DESIGN OF SLIDING MODE CONTROL FOR DC MOTOR USING LABVIEW

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***Abstract*—** This paper presents alternative way of controlling DC motor. Sliding Mode Control (SMC) technique is insensitive to the presence of uncertainty and a disturbance due to its robustness property It is suitable method for wide classes of linear and nonlinear system. The performance of the system with Sliding Mode Control is compared and analyzed with the responses of the system with proportional integral derivative [PID] control. The proposed controller is simulated using LabVIEW 7.1 simulation and control design toolkit and obtained result indicates effectiveness of the proposed strategy.

***Keywords*—PID Controller, Sliding Mode Control (SMC), DC motor, LabVIEW.**

I. INTRODUCTION

DC motors are extensively used in robotics, actuators and electrical equipment. Therefore, the control of the position or/and speed of a DC motor is an important issue and has been studied since the early decades in the last century. Extensive use of DC motors is arisen from the controllability of their speed and their compatibility with the new electronic/mechanical equipments such as digital system sets. many of applications require high performance controllers like variable structure control. It posses several attractive advantages like fast transient performance, insensitivity to parameter variation and compared with conventional controllers.

The Sliding Mode Control theory (SMC) is based on the concept of varying the structure of the controller based on the changing state of the system in order to obtain a desired response [1]. A high speed switching control action is used to switch between different structures and the system state trajectory is forced to move along a chosen manifold in the state space, called the switching manifold. The behavior of the closed loop system is thus determined by the sliding surface [2, 3].

It is designed so that the system trajectories move onto a prespecified surface in a finite time and tends to an equilibrium point along this surface [5].

The closed-loop dynamics are completely governed by sliding surface equations as long as the system trajectories remain on this surface. In fact, the system in the sliding mode has less order than the original system except when a compensator is designed for the sliding mode system. There are many advantages for using SMC, including flexibility of design and robustness [3, 6]. A robust stabilization of uncertain systems based on sliding surfaces and output feedback control schemes have been studied through the development of a number of algorithms.

II. REVIEW OF PID CONTROLLER

The PID controller has been in use for over a century in various forms. It has enjoyed popularity as a purely mechanical device, as a pneumatic device, and as an electronic device. The digital PID controller using a microprocessor has recently come into its own in industry.

PID stands for "proportional, integral, derivative." These three terms describe the basic elements of a PID controller. Each of these elements performs a different task and has a different effect on the functioning of a system.

In a typical PID controller these elements are driven by a combination of the system command and the feedback signal from the object that is being controlled (usually referred to as the "plant"). Their outputs are added together to form the system output. Fig.1 shows a block diagram of a basic PID controller. The plant feedback is subtracted from the command signal to generate an error. This error signal drives the proportional integral and differential elements. The resulting signals are added together and used to drive the plant.

The transfer function of the PID controller looks like the following:

$$K_P + \frac{K_I}{S} + K_D S = \frac{K_D S^2 + K_P S + K_I}{S} \qquad (1)$$

Where Kp is Proportional gain K_I is Integral gain K_D is Derivative gain. First, let's take a look at how the PID controller works in a closed-loop system using the schematic shown in fig.. The variable (e) represents the tracking error, the difference between the desired input value (R) and the actual output (y). This error signal (e) will be sent to the PID controller and the controller computes both the derivative and the integral of this error signal. The signal (u) just past the controller is now equal to the proportional gain (Kp) times the magnitude of the error plus the integral gain (Ki) times the integral of the error plus the derivative gain (Kd) times the derivative of the error.

$$u = K_p + K_I \int e\, dt + K_D \frac{de}{dt} \tag{2}$$

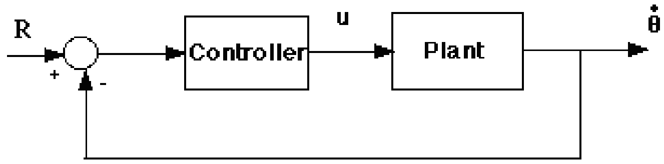

Fig. 1. PID controller Schematic

This signal u will be sent to the plant, and the new output (y) will be obtained. This new output (y) will be sent back to the sensor again to find the new error signal (e). The controller takes this new error signal and computes its derivative and it's integral again. This process goes on and on.

