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Minimization of Torque Ripples in Switched Reluctance Motor by Using PI and Fuzzy Logic Controller Methods

Kolli Nageswar Rao, B.Chandra Mouli, D.Vijay Kumar, S. Prudhvi Raj, Ch. Anusha

Assistant Professor, Students, Department of Electrical and Electronics Engineering, Sree Vahini Institute of Science and Technology, Andhra Pradesh, INDIA

ABSTRACT: The generated torque ripple and acoustic noise in switched reluctance motors (SRM) can be considered as one of the major disadvantages of the motor in order to improve the performance of SRM and extend its applications in industry, it is essential to reduce these torque ripples. So far, many torque ripple reduction methods have been introduced. These have been done through changing and improving the structure and geometry of the motor or using some control strategies. This paper reviews a variety of control strategies to reduce the torque ripple in SRM. Each of the methods described in details. PI and Fuzzy logic techniques are compared and the best and most efficient methods are introduced.

I. INTRODUCTION

The switched reluctance motor (SRM) drives for industrial applications are of recent origin. Since 1969, a variable reluctance motor has been proposed for variable speed applications. The origin of this motor can be traced back to 1842, but the "reinvention" hasbeen possible due to the advent of inexpensive, high-power switching devices. Even thoughthis machine is a type of synchronous machine, it has certain novel features. Electric machines can be sorted into two categories on the basis of how they produce torque i.e. Electromagnetically or by variable reluctance. Electromagnetically means motion is produced due to the interaction of two magnetic fields, generated by the stator and the other by the rotor which is mutually coupled to produce an electromagnetic torque tending to bring the fields into alignment. The vast majority of motors used today operate on this principle. Some examples include DC and induction motors. Some ways of generating these fields are by energizing windings, with permanent magnets, and through induced electrical currents.

This paper proposes the design of switched reluctance motor to obtain high motor efficiency. The first step of design makes the principle improving motor efficiency clear. Next the cross sections and axial shapes of rotor and stator cores.The switched reluctance motor (SRM) drives for industrial applications are of recent origin. This paper introduction to SRM, its principle of operation and design considerations.Key to an understanding of any machine is its torque expression. The implications of machine operation and its salient features are inferred from the torque expression. The torque expression requires a relationship between machine flux linkages or inductance and the rotor position. The machine operation in all of its four quadrants of torque vs. speed is derived from the inductance vs. rotor position characteristic of the machine, and the dynamic equivalent circuit for SRM is formulated

II. APPLICATIONS OF SWITCHED RELUCTANCE MOTOR

The simple motor structure and inexpensive power electronic requirement have made theSRM an attractive alternative to both AC and DC machines in adjustable-speed drives. Fewof such applications are listed below.

a) General purpose industrial drives;
b) Application-specific drives: compressors, fans, pumps, centrifuges;
c) Domestic drives: food processors, washing machines, vacuum cleaners;
d) Electric vehicle application;

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e) Aircraft applications;
f) Servo-drive.

III. DIFFERENT TORQUE RIPPLES REDUCTION METHODS IN SRM

A.Torque-Sharing Function Technique:

A novel and simple nonlinear logical torque-sharing function (TSF) for a SRM drive is proposed in [22] that use nonlinear TSF to change currents in two adjacent phases during commutation, so that efficiency and torque ripple in an SRM drive can be considerably improved. The incoming phase produces the majority of torque and the current of outgoing phase is decreasingly controlled by the logical condition.

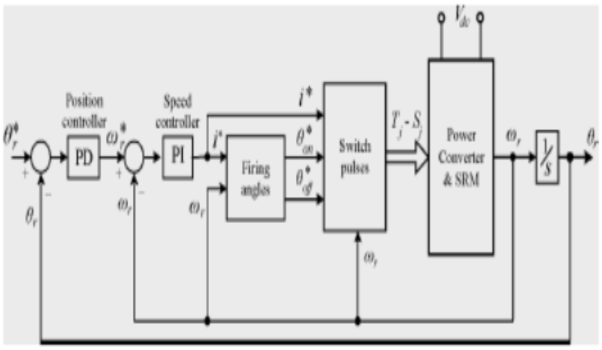

Fig. 1 General block-diagram of the SRM speed and position closed loop control system.

