PERFORMANCE ANALYSIS AND COMPARSION OF BI- DIRECTIONAL DC-DC CONVERTER

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Abstract—*The paper presents the experimental results are provided for both converter types. performance analysis and comparison of two types of bidirectional DC-DC converters - Cascaded Buck-Boost- Capacitor in the middle (CBB-CIM) and Cascaded Buck-Boost-Inductor in the middle (CBB-IIM) for use in plug-in electric and hybrid electric vehicles. The comparison of the two converters is based on device requirements, rating of switches and components, control strategy and performance. Each of the converter topologies has some advantages over the other in certain aspects. Efficiency analysis has been carried out for specific scenarios in vehicle applications.*

1. INTRODUCTION

Our human activity is polluting our atmosphere with carbon dioxide and also petroleum resources across the world is degrading at a very high speed. This has led to the increased rate of the development of the Electric Vehicle (EV) and Hybrid Electric Vehicle (HEV) technologies in past two decades. Hybrid energy sources complement drawbacks of each single device. The usage of light electric vehicles (LEV) is fostered by the public administrations to reduce pollution and traffic congestion in the city areas, therefore An HEV uses combination of both energy storage system (ESS) and ICE technology. Since the vehicle is no longer dependent on only one type of fuel, they have many benefits like increase in the efficiency and drivability and at the same time reducing the emissions. It is very unlike conventional vehicles which solely depend on an ICE engine for the traction power. The integration of the electrical storage system also makes the provision for the regeneration during braking which can further boost up the efficiency of the overall system. The use of bidirectional dc-dc converters which is increased for various applications such as battery charging- discharging, electrical vehicles and UPS system can be applied in Hybrid Electrical Vehicle (HEV) with a battery as an energy storage element to provide desired management of power flow.

In addition, it gives briefing about various hybrid ESSs that combine two or more storage devices. As it is very well known that the fuel economy and all-electric range (AER) of hybrid electric vehicles (HEVs) are highly dependent on the onboard energy- storage system (ESS) of the vehicle. But if we increase the AER of vehicles by15% then there is rise in incremental cost of the ESS almost two times. This is due to the fact that the ESS of HEVs requires higher peak power while preserving high energy density. Hence, Ultra capacitors (UCs) are used which have higher power densities in comparison with batteries. A hybrid ESS is made up of batteries, UCs, and/or fuel cells (FCs) could be a more appropriate option for advanced hybrid vehicular ESSs.

In case of the battery fed electric vehicles (BFEVs), electric energy flows between motor and battery side. For achieving zero emission, the vehicle can be powered only by batteries or other electrical energy sources. Batteries have widely been adopted in ground vehicles due to their characteristics in terms of high energy density, compact size, and reliability. This can be applied in Hybrid Electric Vehicle (HEVs) with a battery as an energy storage element to provide desired management of the power flows. In hybrid electric vehicle energy storage devices act as catalysts to provide energy boost.

However the high initial cost of BFEVs as well as its short driving range has limited its use. Recently many Bi-directional dc-dc converter topologies have been reported with soft switching technique to increase the transfer efficiency. Bi- directional converters using coupled inductor were introduced for soft-switching technique with hysteresis current controller. For minimizing switching losses and to improve reliability, zero-voltage-switched (ZVS) technique and zero-current-switched (ZCS) technique were introduced for Bi-directional converter. A multi- phase Bi- directional converter is suitable for high power application. To achieve high voltage rating or current rating more number of converters can be connected in series or parallel with low switching frequency.

A unified current controller was introduced for Bi-directional dc-dc converter which employs complementary switching between upper and lower switches. This paper deals with the use of a Bi-directional dc-dc converter for a battery fed electric vehicle drive system. A closed loop speed control technique of the proposed battery fed electric vehicle is designed and implemented using PI controller. The overall drive system reduces the system complexity, cost and size of a purely electric based vehicular system. Half bridge converter is also a option but in that, it is

difficult to maintain high efficiency in wide battery pack voltage range. This problem can be solved by a variable frequency pulse width modulation (VFPWM) scheme. Bi-directional dc-dc converters are widely researched and developed for various applications such as battery charger-dischargers, electric vehicles and UPS systems. Bidirectional dc-dc converters are the key components of the traction systems in Hybrid Electric Vehicles. The use of a Bi- directional dc-dc converter fed dc motor drive devoted to electric vehicles (EVs) application allows a suitable control of both motoring and regenerative braking operations, and it can contribute to a significant increase the drive system overall efficiency.
As, Today's scenario is on plug- in hybrid electric vehicles (PHEV's) due to energy security and greenhouse gas emission issues, as well as the low electricity fuel cost. A charge station architecture for municipal parking decks has been proposed, which has a DC micro grid to interface with multiple DC-DC chargers, distributed renewable power generations and energy storage.

