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A Novel Harmonics-Free Fuzzy Logic based Controller Design for Switched Reluctance Motor Drive

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Abstract

This paper describes the new technique for harmonics elimination in switched reluctance motor with 48 pulse converter with fuzzy logic controller to control the speed of the motor to a reference speed. By using this technique we can achieve the better speed variation and minimum harmonics when compared to existing 18 pulses and 24 pulse control. This proposed method also improve the performance of SRM by the reduced harmonic level, thus the load current will not be affected by ripples.

Keywords: Switched reluctance motor, Fuzzy logic controller, Total harmonics distortion (THD).

Introduction

Switched reluctance motor is used for wide range of speed control for various application. Fuzzy logic controller is implemented for the converter controlled switched reluctance motor in closed loop control. Closed loop control is very accurate and gives better results. Fuzzy controller is used to control the Switched Reluctance motor speed. Speed control is achieved by three level converter controls by fuzzy controller. And also eliminate the harmonics of the switched reluctance motor and improve the performance.

The applications range from consumer products such as cameras, camcorders, washing machines, and microwave ovens to industrial process control, medical instrumentation, decision-support systems and portfolio selection.

Description

Switched Reluctance motor Drive System

Fuzzy logic controller connects with the converter and firing circuit, which can activate the converter of the switched reluctance motor to have the control over the pulsating signals. The main function of the FLC is to take the output voltage of the converter and compared with the reference voltage to produce the actuating signal to have the error signal which will compensate with the set voltage. Converter will activate the windings of the Switched reluctance motor. The torque production in the switched reluctance motor is explained using the elementary principle of electromechanical energy conversion in a solenoid.

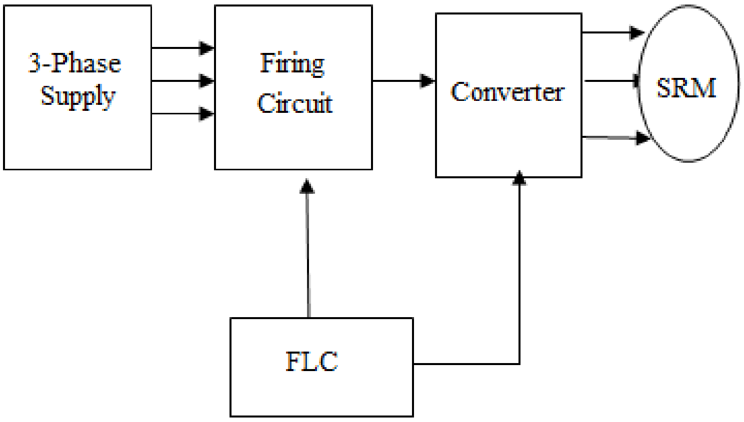

Figure 1: Basic Block Diagram of SRM Drive system.

If the inductance is linearly varying with rotor position for a given current, which in general is not the case in practice, then the torque can be derived as:

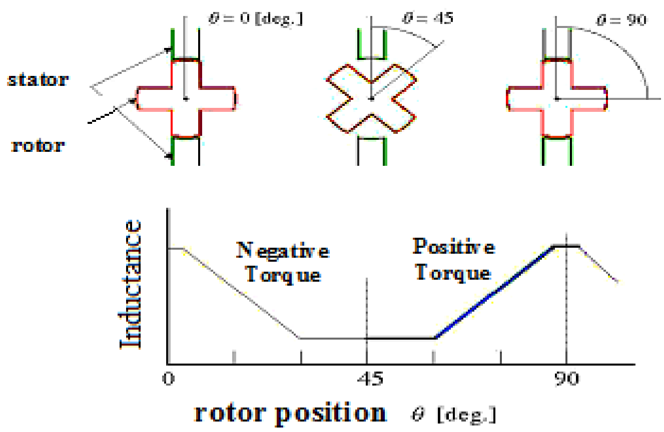

Figure 2: Rotor position and its inductance variation.

