Abstract

Permanent magnet (PM) machines are explored for numerous applications. Some of the applications such as aircraft fuel pump motor, coolant pump motor in nuclear power plant, electric actuators in aerospace applications, electric vehicle, and wind power generators require precise design and control of the PM drives. The accurate prediction of field distribution in the machine is essential for the design process of the machine. Among both the methods, the analytical method is preferable at the initial stage of design over numerical method, because of its fast calculation. In view of this, enormous methods have been reported in the literatures for the analytical analysis of the various topologies of PM machines. Moreover, in the last two decades, the analytical methods have been improved to enhance the accuracy of the machine performance prediction. However, they are limited to analysis of unsaturated PM machines. In addition to this, the analytical method for analysis of special purpose PM machines have not been addressed fully.

In this thesis, the analytical model is developed to deal the magnetic saturation of stator teeth of the PM machine. The developed model predicts the saturated machine magnetic field distribution, cogging torque, and phase voltage. Firstly, an analytical method is developed for the radial flux PM machine and validated with finite element analysis (FEA) results obtained using Ansys Maxwell simulations. With the confirmation of the accuracy of the proposed analytical model, the work is further extended for axial flux permanent magnet (AFPM) machine analysis. For both radial and axial flux machine, the developed model is analysed and verified with four distinct levels of magnetic saturation. The resemblance of analytical and FEA results ensures the correctness of the analysis.

The special designed E-cored stator is inherently fault tolerant machine. Though, the additional magnetic flux gap between two adjacent E-cored stator segments reduces the mutual inductance of the machine, but it also influences the airgap flux density and machine performance. To take account of the additional magnetic flux gap, an analytical

model is developed and field distribution in the E-cored segmented stator machine (commonly known as PM modular machine) is evaluated. The analytical model is developed for both variants of E-cored stator viz., E-cored stator without tooth tips and with tooth tips. The developed analysis is verified with FEA analysis. Further investigations are done to improve the performance of these machine with modification in stator E-core teeth and teeth tips shaping.

To mitigate the cogging torque in PM machine, which essential for the servo drive application. The cogging torque reduction is achieved by skewing the slot opening over the slot in a PM machine. For the performance analysis and investigation of the proposed machine, an analytical model is developed. The obtained results are compared with FEA. To highlight the advantages of the proposed machine, the performance of the existing machine and proposed machine are compared.

Lastly, analytical modeling for the axial flux machine with skewed magnet is developed. The method of analysis used combined approach of the multislice method and sub domain method. The multislice method converts 3D complex problem of AFPM machine in 2D linear machine problem. The developed analysis model is compared with the results obtained from FEM. The advantages of multislice technique is used for the comprehensive investigation of stator slot shapes on the cogging torque developed in machine. It is demonstrated with the help of the analytical modelling that the cogging torque in the machine greatly influenced due to slot opening rather than the slot. Hence, the AFPM with parallel slot opening and trapezoidal magnets is reported to have least cogging torque.