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Minimizing Commutation Torque Ripple and PI control for Brushless DC Motor Based on SEPIC Converter

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***Abstract*—This paper proposes minimizing commutation torque ripple and PI control for brushless DC motor based on SEPIC converter. This mainly depends on speed and transient line current in the commutation interval. This paper presents a novel circuit topology and a dc link voltage control strategy to keep incoming and outgoing phase currents changing at the same rate during commutation. A DC–DC single-ended primary inductor con-verter (SEPIC) and a switch selection circuit are employed in front of the inverter. The desired commutation voltage is accomplished by the SEPIC converter. The dc link voltage control strategy is carried out by the switch selection circuit to separate two procedures, adjusting the SEPIC converter and regulating speed. The cause of commutation ripple is analyzed, and the way to obtain the desired dc link voltage is introduced in detail. Finally, simulation results are inline with the experimental results. This proposed method used to obtain the desired voltage much faster and minimize commutation torque ripple more efficiently at both high and low speeds.**

***Index Terms*—Brushless dc motor (BLDCM), commutation, dc link voltage control, single-ended primary inductor converter (SEPIC), torque ripple.**

I. INTRODUCTION

Brushless DC motor (BLDCM) has been widely used in industrial fields that require high reliability and precise control due to its simple structure, high power density, and extended speeding range [1]–[3]. The performance of such motors has been significantly improved due to the great development of power electronics, microelectronics, magnetic performance of magnets, and motion control technology in re-cent years [4]–[9]. However, commutation torque ripple, which usually occurs due to the loss of exact phase current control, has always been one major factor in preventing BLDCM from achieving high performance. So far, many studies have been performed to reduce commutation torque ripple [9]–[21].An original analytical study on commutation torque ripple is presented in [9], from which a conclusion has been drawn that relative torque ripple is independent of current and varies with speed. A similar analysis is presented in [16], and the strategy of changing the input voltage to reduce commutation torque ripple is proposed. Both papers are based on some necessary assumptions such as ideal trapezoidal back electromotive force (EMF), very small current hysteresis or pulse width modulation (PWM) cycle, and constant back EMF during commutation, and no implementation of voltage adjustment is demonstrated in them. It is proposed in [18] that a single dc current sensor and a current deadbeat control scheme should be used to keep incoming and outgoing phase currents changing at the same rate during commutation, hence effectively suppressing com-mutation torque ripple at both high and low speeds.

It is an effective method to introduce some special topology of a circuit to BLDCM drives to control its input voltage, as shown by some researches presented in [19]–[21]. In [19], a buck converter is used, and commutation torque ripple is then greatly reduced at low speed. In [20], a super lift Luo converter is placed at the entrance of the inverter to produce desired dc link voltage, and the structure is more competent under the high-speed work condition, compared with the method pro-posed in [19]. A developed structure of the inverter is proposed in [21], which avoids the effect of the fly-wheeling process and acquires more exact estimated torque with sampling current. All of the above methods suffer from slow voltage adjustment, and therefore, they can only achieve satisfactory torque pulsation suppression in low- or high-speed regions.

In this paper, a novel topology of a circuit is proposed, and an appropriate dc link voltage is used to drive phase currents to increase and decrease in the identical slope, resulting in the great reduction of pulsated commutation torque. To get the desired dc link voltage, a single-ended primary inductor converter (SEPIC) circuit is used to control the input of the inverter. The adjustment of dc voltage can be completed during non commutation conduction period and switched immediately at the beginning of commutation by the switch selection circuit. Simulation and experimental results show that, compared with common dc–dc converter, the proposed method, when applied in a steady state, can reduce commutation torque ripple both at high and low speeds with much faster dc voltage regulation.

II. CIRCUIT ANALYSIS OF TORQUE DURING

A typical block diagram of BLDCM drive system is shown in Figure 1.

