Speed Control Technique for Induction Motor - A Review

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Abstract— In this paper, various types of speed control methods for the single phase induction motor are described. Speed can be controlled to control the frequency or slip can be controlled to control the torque. Then flux and torque are also function of frequency and voltage. Various methods are used to control the flux and voltage. This paper is focused on sliding mode control technique for induction motor.

***Keywords**:* induction motor, sliding mode control, speed control, non linear control

I. INTRODUCTION

Induction motors are widely used in many residential, industrial, commercial, and utility applications.[1] The control and estimation of ac drives in general are considerably more complex than those of DC drives and this complexity increase substantially if high performances are demanded. The main reasons for this complexity are the need of variable frequency, machine parameter variation, the complex dynamics of ac machines and the difficulties of processing feedback signals in the presence of harmonics. Above all these problems are reduce by using different control techniques of induction motor drives including scalar control, vector (field oriented control), and direct torque control. [2]

However, in AC machine drives, have major drawbacks that are the sensitivity to the system parameters variations and bad rejection of external disturbances. To surmount these drawbacks and improve the induction motor control technique like adaptive (sliding mode) control. [2]

Sliding mode control techniques are used in a wide number of applications to control of switching power converters, electrical machines, robotics, and other machinery. [3]

II. VARIOUS SPEED CONTROL TECHNIQUES

Various speed control techniques are mainly classified in the following categories:

A. *Scalar Control (V/f Control)*

In this type of control, the motor is fed with variable frequency signals generated by the PWM control from an inverter. Here, the V/f ratio is maintained constant in order to get constant torque over the entire operating range. Since only magnitudes of the input variables – frequency and voltage – are controlled, this is known as "scalar control". Generally, the drives with such a control are without any feedback devices (open-loop control). Hence, a control of this type offers low cost and is an easy to implement solution. In such controls, very little knowledge of the motor is required for frequency control. Thus, this control is widely used. [5]

B. *Vector Control*

This control is also known as the "field oriented control", "flux oriented control" or "indirect torque control". In general, there exists three possibilities for such selection and hence, three different vector controls. They are:

(1) Stator flux oriented control
(2) Rotor flux oriented control
(3) Magnetizing flux oriented control

As the torque producing component in this type of control is controlled only after transformation is done and is not the main input reference, such control is known as "indirect torque control". [4]

The most challenging and ultimately, the limiting feature of the field orientation, is the method whereby the flux angle is measured or estimated. Depending on the method of measurement, the vector control is divided into two subcategories: direct and indirect vector control. In direct vector control, the flux measurement is done by using the flux sensing coils or the Hall devices. This adds to additional hardware cost and in addition, measurement is not highly accurate.

Therefore, this method is not a very good control technique. The more common method is indirect vector control. In this method, the flux angle is not measured directly, but is estimated from the equivalent circuit model and from measurements of rotor speed, the stator current & the voltage. [5]

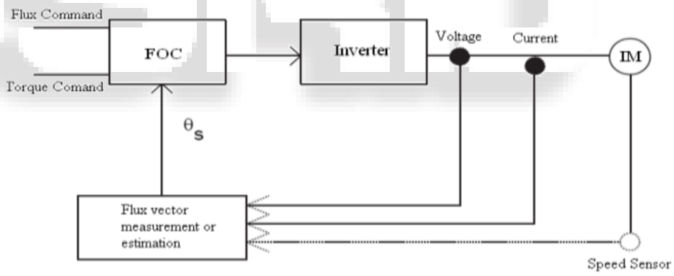

Fig. 1: Direct Vector Control.

