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Sensorless Control of a Switched Reluctance Motor by Using Sliding Mode Observer

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ABSTRACT

This paper presents a sliding mode observer for sensorless operation of SRM (switched reluctance motor) drive. Design of such an observer depends mainly on the nonlinear model of SRM. In this technique, neither extra hardware nor huge memory space arenot required but it only requires active phase measurements. Furthermore, PI (proportional integral) are suggested to operate individually along with the SMO (sliding mode observer) to cover a full speed range of sensor less controller. Both controller schemes operate in PWM (pulse width modulation) control mode. The proposed observer is implemented and using Matlab/Simulink. All results obtained with simulation are presented.

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INDEX TERM: ***Switched reluctance motor, sliding mode observer, PI controller***

I.INTRODUCTION

In recent years, the SRM (switched reluctance motor) has received considerable attention in variable speed drive applications. Its simple construction due to the absence of the magnets, rotor conductors, brushes, and high system efficiency over wide speed ranges make the SRM drive an interesting alternative to compete with permanent magnet brushless DC motor and induction motor drives [1, 2]. However, the speed control of the SRM is not yet a perfected art. The controllable variables of the SRM are the phase current magnitude (i), the turn on angle (α), and the turn off angle (β) [3, 4]. For sensor less operation of SRM, generally speaking, there are two basic types of position estimation methods, active probing and nonintrusive estimation.

In active probing, special testing signals are injected into an unenergized phase. The position-dependent information is extracted by additional decoding circuit. In nonintrusive ways, the dependence of phase current and phase winding flux linkage or inductance on rotor position is utilized [5-8].Recently, intelligent estimation techniques SMO(sliding mode observer) have been used in rotor position an speed estimation. However, offline training based on prestored data is required [9-11].

The use SMO based model has been investigated for the indirect position sensing in SRM drives [12-14].

For estimating the rotor position and speed in this application, the observer requires only terminal measurements of voltage and current. The implementation of the observer generally involves the use of a microcontroller or a digital signal processor. Still, the observer-based approach is relatively simple and can be inexpensive compared to the alternative sensor less diagnostic methods based on pulse injection. Optimal performance of the drive may be described by different figures of merits, such as drive efficiency, torque per ampere, tracking precision and fast response [15, 16].

For speed control of SRM, conventional control methods such as PI (proportional-integral) controllers have many merits like simplicity of operation, ease of design, inexpensive maintenance, low cost, and effectiveness for most linear systems. However, it has been known that conventional PI controllers generally do not work well for nonlinear systems [17]. To overcome these difficulties, various types of modified conventional PI controllers such as auto tuning and adaptive PI controllers were developed recently. Also, a class of non-conventional type of PI controller.

The main objective of this paper is to propose a simplified sensor less speed controller for the SRMdrive system. Drive a simple and compact model forSRM drive which is valid for online control. Present an estimation procedure for speed and rotor position angle of SRM based on sliding mode control technique.

II.PROPOSED SYSTEM

Modelling of SRM

The energy conversion principles show that accurate prediction of the SRM developed torque can be obtained from the relationship between the flux linkage(λ), phase current (i) as well as rotor position angle (θ).These magnetization characteristics can be obtained from direct measurements on an existing motor or alternatively, from sufficiently precise numerical calculations such as FEA (finite element analysis). So, the finite element method FEM (finite element analysis) is used, firstly, to analyze the magnetic circuit of the motor under study. After that a simplified model is developed based on the results of the FEA. Fig. 1depicts the flux distribution for a 3-phase 6/4 SRM [21].

The flux linkage for phase j can be described as

$$\lambda_j(i_j,\theta) = L_j(i_j,\theta)i_j \qquad (1)$$

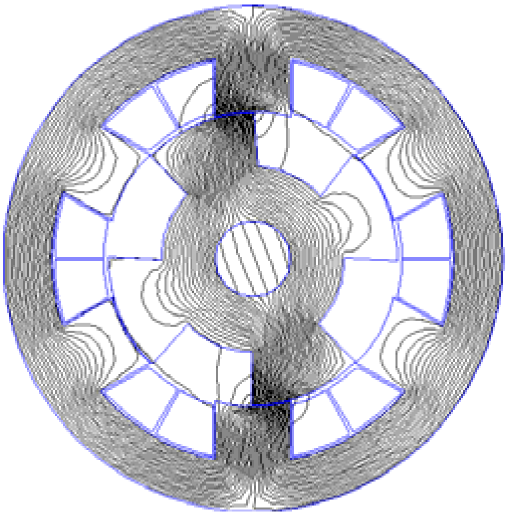


Fig. 1 Flux distribution for 3-phase 6/4 SRM.

