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Harmonic less Improvement in Speed Control and Power Factor Using DSP Based BLDC Motor

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ABSTRACT
This paper is used to design a rugged and low-cost drive, supplied by a battery, using a BLDC motor. The DSP processor is very powerful, compact and multi-functional, containing many inbuilt modules like the Analog-to-Digital converter. The rotor position is sensed by means of Hall position sensors. The CUK converter has advantage of this topology is a continuous current at both the input and the output of the converter and reduces the switching losses and current harmonics. The PWM pulses for each phase are generated by the DSP and are given to the MOSFET driver. The complete system model is simulated in MATLAB/ Simulink environment. Hardware implementation for the speed control has been achieved by DSP controller TMS320C243. The ideal topology for commercial applications that are supplied from the utility.

Keywords
Brushless DC Motor, DSP controller, Pulse Width Modulation (PWM), CUK Converter, MOSFET switch.

I. INTRODUCTION

Due to the high efficiency because of reduced losses, low maintenance and low rotor inertia of the permanent magnet brushless dc motor the demand in high power servo applications has been increased. Modern solid state devices like MOSFET and IGBT Permanent Magnets has widely enhanced the applications of PMBLDC motors in variable speeds. In this work, a DSP controller and CUK inverter is developed which increases the speed control easily with the improved power factor. The drawback of the analog system is their susceptibility to temperature variations, the aging of the components and very difficult in upgrading the systems [1]. This drawback of the analog controller is overcome by the Digital controller which eliminates the drifts. The updation of the systems can be easily accomplished by software using DSP controller. A DSP controller allows performing high-resolution control and minimizing control loop delays. These advantages of DSP controllers make it possible to reduce torque ripples, harmonics and improve power factor in all speed ranges. The permanent magnet brushless dc motor design is optimized due to lower vibrations and lower power losses such as harmonic losses.

II. CUK CONVERTER

The circuit of the CUK converter is shown in Fig. 1.1 It consists of dc input voltage source V_S, input inductor L_1,controllable switch S, energy transfer capacitor C_1, diode D, Filter inductor L_2, filter capacitor C, and load resistance R. An important advantage of this topology is a continuous current at both the input and the output of the converter. Disadvantages of the CUK converters are a high number of reactive components and high current stresses on the switch, the diode, and the capacitor C_1 [2].