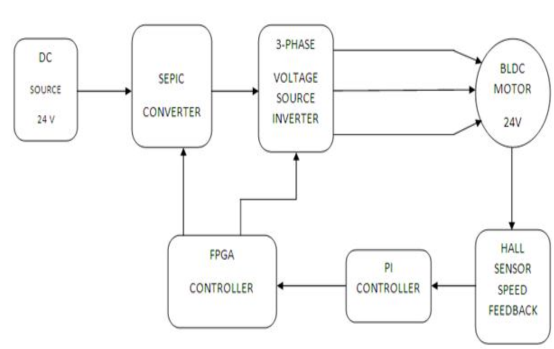

Figure. 1. Block diagram of the BLDCM drive system

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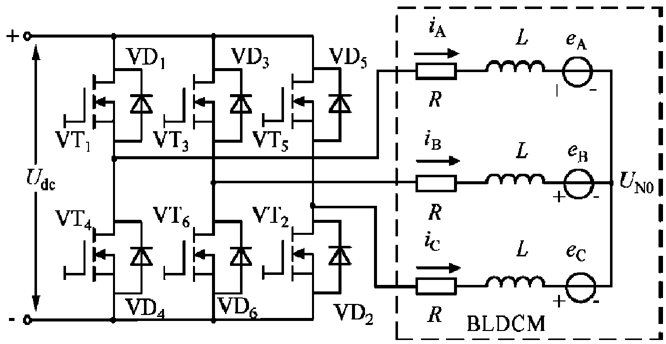

Figure. 2. Circuit diagram of the BLDCM drive system

BLDC motor can be used for precise adjustable speed control. As the name implies, BLDC motors do not use brushes for commutation; instead, they are electronically commutated. To rotate the BLDC motor, the stator windings should be energized in a sequence. It is important to know the rotor position in order to understand which winding will be energized following the energizing sequence. Rotor position is sensed using Hall Effect sensors embedded into the stator. Whenever the rotor magnetic poles pass near the hall sensors, they give a high or low signal, indicating the N or S pole is passing near the sensors. Based on the combination of these three Hall sensor signals, the exact sequence of commutation can be determined.

III`SEPIC CONVERTER

This paper is proposed to suppress commutation torque ripple of BLDC Motor. A SEPIC converter is placed at the input of the inverter. The dc link voltage can be achieved by voltage switch control. The SEPIC Converter output DC voltage is given to the 3Phase Voltage Source Inverter. By using 120 degree mode of operation the inverter three phase controlled AC output voltage is given to the BLDC Motor. Based on the Hall sensor output pulses the stator windings are energised. The PWM pulses are generated from FPGA Controller and it is given to the VSI. The closed loop algorithm using PI controller is achieved. The proposed method can reduce commutation torque ripple effectively within a wide speed range. A digital proportional–integral speed-control algorithm was implemented in a Spartan 3E FPGA.

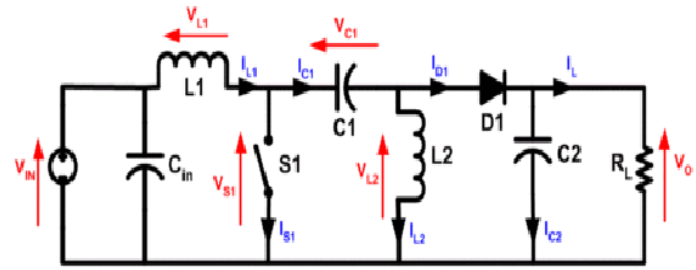

Figure3.SEPIC converter

IV.SIMULATION RESULTS

The simulations are done using MATLAB software. The simulation results are presented in this section. The output voltage is shown in figure4. The backemf result is shown in figure5. The Hall Effect sensor output is shown in figure6. The gate pulses applied to the switches are shown in figure7. The inverter's line to line output voltage is shown in figure8. The stator current is shown in figure 9. The rotor speed in rpm is shown in figure10. The rotor toque is shown in figure11.

