Design & Analysis of Power Factor Improvement of BLDC Motor Drive by Boost PFC using Matlab/Simulink

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Abstract : *Applications of Electric drives are as follows: automation systems, robots, manipulators, metal cutting machines, packaging, printers and plotters, hospital equipment. Working modes of electric drives are characterized by shift in load, which requires the employment of a voltage inverter with speed controller. Many motor systems that consume more than a set amount of power must undergo power mandatory factor correction. This is required by utility companies and governments both. Behind a diode bridge rectifier, but before any input capacitors, PFCs are located at the device's input. The purpose of the PFC circuitry is to ensure that the voltage and current on the input are in phase. The designed PFC Boost converter for BLDC drive improves the system performance. It increases efficiency, reliability & expected life span which decreases THD, ripple and other unwanted parameters from the circuit.*

Key Words: Power Factor Correction(PFC), Continuous Current Mode(CCM), Discontinuous Current Mode(DCM), Hall-effect, Voltage Source Inverter(VSI)

1.INTRODUCTION

People in the household sector prefer to employ a 75W split phase capacitor operated motor for household applications. As a result, in the scenario of rising electricity demand, induction motor ceiling fans are unsuitable. It is critical to reduce domestic appliance power demand, which can be accomplished by using a BLDC motor for household application. BLDC motors are preferred in medium and low-power as it is advantageous due to the factors such as less operating costs, higher efficiency, less noise, and low electromagnetic interference.

To improve the performance of the whole system a PFC unit can be employed, which not only takes care of power factor correction but also handles the DC link voltage supplied to the BLDC a healthy power factor.

1.1 Boost PFC control scheme

The conventional PFC scheme of speed control of the BLDC motor drive using a pulse width modulated voltage source inverter (PWM-VSI) with a constant dc link voltage. It has higher switching losses in VSI. paper.

The speed of the BLDC motor is directly proportional to the applied dc link voltage, so the variable speed operation can be achieved by the variable dc link voltage of VSI [1]. A PFC converter can be operating in two modes of operation. They are as follows 1.Continuous conduction mode (CCM) 2. Discontinuous conduction mode (DCM). In CCM, inductor current or the voltage across the capacitor remains continuous, but it requires the sensing of two voltages (i.e., dc link voltage and supply voltage) and input side current for PFC operation, which is not cost-effective [2]. DCM requires a single voltage sensor for dc link voltage control, and inherent PFC is available at the ac mains, hence DCM is preferred for low power applications [3]-[4].

To drive a BLDC motor, a power converter is needed. In the configuration, an AC-DC PFC converter in series with a VSI (Voltage Source Inverter) is used to drive the BLDC motor. The EMI filter is used to avoid reflection of electromagnetic interference at input AC mains. The BLDC motor ceiling fan efficiency is around 75% [5]-[7].

These motors are electronically commutated motors and performances of these motors are better in comparison of other electrical motors. The physical position sensors are paced in the stator to develop the commutation logic depending up on their output. The switches of VSI are switched with the co-ordination of position of the rotor by using a set of position Hall-Effect sensors [8].

1.2 Boost PFC Control Scheme

The Boost converter with PFC circuit consist of DC source with diode bridge rectifier, switching element, inductor, diode, capacitor, diode bridge rectifier, voltage source inverter fed to BLDC motor. The boost PFC circuit cycles between two modes of operation. The block diagram is shown in Fig 1. Here CCM scheme is used for PFC control. Continuous Conduction Mode controllers are the most widely used among all the three modes. They are mainly used in low power applications like lighting etc. One of the main reasons behind their wide use is they are user friendly & inexpensive. The instantaneous output voltage is fed to an error amplifier. This is compared with a set reference value and an error is generated. This error is rectified by the error amplifier block. This provides the operation of closed loop of the circuit. A rectified version of is multiplied to the output of the error amplifier of the first section. This provides a scaled input signal in DC form. This DC scaled version is the basis of comparison for the PFC operation. This signal is compared with the sensed input current and an error signal is generated. This error signal indicates the phase deviation between the voltage & the current in the circuit. The error signal is passed onto an error amplifier & the phase deviation between voltage & current is sort out. This signal powers a PWM generator logic which is connected to the gate of switch of the Boost Converter.