where Lj is the self inductance of phase j. Hence, the self inductance can be derived from this equation:

$$L_j(i_j,\theta) = \frac{\lambda(i_j,\theta)}{i_j} \qquad (2)$$

The self inductance equation is the key input to the proposed model. Based on the flux linkage and phase current data obtained by FEA, the computer program is built to obtain the self inductance data as a function $ij$and θ. This data is programmed and simulated to obtain inductance-angle curves at different values of phase current as well as inductance-current curves at different rotor positions.

The variation of phase inductance versus rotor position angle, from which it can be observed that: The phase inductance is constant from $\theta 1$ to $\theta 2$ and equal the unaligned inductance value Lu;The phase inductance varies nearly linear from $\theta 2$ to$\theta 3$ and changes with phase current and rotor positionangle;The phase inductance depends only on the phase current from $\theta 3$ to $\theta 4$ and equal the aligned inductance value La for each value of current. On the other hand, the phase inductance can be represented by a group of trapezoidal curves; its bottom value is constant at Lu and the top value La which changes with phase current. So, it can be described as follows:

$$L_j(i_j,\theta_j) = \begin{cases} L_u & \theta_1 \le \theta \le \theta_2 \\ L_u + k\theta_1 & \theta_2 < \theta \le \theta_3 \\ L_a & \theta_3 < \theta \le \theta_4 \end{cases} \qquad (3)$$

Sliding Mode Observer

The SMO along with a state-space model of the SRM is used to estimate rotor position and speed as shown in Fig. 3. The SMO estimates rotor position andspeed from phase current and terminal voltage measurements. There are many possible error functions

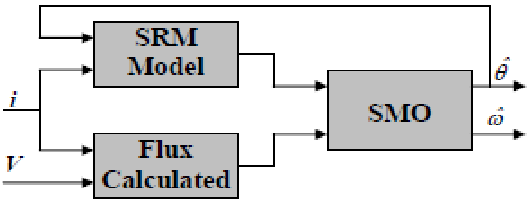


Fig. 3 Block diagram of SMO.

that will stabilize the error dynamics. In general, the error function must compare a variable dependent upon the estimated position and a measurable machine variable. Here, error correction term is computed base on the difference of the flux observed from the mathematical model λ□and that derived from motor terminal measurements *λ*. The actual flux can be obtained using the integral form of the voltage.

III.CONTROL STRATEGY

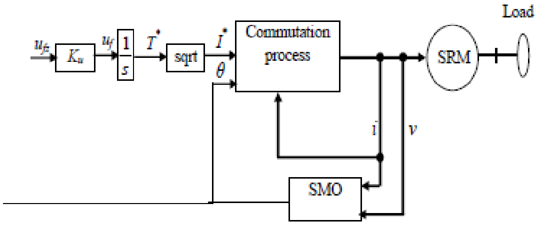
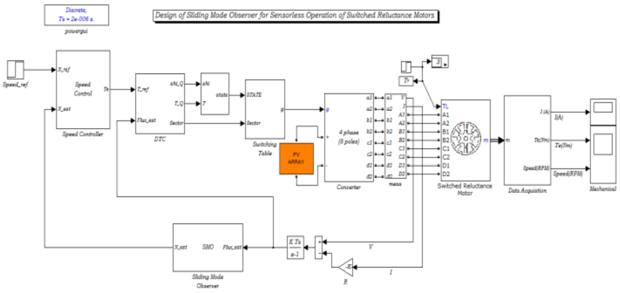


Fig.4 Block diagram of a logic PI controller.