The bus voltage equation in a switched reluctance motor be written as

$$V_{bus} = \frac{d\lambda_\phi(t)}{dt} = \frac{d\lambda_\phi(\theta)}{d\theta}\omega_m$$

The torque equation of SRM based on the reluctance characteristic as well as the one of a conventional motor can be expressed by the rotor position θ and magnetic energy *W*.

$$T = \frac{\partial W}{\partial \theta} \tag{1}$$

In addition, if the nonlinear characteristic of magnetic material is neglected, the magnetic energy can be expressed as:

$$W = \frac{1}{2}L(\theta)i^2 \tag{2}$$

Through the combination of (1) and (2), the correlation between magnetic torque and space distribution of inductance can be obtained.

$$T = \frac{1}{2}i^2\frac{\partial L(\theta)}{\partial \theta} \tag{3}$$

Equation (3) shows that if the slope of inductance is positive, the positive excitation can generate the positive torque. Similarly, a negative torque is formed in the interval of negative slope. Here, giving a 6/4 poles 3-phase SRM as an example as shown in Fig. 1 which is adopted in this paper. Suppose the rotor is on 0 degree when its pole comes into line with stator pole and forms the maximum inductance. On the other hand, the minimum inductance occurs when the rotor pole leaves from stator pole with 45 degrees. That is, the cycle of inductance variation is 90 degrees in this case. In order to generate the continuous rotating torque, the excitation switching to each phase should be corresponding to rotor position in turn. However, since the excited phase is changing, the estimation of rotor position is required

Harmonics

A series of sinusoidal waves whose frequencies are integral part multiples of the frequency of fundamental wave. These sinusoidal components are called harmonics. This unwanted signal can create serious problem on the load side as well as supply side and the effects are excessive temperature rise in the motor, noise due to EMI, rise in motor leakage current, and increasing switching losses because of high frequency switching operation. The harmonics are effectively eliminated by various harmonic elimination techniques. The lower order harmonics are reduced with a help of PWM inverter technique. The higher order harmonics can be eliminated by connecting filter circuit

Total Harmonic Distortion

Any periodic waveform can be shown to be the superposition of a fundamental and a set of harmonic components. By applying Fourier transformation, these components can be extracted. The frequency of each harmonic component is an integral multiple of its fundamental. There are several methods to indicate of the quantity of 12 harmonics contents. The total harmonics distortion (THD) which is defined in terms of the amplitudes of the harmonics, Hn, at frequency nw0, where w0 is frequency of the fundamental component whose amplitude of H1 and n is integer. The THD is mathematically given by

$$\%THD = \frac{\sqrt{H_2^2 + H_3^2 + \ldots + H_N^2}}{\sqrt{H_1^2 + H_2^2 + H_3^2 + \ldots + H_N^2}} \times 100 \tag{4}$$

Fuzzy logic controller

Fuzzy logic controller implemented for the SRM drive system. FLC used in closed loop control and get better performance of reduced harmonics and accurate speed variation as that of the set speed.. In order to design a conventional controller for controlling a physical system, the mathematical model of the system is needed. The conventional controllers are unsuitable for a modelled and non linear system.

Those problems are tackled by fuzzy logic controllers. Compared to the traditional control paradigm, the advantage of the fuzzy control paradigm are twofold. First, a mathematical model of the system to be controlled is not required and second, a satisfactory nonlinear controller can often be developed empirically in practice without complicated mathematics.

Fuzzy modelling is another new modelling paradigm for nonlinear systems. Fuzzy models are non linear dynamic models. Proper use of fuzzy control can significantly shorten product research and development time with reduced cost. In this fuzzy logic controller used in closed loop control and improve the motor performance and get higher speed values approximately 3000 rpm.

Simulation diagram description

Mat lab simulation software used for this fuzzy logic controller based switched reluctance motor control. Simulation diagram fig 3 consists of Switched reluctance motor, converter, three phase supply and fuzzy logic controller. Switched reluctance motor connected with three level converter and also fuzzy logic controller connected in closed loop. So we can improve the better speed variation, less harmonics and ripple free torque. 18 pulse converter is used for existing work, here 48 pulse converter used for this drive system so, we can minimize the harmonic content. Additionally fuzzy logic controller implemented for this system .then improves the switched reluctance motor performance.

