SLIDING-MODE CONTROLLER BASED INDIRECT VECTOR CONTROL OF INDUCTION MOTOR

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ABSTRACT

Induction motors are being applied today to a wider range of applications requiring variable speed. This paper presents a control method with sliding mode controller to regulate the speed of an indirect vector controlled induction motor drive for high performance.The analysis, design and simulation of the sliding-mode controller are carried out. The performances of the sliding mode controller are compared with a PI controller with no load and various load condition .Both controllers are implemented using MATLAB/SIMULINK. The simulation results are very satisfactory. The result demonstrates the robustness and effectiveness of the proposed sliding-mode control.

KEYWORDS: *Indirect vector control, sliding mode control, PI controller, induction motor, speed control.*

Nomenclature

R_s, R_r Stator and rotor resistances
Ls, Lm Rotor and mutual inductances
T_L Load torque
'N_P Number of pole pairs
T_e Electromagnetic torque
ω_e, ω_r Stator and rotor frequency
ω_{sl} Slip angular frequency
Ψ_r Rotor flux component
I_{ds}, i_q Stator torque and flux component of statorcurrent
B Damping ratio of motor
J Inertia constant of motor

I. INTRODUCTION

Induction motors are widely used in many industrial applications due to their low maintenance, robustness and high performance. The vector control or field oriented control methods have been proposed so that the induction motor can be controlled like a separately excited d.c.motor. Indirect vector control has been applied in wide range of industrial application. In order to accomplish variable speed operation, conventional PI controllers have widely used [2]. By applying this controller induction machine achieves control performance similar to separately excited d.c machine. Due to nonlinear characteristic of induction motor, linear controller such as PI controller fails to give optimum performance. This controller is also sensitive to parameter. Variation, external disturbance, loads change. To solve these problems, recently intelligent controller such as sliding mode controller (SMC), Fuzzy logic Controller (FLC) etc. have been applied to drive systems. Sliding-mode controller (SMC) is one of the effective ways for controlling the induction motor drive system. It is a robust control because the feedback input with high gain cancels the nonlinearities, parameter uncertainties and external disturbances. It also offers fast dynamic response and stable control system [3].However one of the drawback of this controller is the chattering phenomenon caused from the discontinuous control action. Mainly the chattering phenomenon is alleviated by the boundary layer neighboring to the sliding surface. This method can leads to stable close loop system with avoiding chattering problem [4]. This paper presents a sliding-mode control scheme (SMC).The performance of SMC has been successfully compared with conventional PI controller. An indirect vector control is reported in section-2.A sliding-mode control is discussed in section-3. Test results are discussed in Section-4 and finally some concluding remarks are stated in section-5.

II. INDIRECT FIELD-ORIENTED INDUCTION MOTOR DRIVE

The block diagram of an indirect field-oriented induction motor drive is shown in fig.I. Here the induction motor is fed by a hysteresis current controlled pulse width modulated (PWM) inverter.

