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Torque Ripple Minimization for Switched Reluctance Motor Using Instantaneous Torque Control Theory

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ABSTRACT

In this project design and implement a ripple low torque using torque control theory for switched reluctance motor.This project presents minimizing the torque ripples in the switched reluctance motor using IDTC method. The SRM has run by BR converter, this converter is used to give the voltage to the motor with respect to motor sensor signals. The closed loop speed control can be achieved by PI control, Fuzzy, Neuro fuzzy controller. IDTC control overcomes the existing peak to peak current control method and it provides better torque ripple reduction. The model used in the simulation is the linear magnetic model which has the 8/6 structure. The mat lab simulation results illustrate the capability of Switched Reluctance Motors (SRM) being used in the motor drive industry with minimum copper loss.

KEYWORDS: Torque, Ripple, Reluctance, Motor, Fuzzy, controller, IDTC control

1.INTRODUCTION

Switched reluctance motor (SRM) is a special type of variable reluctance motor designed for rugged operation. Being light weight, SRM has the capability of driving high torque, which makes it attractive in the fields of electric vehicle and aerospace applications. SRM has simple manufacturing process which makes it cheaper as compared to other motors. SRM is fault tolerant, reliable, and have high power density. The Switched Reluctance Motor is an old member of the electric machine family. SRM, especially for use inservo-type applications, but its having high torque ripple .The torque ripple is a consequence of the nonlinear torque-current-angle (T-i-θ) characteristics of SRM and the discrete nature of torque production. The existence of the torque ripple leads to the generation of annoying noise and undesired vibration during the operation, the torque ripple can be reduced by improving the magnetic design of the motor [1].A modified torque sharing function based on the change of the overlap angle during the commutation process depending on the motor speed is presented [2].Torque ripple minimization can be achieved through machine magnetic design or through electronic control [3].It is very important problem to determine randomly the neural parameters initially and then the parameters are adjusted to optimize the torque error [4].An improved asymmetric half bridge converter (AHBC) to enhance the output performance of a segmented-stator hybrid-excitation switched reluctance motor (SSHE-SRM) driveConverter circuit is expensive [5].SRM drive is fed with a simple diode bridge rectifier (DBR) followed by a bulky capacitor, which draws peaky current at low power factor and high input current THD and It requires high maintenance that gives an increased ripples [6]. In automotive drives, the application of a dedicated algorithm for torque ripple reduction at low to medium speed is indispensable to avoid excitation of mechanical resonances in the drive train [7].The mechanism of the radial vibration and torque ripples inherent in the motors, and then focuses on the state-of-the-art technologies to mitigate the radial force and torque ripples [8]. The SRM torque is indirectly controlled by the phase current. A deadbeat current control method is used to improve the SRM phase current control accuracy, so that SRM torque control error can be reduced significantly [9].Switched reluctance motor (SRM) drives conventionally use current control techniques at low speed and voltage control techniques at high speed.A constant instantaneous torque is obtained by regulating the rotational speed of the stator flux linkage. [10].Here this project proposes an IDTC method which minimizing the torque ripples in the switched reluctance motor. As SRM has the doubly salient structure, the torque ripple is particularly enhanced at the commutation instants. The instantaneous torque of individual phases is defined through the suitable torque-sharing function (TSF). IDTC control overcomes the existing peak to peak current control method and it provides better torque ripple reduction Many TSFs can be specified to provide ideally torque sharing between individual phases and has low torque ripple.The SRM has run by BR converter, this converter is used to give the voltage to the motor with respect to motor sensor signals.

2. PROPOSED SYSTEM

The proposed system consists of SRM structure implemented by Fuzzy algorithm this system design a torque less switched reluctance motor by using fuzzy and neuro algorithm.

