ABSTRACT

The permanent magnet brushless DC motor (PMBLDCM), is gradually replacing conventional DC motors and AC motors, due to their compact size, high energy density, silent operation, ease of control, maintenance free operation and high efficiency. Application areas of PMBLDC motor are increasing day by day, due to the availability of high speed processors and advancement in power electronics. In the recent past PMBLDC motors have been used as the most promising motor for low to medium power applications. At present, PMBLDC motors are being used in variety of applications such as aerospace equipment, electrical vehicles, hybrid electrical vehicles, household appliances, toys, power tools, sophisticated position control applications and low to medium power industrial drives.

This research work targets on position sensorless control of PMBLDC motor for various low power applications having variable speed operation also. To obtain the desired rotation in a PMBLDC motor, a three-phase voltage source inverter (VSI) is required to be operated as an electronic commutator based on its rotor position. Generally, a PMBLDC motor is operated with three Hall Effect position sensors for obtaining its rotor positions, according to which the stator power supply is synchronized using VSI. These Hall sensors require accurate position and extra assembly space for installation, thereby increased cost of the motor. Further, they do not perform adequately at higher temperature and when immersed in liquid. Therefore to increase the reliability, acceptability and to reduce the cost and volume of PMBLDC motors, it is desirable to control the motor without Hall sensors, which is known as position sensorless control of PMBLDC motor. There are various methods reported in the literature for estimation of rotor position using the voltage and current waveforms at PMBLDC motor terminals, however, operation of PMBLDC motor in position
sensorless control has not been demonstrated from standstill to the desired speed. Further, a comprehensive drive solution for complete position sensorless operation of PMBLDC motor is yet to be developed, which is the aim of this research work.

The three phase VSI for PMBLDC motor is generally powered from a single phase AC source through a diode bridge rectifier followed by a bulky DC capacitor. This conventional arrangement results in a narrow pulsed AC mains current due to uncontrolled charging of DC link capacitor. This leads to various power quality problems at AC mains such as poor power factor (<0.7), high crest factor (>1.41) and increased total harmonic distortion (THD) in AC mains current (>80%). These power quality problems result in increased losses in the connected systems (transmission lines and transformers) and equipments. Therefore there is an urgent need to mitigate these power quality problems. There are various norms and standards framed by international regulatory authority for power quality such as IEC 61000-3-2, which should be followed for the electric drives. A DC-DC converter employed between the DBR and VSI having control for power factor correction (PFC) has the potential of harmonic mitigation or power quality improvement at AC mains.

There are many DC-DC converter topologies available having single switch that can be used as PFC converter such as buck, boost and buck-boost for low power applications. The mostly used control schemes to improve power quality at input AC mains are current multiplier approach with continuous conduction mode (CCM) and voltage follower approach with discontinuous conduction mode (DCM) operation. The CCM operation of PFC converter requires additional sensors for current and voltage thereby increased control complexity however DCM operation uses only one voltage sensor so reduced control complexity but at the cost of increased switch stress.

In this research work, modeling, simulation and hardware implementation of
position sensorless controlled PMBLDC motor is aimed with power quality improvement at input AC mains so that a complete drive can be developed. The operation of PMBLDC motor in position sensorless control is targeted from standstill condition to any desired speed. The major emphasis is to operate the PMBLDC motor at lower speeds in position sensorless control so that a wide range speed control is possible. The line back-EMF sensing method is used along with alignment of rotor to a known position for starting and speedup. This has reduced many control complexities and resulted in a cost effective solution. Further, to improve the power quality at input AC mains PFC converter fed PMBLDCM operated in position sensorless control is analysed, designed and their performance is simulated on Matlab-Simulink environment. These PFC converters are operated in CCM and DCM operation to achieve improved power quality at input AC mains. A digital signal processor (DSP) TMS320F2812 is used for validation of simulated performance of proposed controllers on a PMBLDC motor rated at 1 kW, 2.2 Nm. It is an easy to use and low cost controller design platform which suits the requirements of PMBLDC motor drives in various applications. The speed control of PMBLDC motor is obtained using DC link voltage control of VSI. The PFC controller and DC link voltage controller along with position sensorless control of PMBLDC motor are implemented from this single digital signal processor successfully.

Test results have validated the simulation results while performing speed control and PFC control in position sensorless operation of PMBLDC motor. The position sensorless operation at less than 2% of the rated speed obtained from this research work using line back EMF of PMBLDC motor has resulted in reduction of control complexity in the complete drive and has consistently shown improved power quality at AC mains in wide range of speed and input AC voltage.