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HYBRID ENERGY SOURCE BASED THREE LEVEL DC-DC CONVERTER FOR ELECTRICAL VECHILES

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Abstract: To enhance the opulence of hybrid energy source in electrical vehicles and to have a sophisticated usage which results in bi-directional power flow capability with wide voltage conversion range thus a three level dc-dc converter for electrical vehicles are proposed. This unique technology was extracted from buck and boost three level dc-dc converter with high voltage gain and non extreme duty cycle. One of the most critical issues for the environment today is pollution generated by hydrocarbon combustion, which is one of the main sources of power for transportation. In recent years, energy storage systems assisted by super capacitor have been widely researched and developed to progress power systems for the vehicles. In this paper, a bi-directional DC-DC converter and its control methods are proposed. From the results of detailed experimental demonstration, the proposed system is able to perform adequate charge and discharge operation between low-voltage and high-voltage with drive vehicles and main battery. In a hybrid or electric vehicle, a dc-dc converter enables reduction of the size of the electric machine and optimization of the battery system. The experimental results validate the feasibility of the proposed topology and the correctness of its operating principles.

Keywords—: Bidirectional DC-DC converter, Capacitor voltage balance, High voltage-gain, Non-extreme duty cycles.

I. INTRODUCTION

In recent years, the global energy crisis has become increasingly intensified. As a result, the greenhouse effect, air pollution and other environmental issues have been gradually getting worse. The environment and human lives have been seriously affected by the massive amount of automobile exhaust emissions. It is an effective solution to replace conventional vehicles with new energy vehicles which can greatly reduce the environmental impact because of their pollution-free characteristics. As an important part of new energy vehicle technology, electric vehicles have become the inevitable trend of the automobile industry. The energy-storage systems used in electric vehicles must provide a high specific energy and a high specific power for long time operations. Although the energy density of battery stacks is very high, the power density is low, so they are not suitable for large current charge or discharge. A possible solution for this problem is combining battery stacks with super-capacitors, which can provide a high specific power and a high specific energy Therefore, the hybrid energy source system can greatly improve the performance of electric vehicles. Super-capacitors are connected to the battery stacks in parallel through a bidirectional DC-DC converter. The battery stacks provide stable levels of energy to extend the driving range of electric vehicles, while the super-capacitors discharge during acceleration and charge during braking, in which instantaneous pulse powers are needed and generated. This shows the important role of the bidirectional DC-DC converters in the hybrid energy source electric vehicles.

II. EXISTING SYSTEM

The existing system described a battery charging method using DC-DC converter. The full-bridge DC-DC converter assisted with passive auxiliary circuit offers ZVS for all main switches throughout the battery charging range. It also minimizes the voltage spikes across secondary rectifier diodes as the converter is integrated with clamping diode network of the primary side. The output voltage is controlled using asymmetrical pulse width modulation (APWM) technique and also this system discussed the steady-state analysis of the auxiliary circuit with PSM and APWM, and ZVS transition of main switches.

III.PROPOSED SYSTEM

Hybrid electric vehicles (HEV) and full electric vehicles (EV) are rapidly advancing as alternative power for green transportation. The vehicles' electrification not only involves the traction parts, but it is also generating new applications

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for electric power conversion. One of the key blocks inside hybrid electric vehicles is the DC–DC converter for auxiliary power supply of electric loads .This system develop a bidirectional DC-DC converter drive system for an electric vehicle which consists of a battery, motor, DC-DC Converter and control system. The DC-DC converter is required to perform mainly two functions: first to match the battery voltage to the motor rated voltage, and second to control the power flow under acceleration and braking conditions. During acceleration and normal modes the power flows from battery to motor, and during braking or regenerative mode the kinetic energy of the motor is converted into electrical energy and fed back to the battery.

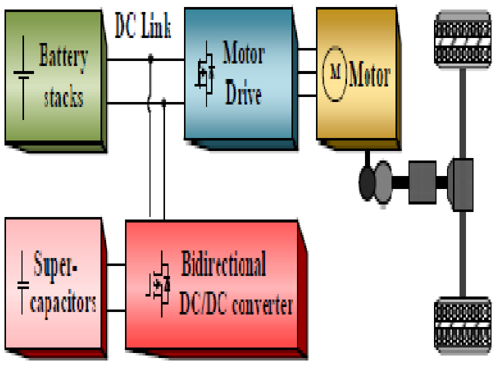
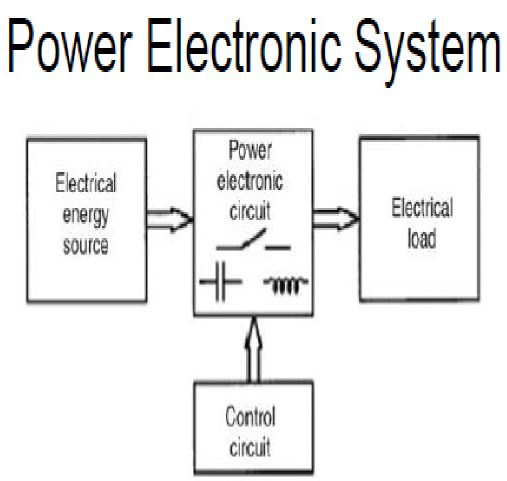


