Determination of Parameters of Motor Simulation Module Employed in ADVISOR

Tao Sun [1], Suk-Hee Lee [1], Soon-O Kwon [1], Jung-Pyo Hong [2]
[1] Dept. of Electrical Engineering, Changwon National University,
[1] Changwon, 641-773, Korea
[2] Dept. of Automotive Engineering, Hanyang University
[2] Seoul, 133-791, Korea
[1] laplace_sun@hotmail.com, [2] hongjp@hanyang.ac.kr

Abstract — This paper deals with the determination of parameters in the motor simulation module employed in ADVISOR which is an advanced vehicle simulator software. In the ADVISOR, the traction motor of a Hybrid Electric Vehicle or Fuel Cell Vehicle is defined by efficiency map, maximum torque/speed curve, moment of inertia, mass and so forth. The moment of inertia and mass of motor can be calculated by common methods, while the efficiency map and maximum torque/speed curve become more important but much difficult to predict. Owing to the prevalence of Interior Permanent Magnet Synchronous Motor (IPMSM), this paper mainly focuses on the calculation of efficiency map of IPMSM considering magnetic nonlinearity. Firstly, by means of finite elements analysis, the inductance and iron loss resistance are calculated. Next according to equivalent circuits, the motor characteristics including speed, torque and efficiency are analyzed. The total calculated parameters will be loaded and implemented in ADVISOR for testing.

I. INTRODUCTION

These years, Hybrid Electric Vehicle (HEV) and Fuel Cell Vehicle (FCV) have been paid more and more attention by automotive companies and engineers because of the environmental and economic benefits. In their design process, however, due to the complex integrate system, it is difficult to determine the specification of each component as well as to estimate the overall performance. Thanks to the advanced vehicle simulator (ADVISOR) software developed by National Renewable Energy Laboratories (NREL), the mentioned problems can be solved by it conveniently [1]. ADVISOR dose not only offer the practical vehicle and components model for choosing, but also support self-specified parameters of each components. In despite there have been many literatures [1], [2] to introduce the use methods, none of them mentions the self-specified parameters. Therefore, this paper will focus on the determination of parameters of motor module used in ADVISOR. Owing to the prevalence, the Interior Permanent Magnet Synchronous Motor (IPMSM) is chosen as the analysis and simulation model. The parameters of motor module employed in ADVISOR mainly are efficiency map, maximum torque/speed curve, mass of motor and inverter, moment of inertia and so on. Here the efficiency map and maximum torque/speed curve are the dominate factors, which requires an accurate and relatively easy estimation method to get them. This paper presents a method to calculate the efficiency of IPMSM considering magnetic nonlinearity, which is consisted with Finite Elements Analysis (FEA) and Equivalent Circuit analysis.

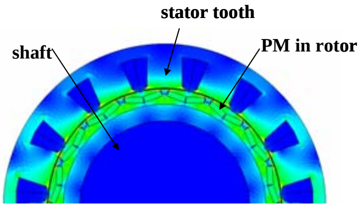

Fig. 1 the half cross section of analysis motor model

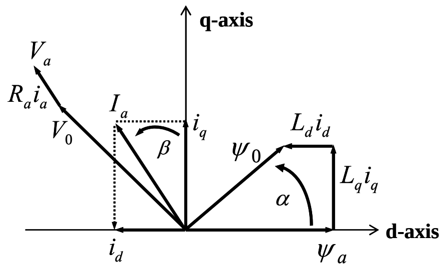

Fig. 2 the synchronous d-q reference frame of IPMSM

The former is for calculating the nonlinear parameters, and the latter will calculate the characteristics including the maximum torque, speed and efficiency by the previous results. The total calculated parameters will be loaded and implemented in ADVISOR for testing.

II. PARAMETERS CALCULATION IN FEA

The Analysis motor model is a 12 kW soft-type IPMSM, and its half of cross-section as shown in Fig. 1. The inductance calculation is based on a synchronous d-q reference frame which presents the vector relationship of motor parameters as shown in Fig. 2 [3]. By means of FEA, the d- and q-axis inductances can be calculated. It is obvious that the relationship of no-load flux linkage ψ_f, flux linkage of winding ψ_o, d-axis inductance L_d and q-axis inductance L_q equate to (1-3)

$$L_d = \frac{\psi_o \cos\alpha - \psi_a}{i_d} \tag{1}$$

$$L_q = \frac{\psi_o \sin\alpha}{i_q} \tag{2}$$

where the ψ_a is

$$\psi_a = \sqrt{\frac{3}{2}}\psi_f \tag{3}$$

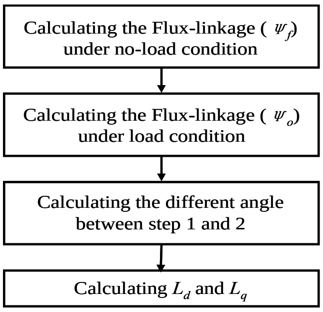

Fig. 3 the calculation process of inductances

The inductance calculation process is summarized in Fig. 3. It can be seen the flux linkages under no-load and load cases are the keys of inductance calculation.