Due to the same switching condition in an unregulated phase and the reduction of commutation period in the proposed control method, the number of switching can be significantly reduced, and hence, the switching loss can be reduced. A two-phase regulation mode is employed in the novel nonlinear TSF. In order to include nonlinearity in torque control and decrease the tail current at the end of commutation, the current of the incoming phase needs to be controlled in an increasing manner, and at the same time, the outgoing phase current should be tracked on an opposite direction; so that torque sharing between two phases is smoothly achieved with a minimum current crossover. Comparison between the total torque chart of the proposed TFS method with the two conventional methods clearly shows superiority of the proposed method in reducing torque ripple. At low speeds the efficiency of the proposed method is better than other traditional methods (linear TSF and sinusoidal TFS). At high speeds, efficiency of the three methods is similar. For practical implementation of DSP, analog to digital converter and encoder for positioning are required. In addition, this method needs the characteristics of torque-angle- current of the motor.

B.Modern Method of Fuzzy-Logic Controller:

A fuzzy-logic-based turn-off angle compensator has been proposed in [31] to reduce the torque ripple in SRM. The turn-off angle is automatically changed for a wide range of motor speed to reduce torque ripple. Block-diagram of the proposed compensator is shown in Fig. 14.

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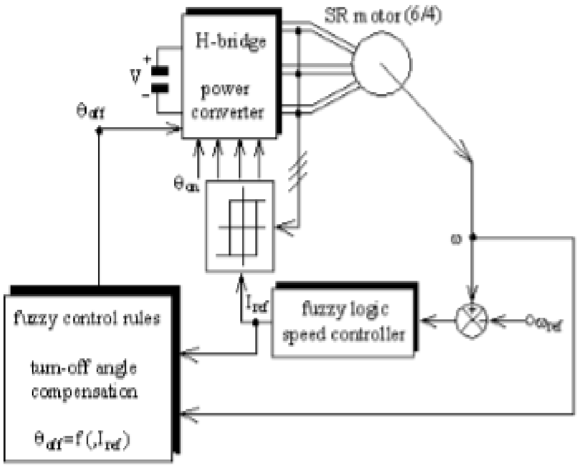

Fig. 2 Block-diagram of the proposed compensator

Two procedures are used to measure the torque smoothness: 1) The variance value of speed error variation and 2) Its frequency spectrum. Analyzing power frequency spectrum diagrams and also table of variance values before and after compensation, improvement in the performance of the drive system is clear in reducing speed and torque ripple. The proposed compensator also has the ability to reduce the noise and machine vibration. In addition, no torque signal has been used in this scheme that increases the simplicity and reliability of the compensator.

A high performance drive based on high speed and low speed dynamic observer (HSO and LSO) has been introduced in [32]. The dynamic observer estimates the rotor position and speed over wide speed range using currents and phase voltages. In this approach, observer gains are corrected on-line using fuzzy-logic hybrid algorithm (FLHA) regarding estimation errors. In addition, a fuzzy-logic current compensator (FLCC) has been presented to reduce torque ripple. In the torque reducing regions, the FLCC injects additional current into each phase. Simulation results show that the proposed scheme estimates the rotor position and speed with high precision for all speeds (near zero up to the rated speed). Also, FLCC minimizes the torque ripple and reduces the speed estimation error. Some advantages of this drive are robustness, high reliability and very good performance in the steady-state.

A novel adaptive TSK-fuzzy controller (ATSKFC) has been presented in [25] to regulate the speed of an SRM. The proposed controller comprises two parts: 1) a TSK-fuzzy controller and 2) a compensated controller. In this paper, the TSK-fuzzy controller is the main controller, which is used to approximate an ideal control law. The compensated controller is designed to compensate the approximation error between the TSKfuzzy controller and the ideal control law. The parameter variations and the external load of the SRM drive are taken into account to ensure the robustness of the proposed scheme.

An on-line tuning methodology based on Lyapunov is utilized to adjust the parameters of the ATSKFC, so that the stability of the control system can be guaranteed. Also, three control schemes namely ATSKFC, fuzzy control and PI speed control are experimentally investigated and their results are compared with each other. Configuration of the proposed scheme is presented in Fig.