Fuzzy rules description

Fuzzy rules for the FLC to control the error in speed can be given as follows:

1. If (Error is less) and (Change in error is low) then (voltage is low voltage)
2. If (Error is less) and (Change in error is medium) then (voltage is low voltage)
3. If (Error is less) and (Change in error is high rate) then (voltage is high

voltage)

4. If (Error is moderate) and (Change in error is low) then (voltage is low voltage)
5. If (Error is moderate) and (Change in error is medium) then (voltage is medium voltage)
6. If (Error is moderate) and (Change in error is high rate) then (voltage is high voltage)
7. If (Error is high) and (Change in error is low) then (voltage is low voltage)
8. If (Error is high) and (Change in error is medium) then (voltage is medium voltage)
9. If (Error is high) and (Change in error is high rate) then (voltage is high voltage)

Simulation and its results

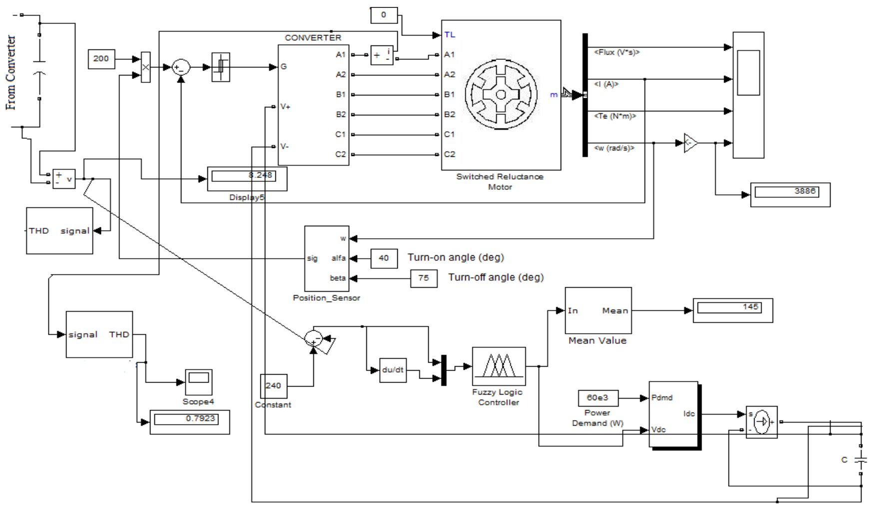

Figure 3: Simulation diagram of SRM with FLC.

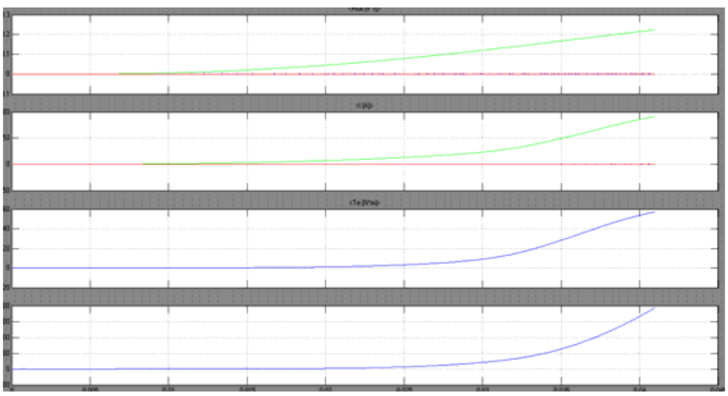

Figure 4: Output waveforms of SRM Flux, Current, Torque and Speed.