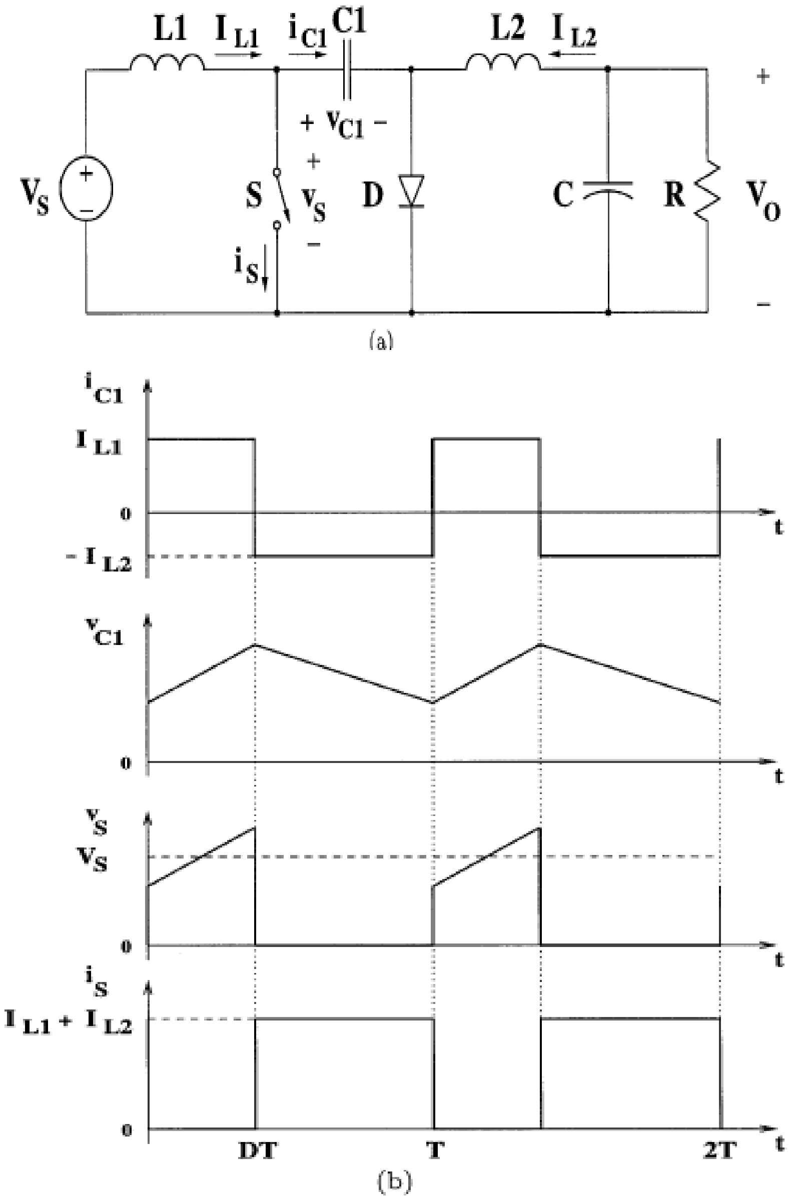

Fig. 1.1 CUK CONVERTER : (a) CIRCUIT DIAGRAM; (b) WAVEFORMS.

When the switch is on, the diode is off and the capacitor C_1 is discharged by the inductor L_2 current. With the switch in the off state, the diode conducts currents of the inductors L_1 and L_2, whereas capacitor C_1 is charged by the inductor L_1 current [5]. To obtain the dc voltage transfer function of the converter, we shall use the principle that the average current through a capacitor is zero for steady-state operation [6]. Let us assume that inductors L_1 and L_2 are large enough that their ripple current can be neglected. Capacitor C_1 is in steady state if

$$I_{l2}\, DT = I_{l1}\, (1-D)\, T \qquad (1.1)$$

For a lossless converter,

$$Ps = VsI_{l1} = - V0I_{l2} = P0 \qquad (1.2)$$

Combining these two equations, the dc voltage transfer function of the CUK converter is

$$MV = \frac{V0}{Vs} = \frac{-D}{1-D} \qquad (1.3)$$

This voltage transfer function is the same as that for the BUCK-BOOST converter [3]-[4]. The boundaries between the CCM and DCM are determined by

$$L_{b1} = \frac{(1-D)\,R}{2Df} \quad (1.4)$$

For L1 and

$$L_{b2} = \frac{(1-D)\,R}{2f} \quad (1.5)$$

For L2,

The output part of the CUK converter is similar to that of the BUCK converter. Hence, the expression for the filter capacitor C is

$$C_{min} = \frac{(1-D)\,Vo}{8VrL2f^2} \quad (1.6)$$

The peak-to-peak ripple voltage in the capacitor C_1 can be estimated as

$$V_{r1} = \frac{D\,V_o}{C_1 R_f} \quad (1.7)$$

A transformer (isolated) version of the CUK converter can be obtained by splitting capacitor C_1 and inserting a high frequency transformer between the split capacitors.

2.1. Proposed CUK Converter CSI Fed BLDC Drive

The proposed BLDC drive consists of three parts (1) diode bridge rectifier (2) dc-dc voltage to current converter and (3) the SCR based inverter and the BLDC motor.

The models of these three parts are shown in Fig. 1.2 a, b and c respectively [7]. The diode bridge and the sinusoidal ac source are modeled by a rectified sinusoidal ac voltage source.

Assuming that the CSI is ideal, we need to consider only the distortion due to the phase advance in the thyristor gating. The CSI rectifies the back-emf of the BLDC so that it appears as if it were a dc motor [8], [2].

Thus, the problem reduces to that of controlling a dc motor with a slightly distorted back-emf. The SCR based inverter together with the BLDC motor is modeled by a voltage source E_t. The voltage source E_t can also be considered as a rectified three-phase source of magnitude corresponding to the phase-to-phase back-emf of a BLDC motor. Viewed from the side looking into the motor, the CSI mimics a controlled rectifier, and the pulsation of E_t depends on the firing angle of the SCRs, which in our case is 10°.

