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Speed Control of SR Drive Using FLC

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Abstract

SRM drives might be used in distant viable applications owing to their simplicity and low cost. In this paper, the SRM Drive is described as that which is used for fuzzy modeling, estimation, prediction and control. A fuzzy-logic-based model is constructed from both static and real-time motor data, and from this model the rotor position is estimated and controlled. The system also incorporates fuzzy logic-based methods to provide a high robustness against noise. In addition, the method uses heuristic knowledge to choose the most desirable phase for angle estimation in order to minimize the effect of feedback error. It is also shown that, by using fuzzy logic, the drive control scheme offers a high robustness and reliability and be suited to a wide range of applications. Simulation results are presented to verify the proposed scheme by using in simulink /mat lab.

Key words: *FLC, SRM, PWM*

1. Introduction

Switched reluctance motor has unique characteristic features as highly nonlinear behavior, simple construction, low cost and suitable for low and high speed regimes. Due to nonlinearity the machine is producing high torque ripples, acoustic noise [2, 9]. The most significant criteria for designing an electric drive system are to have a good awareness of the motor dynamic performance. It is to be considered that, the drive system of an electrical motor interacts with power electronic converters. Therefore, power converters are employed to realize the desired torque and speed from the motor [1, 3]. In comparison with other drive systems such as combustion engines and hydraulic engines, electric drives have enormously wide field of applications. It also has the advantages of making a large speed control range, adaptable control ability and slight acoustic noise operation.

The SRM Drive control is a highly developed technology, starting from mercury-arc to Thyristors and presently to Integrated Gate Bipolar Transistors and Integrated Gate Commutated Thyristors valves, from conventional PI controllers to more advanced control techniques [5]. The proposed Adaptive Techniques to be done on the control aspects to uprise the drive performance and efficiency of motor. The SRM has a highly nonlinear characteristics and it operates in a constantly changing environment where loads, torque outputs and operating parameters change continuously [7, 8, 10]. The performance of SRM depends on the control method which is being used.

The speed control of SRM used adaptive control technique for obtaining the dynamic response under various operating conditions [4, 6]. It is difficult to develop an accurate mathematical model for the SRM because it is highly non-linear in nature. Hence, a control method or technique must be developed to eliminate the drawbacks of the mathematical model based schemes. The control method must be simple to design and in implementing it should have a better performance.

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2. FLC Design for SRM

The requirement of the mathematical model for conventional control method and the performance of the system are not adequate owing parametric variations, but is FLC based system designed without using mathematical model. In additional, a rule-based FLC is designed and used to control the speed of SRM, which is proposed in this paper. It has a very good accuracy, low cost and simplicity.

The proposed FLC approach is based on a set of control rules, called the fuzzy rules among the linguistic variables. These rules are expressed in the form of conditional statements. The internal structure of developed controller is shown in Figure 1.