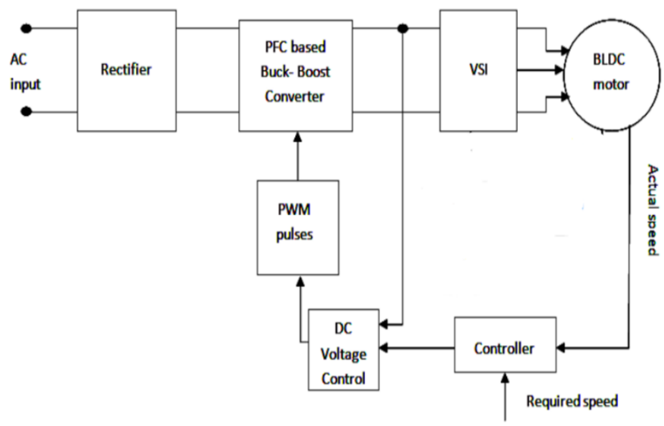

Fig -1: Block Diagram of PFC based BLDC Drive

The BLDC Speed drive control is cascaded with the Boost PFC control scheme. The controller compares the required speed with the actual speed. The difference generated is compared against the DC link voltage in the DC voltage control block .This block controls the voltage corresponding to the speed required. This provides the closed loop control scheme.

2. SIMULATION AND RESULTS

The selected topology for PFC unit for BLDC drive is simulated in MATLAB/SIMULINK environment. The effectiveness of the controller designed is validated and performance of the converter is checked. Table 1 shows the parameters considered for the MATLAB simulation of the Converter

Table -1: PFC Simulation parameters

PARAMETER	SYMBOL	PARAMETER
INPUT VOLTAGE & FREQUENCY	Vin & Fs	220VAC & 100KHZ
OUTPUT CURRENT	Io	2A
OUTPUT VOLTAGE	Vo	400V
DUTY CYCLE	D	0.777
INDUCTOR & RIPPLE CURRENT	L & ΔI_L	2.23mh & 0.4A
OUTPUT CAPACITOR	C	1.23µf

In a boost converter, output voltage is higher than the input voltage (Vin). As input voltage is 220V, the expected boost output voltage is 400V. When the voltage is approaching output, power factor is improved. The simulation results obtained were in accordance to the PFC model that was chosen. The output voltage waveform is shown in Fig 2.

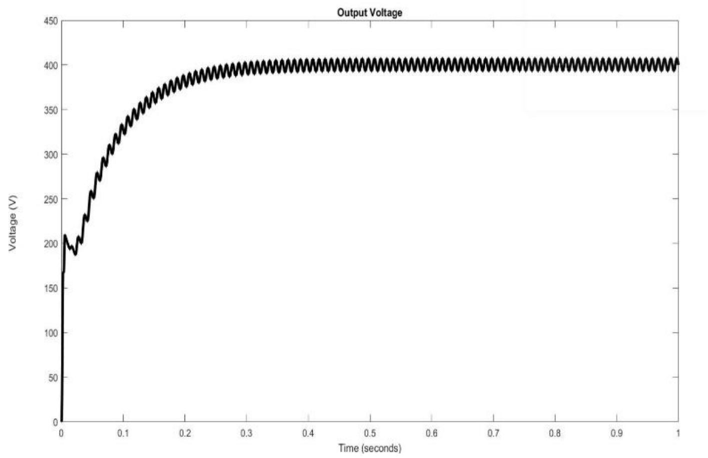

Fig -2: Output Voltage

The purpose of the PFC circuit is to minimize the input current waveform distortion as shown in Fig 3 and make it in phase with the voltage. Without PFC unit, for nonlinear loads, increase of the harmonic content of the line current is more. This leads to lessen the efficiency of the system and is not approachable.

