SIMULATION OF SPEED CONTROL OF INDUCTION MOTOR WHEN SUBJECTED TO NON-LINEAR VARIATIONS IN MOTOR PARAMETERS

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Abstract – Today induction motor requires a variable speed control to serve wide range of applications. The objective of this work is to control the position of a field oriented induction motor for a given reference input signal. This work addresses the design of a speed control scheme based on total sliding-mode control (TSMC) theory for a field-orientated induction motor (IM). The total sliding mode control comprises an equivalent control design and a robust control design. In this work the control strategy is derived in the sense of Lyapunov stability theorem such that the stable tracking performance can be ensured under the occurrence of system uncertainties. The salient feature of this control scheme is that the controlled system has a total sliding motion without a reaching phase. The work is been accomplished using Matlab/Simulink. In this work a comparison is been done for a fixed torque & change in torque (Change in motor parameter).

Keywords – *Induction Motor (IM), Total Sliding Mode Control (TSMC), Lyapunov Theorem, Field-Control Operation.*

I. INTRODUCTION

The recent researches and advances in the domain of field-oriented control side by side with the dynamic development and cost reduction of power electronics devices and microprocessors have made variable speed induction motor drives a cost effective alternative for many industrial applications such as factory automations, robot manipulators and transportation applications. Due to the coupled and nonlinear time-varying dynamics complexities of IMs, IMs have more complexities in control characteristics than DC motors. Many techniques for the control of IMs have been developed in the past years. Among them, the field-oriented control is the most popular one. With the technique of field orientation, the rotor speed is asymptotically decoupled from rotor flux, and the speed is linearly related to torque current. Thus, the IM possesses the same behaviour of a separately excited DC motor [1]. When the motor parameters are considered, particularly the torque, the field-oriented control performance becomes sensitive with the deviation of motor parameters.

In order to achieve both high dynamic performance and high power efficiency, squared rotor flux has to be precisely controlled with the motor speed and torque because the power efficiency in Induction Motors in steady state operation is related to the squared rotor flux. This can be achieved by either flux measurement or estimation mechanisms. In general, the flux measurement with Hall sensors will usually produce the problem of degradation in mechanical robustness, and increase cost or volume. Therefore, the flux estimation is a more suitable way for field-oriented control than the direct flux measurement. The common problem associated with the estimation is accuracy and robustness under the possible occurrence of uncertainties.

Sliding mode control (SMC) is suitable approach for a specific class of nonlinear systems. This is applied in the presence of modeling inaccuracies, parameter variation and disturbances, provided that the upper bounds of their absolute values are known. Modeling inaccuracies may come from certain uncertainty about the plant (e.g. unknown plant parameters), or from the choice of a simplified representation of the system dynamic. Sliding mode controller design provides a systematic approach to the problem of maintaining stability and satisfactory performance in presence of modeling imperfections.

At the same time the insensitivity of the controlled system to the uncertainties exists in the sliding mode, but not during the reaching phase. Thus the system dynamic in the reaching phase is still influenced by uncertainties. That is system robustness can't be maintained in the whole process .If we speed up the period of reaching phase via larger control gain we can overcome this problem. To keep robustness in the whole sliding mode control system, several researches have focused on eliminating the effect of the reaching phase. The common drawback is the complicated design of a specific sliding curve, and it may lead to heavy computation burden or increase the switching frequency such that the system responses are still subjected to system uncertainties. Ones the system dynamics are controlled in sliding mode, uncertainties will not affect the system.

II. THEORETICAL BACKGROUND

A. Need for Sliding Mode Control Scheme

Computed torque or inverse dynamics technique is a special application of feedback linearization of nonlinear systems. The computed torque controller is utilized to linearize the nonlinear equation of robot motion by cancellation of some, or all, nonlinear terms. Then, a linear feedback controller is designed to achieve the desired closed-loop performance. Consequently, large control gains are often required to achieve robustness and ensure local stability. Thus, it is natural to explore other nonlinear controls that can circumvent the problem of uncertainties in the computed torque approach and to achieve better compensation and global stability.