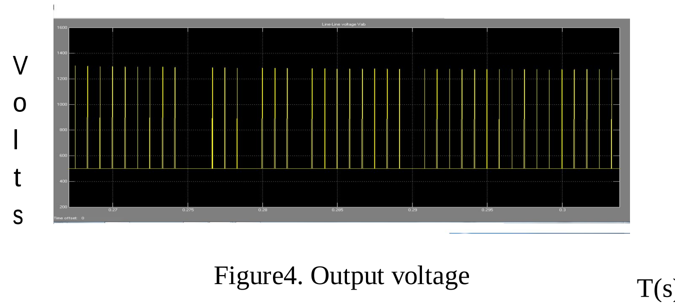

Figure4. Output voltage

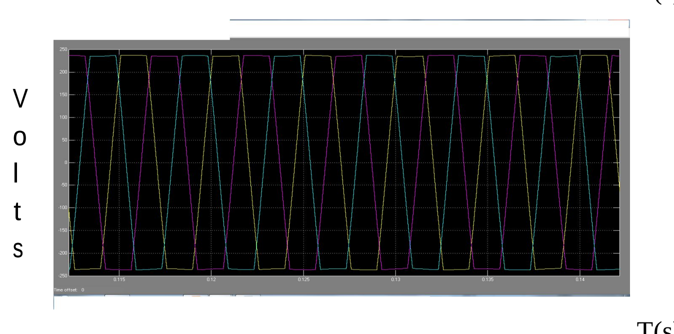

Figure5. Back EMF voltage

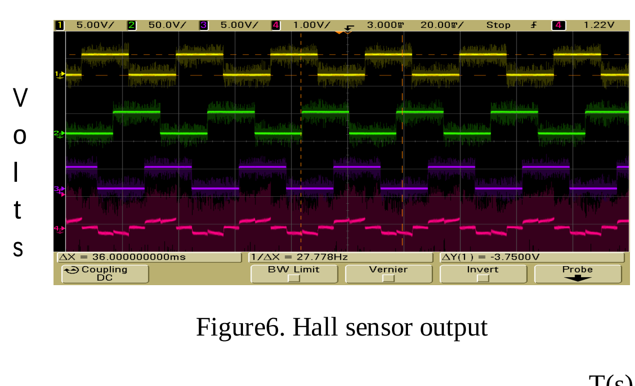

Figure6. Hall sensor output

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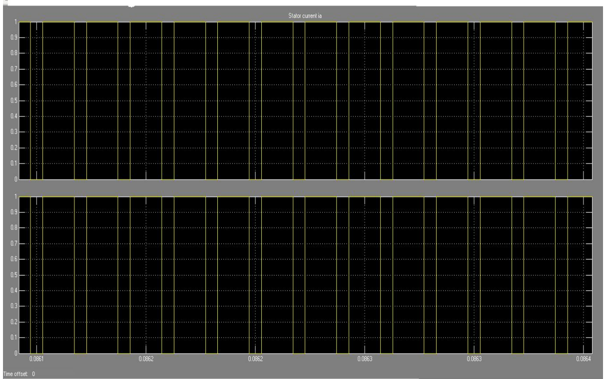

