International Journal of Emerging Technology in Computer Science & Electronics (IJETCSE)
ISSN: 0976-1353 Volume 22 Issue 1 – MAY 2016.

A BI-DIRECTIONAL POWER CONVERTER FOR BATTERY OF HYBRID ELECTRIC VEHICLE

SasikumarS[1], KrishnamoorthiS[2], keerthanaS[3]

[1]Ph.D Scholar, Department of Electrical Engineering,Sona College of Technology
[2]Associate Professor ,Department of Electrical Engineering,Sona College of Technology
[3.]PG student , Department of Electrical Engineering,Sona College of Technology

***Abstract*--As more and more power electronics systems (PES) are packaged into the latest hybrid electric vehicles (HEVs), it is important to keep the PES at low cost and small volume while maintaining high reliability. To fulfill these requirements converters with bidirectional power flow capabilities are required to connect the accumulator (battery) to the dc link of the motor drive system. Hence, the main purpose of this research work is to propose a bidirectional power converter for the bidirectional power management of a HEV battery. The DC/DC converter is constructed by a buck-boost circuit, which is a buck circuit when charging and a boost circuit when discharging. In the present work closed loop operation of bi-directional dc-dc converter feeding a dc motor and its energy recovery due to regenerative braking has been demonstrated. The characteristics of battery operated electric vehicle under different drive condition are also presented. The effectiveness of the system is verified through the simulations using Simulink/ MATLAB 7.6.0 (R2008a) package.**

Keywords: Bi-directional dc-dc converter,separately excited dc motor, Battery

I. INTRODUCTION

Bidirectional DC-DC converters have been widely used in various industrial applications such as renewable energy systems, hybrid electric vehicle, fuel cell vehicle, uninterruptible power supplies and satellite. In those applications, bidirectional DC-DCconverters control the power flow between the dc bus and the low voltage sources such back-up batteries, fuel cell batteries, and super capacitors. 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. Bidirectional dc-dc converters are the key components of the traction systems in Hybrid Electric Vehicles. Recently many Bi-directional dc-dc converter topologies have been reported with soft switching technique to increase the transfer efficiency (Zhang *etal*., 2007). Bi-directional converters usingcoupled inductor were introduced for soft-switching technique with hysteresis current controller (Zhang and Sen, 2003). 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 (Jain *et al*., 2002). 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 (Yu and Lai, 2008). A unified current controller (Zhang *et al*, 2008) was introduced for Bi-directional dc-dc converter which employs complementary switching between upper and lower switches.

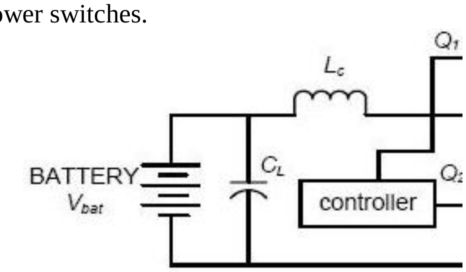

Figure1. Bidirectional dc-dc converter with battery and dc motor

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. Figure1 shows the proposed Bi-directional dc-dc converter fed DC motor drive. In this topology, boost converter operation is achieved by modulating Q2 with the anti-parallel diode D1 serving as the boost-mode diode. With the direction of power flow reversed, the topology functions as a buck converter through the modulation of Q1 , with the anti-parallel diode D2 serving as the buck-mode diode. It should be noted that the two modes have opposite inductor current directions. A new control model is developed using PI controller to achieve both motoring and regenerative braking of the motor. A Lithium-ion battery model has been used in this model to verify the motor performance in both motoring and regenerative mode. This controller shows satisfactory result in different driving speed commands.

II. CIRCUIT DESCRIPTION

Converter operation: The bidirectionaldc-dc converter shown in Figure1 is operated in continuous conduction mode for forward motoring and regenerative braking of the dc motor. The MOSFETs *Q1* and *Q2* are switched in such a way that the converter operates in steady state with four sub intervals namely interval *1(t0-t1),* interval *2(t1-t2)*, interval *3(t2-t3)* and interval *4(t3-t4)*. It should be noted that the low voltagebattery side voltage is taken as *V1* and high voltage load side is taken as *V2*. The gate drives of switches *Q1* and *Q2* are shown in Figure 3. The circuit operations in steadystate for different intervals are elaborated below.

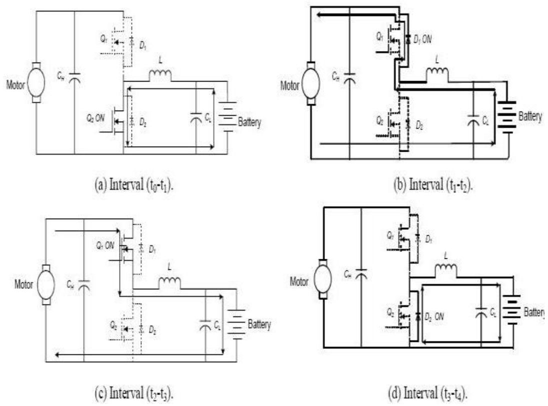

Figure 2. Converter operating modes

Interval 1(t0-t1): At time *t0*, the lowerswitch *Q2* is turned ON and the upper switch *Q1* is turned OFF with diode *D1*, *D2* reversebiased as shown in Figure 2(a). During this time interval the converter operates in boost mode and the inductor is charged and current through the inductor increases

