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SIMULATION AND ANALYSIS OF SLIDING MODE CONTROLLER FOR INDUCTION MOTOR DRIVES

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ABSTRACT

Induction motors are being applied today to a wider range of applications requiring variable speed. Generally, variable speed drives for Induction Motor require both wide operating range of speed and fast torque response, regardless of any disturbances and uncertainties (like load variation, parameters variation and un-modeled dynamics). This leads to more advanced control methods to meet the real demand. The recent advances in the area of field-oriented control along with the rapid development and cost reduction of power electronics devices and microprocessors have made variable speed induction motor drives an economical alternative for many industrial applications. One particular approach to robust-control controller design is the so-called sliding mode control methodology.

In this paper, a sliding mode controller is designed for an induction motor drive. The gain and band width of the controller is designed considering rotor resistance variation, model in accuracies and load disturbance, to have an ideal speed tracking. The chattering effect is also taken into account. The controller is simulated under various conditions and a comparative study of the results with that of PI controller has been presented.

Key words: Mode, Motor drives, Induction

INTRODUCTION

The industrial standard for high performance motion control applications require, four quadrant operation including field weakening, minimum torque ripple, rapid speed recovery

under impact load torque and fast dynamic torque and speed responses. DC motors with thyristor converter and simple controller structure have been the traditional choice for most industrial and high performance applications. But they are associated with certain problems related to commutation requirement and maintenance. Low torque to weight ratio and reduced unit capacity add some more negative points to DC machine drives. On the other hand AC motors, especially induction motors are suitable for industrial drives, because of there simple and robust structure, high torque to weight ratio, higher reliability and ability to operate in hazardous environments. However there control is a challenging task because the rotor quantities are not accessible which are responsible for torque production. DC machines are decoupled in terms of flux and torque. Hence control is easy. If it is possible in case of induction motor to control the amplitude and space

angle (between rotating stator and rotor fields), in other words to supply power from a controlled source so that the flux producing and torque producing components of stator current can be controlled independently, the motor dynamics can be compared to that of DC motor with fast transient response. Presently introduction of micro-controllers and high switching frequency semiconductor devices, and VLSI technology has led to cost effective sophisticated control strategies.

Scalar control
The name scalar control indicates the magnitude variation of control variables only. The control of an induction motor requires a variable voltage variable frequency power source. With advent of the voltage source inverter (VSI), constant voltage/hertz (V/f) control has become the simplest, cheapest and hence one of the popular methods for speed control of induction motor. This aims at maintaining the same terminal voltage to frequency ratio so as to give nearly constant flux over wide range of speed variation. Since flux is kept constant the full load torque capability are maintained constant under steady state condition except low speed(when an

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additional voltage boost is needed to compensate for stator winding voltage drop).In this control scheme, the performance of machine improves in the steady state only, but the transient response is poor.

Sliding Mode Controller

Sliding mode controller is suitable 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. The sliding mode control is especially appropriate for the tracking control of motors, robot manipulators whose mechanical load change over a wide range.

Induction motors are used as actuators which have to follow complex trajectories specified for manipulator movements. Advantages of sliding mode controllers are that it is computationally simple compared adaptive controllers with parameter estimation and also robust to parameter variations. The disadvantage of sliding mode control is sudden and large change of control variables during the process which leads to high stress for the system to be controlled. It also leads to chattering of the system states.

Induction Motor Modeling

A proper model for the three phase induction motor is essential to simulate and study the complete drive system. The model of induction motor in arbitrary reference frame is derived in [16-17].

Following are the assumptions made for the model:

1. Each stator winding is distributed so as to produce a sinusoidal mmf along the airgap, i.e.

space harmonics are negligible.

2. The slotting in stator and rotor produces negligible variation in respective inductances.

3. Mutual inductances are equal.

4. The harmonics in voltages and currents are neglected.

5. Saturation of the magnetic circuit is neglected.

6. Hysteresis and eddy current losses and skin effects are neglected.

Estimation of Speed

It is desirable to avoid the use of speed sensors from the standpoints of cost, size of the drive, noise immunity and reliability. So the development of shaft sensorless adjustable speed drive has become an important research topic. Many speed estimation algorithms and sensorless control schemes [22] have

been developed during the past few years. The speed information required in the proposed control technique is estimated by the algorithm described in this section. The speed of the motor is estimated by estimating the synchronous speed and subtracting the command slip speed. The synchronous speed is estimated using the stator flux components, because of its higher accuracy compared to estimation based on rotor flux components.

