ANALYSIS, DESIGN AND CONTROL OF POWER FACTOR CORRECTION CONVERTERS FED PERMANENT MAGNET BRUSHLESS DC MOTOR DRIVES

By

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CERTIFICATE

It is certified that the thesis entitled "**Analysis, Design and Control of Power Factor Correction Converters Fed Permanent Magnet Brushless DC Motor Drives,**" being submitted by **Mr. Sanjeev Singh** for award of the degree of **Doctor of Philosophy** in the Department of Electrical Engineering, Indian Institute of Technology Delhi, is a record of the students own work carried out by him under my supervision and guidance. The matter embodied in this thesis has not been submitted for award of any other degree or diploma.

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ABSTRACT

In the quest of energy efficiency improvement, researchers have developed many new electrical machines and permanent magnet brushless DC motors (PMBLDCMs) are one of them. Their high efficiency, silent operation, compact size, high reliability and low maintenance features make them a suitable choice for many industrial, commercial and domestic applications. The advancement in geometries and design innovations has made possible the use of PMBLDCMs in any shape and size to fit many of the domestic, commercial and industrial applications. At present, PMBLDCMs are finding applications in diverse fields such as household appliances, automobiles, transportation, aerospace equipments, power tools, toys, healthcare equipments, sophisticated position control applications and medium size industrial drives.

This research work aims on the power factor correction in the PMBLDCM drive for various low power applications with speed control. The PMBLDCM requires a three-phase voltage source inverter (VSI) to be operated as an electronic commutator based on the rotor position signals of the PMBLDCM obtained using Hall effect sensors. The three-phase VSI of the PMBLDCM drive (PMBLDCMD) is fed from a single-phase AC mains through a diode bridge rectifier followed by a smoothening DC capacitor, which draws an uncontrolled charging current resulting in a pulsed current from AC mains, thereby, many power quality (PQ) disturbances arise at AC mains such as poor power factor (PF), increased total harmonic distortion (THD) of AC mains current and its high crest factor (CF). Moreover, various international standards such as IEEE 519, IEEE 1159 and IEC 61000-3-2 impose strict limitations on the harmonic current emissions by various loads. Therefore, power factor correction (PFC) converter based drive is essential for a PMBLDCM in most of small rating domestic and commercial applications.

The selection of a PFC converter for feeding PMBLDCMD needs emphasis on conformity to the PQ norms, cost, and performance of the controllers. There are many DC-DC converter topologies available which can be used as PFC converters such as buck, boost and buck boost converters with single switch, two-switch and four-switch converters with and without high frequency transformer to name a few, forward, flyback, Cuk, SEPIC, Zeta, Push-pull, Half-bridge and Full-bridge converters. The mostly used control schemes for PFC converters are current multiplier control with continuous conduction mode (CCM) and voltage follower control in discontinuous conduction mode (DCM) of operation. The current

multiplier control uses average current control strategy and yields good results as compared to the voltage follower control. However, the voltage follower control requires less number of sensors and has reduced control complexity.

In this research work, analysis, design and control of PFC converters for improvement of power quality at AC mains are aimed for a PMBLDCMD. The other major emphasis of the investigation is on simple control, reduced number of sensors and circuit components, leading to reduction in overall cost. A wide range of PFC converter configurations for PMBLDCMs are analyzed, designed and their performance is simulated for various applications. For the possibility of sensor reduction in the existing PFC converter fed PMBLDCMD, a novel DC link voltage control scheme is analyzed, designed and implemented to demonstrate effective speed control of the PMBLDCM along-with improvement in PQ at AC mains. These PFC converters are further investigated in DCM operation with possible reduction of various sensors for PMBLDCMD.

A digital signal controller (DSC) dsPIC 30F6010 is used for validation of simulated performance on a 2 hp, 5.2 Nm rated PMBLDCM. It is an easy to use and low cost controller design platform which suits the requirements of PMBLDCMDs in various applications. Test results have validated the simulation results while performing speed control and PFC control from a single processor. The DC link voltage control scheme has evolved out of this research work for the speed control of PMBLDCM which has resulted in reduction of sensors in the PMBLDCMD and has consistently shown improved power quality at AC mains in wide range of speed and input AC voltage.

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