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Simulation and Hardware Implementation on Power Factor Improvement of BLDC Motor Drive using Boost PFC Converter

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Abstract: This paper presents brushless dc (BLDC) motor drive with boost power factor correction to overcome power quality problem at AC mains. Boost PFC converter is applied to achieve unity power factor at AC mains. A reduction in harmonics is also observed. Here we are analyzing a conventional BLDC motor drive and comparing with Boost PFC based BLDC motor drive and expected improvement in overall power factor is seen. In this paper we simulate two cases of BLDC motor drive with and without PFC converter using Matlab/Simulink. The unity power factor improvement achieved was verified by hardware implementation and testing.
Keywords: BLDCM, Power Factor Correction(PFC), THD, Boost converter

I. INTRODUCTION

Better reliability; lower electric noise and durability are some of the features behind popularity of BLDC motor over past few decades. Along with these, wide speed range; better efficiency are some of the additional features but their use needs specially designed control circuits for their operation. In general, electrical noise is the product of the strong sparks that tend to occur in places where the brushes cross the gaps in the commutator and therefore not desirable for certain applications where electrical noise cannot be tolerated.

The implementation of BLDC motor requires properly placed Hall Effect sensors. Rotor position is obtained with respect to stator of motor by hall effect sensors. They produce digital signals (high and low) based upon which a voltage source inverter (VSI) is operated. Thus the commutation of BLDCM is totally electronic. The low power BLDC motor drive consist of single phase AC supply, diode bridge rectifier (DBR) followed by DC capacitor and voltage source inverter [2]

A PWM-based BLDCM drive for speed control is shown in fig.1. The current from AC mains drawn by the BLDC motor is not of pure sinusoidal, as it is driven by a rectifier circuit with uncontrolled charging of DC link capacitor. If the diodes are forward biased, it means the AC voltage is greater than the rectified DC voltage. Therefore rectifier draws large current from AC mains with THD of the order 65-70% and low power factor is in range of 0.7-0.72 [2]. Such power quality catalogues are not within the limits imposed by standard IEC 6100-3-2[3]. Using power factor optimization methods [4-5], these limitations of the rectifier circuit can be corrected for improved performance of BLDCM drive. As a PFC converter, a boost converter is used. It is connected between the VSI and DBR. It is output voltage is controlled

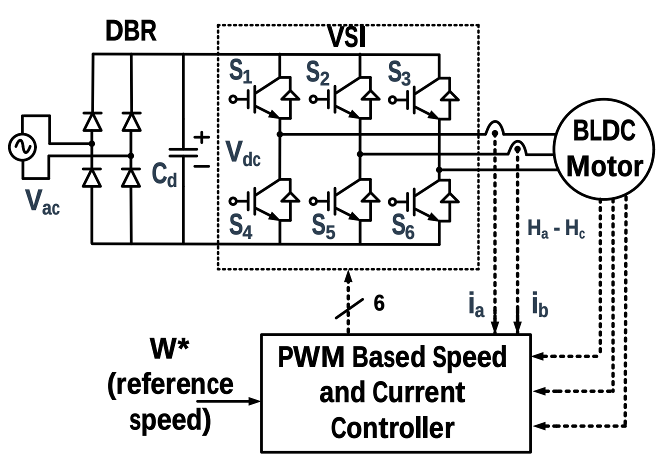

Fig. 1.Conventional DBR fed BLDC motor drive by PWM switching, results in enhancement of power quality at AC mains [6].

The overall result is better performance of drive such as reduction in THD of AC mains current, acoustic noise and reduction of electromagnetic pollution, less number of component, better efficiency, maximum voltage range utilization. Due to simple construction and minimum component requirement, the topology of the boost converter is selected in this work.

There are two modes of operation of PFC converter discontinuous conduction mode (DCM) and continuous conduction mode (CCM) [6]-[8]. CCM-operated PFC converter provides low stress on converter switches but includes sensing of supply side voltage as well as current and dc link voltage. This requires three sensors that are an expensive option and therefore preferred for applications with high power ratings.

