NOVATEUR PUBLICATIONS
International Journal Of Research Publications In Engineering And Technology [IJRPET]
ISSN: 2454-7875
VOLUME 2, ISSUE 7, July -2016

APPLICATIONS OF MULTI BOOST AND FULL BRIDGE CONVERTERS FOR SUPER CAPACITORS AND BATTERY POWER MANAGEMENT FOR ECCE HYBRID VEHICLE

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ABSTRACT:

This paper presents Methodology based on super capacitors and battery power management for applications of the ECCE Hybrid Vehicle using the principle of multi boost and full bridge rectifiers. In collaboration with the Electrical and Electronics Research center in Belfort (CREEBEL) and French innovators ECCE for Hybrid vehicle system was developed as an experiment at L2ES Laboratory. An experiment ECCE for the Hybrid Vehicle incorporates the dc motors coupled with the alternator with the rated voltage of 540V. Energy source to the system is by using two super capacitors bank, each bank consists of the 108 cells with provision of maximum voltage of 270V.To embarked the best power management topology for the Hybrid vehicle application, author proposed the multi boost and full bridge converter topologies for it. In this paper the two converter topologies are presented with experimental and the simulation results.

KEYWORDS: multi boost converter, full bridge converter, power management, Simulation, hybrid, vehicle, topology

INTRODUCTION:

In recent years, the world faces the biggest problems of the energy crisis and the tremendous increase in pollution mainly air pollution. Main causes behind that the rise in the vehicles around the world and emission of poisonous gases into planetary atmospheres. In Nineties, car manufactures started to react about increase in the problems of pollution by exploiting the electric vehicle or hybrid vehicles. But till date Hybrid vehicles not turn into exact replacement for the fuel operated vehicles as battery weight and cost problems were not solved. During transient states, conditions are more severe in case of batteries as unable to provide regulated energy and power supply. A promising solution to these severe problems is nothing but the super capacitors and good battery power management [10]. In hybrid vehicle, to ensure a good battery power management among various topologies, the multi boost and multi full bridge converters topology is proposed. Following are the two different topologies are proposed for ECCE Hybrid vehicle model.

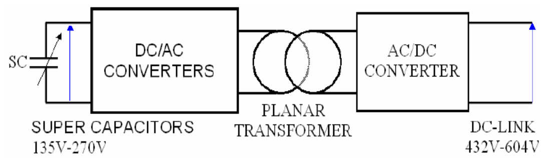


Figure 1.1: First proposed model

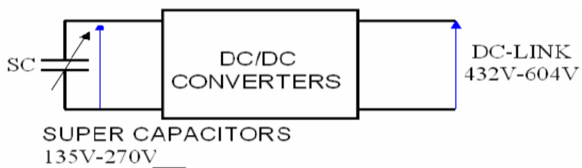


Figure 1.2: Second proposed model

TOPOLOGIES AND MODELING:

MODELLING FOR THE MULTI FULL BRIDGE CONVERTER AND MULTI BOOST:

Following is the generalized model for the multi boost converter topology proposed in this paper.