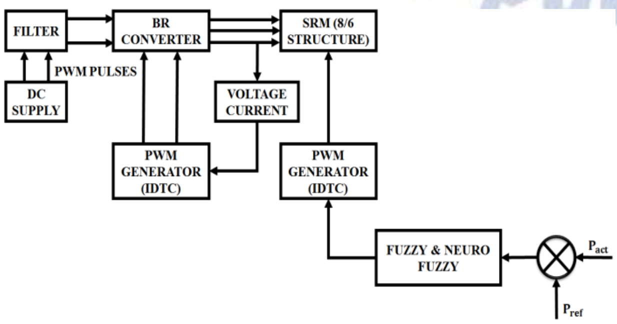

Figure 1: Proposed block diagram

The Switched Reluctance Motor is an old member of the electric machine family. SRM, especially for use in servo-type applications, but it's having high torque ripple. The torque ripple is a consequence of the nonlinear torque-current-angle (T-i-θ) characteristics of SRM and the discrete nature of torque production. IDTC control overcomes the existing peak to peak current control method and it provides better torque ripple reduction .The output voltage from the filter is enhanced with the aid of a BR converter.The output from the BR converter is fed to the SR Motor. In order to maintain constant dc link voltage, fuzzy and neuro- fuzzy controller based closed loop technique is employed The output from the fuzzy and neuro fuzzy controller is fed to the BR converter, through a PWM generator, which increases the on time of the duty cycle. Further, the defined technique is implemented in MATLAB/SIMULINK and the results are verified.

A. SWITCHED RELUCTANCE MOTOR

In modern industries, electrical drives plays vital role. The switched reluctance motor (SRM) drives for industrial applications are of recent origin. SRM are electrically commutated AC machines and are known as variable reluctance motor. As compared to the induction motor or the permanent magnet synchronous motor, the SRM has many advantages. For example, it is economical, reliable, simple rugged construction; it has higher efficiency than the induction motor. Also, there is no rotor winding. The SRM drive, therefore, can be operated in hostile environments and designed to operate for wide range of speed and torque and with rotor position sensing.

Speed Controller

Similar to other type of motor Drives, the speed controller selected for SRM is Proportional plus Integral (PI). This paper design Speed Controller (PI) for SRM the speed signal is processed through PI and generate the output current command.

Current Controller

The key to control any drive is its current. As SRM is non – linear. Therefore it is difficult task, to control the current and to design current controller which is future work of this paper.

Converter

To control torque and speed, SRM requires controllable converter and it cannot operated directly from line supply. The previous work of this paper was to design converter. In this paper SRM fed with asymmetric bridge and R-dump converters.

Rotor position sensor

Rotor position sensor integrates the SRM speed and generates phase switching signals periodically. Initial angular conditions are specified in rotor position sensorIf rotor position satisfies the condition, then it generates the phase switching signal and corresponding stator phase is activated. Current start circulating through that phase stator becomes electromagnet and stator pole pull the rotor pole. Therefore stator and rotor poles are aligned with each other. As SRM runs, again rotor position changes and it compare with specified initial angular condition. If condition not satisfied rotor position sensor do not generate phase switching signal. Similarly, other phases are activated and electromagnetic torque developed by each stator

Mathematical Model of SRM

The mathematical model of a 4-phase 8/6 SRM is given by

$$V = R_S i + \frac{d\varphi(\theta,i)}{dt} \quad (1)$$

Where v,i,R_S, $\varphi(\theta, i)$ are the per-phase voltage, current, resistance, and flux linkage respectively of the stator winding and θ is the rotor position. The per phase flux linkage, ψ (θ, i) is given by

$$\varphi(\theta, i) = L(\theta, i) * i \quad (2)$$

Where L (θ, i) denotes the inductance of the given phase. For a given excitation, the torque per phase is given by

$$T_e = \frac{\partial(\int L(\theta,i)\, i\, di)}{\partial\theta} \quad (3)$$

Considering linear operating region ($\frac{dL}{d\theta}$ (θ, i) is constant), the per phase torque can be obtained as

$$T_e = \frac{dL(\theta,i)}{d\theta} * i^2 \quad (4)$$

Mathematical approach is adopted using modulating factor k (θ, i) to calculate the reference current of one phase from the actual current of other phase in order to maintain the net torque constant. This approach not only requires lesser computations but also ensures that the ripple is minimized for any current and rotor position.

