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Bridgeless SEPIC Converter for Automobile Applications

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Abstract—SEPICs are useful in applications where a battery voltage can be above or below the regulator's intended output. The proposed converter reduces the conduction loss and reduces the number of components. Here the control circuit is simplified and there is no current loop required when the comparator operates in discontinuous conduction mode. BLDC motors are widely used in many of the industrial applications. Various converter topologies used for feeding these BLDC motor drives Topology is fed with PMBLDC motor, thus can control the speed of motor very effectively. DC-DC converter fed PMBLDC motor has been designed and simulated using MATLAB.

Index Terms— Bridgeless SEPIC, BLDC motor, DC-DC converter, Hall Effect sensor, SEPIC converter.

1 INTRODUCTION

There are many DC-DC converters like SEPIC converters which are used for obtaining relatively high (over 10:1) boost ratios with low input current ripple. However, a bulk inductor is used to minimize the current ripple. Input current ripple becomes one of important requirements due to the wide use of low voltage sources such as batteries, super capacitors, and fuel cells because of large ripple current which may shorten the lifetimes of those input sources. Now a days various automobile applications are satisfied by these cost effective and reliable brushless technology operated motors. These motors are actually permanent magnet AC motors resembling the torque-current characteristics of a DC motor. It is a modified form of Permanent Magnet Synchronous motor in which the back emf is trapezoidal which is sinusoidal in case of PMSM motors. In sensor based control, the position of the rotor is identified with the Hall sensors which are provided at 120^0 apart. Since the technology is simple and highly reliable, BLDC motors are selected for low power applications. DC-DC converters are used for feeding these BLDC motor drives. Apart from the input voltage control of the inverter driving motors, they are also performing the isolation between input and the load side. Modern days various converter topologies are used depending on the requirements. Inverters are mainly used to supply power for BLDC motor which is a three phase inverter. Voltage source inverters are commonly used and the BLDC motor control through electronic commutation is made possible by controlling the gating sequence of inverter switches. In this paper, the bridgeless SEPIC converter topology is proposed for automotive applications to achieve high efficiency and reduces the conduction losses.

1.1 Existing Topologies

Unlike the boost converter, the SEPIC and Cuk converters offer several advantages in PFC applications such an easier implementation of transformer isolation, limiting the inherent inrush current during startup and the overload conditions, lower the input current ripple, and lesser electromagnetic interference (EMI) associated with the DCM topology [2]. The SEPIC converter is combined with the input rectifier and operates like a conventional SEPIC PFC converter. The converter operation is symmetrical in two half-line cycles of input voltage. Therefore, the operation of converter is explained during one switching period in the positive half-line cycle of the input voltage. It is assumed that it operates in DCM. It means the output diode turns off before the main switch is turned on. To simplify the analysis the converter is operating at a steady state, and all the circuit elements are ideal.

2. PROPOSED BRIDGELESS SEPIC CONVERTER FEEDING PMBLDC MOTOR DRIVE

The proposed system consists a bridgeless SEPIC converter feeding a PMBLDC motor drive. The converter is operating in discontinuous inductor current mode for reducing the switching stress. The component count is reduced and it shows high efficiency due to the absence of the full-bridge diode. However, in this converter, an input inductor with large inductance is used in order to reduce the input current ripple. An auxiliary circuit, which consists of an additional winding of the input inductor, an auxiliary inductor, and a capacitor, is utilized to reduce the input current ripple. Coupled inductors are often used to reduce current ripple [1].

2.1 Circuit Diagram

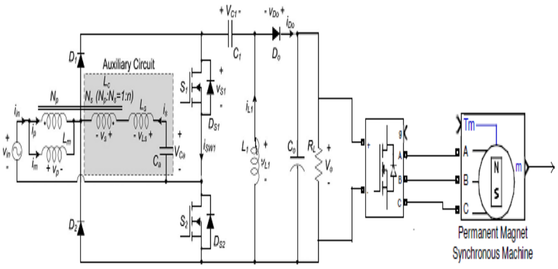

Fig.1. Proposed bridgeless SEPIC converter

2.2 Principle of Operation

The converter is a bridgeless SEPIC converter operating in both positive and negative half cycles of input supply voltage. It is performed in three different modes in each of the half cycles which is given below.

