CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The two major challenges on which the improvements required for the permanent magnet brushless DC motor drive systems are:

a) Harmonics present in the voltage and current input to the motor

b) The torque ripple present in the output of the motor

Research works are being extensively carried out in the area of harmonics minimization in power system, motor drives and other nonlinear applications. Different techniques and different filtering methods are adopted to minimize the Total Harmonic Distortion (THD) and the torque ripple of the motor drive system. This thesis concentrates on minimizing the harmonics present in the input of the brushless DC motor and the possible methods of reducing the torque ripple output for enhancing the performance of the motor. This chapter discusses the related research works carried out by researchers on reducing the harmonics and torque ripple of the brushless DC motor.

2.2 HARMONICS MINIMISATION

Current and voltage harmonics become a real problem to be addressed in motor drives in order to enhance the performance of the motor. Due to the power electronic commutator present in the drive system of BLDC
motor, the fundamental component of the stator current and voltage are combined with harmonic components. The fundamental frequency of the power system will be constant irrespective of applications. But in the case of motor drives (BLDCM), the fundamental frequency will vary with the instantaneous speed of the motor.

Various filter topologies are suggested by researchers for filtering the harmonic components present in the voltage and current input of the motor. Passive filters are the low cost solution for reducing the current harmonics in the motor drive applications. Gulez et al (2008) presented an active filter (AF) topology to reduce the torque ripple and harmonic noises in a permanent-magnet synchronous motor. The active filter is designed to detect the harmonics in the motor phase voltages by comparing the measured phase values with the reference voltages. The reference voltage is generated as a function of the motor parameters and the field-oriented control is performed. This active filter uses the hysteresis voltage control method, while the motor main circuit uses the hysteresis current control method and both the control methods independently work together to provide an almost sinusoidal voltage to the motor windings. Harrori et al (2001) and Kim et al (2002), suggested a suspension control method for motor frame vibration and rotational speed vibration of Permanent Magnet Synchronous Motor (PMSM) by utilizing the feed forward compensation control signal that suppress the harmonics. These techniques are applied for sinusoidal voltage/current profile PMSM.

Soft switching techniques are adopted for minimizing the switching losses of the power electronic commutation systems. Pan & Luo (2005) proposed a resonant pole inverter for Brushless DC motor drive system for obtaining sinusoidal current and voltage profile. Resonant pole inverters are applied for reducing the harmonics and to improve the smooth torque profile
of the BLDC motor. The resonant converters are having higher complexity in controllers and uses additional components to employ Zero Voltage Switching and Zero Current Switching to enhance the performance of the inverter. This includes the additional cost and complexity of the controller and the drive system.

Ambrish et al (2000) proposed that the Shunt active filters (SAF) are the ideal choice for nonlinear systems for reducing the harmonics and to improve the power quality. These techniques are applied to the sinusoidal voltage and current profile applications with a fixed frequency of operation. But a difficulty arises when applying the SAF for variable speed drives, trapezoidal voltage and current profile applications like Brushless DC motor and so on. Singh et al (2006) emphasized that the SAF can be effectively utilized in non sinusoidal current systems for minimizing the current harmonics. Saad & Zellouma (2009) expressed that the filtering performance of the SAF can be improved by multilevel inverter with DC link capacitors and line inductors which forms the multilevel SAF for effective minimization of harmonics. The performance increases while using a multilevel inverter as the SAF. Cheng & Yuan (2000) emphasized that the SAF exchanges the energy between the phases and average power absorbed by the SAF is zero. Due to the presence of reactive elements like an inductor and capacitor in the SAF, the power shall not be dissipated in SAF, instead it just exchanges energy between phases.

Multi level inverters are extensively used in inverter systems for improving the voltage profile. Rodriguez et al (2002) presented a survey on multilevel inverters with different topologies and applications. This gives a better understanding the possibilities of applying a three level diode clamped inverters with suitable modifications for a brushless DC motor applications. Zare et al (2011), Bouhali & Rizoug (2013), Jouanne et al (2000) suggested
different topologies of multi level, inverters for fixed frequency applications. The difficulty arises when applying the multilevel inverter for variable frequency applications. Akagi & Tamura (2004) presented a 400V three-level diode-clamped inverter with a passive filter for an adjustable-speed motor. A three level inverter cascaded with a passive filter for an asynchronous motor application is discussed where the fundamental frequency of the supply is constant. It is suggested that a low pass filter with the multi level inverter in cascaded form shall reduce the higher order harmonics.