B. NEURO-FUZZY CONTROLLER

In recent years, there has been an increasing interest in the development of efficient control strategies to improve dynamic behaviour of the SRM by using fuzzy logic controller (FLC), artificial neural network (ANN), and neuro-fuzzy controller (NFC).Neuro-fuzzy systems have found a wide gamut of industrial and commercial applications that require analysis of uncertain and imprecise information. ANNs and fuzzy inference systems (FISs) are complementary technologies in the design of adaptive intelligent systems. ANNs learn from scratch by adjusting the interconnections between neurons. A valuable property of ANN is that of generalization, whereby a trained ANN is able to provide a correct matching in the form of output data for a set of previously unseen input data. FIS is a popular computing framework based on the fuzzy set theory, fuzzy if–then rules, and fuzzy reasoning. FIS implements a nonlinear mapping from its input space to output space by a number of if–then rules.

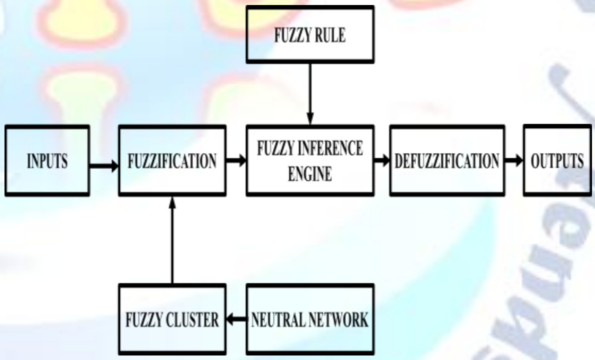

Figure 2: Neuro fuzzy block diagram

A Neuro-fuzzy network is the combination of neural networks with the fuzzy logic; this combination has the explicit knowledge representation of a Fuzzy Inference System (FIS) with the learning power of ANNs. FIS forms a useful computing framework based on the concepts of fuzzy set theory, fuzzy if–then rules and fuzzy reasoning. ANFIS is a FIS implemented in the framework of an adaptive fuzzy neural network .The main objective of ANFIS is to optimize the parameters of the equivalent FIS by applying a learning algorithm using input–output data sets. The parameter optimization is done in a way such that the error measure between the target and the actual output is minimized. A typical architecture of an

ANFIS for two inputs is shown in fig. 5, in which a circle indicates a fixed node whereas a square indicates an adaptive node.

The neuro-fuzzy compensator is a Sugeno-type fuzzy logic system with five fixed membership functions for each input. The types of membership functions used in this work are triangular, bell shape, and two models of Gaussian shape. The rotor angular position and the PI controller's output signal are used as inputs to the compensator, by means of a relation as. The training procedure consists on adjusting the rule consequents by a hybrid-training algorithm, which combines back-propagation and least squares minimization. At each learning iteration, the dc component is removed from the compensating signal, so that the ripple compensator does not try to change the mean value of the output torque. As a result, when the control system operates in steady-state, after the training, the PI controller will really produce a constant output signal, while the neuro-fuzzy compensator will produce a zero-mean-value compensating current reference, the signal. Training data are obtained from simulations of steady-state operation of the complete SR drive system. At each learning iteration, the dc component is removed from the torque signal, so that just the ripple remains. This torque ripple data is then tabulated against the mean value of the PI output reference current, and against the rotor angular position. This data set is then passed to the training algorithm, so that the torque ripple is interpreted as error information for each current-angle pair. The output of the neuro-fuzzy compensator is then readjusted to reduce the error (which is in fact the torque ripple), being this process repeated until some minimum torque ripple limit is reached.

3. RESULTS

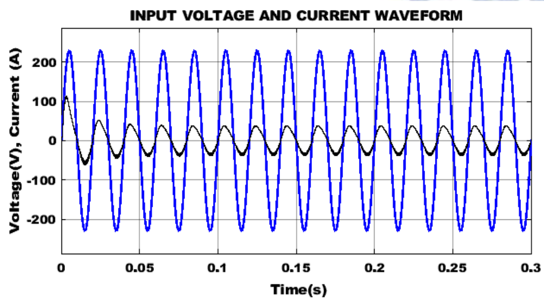

Figure 3 Input voltage and current waveform

Figure 3 represents the input waveforms of voltage and current of the converter. An input voltage of $230V$ is applied to the converter and the value of the input current applied is about $5A$. certain variations occur in the input current waveform initially and later a constant value of $5A$ is applied to the converter.