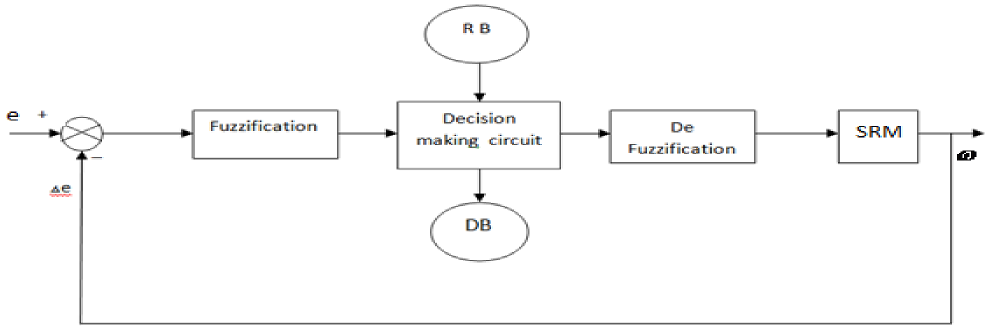

Figure 1. Block Diagram of FLC for Switched Reluctance Motor

The error and change in error are modeled using Equations. (1) And (2) as

$$e(k) = \omega_{ref} - \omega_{act} \tag{1}$$

$$\Delta e(k) = e(k) - e(k-1) \tag{2}$$

Where ω_{ref} → Set speed,

ω_{act} →actual speed,

$e(k)$ →error,

$\Delta e(k)$ → Change in error

The decision-making unit uses the conditional rules of 'IF-THEN-ELSE'. In the first stage, the crisp variables *e(k)* and *Δe(k)* are converted into fuzzy variables. The fuzzification maps the error, and the change in error to linguistic labels of the fuzzy sets. M-FLC is one of the most commonly used fuzzy methodologies for control applications. Mamdani controller was the first control system developed on the basis of the fuzzy set theory.

3. Fuzzy Logic Controller

The usual PI controllers are used for the control of a SR Drive but these controllers do not achieve well during all conditions of the motor, when there is a large torque ripple. The fixed proportional (P) and Integral (I) gain controllers are optimized only for a Small operating range and thus it deteriorates in system performance due to repetitive commutation failures and could not cope up with the sudden change in the operating condition of the system. The problem can be solved by updating the gain of the PI controllers with Fuzzy Logic control scheme.

The parameters of input are error and rate of change of error. Both the inputs are normalized and they fall within the range of the Universe of Discourse [-1, 1] and these normalized inputs are associated to the fuzzification block, consisting of three membership functions which are implemented in MATLAB.

In the proposed work, a rule base comprises of Three X Three *i.e*. Nine rules in the rule base which is used in corresponding two inputs fuzzified using three membership functions. The rule base is used to update the proportional and integral gains of the conventional PI controller. In the proposed work, the N (negative), P (positive) and Z (Zero) represents the linguistic values. One of the rules is of the following form.

Rule: IF change in error (Δe) is Zero and error (e) is Negative then fuzzy output (y) is Positive Where e, Δe represents the crisp input from the process, y is the fuzzy output. Overall, the fuzzy rule base provides the platform to include expert knowledge or human intelligence into the control system. The fuzzy rules are summarized in Table 1. The rules show that using three input membership functions (P, Z, N) and three output membership functions (P, Z, N) provide the necessary functionality. The rules dictate that the results of each input membership function are combined using the AND operator, which corresponds in taking the minimum value.

Table 1. Fuzzy Logic Rules for Decision Making

		Error		
Error rate of change		P	Z	N
	P	P	P	Z
	Z	P	Z	P
	N	Z	N	N

The proportional and integral gain of the conventional PI controller updates using the rule base which is given in Table 2 and 3.

Table 2. Rule Base for ΔK_p

e / Δ e	Rate of change in Error			
Error		N	Z	P
	N	P	P	Z
	Z	P	Z	N
	P	Z	N	N

Table 3. Rule Base for ΔK_i

e/ Δe		Rate of change in Error		
Error		N	Z	P
	N	N	N	Z
	Z	N	N	P
	P	Z	P	P

Table 4. The Performance Analysis of FLC for SRM

	Setting Time (sec)	Rise Time (sec)	Peak overshoot	Peak Time (sec)
No load condition speed command 3000 rpm	0.5019	0.2734	2.47%	0.4676
No load condition with speed command 4000 rpm	0.2967	0.1229	1.39%	0.8049
Under load condition	-----	0.0014	Setting main (RPM) 2860	----

4. Results and Discussions

The proposed SRM speed controller has been simulated by using the motor parameters in Matlab/Simulink.The SRM performances are calculated and investigated while it is running at different conditions such as steady-state, dynamic state and starting from stand-still.It is observed that from the output response that initially the motor is at rest and the speed command is 3000 rpm at t=0, the motor is operating under no load condition and the Controller generate the pulses for the required current as shown in Figure 4.

The speed responses of switched reluctance motor by using Fuzzy controller. The system was operated at a reference speed of 3000 rpm when the motor shaft is under no load. The performance of Fuzzy controller in terms of The Rise time, settling time and Overshoot are shown in the table 4. Torque-Speed responses of switched reluctance motor for FLC controller is exhibits in the Figure 5.

The speed response of the switched reluctance motor using AI controllers (fuzzy) and Obtained output response is observed that initially the motor is running with 3000 rpm speed, and the speed command changes to 4000 rpm at t=0.6 sec. the controller increases the current command and hence torque increases which is shown in fig in the Figure 6.

