International Journal Of Modern Engineering Research (Ijmer)
www.ijmer.com Vol. 3, Issue. 5, Sep - Oct. 2013 Pp-2786-2791 Issn: 2249-6645

A ZVS Interleaved Boost AC/DC Converter Using Super Capacitor Power for Hybrid Electrical Vehicles

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ABSTRACT: *This paper presents the supercapacitor power management method for the Hybrid Electricals Vehicles.A simple zero-voltage switching(ZVS) interleaved boost power factor correction(PFC) AC/DC converter is used to charge the traction battery of an Hybrid Electrical Vehicle. The auxiliary circuit provides limited current to charge and discharge the MOSFETs output capacitors during turn-On times at zero voltages. The circuit maintains ZVS for the universal input voltage (85 to 265 Vrms), and having the very wide range of duty ratios (0.07 to 1). The proposed tropology consist of super capacitor, which connected across the hybrid electrical vehicle. The main objective of this paper is to study the management of the energy provided by supercapacitor by using multi full bridge converter tropology, which is having maximum voltage of 270v. The output of the full bridge converter is connected to the hybrid electrical vehicle. The supercapacitor output is connected to the load through planar Transformer, it provides peak voltages at starting of Electrical Vehicle.The experimental and simulation results are presented.*

Keywords: *AC/DC converter, Interleaved boost converter, Zero voltage switching, power factor correction, supercapacitor, boost converter, full bridge converter.*

I. INTRODUCTION

In the last few years the pollution problems and the increase of the cost of fossil energy (oil,gas) have become planetary problems. The car manufacturers started to react to the urban pollution problems in nineties by commercializing the electric vehicle. But the battery weight and cost problems were not solved. The batteries must provide energy and peaks power during the transient states. These conditions are severe for the batteries. To decrease these severe conditions, the super capacitors and batteries associate with a good power management present a promising solution.

In the electric traction system, Electric Vehicle (EV) power conditioning systems usually utilize a high-energy battery pack to store energy. This is typically charged from a utility ac outlet. The energy conversion during the battery charging is performed by an ac/dc converter. The need of Ac to Dc conversion is, while the Electrical Vehicle (EV) is moving it is not possible to connect the moving electrical vehicle to AC utility mains. The energy is supplied by the storage Energy batteries which is stores the energy in the form of DC. Thuts why we have to perform the AC/DC conversion. The conduction losses caused by the auxiliary circuit are minimized based on the operating condition. A control circuit is proposed to control the ZVS interleaved boost PFC converter.

At starting of Electric vehicles it draws more current. Then the electric vehicles are operating in unstable operating condition. To get the stable operation the superapacitor power is used in the ZVS interleaved boost converter of an Electrical vehicle.

II. ANALYSIS OF THE ZVS INTERLEAVED BOOST PFC CONVERTER:

The Fig. 1 shows the power circuit of the ZVS interleaved boost PFC converter. In this converter, two boost converters operate with 180◦ phase shift in order to reduce the input current ripple of the converter. This 180◦ phase shift can be used to provide reactive current for realizing ZVS for power MOSFETs. This auxiliary circuit consists of a HF inductor and a dc-blocking capacitor. Since there may be a slight difference between the duty ratios of the two phases, this dc-blocking capacitor is necessary to eliminate any dc current arising from the mismatch of the duty ratios of the main switches in the practical circuit.

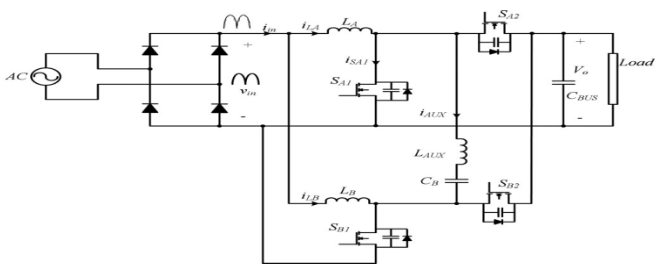


Fig.1. ZVS Interleaved boostconverter

The converter operates for two types of Duty ratios, those are D > 0.5 and D < 0.5.,and analysis of wave forms are explained by modes of operation Mode

1. Mode *1(t0 < t < t1)* 2. Mode *II (t1 < t < t2)* 3. Mode *III (t2 < t < t3)* 4. Mode *IV (t3 < t < t4)*
5. Mode *V (t4 < t < t5)* 6 Mode *VI (t5 < t < t6):* 7. Mode *VII (t6 < t < t7)* 8 Mode *VIII (t7 <t<t8):*

