Design and Implementation of Six Switch Three Phase Inverter BLDC Motor Drive for Commercial Applications

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***ABSTRACT*— This paper proposes a six switch three phase inverter (SSTPI) fed BLDC motor drive for commercial applications. BLDC motor having high efficiency, compact size, rugged construction, reduces mechanical strength, high dynamic response. The 120 degree mode generation used for switching the SSTPI. Thereby, the speed adjustment of three phase BLDC motor drive can be easily obtained. The objective of using SSTPI for three phase BLDC motor drive is that the third harmonics and its corresponding multiples are carried out in the output and ripple voltages is less comparing to single phase inverter. This proposed system is developed for commercial applications such as refrigerators, air conditioning systems, CPU cooling fans, CD/DVD players.This type of three phase BLDC motor drive system is developed and analyzed using MATLAB/SIMULINK in which effective results can be carried out successfully.**

Keywords: BLDC motor drive, Six Switch Three Phase Inverter (SSTPI), 120 degree mode generator,Hall sensor

I. INTRODUCTION

In recent years BLDC have been widely used in commercial applications. The BLDC motor has many advantages over induction motor and brushed DC motor [2], [13]. The three phase BLDC motor consist of three phase stator windings and permanent magnet rotor and BLDC motor have trapezoidal back EMF.

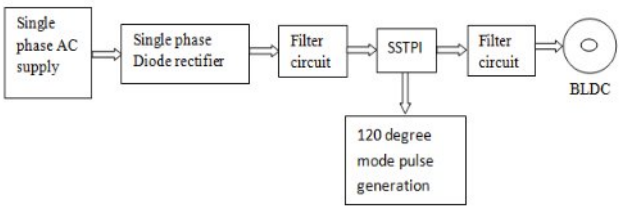

Figure 1: Block diagram of proposed system

The proposed system is single phase to three phase AC-AC conversion and its objective is reducing the DC link voltage fluctuation [1], [18].The new control scheme is used to single phase to three phase system, which eliminate the DC link voltage ripple on the SSTPI output current [7], [18]. This system consists of single phase diode rectifier (uncontrolled rectifier), which converts AC power to DC power. The output of this DC power is given to SSTPI through filter circuit[15], [19]. This filter circuits are used to reduce the harmonics. This SSTPI has three legs with a pair of complementary power electronics switches per phase. This SSTPI having the 120 degree mode gate pulse generation which leads to the conversion of DC power to Ac power conversion system with desired output voltage and frequency. This AC power is fed to the BLDC motor drive operation. In normally the inverter side filter is reduce the high frequency harmonics.

II. ANALYSIS OF A SSTPI-BLDC MOTOR DRIVE

The BLDC motor can be analyzed mathematically in abc phase variable model. The configuration of a six-switch three phase inverter (SSTPI) BLDC motor is shown in below figure 2.

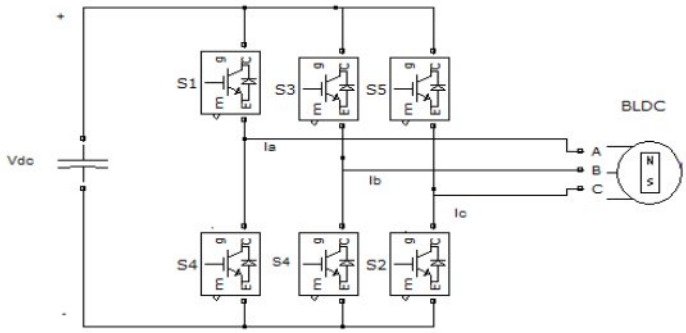

Figure 2: Six switch three phase BLDC motor drive

The BLDC motor represented as below equations

$$\text{(1)}$$

$$\text{(2)}$$

$$\text{(3)}$$

- Three phase voltages
R - Resistance
i_a, i_b, i_c - Three phase currents
L_s - Self inductance
M - Mutual inductance
-Three phase back EMF

The electromagnetic torque is

$$\text{(4)}$$

- Mechanical speed of rotor
- Electromagnetic torque

The mechanical speed for BLDC motor

$$\omega_r = \frac{\omega_m}{P} \quad (5)$$

P - Number of pole pairs

The rotor angle is

$$\theta_r = \int \omega_r dt \quad (6)$$

The instantaneous induced EMF is obtained as

$$e_a = f_a(\theta_r)\omega_r K_e \quad (7)$$

$$e_b = f_b(\theta_r - \frac{2\pi}{3})\omega_r K_e \quad (8)$$

$$e_c = f_c(\theta_r + \frac{2\pi}{3})\omega_r K_e \quad (9)$$

ω_r - Rotor mechanical speed

The back EMF and three phase current used to torque calculation. The rotor speed is proportional to the shape function [9], this shape function and stator current is utilized. So the torque calculation is easily performed [11-12].

