A STUDY ON SIMULINK MODEL OF SENSORLESS SPEED CONTROL OF INDUCTION MOTOR

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Abstract— **The latest development in induction motor speed control is the Sensor less control technique. Controlled ac drives in the case of 'Sensor less control' without mechanical sensors for speed (or) motor shaft position have the attraction of lower cost and high reliability. With the sensor less speed control technique the speed information is obtained without the use of speed or position sensor. In this paper we are studying different types of speed control techniques and estimation of sensor less induction motor.**

Index Terms— **Sensor less induction motor, Speed control techniques, fuzzy logic control.**

I. INTRODUCTION

With the developments in power electronics, variable speed applications of both DC and AC machines gained momentum. The DC drives use thyristor controlled rectifiers to provide high performance torque, speed and flux control. The variable speed induction motor drives use mainly dc-ac inverters with pulse width modulation (pwm) techniques to generate a poly-phase supply of a given frequency. Most of the industrial applications that require good torque, speed or position control traditionally use DC motors. But, the advantages of induction motors are clear in terms of robustness, high torque-to-weight ratio, higher reliability, ability to operate in hazardous environment and price. After the development and implementation of field oriented control of induction motors, they became able to compete with DC machines in high performance applications. The induction motor dynamics can be compared to that of a DC motor with fast transient response if the flux producing and torque producing components of the stator current can be controlled independently which means it is possible to control the amplitude and phase angle independently. Speed control of an induction motor usually requires position feedback information from an encoder, a resolver, or a Hall sensor to a controller unit. These feedback signals, which often pickup noise due to electromagnetic interference, can affect the performance of the motor control system. As such, the feedback cable is shielded and the signals are provided in differential form, which increases the sensing cost. Therefore, motor-drive manufacturers have been focusing on position sensor less control. However, universal applicability of the position sensor less algorithms for speed control, especially at or near-zero speed and at full-load torque, has not been fully achieved yet. In this paper, we outline an intelligent technique for implementing a field oriented induction motor control using an Adaptive Neural Fuzzy Inference Systems (ANFIS) as a rotor speed estimator to avoid using mechanical sensor. Also control loops of rotor speed and stator currents employ Fuzzy-PI (FPI) controller to achieve a high-quality speed control algorithm for IMs.

Modern high-dynamic ac drives are equipped with a mechanical shaft sensor in order to estimate the flux position, which is required for field -oriented or direct torque control. Such control increases the drive cost, size, and maintenance requirements which decrease system reliability and robustness. Different techniques for the speed-sensor less control of induction motors have been proposed in these last years. However, parameter sensitivity, high computational effort, and stability at low and zero speeds can be the main shortcomings of sensor less control. Using fundamental wave models with accurate sensors for the voltage and current, the speed sensor less operation of induction machines is possible down to around slip frequency, corresponding to mechanical standstill. Much recent research effort is focused on extending the operating region of sensor less drives near zero stator frequency. At zero frequency, the speed sensor less operation is only possible using signal injection methods. The injected signal may be either high-frequency harmonic (pulsating or rotating or transient (voltage pulses). These schemes are based on either second-order effects or a specially modified rotor structure.

Various control algorithms for elimination of the speed
sensor have been proposed: algorithms using state equations, model reference adaptive systems , Luenberger- or Kalman-filter observers, saliency effects, sliding mode controls, artificial

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intelligence, sensor less vector control, direct controls of torque and flux, nonlinear inverter model and parameter identification. These algorithms are mainly based on the flux and speed estimations, which are obtained from the terminal electrical quantities, and they are complicated and have difficulties in the speed estimation.

The designs of Soft computing tools like Fuzzy Inference System (FIS), Artificial Neural Networks (ANN) and Adaptive Neuro-Fuzzy Inference (ANFIS) do not need an exact mathematical model of the system. Soft computing techniques have been used in some power electronic applications, such as inverter current regulation, DC motor control, flux estimation, speed estimation and observer-based control of induction machines .The simple and less-intensive mathematical design requirements are the main features of intelligent systems, which are suitable to deal with nonlinearities and uncertainties of electric motors. However, a simple fuzzy-logic controller (FLC) has a narrow speed operation and needs much more manual adjustment by trial and error if high performance is desired. On the other hand, it is extremely tough to create a series of training data for ANNs that can handle all the operating modes. The concept of an ANFIS has emerged in recent years, as researchers have tried to combine the advantages of both FIS and ANN. The ANFIS utilizes the transparent linguistic representation of a fuzzy system with the learning ability of ANNs. Some of the advantages of ANFIS are the very fast convergence, due to hybrid learning, and the ability to construct reasonably good input membership functions. The most striking feature of ANFIS is that it provides more choices over membership functions. It has more tracking ability and adaptability than the other controllers.