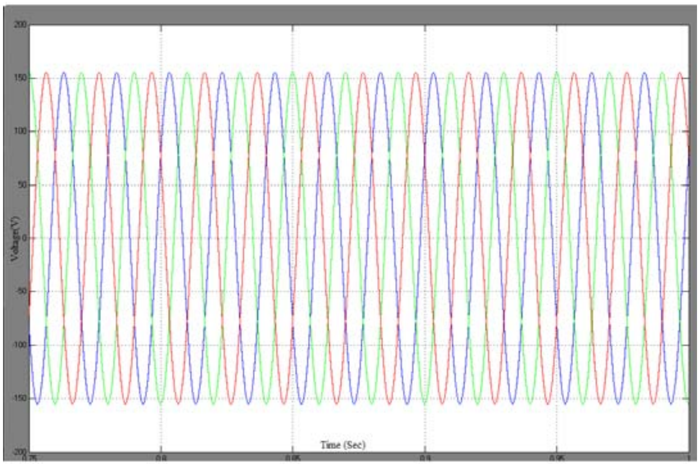

Figure 5: Input 3 phase supply.

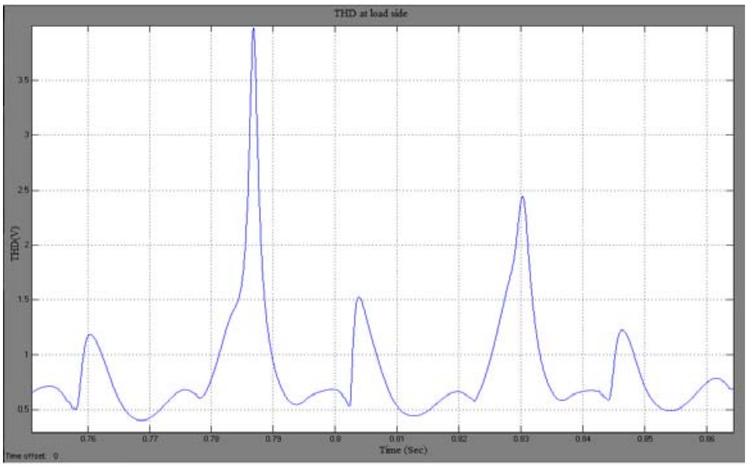

Figure 4: THD at Loading condition

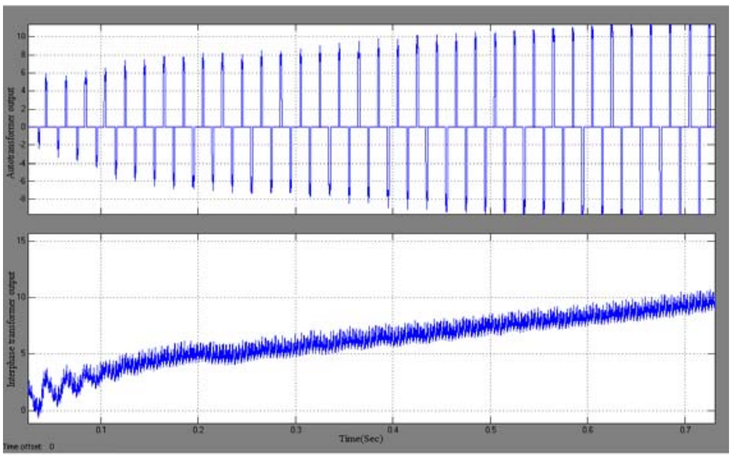

Figure 5: Autotransformer and interphase transformer outputs.

Above simulation results shows the performance of SRM with improved performance by using the fuzzy logic controller based control of switched reluctance motor.

Comparison table

Parameters	18 Pulse converter based controller	48 pulse without FLC (open loop)	48 pulse with fuzzy logic controller
Speed	420 rpm	400rpm	3000rpm
torque	10 Nm	80Nm	60Nm
current	50A	100A	100A
Flux	0.2Wb	0.4Wb	0.3Wb

Compare the existing work ie 18 pulse converter based controller getting low speed and low torque values and 48 pulse converter without FLC also getting lower values .but proposed method ie 48 pulse converter with FLC controller getting better results compare with other two methods.

Conclusion

This paper has developed a new type of converter circuit for switched reluctance motor drive. The new fuzzy logic controller based converter implemented for 1 hp switched reluctance motor. Experimental results are obtained from Mat lab simulation and results are shown. By using this technique, the switched reluctance motor performance is improved by fuzzy logic controller and the motor speed variation is controlled to have the rated speed of the motor.

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