2. Component Required

Power MOSFET	:	IRF840
Driver IC	:	IR2112
Capacitor	:	470uF (25V) ; 1000uF
Controller	:	PIC16F877A
Regulators	:	LM7805; LM7812
Diodes	:	1N4000; 1N5408
Inductors	:	100uH ; 200uH; 1mH

3. Idea Details

THE NEED FOR A BIDIRECTIONAL DC-DC CONVERTER IN THE HEV IS DUE TO THE FOLLOWING REASONS
1)The system is operating at the high power and low voltage making the current to rise too high, which causes high electrical and thermal stresses in the passive as well as the active components of the system, also it increases the ohmic losses and hence decrease efficiency
2)Device voltage and current stresses is even further increased up by the wide variation in the input voltage range of the system. Since device stresses depends on the output to input voltage ratio, input voltage variation further increases the components ratings to be used. Further along with the above two factors, the parasitic ringing due to the parasitic components causes EMI emission and therefore ,the proper shielding has to be provided. All above three factors makes the converter packaging bulky, heavy and expensive. Thus there is a need for an efficient DC-DC converter to deal with this issue.
3)To be able to recharge the electrical energy storage system during the re- generative braking, and hence therefore there should be the provision of bidirectional power flow.
Some of the requirements for the Bidirectional DC-DC converters design for the HEV applications are as follows:

- High efficiency
- Lightweight & compact size
- Lower electromagnetic Interference
- Lower input and output current ripple
- Controlled power flow in spite of wide input voltage variation

4. CONVERTER TOPOLOGIES OF INTEREST

Fig.1 and Fig.2 show the two different converters of interest. Fig.1 presents the conventional Cascaded Buck Boost Inductor in the middle (CBB-IIM) having an interfacing inductor between the input and output sides [6]. Fig.2 on the other hand presents the Cascaded Buck Boost Capacitor in the middle (CBB-CIM) topology where the two half bridge converters are cascaded together with a common dc bus capacitor [7].
The DC bus voltage is typically higher than the battery voltage in electric vehicles with a boost stage, but depending on the characteristics of the batteries and design of the propulsion system the nominal DC bus voltage. Therefore, the converter must have the capability to handle the input and output side voltages with overlapping ranges. Both the converters, CBB-IIM and CBB-CIM, have the input and output voltage overlap capability. battery voltage may overlap with the

5. CONTROL STRATEGY

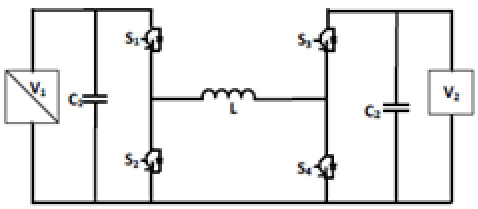


Fig.1: Cascaded Buck Boost Inductor in the middle (CBB-IIM)

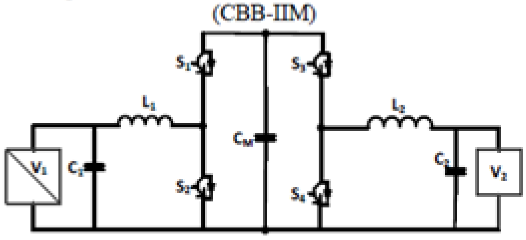
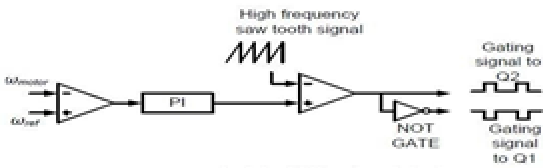


