International Journal of Electronic and Electrical Engineering.
ISSN 0974-2174, Volume 7, Number 4 (2014), pp. 335-340

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Operation of DC/DC Converter for Hybrid Electric Vehicle

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Abstract

Hybrid Electric Vehicle (HEV) technology has gained enormous attention because of depleting conventional resources and measured carbon emission. HEV reduces harmful emission, provides better fuel efficiency and enhances performance. In this paper a bidirectional dc/ dc converter with interleave control, which minimizes current and output voltage ripple is proposed. This leads to reduce size of passive component with higher efficiency and make whole system more reliable.

Keywords: Hybrid electric vehicle (HEV), Permanent magnet synchronous motor (PMSM), propotional integral (PI) controller, battery.

1. Introduction

HEV stands for hybrid electric vehicle, these vehicles comprise of two different sources of energy to propel the vehicle. In this paper we used two different sources of energy one is conventional ICE(Internal Combustion Engine) and battery powered traction motor to propel the vehicle. One of the aforementioned sources of energy has high energy storage capability known as “main energy source” (MES) and other have high power capability and reversibility known as “rechargeable energy storage” (RES). The primary function of MES is to provide extended driving range, where as that of RES is to provide smooth acceleration and regenerative braking [1]. The conventional ICE poses a great threat to environment due to increase in tail pipe emission. This is the main reason that automobile industry is shifting to more environment friendly and cost effective technologies and one such technology is HEV which may meet electric power demand, vehicle performance, and higher passenger comfort along with increased safety [2].

With the increase in consumer comfort demand, luxury loads have also increased drastically in recent time further increasing demand of electric power [3]. The aforesaid increased power requirement of advanced vehicle justifies the vital role of power electronics in development of such vehicular systems. The use of power electronic based systems, such as DC-DC Converter, Inverter and Distribution systems.The vehicular application has several advantages such as increased efficiency, isolation, better voltage regulation and flexibility, controlling power quality to each separate board, reduced weight and size [4-5].

In technical literature various interleave structure have been proposed. Initially Hedel. [6] proposes boost converters with interleave technology for low power application. Morkal. proposes bridge interleave converter [7]. Various interleave converters with different configurations for high power applications have been proposed in [6-9].

This paper proposes 4- phase dc-dc converter working in bidirectional mode withinterleave control used in HEV between battery and inverter feed permanent magnet synchronous motor (PMSM). The proposed technology has various advantages such as minimum size of passive component, reducing input current ripple, make system more reliable in high power application, increasing converters efficiency, decreasing voltage and current ratings of power electronic devices these above mentioned advantages of proposed converter makes it more reliable in high power hybrid electric vehicle application.

2. Proposed Converter

Fig. 1 depicts a 4-phase dc-dc converter working in bidirection mode with interleave control.A unified PI voltage controller is used for controlling the switching pulses for each MOSFET switches. The objective of PI controller is to obtain a constant output voltage discounting the effect of variation in load.A complementary gating signal is provided by above mention controller. For interleave control switching pattern is adjusted by 2π/N, where N is number of phase. The proposed converter is made to work in CCM (continuous conduction mode).

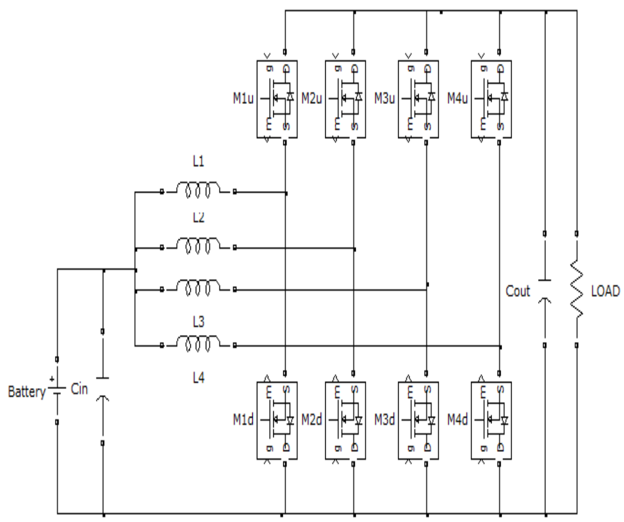

Fig. 1: Circuit of interleaved converter.

3. Design of Converter

Passive element (Inductors and capacitors) have a consequence impact of converters performance, efficiency and their size.Designing equations of bidirectional buck boost converters are given below:

$$\frac{V_{out}}{V_{in}} = \frac{D}{1-D} \tag{1}$$

$$C = \frac{I_{out} D}{2 f_s \Delta V_{out}} \tag{2}$$

$$L = \frac{V_{out} D T_s}{\Delta I_L} \tag{3}$$

Where L is the inductance, C is the capacitance, D is the duty ratio, V_{out} is the output voltage, V_{in} is the input voltage, f_s is the switching frequency, T_s is the switching period, ΔI_L is the inductor current ripple, ΔV_{out} is the output voltage ripple.