Interval 2(t1-t2): During this intervalboth switches *Q1* and *Q2* is turned OFF. The body diode *D1* of upper switch *Q1* starts conducting as shown in Figure 2(b). The converter output voltage is applied across the motor. As this converter operates in boost mode is capable of increasing the battery voltage to run the motor in forward direction

Interval 3(t2-t3): At time *t3*, the upperswitch *Q1* is turned ON and the lower switch *Q2* is turned OFF with diode *D1*, *D2* reversebiased as shown in Figure 2(c). During this time interval the converter operates in buck mode

Interval 4(t3-t4): During this intervalboth switches *Q1* and *Q2* is turned OFF. The body diode *D2* of lower switch *Q2* starts conducting as shown in Figure 2(d)

2.2 Converter design: The bi-directionalconverter is designed based on the input supply voltage and output voltage requirement to drive the electric vehicle at desired speed. The converter power topologyis based on a half bridge circuit to control the dc motor.

III. CONTROL STRATEGY

The control circuit of the bidirectional converter is shown in Figure 4.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 throughthe 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

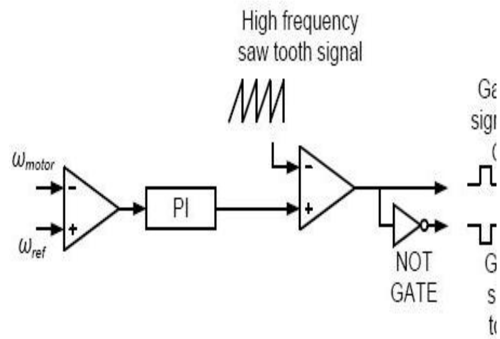

Figure 4. Control of the bidirectional dc-dc converter

IV. 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

V. SIMULATION RESULTS

Performance of the dc motor drive with the above battery model and bidirectional converter is simulated under different speed command. The simulations are carried out using MATLAB/SIMULINK. The inductor parasitic resistance and MOSFET turn-on resistance are not considered in this case. For the test condition of the proposed drive topology the following values of the different components of the converter are considered. A separately excited DC motor model is used as load to the bidirectional dc-dc converter. The motor rated at 5 hp, 240 V, and 1750 rpm. Principal parameters of the bidirectional converter are: *L = 1600 µH, CH=470 µF, CL= 470 µF, fSW =20 kHz Battery voltage=4, Battery capacity=16 Ah, SOC=88%.*

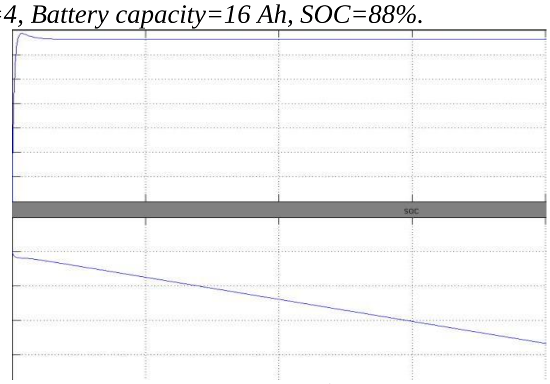

Figure 6(a). Output Voltage of the BoostMode

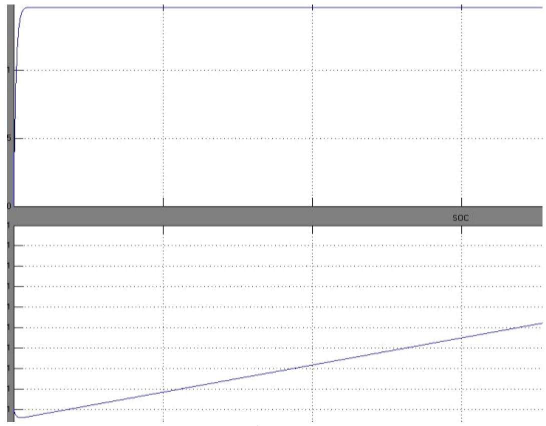

Figure 6(a). Output Voltage of the BuckMode

VI. CONCLUSION

In this work we demonstrate the performance of 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 overall cost and volume of the battery operated electric vehicle is less with the least number of components used in the system.

REFERENCES

[1]Jain P.K., Kang W., Soin H., Xi Y., 2002 Analysis and design consideration of a load and line independent Zero voltage switching Full bridge DC/DC Converter topology, *IEEE Transaction onPower Electronics*, Vol.17, No.5,September. pp 649-657

[2]Yu W., Lai J.-S., 2008. Ultra High Efficiency Bidirectional DC-DC Converter With multi frequency pulse width modulation APEC 2008,pp 1079-1084

[3]Zhang J., Lai J.-S., Kim R.-Y., Wensong Yu, 2007. High power density design of a soft-switching high-power bidirectional dc-dc converter, IEEE Transactions on power electronics, Vol.22, No.4, pp 1145-1153, July

[4] Zhang Y., Sen P.C., 2003. A new soft switching technique for buck, boost, and buck-boost converters, *IEEEtransactions on Industry Applications*,Vol. 39. No.6, November/December, pp. 1775-1782

[5]Zhang J., Lai J.-S., Yu W., 2008. bidirectional dc-dc converter modeling and unified controller with digital implementation, *AppliedPower Electronics Conference and Exposition*, APEC 2008, pp.1747-1753, Feb