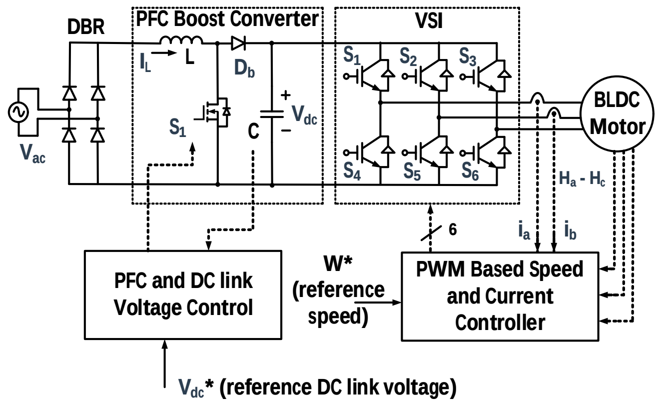

Fig. 2.BLDCM drive based on Boost PFC

PFC converter operating in DCM mode, however, requires only one voltage sensor to regulate dc link voltage. There is a trade-off between the improvement of the inherent power factor and high stress on PFC converter switches. Thus DCM mode of operation is limited to low power application. To improve the power quality (PQ) at AC mains, a Boost PFC converter feeding the BLDCM drive is proposed by Ozturk et al and Wu and Tzou [9-10]. In boost converter topology, the dc link capacitor maintains constant value of voltage. The speed of BLDCM is controlled by PWM-based switching of VSI. The common methodology of the boost PFC converter is to turn switch (S_w) ON and Off rapidly to change the duty cycle in order to make input AC mains current sinusoidal and in phase with the input voltage.

II. DESIGN CRITERIA OF BOOST CONVERTER

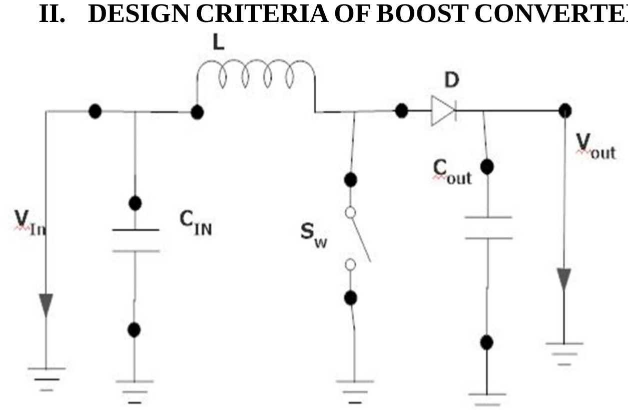

Fig 5. Boost converter power stage

In Fig 5 shows basic configuration of boost converter where switch is integrated used IC. For the calculation of power stage following parameter is used [11]

1) Input voltage range: $V_{IN(min)}$ and $V_{IN(max)}$
2) Rated output voltage V_{out}
3) Maximum output current $I_{out(max)}$
4) Integrated circuit (IC) used to build boost converter

A. Maximum Switch Current Calculation

Duty cycle (D) is determine for minimum input voltage as it results into maximum switch current

$$D = \frac{V_{IN(min)} * \eta}{V_{out}} \qquad (1)$$

Where η=80% (efficiency of converter) which gives realistic duty cycle. The next step in determining the maximum switch current is to evaluate the current ripple of the inductor. Use the specific inductor value or range of inductor value which is compatible to IC given in the data sheet.

$$\Delta I_L = 1 - \frac{V_{IN(min)} * D}{f_s * L} \qquad (2)$$

f_s = minimum value of switching frequency

L = selected value of inductor

Maximum output current for selected IC is,

$$I_{max(out)} = (I_{lim(min)} - \frac{\Delta I_L}{2}) * (1 - D) \qquad (3)$$

$I_{lim(min)}$= Integrated switch's minimum value of current limit (given in data sheet)

ΔI_L= Current ripple of inductor in (2)

D = Duty cycle calculated in (1)

IC having higher switch current is used provided $I_{max(out)}$ for designated IC is less than circuit required maximum output current. Increase in maximum output current as ripple current reduces by higher value of inductance.

Provided calculated value is above the maximum output current of application, the maximum switch current is given as