4. Implementation Details

In this section proposed converter design and cascaded with HEV Matlab Simulink model. The proposed converter is cascaded in between battery and PMSM (Permanent magnet synchronous motor). Converter is working in boost mode by providing a constant dc bus voltage of 500 V to PMSM and control SOC (state of charge) of battery during acceleration and deceleration mode of HEV. The specification of model used is listed in Table 1.

Table 1: System RATINGS

S. No		Power (KW)	Voltage (V)	Type
1.	Motor	50	500	8 Pole PMSM
2.	Generator	30	500	2 Pole PMSM
3.	Battery	21	200	Nickel Metal Hydride
4.	I.C.E	50	-	-

5. System Operation

Mode 1

HEV at rest at initial position i.e. t=0 sec and simultaneously pushing the pedal 2/3rd of acceleration vehicles moves only through the electric motors being fed by battery only, if required power remaining below than 12KW.

Mode 2

The power requirement below than 12KW at time t=1.4 sec hybrid mode is triggered. The ICE and battery provides power to HEV through the motor. The generator and battery feeds power to motor. The acceleration is provided through this process.

Mode 3

At t=4 sec the acceleration is decreased slightly, the torque cannot be reduced by ICE alone therefore the generator is absorb by the battery.

Mode 4

At t=4.4 sec only battery provides power required by HEV and generator is stopped.

Mode 5

At t=8 sec ICE restart as acceleration is at nearly 4/5 of total, which provides the extra required power.

Mode 6

At t=13 sec acceleration is down to 2/3rd as in mode 1. The generator switches off in half a second. The motor runs generator this whole operation known as regenerative braking.

6. Simulation Result

Current in every inductor branch showed in Fig.2 Where average value of current is 27A and current ripples are very high. Peak to peak ripples as we see from, Fig is around ± 50A. This is quite high. In order to reduce the above mentioned ripples at the output interleave control is provided by phase shifted signal. Fig.3 shows the response of electrical system of used HEV model Fig.3 illustrates Output dc bus voltage, battery output voltage, SOC of battery, motor, generator and battery current in every above mentioned mode.

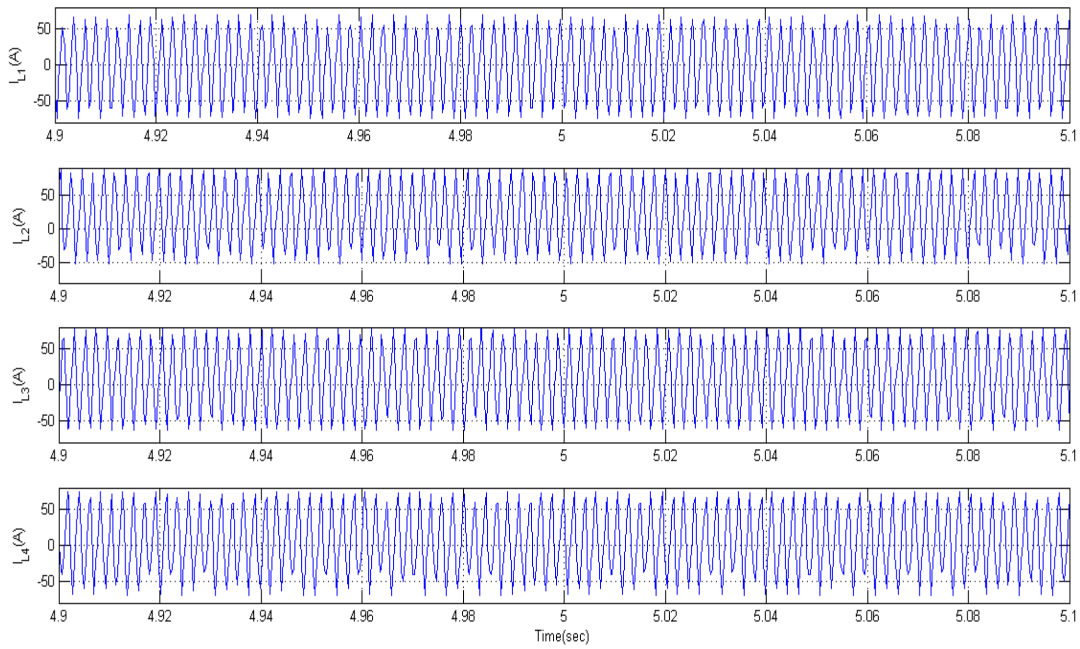

Fig. 2: Per phase inductor current ripple.