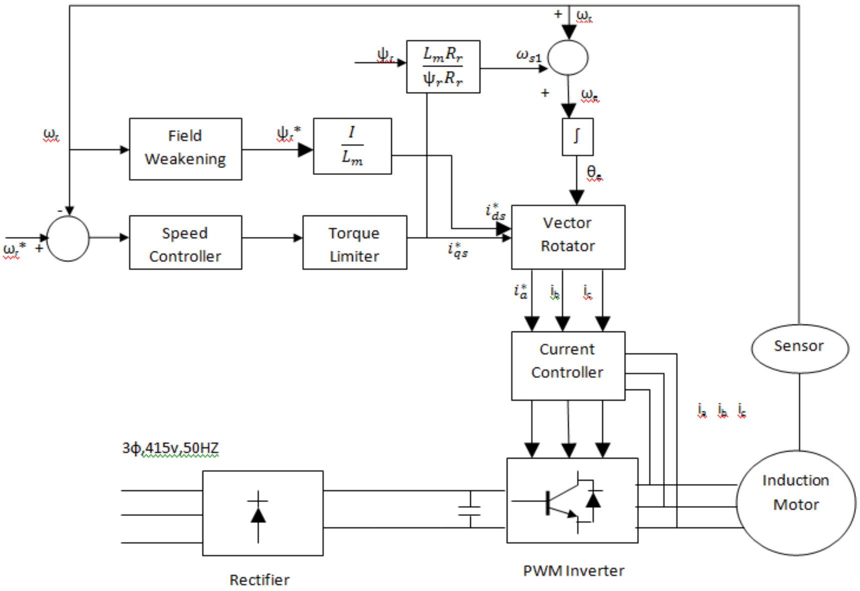

Figure 1: Indirect vector controlled Induction Motor Dive

The torque component of current $i_{qs}{}^{*}$ is generated by speed error with the help of PI or any intelligent controller. The flux component of current ids* is obtained from the desired rotor flux $\widehat{\Psi}_r$ is determined from the following equation,

$$\widehat{\Psi}_r = L_m i_{ds} \quad (1)$$

The slip frequency ω_{sl} * is generated by the current i_{qs} * is determined from the equation,

$$\omega_{sl} = \frac{L_m R_r}{\widehat{\Psi} L_r} i_{qs} \quad (2)$$

The slip speed signal ω_{sl}* added with feedback rotor speed signal ω_r to generate frequency signal ω_e. The slip speed together with the rotor speed is integrated to obtain the stator reference space vector position θe.

$$\theta_e = \int \omega_e dt = \int (\omega_r + \omega_{sl}) \quad (3)$$

The vector rotator converts the two phase d-q axis reference currents $i_{qs,}{}^{*}$and $i_{ds}{}^{*}$to three phase currents $i_{a.}{}^{*}$,$i_b{}^{*}$,$i_c{}^{*}$.The reference currents are compared with the actual currents $i_{a.}$,i_b,i_c from induction motor. The currents error is fed to the hysteresis band such that the required performance of the machine is obtained [5]. The mechanical equation of an 1M drive system can be represented as

$$J\dot{\omega}_r(t) + B\omega_r(t) + T_L = T_e \quad (4)$$

Where ω_r is the rotor speed, J is the moment of inertia, B is the damping coefficient and T_L is the external load disturbance.Te denotes electromagnetic torque is given by

$$T_e = K_t i_{qs}{}^{*} \quad (5)$$

Where, K_t is the torque constant is defined as

$$K_t = \left(\frac{3n_p}{2}\right)\left(\frac{L_m^2}{L_r}\right) i_{ds}^{*} \quad (6)$$

Substituting equation (5) into equation (4) The mechanical equation of an 1M drive system can be represented as

$$\dot{\omega}_r(t) = -\frac{B}{J}\omega_r(t) + \frac{K_t}{J} i_{qs}^{*}(t) - \frac{1}{J}T_L \quad (7)$$

$$\dot{X}(t) = A_p\omega_r(t) + B_p U(t) + C_p T_L \quad (8)$$

Where X(t) = ω_r (t), A_p = -B/J, B_p = Kt/J, C_p =-I/J, U(t) = i^*_{qs} is the control effort. The system uncertainties including parameter variations, external load disturbance influence the1M seriously, though the dynamic behaviour of 1M is like that of separately excited motor. Therefore a SMC system is investigated in this paper to enhance the robustness of the 1Mdrive for high performance application. Now assume, the parameters without external loaddisturbance, rewriting (8) represents the nominal model of the 1M drive system

$$\dot{X}(t) = A_{pn}\omega_r(t) + B_{pn}U(t) \quad (9)$$

Where $A_{pn} = -\bar{B}/\bar{J}$ and $B_{pn} = -\bar{K}_t/\bar{J}$ are the nominal values of A_p and B_p .By considering parameter variations and external load disturbance, the equation (9) can be modified as

$$\dot{X}(t) = (A_{pn} + \Delta A)\omega_r(t) + (B_{pn} + \Delta B)U(t) + C_pT_L = A_{pn}\omega_r(t) + B_{pn}U(t) + L(t) \quad (10)$$