B. Control Principle of Sliding Mode Control

Consider a simple second order under damped linear system with variable plant gain K. It can be easily being seen that the system is unstable in either negative or positive feedback mode. However, by switching back and forth between the negative and positive feedback modes, the system cannot only be made stable, but its response can be made independent to plant parameter K. The block diagram of sliding mode control of second order system is shown in figure 1. The Phase plane trajectory for negative feedback and positive feedback is shown in figure 2.

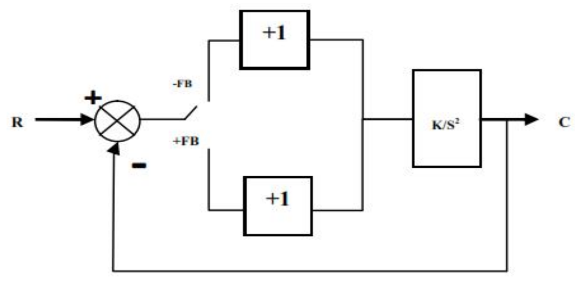

Fig. 1: Block diagram of Sliding mode control for Second order system

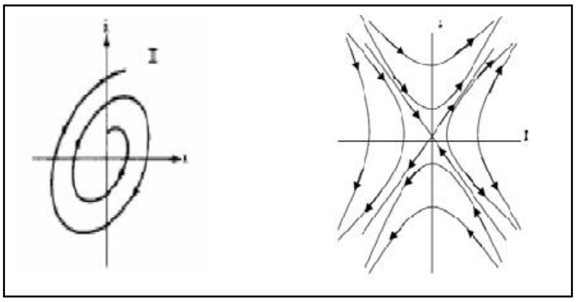

Fig. 2: Phase plane trajectories for negative feedback and positive feedback

C. The Sliding mode control:

The sliding mode control (SMC), is one of the most efficient nonlinear robust control approaches as it provides system dynamics with invariance to uncertainties once the system dynamics are controlled in the sliding mode. The first step of SMC design is to select a sliding surface that models the desired closed-loop performance in state variable space. Then the control should be designed such that system state trajectories are forced toward the sliding surface and stay on it. The system state trajectory in the period of time before reaching the sliding surface is called the reaching phase. Once the system trajectory reaches the sliding surface, it stays on it and slides along it to the origin. The system trajectory sliding along the sliding surface to the origin is the sliding mode. The insensitivity of the control system to the uncertainties exists in the sliding mode, but not during the reaching phase. Thus the system dynamics in the reaching phase is still influenced by uncertainties. The idea of sliding mode is shown in figure 3 and 4.

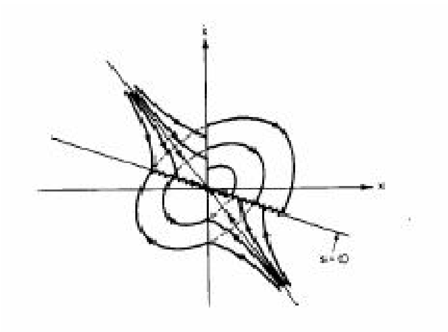

Fig. 3: Sliding mode control in phase plane

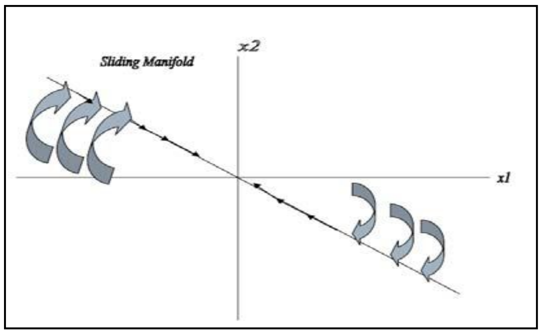

Fig. 4: Idea of Sliding Mode

D. Need for Total Sliding Mode:

As mentioned earlier the insensitivity of the controlled system to the uncertainties exists in the sliding mode, but not during the reaching phase. Thus the system dynamic in the reaching phase is still influenced by uncertainties. That is, the system robustness cannot be maintained in the whole control process. To overcome this problem, one effective way is to speed up the period of reaching phase via the larger control gain. To keep robustness in the whole sliding mode control system, several researches have focused on eliminating the effect of the reaching phase. The common drawback is the complicated design of a specific sliding curve, and it may lead to heavy computation burden or increase the switching frequency such that the system responses are still subjected to system uncertainties. Therefore, we go for a total sliding mode control, to get a sliding motion through the entire state trajectory. Thus the control system through the whole control process is not influenced by system uncertainties.