III. Sliding Mode Control Design

VSC includes several different continuous functions that map plant state to a control surface and switching among different function is determined by plant state that is represented by a switching function. Switching function change its state according to sliding equation .basic block diagram sliding mode controller is shown in fig.2

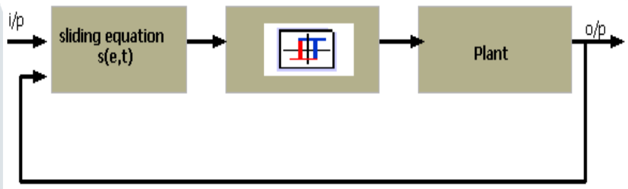

Fig. 2.schematic of Sliding Mode Control

The controller design procedure consists of two steps. First, a feedback control law u is selected to verify sliding condition However, in order to account for the presence of modeling imprecision and of disturbances, the control law has to be discontinuous across S(t). Since the implementation of the associated control switching is imperfect, this leads to chattering. Chattering is undesirable in practice, since it involves high control activity and may excite high frequency dynamics neglected in the course of modeling. Thus, in a second step, the discontinuous control law u is suitably smoothed to achieve an optimal trade-off between control bandwidth and tracking precision. The first step achieves robustness for parametric uncertainty; the second step achieves robustness to high- frequency modeled dynamics.

Consider the system described by the following equation

$$\dot{x}_1 = x_2$$

$$\dot{x}_2 = a_1 x_1 + a_2 x_2 + u \tag{3}$$

The control input and the sliding surface are chosen as [1]

$$u = -K sign\,(s)$$

$$s = \lambda x_1 + x_2 \tag{4}$$

Where λ and K are positive constants. The ideal sliding mode cannot be expected to occur in this case since $x_1$becomes a continuous time function and chattering will be generated.

The state dependent gain method may be implemented for the other control tasks. Following controller may be proposed using state-dependent gain method to substitute the controller provided in (4),

Sliding surface can be defined as [1]

$$e = x_d - x_1$$

$$s = \left(\frac{d}{dt} + \lambda\right)^{n-1} e = 0 \tag{5}$$

Where n is the system order and λ >0 for second order system n=2, sliding surface

$$s = \dot{e} + \lambda e = 0 \qquad (6)$$

Trajectory move toward and stay on the sliding surface s=0 from initial condition if following condition meets

$$\frac{1}{2} * \frac{d}{dt} s^2 < 0 \qquad (7)$$

$$s\dot{s} < -\eta |s| \qquad (8)$$

Where η is positive constant that decides the system trajectory reach at surface in finite time

IV. DC MOTOR MODEL

In proposed paper

E_b: The back emf,(volt);
R: The armature resistance, (ohm);
I: The armature current (Amp);
L: The armature inductance,(H);
J : J: The moment inertial of the motor rotor and load,(kg.m^2/s^2);
K $K = K_b$ The motor constant (v-s/rad).
$K = Kt$: The torque factor constant, (Nm/Amp);
ω:Angular velocity(rad/s)
B:The damping ratio of mechanical system(Nms)

$$\begin{bmatrix} \dot{\omega} \\ \dot{I} \end{bmatrix} = \begin{bmatrix} -\frac{B}{J} & \frac{K}{J} \\ -\frac{K}{L} & -\frac{R}{L} \end{bmatrix} \begin{bmatrix} \omega \\ I \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{1}{L} \end{bmatrix} Vs \qquad (9)$$

Let $z_1 = \omega$, $z_2 = I$, $a_{11} = -\frac{B}{J}$, $a_{12} = \frac{K}{J}$, $b_1 = 1/L$, $a_{22} = -\frac{R}{L}$ $a_{21} = -\frac{K}{L}$

$$\dot{z}_1 = a_{11} z_1 + a_{12} z_2 \qquad (10)$$

$$\dot{z}_2 = a_{21} z_1 + a_{22} z_2 + b_1 u \qquad (11)$$

$$y = z_1$$

Where y is the output of the system. To obtain reduced order system, the system is converted to a canonical form (result presented in actual physical state) in following form, Assume that

$$x_1 = z_1$$
$$\dot{x}_1 = z_2$$

The system can be converted to canonical form [7]

$$\dot{x}_1 = x_2$$
$$\dot{x}_2 = a_1 x_1 + a_2 x_2 + bu \qquad (12)$$
$$y = x_1$$