Where ΔA and ΔB denote the uncertainties due to system parameters J and B, U(t) is the speed command, ω_r is the feedback rotor speed, L(t) is the lumped uncertainty and defined as

$$L(t) = \Delta A\omega_r(t) + \Delta BU(t) + C_pT_L (11)$$

III. DESIGN OF SLIDING- MODE CONTROLLER FOR INDUCTION MOT DRIVE

The overall scheme of sliding mode controller (SMC) is shown in fig.2, in which a simplified indirect field oriented 1M drive is used to represent the real controlled plant [6]. The control aim to design a suitable control law so that the motor speed ω_r can track desired speed commands ω r *.In sliding mode control, the system is controlled in such a way that the tracking error, e and rate of change of error e always move towards a sliding surface.

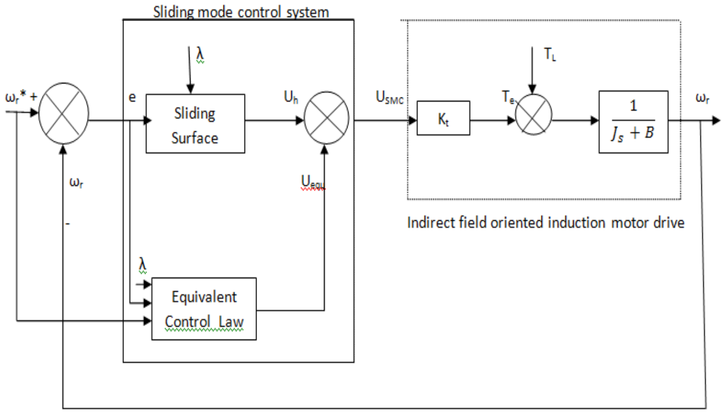

Figure 2: Block Diagram Of Sliding ModeController

The sliding surface is defined in the state space by scalar equation in the state space by scalar equation

$$s(e,\dot{e},t)=0 \quad (12)$$

Where, the sliding variables is

$$s(t)=\dot{e}(t)+\lambda\overline{e(t)} \quad (13)$$

Where A is a positive constant that depends on the bandwidth of the system, e(t) = (j) r*- ω_r is the speed error, in which ω_r*is the reference speed and ω_r is the actual speed. Take the derivative of the sliding surface with respect time and use equation (10), then

$\dot{S}$(t) =$\ddot{e}$(t)+λ$\dot{e}$(t)

$$\dot{S}(t)= \omega_r^*(t) - A_{pn}\omega_r(t) - B_{pn}U(t) - L(t) + \lambda\dot{e}(t) \quad (14)$$

Referring to (14), the control effort being derived as the solution of S(t) =0 without considering the lumped uncertainty (L(t)=0) is to achieve the desired performance under nominal model and it is referred to as equivalent control effort as follows

$$U_{eq}(t)=B_{pn}^{-1}[\omega_r^* - A_{pn}\omega_r(t) + \lambda\dot{e}(t)] (15)$$

However, the indirect vector control is highly parameter sensitive. Unpredictable parameter variation, external load disturbance, unmodelled and nonlinear dynamics adversely affect the control performance of the drive system. Therefore the control effort cannot ensure the favourable control performance. Thus auxiliary control effort should be designed to eliminate the effect of the unprectiable disturbances. The auxiliary control effort is referred to as hitting control effort as follows

$$U_h(t) = g_h sgn(S(t)) \quad (16)$$

Where g_h is a hitting control gain concerned with upper rt bound of uncertainties, and sgn(.) is a sign function. Now, totally the sliding mode control law as follows:-

$$U_{SMC}(t) = U_{eq}(t) + U_h(t) \quad (17)$$

But this controller gives unacceptable performance due to high control activity, resulting in chattering of control variable and system states. To reduce chattering a boundary layer in generally introduced into SMC law, then the control law of equation (17) can be rewritten as