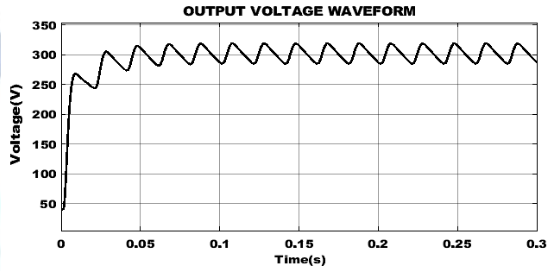

Figure 4 Output voltage waveform

Figure 4 indicates the waveform for the converter output voltage. An input voltage of $230V$ is enhanced to $325V$ with the help of Buck-boost converter. At varying time period, the obtained voltage remains constant even under the application of different load conditions.

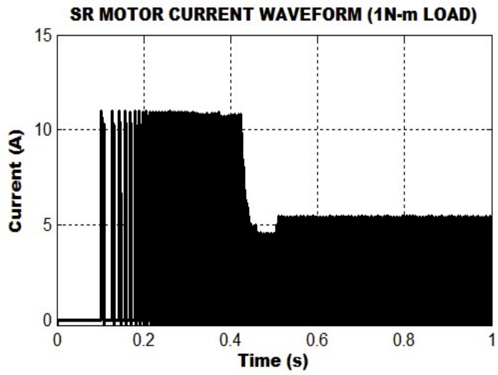

Figure 5 Current waveforms

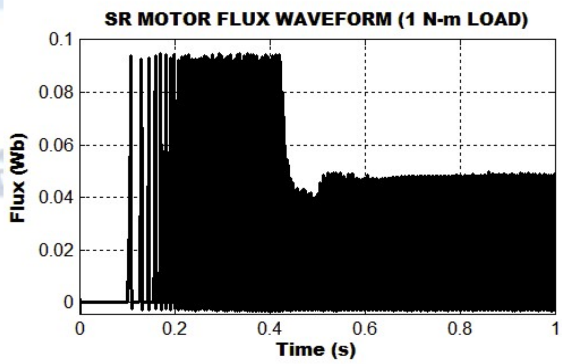

Figure 6 SR Motor flux waveform

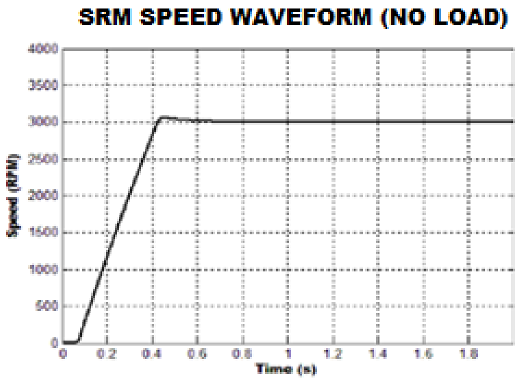

Figure 7 Speed waveforms

Figure 7 shows the speed waveform, at varying time period, the speed increases and after 0.4s, a speed of 3000rpm is maintained at the output.

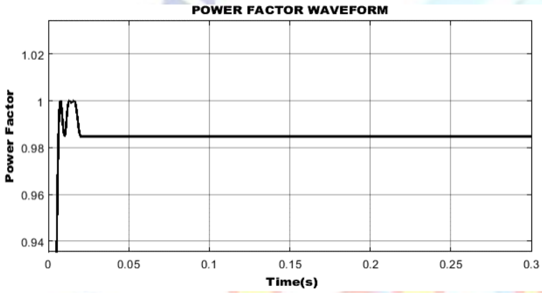

Figure 8 Power factor waveform

Figure 8 indicates the waveform for power factor in which a unity power factor is maintained. Even though power factor correction is performed, the output waveform comprises of mild distortions.

4. CONCLUSION

This project presents minimizing the torque ripples in the switched reluctance motor using hysteresis current control method. The closed loop speed control can be achieved by PI control. Hysteresis current control overcomes the existing peak to peak current control method and it provides better torque ripple reduction.This system implements IDTC based SR motor drive which reduce the torque ripples as well as reduce the copper loss in the SR motor.Switched reluctance motor is a special type of variable reluctance motor designed for rugged operation. Being light weight, SRM has the capability of driving high torque, which makes it attractive in the fields of electric vehicle and aerospace applications.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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