Mode 1 [t_0, t_1]: At t_0 , the switch S_1 is turned ON and the switch S_2 is still conducting. Since the voltage V_p across L_m is V_{in} , the magnetizing current im increases from its minimum value I_{m2} linearly with a slope of V_{in} /L_m as shown in Fig 2.

Mode 2 [t_1, t_2]:in this mode of operation, at t_1 , the switch S_1 is turned OFF and the switch S_2 is still conducting. Since the voltage V_p across L_m is $-V_0$, the magnetizing current im decreases from its maximum value Im1 linearly with a slope of $-V_0$ /L_m as shown in Fig 2.

Mode 3 [t_2, t_0]: At t_2 , the current i_{D0} becomes zero, and the diode Do is turned OFF. Since $i_{in} = i_m - ni_s = -i_s - i_{L1}$ in this mode. The key waveform of each mode is shown in fig. 3.

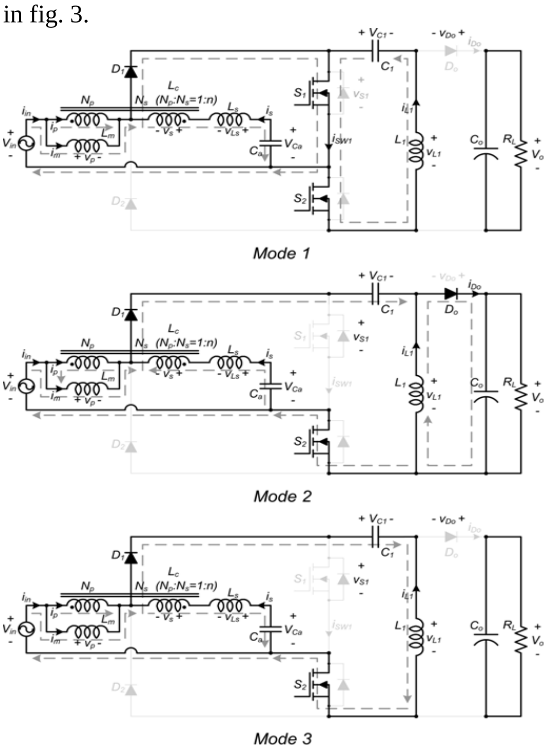

Fig.2 Mode of operation

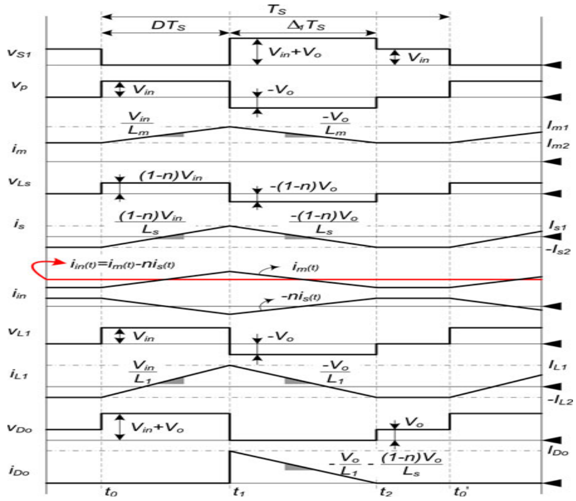

Fig . 3 Waveforms of the proposed converter

2.3 Control of Bridgeless Sepic Converter

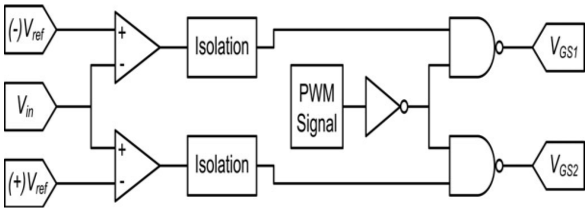

Fig. 4 Input voltage detecting circuit block diagram

In order to reduce the conduction losses by forcing the reverse current of the switches to flow via channel, the input voltage detecting circuit is used. Fig. 5.1 shows the block diagram of the detection circuit. By using comparators, the sign of the input voltage is detected. Optical couplers are utilized for electrical isolation. Logic gates are employed to make one of the switches conduct continuously and the other operate with PWM signal.

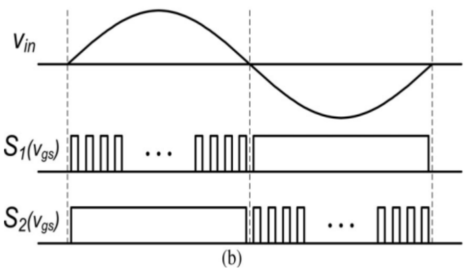

Fig .5 Gate signal for S_1 and S_2

The operation of the converter is symmetrical in two half-line cycles of input voltage. Therefore, the converter operation is analyzed during one switching period in the positive half-line cycle of the input voltage. It is assumed that the converter operates in discontinuous conduction mode (DCM), so the output diode D_0 is turned OFF before the main switch is turned ON. The capacitance of the output capacitor C_0 is assumed sufficiently large enough to consider the output voltage V_0 as constant. Also, the input voltage is assumed constant and equal to V_{in} in a switching period T_s .