Where $a_1 = a_{12}a_{21} - a_{11}a_{22}$, $a_2 = a_{11} + a_{12}$, $b = a_{12}b_1$
select the sliding surface

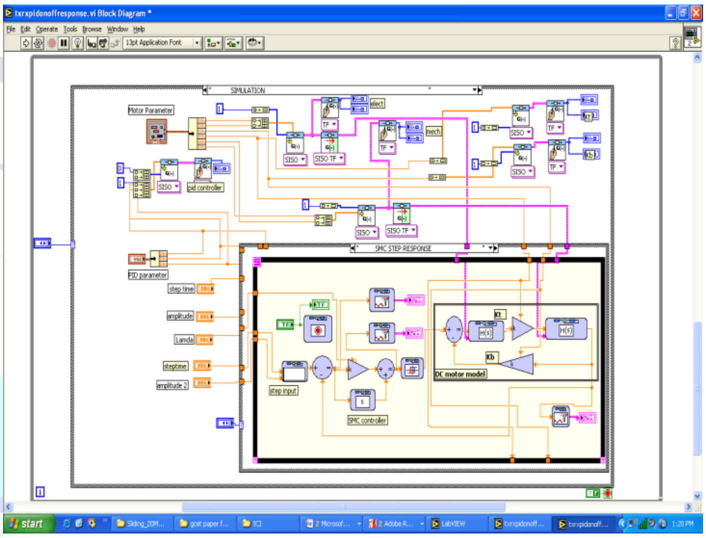

Fig. 3. LabVIEW Graphical Code for Sliding mode control

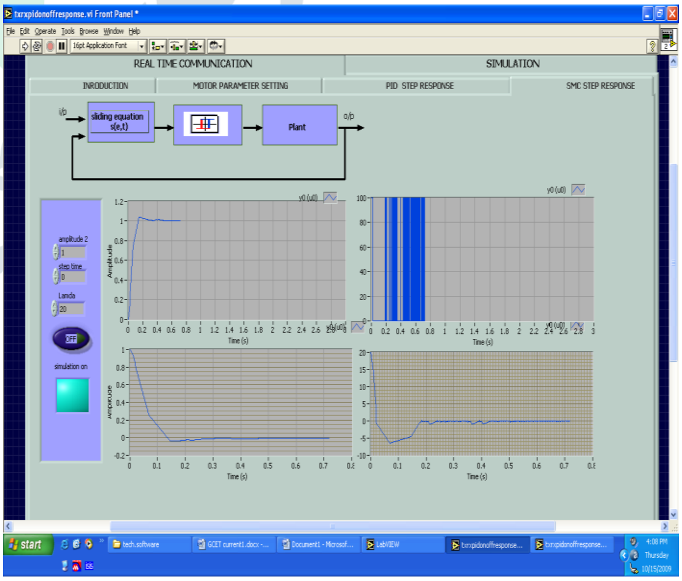

Fig. 4. LabVIEW Front panel Diagram

$$s = \lambda(x_d - x_1) + x_2 \ , \lambda > 0 \qquad (13)$$

V. SIMULATION RESULT

To verify the performance of the proposed robust controller and PID controller closed loop is simulated using labview7.1. The parameter selection option is given in front panel of the labVIEW software. For proposed method motor parameters are selected as shown in table I. The simulation graphics G code for SMC is shown in figure.3. All the blocks inside simulation block diagram are from simulation toolkit of Labview. The response using the proposed sliding mode controller is depicted in fig.9.Comparison shows rise time and setting time for sliding mode controller is higher than PID step responses at same peak overshoot.

Step response of Sliding Mode Control and PID Controller are shown in figure.6 and figure.9. The result is obtained at following parameter.