III. CONTROL SYSTEM FOR THE ZVS INTERLEAVED BOOST PFC

The peak value of the auxiliary circuit current should be adjusted based on the load condition in order to optimize the circulating current between the two phases of the interleaved boost converter**.** Therefore, in order to optimize the circulating current, the envelope should be just enough to overcome the valley current of the boost inductor in the half cycle. There are two main difficulties related to the optimization of the circulating current in the proposed converter. The first problem is the operation with duty ratios lesser than 0.5 and the second issue is optimizing the circulating current for different load conditions. Fig. 2 shows the block diagram of the proposed control system. The proposed control system includes an external voltage loop, internal current loop, and a switching frequency control loop.Therefore, afrequency loop is added to the control system to optimize the circulating current of the auxiliary circuit based on the load and duty ratio of the converter. Such load-adaptive switching frequency variation has been proved to increase efficiency in ZVS converters.

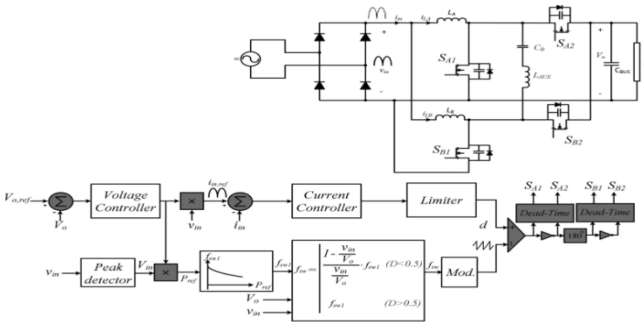


Fig:2. block diagram for the control system of ZVS interleaved boost PFC

Fig. 3 shows the typical switching frequency variation at heavier and lighter loads. At heavy loads, the frequency is lower to provide more reactive current in the auxiliary circuit to overcome higher values of *Iv* and charge and discharge the output capacitors. Whereas at light loads, the frequency is higher to reduce the auxiliary circuit current in order to avoid any extra circulating current between the two phases.

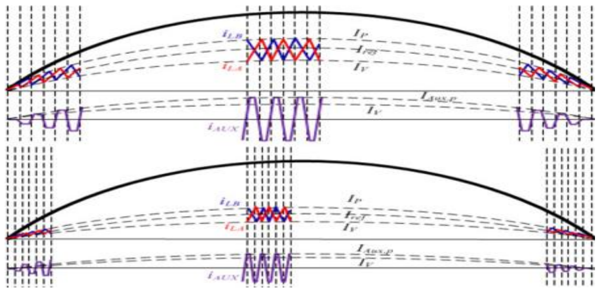


Fig: 3 Change in frequency for different loads

The variation of the frequency with respect to the converter output power is shown in fig.4. Owing to the change of frequency, the circulating current is optimized for a very wide range of operation. Since the converter is used to charge the traction battery, there is actually a need for very wide range of operating conditions and the converter has to work at very light loads for a long period of time also. Thus, this optimization is imperative in this particular application.

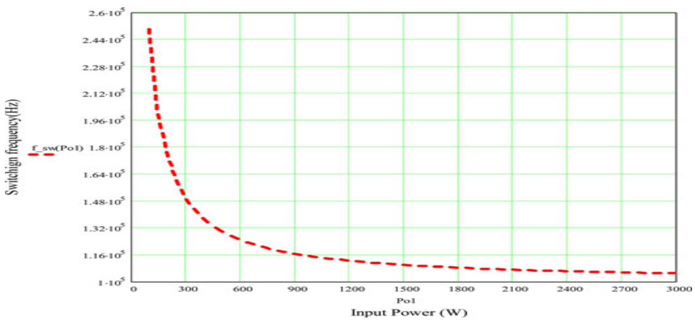


Fig: 4 switching frequencyfor variation versus load

There are two main points related to the control system. Those are (1) the frequency loop is completely decoupled from the duty cycle loop. Fig.5. illustrates the fact that by changing the frequency of the saw-tooth counter, the duty cycle does not change (i.e., D1 = D2). (2) the frequency change does not tamper the operating modes of the converter in terms of operating under CCM of the input inductors. Since the frequency is higher for light loads, the control system helps the converter to work in CCM for wider range of loads. In addition, for higher input voltage, frequency decreases at the peak value of the input current. Therefore, reducing the frequency does not bring the converter into discontinuous conduction mode.