3. SIMULATION RESULTS

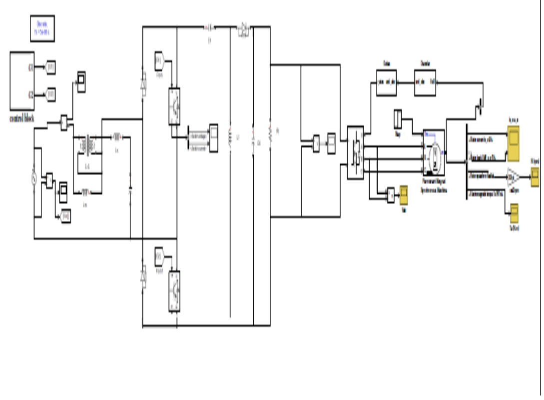

Fig. 6 Simulation for the proposed system.

A closed loop operation of the proposed bridgeless SEPIC converter fed PMBLDC drive for automobile application circuit is modeled and simulated. Here the output of the bridgeless SEPIC converter is fed into a PMBLDC motor .By controlling the output voltage across the armature terminal of the PMBLDC motor, we can control the speed of the PMBLDC motor. The parameters of the BLDC motor such as speed, electromagnetic torque and the stator current are analyzed for proper functioning of BLDC motor.

BLDC motors use electronic instead of mechanical commutation to control the power distribution to the motor. Hall-effect sensors are mounted in the motor, are used to measure the position of the motor, which is communicated to the electronic controller to spin the motor at the right time and right orientation. Hall-effect sensors are operated by a magnetic field from a permanent magnet or an electromagnet, responding to South (operate) and North (release) poles. These magnetic sensors determine when the current should be applied to the motor coils to make the magnets rotate at the right orientation. Torque, the force that produces motion, is developed in DC motors by the permanent magnetic field interacting with the current flow through the windings. In brush-type motors, the commutator switches the armature windings in order to provide proper magnetic flux and armature current interaction. In brushless motors, a Hall-effect position sensor IC detects the position of the rotating magnet and excites the proper windings through logic and driver circuitry.

The frequency of the hall sensors are not same. Their variation in active states are decoded for making the following switching sequence. The upper leg switches should be provided with a bootstrap oriented gate control since the switch is connected in the higher voltage side.