$$I_{sw(max)} = \frac{\Delta I_L}{2} + \frac{I_{max(out)}}{1-D} \qquad (4)$$

ΔI_L = inductor ripple current

$I_{max(out)}$= maximum output current of application

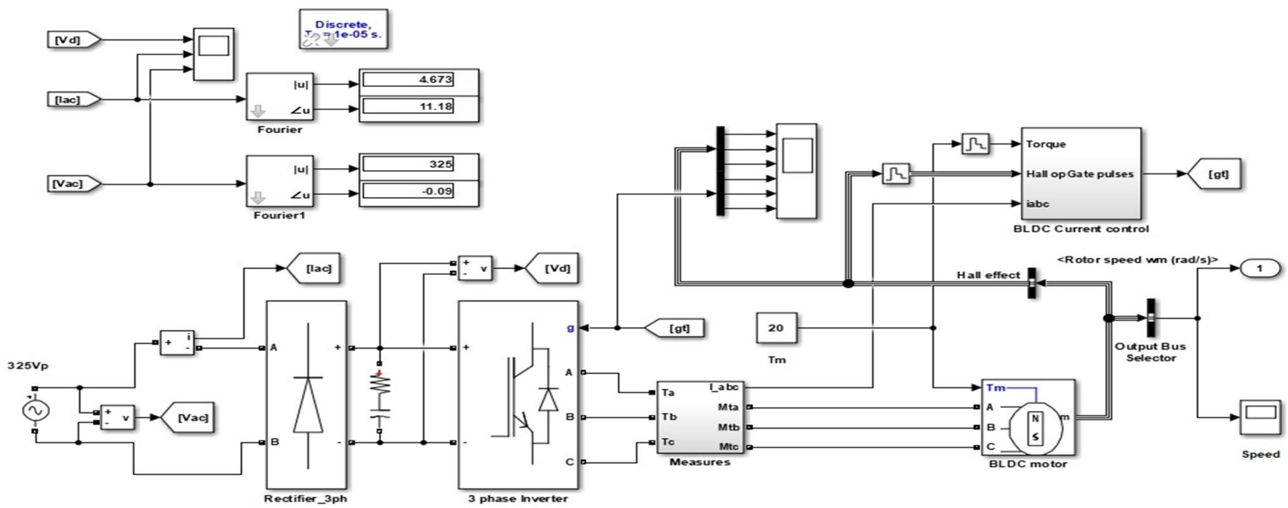

Fig. 6 Simulink model of BLDC motor drive without PFC

This is peak current value need to withstand by inductor, integrated switch and external diode.

B. Inductor Selection

The inductor can be chosen from range given in data sheet. High value of inductor means maximum output current as small amount of ripple current. Following formula can be used if inductor range is not given.

$$L = \frac{V_{IN} * (V_{out} - V_{IN})}{\Delta I_L * f_s * V_{out}} \qquad (5)$$

The ripple current of the inductor can be measured as 20% to 40% of the output current.

$$\Delta I_L = (0.2 to 0.4) * I_{max(out)} * \frac{V_{out}}{V_{min}} \qquad (6)$$

C. Selection of Output Capacitor

It is recommended to use small equivalent series resistance (ESR) capacitor to minimize the ripple in the output voltage. The following formula with external compensation is used to change the value of capacitor required to obtain the desired output voltage ripple.

$$C_{out} = \frac{I_{out(max)} \times D}{f_s \times \Delta V_{out}} \qquad (7)$$

f_s = switching frequency

ΔV_{out}= desired output voltage ripple

III. MATLAB SIMULATION AND RESULT

MATLAB/SIMULINK used to simulate BLDCM drive.

A. BLDCM Drive Without PFC converter

Fig. 6 shows the Simulink model of BLDCM drive without PFC. Source voltage with source current waveform of BLDCM drive without boost PFC converter is shown in fig 7. Harmonics are observed by input source current. The nature of source current is peaky. In the fig. 8 the DC bus voltage of BLDCM drive is shown. The fig. 9 display three phase stator current taken by BLDC motor. Fig 10 shows the speed of BLDCM. Fig. 11 shows torque produced by BLDCM. Source current contains harmonics which results in high value of THD shown in fig 12.

