Preface

This thesis presents an analytical method for the Design Analysis of Surface Mounted Permanent Magnet (SMPM) Brushless motors viz., Radial Flux SMPM (RFSMPM) and Axial Flux SMPM (AFSMPM) motors using Fourier Transform technique. The thesis contributes towards selecting a suitable method for the computation of electromagnetic field distribution as well as performance characteristics of the PM motors simultaneously. With different methods present for the analysis of SMPM motors, the analytical method provides better results with negligible computation time and reasonable accuracy.

In literature available, a number of analytical tools are reported for the solution of governing field equations involved for the analysis of SMPM motors. Based on the geometry preparation time, computation and simulation time, a suitable method for the performance calculation is required. Magnetic equivalent circuit (MEC), Fourier series and Conformal Mapping (CM) are the common analytical tools available for such purpose. These methods are good enough for the computation of electromagnetic field and performance characteristics of the PM machines. MEC gives accurate results as good as Finite Element Method (FEM), however it involves large computational and geometry preparation time when the number of elements such as stator slotting, saturation effect in various parts increases. CM involves the conversion of slot geometry into the shape for which the field solution is known making the whole process tedious. Analytical models based on Fourier series method uses superposition of field by permanent magnets and stator windings. Furthermore its computation time is speed dependent, which is large for high speed operation.

In the present thesis, Fourier Transform approach has been adapted as an analytical tool for the solution of governing field equations in and around the geometry of the machine. The Fourier Transform method applicable to linear induction motor (LIM) introduced by Yamamura has been modified and adapted for use in the SMPM motors. The method computes the performance parameters as the product of physical quantities like current, voltage, MMF, etc. It has also been useful for the computation of parameters like cogging torque, back-EMF, force distribution in the machine.

The prototypes for the axial flux and radial flux SMPM motors have been developed for validation of proposed method by experimental results. The results obtained from the prototype test motors are validated with the results obtained from the proposed analytical model. Rotor position sensing is an integral part of PM motor drive. A new back-EMF sensing approach .i.e., PM enhanced sensing scheme using shadow coil for the detection of zero crossing of back-EMF has been introduced. The proposed rotor position sensing method also adds fault tolerant feature to the drive and is perfectly suitable for the applications where continuous operation of the motor is highly required in the event of fault in one or more phases.

The two variants of the proposed analytical model viz., isotropic (without slotting effect) and anisotropic model (with stator slotting effect) have been discussed. The experimental results show a good agreement with that obtained from the proposed method. The proposed model gives a good accuracy with negligible computation time for the prediction of magnetic field and the performance characteristics of the SMPM motor simultaneously.

The whole work has been divided and presented in five chapters. The introductory chapter- **Chapter 1** gives an introduction to PM machines, its various topologies and the necessity of modeling of the PM machines. A brief review of literature survey on the methods of analysis of PM machines reported has been presented. Based on the problems persisting in present methods of analysis, the motivation of the present work has been sketched out. The scope of the present work has been outlined.

In **Chapter 2,** a discussion on the selection of the methods of analysis has been reported. Depending on literature presented in the present Chapter for the analysis of SMPM machines, the basis of the proposed method has been laid down. The assumptions and boundary conditions required for the proposed method are reported and calculations for the two different types of model have been completed. A slot/pole slotted model for the calculation of cogging torque is also discussed in the chapter.

Chapter 3 deals with the design, fabrication and operation of the SMPM machines developed for the validation of the proposed method. The prototypes for RFSMPM and AFSMPM machines with different number of slot-pole combinations have been fabricated and operated using PM Enhanced Sensing Scheme. The preliminary results obtained from the prototype have been discussed.

The results obtained from the proposed approach with two different variants have been compared with that obtained from the prototypes and are shown in **Chapter 4**. The characteristics and results obtained from the proposed model have been validated. The mechanical constraints in the development and fabrication of the RFSMPM and AFSMPM motors have also been included.

Chapter 5 briefs the research contributions and importance of the work presented in the thesis. Chapter wise summary of the work and suggestions for the future work have been mentioned.