Fig. 1. Electrical architecture of hybrid energy source electric vehicles.

A. *POWER ELECTRONIC SYSTEM*



A power electronic system consists of power electronic switching devices, linear circuit elements, digital circuits, microprocessors, electromagnetic devices, DSPs, filters, controllers, sensors, etc….

B. *LITERATURE REVIEW*

Looked at the required operating points of power devices for different applications and concluded that SiC devices are well suited for automotive applications, because SiC devices can endure the higher ambient and junction temperature and have lower switching losses. Reference also looked at the application of SiC devices on a vehicle from the system level. It claimed a reduction of 69.1% in motor and inverter loss, and an increase of 21.3 % in drive train efficiency for a plugin hybrid electric vehicle. Reference compared the loss of SiC MOSFET inverter and Si IGBT inverter used in hybrid vehicles and the corresponding fuel consumption of the vehicles during drive cycles.

As a result of high switching speed of SiC devices, very large voltage and current transition rates are observed during turn-on and turn-off process, which can induce unwanted voltage spikes across parasitic elements, especially parasitic inductances. Furthermore, the energy stored in parasitic inductances is difficult to dissipate because of the low loss property of these devices. Thus, SiC devices are more vulnerable to parasitic ringing problems . For the parasitic influence, many efforts are spent on the Si MOSFET with a single structure. However, not much research is done on the SiC devices in the area of parasitic influence. Especially, in high power rating applications, such as hybrid/electric vehicles, where several SiC devices need to be paralleled to attain the current rating of the converters required, the impact of each interconnection inductance will be different. The paper aims to analyze the effect of the interconnection parasitic inductance to the performance of a DC-DC converter using a hybrid vehicle application as a study case.

Usually the conventional Boost two-level DC-DC converter is employed due to its simple structure, but, it suffers from disadvantages including limited voltage-gain, and high voltage stress for its power semiconductors. To alleviate the problem of mismatched voltage levels, the rated voltage of the fuel cell stack has to be increased (increasing the difficulty of assembling the fuel cell stack). At the same time, power semiconductors with higher rated blocking voltage need to be employed and consequently the conduction losses can be improved.

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However, there remain two essential problems concerning the interface between the fuel cell stack and the DC-link bus, namely the same limited voltage-gain with that of the Boost two-level converter, and the complicate control required for the flying-capacitor voltage balance of the Boost three-level converter, especially the voltage imbalance of the flying-capacitor in the transient state - this latter may cause power semiconductor failure.

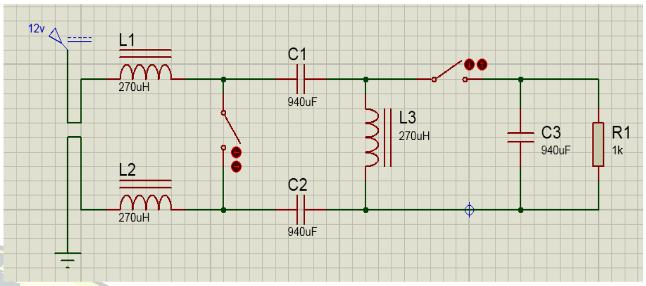
However, the conventional full-bridge converter has the following disadvantages: loss of zero voltage switching (ZVS) during turn-on at light loads, secondary duty cycle loss, high circulating current and high voltage spikes on output rectifier diodes due to the leakage inductance of the transformer and the external series inductance.