Here, input variables of TSKFC are the speed error and the speed error variation and its output is designed to obtain control law. Three experiments are presented in this paper. Analyzing the experimental results of different controllers in experiment 1 with three different reference speeds, the proposed scheme clearly has a lower speed error. It is clear in experiment 1 that fuzzy controller performs well in the steady-state but shows larger speed error in the transient mode. The PI speed controller also works well, when it is well tuned; however, the PI speed control does not perform satisfactorily over a wide range of speed. Unlike the PI speeds controller.

C. Proportional-Integral (PI) controller:

The combination of proportional and integral terms is important to increase the speed of the response and also to eliminate the steady state error

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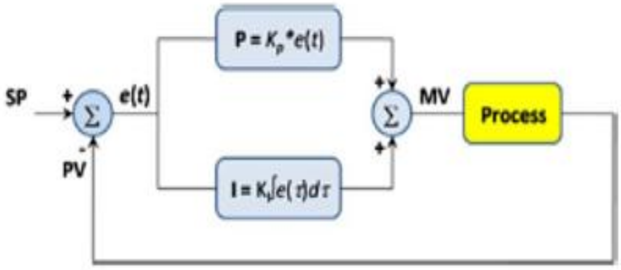

The Proportional-Integral (PI) algorithm computes and transmits a controller outputsignal every sample time, T, to the final control element. The computed output from the PI algorithm is influenced by the controller tuning parameters and the controller error (Δ).Integral action enables PI controllers to eliminate offset, a major weakness of a P-only controller. Its function is to integrate or continually sum thecontroller error.

The proportional term of the PI controller adds or subtracts based on the size of controller error. As error grows or shrinks, the amount added grows or shrinks immediately or proportionately. While the proportional term considers the current size of error only at the time of the controller calculation, the integral term considers the history of the error, or how long and how far the measured process variable has been from the set point over time. Thus the integral action eliminates offset. It continually resetsthe bias value of controller toeliminate offset as operating level changes. Thus the PI controller eliminates offset error and increases the speed of the response.

IV. CONCLUSION

In this chapter, PI and Fuzzy logic controllers for SRM position control are presented. The parameters of the speed PI controller are on-line adjusted according to the load torque and rotor speed. The analysis of the SRM control system is conducted using a small displacement version of the non-linear electromagnetic torque model. Intelligence techniques such as fuzzy-logic, neural network, or a combination of these methods, have the advantage of using SRM non-linear models. Thus, more accurate results are obtained. Using fuzzy-logic as speed controller or controller which can work along PI speed controller has better and more accurate results than a single PI controller.

It has better performance than that of fuzzy and PI controllers in reducing the ripple; it has better dynamic response and more robust against external fluctuations. Online control method shows better results among the optimal fire angle control methods. Knowledge of the characteristics of torque-angle-current or magnetization characteristics is not required in this method. Moreover, it can be used at both high and low speeds. Results of the torque sharing function method, which is one of the most popular methods, is very good and satisfying.

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AUTHOR'S BIOGRAPHY

Kolli Nageswararao was Born in 1986.He Graduated from JNTU Hyderabad in the year of 2009. He received M.Tech degree from JNTU Hyderabad in the Year 2013.He is Working As Asst Professor in Sree Vahini Institute of Science and Techonology, Tiruvuru.A.P. He Research interests include power electronics, multi Level Converters, Facts,PWM Techniques and Electric Machinery Analysis.

B.Chandra Mouli Was Born in 1999 .He was Completed DIPLOMA in Electrical and Electronics Engineering in Sree Vahini Institute of Science and Techonology,Tiruvuru.A.P .Presently He is Pursuing his B.Tech in Sree Vahini Institute of Science and Techonology,Tiruvuru.A.P.

D Vijay Kumar Was Born in 1998 .He was Completed DIPLOMA in Electrical and Electronics Engineering inVikas Polytechnic College Vissanapeta.A.P .Presently He is Pursuing his B.Tech in Sree Vahini Institute of Science and Technology, Tiruvuru,A.P.

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S Prudhvi Raj Was Born in 1999 .He was Completed DIPLOMA in Electrical and Electronics Engineering in Sree Vahini Institute of Science and Techonology,Tiruvuru.A.P .Presently He is Pursuing his B.Tech in Sree Vahini Institute of Science and Technology, Tiruvuru,A.P.

CH.Anusha Was Born in 1999 .Presently She is Pursuing her B.Tech in Sree Vahini Institute of Science and Techonology, Tiruvuru,A.P.