Figure7. Gate pulses

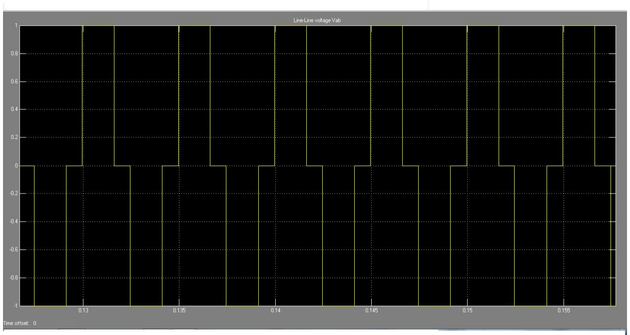

Figure8. Line to Line voltage

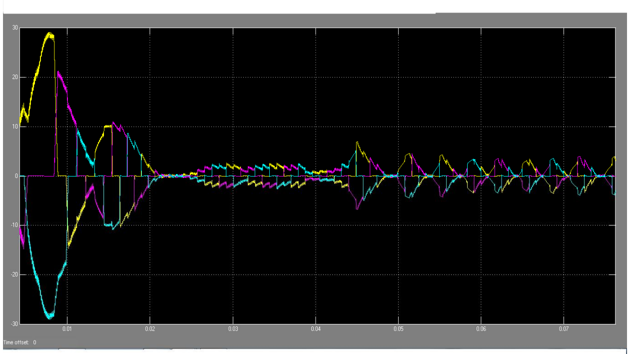

Figure9. Stator current

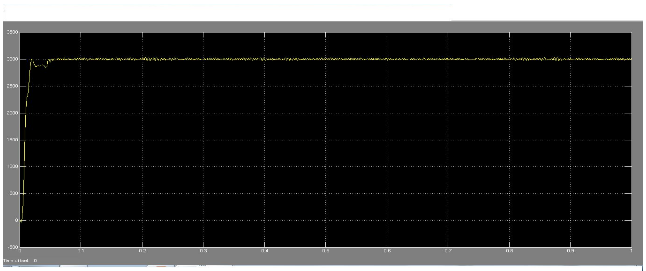

Figure10. Rotor speed

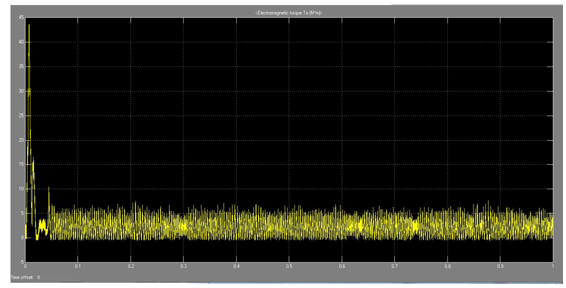

Figure11. Rotor Torque

V.EXPERIMENTAL RESULTS

The experimental setup is shown in figure12. The experimental circuit layout is shown in figure 13. The gate pulses applied to the switches are shown in figure14. The inverter line to line voltage is shown in figure 15.

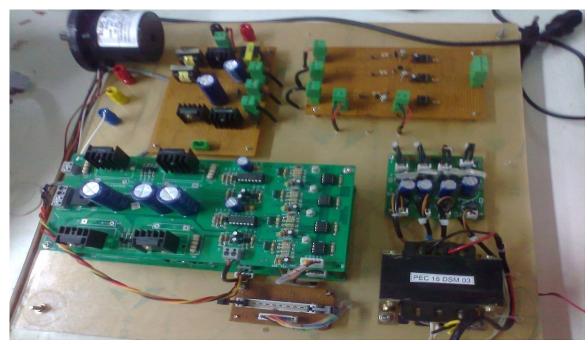

Figure12. Experimental setup

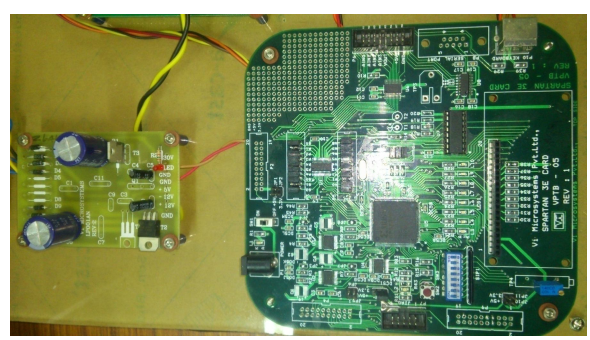

Figure13. Experimental circuit

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V o l t s

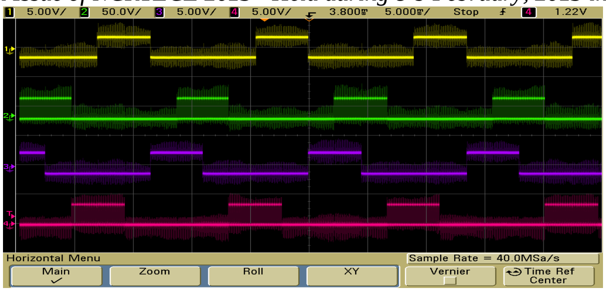
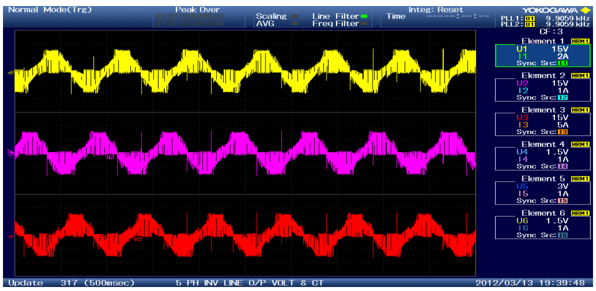


Figure14. Gate pulses T(s)

V o l t s



T(s)

Figure15. Line to Line voltage

VI.CONCLUSION

A PI control strategy is proposed to suppress commutation torque ripple of BLDCM. A SEPIC converter is placed at the input side and desired output voltage can be obtained by proper switch control. With the adjustment of SEPIC converter the speed regulation and torque robustness can be improved during transient commutation. Finally the simulation results are verified with the experimental results.

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