Another major problem of the conventional full-bridge converters is the voltage spikes across secondary rectifier diodes due to the ringing between junction capacitance of rectifier diodes with the transformer leakage inductance. The voltage spikes are intensified with the increase in the leakage inductance of the power transformer and in the operating switching frequency of the converter. Therefore, the output rectifier diodes and the output filter have to be overrated to withstand voltage spikes. Overrated diodes lead to increased losses due to higher forward voltage drop and poor reverse recovery characteristics. Additionally, the voltage spikes significantly increase the electromagnetic interference (EMI) and reduce the reliability of the converter. Resistor-Capacitor-Diode (RCD) snubber circuits proposed. The disadvantage of RCD snubber circuit is that the energy stored in the capacitor is dissipated in snubber resistor which considerably reduces the efficiency of the converter. Active clamp snubber circuit increases the cost and complexity of the converter and alsoreduces the efficiency resulting from hard switching. The converter proposed is minimizes the secondary voltage spikes with clamping diode network on the primary side of main transformer.

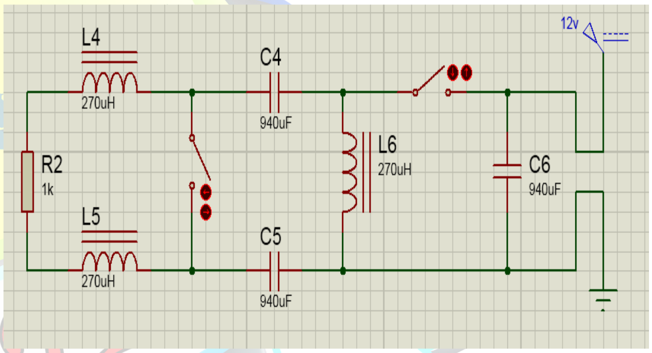
Several modified full-bridge DC-DC converter topologies and control methods have been proposed to overcome the drawbacks as mentioned earlier. ZVS full-bridge converter topologies assisted with passive auxiliary circuit. However, the applicability of these topologies is limited by reduced effective duty cycle and high voltage spikes across rectifier diodes. ZVS full-bridge converter topologies assisted with active auxiliary circuit have been proposed and analyzed. The major drawbacks of these topologies include reduced efficiency for higher input voltage, ineffective in achieving ZVS for leading-leg switches at very light-load conditions, and increased control complexity.

1.circuit diagram

Boost converter



Buck converter



IV. CONTROL STRATEGIES

It includes coordination control and duty cycle disturbance control for capacitor voltage control

A. *COORDINATION CONTROL BETWEEN INDUCTOR CURRENT RIPPLES AND NON-EXTREME DUTY CYCLES*

To reduce the power losses of the converter, it is better to switch power semiconductors without extreme duty cycles, and reduce the inductor current ripples. However, both requirements cannot be met at the same time. It is obviously that the longer the power switches are off (in the Buck mode), or on (in the Boost mode), the larger inductor current ripples become. Therefore, it is required to make a trade off between the inductor current ripples and non-extreme duty cycles, according to the permitted high voltage-gain M and duty cycles of the chosen power switches .Therefore, k Buck can be worked out by means of the permitted voltage-gain M Buck, and the duty cycles d1 (d8) and d2 (d7) of the chosen

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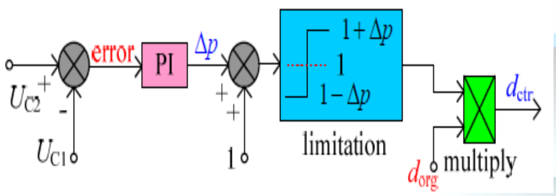
power switches. When the bidirectional DC-DC converter operates in the Boost mode, the restriction function ma b=f (M Boost, k Boost).In fact, k Boost can also be determined from the permitted voltage-gain M Boost, and the duty cycles d3 (d6) and d4 (d5) of the chosen power switches. it is concluded that the larger restriction factors (k Buck and k Boost), the shorter the transferring or storing energy time of the inductor. Therefore, the inductor current ripple can be decreased by determinate the restriction factors, although all of the duty cycles of the power switches get closer to extreme ones (farther away from 0.5 through two directions). Namely, if certain duty cycles (closer to extreme ones) of the power switches are permitted, the inductor current ripple can be effectively reduced.

B. DUTY CYCLE DISTURBANCE CONTROL FOR CAPACITOR VOLTAGES BALANCE

If power semiconductors (Q1~Q8) can operate in the ideal state, and the series-connected capacitors C1 and C2 have permanent equal capacitances, this part could be omitted.

Unfortunately, although the series-connected capacitors and power semiconductors have the so-called identical electrical characters. They may not accord with each other in practice. The capacitance of series-connected capacitors may change during long operation. Furthermore, the rise and fall times for each of the power switches may be different when converters operate. . In addition, the charging and discharging time of C1 and C2 are equal, namely tBuck1=tBuck3 and tBuck2=tBuck4 can be obtained.



