COMPARATIVE STUDY OF PI AND FUZZY CONTROLLERS TO MINIMIZE PERIODIC TORQUE AND SPEED RIPPLES IN SWITCHED RELUCTANCE MOTOR

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ABSTRACT:

The switched reluctance motor has used in high performance motor control application such as aircraft starter or generator system, electric traction, mining drives, washing machines, door actuators, etc. this use is due to high reliability, high torque, robust construction, low cost of switched reluctance motor. In all applications of switched reluctance motor smooth torque is the major need but due to air gap flux harmonics increases torque ripples further increases periodic speed ripples in switched reluctance motor. Due to this, performance of drive deteriorates. The main and major objective of this paper is to analyse speed control method of switched reluctance motor with pi and fuzzy controller in MATLAB/Simulink environment. Simulation will be carried out with pi and fuzzy controller for reduction of periodic speed ripples in switched reluctance motor. Fuzzy logic controller is introduced to give an effective and outstanding performance to minimize periodic speed ripples in switched reluctance motor.

KEYWORDS: Switched Reluctance Motor (SRM), Asymmetric Converter, PI Control, Fuzzy Control, Torque Ripple.

INTRODUCTION:

Torque ripple reduction in switched reluctance motors (SRM) has become a major research theme for this machine today. In servo control applications or when smooth control is required at low speeds, reduction of the torque ripple becomes the main issue in an acceptable control strategy. In this case, even using a fuzzy PI-like control as the one described in , the results are not Satisfactory because the controller's output signal, which is used as a reference signal for the current Control in the power converter, causes sustained torque oscillations in steady-state. Furthermore, torque ripple alters with the speed of the SR motor and with the magnitude of the load applied to it. The first approach for torque-ripple reduction in SRMs using an off-line learning technique is proposed in. A step forward off-line approach is presented in and, which also uses soft computing Techniques to learn the best function to reduce the ripple. Recently, more sophisticated learning control algorithms were proposed that enhanced on-line approaches adapting the controller to changes in the motor's characteristics. However, these approaches need to be improved concerning two aspects: Instead of starting from a zero knowledge (all rules at a zero value), the fuzzy system responsible for the ripple reduction can be initialized with rules obtained from a previous simulation study with the SRM. In this paper, a new off-line learning strategy, which has used a simulation model of the SRM to acquire the initial knowledge rule-base, is proposed. use of the machine torque, measured or estimated, to implement the torque-ripple reduction techniques on-line, decreases their robustness and limits the application of the online Control algorithm mainly due to costs. Hence, a compensation scheme that allows its online use without measurement or estimation of the torque signal needs to be researched.

TORQUE RIPPLE REDUCTION STRATEGY:

Construction of switched reluctance motor (SRM) is simple and robust which is used for high speed and high temperature applications. But this switched reluctance motor (SRM) has one disadvantage that there is pulsation of torque due to harmonics of flux which cause the ripples in periodic speed. For high speed applications speed oscillations is natural but in low speed applications it creates periodic speed ripples which deteriorates performance of switched reluctance motor. The pulsation of torque in switched reluctance motor (SRM) is produced due to harmonic flux in the air gap and also due to cogging torque. This cogging torque produces due to variables reluctance between stator and rotor side. Therefore to minimize periodic speed in switched reluctance motor (SRM) two methods are used such as

A) Improvement in design of magnetic circuit.

B) Improvement in performance of electronics control technique.

First method reduces the torque ripples but it is costly whereas second method is feasible and more effective which can improve the performance of speed control technique. In this paper switching strategy with H-Bridge asymmetric type converter is proposed for switched reluctance motor (SRM) which will gives good control and flexibility. The H- Bridge asymmetric type converter is as shown in following fig.1

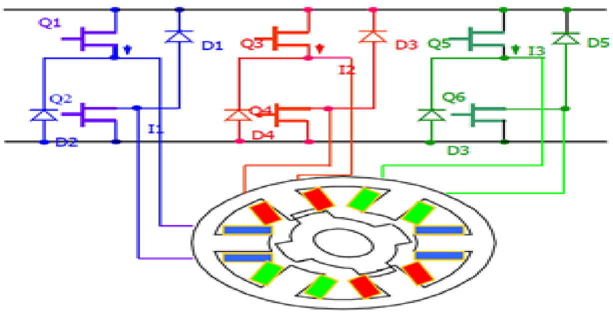

Fig .1 H-Bridge Asymmetric converters

In the proposed strategy torque ripple is defined as an objective function and control must do in such a way that reduces this function. Torque ripple is not defined as the difference between maximum and minimum value of torque because this value is not a good signal to properly analyze and evaluate the motor torque. Harmonic analysis is implemented to produce a signal which can be used in fuzzy sliding control and can be proportional to motor torque ripple. Because torque ripple doesn't depend on the DC value of torque, this value is subtracted from the motor torque. At the next step, the RMS value of fundamental harmonic is extracted and used as a torque ripple factor. This factor is proportional to the motor torque ripple and can efficiently predict torque agitation, so it is used as an objective function in fuzzy sliding controller. The torque ripple control loop is shown in Figure 2.