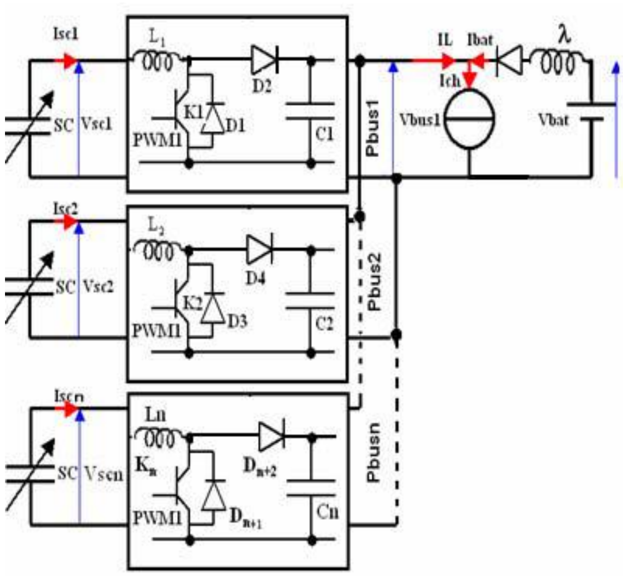


Figure 1.3: Topology for the Multi boost converter

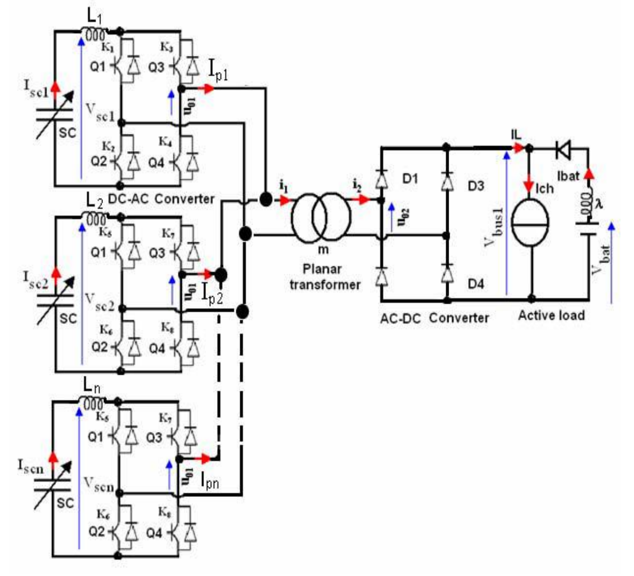


Figure 1.4: Topology for the Multi full bridge converter

Following are the equations derived from the topologies specified above [3]. In following equations (α1) and (n) are the duty cycle and parallel input converter number respectively.

$$\begin{cases} L_n \cdot \frac{d}{dt}(I_{scn}) = V_{scn} - \alpha_1 \cdot V_{bus1} \\ n = 1,2,\cdots,N_p \\ I_L \cdot V_{bus1} = P_{bus1} + P_{bus2} + \cdots + P_{busn} \\ \lambda \cdot \frac{d}{dt}(I_{bat}) = V_{bat} - V_{bus1} \\ I_{ch} = I_{bat} + k \cdot I_L \end{cases}$$

……………….equation (1)

In above topologies the voltage drops in the Ln and λ inductances are given by the equations (2) derived

$$\begin{cases} V_{Ln} = L_n \cdot \frac{d}{dt}(I_{scn}) \\ V_{\lambda} = \lambda \cdot \frac{d}{dt}(I_{bat}) \end{cases}$$

…………………equation (2)

The average model of converter has a nonlinear behavior. It crosses between control variable (α1) and the parameter Vbus1.

The control of the model can be disturbed by Vbus1, Vsc1, Vsc2, Vscn , Ich and Vbat variables . So, these variables must be measured according to proposed topology and used to ensure a dynamics of control in the estimation of the control law[2]. The control law topology for the multi boost converter which results from the boost converter modeling is proposed by duty cycle α1given in the following equation (3); where Np = max(n) is the maximum number of parallel converters.

$$\alpha_1 = 1 - \frac{1}{N_p} \cdot \frac{(V_{sc1} + V_{sc2} + \cdots + V_{scn}) - (V_{L1} + V_{L2} + \cdots + V_{Ln})}{V_{bat} - V_{\lambda}}$$

…….equation 3

The control strategy for the multi boost converter is proposed in Figure 1.5. It observed that the super capacitor modules discharge with variable current after implementing this topology. Also, Iscref i.e. super capacitors reference current is obtained starting from the power management between two; hybrid vehicle DC-link and batteries.

