Abstract: This paper presents boost converter configuration in permanent magnet brushless DC motor drive to overcome power quality problems at utility of ac mains. The use of this DC-DC boost converter will ensure near unity power factor and reduction of AC mains current harmonics. For this purpose, voltage controller is employed in input side to provide controlled DC link voltage which is applied to BLDC motor through voltage source inverter. Also speed control of PMBLDC motor with maximum torque is to be achieved by using speed controller. This is great significance in variable speed application. Both voltage controller and speed controller is to be realized by using PI controller. Simulations are done using MATLAB/SIMULINK software and result is compared with hardware implementation.

Keyword: Boost Converter, Voltage Controller, Speed Controller, PMBLDCM Drive, Power Factor Correction

1. Introduction

Permanent magnet brushless DC motors are the latest choice of researchers because of its high efficiency, silent operation, compact size, high reliability and low maintenance requirements. It has number of advantage over the brushed DC motor in terms of efficiency. Near about 90% efficiency is achieved by using BLDC motor. Usually PMBLDC motor is employed for low power application which is powered from single phase AC mains through a bridge rectifier with smoothening DC capacitor and voltage source inverter (VSI).
provided by three phase rectangular current blocks of 120° electrical duration in which back emf is trapezoidal. Therefore PMBLDC motor need rotor position information only at the commutation points i.e every 60° electrical in three phases. The rotor position can be sensed using Hall sensors, resolvers, or optical encoders.

2. Review of Boost converter

A boost converter (step up converter) is a DC to DC power converter that steps up voltage (while stepping down current) from its input (supply) to its output (load). It is a class of switched mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor) and at least one energy storage element: a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter’s output (load – side filter) and input (supply – side filter).

3. Modeling of PMBLDC Motor

The modeling of PMBLDCM drive includes modeling of voltage control loop which consists of voltage controller, PWM controller and speed control loop consists of speed controller, reference current generator and PWM current controller. The modeling of speed controller has more importance as performance of total system depends on this controller. Both voltage controller and speed controller is realized using PI controller.

A] PMBLDCM Drive

Assuming that at t\textsuperscript{th} instant of time, m(t) is actual rotor speed, m′(t) is the reference speed, then the speed error m\textsubscript{e}(t) can be calculated as

\[ m\textsubscript{e}(t) = m'(t) - m(t) \]

The speed controller as PI controller is used to process this speed error to get desired control signal.

1. Speed Controller

The PI controller output at t\textsuperscript{th} instant T(t) is given as

\[ T(t) = T(t-1) + k_p \{ m_e(t) - m_e(t-1) \} + k_i m_e(t) \]

where kp and ki are proportional and integral gains of the PI controller respectively.

Let \[ I^* = T(t)/K_b \] where K_b is the back emf constant of the PMBLDCM.

2. Reference Current Generation

The reference phase currents of the motor windings are I\textsubscript{a}, I\textsubscript{b} and I\textsubscript{c} for phases a, b, c, respectively. For duration of 0-60\textdegree the reference currents can be given as

\[ I_{a} = I^*, \quad I_{b} = -I^*, \quad I_{c} = 0 \]

Similarly, the reference currents for other duration can be generated, which will follow the trapezoidal voltage of respective phases. These reference currents are compared with sensed phase currents for error current generation as

\[ \Delta I_a = (I_a^* - I_a), \quad \Delta I_b = (I_b^* - I_b), \quad \Delta I_c = (I_c^* - I_c). \]

3. Current Controller

The switching sequence for the VSI is generated by current controller, after comparing the current error of each phase with fixed frequency carrier waveform. The current errors \[ \Delta I_a, \Delta I_b, \Delta I_c \] are amplified by gain k\textsubscript{l1} before comparing with carrier waveform m(t). The switching sequence is obtained based on the logic given for phase ‘a’ as a reference signal. This reference signal is compared with the Boost converter output current so as to give modulating signal for PWM. This signal is compared with triangular carrier signal to generate the PWM pulses for turning on/off the VSI switches.

B] PFC Converter

The PFC converter modeling consists of the modeling of a voltage controller and a PWM controller as given below.

1. Voltage Controller

The voltage controller is a proportional-integral (PI) controller which accurately monitors the voltage error and generates control signal (Ic) to minimize the voltage error. If at t\textsuperscript{th} instant of time, E\textsuperscript{*dc}(k) is reference DC link voltage, Edc(k) is sensed DC link voltage then the voltage error E\textsubscript{e}(k) is calculated as

\[ E_e(k) = E^*_{dc}(k) - Edc(k) \]

The output of the controller Ic(k) at k\textsuperscript{th} instant is given as,

\[ Ic(k) = Ic(k-1) + K_pv \{ E_e(k) - E_e(k-1) \} + K_i E_e(k) \]
where $K_{pv}$ and $K_{iv}$ are the proportional and integral gains of the voltage PI controller.

2. PWM Controller

The output of PI controller is amplified by gain $k$ and compared with fixed frequency ($f_s$) saw-tooth carrier waveform $p(t)$ to get the switching signals for the MOSFET of the boost PFC converter given as,

- If $I_c(k) > p(t)$ then $S = 1$
- If $I_c(k) \leq p(t)$ then $S = 0$

where $S$ is the switching function representing ‘on’ position of the MOSFET of the PFC converter with $S=1$ and its ‘off’ position with $S=0$.

4. Proposed Model of PMBLDC Drive with PFC Converter

The proposed boost converter PFC topology for PMBLDCM drive are modeled in MATLAB/Simulink environment for a voltage source inverter fed PMBLDC motor. Boost PFC topology is evaluated for a dc link voltage of 400V to drive PMBLDC motor with speed ranging from 500rpm to 2000rpm i.e speed is to be controlled without changing power factor in this range. The PI controller is employed for voltage as well as speed control and PWM signal is generated for VSI and PFC converter using 40 kHz triangular carrier waves. The power quality is observed through FFT analysis of source current under steady state condition. Boost PFC converter shows very good response with input AC main current THD of 0.11% along with PF of 0.9994.

The harmonic spectrum in conventional system shows near about 72% total harmonic distortion in AC main current at rated torque. So THD of AC main current is reduced to 0.11% by using Boost PFC topology. The PQ performance analysis of proposed PFC topology shows that the THD of AC mains current always remains within the limit imposed by IEC 61000-3-2 and other international PQ standards.
Figure 4: Power Factor

Figure 5: Rotor Speed, Torque and Stator Current

Figure 6: Current at AC mains and its harmonic spectra of Boost PFC converter feeding VSI based PMBLDCM drive.

6. Hardware of Proposed Work

7. Conclusion

To provide depth understanding on every aspect of parameters of PMBLDCM drive, it is designed, modeled and simulated in MATLAB/SIMULINK environment. The performance of PMBLDCM drive with PFC converter shows that boost PFC topology used in proposed work is best option for applications having rated voltage is higher than single phase supply RMS voltage. The PMBLDCM drives incorporating Boost PFC converter can be a milestone towards the widespread application of these drives.
8. References