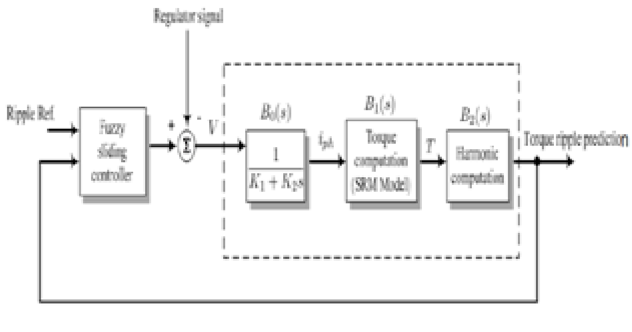

Fig .2 Torque Ripple Reduction Loop

This paper focuses on minimization of periodic speed ripples and improvement in performance of switched reluctance motor by using PI and Fuzzy control in MATLAB/ SIMULINK environment.

METHODOLOGY:

A. MODELING OF SWITCHED RELUCTANCE MOTOR (SRM) WITH PI CONTROLLER:

The combination of proportional and integral terms is essential to refine the speed of the response and also to eliminate the steady state error. By giving feedback to the converter the performance of the PI controller can be improved and it conquers the disturbances. The forced oscillation and steady state error can be eliminated in PI controller during on-off controller respectively. However, introducing integral mode has a negative effect on stability of the system and in speed response. So that speed response will not increase in PI controller. This problem can be detected by introducing derivative mode. It has the capability to predict the errors and to decrease the reaction time of the controller. If the speed response is not a criteria normally PI controllers are used.

The simulink model is designed for the speed control of switched reluctance motor using PI controller. If set speed is 4000, the actual speed displayed is 4003 and the settling time is 2 seconds. From speed waveform it can be notified that the introduction of PI controller reduces the steady state error.

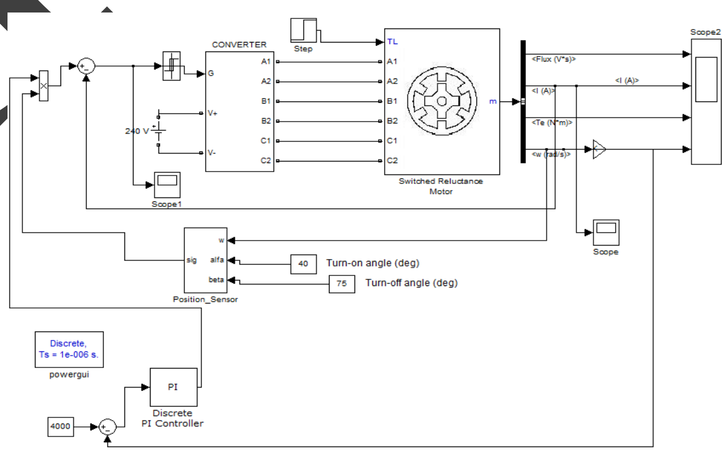

Fig.3 Simulink model of SRM with PI

B. MODELING OF SWITCHED RELUCTANCE MOTOR (SRM) WITH FUZZY CONTROLLER:

Fuzzy logic was proposed by Lotfi Zadeh in 1965, it has various applications in all inventive fields. The merits of fuzzy logic controller are the clarification for a problem can be easily analyzed and the design of the controller can be implemented. The design of fuzzy logic system is not based on the mathematical model of process. The four main stages in fuzzy logic controller are fuzzification, rule base, inference mechanism and defuzzification. The fuzzification is nothing but it comprises the process of transpose crisp values into grades of membership for linguistic terms of fuzzy sets. The transpose from a fuzzy set to a crisp number is called a defuzzification. The inference engine and the knowledge base were the components of an expert system. The knowledge base stores the factual knowledge of the operation of the concern experts. Fuzzy inference engine is the process of calculating from a given input to an output using fuzzy logic. In inference engine, If Then type fuzzy rules convert fuzzy input to the output Mamdani type fuzzy logic controller. It is most commonly used in a closed loop control system, because it reduces the steady state error to zero. The designed fuzzy rules used in this research are given in Table 1. The fuzzy sets have been defined as: Negative Big (NB), Negative Medium (NM), Negative Small (NS), Zero (Z), and Positive Small (PS), Positive Medium (PM) and Positive Big (PB) respectively. Many research papers have developed SRM models based on fuzzy logic, hybrid fuzzy and neural techniques. The simulink model is designed for the speed control of Switched Reluctance Motor using Fuzzy logic controller and their corresponding waveform is shown in Figures.