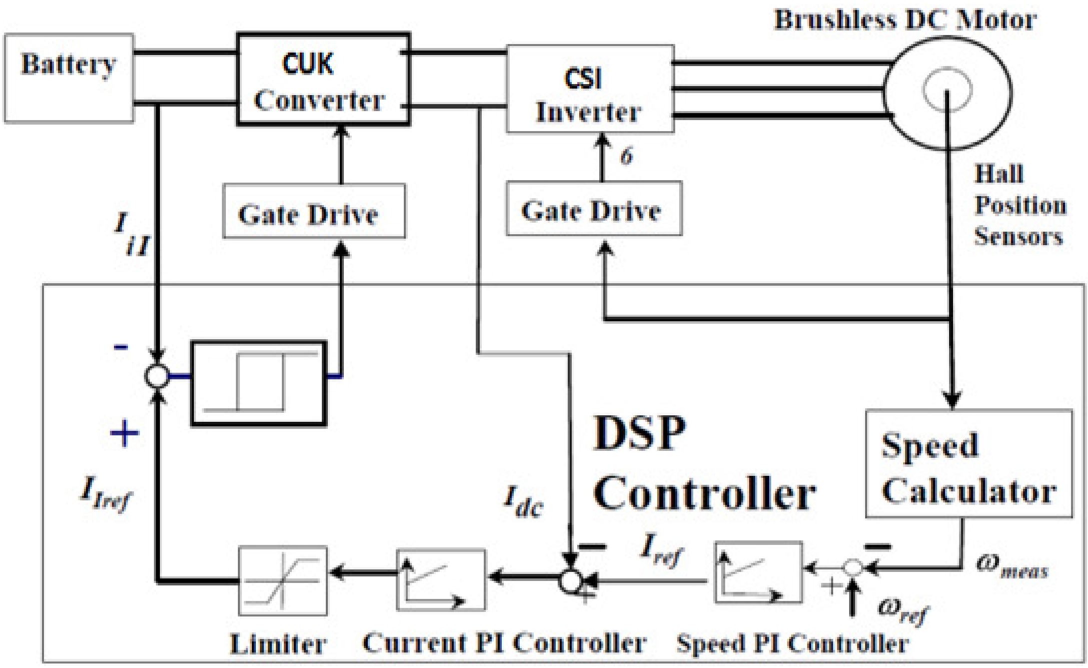

Fig. 1.2 BDLC MOTOR USING CUK CONVERTER & CSI INVERTER

The voltage ripple V_c is due to the current commutation in the SCR-based inverter. The shape, peak value and the frequency of this ripple depend on load current, the motor leakage inductance and the motor speed [9].

III. HARDWARE IMPLEMENTATION

Since the simulation results were promising, the CUK converter fed CSI BLDC drive has been implemented. Each block of the implementation is described and the relevant experimental results are presented [10], [5]. The hardware blocks that have been described are the motor, the Hall position sensor, the Capture Unit, the Analog-to-Digital converter, the Digital-to-Analog converter, the current sensors, the Current Source Inverter, the thyristor drivers, the dc link inductor and the CUK converter [11].

Fig. 1.3 Brush less DC (BLDC) MOTOR Drive

3.1 Features:

Floppy Disk Drive DC Motor, Shinano Type: **YG-437F**, Toshiba Number: **6R020021,** RPM: **300 - 12 VDC,** MFG: Shinano Kenshi Co., LTD, Made for Toshiba, Magnetic and static shield, Excellent quality - **Made in Japan,** Aluminum Hub 37 [mm] Diameter, 28.5 Internal Diameter, 5 mm wide,4 wire terminals and 4 pin connector, Excellent for data recovery work, Driver IC and circuitry is on PCB, Great for science or show-and-tell project, Motor size: 90 Diameter, 22 D [mm],Rotor size: 88.5 Diameter, 20 D [mm],PCB size: 127 L, 98 W, 20 D [mm],Weight: 263 Grams – assembly.