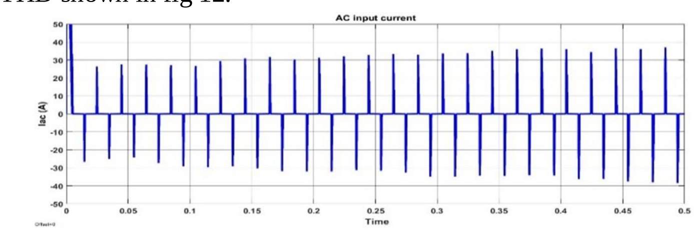

Fig. 7 Source voltage and source current waveforms without Boost PFC

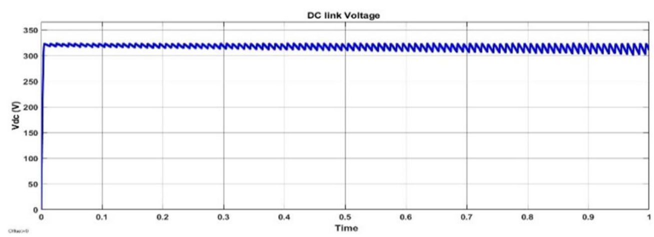

Fig. 8 DC bus voltage

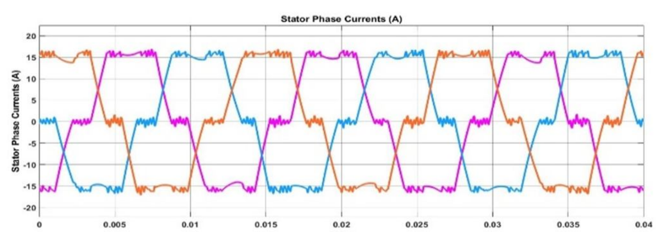

Fig. 9 Stator phase currents of BLDCM drive without Boost PFC

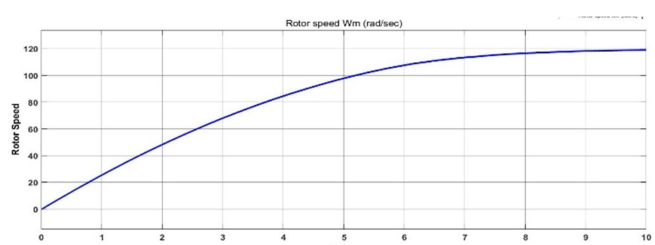

Fig. 10 Speed of BLDCM drive

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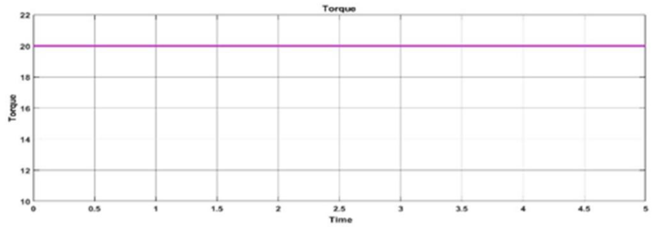

Fig. 11 Torque of BLDCM without PFC converter at starting

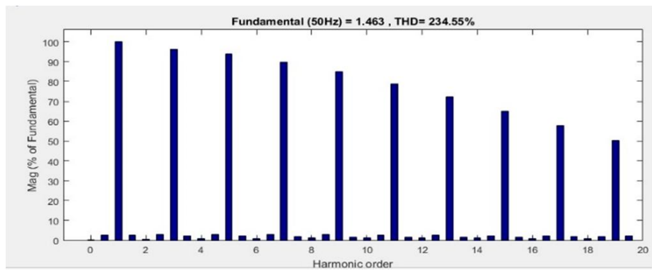

Fig. 12 THD of source current without PFC converter

Fourier block extracts the magnitude as well as phase angle of fundamental frequency source current and voltage. It is seen that difference in phase angle is 21.7 degree.

B. BLDC Motor Drive with Boost PFC

In Fig.13 shows Simulink model of the Boost PFC based BLDCM drive. BLDCM drive is driven by VSI, feeded by single phase AC mains supply followed, a rectifier circuit and boost converter. The boost converter is functions as inherent power factor pre-regulator, operating in DCM mode. Fig. 14 shows Simulink model of power factor controller and current envelope generator. This block generate sinusoidal current envelope such that supply side current get vary accordingly resulting in phase with supply voltage. Single voltage sensor controls the speed of the BLDC motor by controlling the VSI DC bus voltage. This allows VSI to operate at fundamental frequency switching, resulting in lower switching losses; which are significantly high in a PWM VSI-based BLDC motor drive. The system is intended and its output is tested in order to achieve an increased AC supply power factor. In Fig. 16 indicate that input side supply voltage and current are almost in phase with each other resulting near unity power factor. Fourier block extracts the magnitude as well as phase angle of fundamental frequency source current and voltage. It is seen that difference in phase angle is zero degree which indicate unity power factor.

