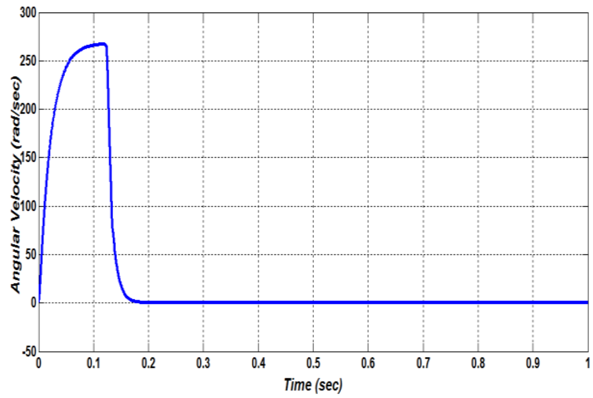

Fig.5. Angular Velocity of Servo system with SMC

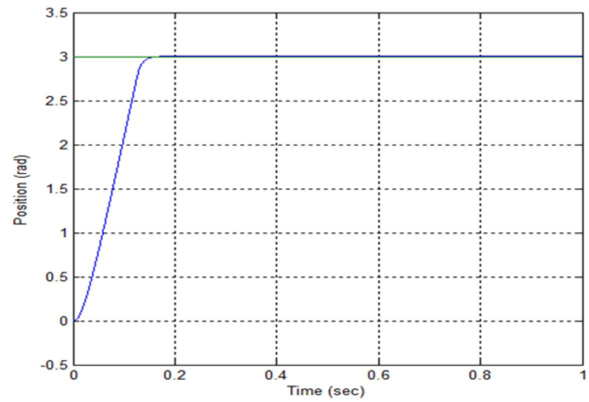

Fig.8. The position of Servo system with SMC at load

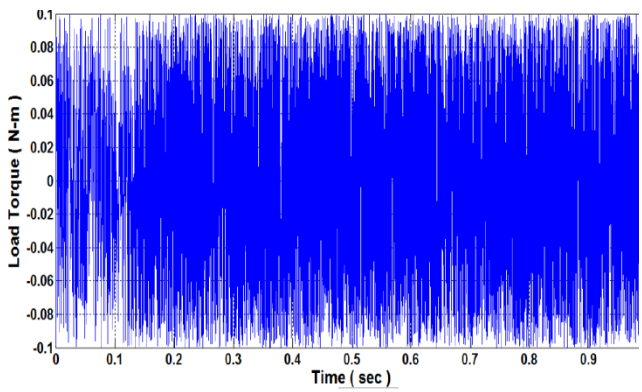

Fig.6. Load Torque as a disturbance

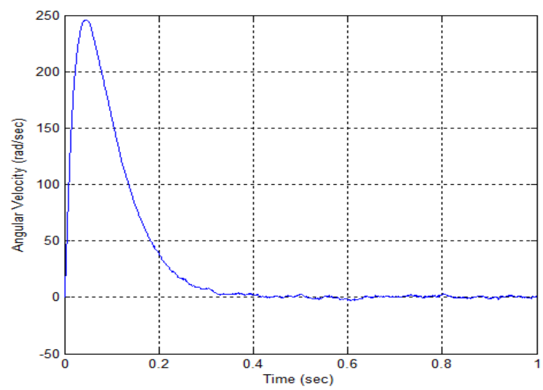

Fig.9. Angular Velocity of Servo system with PID at load

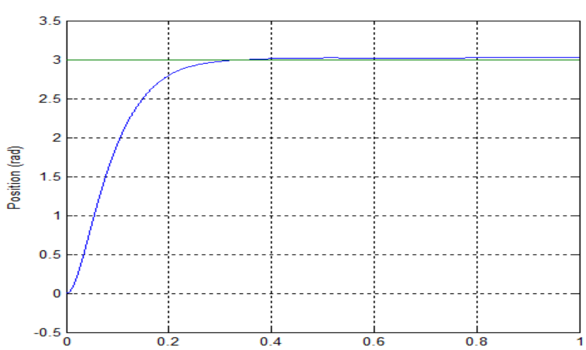

Fig.7. The position of Servo system with PID at load

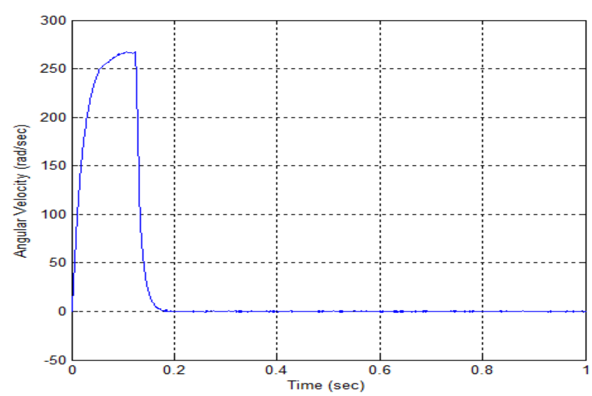

Fig. 10.Angular Velocity of Servo system with SMC at Load

Table 2. System Time response specifications

Control Variable	Time Response Specifications	PID	SMC
Position of Servo system	Settling time (sec)	>13sec	0.146 sec
Angular Velocity of Servo system	Settling time (sec)	>3.05rad	No overshoot

VI. CONCLUSION

In this paper, we have been discussed the dynamic modeling and two methodologies for stabilizing and tracking of DC Servo Motor, DC servomotor has been considered as a plant. A dynamic model of the complete plant was derived. PID control endows with the stabilization; equally, SMC yields the robustness to the parametric uncertainty and exhibits disturbance rejection capabilities. Both stabilizing and tracking control of DC Servo Motor has been scrutinized using PID and SMC according to Time response domain analysis.A near investigation of the fixed gain PID controller and Sliding Mode Controller have been improved the situation controlling the position and the speed of DC motor in servo drive system which outcome that the aftereffect of sliding mode controller is vastly improved than traditional PID controller, The robustness of the proposed controller is confirmed through no heap and on stack circumstance as an inconvenience.

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