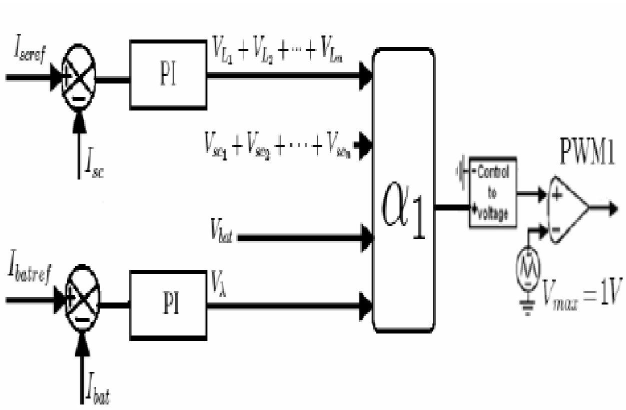


Figure 1.5: Multi boost control strategy

In this topology, the control strategy which includes the super capacitors and batteries current control loops. The normal operation of the multi boost converters control is ensured by the PWM1 signal during super capacitor modules discharge.

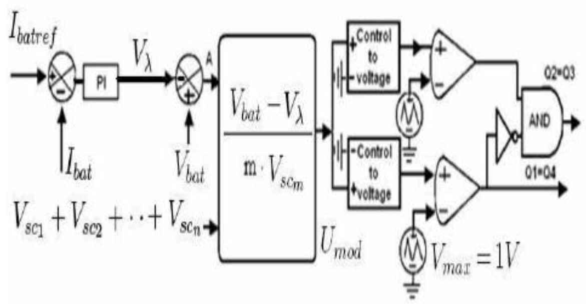


Figure 1.6: Multi full bridge control strategy

It is easy to write the super capacitors current references for the energy management between the modules and the hybrid vehicle DC link as the modules are identical in nature as per the equation (4)

$$\begin{cases} I_{sc} = I_{sc1} + I_{sc2} + \cdots + I_{scn} \\ I_{screfn} = \dfrac{1}{N_p} \cdot \dfrac{V_{bus1}}{\eta \cdot V_{scn}} \cdot (I_{ch} - I_{batref}) \\ I_{scref} = I_{scref1} + I_{scref2} + \cdots + I_{screfn} \end{cases}$$

.........equation 4

The efficiency (η) of the multi boost converter was fixed at 85%, so as to simplify current references estimation for the super capacitors. The control strategy proposed for the multi full bridge converter consists to establish the full bridge converters standardized voltage. The control law is presented by equation 5 which result from the modeling of multi full bridge converter, where (m) defines the transformer turns ratio.

$$\begin{cases} U_{mod} \approx \dfrac{1}{m} \cdot \dfrac{V_{bat} - V_{\lambda}}{\eta \cdot V_{scn}} \\ V_{scn} = \dfrac{V_{sc1} + V_{sc2} + \cdots + V_{scn}}{N_p} \end{cases}$$

.........equation 5

The two triangular carrier waves of amplitude Vmax = 1V with a switching frequency of 20 kHz are compared with above standardized voltage V_{scn} .

The inverter control strategy is proposed in above Figure 1.6; where applied control signals Q1, Q2, Q3 and Q4 to the gate of K1, K2, K3 and K4 switches. The simulations and experimental results for the given parameters are presented in table below.

FULL BRIDGE CONVERTER SIMULATION RESULTS FOR Np = 2:

The simulation results has been drawn the parameter for Np = 2 [7]. The maximum and minimum voltages limit for the super capacitor modules proposed in his paper is respectively fixed at 270V and 135V. The requested different ranges for the parameter current (Ich) for the hybrid vehicle are respectively fixed at 100A from 0 to 0.5s, 400A from 0.5s to 18s and 100A from 18s to 20s. So, for the proposed model, Battery reference current (Ibatref) is fixed at 100A independently of the hybrid vehicle power as per the request.