TABLE I. Rule Based for Speed control

D_U		DE_n						
		NB	NM	NS	Z	PS	PM	PB
E_n	NB	NB	NB	NB	NB	NM	NS	Z
	NM	NB	NB	NB	NM	NS	Z	PS
	NS	NB	NB	NM	NS	Z	PS	PM
	Z	NB	NM	NS	Z	PS	PM	PB
	PS	NM	NS	Z	PS	PM	PB	PB
	PM	NS	Z	PS	PM	PB	PB	PB
	PB	Z	PS	PM	PB	PB	PB	PB

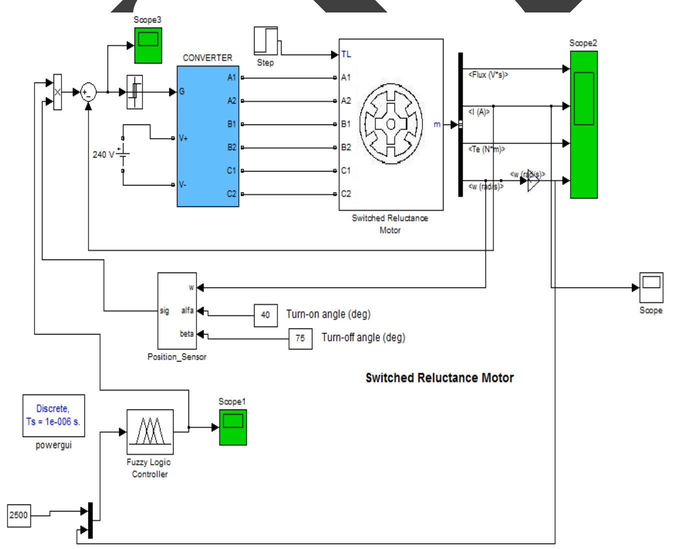

Fig. 3 Simulink model of SRM with Fuzzy

SIMULATION RESULTS AND ANALYSIS:

Simulation results with the proposed technique are presented for different parameters as shown in below figures.