2.3 TORQUE RIPPLE MINIMISATION

Permanent Magnet Brushless DC (PMBLDC) motor drives are preferred in high performance and high precision applications where steady torque output is essential. The electronic commutator associated with the motor energizes the stator with reference to the instantaneous position of the rotor. The commutation torque ripple occurs in every 60° electrical degrees changing over of the stator current from one phase to another. The commutation torque ripple affects the performance of the motor for the wide range of speed and load conditions.

Kenjo & Nagamori (1985), Sokira & Jaffe (1989) and Hendershort & Miller (1994) discussed the construction, electro mechanical characteristics and torque analysis of the BLDC motor. Ki-Yong et al (2006) have proposed a system, in which the torque ripple of a BLDC motor is reduced by varying input voltage. The proposed method varies the input voltage to reduce the current ripples causing the torque ripples in the conduction region. Other methods eliminate the conduction torque ripple in the BLDC motor using a cascade buck converter.

Joong-Ho & Ick (2004) have proposed a method using a single DC current sensor method for reducing the ripple torque of the BLDC motor. This
method is based on a strategy, in which the current slopes of incoming and outgoing phases during the commutation interval can be equalized by proper duty-ratio control. The method shows a suppression of the spikes and dips superimposed on the current and torque responses during the commutation intervals.

Han et al (2007) compared the brushless DC motors with 180/120-degree inverters and the average-value modeling of these systems. The commutation torque ripple comparison is done on both 120 and 180 degree mode of conduction in three phase inverter systems.

The ripple torque of the motor is directly related with the ripple current of the motor, if current can be controlled properly, the BLDC Motor torque ripple can be minimized effectively. They described the method of hybrid commutation, both 60° and 120° electrical, combined that the torque ripple can be minimized. Also Liu & Zhu (2007) derived a method for commutation torque ripple minimization in direct torque controlled PMBLDC drives. Husain & Ehsani (1996) proposed a torque ripple minimization in switched reluctance motor drives by PWM current control. The strategy of the PWM current control includes a current control strategy during commutation, in which torque ripple minimization is performed for low-speed switched reluctance motor drives.

Sathyan et al (2009) proposed a digital PWM controller for a BLDC motor. The BLDC system is only allowed to operate at a low duty (DL) or a high duty (DH). Speed regulation is achieved by alternating between low duty and high duty ratio. Only two steps variation of duty ratio, and the design is simple. The torque ripple is still to be minimized and the performance to be enhanced.
Roque et al (2008) implemented an FPGA based higher degree polynomial acceleration profile for peak jerk reduction in servo motors. A hardware polynomial based profile generator was used for minimizing the torque ripple. This methodology is applied to the sinusoidal voltage and current profile motors and not on the trapezoidal profile motors such as BLDC motors.

Singh & Kuldip (2003) and Monmasson & Cirstea (2007) emphasized that FPGA based systems are flexible and can be reprogrammed unlimited number of times. The digital implementation of industrial control system such as field programmable gate arrays (FPGAs) can also be considered as an appropriate solution in order to boost the performance of the controllers. Kos et al (2006) suggested that BLDC motor is well suited for digital control methods. Thus FPGA based controller is ideal for controlling this motor characteristic.

2.4 CONCLUSION

The work done by different authors are focused on the harmonics minimization in power system applications or in the sinusoidal profile systems. But a few works are done on the possibilities of minimizing harmonics and torque ripple in Brushless DC motor drive system. Most of the experimentation done on minimizing the harmonics is on the supply side of the motor drive system which concentrates on the power quality enhancement of the power system. Moreover the power system based experimentations are done on the fixed power frequency.

The research works presented in this thesis concentrates on the minimization of harmonics present in the voltage and current input of the permanent magnet BLDC motor that is supplied from the voltage source inverter which acts as the commutation circuit. It also concentrates on the
minimization of the torque ripple output of this motor. This research work is distinct from the other research works because of the variable frequency application, which is due to the variation of the fundamental frequency of voltage and current with reference to the speed of the motor. The forthcoming chapters discuss on various experimental methods adopted for reducing the harmonics and torque ripple for the variable frequency trapezoidal voltage and current profile brushless DC motor. The next chapter discusses the effect of simple cost effective passive filter in enhancing the performance of the brushless DC motor.