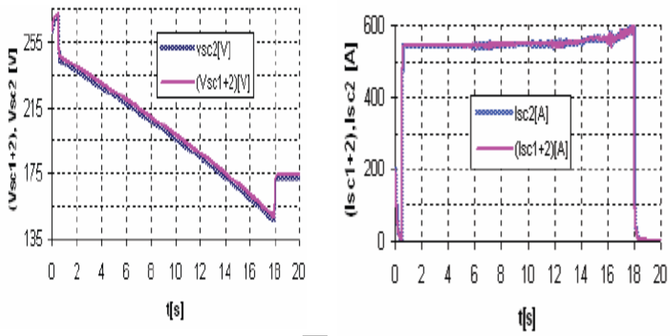


Figure 1.7: Super capacitor modules voltages, 1.8: Super capacitor modules currents

After the simulation results it ensures that, Super capacitor modules voltages (Vsc1, Vsc2) presented in Figure 1.7 are identical. The currents amplitudes (Isc1, Isc2) presented in Figure 1.8 are also identical in nature. Control enables to maintain the battery current (Ibat) at 100A; but the battery current control loop has not enough time to react at 0.5s and 18s as per the results Fig 1.7. Simulation parameters are tabulated are as follows.

TABLE: SIMULATIONS PARAMETERS FOR FULL BRIDGE TOPOLOGY

Symbol	Value	Name
λ	25μH	Battery current smoothing inductance
m	3	Planar transformer turns ratio
V_{bus1}	604V-432V	DC-link voltage
L_1=L_2	50μH	Super capacitors currents smoothing inductances

DESIGN AND EXPERIMENTAL RESULTS:

High voltage fluctuations caused due to instantaneous fluctuations in the current and inductance in the communication cell due to the switching action of the semiconductors and these high voltage transitions are necessary to control within the desirable limits.

The cells in the single phase inverter include the two switches decoupled with the capacitor playing the double role while in operation. First it creates the instantaneous voltage source nearer to the inverter. The main function of the capacitor associated with the inductor to filter the harmonic components present in the currents. Capacitor inductance, the internal; inductance of the semiconductor and the inductance due to the electric connections are the other ways of inductance included in the mesh acts as parasitic inductance which can be removed by good choice of wiring cables used. But problem remain the same as residual inductances remain too high. So, Chopping devices are necessary to overcome on these problems. The different parameters used are presented in

TABLE[8] and the principle operation of such circuits is given in Figure 1.9

TABLE: FULL BRIDGE EXPERIMENTAL PARAMETERS

Symbol	Value	Name
$R_1 = R_2 = R_3 = R_4$	10Ω	Chopping circuits resistances
$C_1 = C_2 = C_3 = C_4$	220µF	Chopping circuits capacitors
λ	25µH	Battery current smoothing inductance
m	3	Planar transformer turns ratio
V_{bus1}	60V-43V	DC-link voltage
C	6800 µF	Super capacitors voltage smoothing capacitor
L_1	50µH	Super capacitors currents smoothing inductance

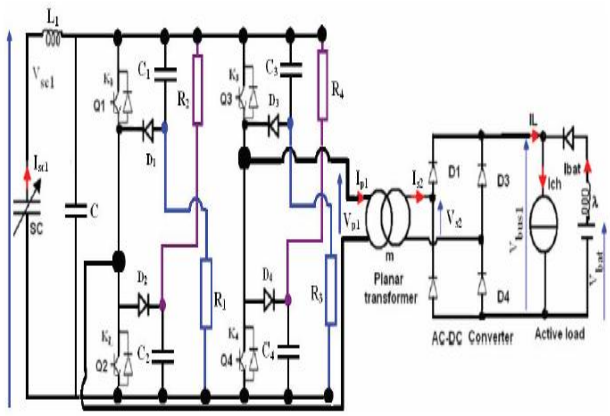
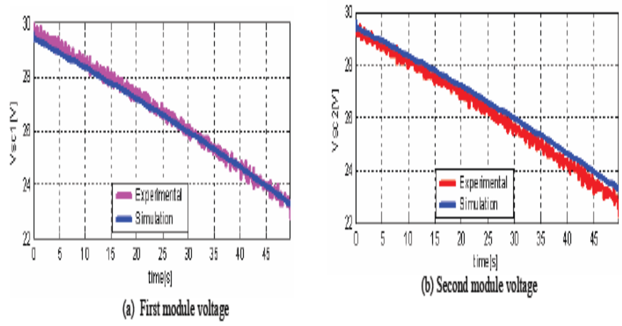