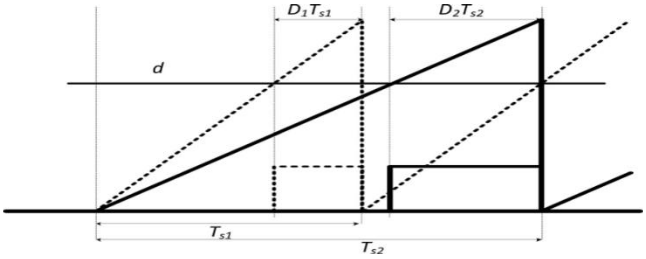
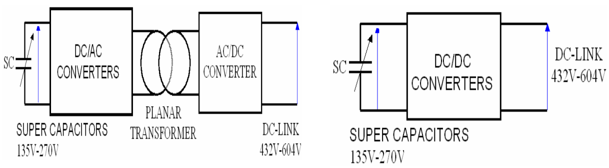


Fig: 5. PWM pulses for different frequencies

IV. SUPERCAPACITOR POWER MANAGEMENT FOR ZVS PFC

Supercapacito rare storage devices which enable to supply the peaks of power to hybrid vehicle during the transient states. During the steady states, batteries will provide the energy requested. This methodology enables to decrease the weight and increases the lifespan of the batteries. The multi boost and multi full bridge converters will be investigated because of the high power.

For range problems, traction batteries used until now cannot satisfy the energy needed for future vehicles. To ensure a good power management in hybrid vehicle, the multi boost and multi full bridge converters topologies and their control are developed. Two topologies proposed for the power management in ECCE Hybrid Vehicle are presented in Fig.6.



Fig(a): First solution Fig:(b): second solution
Fig:6 converter tropoiogies for ECCE hybrid vehicles

V. DESIGN OF THE CONVERTER CIRCUIT

Wiring in power electronic design is a general problem for electrical energy system and the voltage inverters do not escape to this problem. The switch action of semiconductors causes instantaneous fluctuations of the current and any stray inductance in the commutation cell will produce high voltage variations. Semiconductors, when switching off, leads to high voltage transitions which is necessary to control within tolerable limits. The energy stored in parasitic inductances, during switching on, is generally dissipated by this semiconductor.

In the case of the single-phase inverter, each cell includes two switches and a decoupling capacitor placed at the cell boundaries, which presents a double role. It enables to create an instantaneous voltage source very close to the inverter. The capacitor associated to an inductor enables to filter the harmonic components of the currents which are generated by the inverter. Parasitic inductances staying in the mesh include the capacitor inductance, the internal inductance of semiconductors and the electric connection inductances.

A good choice of the components with an optimal wiring enables to parasitic inductances. Using the semiconductors modules solves the connection problems between components. All these efforts can become insufficient, if residual inductances remain too high or if the inverter type is the low voltages and strong currents for which the voltage variations are much important. In both cases, the use of the chopping devices is necessary. These devices must be placed very close to the component to avoid any previous problem. The parameters used for experimental tests are presented in Table 2 and the principle of such circuits is given in Fig.7.

Table: parameters for full bridge topologie

Symbol	Value	Name
R1= R2=R3 = R4	10Ω	Chopping circuits resistances
C1=C2=C3=C4	220µF	Chopping circuits capacitors
λ	25µH	Battery current smoothing inductance
m	3	Planar transformer turns ratio
Vbus1	60V-43V	DC-link voltage
C	6800 µF	Super capacitors voltage smoothing capacitor
L1	50µH	Super capacitors currents smoothing inductance