III. SIX SWITCH INVERTER FOR BLDC MOTOR DRIVES

In 120 degree pulse generation control signal, each IGBT switches conducts for 120 degree [2], [8]. The 120 degree mode conduction gate signals are shown in below figure 3.

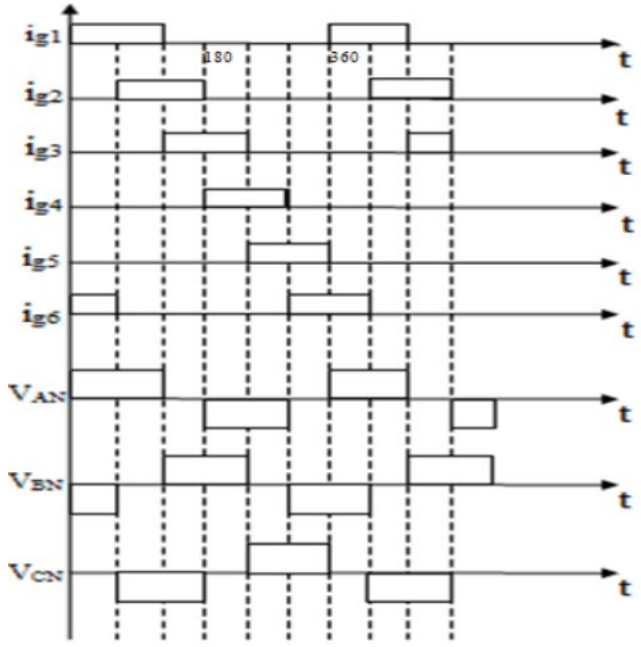

Figure 3: 120 degree conduction mode pulse generation

Only two IGBT switches remain on at any instant time. The conductance sequence of IGBT switches is 61, 12, 23, 34, 45, 56 and 61. There is a delay of 30 degree between the turning off s1 and turning on s4. Thus, there should be no short circuit of the DC supply through one upper and one lower switch. At any time, two load terminals are connected to the DC supply and third one remains open. The potential of this open terminal depends on the load characteristics and would be unpredictable.

SIMULATION AND RESULTS

The implementation of six switch three phase BLDC motor drive system in simulink is shown in figure 4.

