PFC for Buck-Boost Converter Fed Sensor less BLDC Motor Drive with Speed Control

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Abstract— Brushless DC (BLDC) motor drives have gained much popularity and are widely used in industrial and traction application. They are more superior because of their high power to weight ratio, low maintenance, high-efficiency, high flux density per unit volume. They are generally preferred over brushed DC motors for several other applications. This proposed approach presents BLDC motor drive without sensors for low power applications. A PFC (Power Factor Corrected) BL (Bridgeless) buck-boost converter is operated in DICM (Discontinuous Inductor Current Mode) to supply a unity Power issue at AC mains. In case of sensorless motors the control of the motor will be achieved by monitoring the back EMF zero crossing as a feedback. The concept of BLDC motor is well simulated in MATLAB/Simulink atmosphere.

Key words: PFC, BLDC

I. Introduction

In the industries where the electric motors are powered by plant energy the value of power factor is low. It is lowest when the induction motors tend is under-loaded and oversized. A power factor which is less than 1 causes additional energy loss because of high current requirement. Correcting power factor can be an appropriate and cost-effective measure but not an energy saving method. Low power motor drives demands for good efficiency, low cost and compact design. The Brushless Direct Current (BLDC) is replacing DC motors in areas as in the case of automotive (electric vehicles (EV)) and in industries. BLDC motor uses electronic commutator for the reliability and durability improvement. It provides high torque value, better efficiency, dynamic response, long service life, elimination of ionization sparks from the commutator, noiseless operation and higher speed ranges. BLDC motor's basic constructional components are stator part and rotor part. The Rotor of a BLDC motor is made up of permanent magnet and the Stator has star patterned windings. The BLDC motor is most popularly called as electronically commutated motor. The controlling of BLDC motor requires the prior information about rotor's position and commutation mechanism. For closed loop system some parameters like motor speed/current and Pulse Width Modulation (PWM) signal are additional requirement. Position sensor such as Hall Effect sensors senses the rotor position of BLDC motors, which increases the number of wires and cost. Sensor less BLDC control eliminates the use of Hall Effect sensors, using the Back-EMF (electromotive force) of the motor instead to estimate the rotor position. BLDC motors are used in the application where there is low horsepower requirement. Sensorless control is essential for low-cost variable speed applications such as fans and pumps. However, customer demands are going high i.e. good performance, small size and highly efficient motors. To fulfill these requirements BLDC motors have been introduced.

II. Proposed Model

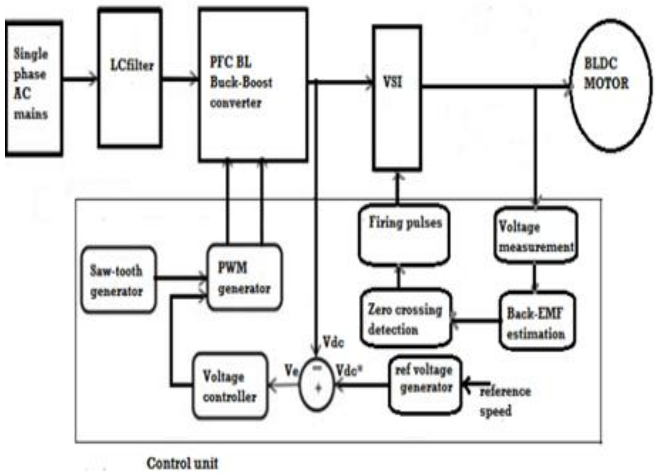

Fig. 1: Block diagram of proposed model

The proposed system is designed by examining the other configurations. The block diagram explains the components involved in the implementation of the system. It consists of bridgeless Buck-Boost converter operating in discontinuous conduction mode with PFC is fed to BLDC motor. The single phase AC mains is connected to low pass LC filter which smoothes out the higher order harmonics in the supply system. The speed control is provided by controlling the VSI based on PWM method. The switching losses in the system can be reduced by variable DC link voltage for speed control. VSI is operated at low frequency range for electronic commutation of BLDC motor, thus it mitigates the switching losses. DBR is eliminated from the design as it introduces high conduction losses. Control unit is used for the determination of rotor position and error detection.