The block diagram of the described speed estimation algorithm with the sensorless speed control scheme is shown in fig 2.1
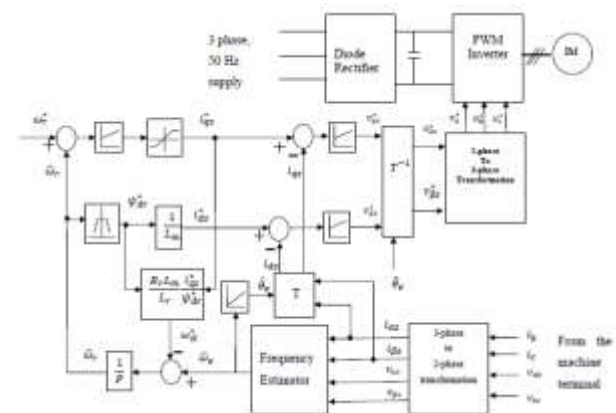

Fig 2.1 Induction motor drive system with sensorless speed control scheme

SIMULATION RESULTS AND DISCUSSIONS

The induction motor drive system is simulated with (*i*) P-I controller and (*ii*) sliding mode controller in the mechanical subsystem. Both the controllers are tested for speed tracking and load torque variation conditions. Results are compared among both types of controllers. The drive is subjected to load disturbance to test the robustness of the sliding mode controller. Different cases under which the simulation tests are carried out are:
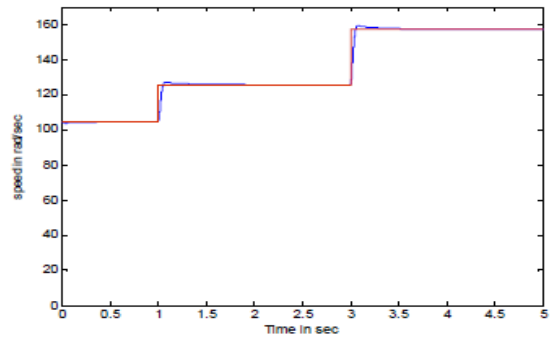
(a) Step change in reference speed.

(b) Tracking of reference speed in trapezoidal form.

(c) Robustness test against load torque variation.
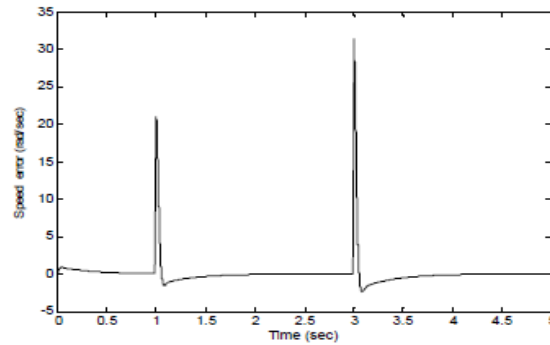
Step change in reference speed

The reference speed is changed from 1000 rpm to 1200 rpm at time, t = 1 sec, and again 1200

rpm to 1500rpm at time, t = 3 sec. The reference d-axis rotor flux linkage is kept at 0.45

V.sec and load torque is kept at zero. From the figures it is clear that in case of sliding mode controller, the speed error of the system comes to zero faster than fixed gain controller. The q-axis input voltage at the time of transition from one level to anther is nearly 20times larger in case of sliding mode controller.

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Fig. 3.1 shows the responses of the controllers during variation of load torque. It is clear
that the P-I controller speed response is affected by the load disturbance, where as the sliding
mode controller has proved its robustness against load variations

(a)

(b)

Fig. 3.1 Step change in reference speed with P-I controller
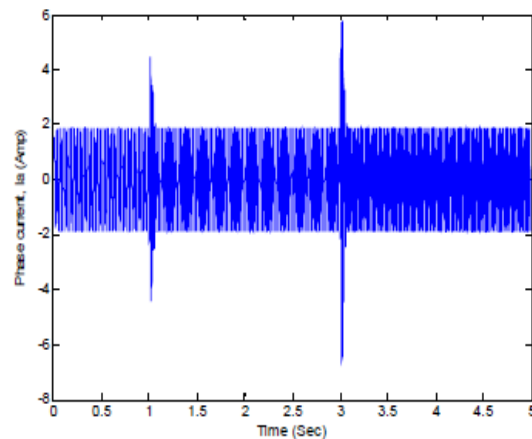(a) q- axis stator input voltage
(b) d- and q-axis stator current