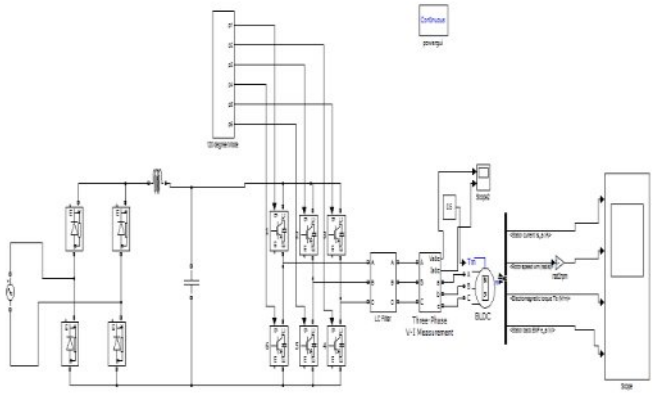

Figure 4: Simulation of SSTPI fed BLDC motor

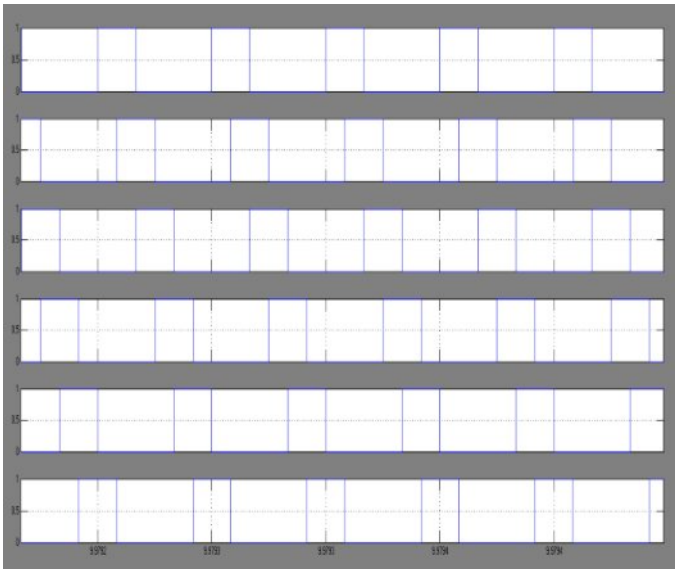

Figure 5: 120 degree mode pulse generation

The performance parameters such as output voltage and output current waveforms of SSTPI motor are given by the following figures 6-7.

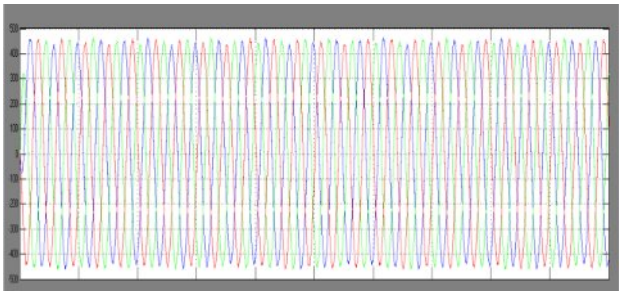

Figure 6: Three phase output voltage waveform of SSTPI

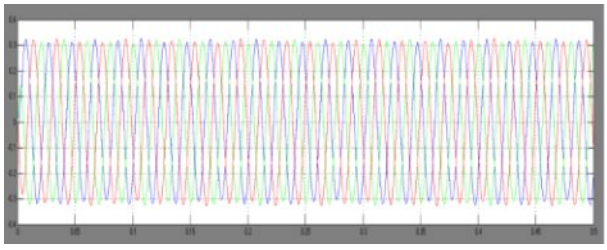

Figure 7: Three phase output current wave form of SSTPI

Stator current, rotor speed, torque and back EMF waveforms of BLDC motor are given by the following figures 8-11.

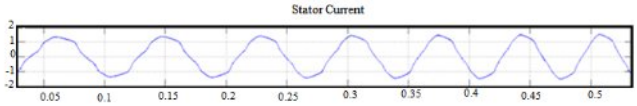

Figure 8: Stator current of BLDC Motor

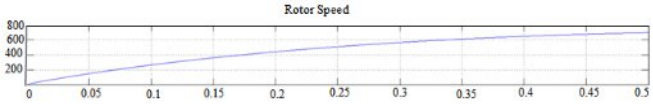

Figure 9: Rotor Speed of BLDC motor

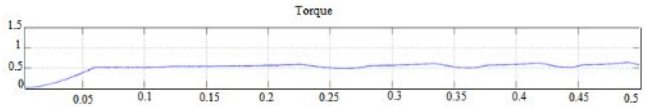

Figure 10: Torque of BLDC motor

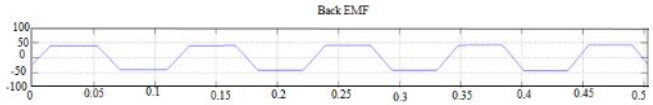

Figure 11: Back EMF of BLDC motor

The BLDC motor specifications are listed in below Table-I.

TABLE I: MOTOR SPECIFICATIONS

R_s	0.18 [ohm]
L_s	8.5e-3[mH]
J	6.2e-4[kg.m^2]
K_f	0.57[N. m/A]
Z_p	4[pole]
P_n	430[W]
T_n	8[N. m]
K_e	0.62[V/rpm]
M	0.105[mH]

EXPERIMENTAL AND RESULTS

In the hardware system, the PIC microcontroller board and driver circuit board get the power to potential transformer [10]. The single phase diode (uncontrolled) rectifier is used to convert AC power to DC power, and the filter circuit is reducing the harmonics. Six IGBTs are used to SSTPI. The IGBT switch has high input impedance and low on-state conduction loss [3-4], [20]. The output of the SSTPI is connected to 0.5 hp, three phase BLDC motor.