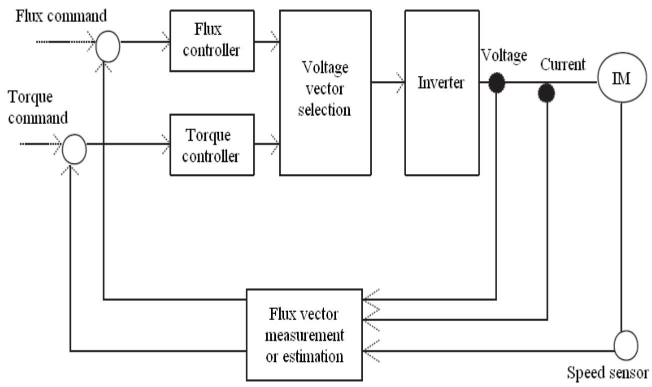

Fig 2**:** Indirect Vector Control**.**

C. *Direct Torque Control (DTC)*

This model is based on the mathematical expressions of basic motor theory. This model requires information about the various motor parameters, like stator resistance, mutual inductance, saturation co efficiency; etc

Torque vector controlled drives are capable of controlling the stator flux and torque more accurately than vector controlled drives, while the controller complexity is reduced considerably.

Field orientation is achieved without rotor speed or position feedback using advanced motor theory to calculate the motor torque directly without using modulation. The controlling variables are motor magnetizing flux and motor torque. The external speed set reference signal is decoded to generate the torque and flux reference. [6]

Thus, in the DTC, the motor torque and flux become direct controlled variables and hence, the name – Direct Torque Control.

The advantage of this technology is the fastest response time, elimination of feedback devices, reduced mechanical failure. The disadvantage is due to the inherent hysteresis of the comparator, higher torque and flux ripple exist. [7]

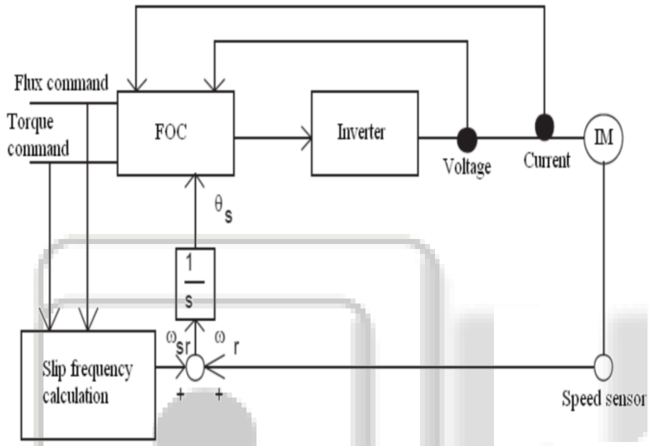

Fig. 3: Direct Torque Control

D. Sliding mode control(SMC)

1) 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. [8]

2) Control Principle of Sliding Mode Control

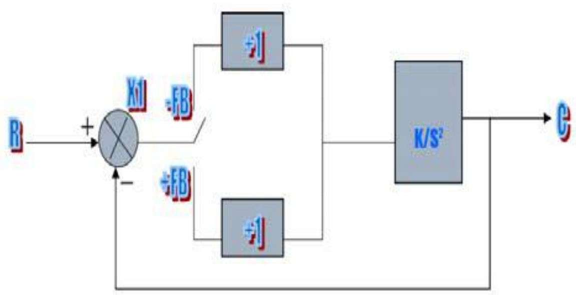

Fig. 4: Block diagram of Sliding mode control for Second order system.

Consider a simple second order under damped linear system with variable plant gain K. It can be easily be 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 4. The Phase plane trajectory for negative feedback and positive feedback is shown in figure 5.