The commutation sequence for a typical 3-Phase BLDC Motor. Each phase is active for 120 electrical degrees. At any given time/step interval that has only two phases are active. The third phase is inactive or floating. This mechanism has built-in dead time and assures that the two MOSFETs in the same bridge are not active at the same time.

The commutation sequence as shown above will be AB-AC-BC-BA-CA-CB-AB-AC… and repeats from there on. During AB sequence, the upper side of the A bridge is active while the lower side of B bridge is active. So current flows from DC+ through the A high side to the motor winding across A and B, passes through the low side of the B bridge and to DC-. The commutation timing is determined based on the position of the rotor. In the case of a sensored drive, the Hall Effect sensor digital outputs determine the position of the rotor, which can be used to move to the next logical sequence [12].

IV. SIMULATION RESULTS AND TABULATION

The motor parameters are assumed to remain the same. The only difference is that we use the rectified AC source as the input. This makes the control more challenging, but nevertheless it is the ideal topology for commercial applications that are supplied from the utility.

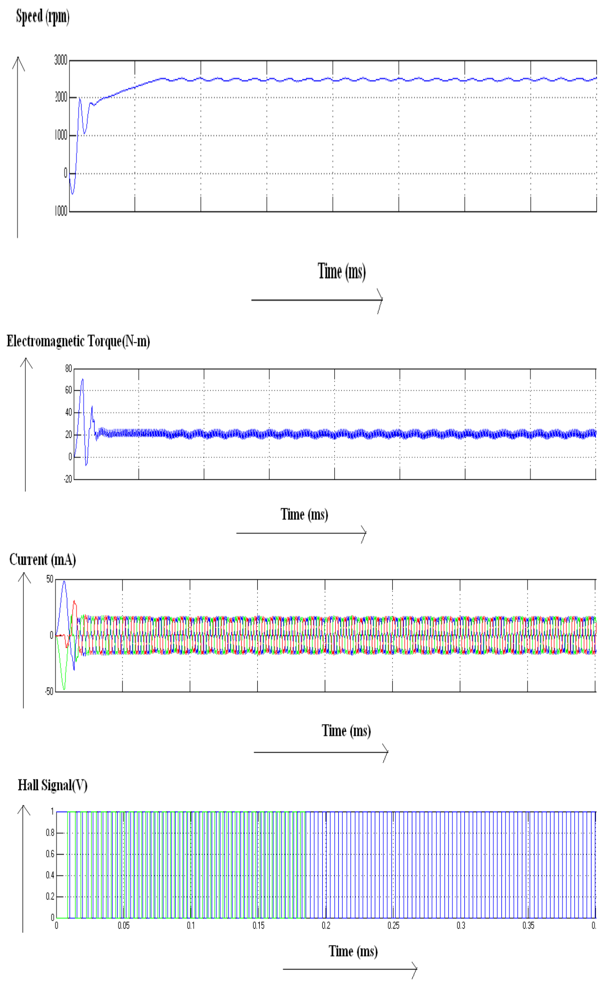

Fig 1.4 Simulation output of CUK converter CSI fed drive

Table 4.1 COMPARATIVE RESULTS OF BUCK AND CUK CONVERTER CSI FED BLDC DRIVE SYSTEM

S.no	Measurements	Buck converter (hardware output)	Cuk converter (simulation output)
1	Current	1.2 mA	20 mA
2	Back Emf	12V	300V
3	Speed	300 rpm	2500 rpm
4	Electromagnetic Torque	1.2 N-m	20 N-m
5	Hall Signal	1V	1V

V. CONCLUSION

Performance analysis of CUK converter based CSI fed BLDC motor for an automotive application is presented in this project. The CUK converter based CSI fed BLDC Motor is implemented by hardware, designed successfully. CUK converter based CSI fed BLDC motor has more advantages than the BUCK converter, which significantly reduces the switching losses, value of inductance, resistive losses, current ripples and also improve the reliability with the good power factor and less harmonics efficiency of the BLDC Drive System. The above analysis has been successfully verified with the simulation results.

VI. FUTURE WORK

The Performance analysis of CUK converter based CSI fed BLDC motor had been implemented by hardware and as a modification point of view, we can suggest BOOST converter based implementation for requirement of good response.

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