Advances in Environmental Biology, 8(12) July 2014, Pages: 1657-1661

AENSI Journals

Advances in Environmental Biology

ISSN-1995-0756 EISSN-1998-1066

Journal home page: http://www.aensiweb.com/AEB/

Torque Ripple Reduction and Speed Control Using Fuzzy Logic Control Method in Switched Reluctance Motor

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ARTICLE INFO

Article history:
Received 25 May 2014
Received in revised form
26 July 2014
Accepted 22 August 2014
Available online 28 November 2014

Keywords:
Information and communication technology environment telephone lines internet CO2

ABSTRACT

This paper presents a control structure to reduce torque ripple and speed control using fuzzy logic control method in switched reluctance motor. Although SRM possesses many advantages in motor structure, it suffers from large torque ripple that causes some problems such as vibration and acoustic noise. In this paper another control loop is added and torque ripple is de ned as an objective function. By using fuzzy mode strategy. Simulation results have demonstrated the proposed control method

To Cite This Article: Shervin Goudarzi, Abdolreza Esmaeli and Fatemeh Dadgarnejad., Torque Ripple Reduction and Speed Control Using Fuzzy Logic Control Method in Switched Reluctance Motor . ***Adv. Environ. Biol., 8(12),*** *1657-1661, 2014*

INTRODUCTION

In recent years, Switched reluctance motor (SRM) has been focused on by many researchers. This motor has individual features than the others. These features such as simplicity, robust structure, low cost, high ratio of torque to rotor volume, reliability, high efficiency, suitability for variable speed application [1], brushlessconstruction, controllability and many other features are the advantages of SRM presented in some papers. These advantages and inherent efficiency make it considerable for researchers. Besides these advantages, it has some problems[2]. The SR motor has a nonlinear model and torque ripple is a prevalent disadvantage resulting in acoustic noise and rotor vibration. Hence reduction of such problems is an important subject in SRMs[3]-[5].Motor structure makes its characteristic nonlinear and the simulation results of linear control are not acceptable [6],[7] .therefore nonlinear control strategy is used in the paper. There are two categories in which the torque ripple may be studied and reduced; some methods use control and drive strategies to overcome torque ripple but in some others, motor design is considered for torque ripple reduction. Control and drive strategies may reduce torque ripple, but the intrinsic structure of the motor such as saliency limits their efficiency. Therefore, it is necessary to discuss the geometric design of SRM. Some trends aimed at improving the performance of SRM, have discussed torque ripple reduction in drive and control systems[8]-[10]. Several attempts have been made to optimize the geometric shapes of SRM by designing of the stator pole face with a non-uniform air gap and attached pole shoe to the lateral face of the rotor pole in[11], by designing of a notched tooth rotor to optimize the inductance profile and reduce torque ripple in [12], by deterministic methods to determine design parameters using genetic algorithm in [13], by some soft computing methods such as fuzzy method in[14], and by some new structures of SRM in recent years [15],[16].

Proposed Method:

At first, we need to define errors in order to design a fuzzy controller. This issue depends on the dynamic which is measured by the feedback system output and dynamic reference. Since the purpose of this article is to control the output speed of motor, the feedback engine speed is measured by reference speed and the resulted error is the speed error. For this reason, the Speed error and changes in speed error are two inputs to the fuzzy controller. Since the SR motor can be stimulated with a voltage which is in its phases terminal, the output of fuzzy controller can be defined as the SR motor switching voltage. Because our goal is to control the input flow not the SR motor terminal voltage, the output of controller is defined as flow and can be moved to the motor in

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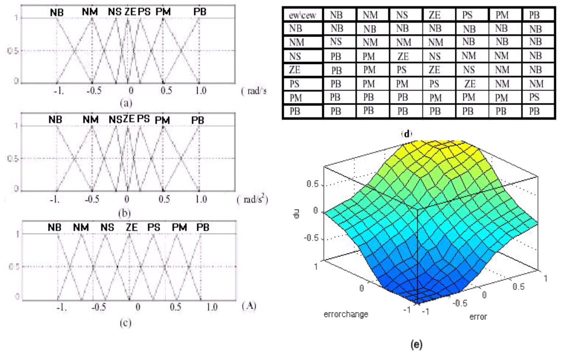
the simulation by an inverter. Figure (1-a) and (1-b) show the fuzzy functions set and levels to detect error conditions (the error degree and slope error). The fuzzy functions set which is needed for the output are given in figure (1-c).



ew/cew	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NB	NB	NB
NM	NS	NM	NM	NM	NB	NB	NB
NS	PB	PM	ZE	NS	NM	NM	NB
ZE	PB	PM	PS	ZE	NS	NM	NB
PS	PB	PM	PM	PS	ZE	NM	NM
PM	PB	PB	PB	PM	PM	PM	PS
PB	PB	PB	PB	PB	PB	PB	PB

Fig. 1: fuzzy functions.