III. Bridgeless Buck-Boost Converter and its Operating Modes

The circuit consists of low pass filter fed with the AC source with Lf and Cf as its components. Since the converter is operating in DCM therefore LPF reduces the stress on the switches. The circuit operates in two half cycle i.e. positive and negative half cycle. The components which are active in positive half cycle are S1, L1 and D1, in negative half cycle are S2, L2 and D2. An additional dc link capacitor is used to fed the BLDC motor.

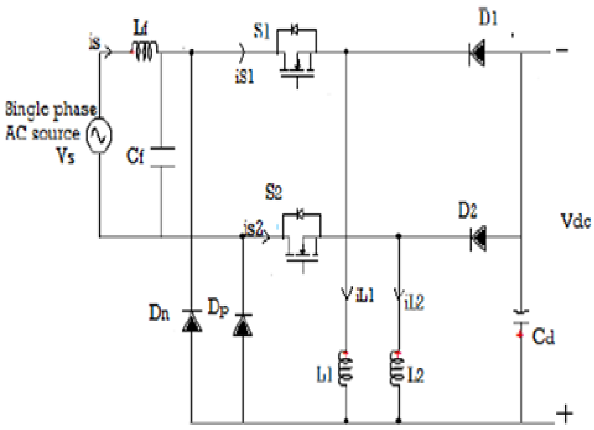

Fig. 2: Bridgeless Buck-Boost converter

A. Operating Modes During Positive Half Cycle:

There are three different mode of operation during positive half cycle.

In mode I the conducting components are S1, L1, Dp and Cd. For the time period ton the switch S1 conducts and charges L1, the current through the inductor L1 increases. The switch S1, inductor L1, diode Dp along with LPF forms closed loop. The remaining charge in the capacitor Cd is fed to the BLDC motor.

In mode II S1 is turned OFF, the charged inductor discharges to zero through load via DC link capacitor

In mode III none of the components are conducting since the inductor is discharged hence the capacitor Cd continuous to fed BLDC motor.

B. Operating Modes During Negative Half Cycle:

In mode I the conducting components are S2, L2, Dn and Cd to transfer energy from input to the load. The switch S2 conducts and charges L2, the current through the inductor L2 increases. The switch S2, inductor L2, diode Dn along with LPF forms closed loop. The remaining charge in the capacitor Cd is fed to the BLDC motor.

In mode II S1 is turned OFF, the charged inductor discharges to zero through load via DC link capacitor.

In mode III none of the components are conducting since the inductor is discharged hence the capacitor Cd continuous to fed BLDC motor.

IV. SENSOR LESS CONTROL

When the rotor placement is in closed housing and the applications where the motor is immersed in liquid sensor cannot be used. Therefore, sensorless control is introduced. BLDC motor requires the information of rotor position for phase voltage control and for determination of which phase pair to be energized. In sensorless control the information of the rotor position is extracted from the Back EMF of the stator coil when the motor is in motion. The potential generated within the stator winding are measured in terms of Volts is called as an Electromotive Force (EMF). The generated EMF produces magnetic field that opposes the change in the magnetic flux driving the motor. In other words the motor resists the movement of the motor referred as Back EMF. The magnitude of the EMF is proportional the velocity (angular) of the rotor with the condition that there should be fixed number of windings and magnetic field. The sensorless commutation reduces motor cost and motor design is simplified. In dusty environment it does not require cleaning whereas in brushed the brushes require occasional cleaning.

A. Advancement in Sensor Less Control:

Three-phase BLDC motor have only two of the stator windings are in conducting phase at a time and the third winding will carry the Back EMF. Sensing the back EMF of the non-energized winding is the cost effective method to guess the commutation sequence in the star connected pattern of the stator. The back EMF method cannot be applied when the motor is at rest since its value is zero at standstill position. It is not suitable for high speed applications; the terminal voltage cannot detect zero crossing which has high SNR (Signal to Noise Ratio). Therefore, open loop starting technique is used. The procedure starts by exiting two phases till the preset time. At the end of present time when 1200 open loop commutation is done then the motor polarity is reversed. The motor turns according to excited phases. When the commutation sequence is completed then sensorless position drive is attained.

