

Conformal Mapping technique for magnetic saliency analysis of Double-layer Interior Permanent Magnet Motor

Liang Fang, Soon-O Kwon, Peng Zhang, Jung-Pyo Hong
 Department of Electrical Engineering, Changwon National University
 #9 Sarimdong, Changwon, Gyeongnam, 641-773, KOREA
 fangliangicw@hotmail.com

Abstract— In this paper, an analytical method based on Conformal Mapping technique is applied to the rotor design of Interior Permanent Magnet Synchronous Motor (IPMSM). A Single layer IPMSM is developed to a double-layer IPMSM to improve saliency ratio with design of experiment (DOE) and response surface methodology (RSM). The increased reluctance torque of the double-layer IPMSM is verified by Finite Element Analysis (FEA). With this analytical method, the estimation of saliency effect related to reluctance torque can be achieved by simple calculation of equations. Therefore, time and effort in the initial design of the model having complex geometry can be saved.

I. INTRODUCTION

The Interior Permanent Magnet Synchronous Motor (IPMSM) has advantage in high torque density, because it can utilize both magnetic and reluctance torque. Due to the rotor saliency, the reluctance torque is generated and added to the magnetic torque. The improvement of the rotor saliency in IPMSM can reduce the dependency on the magnetic torque, that is, it will lower the amount of PM buried in rotor part [1].

Through optimizing design of the PM and buried air-gap in the rotor part, the higher rotor saliency can be obtained. An analytical approach for the rotor saliency analysis is presented in this paper, which can guide the rotor part design easily and fast comparing with the Finite Element Analysis (FEA).

The rotor saliency is considered in an improved relative permeance function (1)[2]. With the help of the Conformal Mapping (CM) technique, the effect of curvature of the rotor is fully considered by transforming the cylindrical rotor into a square region, where the effective air-gap length g_{CM} can be determined. The CM region is shown in Fig.1.

$$\lambda_{\text{pole-salient}} = g_a / g_{CM} \quad [g_a = g_{\text{airgap}} + H_{PM} / \mu_r] \quad (1)$$

where, g_{airgap} : actual gap between stator and rotor, μ_r : relative permeability.

From some researches about IPMSM design, the rotor saliency can be effectively increased through multi-layer IPM design. Here, the presented analytical approach is applied in a surface-type (S-type) IPM rotor multi-layer design.

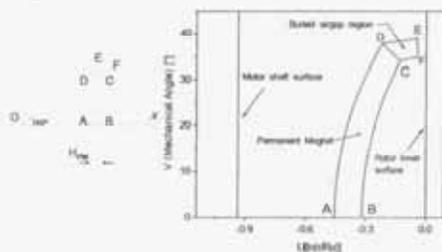


Fig1. CM of (1/8) rotor cross section region in an IPMSM

II. ANALYSIS MODEL AND RESULTS

The prototype model of a single layer IPMSM, with 4 poles and 6 slots, is shown in Fig 2(a). With identical total PM volume and back e.m.f characteristic, a double-layer IPMSM is designed from the prototype model for improving the reluctance torque. The presented analytical method is used for building a higher saliency rotor structure by the relative permeance of rotor saliency calculation.



Fig 2. (a) Prototype single layer and (b) Re-designed double-layer IPMSM

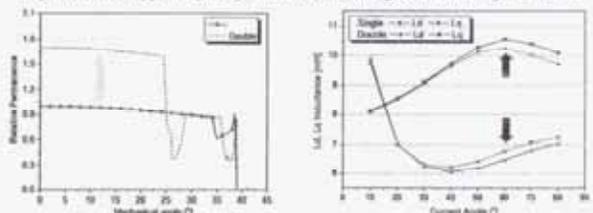


Fig 3. The relative permeance of rotor saliency variation

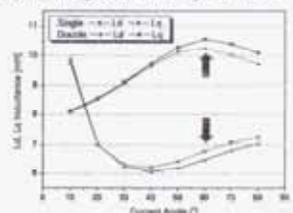


Fig 4. Improved d-axis and q-axis inductances by double-layer IPM design

In Fig.3, the improvement of rotor saliency is observed from the analytical calculation. In Fig.4, the increase of reluctance torque is revealed from the computation of d, q-axis inductances by FEA. These two results show an identical increasing tendency, so the availability of this rotor saliency analysis method is verified for using in the IPMSM rotor design for reluctance torque improvement.

III. CONCLUSION

The analytical method for rotor saliency analysis in IPMSM has been presented and applied in a S-type IPMSM rotor multi-layer design. A single layer IPMSM was optimally re-designed with the double-layer IPM rotor structure, in order to obtain an improved reluctance torque. This analytical approach can save a lot of computation time in designing IPMSMs having complex rotor structure.

IV. REFERENCES

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- [2] Liang Fang, Soon-O Kwon, Jung-Pyo Hong "Conformal transformation technique for prediction of the magnetic field distribution in an IPM motor," ICEMS 2005, Nanjing, China. vol. III pp.2124-2128, Sep. 2005

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POSTER SESSION PC6
Optimization and Design III
May 2, 2006, Tuesday
10:30 - 12:10

PC6-1	Balancing Exploration and Exploitation Using Kriging Surrogate Models in Electromagnetic Design Optimization 226 <i>G. Hawe^{1,2} and J. Sykulski¹</i> ¹ University of Southampton, UK, ² Vector Fields Limited, UK
PC6-2	Chaotic Differential Evolution Applied to Electromagnetics Optimization 227 <i>Leandro Coelho and Viviana Mariani</i> University of Paraná, Brazil
PC6-3	Conformal Mapping Technique for Magnetic Saliency Analysis of Double-Layer Interior Permanent Magnet Motor 228 <i>Liang Fang, Soon-O Kwon, Feng Zhang, and Jung-Pyo Hong</i> Changwon National University, Korea