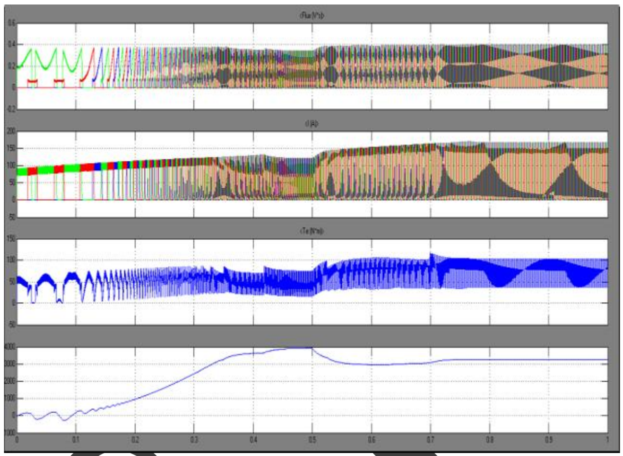

Fig. 4 Simulation Results of SRM with PI

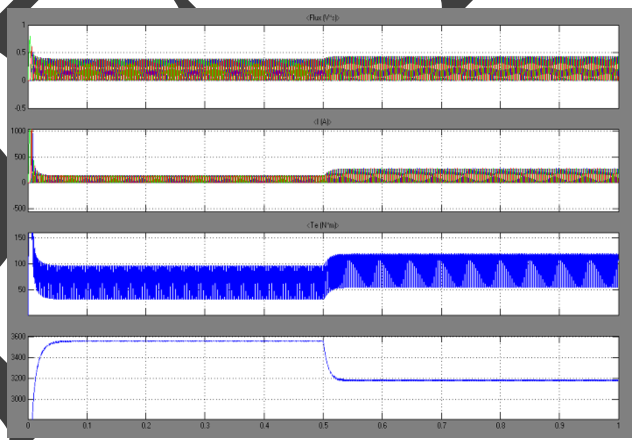

Fig 5. Simulation Results of SRM with Fuzzy

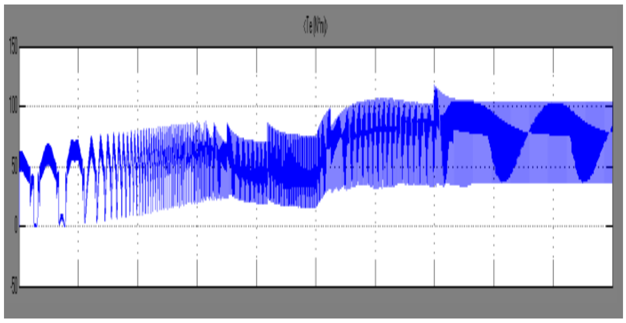

Fig 6. Torque Ripples in PI

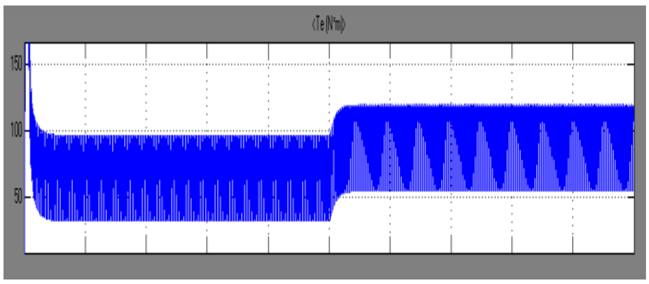

Fig 7. Torque ripples in fuzzy

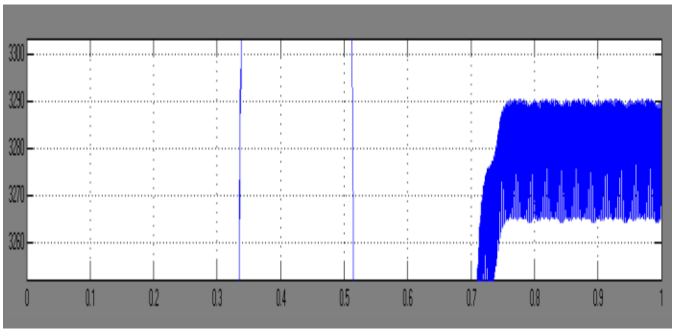

Fig 8. Speed Ripples in PI

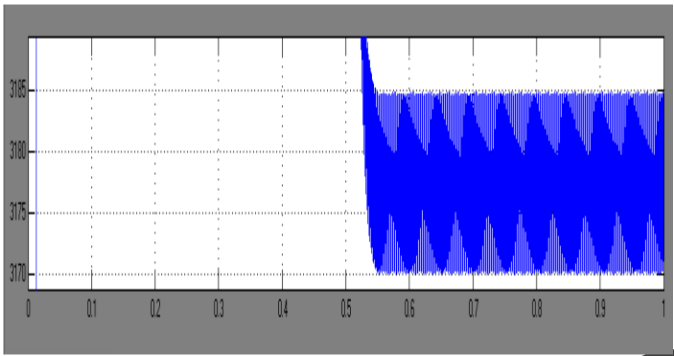

Fig 9. Speed Ripples in Fuzzy

Simulation wave form in fig.4 and fig. 5 shows flux, current, torque and speed with respect to time. As we can see in the simulation waveform, high starting current in fuzzy model is less compared to PI controller and disturbances associated with current is more in PI controller than Fuzzy controller Therefore starting torque of SRM is smooth in fuzzy than the PI controller and as we compare settling time of both controller, fuzzy provides very less settling time than the PI controller

Fig. 6 and 7, indicates Torque Ripple in PI and Fuzzy respectively and from these results we obtained that Torque Ripple in Fuzzy is less than PI. Fig 8 and 9 shows Speed Ripple in PI and Fuzzy respectively and also from these results we analyzed that Speed Ripple in Fuzzy is less than PI.

Below table shows that result analysis of Fuzzy and PI related to Torque Ripple, Speed Ripple and Settling Time.

TABLE 2: Result Analysis of PI and Fuzzy

Controller	Max. Torque T_{max} N-M	Min. Torque T_{min} N-M	Avg. Torque $(T_{max}+T_{min})/2$ N-M	Torque Ripple $(T_{max}-T_{min})/T_{avg}$	Max. Speed N_{max} RPM	Min. Speed N_{min} RPM	Speed Ripple $(N_{max}-N_{min})$	Settling Time T_s Second
PI	105	38	71.5	93.7%	3290	3265	25	0.75
Fuzzy	120	55	87.5	74.28%	3285	3270	15	0.5

CONCLUSION:

The relatively recent approaches of torque ripple minimization attempt smooth torque over a wide speed range. Although the torque ripple will progressively increase with speed, these new approaches are highly desirable for applications where the speed range varies widely.

The proposed technique is suitable for Reduction of periodic speed ripples in switched reluctance motor using PI and fuzzy logic control. It is possible to control and to reduce the periodic speed ripples by using fuzzy logic control in MATLAB/Simulink. Comparison of controllers with PI and Fuzzy logic will be made based on certain performance parameters. From the above Simulation results by using fuzzy controller for switched reluctance motor have shown the good ripple reduction in torque and speed

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