Chapter 9
Chapter 9
Conclusions and Scope for Future Work

9.1 Summary

The drive system investigated in this dissertation consists of a PMBLDC motor fed from a three-phase inverter and coupled to a mechanical load and operated in a closed loop configuration through a controller. The inverter produces a switching waveform, which is applied to the machine terminals. The resulting fundamental phase voltages are determined using Fourier series expansion for analyzing the machine behaviour.

A dynamic d-q axis model required for investigating the steady state and transient performances of the drive system has been developed. An important step here is to relate the dc link voltage with the d-q axis voltages. The model of the energy conversion process in terms of d-q axis currents, the developed torque and the rotor speed is formulated. This defines the forward block of the control system, with the rotor speed as the output variable. Since the machine is self-synchronous and the speed is variable, it is controlled by varying the dc link voltage.

The mathematical solution for the steady state speed of the machine for various dc link voltages under different load torque conditions has been obtained, though the torque balance equation itself is nonlinear in speed. This may be termed as the open loop characteristic of the PMBLDC motor, from which the torque speed
characteristic is also deduced for different dc link voltage values. Further, the solution is extended for closed loop steady state operation using a proportional speed controller for different settings of the reference speed and loading conditions. The above analytical results are cross-verified through simulation using SIMULINK toolbox.

In the context of closed loop operation, the transient response of the drive following a load torque disturbance assumes significance. Here the type of the controller plays a crucial role, since any improvement of transient response depends on the controller configuration and parameters. Chapters 6, 7 and 8 present a graded evolution of different types of controllers for the PMBLDC motor based drive system. Starting with a conventional PID controller, optimization of a chosen performance index in the parameter space of the controller and determination of time domain performance of the drive system are dealt with in Chapter 6. It is found that there is good scope for improving the transient performance by ANFIS and Hybrid controllers. These are incorporated in Chapters 7 and 8.

9.2 Original Contributions

The following aspects of the research work are believed to be the original contributions leading to enhanced knowledge of PMBLDC motors and their controllers.

1. A combined mathematical model of the machine and a three-phase inverter using Fourier series analysis and d-q axis theory is developed and
presented. This model enables analysis of the open loop and closed loop performance of the drive system.

2. Performance characteristics covering the open loop behaviour of the PMBLDC motor under variable dc link voltage with load torque as a parameter are obtained analytically. Further, the solution is extended for closed loop steady state operation using a proportional speed controller for different settings of the reference speed and loading conditions. The above analytical results are cross-verified through simulation using SIMULINK toolbox.

3. The mathematical model is extended to include the dynamics of a conventional PID controller. Design of parameters of a conventional PID controller and optimization of the same through an integral-mean-squared-error criterion has been carried out. The investigation of the variation of the performance index and settling time in the PID parameter space reveals the existence of a convex 3-D surface relating the above. The transient response corresponding to the optimal parameters is obtained and is characterized by minimum overshoot/undershoot and settling time.

4. A controller based on Adaptive Neuro-Fuzzy Inference System (ANFIS) to minimize overshoot and settling time following sudden changes in load torque has been developed. This results in major improvements of the transient performance when compared with that of a conventional controller.

5. Further Improvement of transient performance of the drive system is achieved through the introduction of a Hybrid (ANFIS-PI) controller.
Comparison of drive performance corresponding to the three controller types reveals the superiority of the Hybrid controller in quick settling and eliminating steady state error in speed.

9.3 Scope for Future Work

1. The scope for implementation of genetic algorithm in the control problem can be considered, as the mathematical model of the PMBLDC motor drive system is available. Genetic algorithm can be used for the tuning of scaling factors, membership functions and rules of the Fuzzy Logic Controllers.

2. In the context of direct digital control (DDC), it may be worthwhile to develop a digital model of the PMBLDC motor drive system. There is good scope for developing a micro controller or a DSP based intelligent controllers for real time control of the drive system.