In this study, the process of estimating the rotor speed information required in control of vector controlled IM without sensors has been obtained with ANFIS. First, measurements of stator q-axis current (iqs) – rotor speed and q-axis voltage (vqs) – rotor speed are made for the rotor speed estimation. Then the ANFIS is utilized to estimate the rotor speed. With data obtained from the study made on the DSP application circuit, performance of the speed estimator has been examined. In speed control loops, Three Fuzzy-PI(FPI) controllers are employed to adjust high accuracy speed of the IM. The input and output scale factors of all FPI systems are tuned by GA in order to minimize error of control variables. The experimental results show a high quality response and accurate performance of the proposed method in the estimation and control of the rotor speed for IM.

II. SPEED CONTROLLER AND ESTIMATOR DESIGN

Speed control is widely used in industrial applications of electrical machines. Fig. 1 shows the general control scheme of speed estimation block. Conventional approach for the speed control is that the outer speed feedback is used together with the inner current loop. The proposed FPI regulators have been introduced in the inner and the outer loops. Three controllers are used in the control scheme to regulate ω, iqs, and ids. The outer controller works on error of ω and calculates iqs*. The inner one regulates iqs and calculates vqs and the third one issued to regulate ids and calculate vds. In the sensor less speed control of induction motors with direct field orientation, the rotor flux and speed information are dependent on the observers. However, the exact values of the parameters that construct the observers are difficult to measure and changeable with respect to the operating conditions. A speed estimation algorithm can be used to estimate the motor speed in real time without a speed sensor. This algorithm needs two stator current and voltage signals and employs DSP techniques to filter and manipulate the speed-related harmonics.

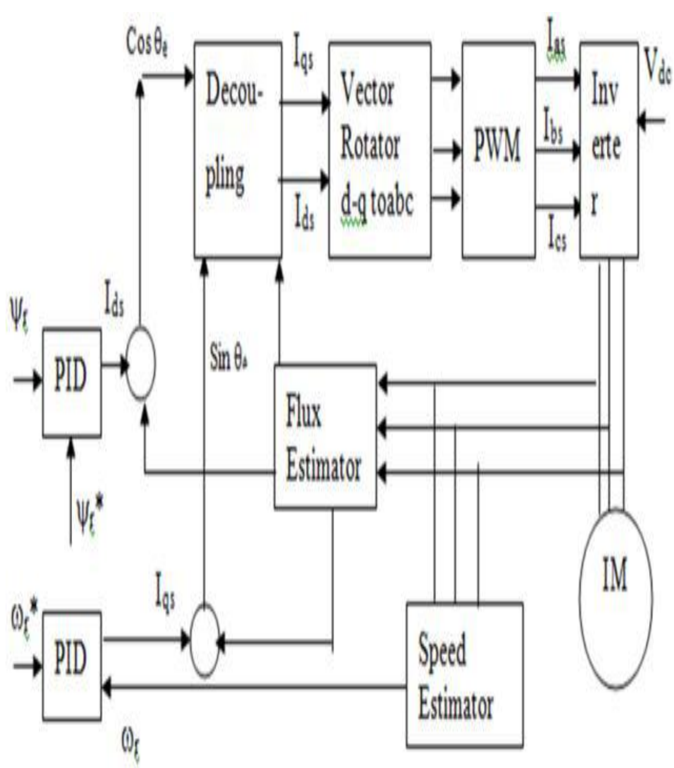

Fig.1 Block diagram of sensor less control of induction motor

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Many speed estimation algorithms and speed sensor less control schemes have been developed. Some of the approaches are:-
Speed estimation by the parameter identification approach. But, the parameter variation affects the performance of the estimator resulting in deterioration of the performance. Kalman filter algorithm and its extensions are robust and efficient observers for linear and nonlinear systems. An extended Kalman filter is used in for speed estimation of vector controlled induction motor drives. Many Model Reference Adaptive Systems (MRAS) based speed sensor less schemes have been studied in . Machine saliency based on fundamental or high frequency signal injection method has also been used for rotor position and speed estimation techniques. This technique is in sensitive to actual motor parameter variations, but at low and zero speed operation, the performance is not much appreciable. Also, it causes torque ripples and vibration and noise at high frequency signal injection.