The motor accelerates to 4000 rpm .if speed reaches the 4000rpm and current command to normal value then torque decrease to develop friction and wind age losses. The performance of Fuzzy controllers in terms of The Rise time, settling time and

Overshoot are shown in the table 4. Torque-Speed responses of switched reluctance motor for FLC controller are exhibits in the Figure 6.

The system was operated at a reference speed of 3000 rpm when the motor shaft is under load of 6 N-m is connected to motor at 0.6 sec. The performance of Fuzzy controller in terms of The Rise time, settling time and Overshoot are shown in the table 4. Torque-Speed responses for FLC controller are shown in the Figure 7.

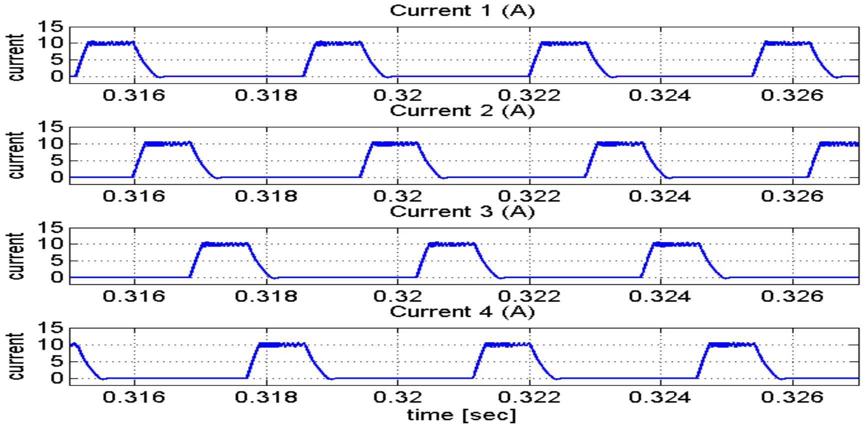

Figure 2. Response of the Current in Phases A, B, C, and D of the Switched Reluctance Motor

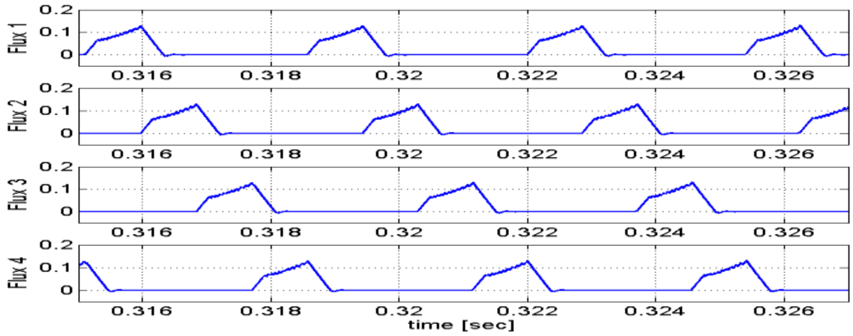

Figure 3. Response of the Current in phases A, B, C, and D of the Switched Reluctance Motor

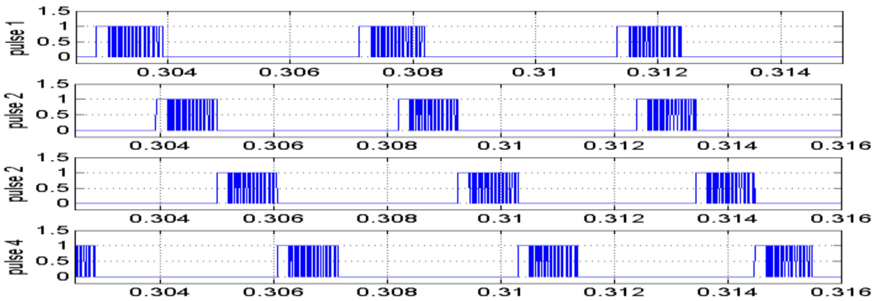

Figure 4. Response of the pulse in phases A, B, C, and D of the Switched Reluctance Motor

