DQ-01

Design and Analysis of New Doubly Salient Permanent Magnet Motors with Minimum Torque Ripples.

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INTRODUCTION

Recently, a new class of brushless motors, namely the doubly salient permanent magnet (DSPM) motor, has been introduced [1]. The DSPM motor combines the advantages of both the switched reluctance motor and the PM brushless motor. Namely the rotor is the same as that of the SR machine so that the advantages of simple configuration and mechanical robustness can be retained while the PMs are located in the stator so that the irreversible demagnetization and mechanical instability can be solved. However, due to the doubly salient structure, the DSPM motor generally suffers from severe torque ripples [2], thus limiting its application to servo control.

In this paper, a new DSPM motor is proposed, which can offer minimum torque ripples. A two-phase 8/6-pole DSPM motor will be used for exemplification. Theoretical derivation, computer simulation, experimentation and quantitative comparisons will be given to illustrate the proposed motor.

DESIGN & ANALYSIS

Fig. 1 shows the proposed two-phase 8/6-pole DSPM motor and system configuration, there are 2 pieces of PM material buried inside the stator, no windings and PMs in the rotor.

Firstly, in order to minimize the cogging torque, the rotor skewing angle is set to about half of the stator pole pitch to achieve a sinusoidal flux distribution. By using finite element analysis of electromagnetic field as depicted in Fig. 2. Secondly, in order to compensate the spatial variation of self-inductances, the windings A and C as well as the windings B and D are reversely connected in series, respectively, constituting the two-phase stator windings. Thirdly, when the sinusoidal phase currents are applied to interact with the sinusoidal back EMFs, the reluctance torque is zero.

RESULTS & VERIFICATION

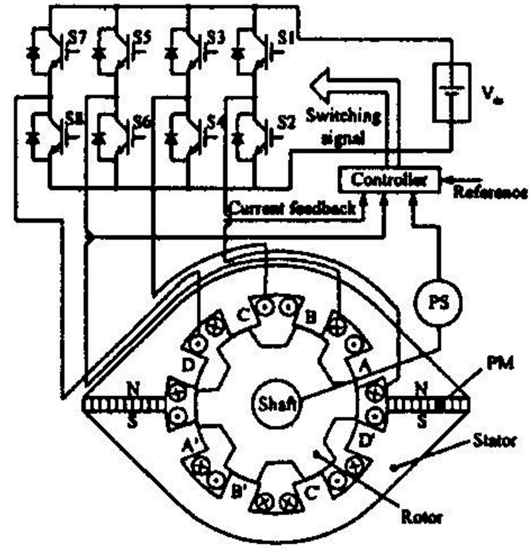
The simulated average torque and torque ripple factor at the rated current versus the rotor skewing angle can be obtained. Also, both the phase current and torque waveforms are measured at the rated load. Fig. 3 confirms that the current is very sinusoidal and the torque ripple is practically minimal. To provide quantitative comparisons, both the simulated and measured torque ripples of the proposed motor are compared with two counterparts as listed in Table I. It confirms that the proposed motor offers the minimum torque ripple. Its specifications are shown in Table II. Moreover, the measured efficiency of the proposed motor at the rated condition is 87.7%, which is significantly higher than that of an induction motor (typically 75.5%) at the same power and speed. Furthermore, the proposed motor possesses 25% higher power density than that achieved by an induction motor.

CONCLUSION

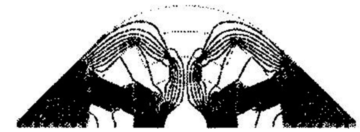
In this paper, a new minimum torque ripple DSPM motor has been designed and analyzed. It not only has the advantages of high power density, high efficiency, high reliability and maintenance-free, but also offers minimum torque ripples. Theoretical derivation, computer simulation, experimentation and quantitative comparisons have been given to illustrate the proposed motor.

1. Y. Liao, F. Liang, and T. A. Lipo, "A novel permanent magnet motor with doubly salient structure," IEEE Trans. Ind. Applicat., vol. 31, no. 5, 1995, pp. 1069-1078

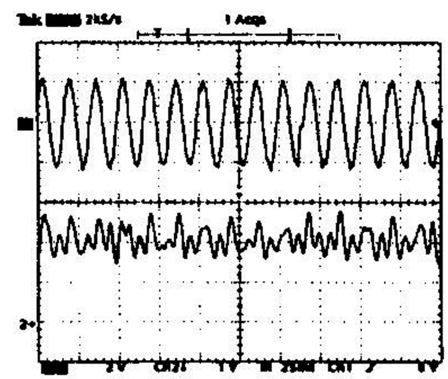
2. K. T. Chau, Q. Sun, Y. Fan, and M. Cheng, "Torque ripple minimization of doubly salient permanent-magnet motors," IEEE Trans.



Proposed DSPM motor and system configuration.



Electromagnetic field distribution.



Measured current and torque at rated load (3.3 A/div, 2.3 Nm/div, 25ms/div).

TABLE I. Torque Ripple Comparison.

Rotor	skewed	unskewed	skewed
Operation	2-phase	4-phase	4-phase
Currents	Sinusoidal	Trapezoidal	Trapezoidal
Simulated	9.7%	17.5%	26.1%
Measured	23.8%	31.0%	42.8%

TABLE II. Motor Specifications.

Parameters	Data
Rated Voltage	200 V
Rated Current	3.3 A
Rated Torque	4.7 Nm
Rated Speed	1500 rpm
Magnet Material	Nd-Fe-B
Magnet Remanence	1.08 T