III. CONTROL SCHEMES

1. P-I Controller

The P-I controllers are widely used in industries for high performances of electric drives. The ordinary method for the selection of the P-I gains is by trial and error method. Also, it makes the steady-state error zero. But, choosing improper P-I gains may affect the system variables. So, they need to be designed properly. The P-I gains can be designed by modulus optimum method. The pole-zero cancellation technique is another method to design the gains. The P-I controllers cause the overshoot and undershoot of the system response. The gains can be optimized by different optimization techniques such as Genetic Algorithm (GA) and Particle Swarm Optimization (PSO). In high performance ac drives, P-I controllers fails to achieve perfect control over the speed and load variation, in the presence of external and internal disturbance in the system and parameter variations. So, the efficiency, reliability and performance of the ac drives may deteriorate, which leads to employment of other nonlinear and hybrid controllers.

2 Sliding Mode Controller (SMC)

Sliding mode control is a nonlinear control technique that makes the system robust to parameter variations, modeling inaccuracies, external disturbances. This controller provides stability, faster dynamics and satisfactory performance for a higher order nonlinear system like induction motor drive. SMC is computationally simple compared to the adaptive controllers. These advantages of SMC can be employed in position and speed control of an ac servo system. An SMC design method based on synchronously rotating reference frame is presented in [22]. The chattering effect is the main disadvantage of the SMC. This chattering effect can be eliminated by introducing a saturation (sat) function. Here, the SMC technique is utilized for a direct field oriented induction motor drive to get a robust nonlinear control law to model uncertainties, inaccuracies and many other aspects.

3 Fuzzy Sliding Mode Controller (FSMC)

Fuzzy sliding mode controller is a hybrid controller that combines the fuzzy logic and the sliding mode technique. Irrespective of the robustness of the sliding mode controller against any uncertainties and disturbances, it is associated with the chattering problem and high controller gains. So, reduction of this chattering effect can be achieved by a hybrid controller like FSMC that can give chattering free response without sacrificing the robustness of the system. The FSMC combines the advantages of sliding mode controller and fuzzy logic controller and reflects it in the system performance. The FLC is a simple rule based control system where the rules for this are decided by the user. Here, the inputs and the outputs, both are in the form of linguistic or fuzzy variables. The fuzzy sliding mode hybrid controller has the ability to account for modeling imprecision and external disturbances while the fuzzy logic controller provides better damping and reduced chattering.

IV Rotor Speed Estimation

The speed estimation is an important aspect for high performance field oriented control of IM drive. Without mechanical speed sensor, the induction machine drive becomes more reliable, less cost and small is size. Many speed estimation algorithms have been developed since last few years. The simple techniques adopted here for the speed estimation are speed estimation from the state equations of the induction motor. From the dynamic state equations of induction machine, the speed signal is generated directly. The rotor angle can be determined from the rotor d- and q-axis fluxes in synchronously rotating reference frame,

$$\text{i.e. } \angle\theta_e = \tan^{-1}\left(\frac{\psi_{qr}}{\psi_{dr}}\right) \quad \text{……(i)}$$

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Differentiating the above eq[n] (i), we get,

$$\frac{d\theta_e}{Dt} = \frac{\psi_{dr} \times \dot{\psi}_{qr} - \psi_{qr} \times \dot{\psi}_{dr}}{\hat{\psi}_R^{2}}$$

……...… (ii)

Thus, the estimated speed r can be calculated by eq[n] (iii) as given below.

$$\hat{\omega}_r = \frac{d\theta_e}{dt} - \frac{L_m}{T_r}\left[\frac{\psi_{dr} \times i_{qs} - \psi_{qr} \times i_{ds}}{\hat{\psi}_R^{2}}\right]$$

V CONCLUSION

In this paper, an intelligent sensor less control algorithm has been implemented in order to obtain a high-precision speed estimation and control for three-phase induction machine (IM) using different speed estimation algorithm and control scheme. In this study of sensor less speed control we are studying different types algorithm. We have to design a simulink model for speed estimation and speed control induction motor. The advantages of the proposed scheme are a minimum number of parameters to be offline optimized robustness to parameters uncertainties and noise, and low computational effort in real-time implementation. Numerical and real-time implementation of the novel sensor less control scheme showed smooth operation at low speed and load speed reversal, and stability at zero speed.

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