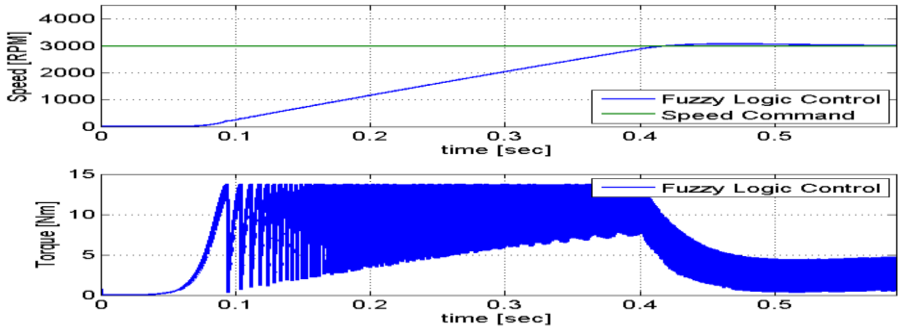

Figure 5.Response of the Speed and Torque Control of SRM Using FLC with Speed Command 3000 Rpm under Unload Conditions

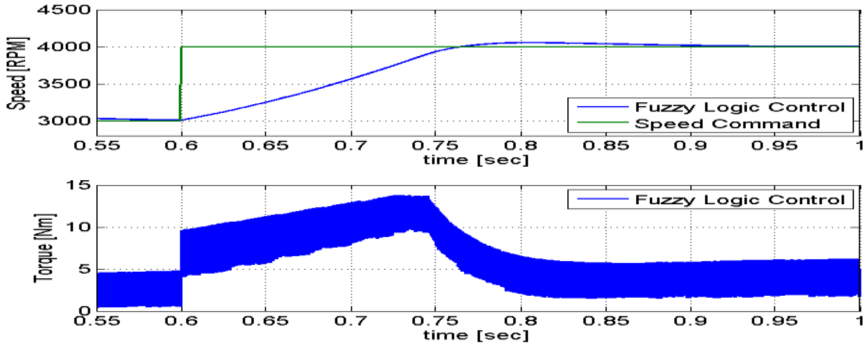

Figure 6.Response of the Speed and Torque Control of SRM Using Fuzzy with Speed Command 4000 rpm

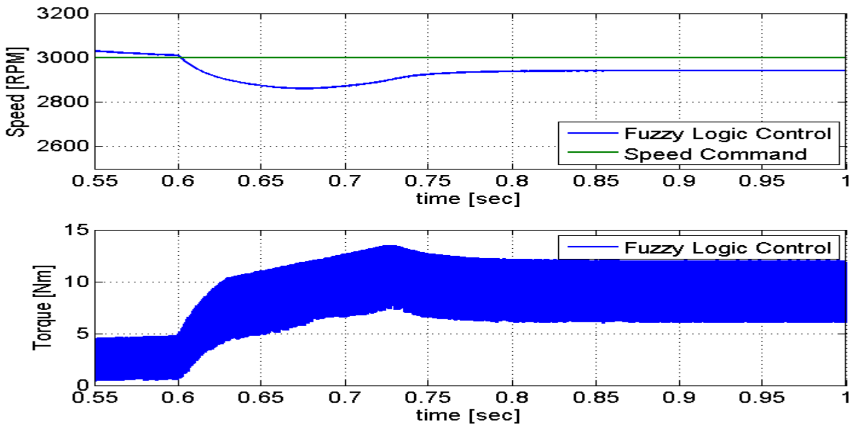

Figure 7. Response of the Speed Control of SRM using FUZZY with Speed Command 3000 RPM under Load Conditions

5. Conclusion

This paper presents a methodical approach of achieving speed control of switched reluctance motor drive by means of various types of control strategies has been Examined and modeled further control strategies, FLC control scheme considered for designing the controller in order to control the speed of the switched reluctance motor(SRM). The simulated results observably lead to the conclusion that the fuzzy controller is able to provide superior performance in the speed control action of the SRM while comparing the earlier. By observing the simulation results, reveals that proposed method FLC delivers outstanding controlling action while controlling the speed of switched reluctance motor.

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