The total levels are related to the error 7 and the error slope is also 7. Fuzzy rules contain 49 rules and are specified in figures (1-d) and (1-e). Figure 2, shows the simple appearance of a fuzzy controller. The integrator function is used Due to the continuous control of the output. Additional descriptions are presented in the simulation section.

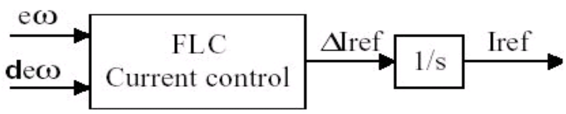


Fig. 2: a simple pattern of fuzzy proportional integral controller.

Simulation Results:

In order to verify the proposed control method, the drive has been simulated in MATLAB/Simulink software. At first, only speed control is used in SRM drive. Motor torque, speed and phase currents are extracted as shown in Figure 3. In the next step, the proposed torque ripple control has been employed in the SRM drive aiming at torque ripple reduction. Figure 3, shows the diagram block of switched reluctance motor speed control using the speed sensor.

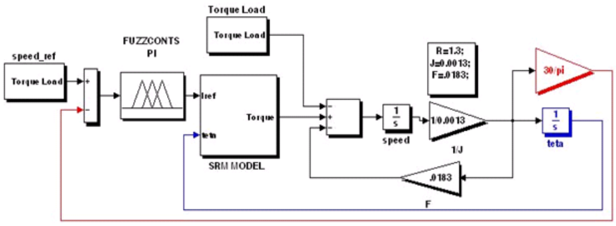


Fig. 3: diagram block for SR motor speed control with speed sensor.

Figure 4, shows the diagram block of the fuzzy proportional integral controller. As it is evident in this figure, the speed error and speed error slope are multiplied by two coefficients and after passing the cramp enter into the controller. Integrator output current required by the motor is for damping the speed error that is done by changing the terminal voltage level.

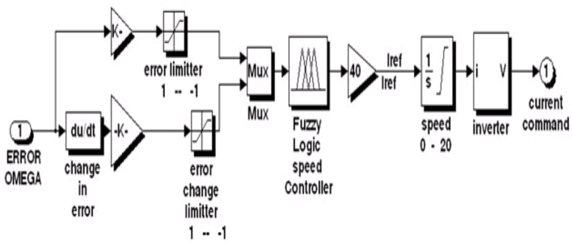


Fig. 4: Diagram block of the fuzzy proportional integral controller.

Simulation is done with two integrator initial value of 0 and 10 and (because of soft starting with full load current) and the full load torque is applied at rated speed of 1500 rpm and the Simulation is done with two integrator initial value of 0 and 10 and (because of soft starting with full load current) and the full load torque is applied at rated speed of 1500 rpm and the results show appropriate behavior of the SR motor dynamics. The integrator is also limited between 0 and 20 so that if the motor went to the saturation zone under a full load, it could be observed in the control signal. Figure 5, shows the motor dynamics as a result of the fuzzy proportional integral controller to the non-linear model with a soft starting.

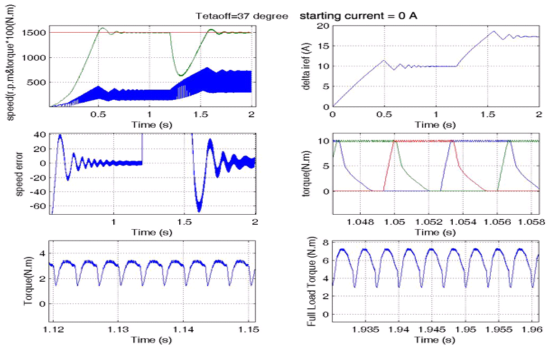


Fig. 5: SR motor dynamics of the fuzzy proportional integral controller with a soft starting.

As Figure 5 , shows (a) speed – torque chart (torque is up to 100 times) And (b) control signal And (c) speed error signal and chart (d) the no-load motor And (e) motor torque in the no-load And (f) the motor torque at full load. The form 5 , shows that the peak time of no-load is about 0.55 seconds and the leakage time is less than 0.65 seconds. The load torque is applied in half a second and the peak time under a full load is about 0.4 seconds and the leakage time is less than 0.2 seconds. The permanent speed error at the full load is zero, and It is clear that after applying the full load torque to the motor, the speed has less jumps than the no-load mode and the speed error at the full load will faster in damping. This phenomenon is due to the dynamic motor because the motor works smoother at the full load but the speed error is increased due to increased the full-load. Since the motor controller increases the flow to provide full-load speed of 1,500 rpm, thus the torque ripple will be increased at the full load. This increases the percentage of steady speed swing at the full load. Figure 6, shows the above simulation with 10 mA starting current. In this simulation, the motor has been launched with full-load current.