Figure 1.9. Full bridge converter with chopping devices

In case 1 when the semiconductors are switched off, the corresponding currents in wiring inductances circulates in the respective meshes C1, D1 ; C2 , D2; C3, D3 and C4 , D4 which limits the voltages applied to the switches Q1, Q2, Q3, Q4. When C1, C2, C3 and C4 capacitors fully charged, the current becomes zero and indirectly the meshes are in closed condition. The C1, C2, C3 and C4 capacitors act as transient energy tank and used to control the voltages at semiconductors. This function is ensured by R1, R2, R3 and R4 resistances which are identical in nature like C1, C2, C3 and C4 capacitors.

BOOST CONVERTERS SIMULATION AND EXPERIMENTAL RESULTS:

The experimental test for the boost converters is carried out in the following conditions: During discharge of the super capacitors, the value of batteries current reference (Ibatref) is fixed at 13A so that, during transient states requested power provided by the the super capacitors modules to hybrid vehicle. For these tests, the current value of hybrid vehicle request (Ich) was fixed at 53A. The various simulation results for the modules voltage and currents are compared in Fig 1.9 and Fig 1.10. The (Isc1) and (Isc2) experimental currents are not identical



F Figure 1.9 Experimental and simulation voltage results for Super capacitor modules

As inequality of the super capacitors dispersion and the power electronic circuits so, two different figures (a) and figure (b)

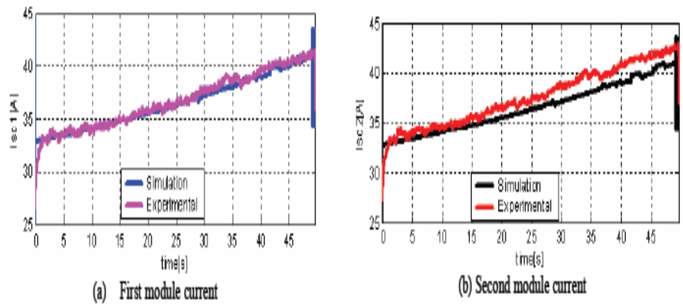


Figure 1.10 Experimental and simulation current results for Super capacitor modules

The first boost converter yield 50% and the second yield also 50% of the DC-link current(IL) by ensuring a (IL) current of 40A to hybrid vehicle as presented in Figure 1.11 (a) below and 13A only is provided by the batteries Figure 1.11 (b).

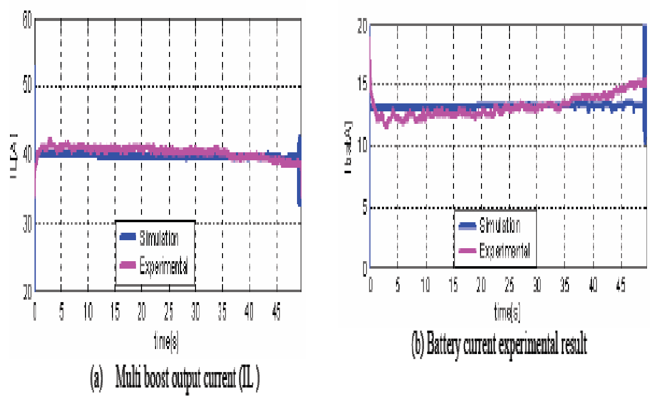


Figure 1.11. DC-link voltage and current experimental validation

CONCLUSION:

This paper based on applications of the multi boost and multi full bridge converter topologies and their implementation by using super capacitors coupling in the hybrid vehicle and Battery management for the same. As Full Bridge converter experimental results were different from that of multi boost converter topology, comparison between the two topologies is proposed in this paper. After simulation and experimental results it ensures that multi full bridge converter topology is good enough for available voltage levels to the DC-link, but due to higher cost of full bridge converter and lower efficiency, full bridge converter is seems to be less accepted for or low voltage and high current applications like super capacitors. To reduce the cost and good power management in hybrid vehicle the multi boost converter is most suitable as compared to multi full bridge converter topology due to of simplicity of design.

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