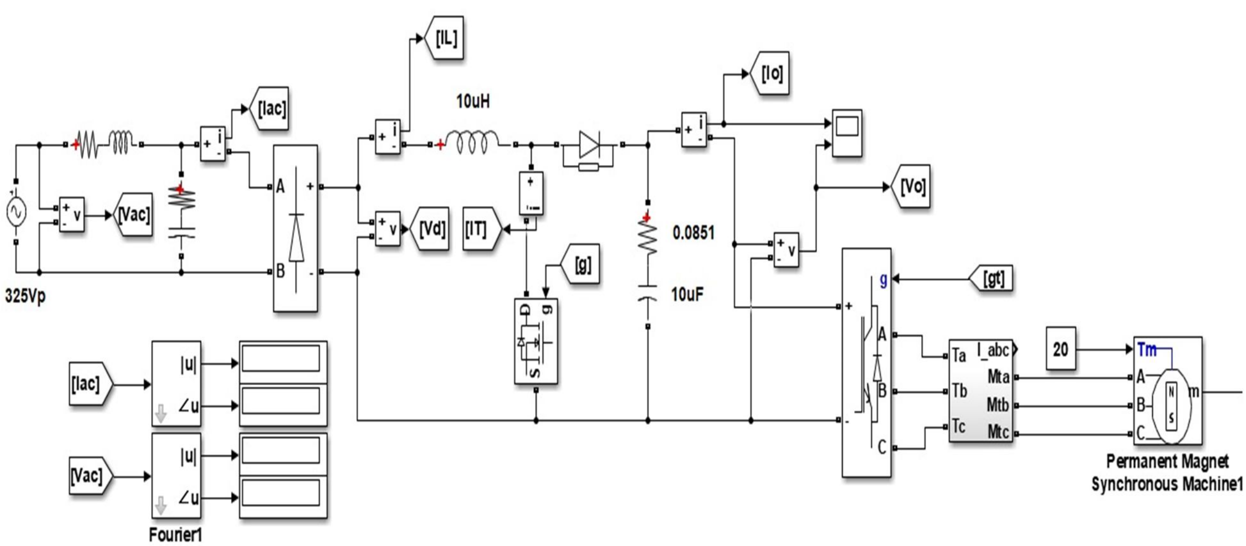

Fig. 13 MATLAB simulink of BLDCM drive with boost PFC

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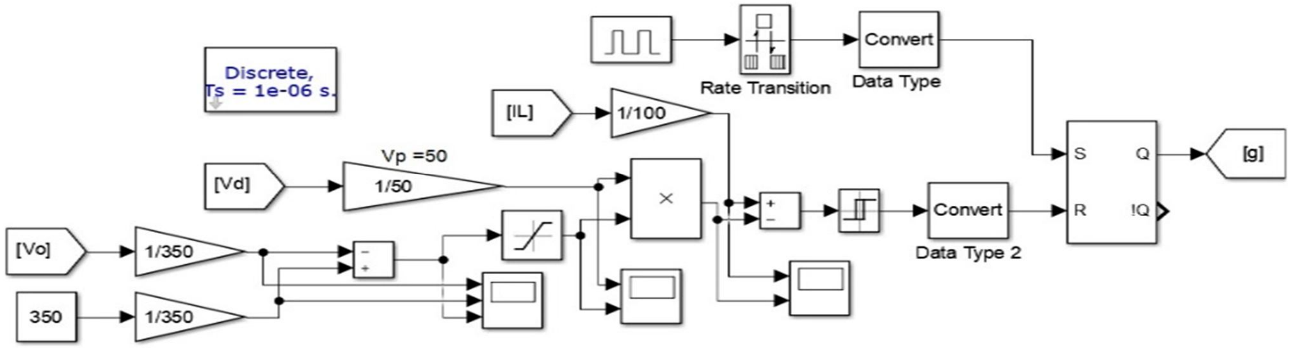

Fig. 14 MATLAB simulink of power factor controller and current envelope generator