TABLE II: HARDWARE COMPONENTS

Components	Ratings
Inverter	IGBT
BLDC Motor	0.5hp,3phase,50Hz,1500rpm
Microcontroller	16F877A
Rectifier	Single phase diode rectifier

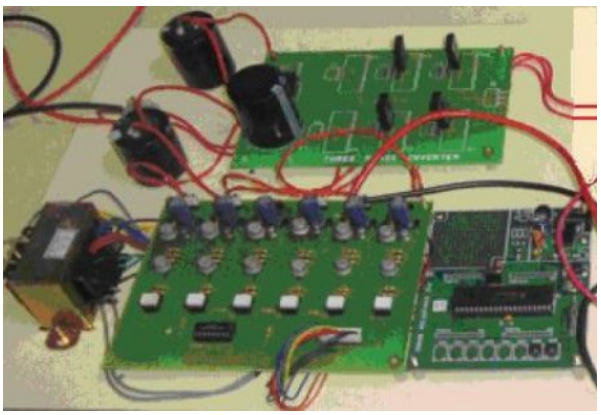

Figure 12: Hardware prototype model of microcontroller based SSTPI

This Proposed system is on low cost back EMF (Electromagnetic force) detection method is using of back EMF zero crossing from the terminal voltages, that is the zero crossing point is directly obtained by detecting the voltage difference between the phase terminal and the midpoint of DC link without sensing the motor neural voltage [5-6], [11], [14], [16]. Hardware prototype model of microcontroller based SSTPI using, the output current of SSTPI, rotor speed, and torque of BLDC motor are given by the following figures 13-15.

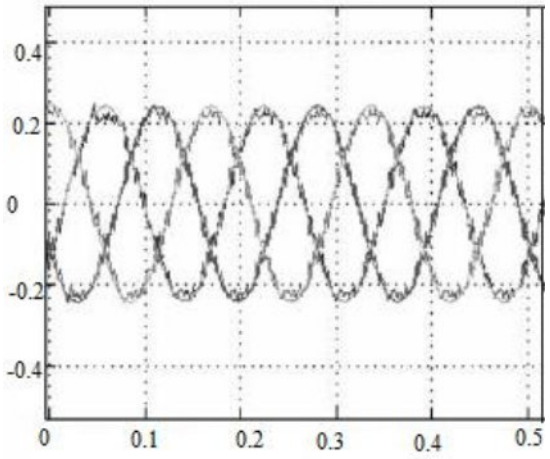

Figure 13: output Current of SSTPI

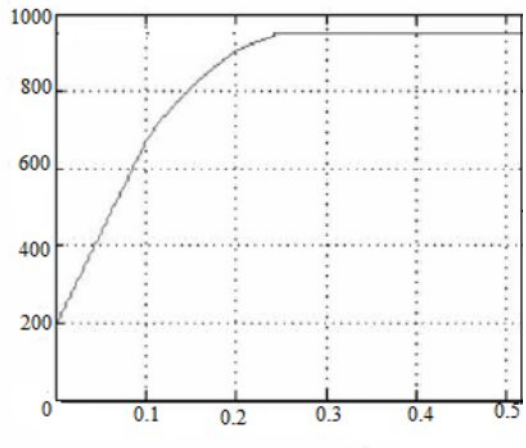

Figure 14: speed of BLDC motor

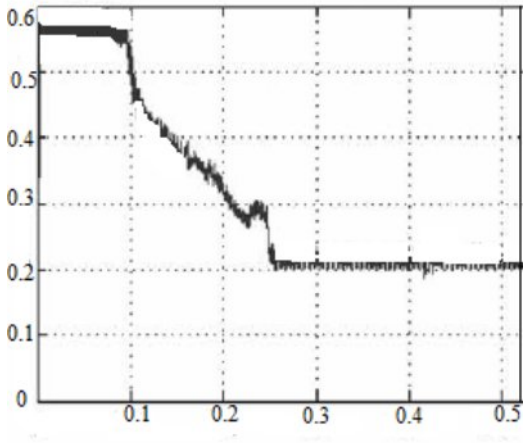

Figure 15: Torque of BLDC motor

CONCLUSION

In this paper presented in the PIC microcontroller (16F877A) based 120 degree mode is used for gate pulse generation in the SSTPI fed BLDC motor drive. The simulation and hardware implementation results are verify the feasibility of the system. The implementation of the proposed work is practically used to commercial applications.

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