Principle of duty cycle disturbance

Meanwhile, the corresponding instantaneous inductor currents (during tBuck1 and tBuck3, tBuck2 and tBuck4) iL are the same as those due to the equal instantaneous voltages Uab, as well as the equal capacitances of C1 and C2.

Therefore, the voltages across C1 and C2 can be balanced by charging or discharging equal quantity of electric charge. In the same way, tBoost1= tBoost3 and tBoost2= tBoost4 can be deducted, as well as the mentioned instantaneous inductor currents iL and voltages Uab in the Boost mode. In addition, the voltages across C1 and C2 can also be balanced. However, the rise and fall times of each power switch (Q1~Q8) may not be identical, as well as the capacitances of C1 and C2. Therefore, an unequal quantity of electric charge flowing through two capacitors will occur during each carrier period. The principle of unbalanced capacitor voltages in the Buck mode based on the assumption that the rise times (fall time leads to the opposite result) of Q1 and Q7 are delayed compared with the driving signals .

Then the discharging time (*t*Buck2) of *C*1 decreases, the discharging time (*t*Buck4) of *C*2 increases, and *t*Buck1=*t*Buck3 still exists. At last, the energy stored in *C*2 is more than that stored in *C*1 during each carrier period. Unfortunately, the voltages across *C*1 and *C*2 are seriously unbalanced, even *U*C2 arrives at zero. Then the energy stored in *C*1 is more than that in *C*2. Finally, the voltages across *C*1 and *C*2 are seriously unbalanced ,even UC1 becomes zero. As for the Boost mode, the principle of unbalanced capacitor voltages based on the assumption that the rise times (the fall time leads to the opposite result) of Q4 and Q5 are delayed compared with the driving signals Then the energy stored in *C*1 is more than that in *C*2. Finally, the voltages across *C*1 and *C*2 are seriously unbalanced, even *U*C1 becomes zero. In order to avoid unbalanced charging and discharging of the capacitors in each carrier period, the duty cycle *d*2 can be chosen to be disturbed in the Buck mode. In addition, *d*4 can be chosen in the Boost mode

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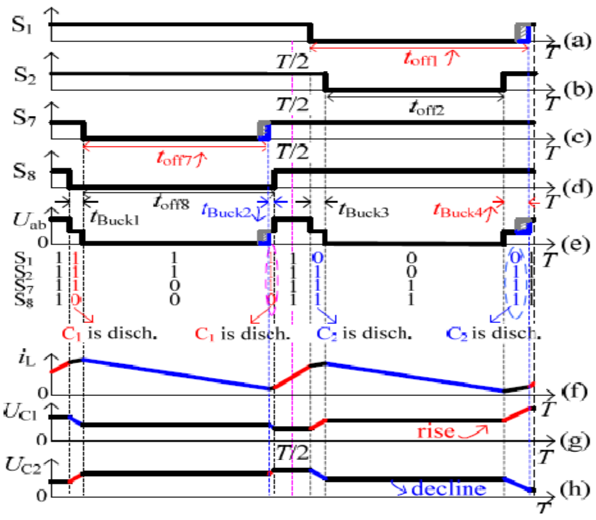

Principle of unbalanced capacitor voltages in buck mode

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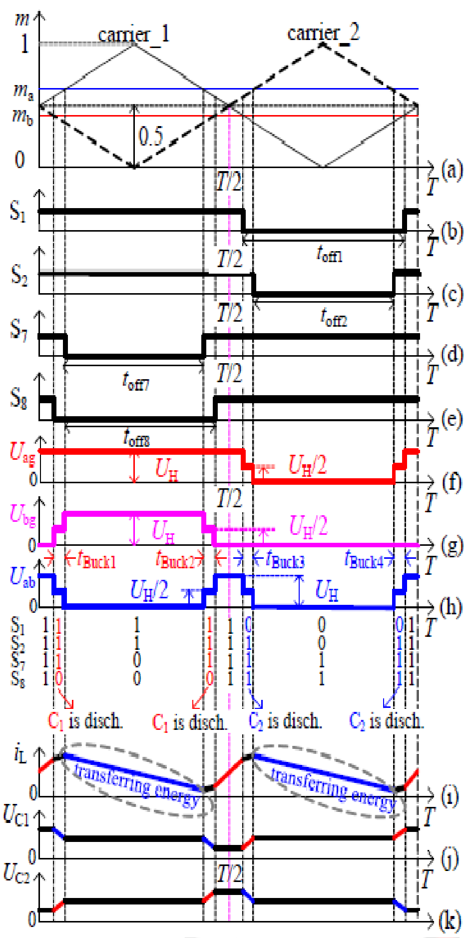