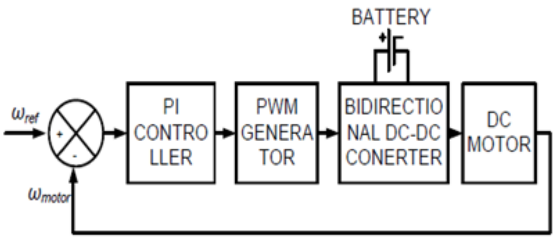
Fig.2: Cascaded Buck Boost Capacitor in the middle (CBB-CIM)

Control strategy of the bidirectional dc-dc converter.
The control circuit of the bidirectional converter is shown in Fig. to control the speed of the dc drive; one possible control option is to control the output voltage of the bidirectional converter.
To control the output voltage of the bidirectional converter for driving the vehicle at desired speed and to provide fast response without oscillations to rapid speed changes a PI controller is used and it shows satisfactory result. In this control technique the motor speed ωm is sensed and compared with a reference speed ωref. The error signal is processed through the PI controller. The signal thus obtained is compared with a high frequency saw tooth signal equal to switching frequency to generate pulse width modulated (PWM) control signals.



Control of the bidirectional dc-dc converter.

6. CLOSED LOOP OPERATION OF THE DRIVE



Closed loop operation of the drive.

The block diagram of feedback speed control system for DC motor drive is shown in Figure; the control objective is to make the motor speed follow the reference input speed change by designing an appropriate controller. The proportional-integral(PI) controller is used to reduce or eliminate the steady state error between the measured motor speed (ωmotor) and the reference speed (ωref) to be tracked.

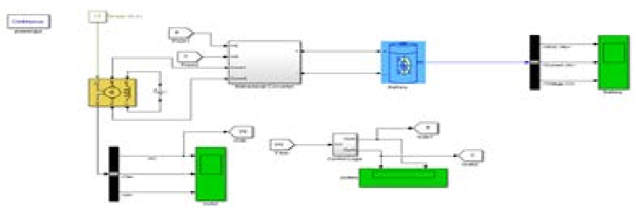
Battery Requirement for Automotive Application.

Mainly Nickel-Metal hydride (NiMH) and Lithium-ion batteries are used in vehicular application due to their characteristics in terms of high energy density, compact size and reliability. The battery is being recharged by the regenerative capabilities of the electric motors which are providing resistance during braking helping to slow down the vehicle. The lithium-ion battery has been proven to have excellent performance in portable electronics and medical devices .

The lithium- ion battery has high energy density, has good high temperature performance, and is recyclable. The promising aspects of the Li-ion batteries

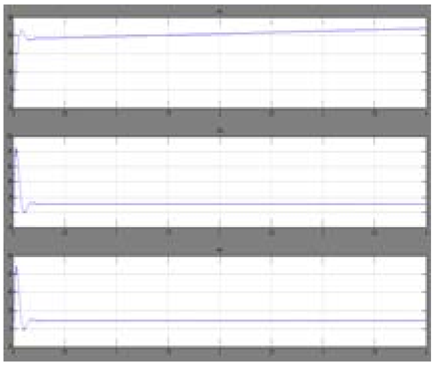
include low memory effect, high specific power of 300 W/kg, high specific energy of 100 Wh/kg, and long battery life of 1000 cycles. These excellent characteristics give the lithium-ion battery a high possibility of replacing NiMH as next-generation batteries for vehicles. The state of charge (SOC) of the battery.

7. SIMULATION AND RESULTS

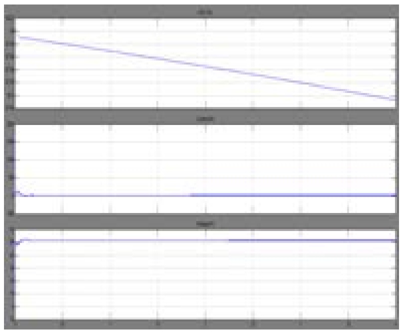


Matlab simulink mode

Normal condition Torque-: 10Nm, ref. speed-120rad/sec:



Motor results



Battery results

8. CONCLUSION

I have studied a battery operated electric vehicle system and it shows satisfactory performance at different driving condition. The proposed control technique with PI controller find suitable for this electric drive. The performance of the BFEV is verified under forward motoring mode, regenerative mode and when there is step change is speed command. The overall cost and volume of the battery operated electric vehicle is less with the least number of components used in the system.

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