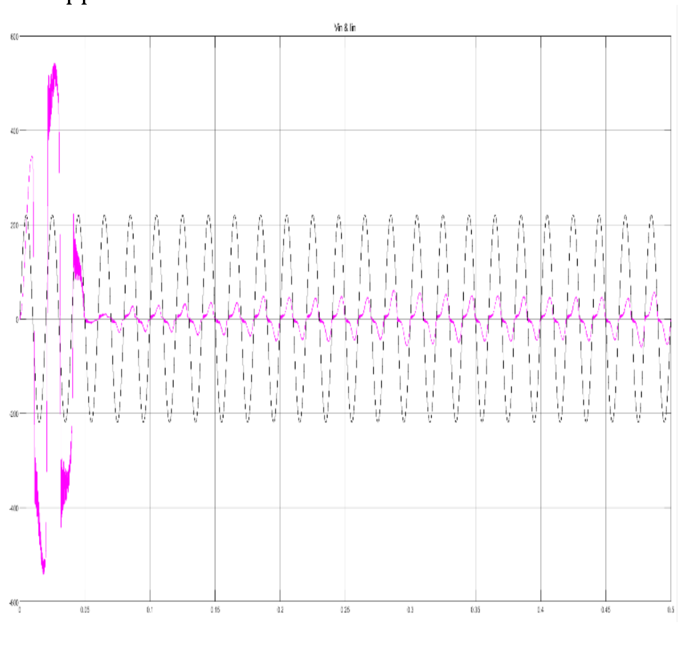

Fig -3: Vs & Is without PFC

Boost PFC converter can remarkably improve both PF and THD. It also improves the power quality at the mains. PFC not only reduces the load on the electrical distribution. system but it also energy efficient and reduces electricity costs. By improving PFC, propensity of instability and failure of equipment decreases. Fig. 4 shows a waveform of phase voltage and phase current which depicts the PFC operation of the circuit.

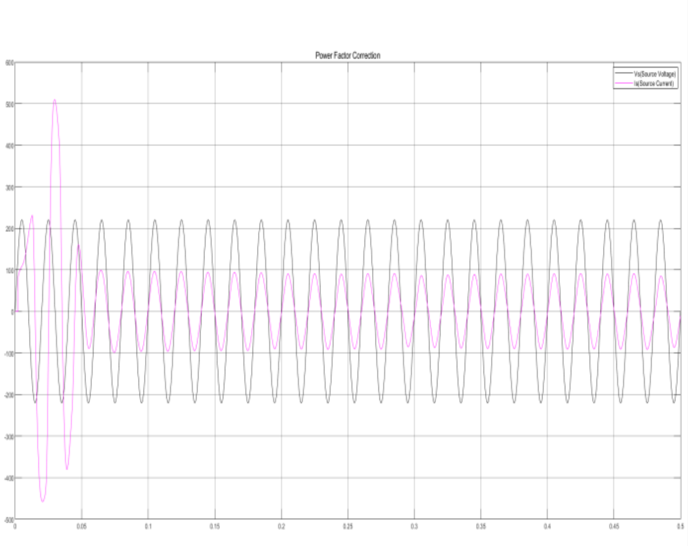

Fig - 4: Vs & Is with PFC

2.1 PFC testing

PFC testing and evaluation is done for proposed PFC based BLDC motor drive. This testing is done with parameters like supply voltage, supply current, Power input and load current as shown in table 2. The testing is done using simulation software SIMULINK/MATLAB:

Table -2: PFC Testing

Is	Pin	IL	THD	PF	Pout	η
0.16	6.7	0.01	5.56	0.17	3.967	59.21
0.2	23.2	0.05	1.77	0.49	19.83	85.51
0.26	43.6	0.10	1.00	0.70	39.67	91.00
0.34	63.6	0.15	0.755	0.79	59.51	93.58
0.42	84	0.20	0.59	0.86	79.35	94.47
0.49	103.6	0.25	0.48	0.89	99.20	95.75
0.57	122.5	0.30	0.419	0.92	119.04	97.18
0.66	142.2	0.35	0.395	0.93	138.89	97.677

3. CONCLUSIONS

Simulations of the PFC circuit were carried out in the MATLAB Simulink environment and results were obtained.

The designed PFC converter with BLDC drive is expected to operate with improved power factor which in turn improves the power quality of the system and also to reduce harmonic distortion in the supply current. Performance of the PFC converter based BLDC drive is simulated in MATLAB and its behaviour has been shown to confirm the design and control of PFC converter BLDC drive system. The power quality performance of this topology is found to adhere the international harmonics standard IEC61000-3-2 for the universal input supply. Speed control of BLDC motor is simple which results in reduced losses & high efficiency. Hall-effect sensors are used for feedback loop, so that the cost is reduced.

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