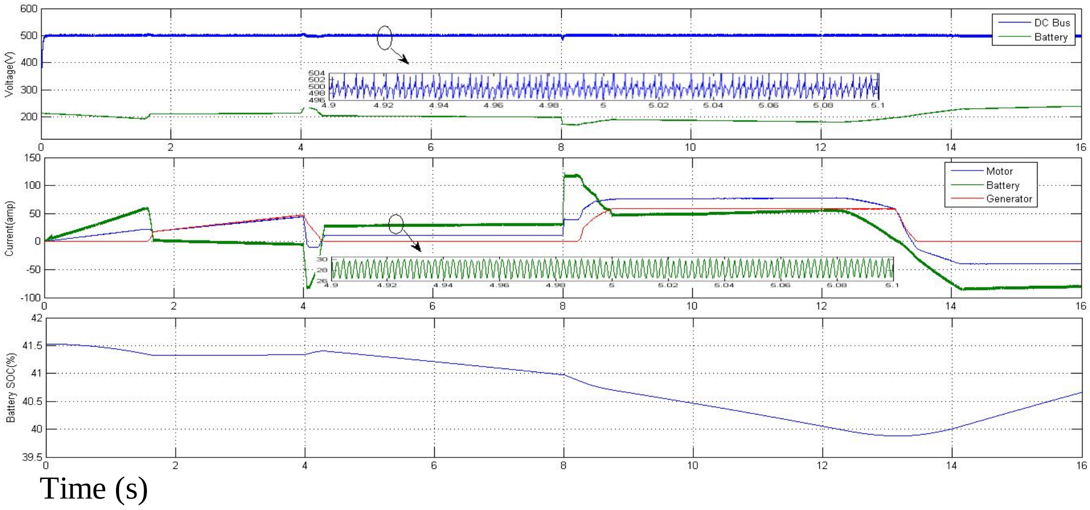

Fig. 3: Response of electrical system

The top graph of Fig.3 illustrates the output voltage of converter and output voltage of battery. Peak to peak output voltage ripples are ± 5V. Below graph of Fig.3 shows variations in motor, battery and generator current according to aforementioned operating modes of HEV. Average current is 27A and peak to peak ripples ±2A. This is quite low as compare to per phase inductor current. The last graph of Fig.3

shows state of charge (SOC) of the battery during charging and discharging mode as mentioned in above operating modes of HEV.Below table shows the comparison between bidirectional buck boost converter and proposed converter. It has been seen that size of passive component reduces considerably as compare to proposed converter.

Table 2: PARAMETER OF DC/DC CONVERTER

Item	Inductor [μH]	Capacitor [μF]	Switching Frequency [kHz]
Buck boost converter	98.7	72.87	40
Proposed converter	25.67	40.50	40
Reduction	73%	44.4%	-

7. Conclusion

A 4-phase dc-dc converter with interleave control technique for HEV is stimulated in this paper to control the charging and discharging of the battery. A single PI controller is designed to control the switching of MOSFET switches. It is found that current ripples are dramatically reduced and sizes of passive elements are also reduced to 44% -73%. Efficiency of proposed converter is around 94%. Therefore proposed converters are seems to be very promising in high power HEV application.

References

[1] Fuji O. *The development and application of hybrid vehicles.* Proc.19th Elect. Vehicle Symp., 2002; 1122–1132.

[2] Saber Y, Venayagamoorthy G.K. *Plug-in vehicles and renewable energy sources for cost and emission reductions.* IEEE Trans. Ind. Electron, Apr 2011; 58(4):1229–1238.

[3] Perreault D. J, Caliskan V. *Automotive power generation andcontrol.*IEEE Trans. Power Electron, May2004; 19(3):618–630.

[4] Moreno J, Ortuzar M.E, Dixon J.W. *Energy-management systemfor a hybrid electric vehicle, usingultracapacitors and neural networks.*IEEE Trans. Ind. Electron, Apr 2006; 53(2):614–623.

[5] Emadi A, Williamson S. S,Khaligh A. *Power electronics intensivesolutions for advanced electric, hybrid electric, and fuel cell vehicular power systems.*IEEE Trans. Power Electron, May 2006; 21(3):567-577.

[6] Hedel K.K, *High-density avionic power supply.*IEEE Transaction Aerospace Electron.Syst.Sept 1980;16: 615–619.

[7] Mulkern J.H, Henze C. P, Lo D. S, *A high-reliablity, low-cost, interleaved bridge converter.*IEEE Trans. Electron Devices,Jan 1991; 38(2):777-783.

[8] Lee P.W, Lee Y.S, Cheng D. k.W. *Steady-stateanalysis of an interleaved boost converter withcoupled inductors.*IEEE Trans. Ind. Electron. Aug. 2000; 47:787–795.

[9] GarciaO,ZumelP,De Castro A, Cobo J.A. *AutomotiveDC-DC bidirectional convertermade with many interleaved buckstages,* IEEE Trans. Power Electron. May 2006; 21(3):578–586,May 2006.