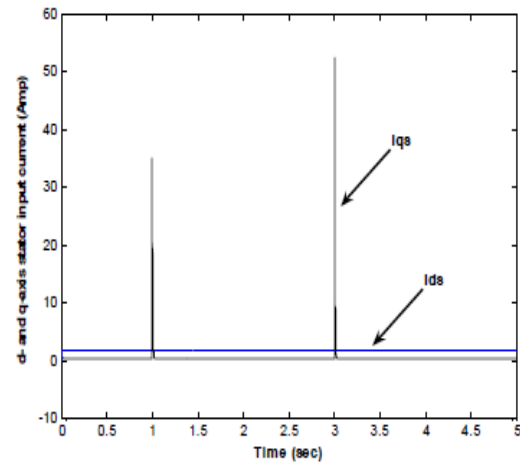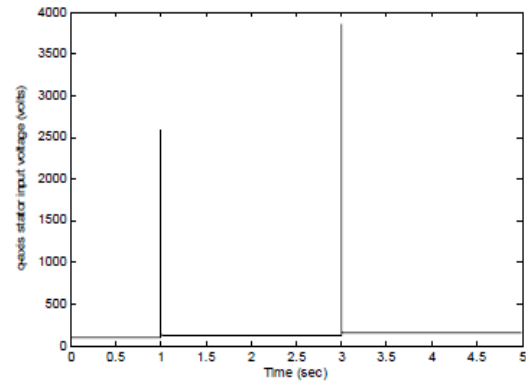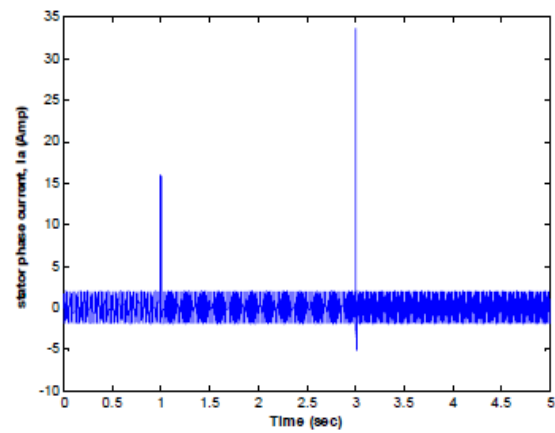Fig. 3.2 stator phase current (Ia) for step change in reference speed with P-I controller

Fig. 3.3 Step change in reference speed with sliding mode controller
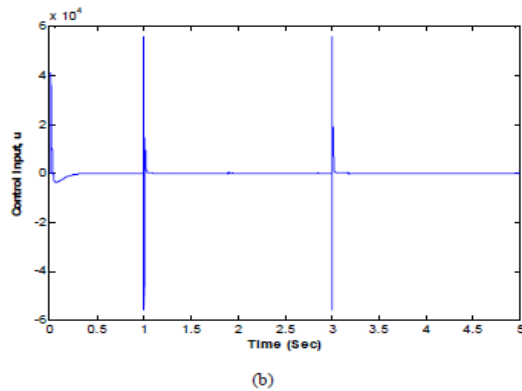(a) q- axis stator input voltage
(b) d- and q-axis stator current

(a)

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(b)

Fig. 3.4 Step change in reference speed with sliding Mode controller
(a) Stator phase current in Amp
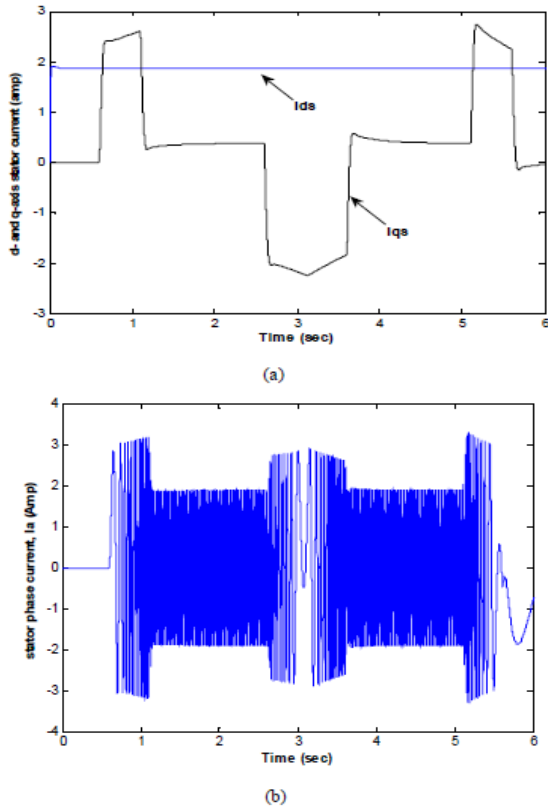(b) Control input, u in rad/s^3

(a)

(b)

Fig. 3.5 Trapezoidal speed tracking with P-I controller
(a) d- and q-axis stator current
(b) stator phase current

CONCLUSION

In this thesis the theory of sliding mode controller is studied in detail. The equationsof the induction motor model are reorganized so as to apply the control technique. The controller gain and band width are designed, considering various factors such as rotor resistance variation, model in accuraies, load torque distrubance and also to have an ideal speed tracking. Considering the case such as load disturbance, the response of the designed sliding mode controller is satisfactory. It also gives good trajectory tracking performance. The speed regulation characteristic is also satisfactory. Only load distrubance is the problem considered in this case and the robustness of the controller is verified. Since the machine rating is small, the resistance variation effect is very small. Hence has negligible effect.

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