The iron loss resistance is calculated according to the process shown in Fig. 4 which will be introduced in detail in the extended paper. In the end of this flowchart, the total iron loss w_{total} is calculated, and then the iron loss resistance is given by

$$R_c = \frac{v_0^2}{w_{total}} \tag{4}$$

III. EQUIVALENT CIRCUITS AND CHARACTERISTICS

A group of equivalent circuits for the IPMSM based on the synchronous d-q reference frame including iron losses is shown in Fig.5 [3]. The corresponding state equations of these equivalent circuits are given as (5-7).

$$\begin{bmatrix} v_d \\ v_q \end{bmatrix} = R_a \begin{bmatrix} i_{od} \\ i_{oq} \end{bmatrix} + \left(1 + \frac{R_a}{R_c}\right) \begin{bmatrix} v_{od} \\ v_{oq} \end{bmatrix} + p \begin{bmatrix} L_d & 0 \\ 0 & L_q \end{bmatrix} \begin{bmatrix} i_{od} \\ i_{oq} \end{bmatrix} \tag{5}$$

$$\begin{bmatrix} v_{od} \\ v_{oq} \end{bmatrix} = \begin{bmatrix} 0 & -\omega L_q \\ \omega L_d & 0 \end{bmatrix} \begin{bmatrix} i_{od} \\ i_{oq} \end{bmatrix} + \begin{bmatrix} 0 \\ \omega \psi_a \end{bmatrix} \tag{6}$$

$$T = P_n \{ \psi_a i_{od} + (L_d - L_q) i_{od} i_{oq} \} \tag{7}$$

where, i_d and i_q are d- and q- axis component of armature current, v_d and v_q are d- and q-axis component of terminal voltage, R_a is armature winding resistance per phase, ψ_a is flux linkage of permanent magnet per phase, L_d and L_q are d- and q-axis armature inductance, and P_n is pole pair. In addition, the i_{cd} and i_{cq} in Fig. 5 are d- and q-axis component of iron loss current.

IV. ANALYSIS RESULTS

Fig. 6 shows the efficiency map calculated by the proposed method. Fig. 7 shows the efficiency figure generated by ADVISOR. Particularly, Fig. 7 includes the efficiency of generating mode which is approximately converted from the one under motoring mode.

V. REFERENCES

[1] Sheldon S. Williamson, Srdjan M. Lukic, etc. "Comprehensive driver train efficiency analysis of Hybrid Electric and Fuel Cell Vehicles based on motor-controller efficiency modeling" IEEE Transactions on Power Electronics, Vol. 2, No.3, May 2006.

[2] National Renewable Energy Laboratory, Advanced Vehicle Simulator (ADVISOR) Documentation see [online]. Available: http://www.ctts.nrel.gov/analysis/advisor_doc

[3] Shigeo Morimoto, etc, *Interior Permanent Magnet Synchronous Motor*, Ohmsha Press, 2001, pp 12-17

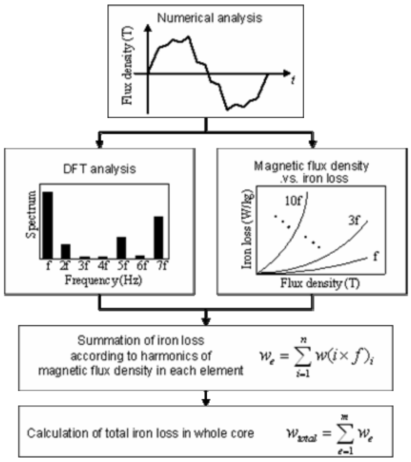

Fig.4 the process of iron loss calculation

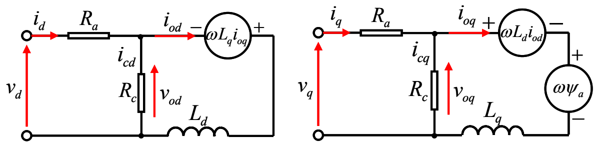

Fig. 5 the equivalent circuits of IPMSM

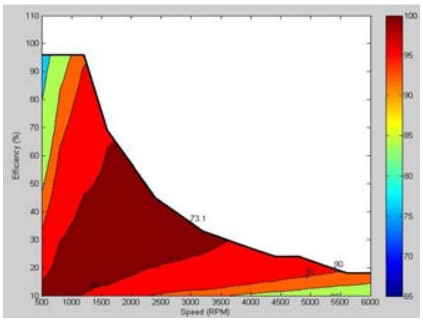

Fig. 6 the analysis result of efficiency

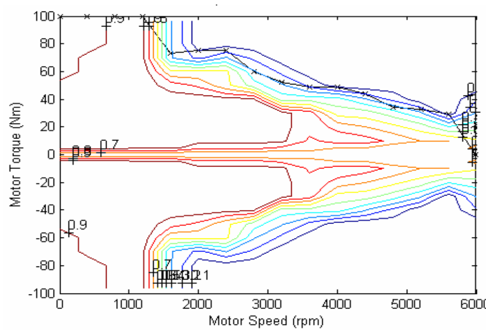

Fig. 7 the efficiency map generated by ADVISOR (including generating state)

Compumag 2007
Aachen, Germany

IEM RWTH
INSTITUTE OF ELECTRICAL MACHINES
CHAIR OF ELECTROMAGNETIC ENERGY CONVERSION
RWTH AACHEN UNIVERSITY

Proceedings of the

16th Conference on the Computation of Electromagnetic Fields

COMPUMAG 2007

June 24th - 28th

Aachen, Germany

ITG INFORMATIONSTECHNISCHE GESELLSCHAFT IM VDE

IET
The Knowledge Network

Wednesday, June 27th

OC1 – Optimisation - Software Methodology EUROPA SAAL

08:30–10:10 Session chair: **Gabriela Ciuprina, Jan Sykulski**

PC1 – Electrical Machines and Drives BALUSTRADE

10:30–12:10 Session chair: **Erich Schmidt, Yoshihiro Kawase**

PC2 – Numerical Techniques BALUSTRADE

10:30–12:10 Session chair: **Igor Tsukerman, Georg Wimmer**