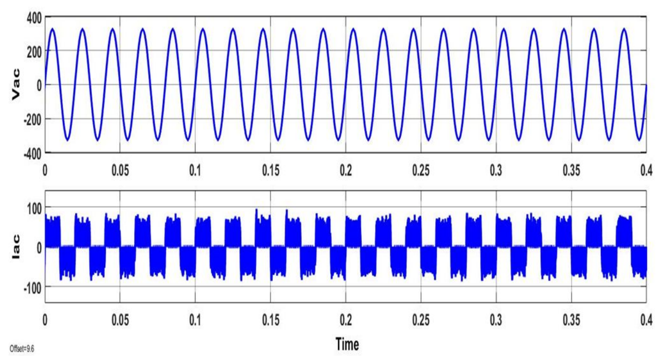

Fig. 15 Source voltage and source current waveforms with boost PFC

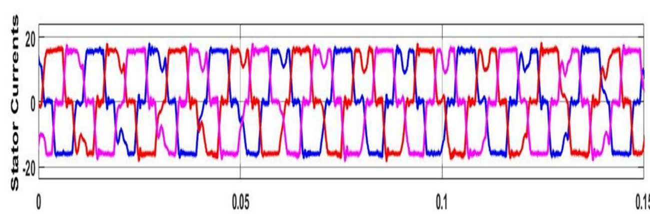

Fig. 16 Stator phase currents of BLDCM drive with boost PFC

IV. HARDWARE IMPLEMENTATION OF BOOST PFC CONVERTER FED BLDC MOTOR DRIVE SYSTEM

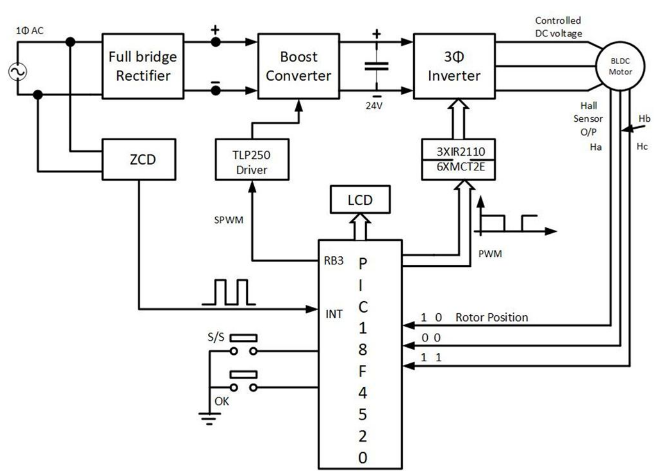

Fig.17 Block diagram of hardware implementation of BLDCM drive with boost PFC

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Hardware setup block diagram of three phase BLDC motor drive system with boost PFC converter is shown in fig.17. Here DC voltage source is full bridge rectifier. DC source gives 5V, 12V and 24V output for the operation of controller, driver and main inverter circuits respectively. Three phase inverter circuits consist of six switches connected in three legs. PIC microcontroller 18f4520 has High Performance RISC architecture, with in built four 16 bit timers, eight channel-10 bit configurable analog to digital controller, 10 bit PWM generator, capture and compare module and many other advanced feature. These advanced features make it useful in all type control application. Microcontroller is used to generate PWM pulses to control on/off time of switching devices in proper sequence based on hall sensor feedback signal. Driver circuit is used to amplify PWM signal. Opto-isolator is used between microcontroller and gate driver of VSI and PFC switch. LCD device is used to display speed and duty ratio of PWM signal and provide interaction between user and system.
PIC microcontroller 18f4520 used to generate PWM pulses at PORTD using its internal TIMER0. It also generates SPWM pulses at RB3 output pin for the boost PFC converter. ZCD output is connected to the interrupt pin of microcontroller. The potentiometer, connected to one of the analog to digital converter channel in PIC microcontroller, is used to set reference speed. Based on this reference input voltage, PWM duty cycle is calculated. PWM pulses of frequency 2.5 kHz is applied to respective gate terminal of inverter switches through gate driver circuit. The hall sensor feedback signal is applied to the PORTE of microcontroller to sense the rotor position.

A. Power Factor Improvement Using SPWM

PWM method is very advantageous to motor control application. The frequency of SPWM pulses generated by microcontroller is 10 kHz i.e. time period of 100microseconds. SPWM signal is synchronized with rectified voltage Vd , resulting AC mains current vary sinusoidaly and in phase with supply AC mains voltage.

V. RESULTS AND DISCUSSION

The hardware setup is shown in fig.18. BLDC motor specification is as shown in table1

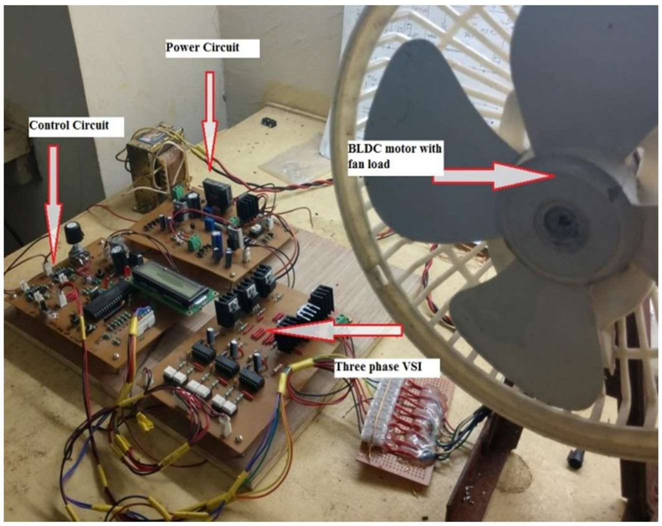

Fig.18 Hardware setup

Table1 BLDC motor specification

Sr. No.	Parameter	Value
1	Rated voltage	24V
2	Rated power	37W
3	Rated speed	3000rpm
4	Impedance	R=0.1Ω, L=1.2mH
5	Number of poles	4
6	Frequency	50Hz

The test result of presented model is as follows

The performance of BLDC motor drive on rated source voltage, designed load at BLDC motor and DC link voltage of 200V is shown in Fig 19.

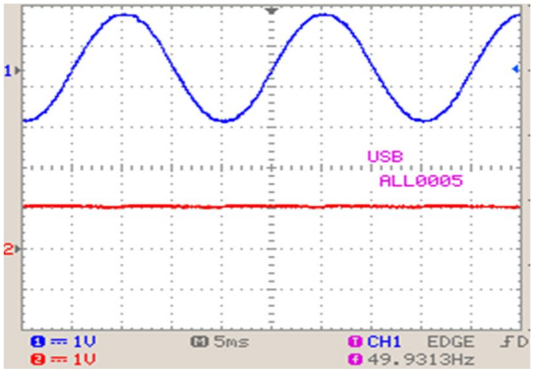

Fig.19 supply AC mains voltage and boost output voltage

The motor hall sensor signal are obtained is shown in Fig.20.