$$U_h(t) = \frac{g_h\,(S(t))}{S(t)+\gamma} \quad (18)$$

Where γ is the width o f the boundary layer

IV. SIMULATION RESULTS AND DISCUSSION

The machine is initially at stand still with no load. The reference speed is linearly increased from zero its rated value 314 rpm with SMC and PI controller. Various simulation were carried out on both PI controller and sliding- mode controller on the indirect-vector control of Induction motor. Fig.3 and Fig.4 shows the PI and SMC with a step command of Speed are applied.It is concluded that SMC offers faster response as compare to PI. Hence SMC based drive system is superior to PI based drive system in all respect rise time, settling time and overshoot. Fig. 5 and Fig. 6 shows the torque response of PI and SMC. Here the PI controller was affected by change in load, but SMC have no affect by the change in load. Fig. 6 shows that the proposed SMC is more robust to load disturbance as compared to PI controller.

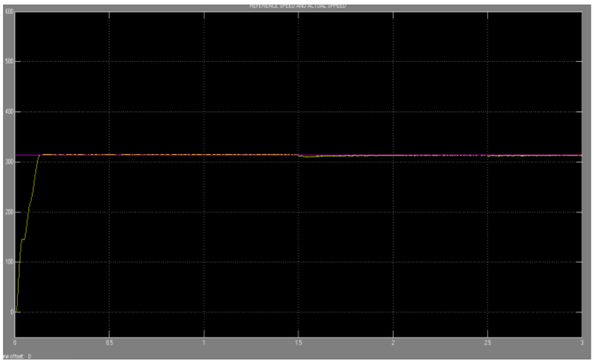

Figure 3: Speed response of PI controller

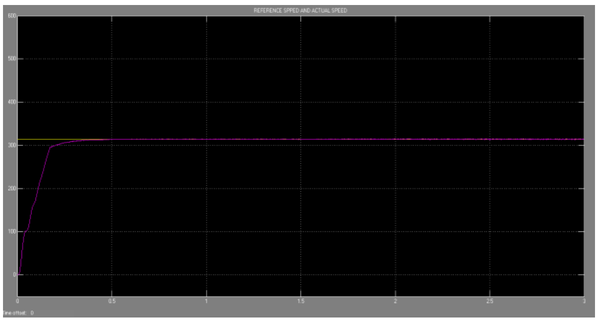

Figure 4: Speed response of Sliding-mode controller

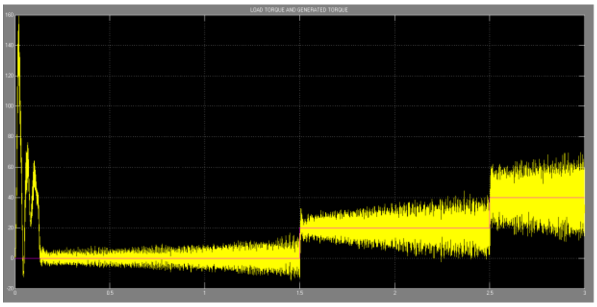

Figure 5: Torque response of PI controller

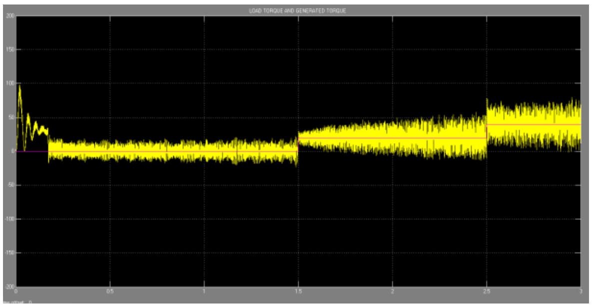

Figure 6: Torque response of Sliding- mode controller

V. CONCLUSION

The performance of the sliding mode controller for the indirect vector controlled induction motor drive has been verified and compared with that of conventional PI controller performance. The simulation results show that the designed sliding mode controller realizes a good dynamic behavior of the motor to sudden changes with a rapid settling time, no overshoot and has a better performance than PI controller. The robustness of the sliding mode control during sudden changes in load has been seen.

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