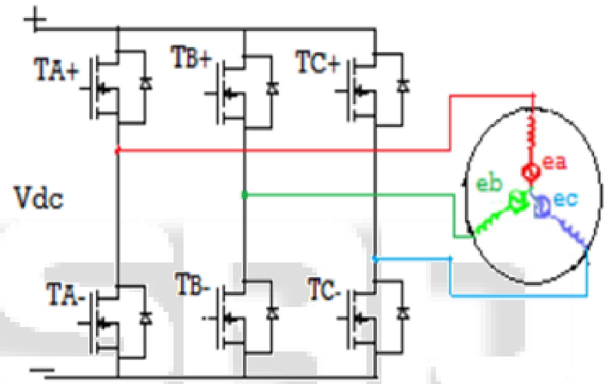

Fig. 3: Three phase voltage source inverter

Inverter is operated in three phase i.e. indicated by the three different colors in the figure. Phase A is indicated by red, phase B by green and phase C by blue. Initial rotor position is determined by the non- linear magnetic property of stator winding. When DC voltage is applied the stator winding is energized then a fixed direction fed magnetic field is established. There will be change in the current response due to inductance difference. Variation in the current contains the rotor position. Hence this proves the stator winding's inductance is the function of rotor position.

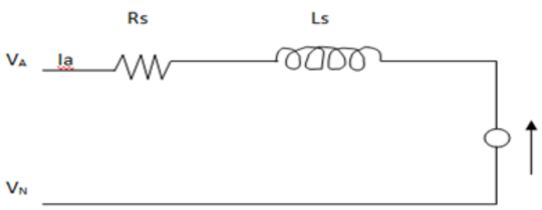

Fig. 4: Equivalent circuit of phase winding

The following assumption should is considered for the phase windings:

The motor used is not saturated. Mutual inductances (M) are zero, stator resistances (Rs) of the windings are equal and self inductances (Ls) are constant.

V. SIMULATION RESULT

The Simulink model is simulated in Simulink environment of MATLAB using the toolbox Sim-Power system.

The simulation results are shown as follows:
The back EMF in three phase

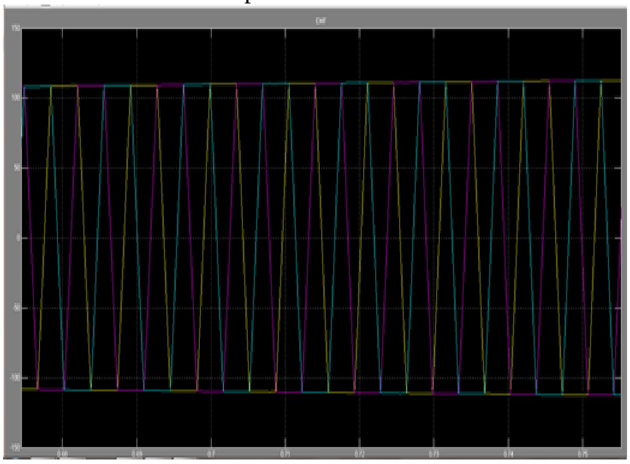

Fig. 5: Back EMF in three phase

The plot shows the electromagntic torque and stator current

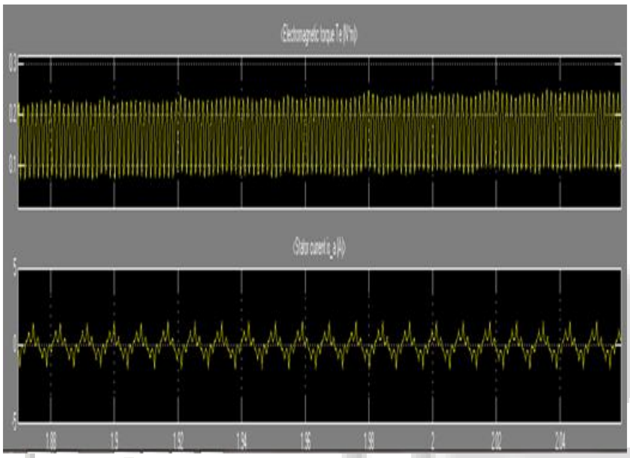

Fig. 6: Torque in Nm (Newton Meter) and the stator current in A(Ampere)

VI. CONCLUSION

PFC for buck-boost converter fed sensorless BLDC motor drive with speed control has been modeled. Speed control is provided by VSI based on PWM. The bridgeless Buck Boost converter operated in DCM is used for PFC. Elimination of hall sensor with Back EMF zero crossing method is done. Variation in the motor speed is achieved by varying DC link voltage. The proposed system shows satisfactory performance with less losses and low component count. Sensorless control provided low cost, less weight and size of the system. Suitable for low power application.

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