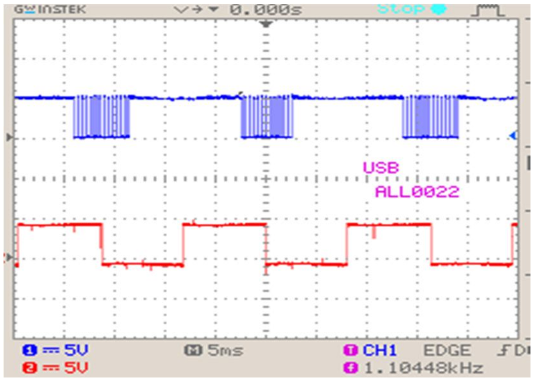

Fig.20 BLDC motor hall sensor signal

The hall sensor signal is similar to one observed in simulation. The SPWM signal corresponding to boost PFC switch is as shown in fig.21.

The unity power factor is achieved AC mains current and AC mains voltage is in phase and nature is sinusoidal.

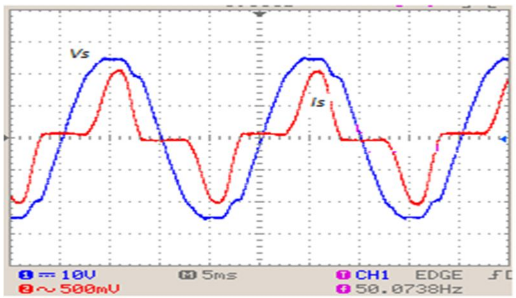

Fig.22 AC mains source voltage and current

VI. CONCLUSION

PFC Boost Converter based BLDCM drive system after comparison with BLDCM drive without PFC, is found to be highly efficient system in terms of power quality parameter such as THD and power factor at AC mains. A prototype of boost PFC converter fed BLDC motor drive has been implemented with satisfactory result. Power factor correction converter has rendered BLDCM drive a good alternative in current scenario where eco-friendly low power consuming highly efficient devices such as water pumps, fans, blowers is enormously required. The Boost PFC base BLDCM drive showed satisfactory results and gives recommended low power BLDCM drive solution

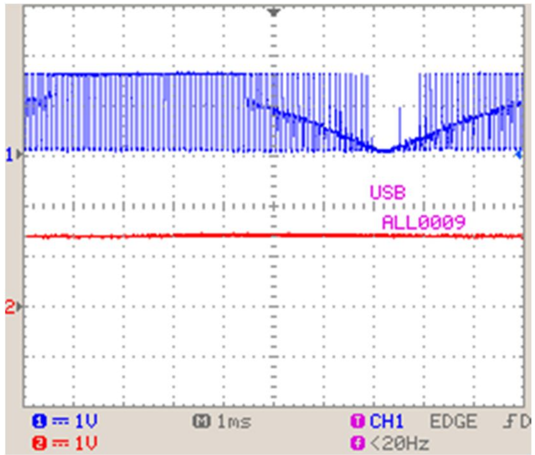

Fig.21 SPWM pulses of boost converter

REFERENCES

[1] S.D. Sudhoff and P.C. Krause, “Operation modes of the brushless DC motor with a 120˚inverter”, IEEE trans. Energy converts, vol.5, no.3, pp.558-564, Sept. 1990.
[2] B.Singh and S.Singh “State-of-Art on Permanent Magnet Brushless DC Motor Drives,”Journal of Power Electronics,vol.9,no.1, pp.1-17,Jan.2009
[3] Limits for Harmonic Current Emission(Equipment input current<16A per phase),International Standard IEC 6100-3-2,2000.
[4] C.L Puttaswamy,Bhim Singh and B.P. Singh,“Invistigation on dynamic behaviour of permanent magnet brushless dc motor drive,”Electric power Comp.& Sys.,vol23,no6,pp689-701,Nov.1995.
[5] N.Mohan,T.M.Undeland and W. P. Robbins “Power electronics:Converter,Application and Design,”3rd Edition,Jhon Wiley and Sons Inc,USA,2002
[6] Vinod Kr Singh Patel, A.K. Pandey, “Modelling and Technique”, IJERA Transaction, vol. 3, issue 3, May – June 2013.
[7] Singh B., Singh S., “Single-phase power factor controller topologies for permanent magnet brushless DC motor drives”, IET Power Electron., Vol 3 (2), pp. 147–175, 2010.
[8] Bhim Singh,B.P.Singh and M.Kumar,“PFC converter fed PMBLDC motor drive for air conditiong,”Journols of Institution of Engineers(India)vol84,pp22-27,June2003
[9] S. B. Ozturk, Oh Yang and H. A. Toliyat, “Power Factor Correction of Direct Torque Controlled Brushless DC Motor Drive,” 42nd IAS Annual Meeting and IEEE Ind. Appl. Conf., pp.297-304, 23-27 Sept. 2007
[10] Chia-Hao Wu and Ying-Yu Tzou, “Digital control strategy forefficiency optimization of a BLDC motor driver with VOPFC,” IEEE ECCE Conf., pp.2528-2534, 20-24 Sept. 2009
[11] Brigitte Hauke “Basic Calculation of Boost Converter Power Stage,”application report,Texas Instument,Nov.2009
[12] C. Gencer and M. Gedikpinar, “Modelling and Simulation of BLDC Motor Using MATLAB/SIMULINK”, Journal of Applied Sciences, vol. 6, issue 3, pp. 688-691, 2006.