Pulse Width Modulation Control Mode

The information of both the phase reference currentsand the actual ones are treated using the feedback PWM (pulse width modulation) technique with adjusted hysteresis-band which is a function of phase current. The current command is added and subtractedfrom the hysteresiswindow, to obtain the maximum and minimum current values that used along with rotor position angle to determine the switching angles for the motor phases. The instantaneous phase current and voltage waveforms

IV. SIMULATION RESULTS



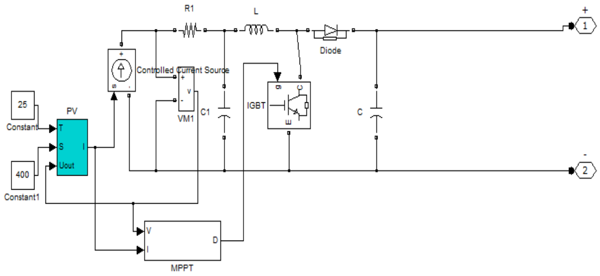


Fig.5 PV+MPPT+ Buck-Boost converter

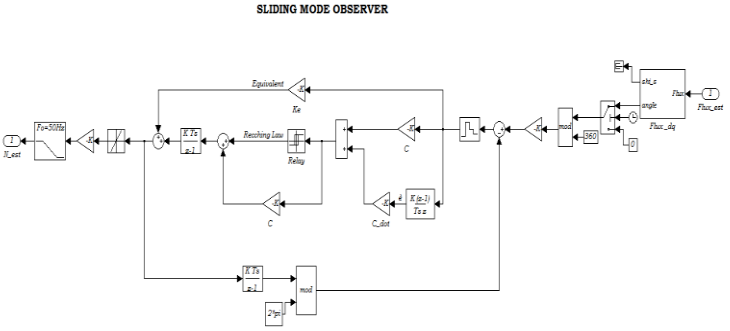


Fig.6 SLIDING MODE OBSERVER BLOCK

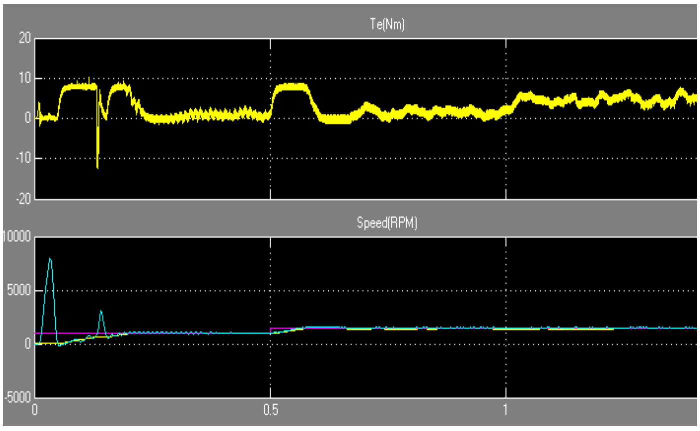


Fig.7 Torque & Speed

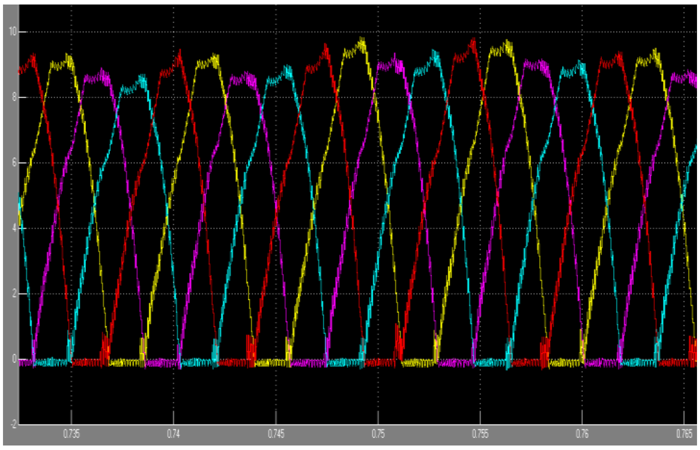


Fig.8 Output Current

V.CONCLUSION

This paper has implemented a sensor less speed controller model for the SRM. The proposed model has yielded a direct relationship between phase current and torque with considering the nonlinearity of the SRMdrive. A sliding mode observer for sensor less of a SRMis presented. Moreover, two control techniques were used, namelywPI controller. A comparison between the results of both cases showed that the fuzzy logic controller reduces the overshoot in the speed, torque and current responses under different operating conditions. On the other hand, the PI control has yielded a longer correction time to reach the command speed when comparing. Thcontroller along with the proposed sensor less has yielded good performance for the SRM. A good correlation simulated results has been found.

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