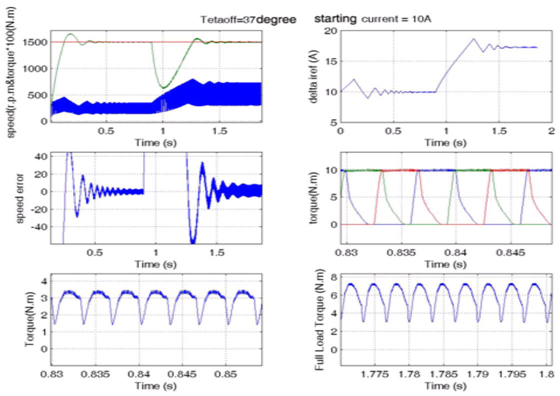


Fig. 6: SR motor dynamics with fuzzy proportional integral controller with a full load starting current.

The comparison of figure 5 and 6 , shows that the peak time and the subsidence time in no-load and the full load torque are less than the soft starting mode, but the percentage of speed swing in the steady mode does not change in the two modes. Figure 7 , shows the diagram block of one phase of the motor in the torque ripple minimization technique with the fuzzy controller. As the figure suggests, the reference current and angle (between 0 to 90 degrees) enter into the fuzzy controller and the final reference will be created for the minimization of ripple torque.

Simulation has been done in two modes of soft starting and full load starting such as the previous modes and has been identified in figures 8 and 9. As the figure 8, shows the current waveform is changed into another form, therefore this current waveforms have higher ripple torque but the full load torque has less ripple.

Figure 9 , shows the motor dynamics at the full load starting .

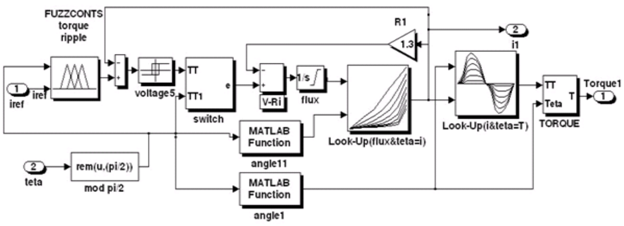


Fig. 7: The diagram block of one phase of the motor in the torque ripple minimization technique with the fuzzy method.

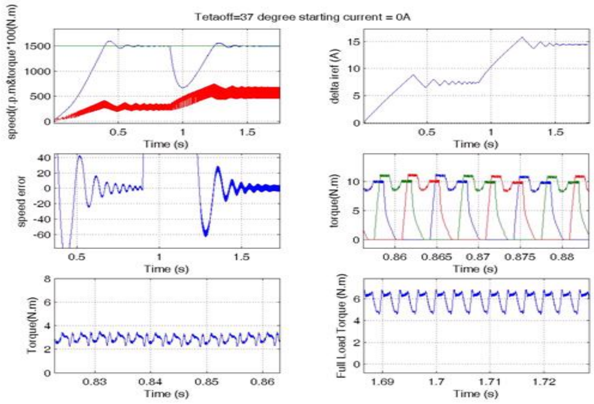


Fig. 8: motor dynamics in the motor torque ripple minimization technique with a fuzzy method (soft starting mode).

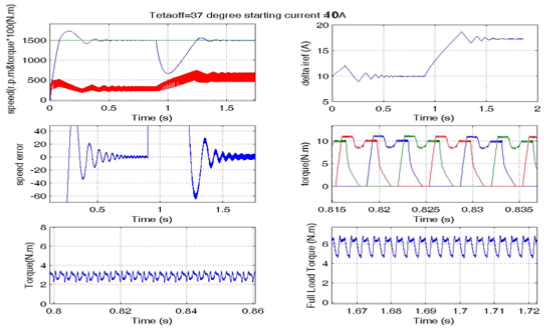


Fig. 9: Motor dynamics in the motor torque ripple minimization technique with a fuzzy method (full-load starting mode).

The peak time and fall time are reduced and the percentage of jumps is reduced.

Conclusions:

The stimulation of fuzzy proportional integral controller model and the mentioned stimulation were done by torque ripple minimization technique. In all these modes the sensor has an effect on the steady and speed error. At the full load starting, the motor approaches quickly to its nominal speed but has a percentage of more jump than a soft starting mode. All the modes that start the full-load current motor, the speed and motor dynamics reach quickly to their steady mode and the reduction of ripple torque is also effective in this regard.

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