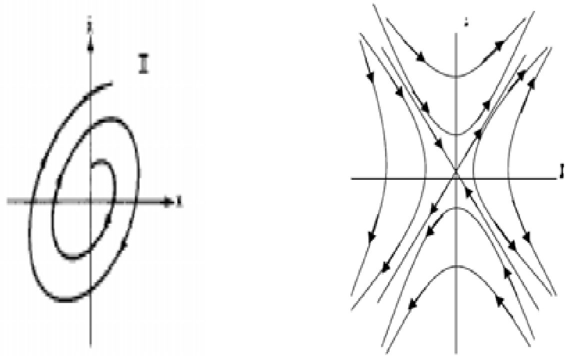

Fig. 5: Phase plane trajectories for negative feedback and positive feedback

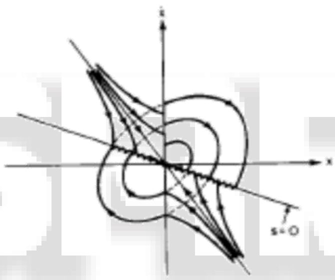

Fig. 6: sliding mode control in phase plane

3) Sliding Mode Control

Variable Structure Control (VSC) with sliding mode, or sliding mode control (SMC), is one of the effective nonlinear robust control approaches since it provides system dynamics with an invariance property 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. [9]

SMC is robust with respect to matched internal and external disturbances.SMC techniques are applicable to any minimum phase systems with relative degree less than the system order. The control algorithm is based on the model of the motor in a frame rotating with stator current vector, which is rarely used in the field oriented control.

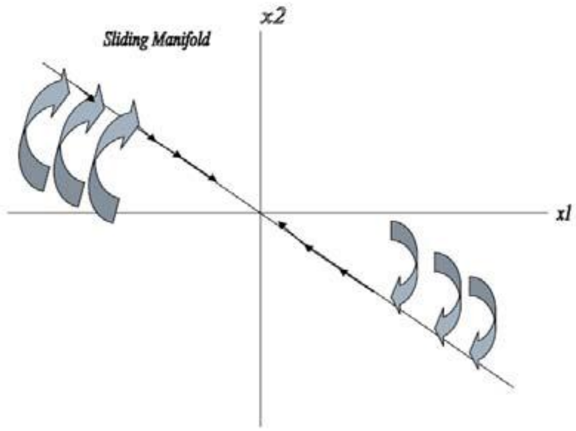

Fig. 7: Idea of Sliding Mode

4) Designing of Sliding Mode Controller

The control system block diagram of an induction servo motor drive with the implementation of field-oriented control can be simplified as shown in Fig: 8.

The idea to make the response insensitive to the plant parameters, that is, the torque constant Kt, moment of inertia j, Friction damping coefficient B, and load toque disturbance TL. [10] Assuming a step command of Ɵr*, we can write the following equations:

$$Te = K_t iqs^* \quad (1.1)$$

$$K_t = \left(\frac{3n_p}{2}\right)\left(\frac{L_m{}^2}{L_r}\right) iqs^* \quad (1.2)$$

$$H_p(s) = \frac{1}{Js+B} \quad (1.3)$$

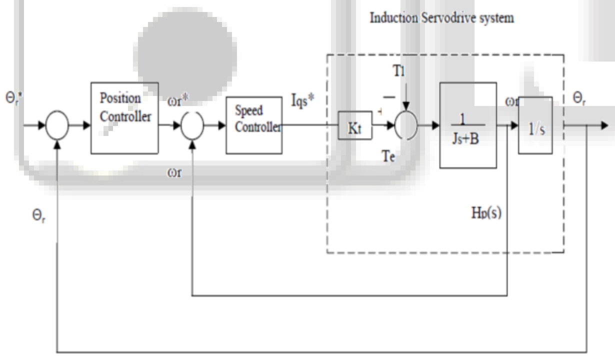

Fig. 8: Simplified block diagram of an induction servomotor drive.

5) The advantages of this SMC method are as follows,

(1) Insensitivity to parameter variations.
(2) External disturbance rejection.
(3) Fast dynamic responses

III. CONCLUSION

This paper has introduced a survey on Induction motor speed control. Three phase induction motor is controlled with an efficient technique called SMC. The SMC helps in controlling the torque and provides better speed regulation. Hence by using this SMC technique has improved the motor performance and efficiency and speed control of the Induction motor is obtained in an accurate manner.

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