E. The Total Sliding Mode:

In total sliding mode, no reaching phase exists in the control process. Compared with the previous variable structure controlled system. Thus, insensitivity of the controlled system to the uncertainties exists in the complete control system. This study has two distinguishing features. First, the sliding surface is with an additional integral term. It is emphasized that the proposed use of an integral term is significantly different from integral terms used by other researchers. In this study, no boundary layer is being considered. The special integral term is designed to eliminate the reaching phase, not to reduce steady state error due to continuous control. Secondly, the equivalent control dynamics in the sliding mode is the second order dynamics. This feature makes it easy to assign the system performance based on overshoot, rise time and settling time specifications.

III. APPROCH FOR IMPLEMENTATION

A special integral term is designed to eliminate the reaching phase & at the same time not to reduce steady state error due to continuous control. Secondly, the equivalent control dynamics in the sliding mode is taken as second order dynamics. This feature makes it easy to assign the system performance based on overshoot, rise time and settling time specifications. There are two PI controllers used one for the mechanical subsystem and one for the electrical. Both the controllers are tested for speed tracking and load torque variation conditions. Different cases under which the simulation tests are carried out are:

(a) A Step change in reference speed was made.

(b) The Tracking of reference speed was done.

(c) Robustness test against load torque variation was done.

An adaptive sliding mode control system was developed which adjusts the bound of uncertainties in real time in the control effort using a simple algorithm. The control scheme for a given induction motor was simulated using MATLAB/SIMULINK. The position of a field oriented induction servomotor drive for a given reference input signal was controlled using the total sliding mode control schemes.

IV. SYSTEM DESIGN

A. Designing of Total Sliding Mode Controller

The implementation of field-oriented control can be simplified with the help of control system block diagram as shown in Fig. 5.

$T_e = K_t i_{qs}$ 3.1

$Kt = (3n_p/2)(L_m^2/L_r)i_{ds}$ 3.2

$H_p(s) = 1/(J_s+B)$ 3.3

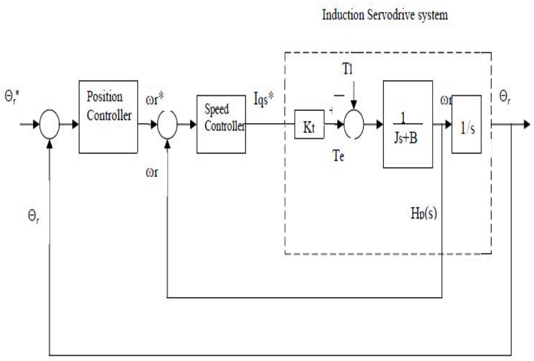

Fig. 5: Simplified block diagram of an induction servomotor drive

The proposed total sliding mode control system is shown in Fig. 6. The presentation of total sliding-mode control for the uncertain (non-linear) induction servomotor drive system is divided into two main parts.

- Base Line Model Design
- Curbing Controller Design

The first part shows performance design. The objective is to specify the desired performance in terms of the nominal model, and it is referred to as base line model design.

In base line model design, two controllers are designed in the control effort. The first controller which is a computed toque controller & is used to compensate for the nonlinear effects and attempts to cancel the nonlinear terms in the model. After the nonlinear model is linearized, the second controller is used to specify the desired the system performance. The stability of the controlled system may be destroyed, to ensure the system performance as desired, regardless of the existence of the uncertain system dynamics, a new sliding-mode controller is designed.