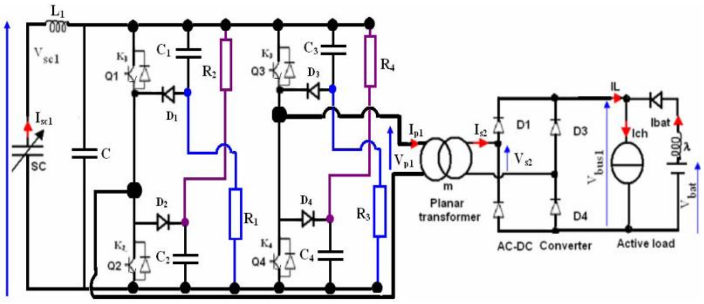


Fig: 7 Full bridge converter with chopping devices

During switching off of the semiconductors, the corresponding current stored in wiring inductances circulates in the following meshes C1, D1 ; C2 , D2; C3, D3 and C4 , D4 which limits the voltages applied to the switches. When electrical energy is fully transferred in C1, C2, C3 and C4 capacitors, the current becomes null and the meshes become closed. The C1, C2, C3 and C4 capacitors are used only for transient energy tank and it is necessary to recycle this switching energy while controlling the voltage at the semiconductors boundary. This function is ensured by R1, R2, R3 and R4 resistances. R1, R2, R3 and R4 resistances are identical and C1, C2, C3 and C4 capacitors are also identical.

In this the supercapacitor power is converted from DC to AC and connect to the planar transformer. The output of the planar transformer is again converted from AC to DC by using the diode converter. These DC output power is connected across the load of the ZVS Interleaved boost converter. The out put of supercapacitor is used at the starting of the Electrical vehicles, because ElectricalVehicles are draw more power at the starting. These extra power is provided by the SuperCapacitor.

VI. ZVS INTERLEAVED BOOST AC/DC CONVERTER WITH SUPERCAPACITOR

The following fig.6.6. shows the ZVS interleaved boost AC/DC converter with supercapacitor. In this the supercapacitor power is converted from DC to AC and connect to the planar transformer, which is having the turns ratio m=3. The output of the planar transformer is again converted from AC to DC by using the diode Rectifier. These DC output power is connected across the load of the ZVS Interleaved boost converter. At the starting the Electrical vehicles are draw more current. Then the System is working with unstable operation. These extra Current is provided by the Supercapacitor to maintain the system with stable operation.

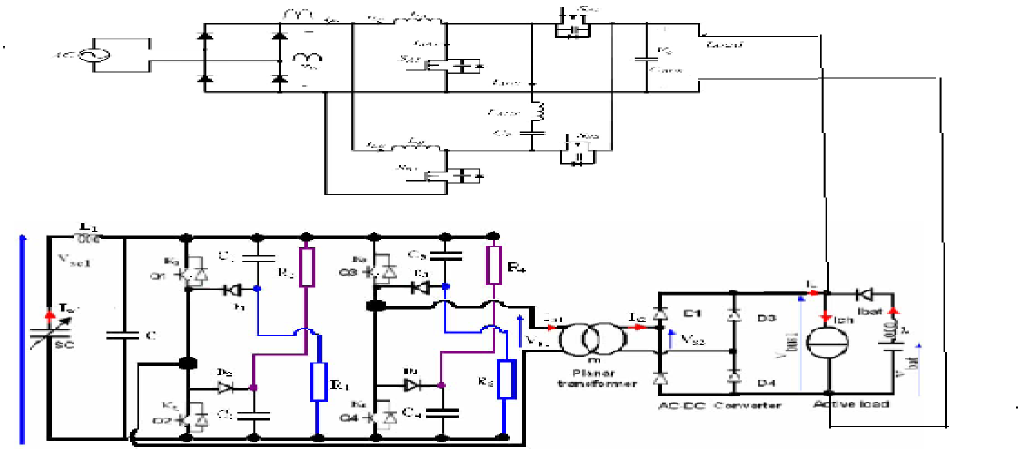
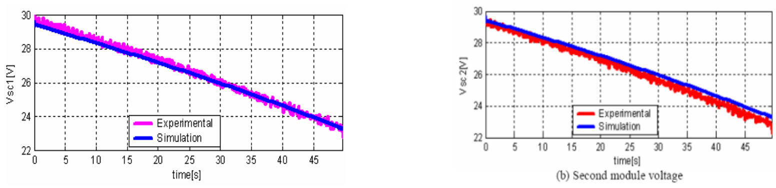


Fig.6.6. ZVS interleaved boost AC/DC converter with supercapacitor

VII. SIMULATION RESULTS

The boost converters experimental test is carried out in the following conditions: During the super capacitors discharge, the batteries current reference (Ibatref) is fixed at 13A so that, the super capacitors modules provide hybrid vehicle power request during the transient states. For these tests, the hybrid vehicle request (Ich) was fixed at 53A. The experimental and simulations results of the modules voltage are compared in Fig.8 (a) and Fig.8 (b). The (Isc1) and (Isc2) experimental currents are not identical Fig.9 (a), Fig.9 (b) because the super capacitors dispersion and the power electronic circuits (boost converters) inequality. The first boost converter ensures 50% and the second ensures also 50% of the DC-link current (IL).