PWM scheme in buck mode

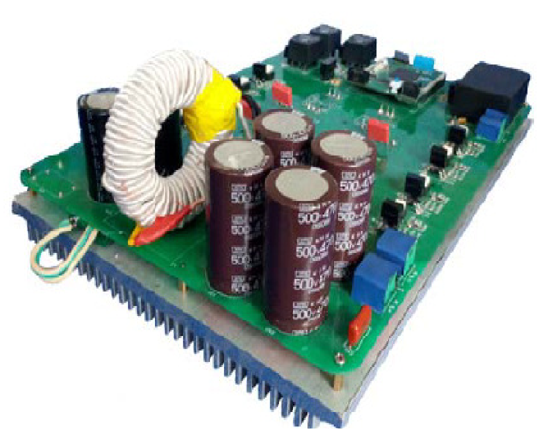
C. CONTROL STRATEGY FOR BIDIRECTIONAL POWER FLOW

The PWM signals for the power switches Q1~Q8 can be obtained based on the mode control signal S and the modulation index M. The bidirectional power flow control strategy.In this paper, the control strategy of the bi-directional DC-DC converter proposed for application to hybrid energy source electric vehicles should comply with the control
strategy of the hybrid energy management system. The main control idea is to use super-capacitors to provide a lot of instantaneous power for the load, and to fully recycle the
regenerative energy when braking. As a result, the power battery can be compensated. In order to avoid unbalanced charging and discharging of the capacitors in each carrier period, the duty cycle d2 can be chosen to be disturbed in the Buck mode. In addition, d4 can be chosen in the Boost mode. As shown in Fig. 7, C2 is discharged extremely. Therefore, d2 can be disturbed to reduce a little according to the voltage error between C2 and
C1. Then toff2 increases to decrease tBuck3 and tBuck4 until the capacitor voltages are balanced in each carrier period.

TABLE 1

Parameters	Values
Rated power P_n	1.2 kW
Series-connected capacitor C_1	940μF
Series-connected capacitor C_2	940μF
Filtering capacitor C_f	940μF
Filtering inductor L_f	270μH
High voltage side U_H	400 V
Low voltage side U_L	60~160 V
Switching frequency	10kHz
Power switches Q_1~Q_8	IXTK 102N30P (300V, 102A)
Diodes D_{c1}~D_{c4}	DSEC 60-03A (300V, 60A)
Non-extreme duty cycle range	0.2~0.8
Restriction factor $k_{Buckmin}$	0.1
Restriction factor $k_{Buckmax}$	1.5
Restriction factor $k_{Boostmin}$	0.1
Restriction factor $k_{Boostmax}$	1.5

Fig. 1. Experimental prototype



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In order to verify that the proposed duty cycle disturbance control method work properly in the Boost mode, an experiment without implementing this method is carried out .

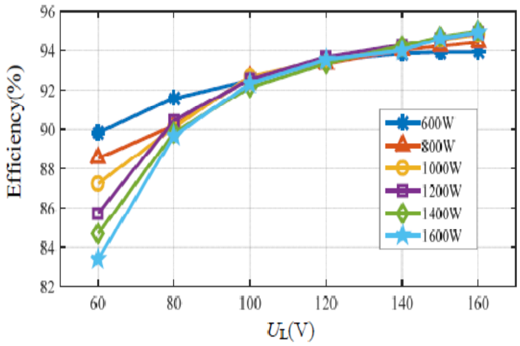

Fig. 2. Efficiency of the converter in buck mode

EXPERIMENTAL RESULT AND CONCLUSION

In order to verify the proposed converter and control strategies, a 1.2kW experimental prototype with voltage and current control loops is established in the lab., and the experiments are carried out in the Buck, Boost, and bidirectional operation modes. In order to verify that the proposed duty cycle disturbance control method work properly in the Boost mode, an experiment without implementing this method is carried out.

In this paper, a wide-voltage-conversion range bidirectional three-level DC-DC converter is proposed for hybrid energy source electric vehicles. This transformer less converter can operate with a high voltage-gain and avoid extreme duty cycles In addition, the discrepant electrical characters (rise and fall times) of the power switches and the unequal capacitances of the series-connected capacitors can be tolerated thanks to the balanced capacitor voltages. The proposed converter and control strategies are suitable for the bidirectional power flow applications in hybrid energy source electric vehicles.

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