TABLE 1

OUTPUT OF THE ELECTRONIC COMMUTATOR BASED ON THE HALL EFFECT SENSOR SIGNALS

Hall Signals			Switching Sequence					
H_a	H_b	H_c	S_1	S_2	S_3	S_4	S_5	S_6
Emf_a	Emf_b	Emf_c	Q1	Q2	Q3	Q4	Q5	Q6
0	0	0	0	0	0	0	0	0
0	-1	1	0	0	0	1	1	0
-1	+1	0	0	1	1	0	0	0
-1	0	1	0	1	0	0	1	0
1	0	-1	1	0	0	0	0	1
1	-1	0	1	0	0	1	0	0
0	+1	-1	0	0	1	0	0	1
0	0	0	0	0	0	0	0	0

TABLE 2

COMPONENTS & PARAMETERS

COMPONENTS	PARAMETERS
V_{in} (Input Voltage)	130V, 60Hz
V_O (Output Voltage)	30V
Switching frequency	100kHz
Ausilliary inductor L_s	127µH
Capacitor C_a	500µF
Magnitizing inductance	600 µH

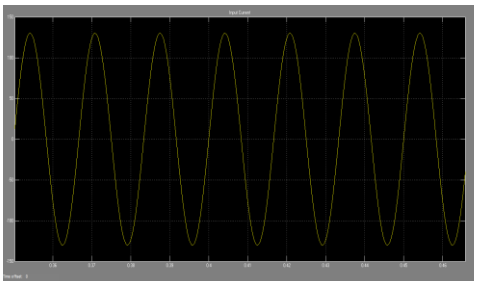

Fig.7 Input current waveform

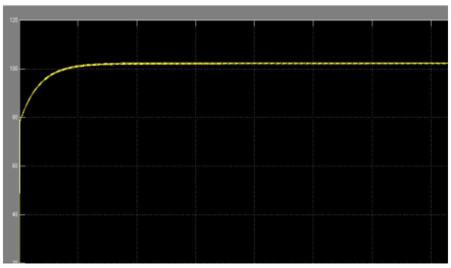

Fig .8 Output voltage waveform

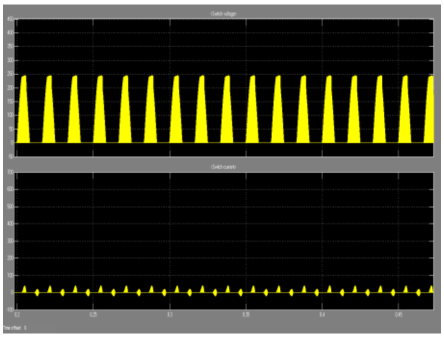

Fig. 9 Switching voltage and current waveform

Input current waveform of the proposed bridgeless sepic converter is shown in fig.7.It is clear that the input current ripple is completely removed by utilizing a coupled inductor which has a small magnetizing inductance. And because of operating in DCM, the output diode *Do* is turned OFF under zero-current switching condition. Fig 8 shows the output voltage .

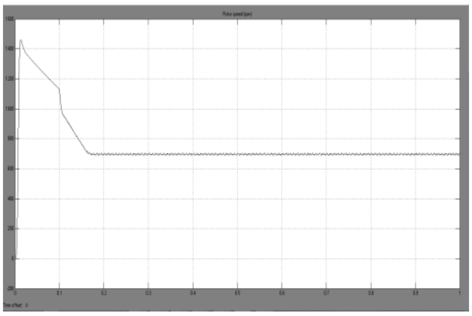

Fig .10 Rotor Speed of PMBLDC motor

4.CONCLUSION

The bridgeless boost rectifier fed PMDC motor is simulated using MATLAB/SIMULINK. This paper presents the simulation of bridgeless SEPIC converter operating in DICM, feeding a PMBLDC motor drive in low power applications. In comparison to conventional bridgeless rectifiers, this employs the minimum number of passive energy storage components, and obtained the maximum conversion efficiency.

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