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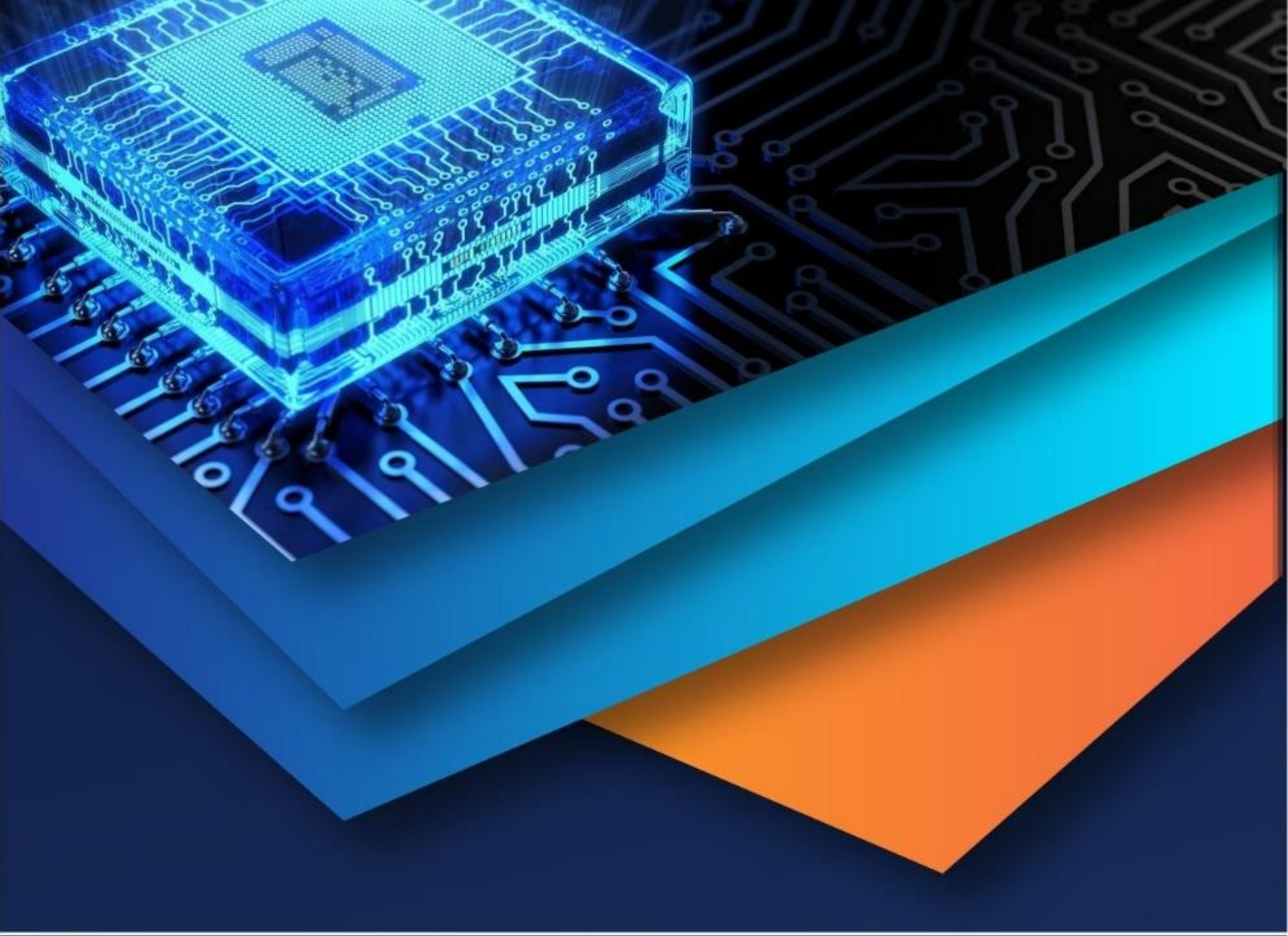

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