

REAL-TIME ELECTROMAGNETIC MODELING AND ANALYSIS TECHNIQUES FOR ELECTRIC MACHINES

Interim project report

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An electric machine is an electromechanical transducer in which electrical energy is converted into mechanical energy. Over the past several decades, development of control of electric machines has typically been viewed using a “black box” approach which typically involves manipulation of voltage and current to generate the desired characteristics. In this approach, not much attention is paid to optimizing the intermediate magnetic energy stored inside the machine. A thorough understanding of the local magnetic field distribution inside the machine plays a significant role in the development of accurate models and control techniques that utilize electromagnetic signatures.

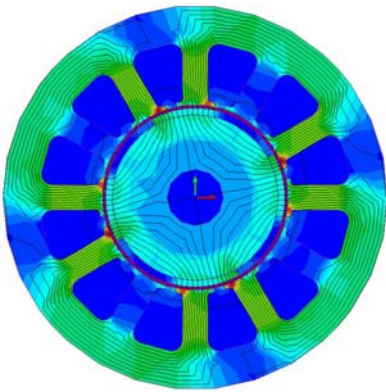


Figure 1: Magnetic field distribution in an PMSM using finite element analysis

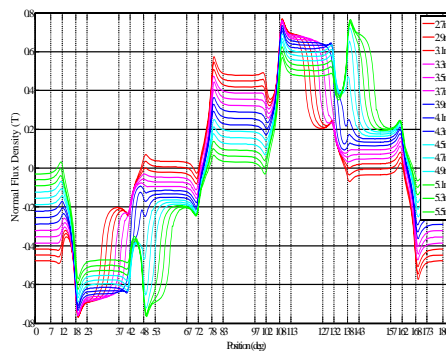


Figure 2: Distribution of normal and tangential components of field distribution in different layers of the airgap

In the first phase of this project, a three-phase, full pitch, distributed winding, radially magnetized surface mount permanent magnet synchronous motor (PMSM) has been designed. The objective has been to analyze the electromagnetic behavior of the machine and calculate force distribution in different parts of the machine using Finite Element Analysis (FEA). Figures 1 and 2 show the FEA model of the PMSM and the field distribution in different parts of the machine. It can be seen that while the force density enclosed by each layer is the same, there is a difference in the concentration of flux lines in different parts. The two main objectives that have been targeted in this phase of the project are as follows:

- **Profiling force distribution:** After obtaining the distribution of magnetic flux density, Maxwell stress method was used to calculate the distribution of electromagnetic force density and analyze the dynamic process of force generation within the PMSM. From the calculated results, normal and tangential force distribution, generated torque and radial vibration in the motor can be obtained, which is valuable in developing high precision control techniques that can strategically optimize specific attributes of the machine. These results can also be used to explain the operation of the machine under different control strategies and develop more efficient machine geometries. This concept will be submitted to the 2011 IEEE- International Electric Machines and Drives Conference to be held in Niagara Falls, Canada in May 2011, which is a forum for presenting innovative concepts in the area of electric machines and drives.

- **Identifying electromagnetic signatures:** Force produced in the machine is a function of local field distribution inside the machine. Therefore any change in the operating condition results in a corresponding change in the field distribution. By applying appropriate methods to calculate the field in different parts of the machine, this technique can be used to determine faults in the machine. This concept has been accepted for presentation at the 2010 IEEE- Vehicle Power and Propulsion Conference (VPPC) to be held in September 2010. The paper has received very high reviews and has been considered eligible for an award at the conference by the reviewers.