K_p=10.31, K_i = 7.24 ,K_d =5.4 for PID Controller and λ=17 for Sliding mode control, we get almost same peak overshoot for both but rise time and settling time for SMC is less but value of K for SMC must be large so that system state trajectory is forced to move along a chosen manifold in the state space

Physical parameter of dc motor

Parameter	Value	Unit
R	2	Ω
L	0.5	H
K_b	0.1	v.s/rad
K_t	0.1	N.m/A
F	0.2	$Kg.m^2/s^2$
J	0.02	N.m.s

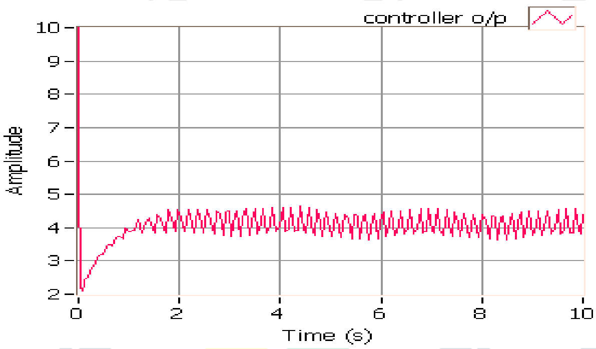

Fig. 5. PID Controller Output

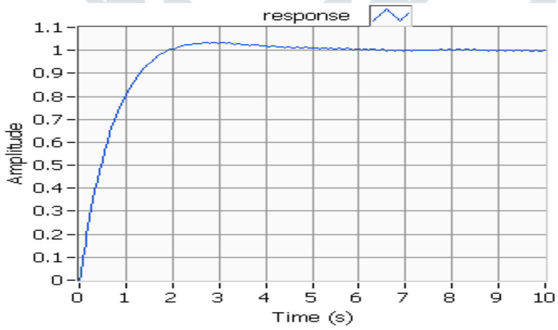

Fig. 6. step response with PID Controller

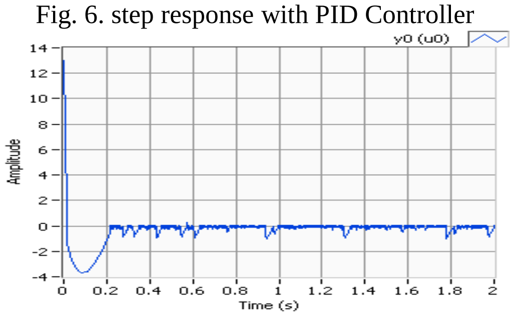

Fig.7.sliding surface s(t)

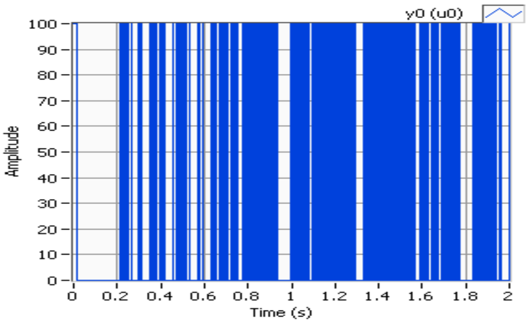

Fig.8. Sliding mode Controller output

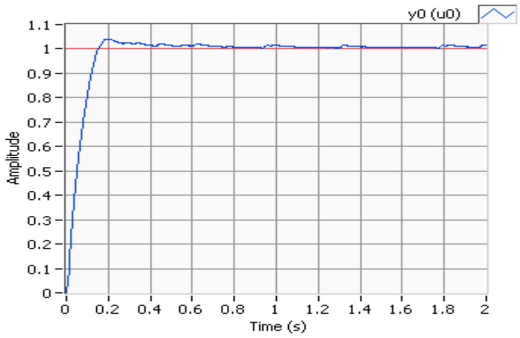

Fig. 9.step response with SMC

VI. Conclusion

SMC and PID controllers have been considered in this paper for controlling DC motor speed. SMC is suitable where less rise time, less settling time is required, moreover disturbance do not affect the system in the sliding mode .we can get desired response by changing the value of lambda only. If there is no disturbance, PID controller is suitable but there is also problem of tuning.

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