(a) First module voltage (b) second module voltage

Fig: 8 supercapacitor modules experimental and simu lation voltage results

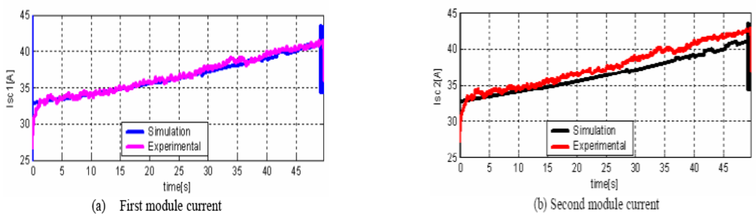


Fig: 9 supercapacitor modules experimental and simulation current results

Actully the voltage across the terminal of a Electrical Vehicle which is connected to Interleaved boost AC/DC converter is high at starting position of Electrical vehicle. So the system operating with unstability. At starting point the super capacitor gives that extra high voltage, So that the system maintains the stability. The output simulation results are shown in fig:10 and fig:11.

The following fig.10. shows the dc motor torque and armature current. In dc motor the torque and armature currents are in proportional. From the figure we observe that armature current waveform follows the torque waveform.

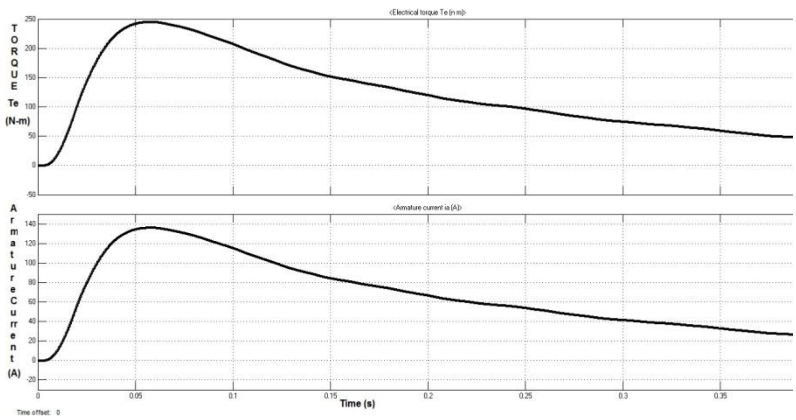


Fig: 10. output viltage of Diode bridge rectifier

The following fig.11 shows load terminal voltage and current waveforms. At starting of hybrid vehivles it draws more current as shown in figure.

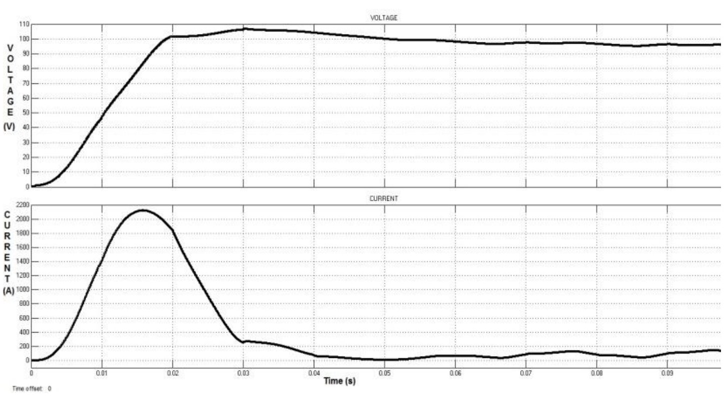


Fig:11. output voltage and currents at load terminal by using supsrcapacitor

VIII. CONCLUSION

The super capacitor power management of a ElectricalVehicle is explained by using multi boost and multi full bridge converters through a planer Transformer. An Interleaved boost PFC provides soft switching for the power MOSFETs, through an auxiliary circuit. The auxiliary circuit provides reactive current during the transition times of MOSFETs to charge and discharge the output capacitors of the MOSFETs. At the starting of Electricalvehicle it draws more voltage and current. This causes unstable operation. The Supercapacitor provides this extra current, and maintain the stability. For reasons of simplicity and cost,the multi boost converter is the most interesting topology regarding the multi full bridge converter topology. It enables a good power managemet in Hybridvehicle.

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