In the curbing controller design an additional controller is designed using a new sliding surface to make sure the sliding motion through the entire state trajectory, which thoroughly eliminates the unpredictable perturbations effect from the parameter variations and external load disturbances. Therefore, in the total sliding-mode control system (TSMC) the controlled system has a total sliding motion without a reaching phase. The objectives of the curbing controller are dual. The first is to keep the controlled system dynamics on the sliding surface. That is, curb the system dynamics on to the sliding surface for all time. Thus it is called a curbing controller. Accordingly, the second objective is to guarantee that the closed loop perturbed system has the same performance as the base line model design.

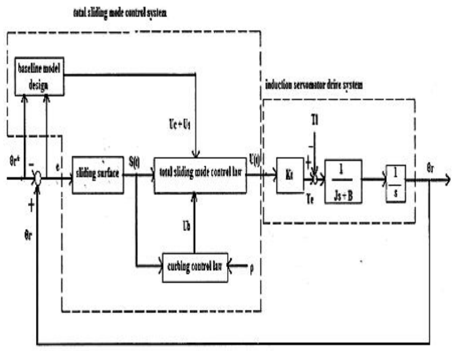

Fig. 6: Block diagram of Total Sliding Mode Control System

V. SIMULATION USING MATLAB

Figure 7 shows the total sliding mode controller designed using SIMULINK. In this work we had done a comparative analysis of sliding mode control & total sliding mode control. This comparative analysis is been done by changing the torque which is one of the non linear motor parameter. Figure 8 & 9 shows the analysis.

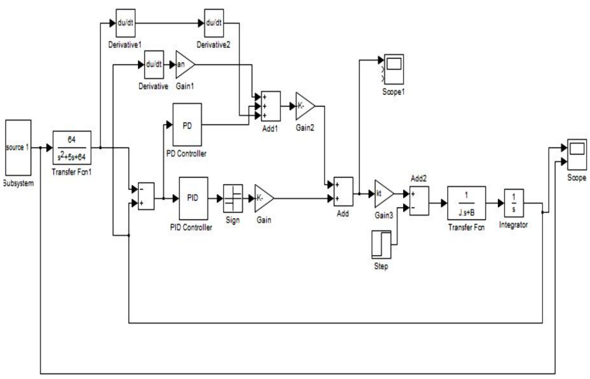

Fig. 7 : Simulation Block Diagram of TSMC

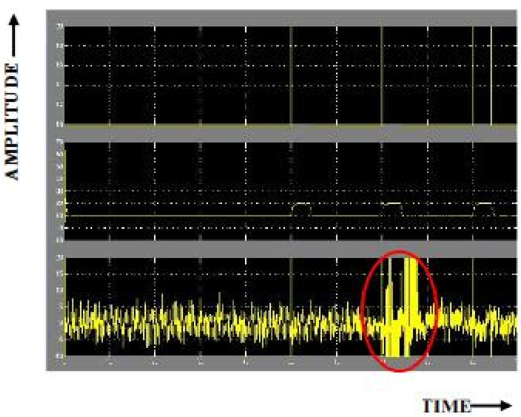

Fig. 8: Wave form of input, output and control effort in SMC

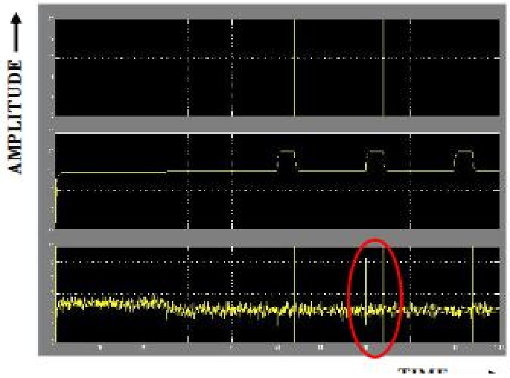

Fig. 9: Wave form of input, output and control effort in TSMC

VI. CONCLUSION

From figure 8 shows the control using SMC & figure 9 shows the control using TSMC. From both the figure it is clear that the control effort is reduced (shown encircled) in TSMC & even after introduction of additional torque i.e. non-linearity the controlled system is stable.

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